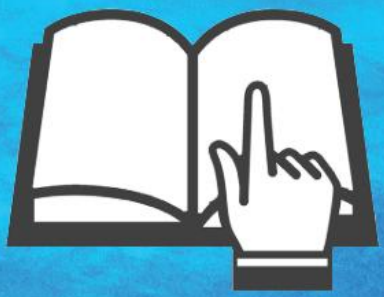
Marine Science



For Australian Students

2016 Edition

Bob Moffatt
Tim Ryan
Leon Zann

Photo Viewfinder Australia

Foreword

In 1978, a Commonwealth Grant for $15,000 was given to establish the Gladstone Oceanographic Studies Program in Queensland. About the same time a similar grant was given to establish a Marine Studies Centre from an old scallop shed at Woodbridge Tasmania.

The idea of the innovative grants scheme was to light a spark in the imagination of young minds and so almost 40 years later, Australian teachers and their students have a textbook and university courses in Marine Science in every Australian State.

This 2016 Edition contains the colour images of those photographs and illustrations that were impossible to publish due to budgetary restraints. I hope these new images along with some minor editing make the ideas and concepts presented easier to understand.

Again I would like to thank all those who have made this book possible, (please see page 4 and appendix 8), I would like to pay tribute to the dedication of the marine teaching profession and their sponsors – especially those who were the first to tackle the subject in their school and become involved in their subject associations. Generations of students to come will benefit from their vision and hard work.

Bob Moffatt

Wet Paper Publications

October 2016

© Copyright 2016

Except as permitted by the copyright law applicable to you, you may not reproduce or communicate any of the content on this website, including files downloadable from this web site, without the permission of the copyright owner.

The Australian Copyright Act allows certain uses of content on the internet without the copyright owner's permission. This includes uses by educational institutions for educational purposes, and by Commonwealth and State government departments for government purposes, provided fair payment is made.

For more information, see www.copyright.com.au and www.copyright.org.au

Published by

Wet Paper Publishers and Consultants
PO Box 540
COOLANGATTA 4225
www.wetpaper.com.au

Code

F01R.pdf

Title

Marine science for Australian Students

ISBN

978-1-86283-167-4

Contents

Part A Oceanography

Chapter 1 Ocean and coastline formation 5
Chapter 2 Oceans and waves 33
Chapter 3 Currents and weather 57
Chapter 4 Coastlines 81
Chapter 5 Coastal engineering 109
Chapter 6 Seawater 129
Chapter 7 Marine pollution 159

Part B Marine biology

Chapter 8 Classification and marine biodiversity 191
Chapter 9 Marine plants (1) 229
Chapter 10 Marine plants (2) 247
Chapter 11 Marine invertebrates (1) 269
Chapter 12 Marine invertebrates (2) 301
Chapter 13 Marine vertebrates (1) 327
Chapter 14 Marine vertebrates (2) 353
Chapter 15 How they survive 383
Chapter 16 Ecosystems 411

Part C Management and conservation

Chapter 17 Problems in our seas 429
Chapter 18 Sustainable use of the sea 455
Chapter 19 Biodiversity and protecting marine life 485
Chapter 20 Fisheries biology 505
Chapter 21 Aquaculture 533
Chapter 22 Marine parks 551
Appendices 587

Photo Bob Moffatt

Acknowledgements

The publishers are grateful to the following people and organisations who have helped compile this book with every illustration, photograph and text piece carefully acknowledged. If we have made a mistake, please let us know.

Illustrations

As well as each individual acknowledgement, special thanks goes to National Oceans Office, Geoscience Australia, Kerry Kitzelman, Rose Bedford, Sue Oates, Steven Byers, Gavin Ryan, Sharyn Madder, Jan Taylor, Trent, Bob and Mark Moffatt, Merran Kilgour, Queensland Museum, Jan Taylor, Brady Moffatt, Greenpeace, Surfrider Foundation, Paul Lennon, Great Barrier Reef Marine Park Authority, Marine Education Society of Australia, Dr Jack Marsh and Dr David Tulip. Cover design — Trent Moffatt.

Photography

As well as each individual acknowledgement, special thanks goes to Kym McKauge and Dawn Couchman, Queensland Fisheries, Lea Crosswell and Louise Bell CSIRO, National Oceans Office, Murray Waite and Associates: Viewfinder Australia; Underwater Rhelms; Below H_20; Jim Kneale; Len Zell; Michael Mitchie, Sea World, Gold Coast City Council – John McGrath, Angus Jackson, Mike Sugden, Neville Coleman, Dr Neville Exon, Peter Hill – Geoscience Australia, Michael Mitchie, Glen Leiper, CSIRO Marine Division, Qld Fisheries, Kimberley Foster, Greenpeace, CALM: Western Australia - Sue Osborne, Karen Shaw and Annaliese Caston AMSA, Great Barrier Reef Marine Park Authority, Surfing Australia, Bob Winters, Dick Hoole, Joli Photography, Jan Taylor, and students at Benowa State High and Teachers from Marine Teachers Associations who participated in conferences and school photoshoots.

Text

Apart from each individual acknowledgement, Chapters 1 - 7 were based on existing and updated Wet Paper Publications, modified by Tim Ryan and Bob Moffatt with comments by Peter Hill, Neville Exon, CSIRO and Geoscience Australia. Chapter 8 was compiled from the works of Tim Ryan, Bob Winters, Harry Briedahl and Nancy Tsernjavski. Chapters 9-14 are based on University of Qld Botany I and Zoology 11a and 11b lecture notes delivered by Tom Hailstone and Jack Greenwood, Year 12 notes by the late Dr Bob Squire and Mick O'Connor. Chapters 15 and 16 were written by Tim Ryan and Bob Moffatt. Chapters 17-22 were written by Leon Zann with numerous case studies and references to the State of the Marine Environment 1996 Environment Australia as well as Robyn Aiello's paper on Marine Ecotourism. Finally the publisher would like to thank the School of Environmental Science and Management, Southern Cross University, Lismore, the Queensland Studies Authority, Education Queensland and Ward Nicholas - Heatley Secondary College for their support.

Activities and advice

Apart from each individual acknowledgement, special thanks to members of the Marine Teachers Associations of Qld and New South Wales who supplied activities – in particular Katie Gill, Tony Courtney, Craig Reid, Ryan Dunn, John McGrath, Angus Jackson, Tony Issacson, Fred Nucifora, Angela Colliver, Tim Ryan, Geoff Jensen, Gwen Connolly, Mick O'Connor, Terry Wright, Adam Richmond and Phil King.

Scientific review (honorary)

Neville Coleman (World of Water)

Educational review (honorary)

Adam Richmond

Chapter questions and index

Bob Moffatt

Initial project meeting group

Len Couzins, Mick O'Connor, Angela Colliver, Mike Halpin, Kathy Steggles, David Oelrichs, Geoff Jensen, Phil Smith, Mike Sugden, David Tulip.

Professional associations and peak bodies

The publishers wish to thank the following agencies, associations and peak bodies for their support in helping promote marine studies in Australia.
Marine Teachers Associations of: Queensland (MTAQ), Western Australia (WAMTA) and New South Wales (MTANSW)
Marine Education Society of Australia (MESA)
Science Teachers Associations of Queensland and Tasmania
Queensland Yachting Association
Australian and New Zealand Safe Education Boating Group
Science Teachers Association of Queensland (who helped print the original set of notes in 1979-1984) and later the Brisbane South Marine Studies Project (1984-1989)
Australian Marine Education Alliance (AMEA)
Australian Marine Environmental Protection Agency (AUSMEPA)

Disclaimer

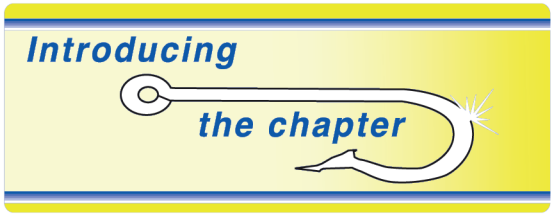
Although every care has been taken to ensure the accuracy of the information and provide safety instructions, offers of training and advice, Wet Paper or any of its employees or consultants accept no responsibility for any accident that may occur as a result of students performing any of the activities in this book. Schools are advised to follow their school or departmental safety procedures before undertaking any experiments and check current material safety sheets for equipment and chemicals mentioned in laboratory or field exercises. As web pages go out of date schools are advised to use corresponding search engine words from the index to locate web addresses.

Photo Bob Moffatt

Chapter 1
Ocean and coastline formation

by
Bob Moffatt and Tim Ryan

Photo Murray Waite



Chapter hooks

- Watch the National Oceans Office sea floor video Available from www.oceans.gov.au
- View the Classroom Video DVD on *Seas of Life*
- Read *the beginning of life - another view* on page 27 and invite an Aboriginal elder to class to discuss the significance of the *Rainbow Serpent* and local aboriginal marine stories in class.
- Discuss the implications of The Law of the Sea convention and the Timor Sea (read page 13).
- Begin Exercise 1.1 — *A matter of time*
- Try the Wet Paper Teachers Web Page activities - *Ocean Shapes and Make a sea mount* (see page 9).

Why study this chapter

Plate tectonics helps us understand the shape of our coastline and lays the foundation for the chapters on coastlines and oceans.

It is also important for us to understand the significance of the Rainbow Serpent in Aboriginal culture.

Exciting new discoveries are being made by the Commonwealth Scientific and Industrial Research Organisation — CSIRO. These are essential if we are to claim our nationals Exclusive Economic Zone as discussed on page 13.

A knowledge of our ocean's topography also has enormous military significance. Deep oceans trenches near East Timor make it possible for submarines to travel between the Pacific and Indian Oceans.

Chapter overview

Earth and its oceans 7
Earth formation 8
Tectonics 10
The earth's crust 14
Oceanic crust movements 16
Australian crust 20
Australia comes of age 23
Exercise 1.1 A matter of time 26
Australian marine research 28
Case study 1.1 Submarine canyons 29
Case study 1.2 — Australia down under 30
Exercises and questions 32

Key concepts

1. Scientists believe the earth was formed by the dust cloud hypothesis and that it is over 4.5 billion years old.
2. Aboriginal people believe the earth was formed by the Rainbow Serpent who made laws for all animals to obey. She created humans from those who obeyed these laws and gave them the land and seas to manage.
3. The oceans lie on a thin layer of crust which is subject to enormous forces from within the earth.
4. The crust of the earth has different densities and can move around causing earthquakes and volcanoes. Earthquakes and volcanoes are caused by moving plates on the earth.
5. Australia was once part of a huge super continent which drifted apart due to plate movements.

   About 200 million years ago Australia was part of a super-continent called Pangaea.

   Pangaea broke up into two continents Laurasia and Gondwanaland.

   Laurasia was made up of North America and Asia, Gondwanaland comprised South America, Africa, India, Australia and Antarctica.
6. There are no lions and tigers in Australia because Gondwanaland split up before they had evolved.
7. Marine dinosaurs existed in Queensland because it was once a shallow inland sea.
8. Our coastline was given its unique features based on this movement. Some examples of this are:
   - Western Australia is flat and geologically very old.
   - The Great Australian Bight was formed as we split from Antarctica.
   - The East coast has the great dividing range with fast flowing rivers creating huge volumes of sand.
   - The tropical reefs have only formed in recent times and are a thin veneer on ancient reefs.
9. Modern oceanographic methods have established that the sea floor has mountains, plains, valleys and hills on a much grander scale that on land.
10. Using computer technology and advanced echo sounding, Australian marine scientists have began to map our oceans with a high degree of accuracy.

Essential references

Law of the Sea

Teacher Notes by Cindy Hann, Geoscience Australia, GPO Box 378, Canberra, ACT, 2601.

Classroom Video

www.classroomvideo.com.au

Earth and its oceans

Our galaxy

For centuries we have gazed into the night sky and seen a wispy path of white that crosses from one horizon to another (Figure 7.1).

This is the milky way which is a band of stars that makes up the edge of our **galaxy** that would take 100,000 light years to cross (Figure 7.2).

Our **solar system** is very small compared with the milky way. Its centre is occupied by the sun, with nine planets orbiting.

- The earth is the only planet in our solar system to have oceans. From space our planet appears blue and white because almost 3/4 of it is covered by water, and clouds encircle our atmosphere.
- The earth's three major oceans are the Pacific, Atlantic and Indian Oceans. The Pacific is about the same size as the Atlantic and Indian. The Arctic Ocean is almost completely covered by ice. Nine seas are enclosed in these oceans.

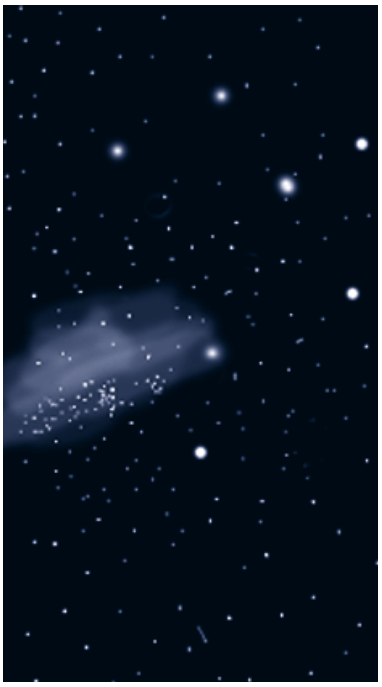


Figure 7.1 The night sky
(Illustration Bob Moffatt)

Our solar system

Today water continues to be added to the earth's atmosphere by volcanoes above and below the earth's surface. In fact that's how water was added to the seas and our atmosphere in the dawn of time. The discussion which follows is a theory, commonly held by most Scientists.

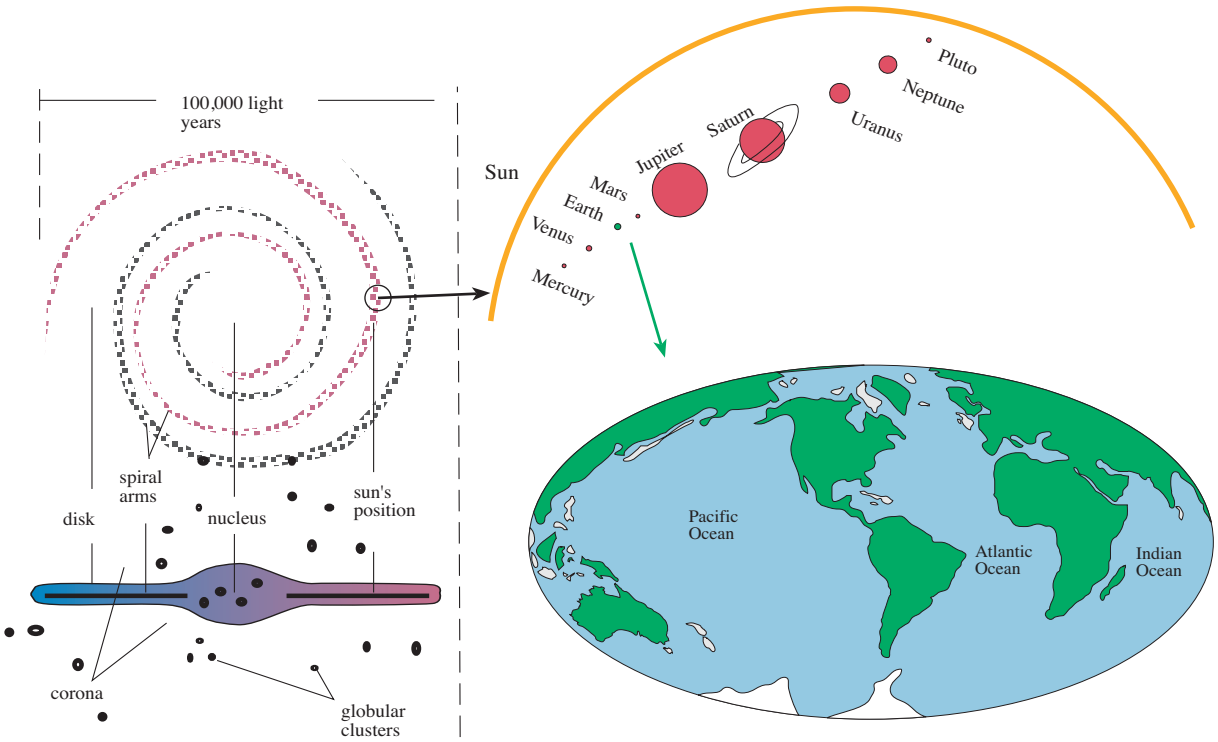


Figure 7.2 An idealised representation of our Milky Way Galaxy and solar system (After Weinhaupt 1979)
(Illustrations Bob Moffatt)

Odd fact

The deepest point measured in the ocean is 11,700 metres at the Marianas Trench in the western Pacific.

It was found during a sonar sea-floor mapping project carried out in 1997 and 2001 by scientists from Hawaii, US.

The Challenger Deep has been visited by a number of manned and unmanned submersibles since its discovery, but at present there is no craft in operation that can survive the crushing pressure at its bottom.

You can read more at:

http://newswww.bbc.net.uk/2/hi/science/nature

Earth formation

The formation of the planets rests in two main theories. Single bodied theories say no forces or bodies affected the formation. Second bodied theories say that some force from outside the system affected our formation.

Single bodied theories are now accepted more than the latter and of these the dust-cloud hypothesis is most widely recognised.

The dust cloud hypothesis

According to the dust cloud hypothesis, both sun and planets were formed from a mass of dust and gas. This was a rotating mass that was marked by smaller internal eddies.

- As the mass rotated, it contracted and most of the gas was either lost to space or gravitated to become part of a central mass (the sun).
- The smaller parts formed the planets of which earth was one.
- As the gas cooled it solidified, however with increasing pressures, the centre became liquid again giving the earth its layers - the core, mantle and crust.
- Gases released through weaknesses in the crust formed our early atmosphere (Figure 8.1).

The interstellar dust was believed to be composed of molecules of hydrogen, helium, carbon dioxide, oxygen, ammonia.

Some 4.5 billion years ago, it is believed the earth formed from the interstellar space, atoms and molecules came together to form molten rock which then cooled. Earth was also bombarded by other condensing matter called meteorites. The molecules to make water existed, but it was just too hot for any to form.

When the earth was formed from the dust and gases of space, it may have retained some of the gases as atmosphere without water. Also the earth at an early stage was so hot that any water on the surface would have evaporated. The early atmosphere of the earth was believed to have been dispersed by meteorites and extreme heat.

As the earth cooled, volatile materials from within it were working their way to the surface and a time came when these gasses accumulated at the surface faster than they were dispersed.

A "second" atmosphere began to grow where hydrogen and helium were driven off into space, but water vapour, nitrogen and carbon dioxide remained.

As the new atmosphere slowly cooled, it eventually reached a temperature at which water vapour and liquid could exist at the same time. The oceans were then formed leaving the land dry, hot and volcanic.

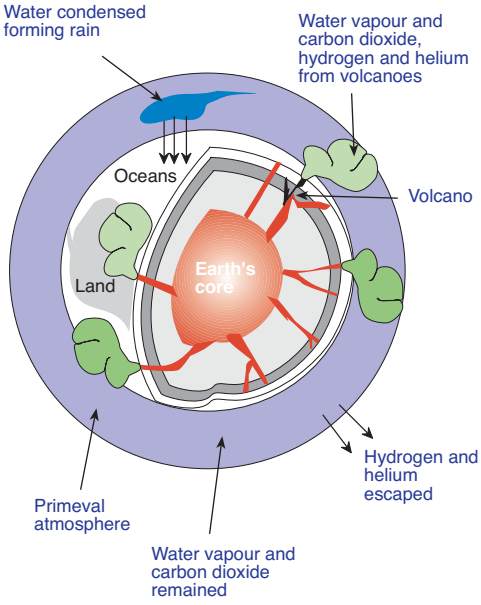


Figure 8.1 Earth's primeval atmosphere

With such a hostile world, it's no wonder that life began in the sea. These early events are summarised in Figure 9.1 below.

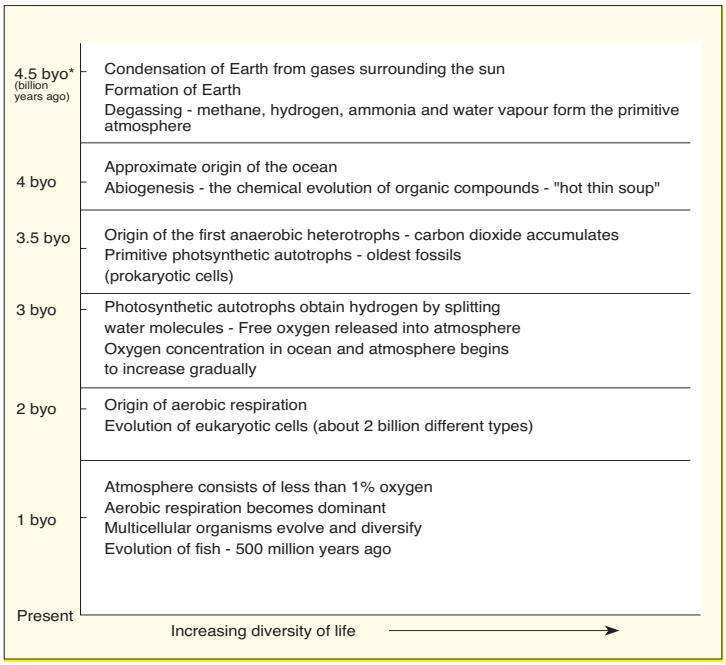


Figure 9.1 Summary of formation of early earth

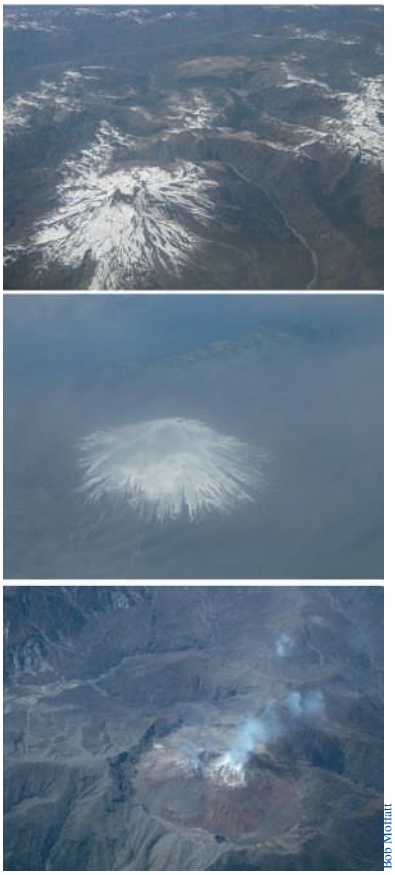


Figure 9.2 Volcanic activity, Andes range, South America.

Ocean depths

Figure 9.3 shows the mean (average) depths of oceans today.

- The mean depth of all the oceans is 3118 m with the deepest part, the Mariana's Trench in the Pacific Ocean, 11 038 m. In fact, this trench dips further below sea level than Mt Everest reaches above.

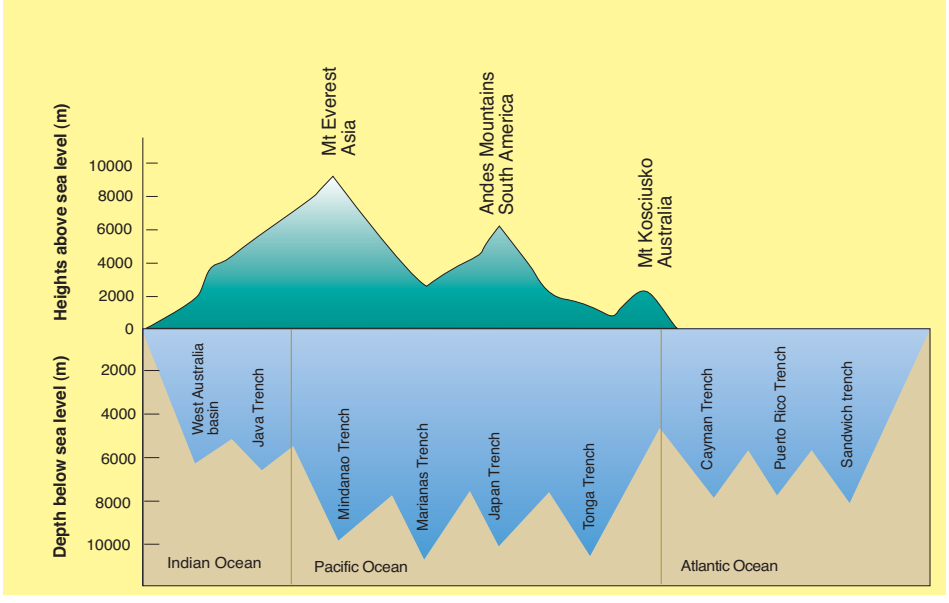


Figure 9.3 Comparison of mountain height to oceanic canyon depth
(Source *Exploration of the Oceans* WEIHAUPT, John G (1979)

Plate tectonics

The unifying theory that explains how geological features of the earth formed from the movement of crustal plates relative to one another. Lerman, 1986.

Tectonics

Tectonics is the study of the origin and development of the broad structural features of the earth.

Scientists have only in the last 40 years gained an understanding of the ocean floor and surprisingly we know more about the atmosphere on other planets in our solar system than we do about the ocean floor.

Exploration of the ocean depths began with oceanographers using long lines with lead weights attached, however this crude method was only effective in shallow waters. A line was marked at intervals and held vertically taut to get a reading and was only useful when the vessel was moving at slow speeds or stationary. The method was called - *swinging the lead*. This method was nearly impossible to use at ocean depths of over 4,000 m, because the large weights needed to reach these depths would require very heavy ropes. Huge winches would then be needed to lift these ropes and weights.

At the end of the nineteenth century a method was introduced by which a weighted line or thin steel wire was dropped to the depths. This method was very slow because of the great depths and the time it took for it to sink. It could take up to one full day to make one reading and therefore, there was limited knowledge of great ocean depths. So oceanographers believed the ocean floor was a flat featureless plain and that the depth of the ocean was fairly constant.

Some of the mysteries of the deep were revealed after the invention of the echo sounder (Figure 10.1) at the end of World War 2. Scientists now had the tools for precise depth recording and quickly built up their knowledge of the ocean floor.

- Sound waves with frequencies between 10kHz and 100kHz are sent out from the ship's transducers and these sound waves travel to the bottom where they are reflected back to the receiver on the ship. The time interval it takes for the sound waves to be detected is used to calculate the depth (Figure 10.2).
- Sound travels at approximately 1500 m/sec in sea water (it varies with temperature, salinity, and pressure). If it takes four seconds for the sound to come back, the depth of the water will equal 3,000 m. This method is a lot quicker than the weighted lines.

Figure 10.1 Echosounder
(Illustration courtesy Koden)

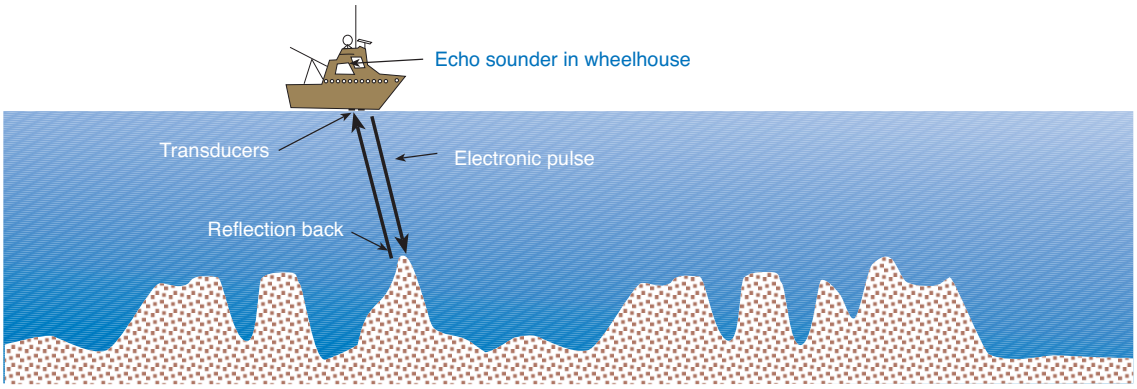


Figure 10.2 Depth sounding
(Illustration Bob Moffatt)

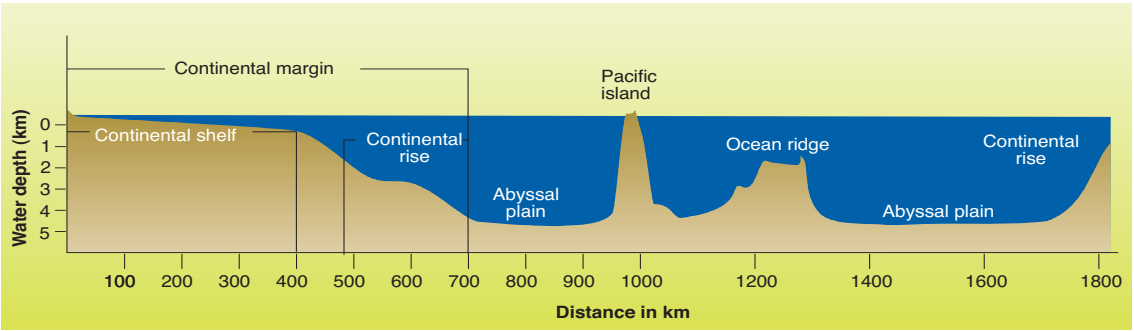


Figure 11.1 Ocean floor topography
(Illustration Bob Moffatt)

Topography

As a result of these new methods, scientists have been able to map the topography of the oceans. The ocean floor is divided into the continental margin, ocean-basin floor and mid-ocean ridges as summarised in Figure 11.1 above.

Continental margin

The **continental margin** stretches out from the land as far as the eye can see.

The average distance for the continental margin is 65 kilometres and its character varies from place to place. In Australia (Figure 11.2), it consists of the **continental shelf** (mostly fairly narrow), the **continental slope**, and the **continental rise**.

In other parts of the world the continental margin can consist of a shelf, slope, deep-sea trench and a broad ridge.

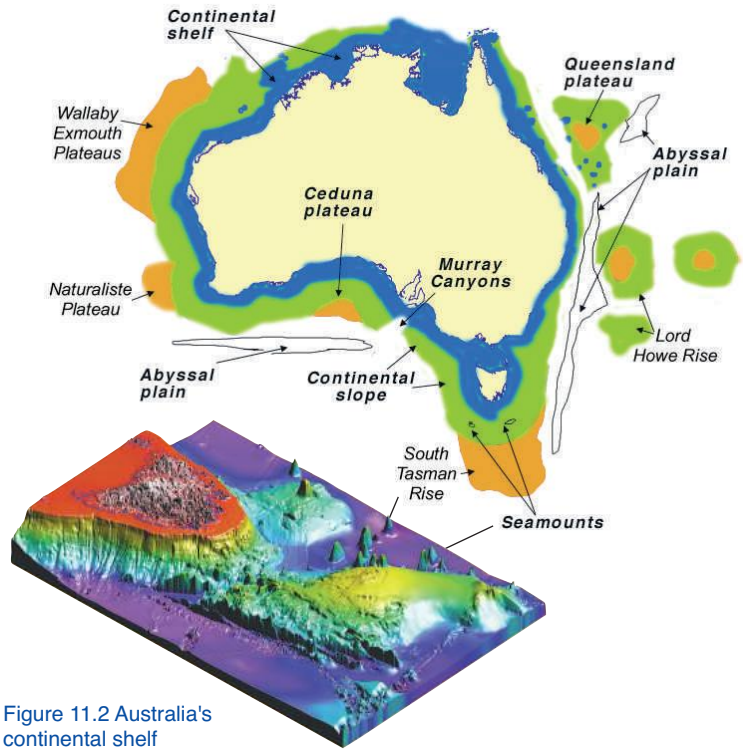


Figure 11.2 Australia's continental shelf
(Illustration Bob Moffatt, source CSIRO)

Odd facts

- The earth's tallest mountain, longest mountain range and deepest canyon are all in the ocean.
- The surface of Venus - millions of kilometres away and hidden by clouds of sulphuric acid - has been better mapped than the earth's sea bed (The Economist, 3 September, 1994).
- The Great Meteor seamount (submarine volcano) in the North East Atlantic has a basal diameter of over 100 kilometres and a height of four kilometres (The Times Atlas of the Oceans).
- Australia's very own underwater Grand Canyons - the Murray Canyons are deeper than America's Grand Canyon and more than twice the height of Australia's highest mountain, Mt Kosciusko.

  Scientists drilled long cores into sediment around the Murray Canyons system that has been deposited over the centuries by the Murray Darling river system. This information will hopefully allow scientists to chart the history of oceans and climate in this region every 100 years for the past 250,000 years.

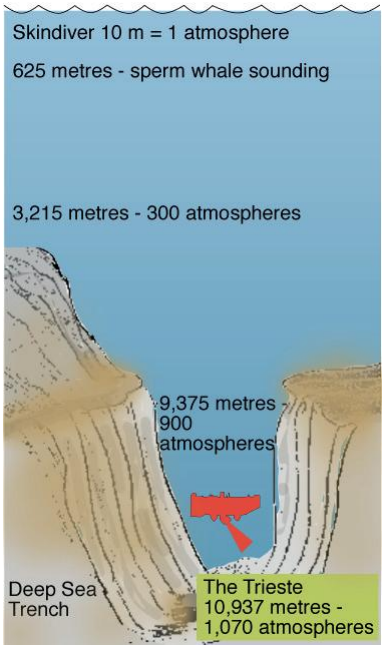


Figure 12.1 Deep sea trench pressure
(Illustration Bob Moffatt)

Odd fact

The Trieste

In 1960 two scientists made a record dive into the deepest part of the ocean into the challenger deep in the Pacific over 10,000 metres and over 1000 atmospheres. The vessel was a bathyscape and was called the Trieste. An illustration is shown in Figure 12.1 to give you some idea as to the depth and scale of this dive and the tanks involved to control the vessel. Eleven of these tanks are filled with 120,000 litres of petrol. The petrol is lighter than water and this makes the craft light enough to float. One tank at each end is left empty just before the dive. Then the tanks are opened and seawater ballast flows in and the bathyscape begins to sink. To come to the surface the Trieste releases its ballast quickly and once on the surface the vessel floats.

Continental shelf

Surfaces of continents are being continually eroded and this eroded material is finally deposited in the sea. Rivers of the land carry millions of tonnes of sand and soil out to sea and these settle to the bottom. So the continental shelf is normally a relatively flat area built up from sediments from the land.

In Australia the continental shelf slopes gently away from the shore to a depth of 200 m but in Antarctic it can stretches out as far as 1,000 km.

Continental slope

Beyond the edge of the continental shelf, the slope of the floor increases rapidly and forms the continental slope. The gradient of the continental slope may be as great as 45˚ but has an average slope of 25˚, and continues to fall for up to 3,000 to 4,000 m. The slope itself is quite irregular and may be eroded by river-like currents to form valleys and canyons.

Larger valleys are called **submarine canyons**. In South Australia off Kangaroo Island there exists deep cuts into the continental shelf (see previous page, Figure 11.2). These canyons can be as large as the Grand Canyon in America and possibly formed because of the action of an ancient river system. Canyons also trap sediments from the land and transport these to the ocean depths.

Continental rise

The slope in some areas then decreases to a gradient of 1:300, a very gentle slope. This area is called the **continental rise**. These areas still have the submarine canyons running through them.

In other parts of the world the continental slope may lead into deep V-shaped sea trenches (Figure 12.1) and can be up to 160 km long, 50 km wide and range in depth from 6,000 - 11,000 m.

Ocean floor

The deep **ocean-basin floor** begins at the foot of the continental margin, and makes up 70% of the ocean's floor area or 50% of the earth's surface. There are two main regions of the ocean- basin floor - the abyssal plain, and the abyssal hills.

Abyssal plains are as flat and as smooth as a skating rink and have a gradient of 1:10,000, and cover extensive areas. All oceans contain abyssal plains and these are interrupted by mountain chains or hills called **abyssal hills**. These are rounded, smooth and can reach up to 300 m high and 3 km wide. These areas contain less sediment than the abyssal plains.

Mid-ocean ridges

The **mid-ocean ridges** occur in all the major oceans and make up 23% of the earth's surface. They are mountain chains up to 1,000 km wide in places and mostly occur, as the name suggests, in the middle of the oceans. These ocean mountain ranges have only been discovered in the last 50 years and because of their vast nature and their great depth, only a small percentage of their area has been studied.

The law of the sea

A knowledge of subsurface geology of the continental slope allows us to claim the resources of our continent under the 1982 international Law of the Sea Convention (UNCLOS).

Continental margin

Article 76.3 of this convention states that '*the continental margin comprises the submerged prolongation of the land mass of the coastal State, and consists of the sea-bed and sub soil of the shelf the slope and the rise*.

It does not include the deep ocean floor with its oceanic ridges or subsoil thereof'.

Figure 13.1 identifies the edge of the rise as the approximate area that Australia can claim but there is a continent - ocean transition region that extends from the edge of the rise to the foot of the slope.

Sediment aprons often cover this area making it difficult to accurately define our border with say Indonesia or New Zealand.

Later in this chapter you will learn that the subsurface geology in this area was created by plate tectonics when two continents rift apart where the continental crust was thinned and stretched and magma created underground sills or lava flows over Australia's ancient surface.

Why study plate tectonics

The reason you are going to study plate tectonics is so that you can understand the need to:

- appreciate the difficulty in mapping our continent's borders;
- identify what undersea resources Australia can claim as its own; and
- prepare management plans for these resources by implementing our Oceans Policy, marine parks and protected areas.

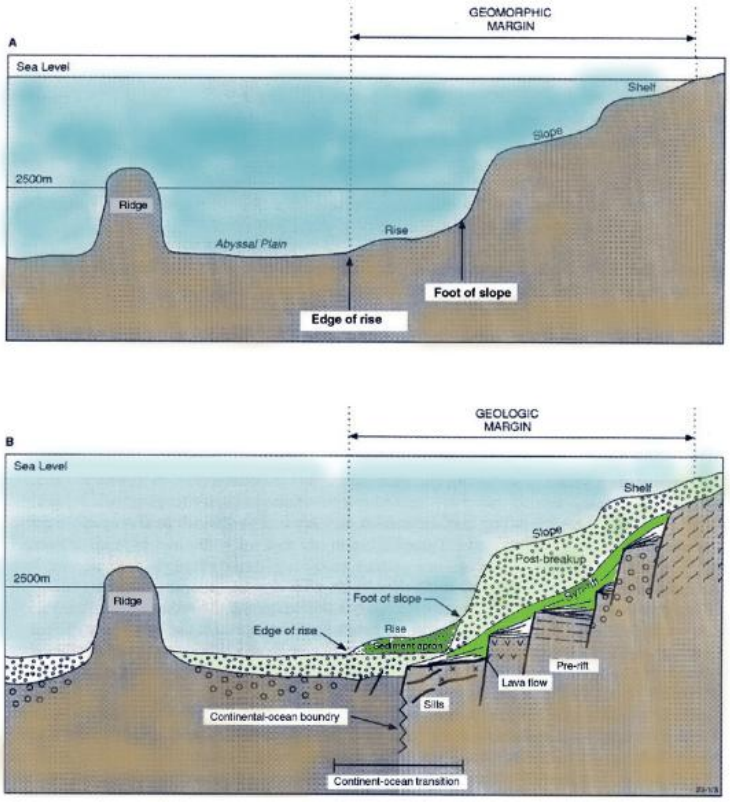


Figure 13.1 Effect of complex sub surface geology on application of UNCLOS in areas of extended continental shelf
(Illustration copyright Geoscience Australia, reproduced with permission)

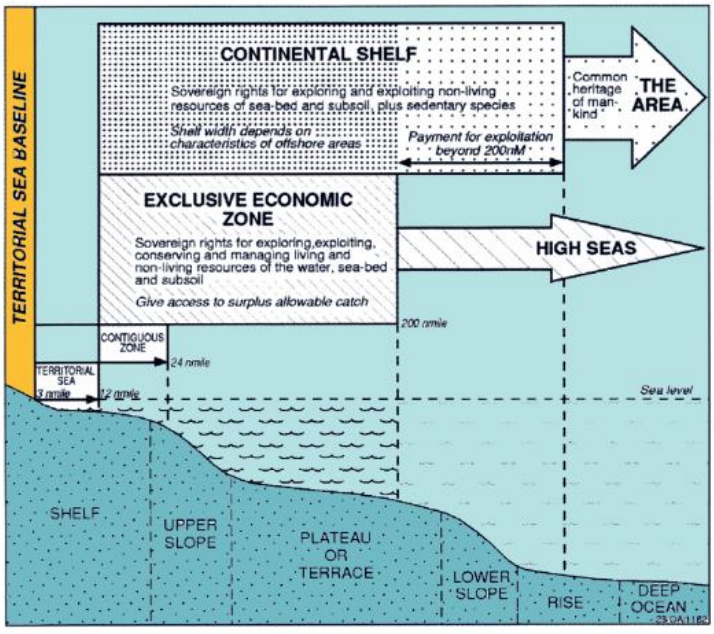


Figure 13.2 Maritime jurisdictional zones based on the United Nations Convention on the Law of the Sea 1982 (UNCLOS), linked to sea floor topography (Illustration copyright Geoscience Australia, reproduced with permission)

See page 435 for latest on Australia's seabed claim

The earth's crust

Composition and structure

The earth is composed of a number of layers (as shown in Figure 14.1). The crust ranges in depth from 10 to 33 km and the mantle and core approximately 2,865 kms and 3,473 kms respectively.

Crust

Crust is more dense* than mantle and so "floats" on the mantle (Figure 14.2).

Continental crust is composed of light coloured, low density granitic types of rock called sial (that's made up of silica and alumina - see page over Figure 15.2).

Oceanic crust is composed of dark coloured high density basaltic rock called sima (that's made up of silica and magnesia). Now oceanic crust is made of three layers A, B and C as shown in Figure 14.3.

- A is sediment formed from materials eroded from the land and comprises parts of the continents that are submerged called continental shelves.

  As the shelf approaches the deeper ocean, the angle increases to about 5 degrees. At this stage it is classed as the continental slope.
- B is mixed with lava and sediment.
- C is made up of basalt.

Note*

Density is the number of grams of substance (its mass) that is found in a given volume (in cubic centimetres). Less dense substances float on top of more dense substances.

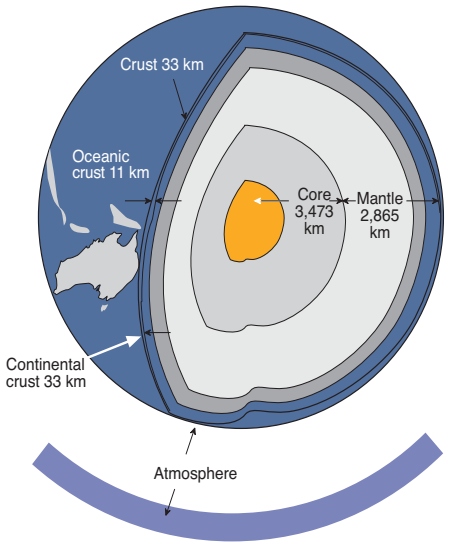


Figure 14.1 The composition of the earth
(Illustration Bob Moffatt)

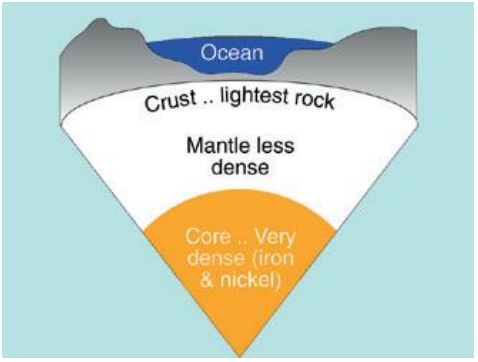


Figure 14.2 Section of earth
(Illustration Bob Moffatt)

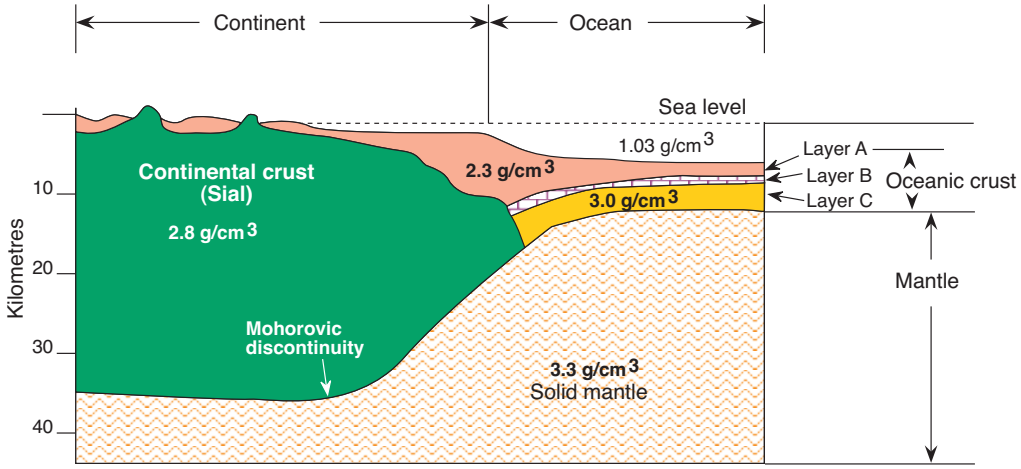


Figure 14.3 Cross-section through oceanic crust
(Based on an original drawing by Bob Moffatt)

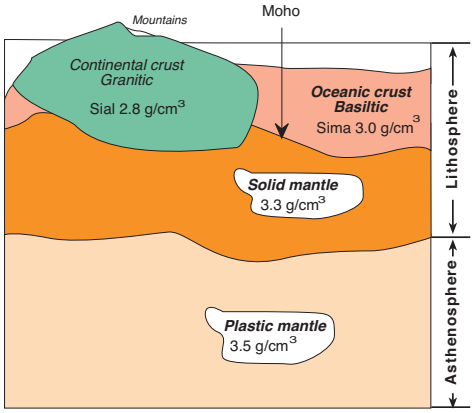


Figure 15.1 Composition of lithosphere and asthenosphere
(Illustration Bob Moffatt)

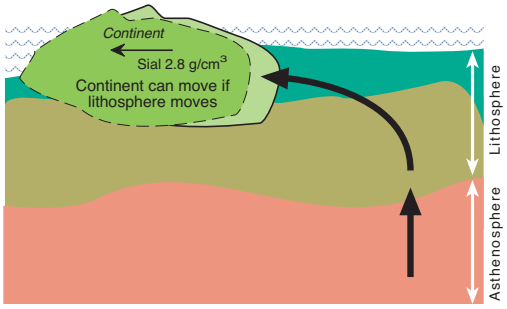


Figure 15.2 Lithosphere and asthenosphere movements
(Illustration Bob Moffatt)

Mantle

The **mantle** is made up of solid and plastic parts, each with different densities (Figure 15.1).

Lithosphere

The crust and uppermost mantle are relatively cold compared to the core. They are called the lithosphere. It is brittle and cracks and fractures when subject to large forces from within the earth.

This comprises the continental and oceanic crust as well as the solid mantle and is a layer of cool and relatively rigid rock.

Asthenosphere

Below the lithosphere is the asthenosphere, which is hot enough and under sufficient pressure to flow. It contains magma which we see on the earth's surface as lava.

It comprises the plastic mantle having a density of 3.5g/cm and is a zone of weakness.

Movement

Constant pressures from inside the Earth cause the lithosphere and asthenosphere to move as is evidenced by earthquakes.

Understanding these movements has lead scientists to discover that continents can move from place to place on top of the mantle as shown in Figure 15.2.

The study of the movements of these layers has lead to the discovery of continental drift and how life on Earth evolved.)

Questions

1 Explain the principle of the echo sounder used to determine the depth of water in an area.

2. Draw a labelled diagram of the ocean floor. Suggest a reason why the continental shelf is normally flat.

3. Distinguish between the terms asthenosphere and lithosphere. Draw up a table to define the terms and illustrate them with a diagram.

4. How much of the earth's surface is made up of deep ocean basin floor? What are the two main regions of the deep ocean basin?

5. Compare the slope of the continental slope and the continental rise.

6. Describe the submarine canyon appearance. Where are they found and how may they have been formed?

7. Explain how the bathyscape, Trieste was able to descend into the depths of the ocean.

8. Draw a diagram of a cross-section through the earth showing its composition and structure.

9. Compare sial and sima. Why will sial float on sima?

10. Discuss the link between of the Law of the Sea 1982, plate tectonics and what Australia can claim as its own territory.

Figure 16.1 Mt St Helens.
(Photo courtesy AAP, reproduced with permission)

Oceanic crust movements

In 1980 Mt St Helens volcano erupted with the force of a hydrogen bomb and in 1990 the Newcastle earthquake shook Australia. These events are connected and a study of the layers of the Earth reveals answers to why these catastrophic events occur.

The Earth has a red hot core which contains radioactive materials, which cause enormous heat. This heat expands upwards and moves towards the surface. As it cools it sinks and returns to the centre. This rising and falling sets up convection currents which cause the lithosphere (crust and upper mantle) to move.

Because of the Earth's gravitational force and depth, extreme pressure causes great heat which is lost from the crust at fracture zones.

This can be either in volcanoes or mid-oceanic ridges (Figure 16.2).

Mid ocean ridges

Oceanic ridges are found in the middle of ocean some 2-3 km deep. *(We would expect that the middle of the ocean would be the deepest. In fact the average depth of oceans is about 4-5 km).*

The two most famous are the mid Atlantic and mid Pacific ocean ridges and a search of any of these two names on the internet will show any number of U tube videos explaining the significance of these.

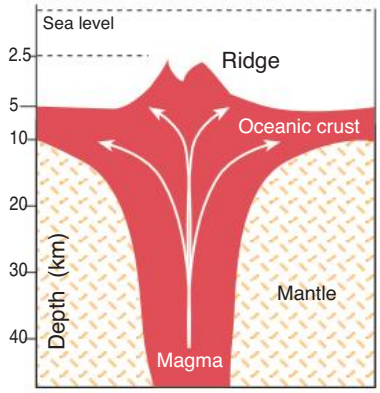


Figure 16.2 Mid ocean ridge events
(Illustration Bob Moffatt)

Ocean plates

Ocean plates are the area of crust which moves in the lithosphere and as they move outwards from ridges, anything on them such as islands or continents, moves as well.

Consider an island moving on a plate as shown in Figure 16.3. When the island is near the mid oceanic ridge it will be out of the water. As the plate moves and the water over the plate becomes deeper, the island will become submerged.

The video *Volcanoes,* has excellent footage on oceanic crust movements. **Available** from click view http://www.vea.com.au

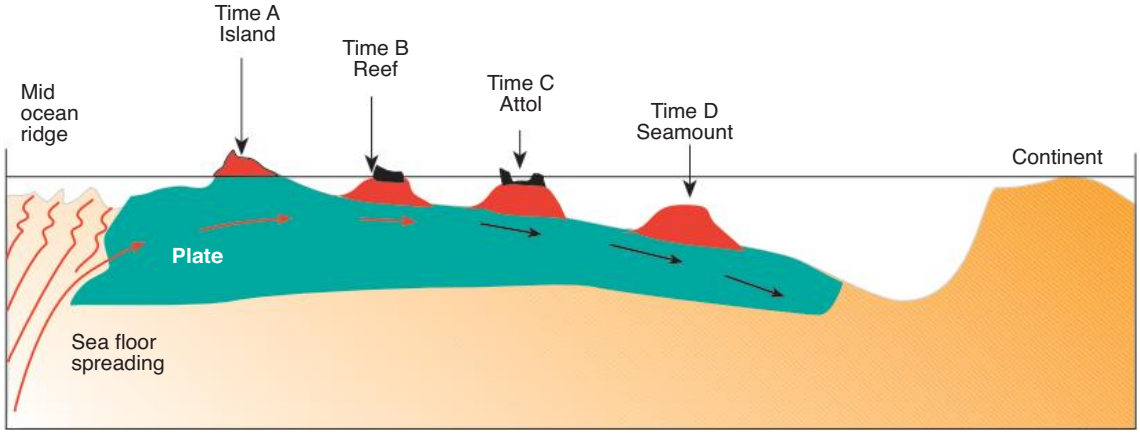


Figure 16.3 Forces from inside the earth move the lithosphere
(Illustration Bob Moffatt)

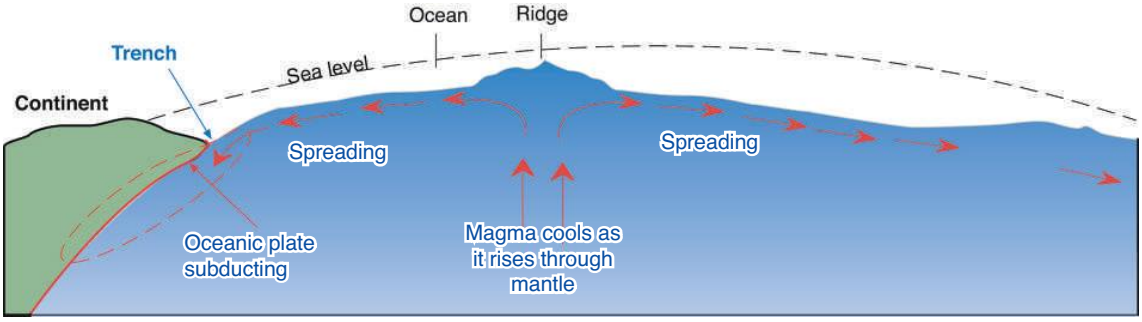


Figure 17.1 If an oceanic plate has an island on it, as it moves it eventually can become a sea mount.
(Illustration Bob Moffatt)

Plates move and must go somewhere so it is in the **trenches** that they disappear or **subduct** as shown in Figure 17.1 . The movement causes friction, resulting in earthquakes and volcanoes (Figure 17.2) .

The Newcastle earthquake and the eruption of Mt St Helens were both caused by the movement of the Pacific plate. If we study the incidences of earthquakes from 1963 in the Pacific region, a pattern emerges as shown in Figure 17.3.

Island chains

If we look at the island chains in the Pacific we can see that they form in a certain way. Mt Kilauea on the island of Hawaii, is an example of how these islands were formed.

The source of the magma remains constant, and as the plate moves over the hot spot, the island forms (Figure 17.4). Mt Kilauea is not a dangerous volcano and people can walk up to the crater and watch it erupt.

It can be seen that the other islands in the Hawaiian group have been formed in this way. One of the most famous Ohau, has a north shore famous for large surfing waves.

Other island chains in the Pacific have been formed this way. Western Samoa has very flat volcanic cones. The islands of Fiji, Tahiti and Tonga all formed from volcanoes.

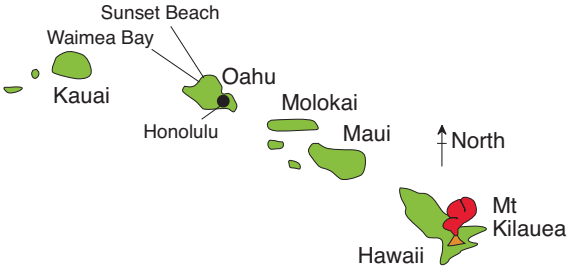


Figure 17.4 The Hawaiian islands have been formed by the plate moving over a hot spot. Why is the new vent of Kilauea always at the South Eastern end of the island?
(Illustration Bob Moffatt)

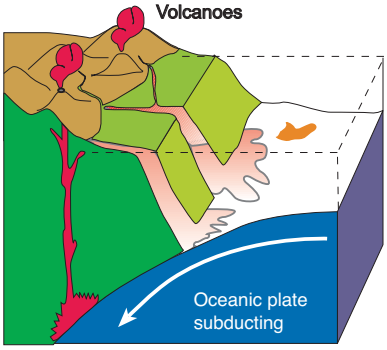


Figure 17.2 Subduction of oceanic plates causes volcanic action.
(Illustration Bob Moffatt)

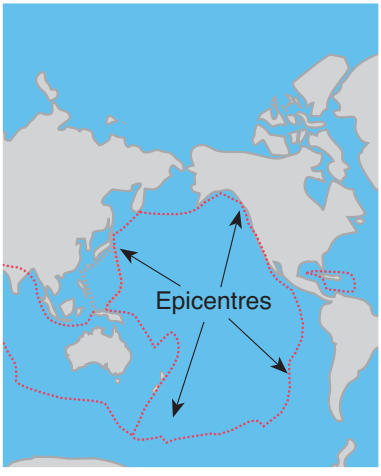


Figure 17.3 Records of earthquakes, 1961 - 67. Each dot (30,000 in all) represents a point on the earth's surface directly above an earthquake.
(Illustration Bob Moffatt)

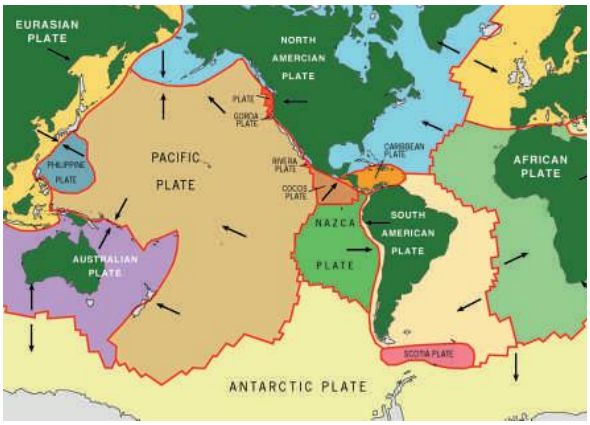


Figure 18.1 The plates of the world today
(Illustration Bob Moffatt)

Figure 18.3 Mountain building in Doubtful Sound New Zealand
(Photograph Bob Moffatt)

Figure 18.4 Franz Joseph Glacier New Zealand
(Photograph Bob Moffatt)

When plates move

Over the past 20 years a great worldwide system of cracks in the oceanic and continental crust has been mapped and interpreted.

These cracks break the lithosphere into plates as shown in Figure 18.1. The Australian plate is moving north at a rate of 2 cm per year or the rate at which your fingernail grows.

We know that when plates move, they take with them all the continental crust they carry. So what happens when they collide and spread?

When plates collide

When two plates collide the continental crust they carry is pushed up into mountain ranges as shown in Figures 18.2 and 18.3.

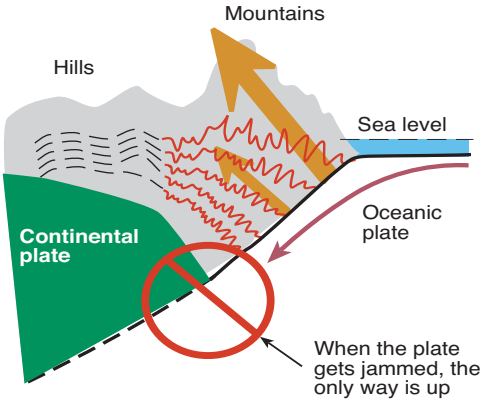


Figure 18.2 Mountain building occurs when two plates get stuck
(Illustration Bob Moffatt)

The Great Dividing Range and mountains in Victoria and South Australia resulted from the Australasian plate colliding with the other plates in our geological history.

Subduction

After collision and mountain building, plates can move under each other in a process called **subduction**.

Erosion and glaciation

The shaping of mountains and coastlines is affected by many forces. **Glaciation** is one such force resulting in enormous erosion of mountains causing deep cuts.

Major glaciers occurred in New Zealand's South Island resulting in fiords (Figure 18.3 and 4). The **fiords** or sounds are so deep that large ocean liners cannot anchor when they bring in tourists.

Evidence for the movement of the plates

Some evidence for the movement of the plates include:

- The fact that most of the earth's earthquakes originate in the areas where the plates collide.
- The ocean floor in the area of the ocean ridges has very little sediment built up on them. This is the area where the ocean floor is spreading and the new crust is being formed.
- Continents have been measured to be moving apart at the rate of 3 cm per year. Scientists have used laser beams to accurately measure the distance between two points either side of the ridge. These measurements were taken in Iceland where the mid-oceanic ridge is above sea level.
- Volcanic island chains of the Pacific show movement of the ocean's floor. When the new crust is being produced at the mid-oceanic ridge, a volcano can form. This volcano will then tend to be pushed away from the ridge and a chain of volcanoes may form over millions of years.

Figure 19.1 Effects of an earthquake
(Photo University of Hawaii MOP program. Thanks Sherwood Maynard and Frank Pottinger)

When plates spread or slip

As one boundary of an oceanic plate is pushed downwards into the asthenosphere by subduction, new oceanic crust is being formed at the opposite end by magma rising from the asthenosphere.

The process is called **sea floor spreading**.

Great cracks can form on the ocean floor and the hot magma pushes up the floor to a ridge (steep slope) or a rise (gradual slope). Transverse faults can occur as plates tend to break into two sections (see Figure 19.2). These can then slide past each other. However great pressure tends to build up and people living on the San Andreas Fault in California regularly experience earthquakes as a result of this pressure buildup (Figure 19.3).

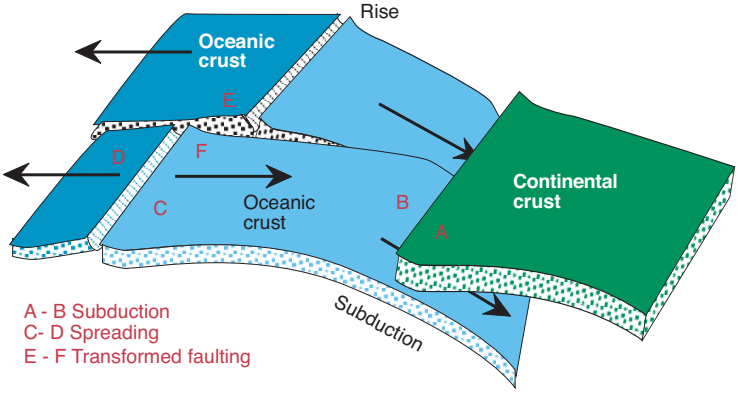


Figure 19.2 The movement of the oceanic crust showing: Subduction (A and B) — one plate beneath another; Spreading (C and D) — two plates are pushed apart; Transformed faults (E and F) two plates slide past each other.
(Illustration drawn Bob Moffatt after Hawaiian Marine Program, thanks Barbara Clemm and Francis Pottinger)

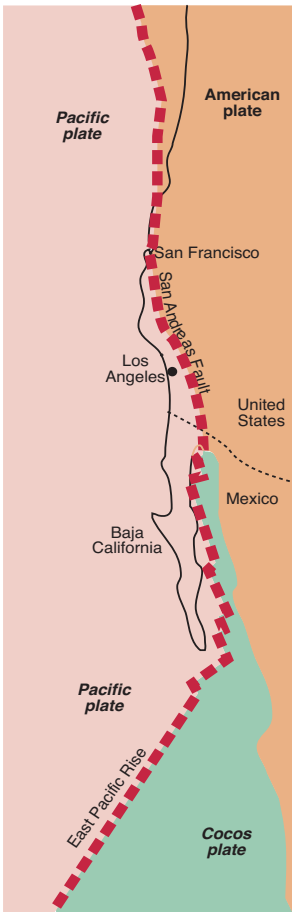


Figure 19.3 San Andreas fault
Illustration Bob Moffatt

Australian crust

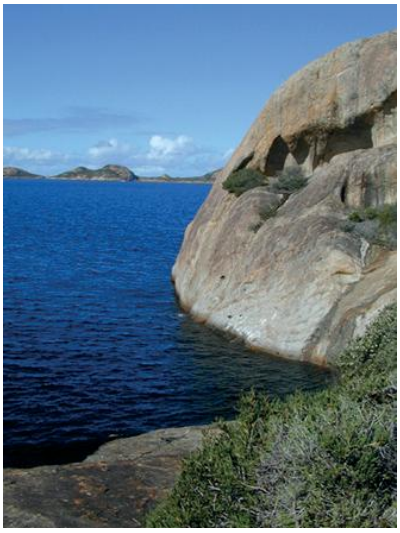


Figure 20.1 Some of the oldest rocks in Australia can be found in Albany
(Photograph Paula Moffatt)

3000 million years ago

Little is known of the shape of the earth before 3000 million years ago, however it is possible to describe the development of blocks of crust as they appear. From a study of these blocks it can be seen that Western Australia was formed first followed by South and North Western Australia with the Eastern States with Tasmania last.

If you live in Western Australia you could say that geologically, you live in one of the oldest places on Earth.

2500 - 1000 mya

Figure 20.2 shows what Australia could have looked like some 2500 million years ago based on evidence from the different blocks.

As the early crustal blocks twisted and fused together, larger forces from within the earth were moving them about.

Tearing at the newly formed crust over millions of years, other blocks of rock moved. To the north the Kimberly, Pilbra formed, while in the south were the Yalgam and Gawler blocks.

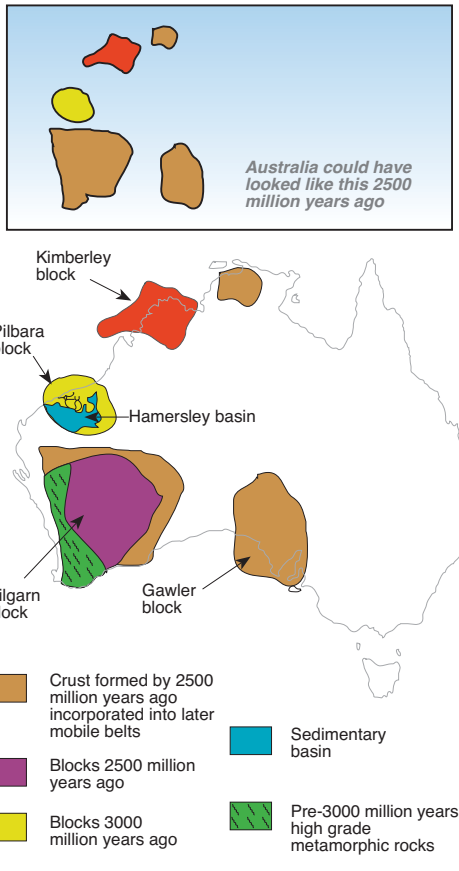


Figure 20.2 Australia some 2500 million years ago
(Illustration Bob Moffatt After Perspectives of the Earth, Australian Academy of Science 1983)

1000 - 400 mya

By 1000 million years Australia was still fused with India, Africa, South America and Antarctica into one super continent called **Gondwana**. A second continent, **Laurasia** was separated from Gondwana by the **Tethys Ocean** (Figure 20.3)

Note on Geological time

The Paleozoic Era, which ran from about 542 million years ago to 251 million years ago, was a time of great change on Earth. The era began with the breakup of one supercontinent and the formation of another. Plants became widespread. And the first vertebrate animals colonized land.

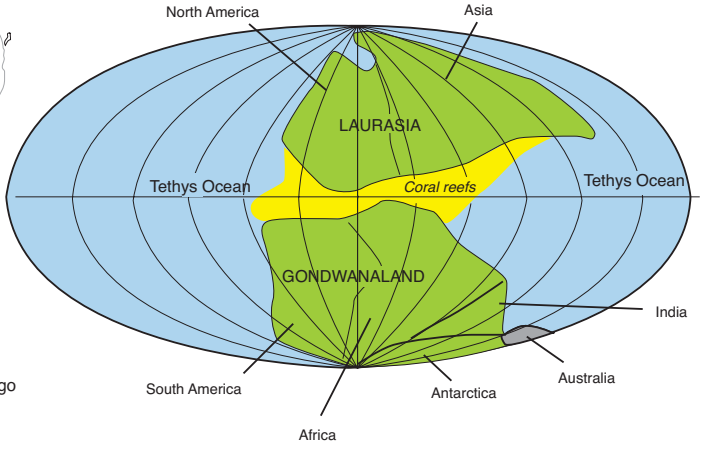


Figure 20.3 Australia some 1000 million years ago
(Illustration Bob Moffatt After Perspectives of the Earth, Australian Academy of Science 1983)

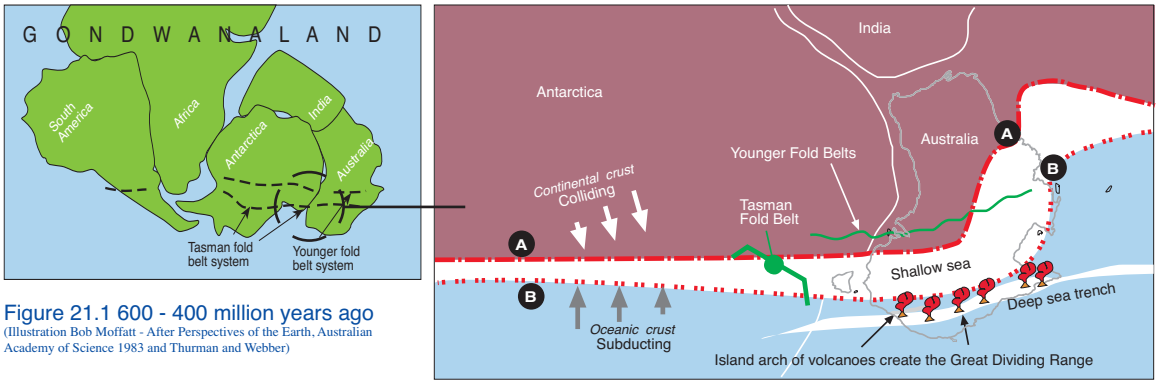


Figure 21.1 600 - 400 million years ago
(Illustration Bob Moffatt - After Perspectives of the Earth, Australian Academy of Science 1983 and Thurman and Webber)

400 mya

During this time (the Paleozoic) ancient seas teamed with the earliest marine life and by about 400 mya a marginal sea flowed through much of Australia as shown in Figure 21.1.

By this time two thirds of the Australian crayton had formed and was joined to a super continent called **Gondwana**. During this period an oceanic plate was subducting under what now is South Australia and a marginal sea lay between it and an island chain which was to become the Great Dividing Range. To the east of this volcanic range lay a deep ocean trench with oceanic crust subducting in the Tasman Sea area, as shown in Figure 21.3). To the south Tasmania was splitting from Antarctica and a new deep sea trench was forming.

Gradually, the continental plate containing the old craytons now fused in Western and South Australia, collided with the subducting plate as shown along the lines AA and BB in Figure 21.1 above.

The **shallow sea** was uplifted and could have become the rolling hills west of the great divide. The volcanoes of the arch crumbled as sedimentary rocks from the deep ocean trench were thrust into the old mountain range.

This created two **fold belt systems** as shown in Figures 21.3 and 21.2. The earlier contributed much to what is now South Australia and the other to the formation of eastern Australia.

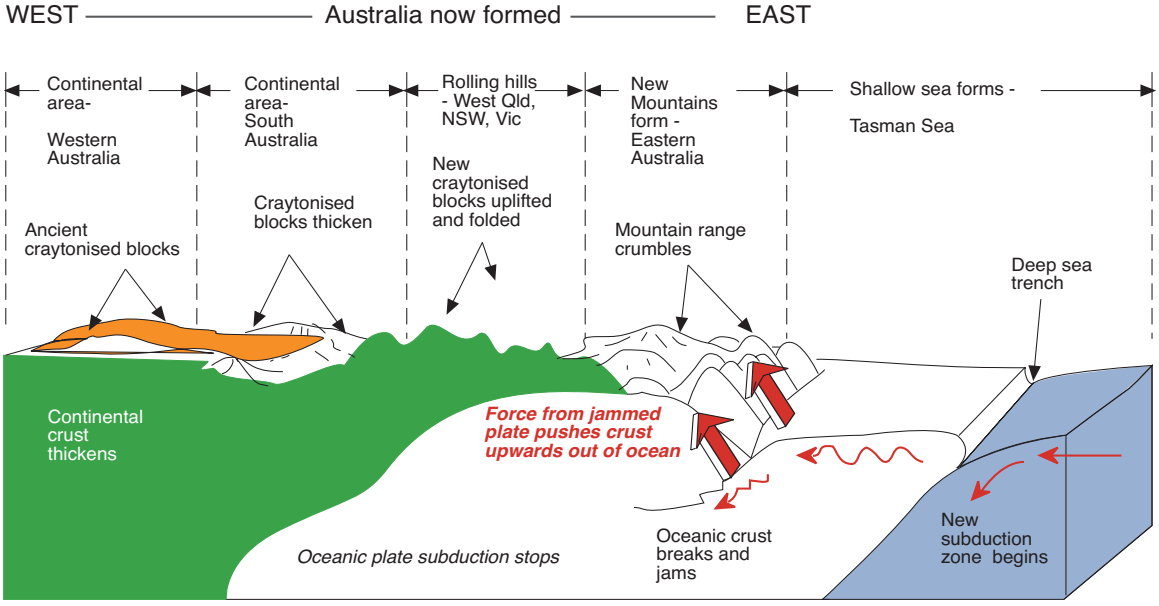
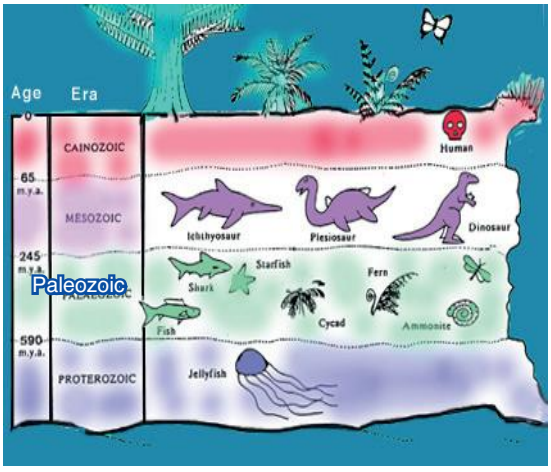


Figure 21.3 Australia in Gondwanaland 600 - 400 million years ago
(Illustration drawn Bob Moffatt, after Wilmont and Stevens 1988)

Sediments

Sediments ran off and covered areas in a deep trench which was later to be uplifted out of the sea to form coastal zones east of what now is the Great Dividing Range. The shallow sea had ancient reefs now found in the Kimberly (Figures 22.1 and 22.5)

This shallow seas also contained paleozoic animal and plant life which can be seen in road cuttings at many places in Eastern Australia (Figure 22.3) and formed the rich coal deposits of eastern Australia Figure 22.6. The old craytons rich in minerals were deformed into the rich mining deposits of Western Australia (Figure 22.2)



(Illustration Queensland Museum)

Figure 22.3 Geological time as seen in a road cutting

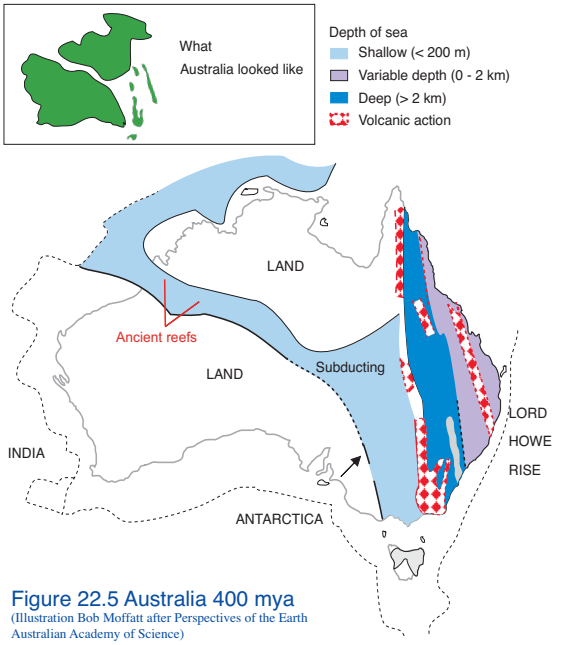
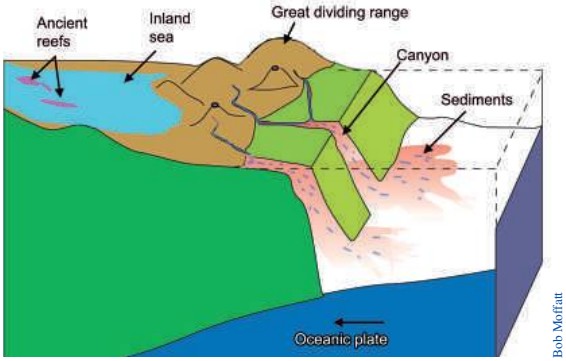
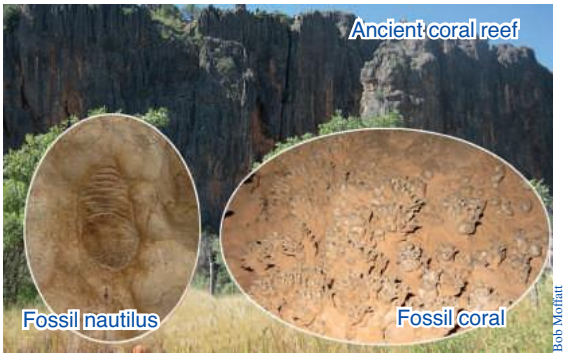


Figure 22.5 Australia 400 mya
(Illustration Bob Moffatt after Perspectives of the Earth Australian Academy of Science)



Bob Moffatt

Figure 22.1 Ancient reefs



Bob Moffatt

Figure 22.2 Winjana George in WA has ancient reefs

Bob Moffatt

Figure 22.4 Cliffs of the Great Australia Bight which were once joined with Antarctica

Mining Australia)

Figure 22.6 Shallow seas contained plant life which decomposed to form coal basins in Eastern Australia .

Geological time

So far we have discussed the precambrian and paleozoic eras as shown in Figure 23.1.

We have also learnt that plates can move around the earth's surface, so it seemed reasonable to assume that the continents on which they had formed could move also.

Figure 23.2 and the discussion below, shows what happens next in the formation of Australia and more importantly the formation of the reefs in the north.

220 mya

About 220 mya, the present continents were joined in the super continent Pangaea.

125 mya

At 125 mya India and Antarctica had separated. Australia was still joined to Antarctica but both had separated from most of the rest of the world apart from South America.

50 mya

By 50 mya Australia had began to separate from Antarctica and had begun its northern journey into warmer waters where it was later to rejoin with Asia.

The Great Australian Bight serves as a reminder of where Antarctica once was joined and the opening of the North West Shelf is where India was once joined.

As India separated from Western Australia a great rift occurred causing the Darling fault. These rifts also occurred in the Great Australian Bight, through South Australia and extending to the Great Ocean Road in Victoria.

50 mya to present

A series of ice ages engulfed the earth during this period. Of importance now to the study of marine science is the effects of different depths of water in the oceans.

When an **ice age** occurs, vast amounts of water become trapped in the polar ice caps and the depth of the ocean decreases. Shallow seas drain and land bridges form that allows movements of human populations as well as other animal and plant life.

These ice ages contributed to the development of present day Australian coastal landforms as well as offshore islands and reefs.

Geological Time Scale

Era	*Geological period*	*Approx time*	*Important events applicable to Australia*
Cenozoic	Recent	18 mya	Coral growth continental shelf
	Oligocene	35 mya	Specialisation of mammals, sediments flowed from rivers onto continental shelves
	Eocene	55 mya	Australian plate still moving north and fracturing
Mesozoic	Paleocene	70 mya	Expansion of mammals, coral sea forms, cato trough forms, foundations for Bowen Basin laid down
	Cretaceous	140 mya	Dinosaurs became extinct, Australia still joined to Antarctica
	Jurassic	200 mya	First mammals and birds
Paleozoic	Triassic	230 mya	First Dinosaurs
	Permian	285 mya	Expansion of primitive reptiles
	Carboniferous	350 mya	Expansion of sharks and fish
	Devonian	400 mya	First Insects
	Silurian	430 mya	First land plants
Precambrian	Ordovician	500 mya	First fish
	Cambrian	600 mya	First marine invertebrates
	Precambrian	4600 mya	The beginning of life in the Sea

Figure 23.1 Geological time scale

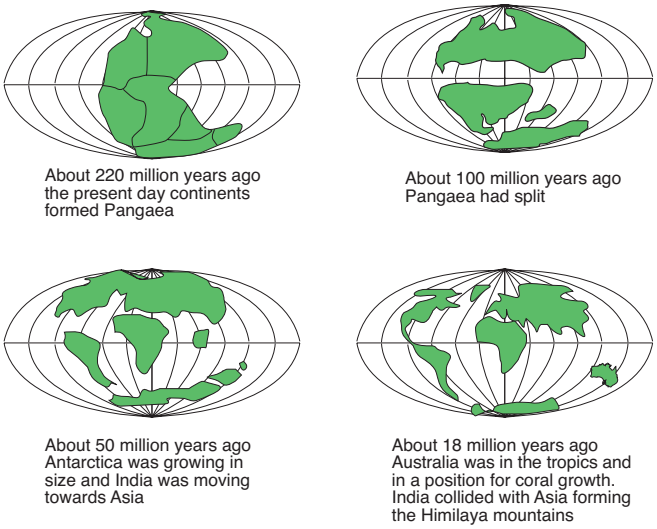


Figure 23.2 Australia 220 - 13 mya
(After Perspectives of the Earth, Australian Academy of Science 1983)

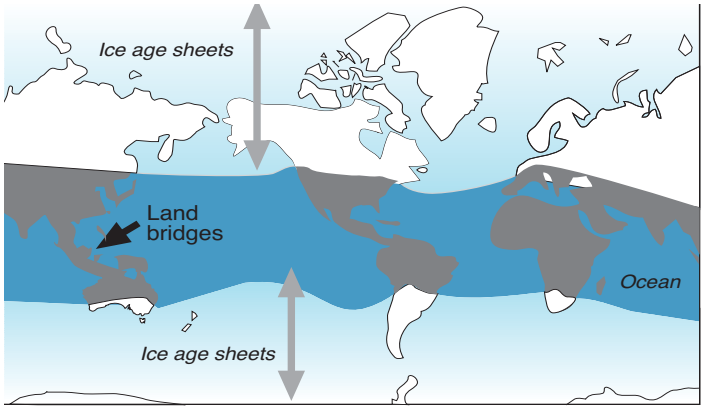


Figure 24.1 Ice age oceans were shallower than todays
(Illustration Bob Moffatt)

Offshore islands and reefs

18 mya

The sequence of events that started the reef's growth began almost 18 million year ago as Australia was at a latitude that promoted coral growth at a rapid rate (Figure 24.1).

As the sea levels rose corals began to grow in large numbers, forming reefs on the outside of the continental shelf (Figure 24.2 A and B).

The sea level gradually rose and with it the corals grew. There were still mountains and plains on the continental crust as the age of the mammals increased and the Australian marsupials were evolving.

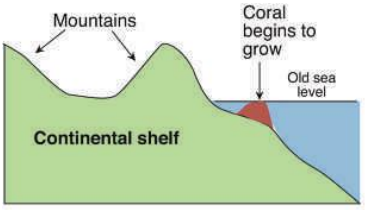
As the sea level rose, so did the reefs forming **fringing reefs** around the new islands and outer reefs on the edge of the continental shelf. Life abounded in the seas and the islands became separated by large expanses of water.

Populations of birds may have developed because of the absence of natural predators such as snakes or dingoes. Turtles could nest and form rookeries also with the absence of larger predators. Then followed a series of ice ages as shown in Figure 24.2C. Where ice formed at the poles it concentrated the water which meant that the sea level fell.

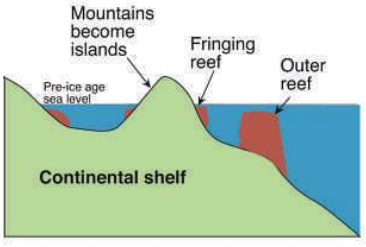
Although it is difficult to calculate, scientists believe this fall to be about 150 metres below the present sea levels. Continental shelf areas were now subjected to river systems and erosion. The limestone caves under and around old limestone cliffs were possibly the homes for our early Aborigines. Trees and shrubs grew and kangaroos hopped around. Figure 24.2D shows the build up of sediments from rivers. About 18,000 years ago ice caps from the last ice age began to melt and water level gradually rose.

With the rising waters more coral grew, forming a thin layer over the old fossil reefs. Gradually this layer increased to a thickness of 15 metres.

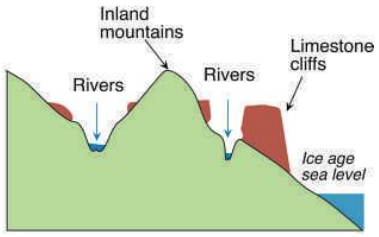
It is important to understand that the major part of a coral reef is non-living limestone and the living plants and animals only form a veneer on its surface.



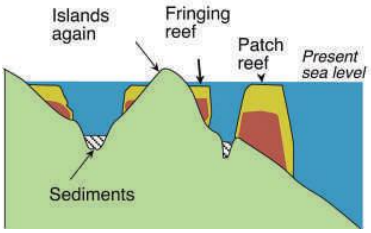
A. By 18 mya Australia was at the right latitude for coral to grow.



B. Corals grew upwards to pre-glacial sea levels forming reefs.



C. Glacial periods saw a drop in sea levels exposing the reefs to wind and rain. Rivers flowed in between accumulating sediments in and around reefs.



D. Present day reefs

Figure 24.2 Series of events leading to the formation of present day reefs.
(Illustrations Bob Moffatt, based on original drawings by GBRMPA)

Figure 25.1 A fringing reef north of Cairns
(Photograph courtesy Great Barrier Reef Marine Park Authority)

Figure 25.2 A coral cay
(Photograph Bob Moffatt)

Figure 25.3 A fringing reef in Ningaloo off Exmouth Western Australia
(Courtesy Department of Conservation and Land Management, W.A.)

On the reefs we see today are layers of new coral growth, about 15 metres deep, covering the old fossil reefs. Figures 25.1 (Fringing) and 25.2 (Patch), show the result of the reef building process.

Reefs off the west coast

Reefs formed off the coast of Western Australia in much the same way as just previously described. The shape of the continental shelf is different as are the ocean currents. The **Leeuwin current** is responsible for coral reef communities growing as far south as Perth, and the national parks of Ningaloo (Figure 25.3), Shark Bay, Abrolhos, Marmion, Swan Estuary and Shoalwater Islands give testament to this fact.

In their book "*Range to Reef*", the authors describe the evolution of the coastal zone as follows: *"Ten million years ago, the north west corner of Australia was covered by a shallow sea. Later the crust of the earth crumpled and a huge anticline rose to form Cape Range Peninsula. The back bone of the range is hard fossil bearing limestones, laid down on the sea-floor in those earlier times. The western side of the peninsula exhibits four distinct terraces. Fringing reef in Western Australia can be found as close to shore as 100 metres and as far out as a few kilometres (as illustrated in Figure 25.4)"*.

Barrier Reefs

Australia's barrier reefs are found off the coast of Australia from as far south as Carnarvon in Western Australia and Bundaberg in Queensland .

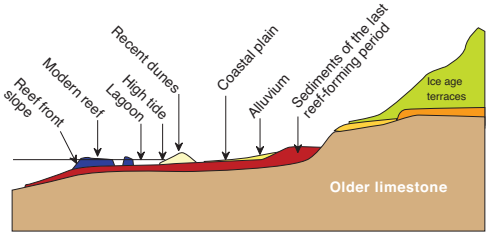


Figure 25.4 Diagrammatic cross section of the range to reef in Western Australia
(Illustration Bob Moffatt after an original drawing published by CALM)

The Great Barrier Reef is made up of approximately 2,900 individual reefs and is approximately 2,000 kilometres long. Visible from the moon, it is the largest single living thing on earth and is only a relatively recent geological event. Its history began many thousands of years ago as the Australian plate was moving northwards in its separation from Antarctica. As the coral polyp grows it secretes a limestone base called **corallite** which is the white coral skeleton seen when a coral colony dies. As the coral colony grows so does the size of the coral skeleton. Chapter 11 describes corals in greater detail.

Exercise 1.1 A matter of time

Based on exercises by Dave Read and Bob Moffatt, illustrations copyright Queensland Museum, reproduced with permission.

Ancient fish courtesy Queensland Museum

Materials

Three pieces of A4 paper taped together, pencil and ruler.

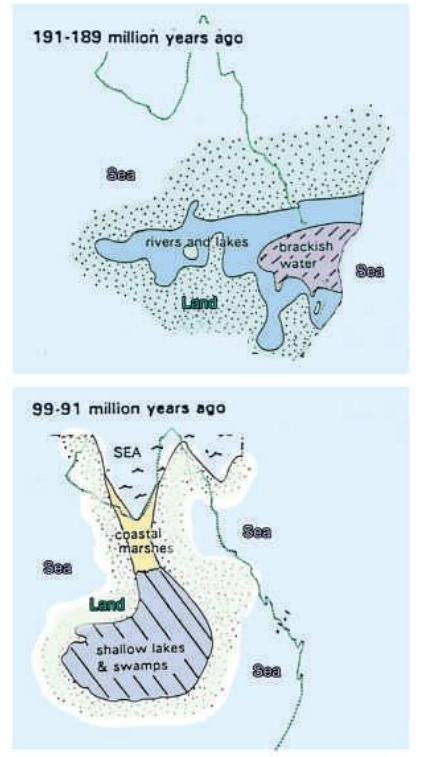
What to do

Part A: Follow the instructions to complete an earth time line

1. At the bottom left hand corner, write in the scale: 15mm = 100 my (million years).
2. Rule a line across the three sheets of paper, 80 mm down from the top. In the top half of the page write, "living events" and in the bottom half, "continental events".
3. Starting at 15 mm in, mark off lines at 15 mm intervals.
4. At the far left on the first mark, write earth begins, -4,600 my. Under the line write, earth congeals, solar system forms. Now mark off in 15 mm spaces writing the years -4,500, - 4,400, -4,300 until you get to...
5. -3,900. Then write "oldest known rocks, Greenland", continue.... to...
6. -3,400, write first life, Procaryotic bacteria.....
7. -3,000, write simple Blue green algae develop produce oxygen from photosynthesis.....
8. -1,400, write first anerobic blue green algae utilize oxygen, first Eucoroytic cells and multicelluar plants.
9. -1,000, write first sea jellies.
10. -700, write first sponges.
11. -570, write corals develop, sea levels are high covering North America, Africa and Australia.
12. Between -500 and -450, write ice age, sea level falls.
13. Between -450 and -430, write ice melts, water level rises.
14. Between -430 and -400, write jawed fishes evolve, sea level rises and Pangaea forms.
15. Between -400 and -350, write Amphibians evolve.
16. Between -325 and -300, write first pine trees, Reptiles evolve.
17. Between -280 and -250, write mammals evolve, Pangaea complete.
18. Between -190 and -150, write dinosaurs and birds evolve, Pangaea breaks apart, Africa and America break apart.
19. Between -150 and -130, write Europe separates from North America and Atlantic Ocean widens.
20. Between - 130 and -100, write Africa and South America separates.
21. Between - 100 and -50, write India separates from Africa, Antarctica and South America unlock. Dinosaurs die off.
22. At the -50 my mark, write Australia separates from Antarctica.
23. At the -20 my mark, write first coral reefs form off Queensland coastline.
24. At the 0 mark write todays date.

Part B: Using Figure 23.1, complete the three sheets of paper for the periods of geological time.

1. Use the table to find the times.
2. Rule lines down to mark the cut offs and write the periods in the spaces between the lines.



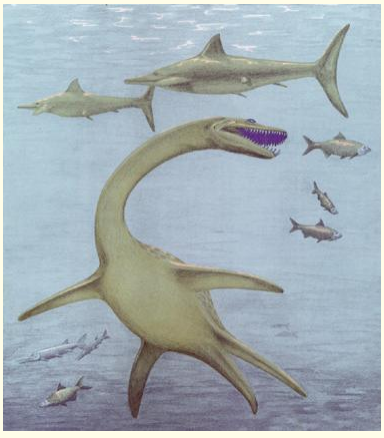


Figure 26.1 Marine reptiles inhabited much of Queensland between 200 and 100 mya when it was flooded by an inland sea.
Illustration courtesy Queensland Museum

The beginning of life - another view

(This is a story adapted from The Beginning of Life by Oodgeroo - in the book *Stradbroke Dreamtime*. Artwork by Joyce Summers).

In the dreamtime the earth lay sleeping and nothing grew or moved. All the animals and plants were under the earth.

One day a Rainbow Serpent woke up and pushed her way through the earth's crust moving all the stones in her path. She travelled a long way and moved a lot of big rocks as she went.

When she rested she left large imprints of where she had slept and when she had finished travelling she lay down to rest at the place she came out of the earth.

She then called out to the frogs in the earth below - "heh frogs come out of the earth".

Now the frogs were slow because they were full of water and the Rainbow Serpent tickled their stomachs.

When the frogs laughed water filled the earth in the places where the Rainbow Serpent had wandered. That's how the lakes and rivers came to be and in the places where she had rested and made a big imprint, that is where the oceans now lie.

Then the grass and trees began to grow and life began on earth.

All the animals, birds and reptiles awoke and followed the Rainbow Serpent across the land. Each had their own tribe - the bird tribes flew in the air, the fish tribes lived in the sea, the reptile tribes lived amongst the stones in the hills and the kangaroo and emu tribes lived on the plains.

Now the Rainbow Serpent made rules which the tribes were to obey but some became quarrelsome and were trouble makers and the Rainbow Serpent disciplined them warning them that if they continued to misbehave they would be turned into rocks and stone.

However those who obeyed her laws were rewarded and given human form. She also decreed that their children and their children's children shall be allowed to roam the earth for all time and it was theirs to manage and look after.

Well as time came to pass, those who broke her laws were turned into stone and became the mountains and hills and left to stand for all time to watch in punishment those with human forms roam the earth at their feet.

And those who obeyed her laws she gave a ***totem*** *of the animal, bird or reptile so the tribes knew who their ancestors were.*

The Rainbow Serpent set a very simple rule in order that none should starve. She ruled that no human should eat of his own totem so that there would be food for all. So if one of the human forms had a barramundi totem, he or she could not eat barramundi, but could share the totem with others.

So the aboriginal tribes lived together on this earth and fished in the seas given to them by the Rainbow Serpent.

Figure 27.1 Fish, turtle, crab and dolphin in a river
(Illustration by Joyce Summers)

Figure 28.1 *The Southern Surveyor*
(Photograph courtesy CSIRO)

Further information

www.csiro.gov.au

Then go to the marine division.

Wet Paper acknowledges the help that CSIRO has given us over all the years we have been publishing

Figure 28.2 The CSIRO Investigator
Bob Moffatt

Australian marine research

Australia's capacity to understand its marine resources and environment, and indeed the oceans supporting them, is linked to a range of observing options used by scientists. Satellites, moored and drifting instruments, commercial shipping and fishing vessels as well as land based facilities are all vital components of a carefully developed ocean-observing network.

CSIRO

CSIRO is Australia's Commonwealth Scientific and Industrial Research Organisation.

The organisation is one of the world's largest and most diverse scientific research institutions. Its work touches just about every aspect of Australian life: everything from the molecules of life to the molecules in space - finding ways to improve our quality of life and economic performance. Their 6500 staff perform research and development over a broad range of areas of economic and social value including marine science.

Geoscience Australia

Geoscience Australia is the national agency for geoscience research and geospatial information. Activities include:

- monitoring earthquakes and nuclear explosions and providing information on the earth's magnetic field for navigation, mineral exploration, geological dating;
- mapping the outer limits of Australia's jurisdiction under the UN Convention on the Law of the Sea ;
- studying the environmental impacts of hydrocarbons ;
- identifying new prospective basins in Australia's offshore territory and promoting them as areas for exploration;
- producing national geoscientific maps, data bases and information systems.

Australian Institute of Marine Science

The Australian Institute of Marine Science opened in 1970 in Townsville and has just completed a major revamp, with more than $17 million spent on infrastructure development in 2002.

Government agencies

Almost every State environmental agency will undertake research in the marine environment. For example all states have fisheries departments. Environment Australia also supports research by allocating research grants to Centres for Research and Development (CRC's).

Australian Universities and private companies

Almost every university in Australia conducts research into the marine environment or aquaculture. In 1970 subjects such as Oceanography and Marine Biology did not exist. Finally our nation has reversed this trend but there is a long way to go.

Private industry undertakes research areas such as fisheries, tourism, aquaculture, navigation or safety and the list could be endless.

Case study 1.1 Submarine canyons off southeast Australia

This article reproduced from CSIRO with permission

In 2001, CSIRO-run research vessel *Franklin,* a national facility, completed a geoscience research expedition off Tasmania. Chief Scientist, Dr Neville Exon of Geoscience Australia, the national geological survey organisation, said "We carried out seismic profiling east of Tasmania and sea bed sampling in three different areas, each addressing different research questions.

The **seismic profiles** revealed a cross-section through the Earth's crust several kilometres thick, and the cores and dredges gave information about various aspects of the geological history of offshore Australia as far back as the Age of Dinosaurs, seventy million years ago."

Among the data brought back by the expedition for further study were 1300 kilometres of seismic profiles, 30 samples of surface sediments, 25 cores of the strata just below the sea bed, and 10 dredges of ancient rocks.

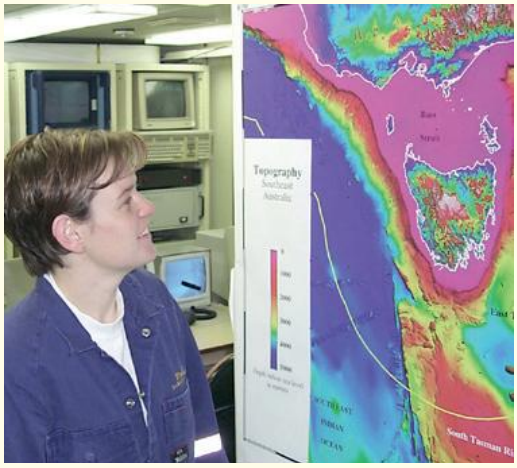


Figure 29.1 Ms Andrea Leach (PhD student) examining a sea floor map of the survey area to select suitable coring targets, *RV Franklin.*
(Photo courtesy Prof. Jock Keene, University of Sydney)

Of the eastern offshore margin of Tasmania Dr Exon said "This poorly known part of Australia extends 100 kilometres offshore with its outer limit 4500 metres deep, and is one-third the size of Tasmania. The margin supports a fishing industry and has some potential for petroleum, but our main aim was to better define its nature and its history since this part of Gondwana broke up 85 million years ago.

The Lord Howe Rise, now a sunken ridge extending from Lord Howe Island to New Zealand, was dry land east of Australia including Tasmania until it was rifted off. The cruise results show that, although the margin subsided steadily after its separation from the Lord Howe Rise, it was not covered by the thick blanket of younger sediment present on most of the world's margins. In fact, the submarine landscape sloping down to the abyssal plain would not be very different to that on dry land in Gondwana when the dinosaurs roamed the land," said Dr Exon.

"The granites, basalts, metamorphic rocks and sandstones familiar to many east coast Tasmanian are right there at the sea bed. Much of the sediment coming from the land has cut underwater canyons on its path to the abyssal plain, but some has been trapped in sedimentary basins that could have produced hydrocarbon deposits."

Figure 29.2 Launching a one tonne corer from the stern of RV Franklin.
(Photo courtesy Prof. Jock Keene, University of Sydney)

Of the cruise as a whole, CSIRO's on-board cruise manager Ron Plaschke said "This was my first geoscience research cruise and I was very pleased that we managed to get so much good work done. For me a highlight was the deployment of a one-tonne piston corer with a ten metre long sampling pipe from *Franklin* (Figure 29.2). I'll long remember the delighted smiles on the faces of the scientists when eight metres of Bass Lake sediments were cut up on deck. I understand that many thousands of years of climate change will be revealed by the core." Preliminary results were published by Geoscience Australia in 2002.

Questions/research

1. Describe what happened in this article.
2. Explain the terms *Gondwana, abyssal plain, metamorphic rock, hydrocarbon deposit, seismic profile*.
3. Examine illustration 13.1B on page 13. Now redraw the illustration and shade in where the *RV Franklin* probably was when seismic profiling was done.
4. How far does the eastern offshore margin of Tasmania extend?
5. Explain what type of data could be derived from the deployment of a one-tonne piston corer with a ten metre long sampling pipe.

Without sea bed habitat maps the ability to achieve sustainable and profitable ocean use is severely limited.

For example, activities such as sea bed trawling and mining that impact on the sea bed, if inappropriately located near vulnerable habitats (eg biologically diverse gardens of structural fauna), may jeopodise future fishing and tourism operations and biotechnology industries which rely on productive and intact sea bed habitats.

Sea bed habitat maps, and knowledge of the productivity and vulnerability of different habitat types, are therefore vital for multiple uses planning to maximise wealth-generating potential while minimising environmental impact. They are also necessary for environmental monitoring, to ensure that marine industries develop sustainably. Finally, sea bed habitat maps are needed to underpin decisions on a national system of marine protected areas that represent the different marine habitat types.

To answer these needs, marine scientists at CSIRO are developing world-leading techniques to rapidly assess sea bed environments. A typical habitat description includes maps of bathymetry (water depth), topographic relief, sediment (eg sand, mud), type and geological nature of substratum (eg rubble, sandstone, fossiliferous bedrock, calcareous reef). CSIRO has produced habitat maps of varying detail for 50,000 sq km of the Torres Strait, 15,000 sq km of the Great Barrier Reef, 64,000 sq km of the North West Shelf and 30,000 sq km of the south-east Australian continental shelf.

World leading rapid marine assessments

Satellite imagery can only be used to study the surface layers of the ocean (to depths of 20 m in clear water). Novel techniques are therefore required to probe to greater depths.

CSIRO marine scientists have been developing and using special acoustic tools to map the ocean floor to depths of 200 m. Computers record acoustic signals that are

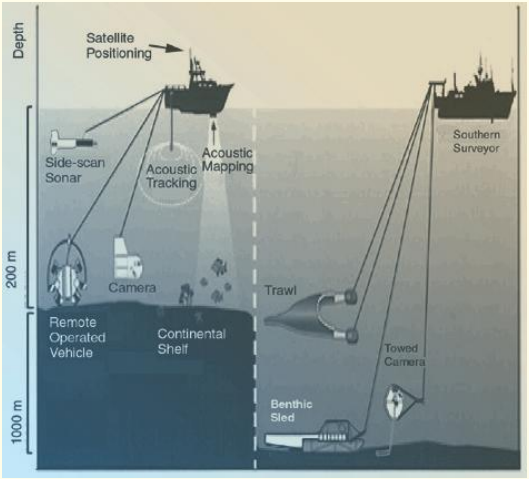


Figure 30.2 Survey methods
(Illustration CSIRO)

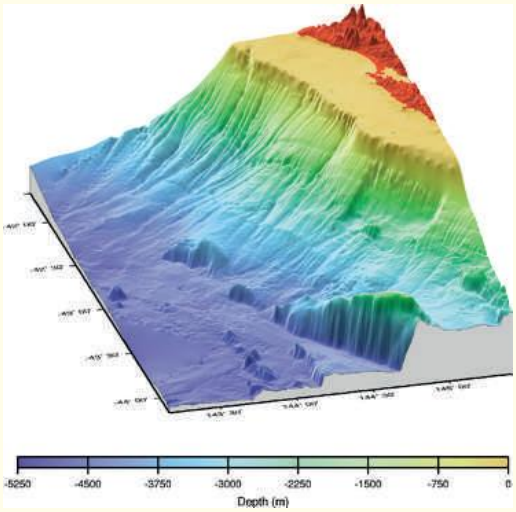


Figure 30.1 Data collected by Geoscience Australia
(Computer image courtesy Geoscience Australia)

bounced off the sea bed and return as high-frequency echoes. Over a continuous track, they record digital acoustic "signatures" of the sea bed. Sophisticated processing techniques and software use the shape of this signature to determine sediment type (e.g. sand or rock), and, potentially, whether there are attached plants or animals (e.g. seagrass, corals, sponges).

Together these tools allow scientists to rapidly form a picture of habitats across the continental shelf. Data from a 500 m strip of shallow sea bed habitat can be collected in 10 minutes. More than a dozen such site descriptions can be achieved in a day, and areas as large as 10,000 sq km can be mapped in 2-3 weeks. Using Geographic Information Systems, this data can be rapidly presented as maps.

Video taken in the field is subsequently analysed to provide detailed information on marine life. Species diversity is measured by sorting the dredge and grab samples. For sea bed habitats deeper than 200 m, wide-swath sonar is used by specially equipped vessels to generate large-scale topographic maps and more expensive while other specialised gear is needed to take samples and photographs of the substrate, sea bed structure, and attached and associated biota (including fish).

CSIRO scientists and instrument specialists have developed and adapted equipment to survey these deeper habitats. CSIRO has used a deep-sea camera system and designed and constructed a heavy-duty deep-sea dredge to conduct the first habitat surveys of the deep-sea (600-2,000 m) seamounts south of Tasmania (Figure 30.2).

Results of the survey lead to the declaration of Australia's first deep-sea marine protected area.

Case study 1.2 — Australia down under

The information in this case study has been supplied by CSIRO and Geoscience Australia and is reproduced with permission

Exploring the marine environment

Geoscience Australia, the national geological survey organisation, completed a significant phase of underwater mapping of the southeastern region of Australia in 2000.

The information collected provides important baseline data to support the development of a Regional Marine Plan for the South-east Region, and will be used by the National Oceans Office as a key component in the ecosystem-based oceans planning and management process. The bathymetric data collected are essential to understanding the unique biodiversity, shape and character of the ocean floor.

Using a multibeam (swath mapping) sonar system, Geoscience Australia has generated detailed bathymetric maps and images of the sea bed off southeastern and southern Tasmania and to the south of Macquarie Island, midway between New Zealand and the Antarctic.

The data collected by Geoscience Australia scientists on board the French survey vessel *L'Atalante* builds on information from past sea bed survey and mapping programs and will contribute to constructing a much more complete picture of the sea bed shape, character and biodiversity of Australia's southern seas.

Designed to complement existing sea bed survey information, this survey mapped the slopes of Lord Howe Island, the upper slope of the Bass Canyon off south east Victoria, the uppermost slope off south east and south west Tasmania, the volcanic seamounts south of Hobart, the Otway Basin off north west Tasmania and Victoria, and mapped the slope of the Great Australian Bight Marine Protected Area.

Additional data gathered by Geoscience Australia scientists during the voyage included:

- Seismic profiles showing the sedimentary strata to five kilometres below the sea bed, in the Gippsland, East Tasmanian, Sorell and Otway Basins;
- High resolution seismic profiles showing details of the strata immediately below the sea bed; and
- Variations in the earth's magnetic and gravity fields, which increase understanding of the nature of geological formations beneath the sea bed.

The results provided the National Oceans Office with a more detailed understanding of parts of the sea bed that will significantly increase scientific understanding of Australia's offshore marine environment.

Figure 31.2 shows some survey methods which enabled mapping the sea bed water depths from 300 to 5,000 metres.

There are still large expanses of the deep sea bed under Australian jurisdiction yet to be surveyed, but marine scientists now have some very detailed images of most of the sea bed of the southeastern continental slope. With additional work on the structure of the sea bed and below, and with dedicated sampling programs they can determine a great deal about its history, nature and character.

Mapping Australia's oceans

Australia has the third largest ocean territory in the world. This area promises wealth generation through mining, fishing, tourism and biotechnology, balanced by an obligation to conserve biological diversity. Geoscience Australia is using world-leading rapid assessment techniques to survey and map Australia's marine environments providing vital baseline information for sustainable use of the oceans.

Australia lays claim to 16.1 million sq km of ocean floor (including the 11 million sq km Exclusive Economic Zone or EEZ) from the coastal shallows to the deep sea.

Yet our knowledge of these areas is very limited. Only 1-2 percent of Australia's EEZ has been surveyed and mapped to show where the different marine habitats are. Even less has been mapped to show the type, distribution and vulnerability of life they support.

Questions

1. How could knowledge of the variations in the earth's magnetic and gravitational fields help our understanding of the formation of the sea floor?
2. In what way will these studies increase scientific understanding of Australia's offshore environment?
3. Define the terms *bathymetric data* and *sedimentary strata*.
4. To what depth can multi-beam sonar systems map? How much of the sea floor has been mapped by the methods described here so far?
5. Who should pay for this research if it is made public and commercial enterprises can be developed to this baseline research? Where has most of the exploration of the marine environment occurred?
6. Redraw Figure 30.2 and explain how each of the various pieces of equipment work.
7. What do you understand by the term — *sea bed habitat map* and why are such maps important?
8. What would a typical habitat description include?
9. Calculate the number of square kilometres that could be mapped in a month using the methods described in this article.

Exercises

From the Wet Paper Publication - *Oceanography Exercises*
See www.wetpaper.com.au

A1 What does the topography of the ocean look like?

A2 What part of the world oceans does Australia own?

A3 What major geological movements have occurred in Australia?

A4 What happened in ice age Australia?

A5 What is climate change and how does it affect the ocean?

Chapter questions

Knowledge

1. Who proposed the theory of continental drift? List some of the evidence to support the idea of continental drift.
2. What was the name given to the super continent when it was believed all continents were joined together?
3. When and where did ancient large marine reptiles inhabit Australia?
4. List the world leading techniques being developed by the CSIRO to rapidly assess sea bed environments.
5. What happens when the plate has a weak spot on it?
6. How fast is the Australia plate moving and in which direction are we moving?
7. Define the following terms: subduction, earthquakes, transverse faults.

Understanding

8. What are land bridges and how have they affected the distribution of animal species? Why did they not affect the distribution of plant species?
9. Draw a diagram of Australia 220 mya showing its nearest neighbours.
10. Describe the dust cloud hypothesis.
11. There are many marine fossils and coal deposits in Queensland. Suggest an explanation to account for their presence.
12. Draw a cross-section through oceanic crust to distinguish between oceanic and continental crust.
13. Explain how modern day reefs came to be in northern Australia.
14. Explain how the ocean plates are thought to move. How do mid ocean ridges form? Describe the age of rocks found at the midocean ridges.
15. Draw a diagram to explain the formation of volcanic island chains that are found in the Pacific Ocean.
16. Describe the Rainbow Serpent story and its significance for Aboriginal people.

Applying

17. Fossils of tropical plant species have also been found in the Antarctic. How do you explain the presence of these fossils?
18. Explain the glacial evidence that supports the idea of continental drift.
19. Use your knowledge of plate movements to explain the formation of the Great Dividing Range and the Kimberleys in WA.
20. Summarise the benefits of mapping Australia's ocean territory.

Analysing

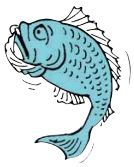
21. How can the discovery of mineral nodules on the ocean floor demonstrate that the sea floor is spreading?
22. Suggest why earthquakes occur more frequently in Los Angeles than in Sydney.
23. Similar fossils are found in Australia, South America and South Africa. Suggest what this may indicate.
24. Many mineral resources are being found in undersea surveys. Outline some of the problems that might surface in developing deep ocean mining. Suggest some environmental problems that deep sea mining might cause. Do you believe off-shore oil resources, if found around the Australian coastline should be exploited?

Creating

25. Compose a rap, poem or rhyme to illustrate the difference between an earthquake and a volcanic eruption in terms of plate subduction.
26. Build a model to explain the difference between mountain building and ocean building plates.

Evaluating

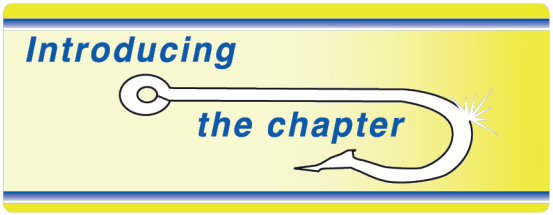
27. Research earthquakes in newspaper cuttings. Can you relate these to plate movements?
28. Extrapolate the question "What studies are necessary for environmental monitoring to ensure that marine industries develop sustainably?"
29. Outline the reasons why the deep sea environments should be protected. Who should be in charge of the policing of this protection? Suggest some policies that should be included in this protection document.
30. Outline the reasons for the need to study plate tectonics and the Law of the Sea declaration.



Chapter 2
Oceans and waves

by
Bob Moffatt and Tim Ryan

Photo Bob Moffatt



Chapter hooks

- Use the words "Jesse Martin sailing Australia" in your search engine. Is there still a record of his voyage in 1998? Has he made any voyages since?
- Watch the DVD *Waves in the Ocean* by Classroom Video (Available -www.classroomvideo.com.au)

Why study this chapter

The ocean

The ocean provides a place for transportation, recreation and employment. For marine life it provides many different types of habitats that are discussed more fully in later parts of this book.

Waves

As wind blows over the ocean it creates waves which travel for thousands of kilometres finally breaking on our shore. Waves can affect us in many ways providing us with recreation, employment and in some cases electrical energy. It is important to understand how waves are formed and how they change as they break on our coastline. This chapter provides a lead into Chapter 4 where this effect is discussed in detail.

The chapter also identifies 4 branches of oceanography as well as some careers in marine science.

Chapter overview

Oceanography 35
Oceans 36
Waves 39
Exercise 2.1 Wave calculations *40*
Exercise 2.2 The heights of waves *43*
Exercise 2.3 Satellite images *46*
Waves and coastlines 47
Effects of waves on beaches 49
Waves and marine life 50
Power from the sea 51
Climate change 52
Exercise 2.4 Waves in the ocean video *52*
Exercise 2.5 Beach field trip *53*
Exercise 2.6 Hypothetical Bay *54*
Exercises and questions *56*

Key concepts

1. There are four main branches of oceanography providing specialist jobs in marine science in either the government or industry.
2. An understanding of the physical processes that move the great ocean currents, and of the physical properties of the water bodies, is essential for an understanding of the patterns of marine life and for their management.
3 Localised seasonal upwellings of nutrient rich water occur in the waters off some Australian States.
4. Australian oceans are largely nutrient poor allowing seagrasses and coral reefs to dominate.
5. Wind-driven continental shelf waves affect inshore currents in most Australian States.
6. Waves have a number of mathematical characteristics which can be clearly defined in physics.
7. The energy in a wave moves forward but the particles in a wave move up and down in a circular motion.
8. Waves are formed in a fetch. The bigger the fetch and the stronger the wind, the bigger the waves.
9. As waves approach the shore, sand causes them to slow down and bunch up. This interaction with the sea floor can cause refraction or diffraction and sets up longshore currents.
10. Waves can have a pronounced effect on our coastline constantly shaping and eroding the shoreline.
11. Storm waves move sand off the beach and small waves put it back.
12. Waves that bounce back are called reflected waves. These can often be used in wave power stations. There are few places in Australia where we can utilize the power of reflected waves.
13. Tsunamis are large waves caused by undersea volcanoes or earthquakes.
14. A storm surge can cause waves to invade the land. This is usually caused by a low pressure system close to the coast.

Oceanography

Oceanographers are scientists who study the oceans.

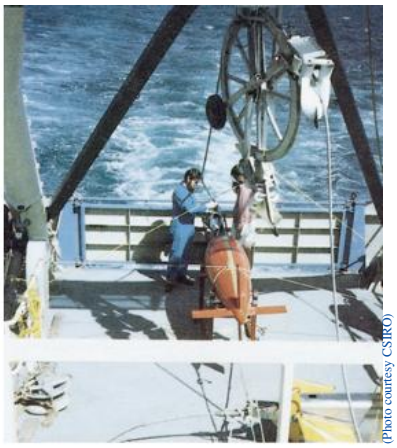
Only in the 20th century has the technology been developed to study the ocean and its depths. However, the enormous volumes and the depths of the oceans make oceanography a great challenge.

The study of the oceans involves four main branches.

- **Chemical oceanography** is the study of the chemical composition of the oceans, salinity and the amount of dissolved gases in the oceans.

  The marine scientists on the cover of this book are about to launch a series of water collection bottles that will collect water samples from a number of depths.
- **Physical oceanography** is the study of the oceans' buoyancy, temperature, the circulation of oceanic water (Figure 35.1) and light penetration.

  Physical oceanographers are very interested in the effects the depletion of ozone in the atmosphere has on the oceans as well as ocean currents, discussed in this chapter.
- **Geological oceanography** is the study of the ocean floor, features of the oceans' depths and coastal features. Careers in marine geology include working on offshore oil rigs relaying data to drilling engineers.
- **Biological oceanography** is the study of marine plants and animals. The marine biologist in Figures 35.2 is examining ballast water under a powerful microscope to identify species of marine plants that have invaded Australian ports. The marine oceanographer in Figure 35.3 is studying the effects of land pollution on seagrass beds. By using a series of sample sites as shown by the fenced off squares, they will make recommendations to planning authorities considering local coastal developments.



(Photo courtesy CSIRO)

Figure 35.1 Physical oceanographers launch ocean current meter

(Photo courtesy Queensland Fisheries)

Figure 35.2 Marine biologist identifies plankton

Careers

To become a marine scientist requires not only a basic science degree in marine biology from an Australian university, but many years of post graduate research and in many cases a PhD (Doctor of Philosophy).

There are however many jobs as marine technicians who work for marine scientists doing work such as collecting water samples, sorting marine sediment, photography, computer analysis, database input, building specialist equipment, designing remote sensing data or in the Navy.

Industry is keen to employ young graduates in the growing fields of **aquaculture** and marine **bioengineering**.

(Photo courtesy Queensland Fisheries)

Figure 35.3 Marine biologist maps a seagrass bed

Figure 36.1 Cape Leeuwin, WA where two oceans meet.
(Photo Bob Moffatt)

Oceans

From space, earth appears as a blue planet (because so much of it is covered by water) and could be called 'Planet Ocean'. However scientists know more about the surface of the Moon than the ocean. For example, we have been recording land temperatures for over 200 years, but only in the late 1950s were ocean temperatures first recorded in an organised manner.

Knowing about the oceans and their resources and origins, and how they interact with the atmosphere, will help us make wise decisions about how we use our planet.

Facts about the oceans

The oceans of the world cover 71 per cent of the earth's surface. The five major oceans are the Pacific (the largest and deepest), Atlantic, Indian, Arctic and Southern. Figure 36.2 shows that of all the water on the earth, over 65 per cent are oceanic - only 1 per cent is suitable for drinking.

These major oceans cover 362 million square kilometres and make up nearly 66 per cent of the earth's water. They are linked by bodies of water called seas and straits. Seas are small areas of salty water partially enclosed by land. Straits are narrow bodies of water connecting large water masses.

Other large masses include gulfs (long, narrow indentations or inlets extending far inland) and bays (wide indentations into a coastline).

If you have an atlas you can locate three major seas, three major bays, three gulfs and three straits on the Australian and New Zealand coastlines.

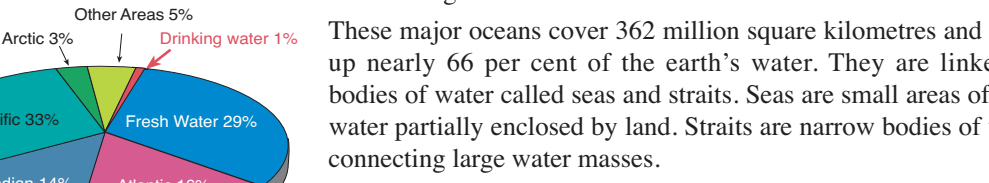


Figure 36.2 Distribution of the earth's water
(Illustration Bob Moffatt)

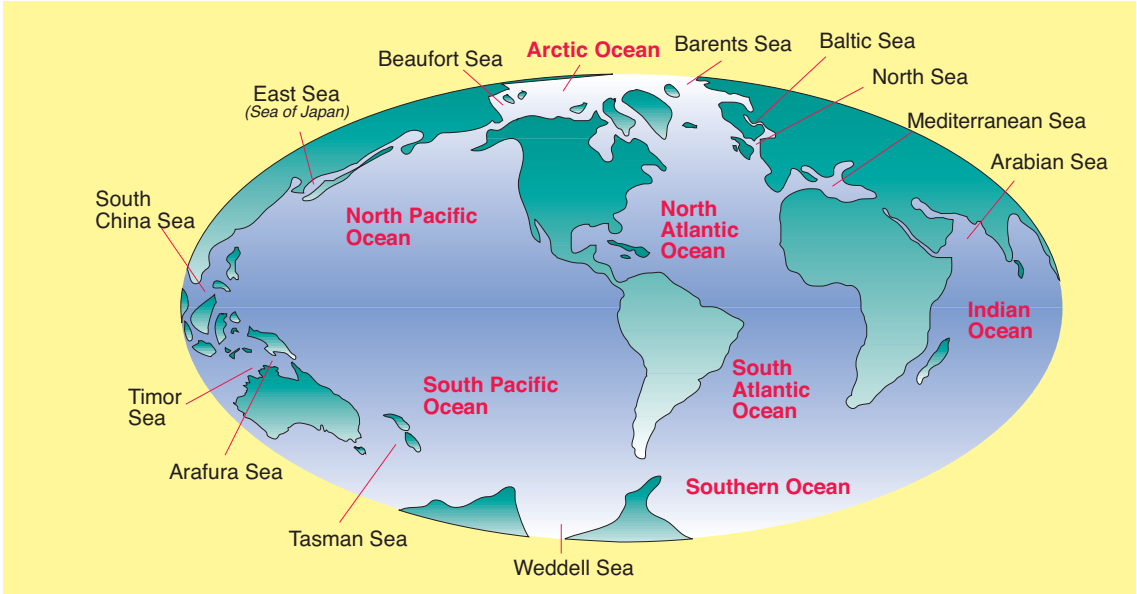


Figure 36.3 World oceans
(Illustration Bob Moffatt)

Australian oceans

(Information for this section from Chapter 2 The Ocean, SOMER 1996 report, adapted with permission, and based on a paper by Professor JH Middleton, Centre for Marine Sciences, University of New South Wales)

The waters surrounding Australia and its external territories are part of three large, interconnected ocean basins of the Southern Hemisphere: the Pacific, Indian and Southern (Figure 37.1).

The basic attributes of these large oceans which affect marine organisms are temperature (affects metabolism), salinity (affects osmoregulation, particularly estuarine species), depth (affects light absorption), currents (affects dispersal) and nutrients (affects plant production).

Temperature

Australia's seas encompass all five of the world's ocean temperature zones: tropical (25 to 31°C); subtropical (15 to 27°C); temperate (10 to 25°C); subpolar (5 to 10°C); and polar (-2 to 5°C). Surface waters in shallow waters can rise as high as 32°C and drop to 9°C in the southern ocean.

Salinities range from 34-35 parts per million but may be higher in shallow tropical water. (Chapter 6 discusses salinity.)

The properties of the upper ocean are controlled by incoming and reflected radiation, rainfall, river flow and evaporation, sea ice formation and melting, and winds, currents and tides.

The main thermocline (the depth at which the temperature changes most rapidly – see chapter 6), is around 500 metres while a second summer thermocline exists around 100 metres.

Convergences

The satellite image shown in Figure 37.2 represents the warm tropical waters from the Coral Sea and the more temperate waters from the Tasman Sea. The zone in between represents the **convergence zone** - the areas in which tropical and temperate waters mix and can restrict the distribution of marine species. For example the common coral banded shrimp (Figure 37.3) can be found in tropical waters. It is doubtful they would breed in cooler waters. Similar convergences occur in Western Australia and South Australia and have lead the formation of biogeographical regions (see Chapter 8, page 211).

Currents

The main ocean currents affecting the marine environment around the continent are the East Australian Current which brings warm equatorial and Coral Sea water down the east coast, and the Leeuwin Current bringing warm, low salinity water down the west coast.

These are not major currents by world standards. Other major ocean features are the sub-tropical and antarctic convergences. The periodic influence of the El Nino/Southern Oscillation has a great effect on ocean temperature and biological productivity, and on Australia's terrestrial climate and agriculture.

Similarly there are the periodic influences of strong winds and storm surges associated with tropical cyclones and mid-latitude low pressure systems.

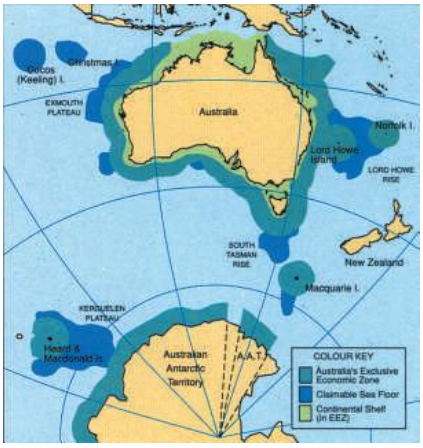


Figure 37.1 Australia and its oceans
(Illustration courtesy Environment Australia)

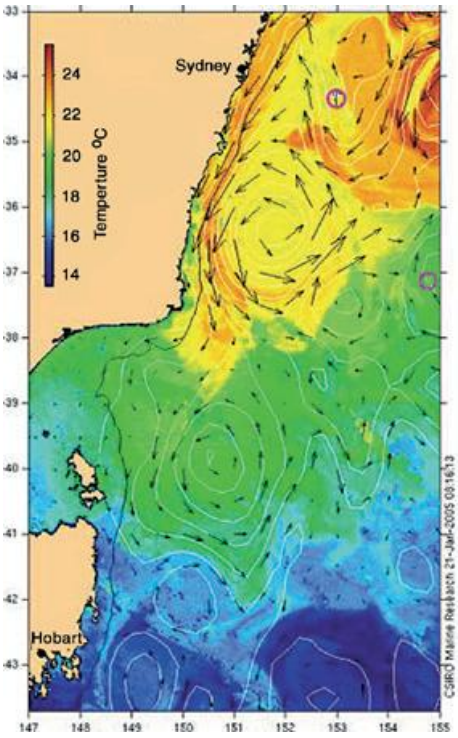
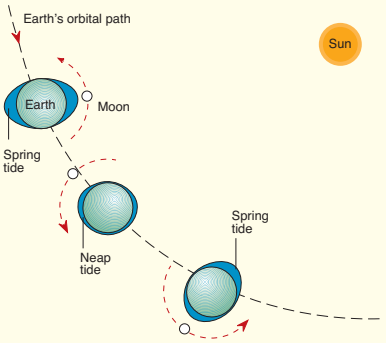


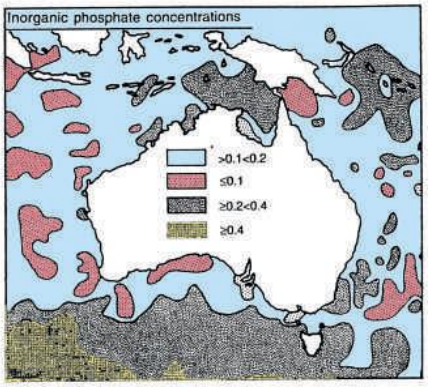
Figure 37.2 Mid latitude convergences
(Illustration courtesy CSIRO)

Figure 37.3 Coral banded shrimp
(Photograph Viewfinder)



The gravitational attraction exerted by the Sun and the moon helps produce tides. Spring tides occur where the gravitational pull of the Sun and the Moon are combined and the tides are at their highest. These tides occur when the Moon is in full or new Moon phases as shown.
Neap tides occur during a first-quarter Moon and again at the last quarter Moon phase, the Sun is at right angles to the Moon.

Figure 38.1 Tides
(Illustration Bob Moffatt)



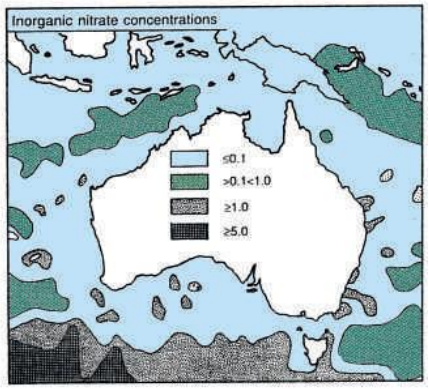


Figure 38.2 Nutrient concentrations (Micrograms per litre) at the surface of the ocean around Australia
(Illustration courtesy Environment Australia - Source Rochford 1980)

Tides and currents

On narrow continental shelves tidal ranges are quite low (2-3 metres), but in places where the continental shelf stretches out many hundred of kilometres, tidal oscillations can be as much as 10 metres (Darwin and Broome). Currents are discussed in Chapter 3.

Weather

Australia is influenced by high and low pressure systems as they move from west to east with mild conditions generally experienced with the highs.

Low pressure systems can bring violent weather to reefs and coasts in the form of cyclones, or freezing conditions from Antarctica for our southern coastlines. Low pressures from the Indian and Southern Oceans can bring huge swells to Western and Southern Australia.

Ocean productivity

The primary production of the sea depends on a supply of nutrients such as nitrates and phosphates and to a lesser extent trace elements to the **photic zone** (See Chapter 6). Here sunlight enables plants to photosynthesise producing food for marine animals.

The main source of nutrients are the enriched waters below the **thermocline**, run off from the land and biological fixing of nitrogen (See Chapter 9). Figure 38.2 shows that the main distribution of inorganic phosphate and nitrate concentrations are in the southern waters well south of our continent. The east and west are also dominated by low-nutrient tropical waters and significant upwellings are lacking. Large areas of the oceans around Australia are deserts however localised areas of New South Wales and South Australia have some **upwellings**. Because of these reduced nutrient levels, the biological productivity of our oceans is low and fisheries are limited. This low nutrient level however has contributed to the dominance of coral reefs in the tropics and huge seagrass areas in southern waters.

Australia's very diverse marine and estuarine habitats range from small estuaries to the extended continental shelf, and from the tropics to the Antarctic and to the island ecosystems of Australia's external territories. The familiar coastal habitats of beaches, dunes, rocky shores, seagrass beds, algae-covered reefs and even mangrove swamps occur in most of the mainland states.

These habitats are the home of a wealth of fauna and flora, most of which is found only in Australia. For example, Australia has:

- the world's largest areas and highest species diversity of tropical and temperate seagrasses,
- one of the largest areas of coral reefs,
- the highest mangrove species diversity, and
- the highest levels of biodiversity for a number of types of marine invertebrates.

Waves

Importance

The study of waves is important because not only do they shape our coastline, move sand along our beaches, determine where marine life is found on a rocky shore, and control our fishing and tourism industries, they also provide a surfing way of life.

The winter waves in Hawaii in Figure 39.1 break with such force that if you lie in bed on the North Shore of the island, you can hear the cutlery rattle in the kitchen drawers. Big waves can provide great thrills, but they can bring great damage to beaches, property and sometimes lives. How can waves cause so much damage, endanger some, and be a source of excitement to others?

To answer these and other questions we need to understand how waves are formed, how they move and where their energy comes from. We also need to understand the factors causing these waves and their effect on the coastline. Firstly, let's have a close look at the structure of waves to observe some of their main features.

Figure 39.1 Reef break at Ohau, Hawaii
(Photo Dick Hoole)

Figure 39.2 Beach break, South Coast New South Wales
(Photo Dick Hoole)

Characteristics

All waves have a length and height as shown in Figure 39.3. The top of the wave is known as the **crest** and the valley between the two crests is called a **trough**. The **wave height** (H) is the vertical distance between the crest and the trough. The distance between two successive crests (or troughs) is the **wavelength** (L).

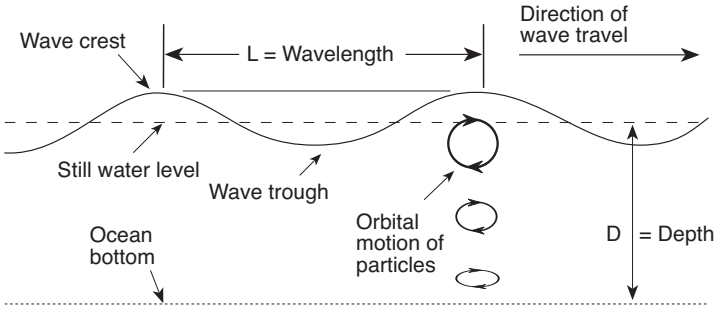


Figure 39.3 Wave characteristics
(Illustration Bob Moffatt)

The time taken for two successive crests (or troughs) to pass a fixed point is known as the **wave period** (T). This wave period is easily observed and is often converted to a wave frequency ie the number of waves per time interval.

The **wave speed** (V) is calculated by dividing the wavelength by the wave period (V=L/T). This simple formula shows that the wave speed, wavelength and the wave period are related and it is possible to calculate one of these values knowing the other two values.

The **steepness of the wave** is calculated by dividing the wave height by the wavelength (S=H/L). The wave steepness is the ratio of the wave height to the wavelength. The speed of the wave depends therefore on its size. Larger waves in the sea will move faster and overtake the smaller waves.

Activities from our 2008 Oceanography exercises book

- What are some characteristics of waves?
- How fast do waves travel?

Who has ridden the biggest wave?

- Research the internet for the biggest wave ever ridden by a surfer. See if you can find the U tube site.

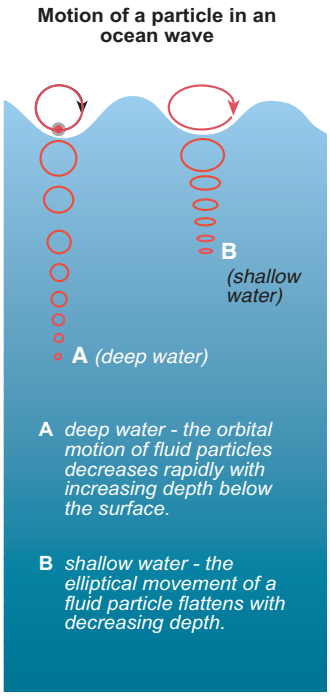


Figure 40.1 Particles on the sea move up and down and in a circular motion
(Illustration Bob Moffatt)

At sea the wind will produce a variety of waves of different sizes and frequencies. A wave of a slightly different frequency may move through another wave or form a new wave.

In the oceans waves simply move through the water. They do not take the water with them. As the wave arrives it lifts the water molecules. These travel forward and circle back. In effect, the water molecules complete a circle. The circling water near the surface sets off smaller circling movements below them.

In deep water the orbital motion of fluid particles decreases rapidly with increasing depth below the surface. In shallow water the elliptical movement of a fluid particle flattens with decreasing depth As shown in Figure 40.1).

Next time you go to the beach, watch unbroken waves as they pass a stationary boat or surfers sitting on their boards. You should see that a boat or surfers only move up and down in the one spot. If you look very closely you will see them move slightly forward, then back in a circular path. This means that although unbroken swell waves appear to be moving forward, they are actually only moving up and down in circular orbit fields as shown in Figure 40.1.

The energy within these waves, however, is carried forward at right angles to the up and down motion of the wave. This is difficult to understand because you cannot actually see the energy. It may help to compare it with a crowd at a major sporting fixture, when the crowd decides to do a Mexican wave. The wave moves around the stadium but the people remain in their own seats.

Exercise 2.1 Wave calculations

Worked example

Surfers at Bells Beach estimated the waves on that day to be 4 metres in height. They estimated that the time between the wave was 10 seconds or approximately 100 metres between each wave. Calculate the approximate wave speed of these waves. What is this speed in km/hr?

Working

V=L/t V= 100m/10s
V=10m/s

1km=1000m
V= 10x60x60/1000
V=36km/hr ANS

Questions

1 If a surfer counts 50 waves washing onto the beach in 15 minutes, calculate:
   a. The wave period (time between waves in seconds).
   b. Wave frequency.

2. If a fisher counts 180 waves washing on the beach in 1 hour, calculate the wave's:
   a. Period
   b. Frequency

3. If waves in the sea have a length of 30 metres and a velocity of 28 m/sec, calculate the wave period.

4. A Tsunami that was caused by an undersea earthquake that occurred off the coast of North America reached Christmas Island in the Pacific Ocean in 6 hours. It was estimated it had travelled 5,000 km

   Calculate the speed at which the wave moved. Calculate the time it would have reached the Hawaiian Islands, which are located 2,000 km from the epicentre of the earthquake. Calculate how long it would be before the next wave hit the island if the wavelength was 300 km.

5. Why would larger waves overtake smaller waves at sea?

6. Who might be interested in these observations or calculations and why?

Wave formation

Wave formation depends on four things. These are

- wind speed,
- length of time the wind blows,
- the distance over which the wind travels, called the **fetch**, and
- the depth of the water.

The winds initially produce small ripples. As these ripples join together, they form waves in a rising sea. Finally the waves move out of the fetch zone and become ocean swells. The length of the fetch zone determines the wavelength: a longer fetch zone creates a longer wavelength.

In short, the size of the wave depends on the amount of energy the wind imparts to the surface of the water. If the wind blows hard enough and long enough in a particular direction, the wind heaps the water into bigger waves. The waves formed in areas of high winds and large fetches have been recorded at 24m. It is believed that a number of smaller waves will heap together to form this large wave.

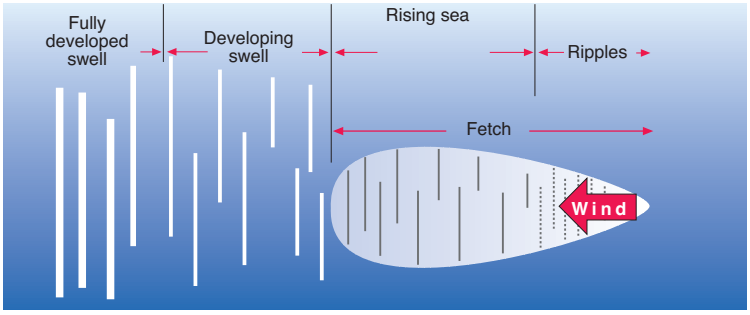


Figure 41.1 How waves are formed in a fetch
(Illustration Bob Moffatt)

Waves visible from the shoreline

As the waves approach the shore the friction between the bottom and the water affects the circular motion of the water molecules. Beneath the surface the pathway of these water movements is circular at the surface, elliptical halfway down and linear on the sea floor.

The wave loses its shape and topples, releasing its energy to form surf. As the waves approach the shoreline the waves also become steeper. This is because wave steepness (H/L) is affected by the length, which decreases as the wave slows down. A wave breaks at a depth of 1.3 times the wave height.

Waves are not influenced by the ocean bottom where the water depth is greater than half the wavelength. In very shallow water wave speed is determined by the depth. The wave speed in shallower waters can be calculated by the formula V (wave speed) = 3.1 $\sqrt{}$ D (depth).

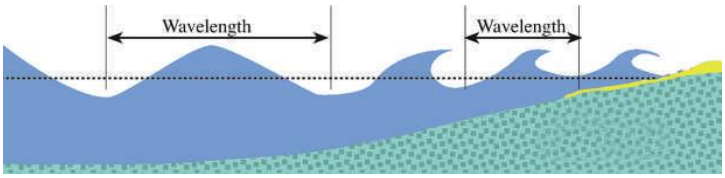


Figure 41.3 Wavelength decreases as depth decreases
(Illustration Bob Moffatt)

Activities from our 2008 Oceanography exercises book

- What causes Tsunamis?
- How does weather affect waves?

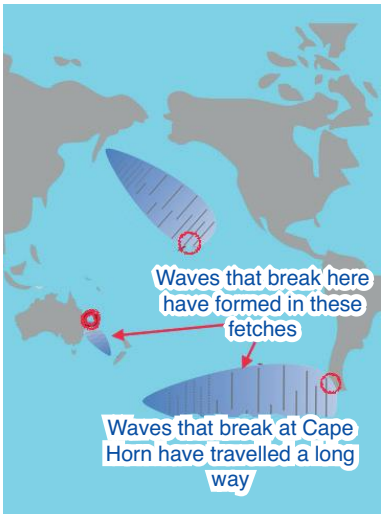


Figure 41.2 The bigger the fetch the bigger the waves
(Illustration Bob Moffatt)

Odd facts

1. During a hurricane in 1933, a 34m (112 ft) wave was measured between Manila, Philippines and California.
2. The highest instrument measured wave was 26m (86 ft) high recorded by the British ship *Weather Reporter,* in the North Atlantic on 30 December 1972.

Bob Moffatt

Figure 42.1 A spilling wave

Bob Moffatt

Figure 42.2 Surging wave

Types

Spilling waves

These waves are normally associated with gently sloping beaches. Spilling waves get their name as the top of the wave "spills" down the face of the wave (Figure 42.1). The angle enclosed by the wave is less than 120 degrees. At sea spilling waves are called "white tops" or "white horses" and are normally a sign that the weather is becoming rougher. These waves are much sought after by keen surfers as they develop into the "tunnel" or "tube waves" when the tide drops.

Surging waves

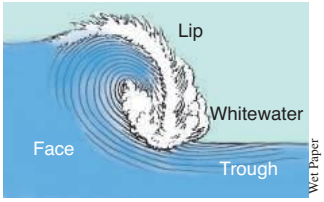
These waves never break as they approach the shore, and are mostly associated with rocky headlands. As surging waves carry enormous power, rock fishermen need to take extreme care when fishing from rocky outcrops (Figure 42.2).

Plunging

Plunging waves or "dumpers" occur more commonly at low tide when the water is shallower. These waves carry a great amount of energy and are dangerous for the inexperienced surfer (capable of spearing the surfer into the sand or reef below the shallow water). Many surfers have suffered spinal injuries after being caught in a "dumper". Plunging waves normally result from the large waves produced by violent oceanic storms.

Swells

Waves are formed in the fetch area and vary in height, period, and direction. These waves are known as the seas and can travel beyond the area the wind is blowing (the fetch area - see Figure 40.1).



Wet Paper

Parts of a wave

Dick Hoole

Figure 42.3 A plunging wave

Exercise 2.2 The heights of waves

PART A

This wave height data was recorded at the O'Connor Reef wave-rider buoy (Figure 43.1) located 7 kilometres east south east of Claire's Island at a water depth of 68 metres.

This location is shown in Figure 43.2. Observations were made at 6 hourly intervals. The 4 readings per day were each of 20 minute duration and the analogue magnetic tape recordings produced were digitized for subsequent computer analysis.

Figure 43.3 shows the percentage wave height frequency distribution for a 12-month period.

QUESTIONS

1. What was the percentage of wave height recordings that ranged between 1 – 2 metres?
2. A total of 1102 observations were recorded. What should have been the total number of observations made and how many observations were not recorded? Suggest an explanation to account for the difference.
3. Identify the variables that the oceanographers need to consider in this experiment.
4. How many days were the wave height recordings over 4 metres?
5. On how many days were the sea conditions ideal for boating? (0 –0.5m waves)

   Express this as a percentage of the year.

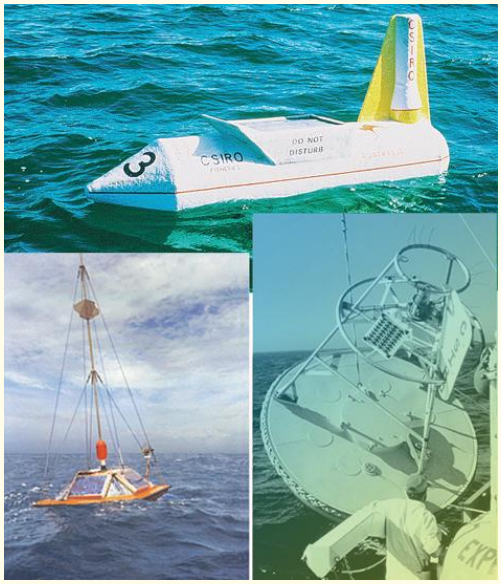


Figure 43.1 O'Connor Reef tracker buoys
(Photograph CSIRO Marine Division)

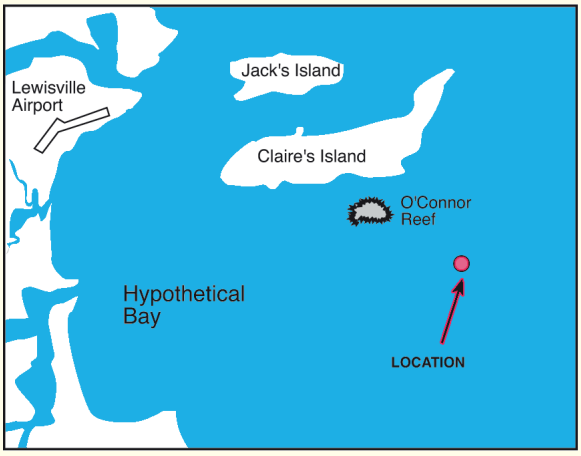


Figure 43.2 Tracker buoy location
(Illustration Bob Moffatt)

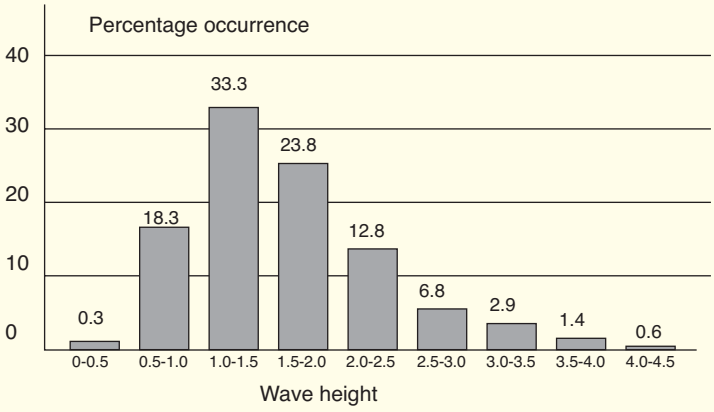


Figure 43.3 Wave data
(Illustration Bob Moffatt)

Part B July

Recordings of the wave heights were compared to wind speed recordings at Lewisville Airport. On-shore winds (direction 0 degrees to 170 degrees) and offshore winds (direction 180 degrees to 360 degrees) were compared to the wave heights. Figure 44.1 shows the estimated or forecast heights for July.

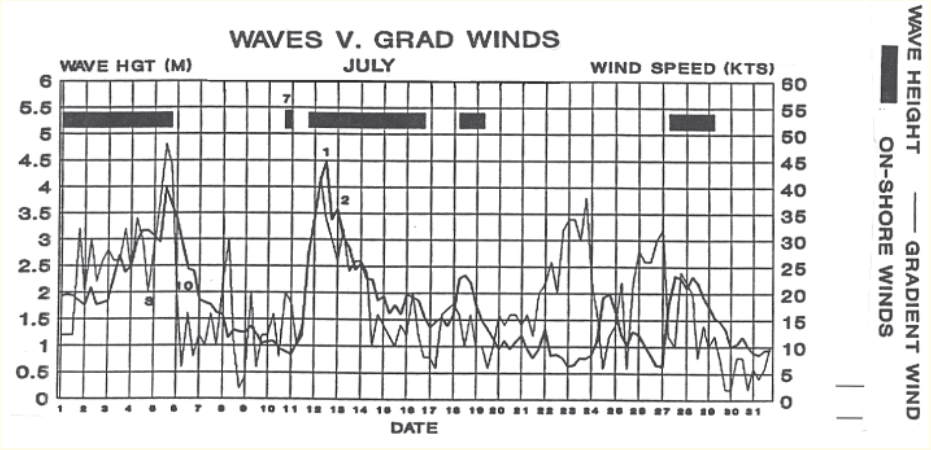


Figure 44.1 Waves and wind speed for July
(Illustration Bureau of Meteorology)

Questions

6. From Figure 44.2 determine the highest offshore wind speed and the date on which it occurred.
7. Determine the highest on-shore wind speed and the date on which it occurred.
8. Determine the highest wave height that occurred in July. On which date did it occur?
9. Suggest a reason for the decrease in wave heights from 6th to 10th July.
10. A student formulated a hypothesis that the speed of offshore winds had no effect on wave height. Do you agree with this hypothesis? Support your argument with data from the graph.
11. Analyse the graph and suggest what conditions are needed for large waves to occur.

Part C August

Figure 44.2 shows the estimated or forecast heights for August.

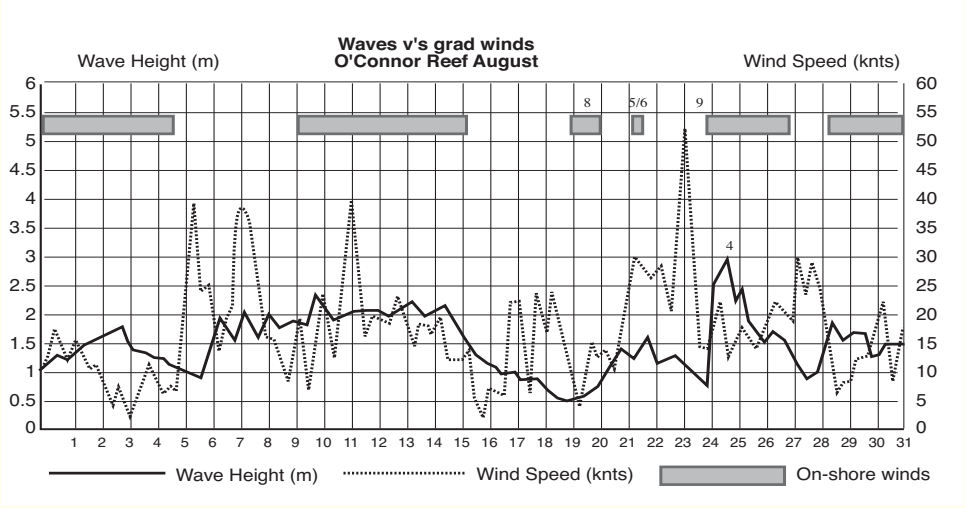


Figure 44.2 Waves and wind speed for August
(Illustration Bob Moffatt)

Questions

12. How did the sea conditions in August compare with the July readings?
13. On 23th August what was the wind speed and direction and what effect did it have on the sea conditions?
14. How do you explain the wave heights recordings on the 28th to 29th of August?
15. Given this data extrapolate the wave height you might expect if the following conditions occurred: off-shore winds blowing at 40 knots for 2 days followed by on-shore winds blowing at 20 - 25 knots for 3 days.

Part D Estimated v's actual wave heights

Figure 45.1 shows the estimated or forecast heights for January.

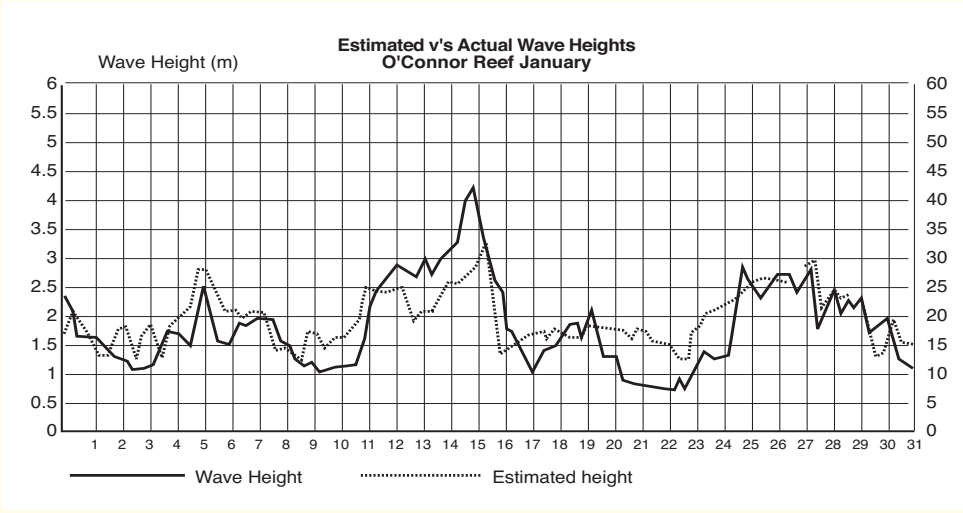


Figure 45.1 Estimated v's actual wave heights January
(Illustration Bob Moffatt)

Questions

These questions refer to Figure 45.1.

16. What was the largest variation that occurred between the estimated and the actual wave heights in January?

    Which was highest, the estimated or the actual height?
17. What percentage of the time was the estimated wave height higher than the actual wave heights?
18. Suggest some of the factors that may have caused the forecaster to "not get it right".
19. Could you suggest that the forecasters did a good job for this period?
20. The forecast for a day you were intending to go boating was for sea heights to 2.5 metres in height.

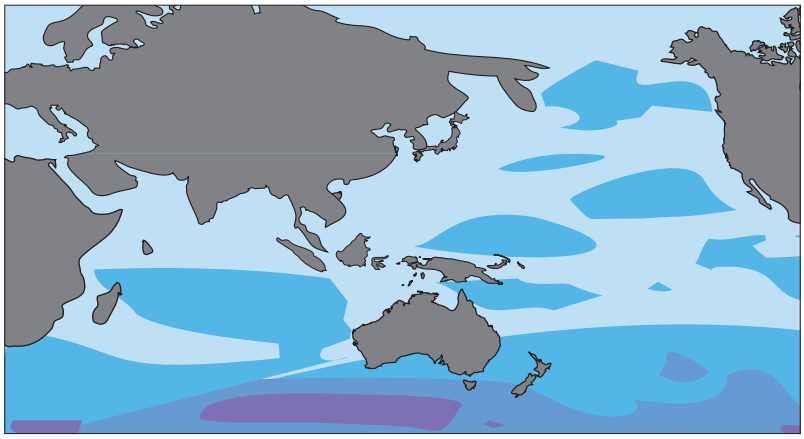
    These conditions are the maximum conditions for safe boating in your vessel.

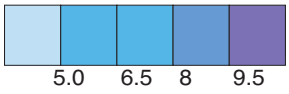
    Would you go to sea?

    Explain your answer with the support of the data in Figure 45.1.

Figure 45.2 Ocean sailing
(Photo Jan Taylor)

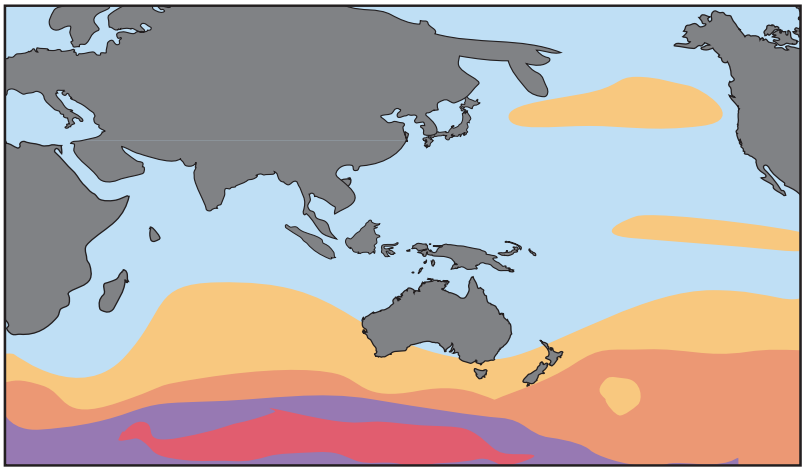
Exercise 2.3 Satellite images





This image is drawn from web satellite radar measurements and shows surface wind speed averages for July in metre/sec.

Figure 46.1 Surface radar wind speeds July (Illustration Trent Moffatt)



This image is drawn from web satellite altimeter measurements and shows wave height averages for July in metres.

Figure 46.2 Surface altimeter wave heights July
(Illustration Trent Moffatt)

Questions

Study the two satellite images above and answer questions 1-8 below.

1. Convert 10.4 metres per second to kilometres per hour.
2. Where were the winds the strongest off the Australian coast and what were their speeds?
3. Locate the areas off the Australian coast that were experiencing wave heights of 3 to 4 metres.
4. Describe the area of the ocean that had wave heights over 5.0 metres. How do you account for these conditions?
5. The patterns vary for the two images. Suggest an explanation for these differences.
6. Analyse the information in Figures 46.1 and 46.2 and draw conclusions about the effect of the wind on sea waves.
7. Construct a graph to illustrate the relationship between wind speed and latitude.
8. Formulate a hypothesis about wave height and wind speed for the Western Australian coast.

Refraction and diffraction

Studies in wave patterns as they react with coastlines are important for engineers when they design ports and boat harbours.

As waves pass into shallow water they slow down, increase in wave height and decrease in wavelength. This effect is called refraction and occurs around headlands (Figure 47.1).

When waves encounter a surface piercing obstacle, such as a breakwater or island, the wave turns due to changes in the wave height along the crest. The apparent bending of waves around a point or the spreading out of waves in a bay as shown in Figure 47.3, is called **diffraction**.

We can trace the direction of spread by drawing lines at right angles to the wave crest, called orthogonals as shown in Figure 47.4.

These orthogonals help coastal engineers plan boat harbour designs, rock walls, foreshore developments and beaches. Boat harbours and river mouths have similar effects where wave energy is dispersed as the wave enters. The wave bends around the rock walls and moves into the boat harbour.

Much of the energy is lost and so the wave height quickly decreases, making for an effective boat and ship-berthing situation. As we will see later, the slowing effect of the waves drops their suspended sediment.

Studies in wave patterns as they react with coastlines are important for engineers when they design ports and boat harbours.

A safe berth should have very little wave action and hence the rates of diffraction need to be as small as possible.

Figure 47.1 Headland wave refraction
(Photograph Geoff Jensen)

Figure 47.2 Waves striking a headland reflect .
(Photo Tim Ryan)

Reflection

Large storm waves travelling from deep water striking headlands expend a tremendous amount of energy on the structures they hit.

A wave which bounces straight back on itself after striking an object straight on is called a **reflected wave** (Figure 47.2).

This reflection often results in the shaping of headlands to form wave cut platforms. Bells Beach as shown in Figure 49.1 in Victoria, is an example of a wave cut platform.

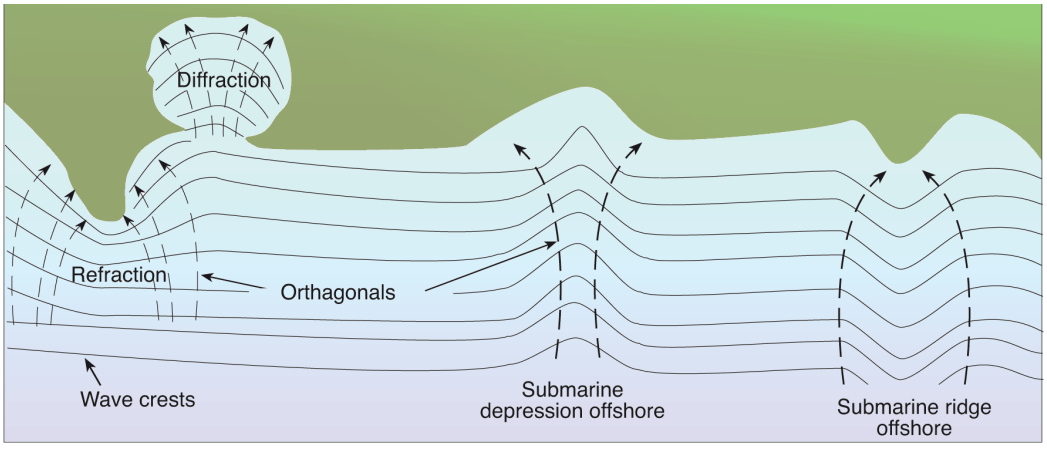


Figure 47.3 Refraction and diffraction
(Illustration Bob Moffatt)

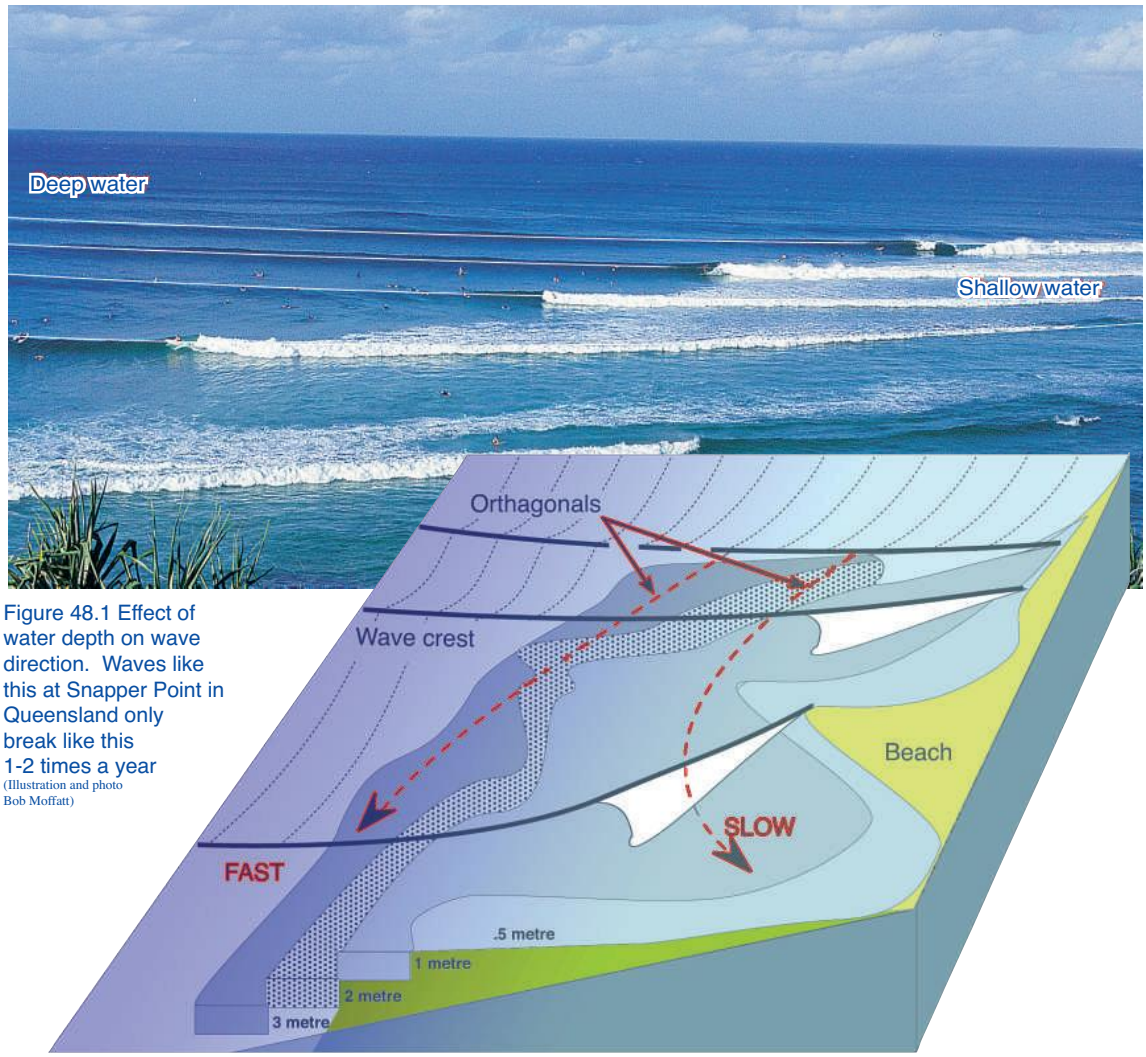


Figure 48.1 Effect of water depth on wave direction. Waves like this at Snapper Point in Queensland only break like this 1-2 times a year
(Illustration and photo Bob Moffatt)

Waves and coastlines

As waves approach headlands the sea floor absorbs the wave energy. However the water depth around headlands slopes off, and one part of the wave slows more rapidly than the other. This causes the wave to bend as shown in Figure 48.1. When a wave bends as a result of shallow water around a point, **refraction** is said to occur. A right angle drawn to the crest is called an **orthagonal**.

Notice how the orthagonals follow the wave refraction in Figure 48.1. As the water depth decreases the energy in the wave is absorbed at different rates. This causes the wave to break at an angle.

If there is an offshore wind blowing, the air inside the breaking wave gets trapped and a tube forms. When the air pressure increases to critical point, water and air can be squeezed out of the tube. If the waves brake directly onto the headland and bounce straight back, the next **wave reflection** would have occurred as shown in Figure 48.2.

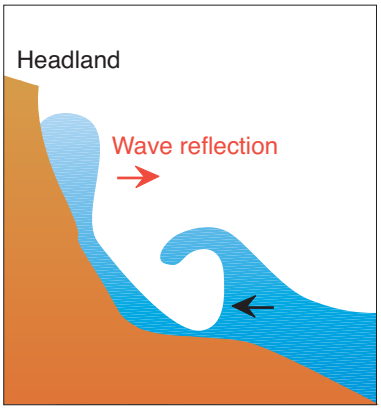


Figure 48.2 Wave reflection
(Illustration Bob Moffatt)

Sand banks, rip currents and wave patterns

As waves approach the beach they are affected by water depth. This depth is never constant near the coastlines with sandy beaches.

Sand banks are found offshore and are constantly changing with tide, current and surf conditions. Waves break on these sandbanks and rush towards the beach. There is a constant movement of sand in this area and a dynamic flow is set up between beach and sand bank. The area of beach that contains broken waves is named the **surf zone**. The surfing beach system is the area where waves break. Also called the surf zone, it is an area of constantly moving sand. **Rips** can form within minutes as the sands are constantly moved around in the long shore current.

Figure 49.1 Surf around a headland

Effects of waves on beaches

Have you ever wondered why the amount of sand on the beach changes between summer and winter? In summer the beach is wider with more sand, and narrower with less sand in the winter. After heavy winter storms, beaches in some areas can temporarily disappear. This is because waves are able to build up and erode beaches in a seasonal cycle.

During a cyclone season (or when deep low pressure systems pass the coastline), high winds and storms make waves larger (Figure 49.2). Violently breaking waves create a strong backwash, which moves sand from the beach, and out to sea, where it forms an offshore **storm bar**. This sand erosion makes beaches steeper and narrower, as shown in Figure 49.3. During summer, waves tend to be smaller so they gradually move sand inward from the offshore sandbank on to the beach where it is deposited in layers.

Beach dynamics is discussed in greater detail in Chapter 4.

Figure 49.2 Storm surf

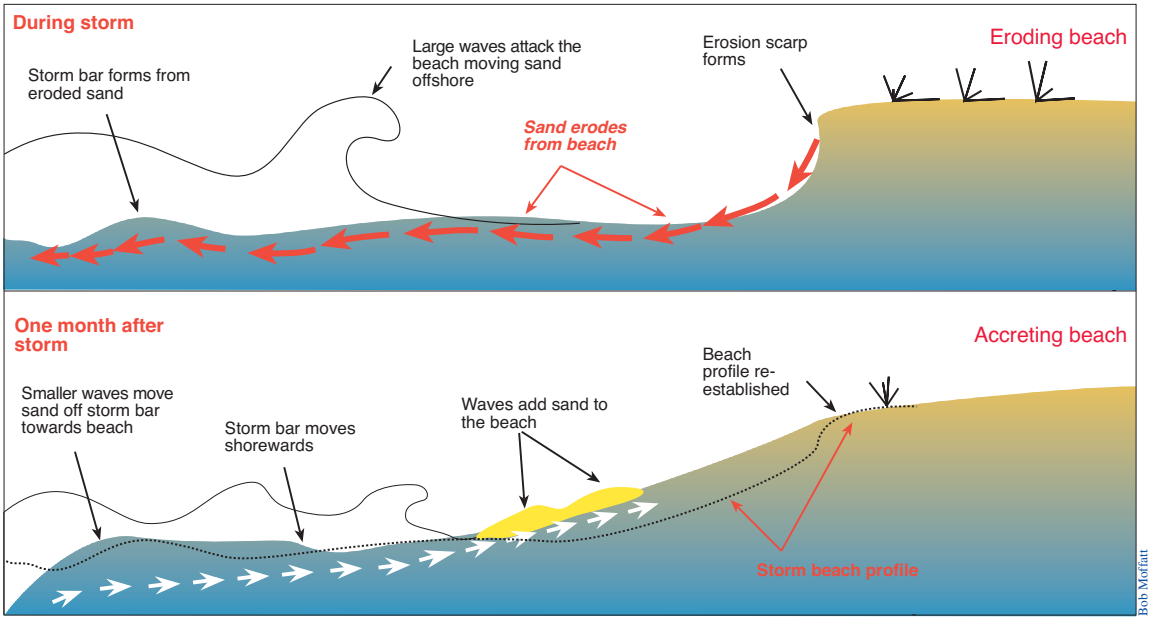


Figure 49.3 Effect of storm surf on beaches

Bob Moffatt

Figure 50.1 Beach erosion Gold Coast 1969

If we cut down the trees, trample the grass and build high-rise buildings on the sand dunes (Figure 50.1 and Figure 50.3), the sand will blow away, the beach will erode and the buildings will fall into the sea.

This happened in Surfers Paradise when a series of cyclones struck the beaches in 1967. Sea walls costing $20,000 per 25 m had to be built and buried to protect the home units from falling into the sea in future storms (Figure 50.2). It would have been less expensive to leave the sand dunes alone.

Waves and marine life

Marine organisms live on the shoreline in various habitats and environments. These inter-tidal organisms have adapted to withstand the destructive power of waves. For example, barnacles (see Figure 50.4) have developed a very hard shell, small size, conical shape and the ability to cement themselves to rocks. Kelp has developed a thick skin, a long, thin shape and a root system called a holdfast, which is second in tenacity only to the barnacle, to keep it attached in its chosen environment.

Figure 50.2 Rock boulder walls just cause waves to reflect
(Photograph Bob Moffatt)

On the beach where the dumpers break, living under the sand is safer, so everything burrows down. Small-shelled animal called pippies use a strong foot to dig themselves in and sandworms' long segments each have a number of legs bristles which bind them to the sand particles.

However, even the best adaptations cannot always withstand the force of the waves. Storms devastate kelp and sea grass beds and plant material can often can be seen piled high many southern beaches in Tasmania, Victoria and South Australia.

The same is true for shells that pile up in places where they are dumped when the wave energy slows. Even barnacles do not escape the destructive power of waves as shifting sand often covers them up.

Figure 50.3 Houses fall into the sea
(Photograph Gold Coast City Council)

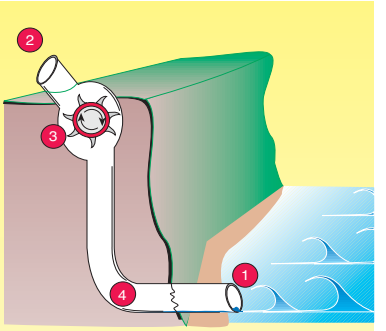
Figure 50.4 Barnacles on a rock
(Illustration Rose Bedford

Power from the sea

Energy from the sea comes from waves, tides and currents. Anyone who has been surfing is well aware of the power (energy) of waves. This energy is now being harnessed in Norway where they use a Multiresonant Oscillating Water Column (MOWC) system. The waves force a column of water up and down in a hollow oscillation chamber. This column moving up and down acts like a bicycle pump and forces air in and out of the top of the cylinder. The Norwegians use the compressed air to drive turbines that generate electricity. When wave action is at a maximum, winds of up to 200 km/hr are produced in the column to drive the turbines.

The experimental station at Bergen in Norway is capable of producing 18 million kilowatt hours at very low cost.

Regions that have a very large tidal range could use power of the flowing water to drive turbines and produce power. Areas such as the Bay of Fundy, Canada, which has 15 m in tidal range, and Derby and Broome in north-west Australia, which have a tidal range of approximately 10 m would be very suitable to harness this form of energy.



1. Waves surge into the openings to the cylinder, pushing air along the cylinder.
2. The air is forced air out of the top of the cylinder.
3. The movement of air drives the turbine (wheel) at the top of the cylinder.
4. As the water recedes, air is drawn back into the cylinder, again driving the turbine.

Bob Moffatt

Figure 51.1 Wave power station

Surfing

We mostly use the energy from waves for sport and recreation, including body surfing, body boarding, surf skiing, sail boarding and board-surfing. The ability to catch waves which is common to all the above surfing activities has the same basic principles.

The surfing conditions can vary greatly during the day at a particular beach. The wave shape is dependant on the strength and direction of the local winds, the slope or gradient of the beach and the tide height, and other currents that may be present.

Surfing can be a difficult and challenging experience, but it is also exhilarating to ride the power of the ocean.

Odd fact

Waves have been measured as being able to carry 80kW of energy in each metre of their length. That means that waves with a 200 m length will have enough energy to power 1000 homes or a small suburb for a day.

Destructive waves

Storm surges

As storms and cyclones approach land, their winds whip up the sea and push a bank of water towards the coast. The height of the storm surge depends on the intensity of the storm and the shape of the coastline. Cyclones in Australia have caused storm surges of 2-5 m. If these storm surges occur at high tide, they can cause massive flooding of low-lying coastal areas.

Bob Moffatt

Figure 51.2 This house was destroyed by a storm surge.

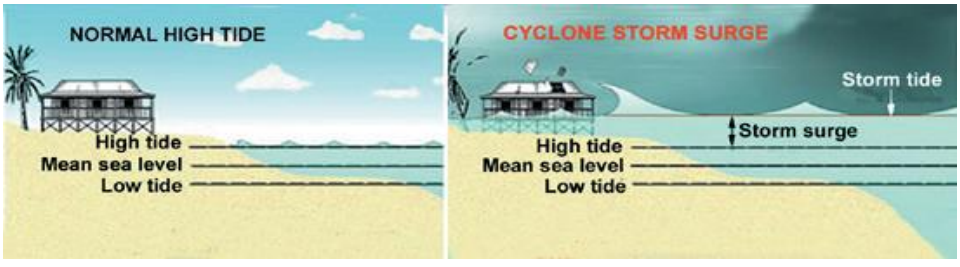


Figure 51.3 Storm surge
(Adapted from Australian Bureau of Meteorology)

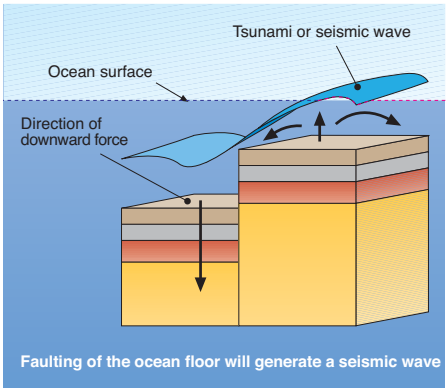


Figure 52.1 Faulting of the ocean floor will generate a seismic wave

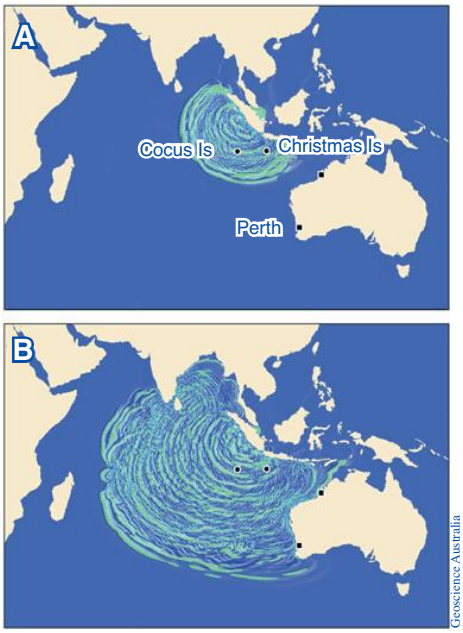


Figure 52.2 Tsunami in 2004

Seismic sea waves (tsunamis)

Seismic sea waves are shock waves caused by the sudden movement of a large volume of water. Underwater earthquakes or volcanoes mostly cause this movement of water. The waves formed travel long distances and have wavelengths of up to 200 km, wave periods of up to 20 minutes and speeds of up to 800 km/h. These waves travel almost halfway around the world as fast as jet airliners. The seismic waves may only be 0.5 m high in the deep oceans, but as they approach the shore they rear up to a great heights.

On December 26, 2004, an undersea earthquake registering 9.0 on the **Richter scale** struck 250 km south-west of Sumatra. The ocean floor dropped almost 40 metres and unleashed a seismic wave that killed over 250 000 people in eight countries across Asia and with effects as far as Somalia in East Africa and even off the west coast of Western Australia. The wave spread many kilometres inland carrying everything in its path from large trees, ships, buildings and bridges. The event was one of the worst natural disasters the world has ever seen and in 2005 the United Nations planned an Indian Ocean tsunami warning system to attempt to warn nations of the impending disasters.

Climate change

Enhanced greenhouse effects

Greenhouse gases are a natural part of the atmosphere. They absorb and re-radiate the Sun's warmth, and maintain the Earth's surface temperature at a level necessary to support life. The problem we now face is that human actions- particularly burning fossil fuels (coal, oil and natural gas), agriculture and land clearing are increasing the concentrations of the gases that trap heat.

The enhanced greenhouse effect is the process by which increased man made emissions trap a greater amount of infrared radiation within the atmosphere causing the planet's surface to warm (Figure 53.1).

Exercise 2.4 Waves in the ocean DVD

Aim

As a result of watching this DVD you should have gained a better understanding of how waves move in the ocean, described what happens when waves approach a shore, recalled the effects of waves as they pass around headlands and breakwaters and appreciated the movements of sediment flow in these regions.

You will need a DVD player and the DVD on 'Waves in the Ocean' from www.classroomvideo.com.au

What to do

Look up the web site www.classroomvideo.com.au, obtain and watch the video, then write a paragraph on each of the following topics.

1. How waves form
2. The waters path in a wave
3. Wave sets or beats
4. Diffraction
5. Reflection of waves
6. Refraction of waves
7. Translator waves
8. Why waves break

Tsunami activity resource

www.agso.gov.au
Tsunami activity book with exercises on how long it would take a tsunami to hit Australia.

Water vapour is the most abundant greenhouse gas. Its concentration is highly variable and human activities have little direct impact on amounts of water vapour in the atmosphere. Humans have most impact on carbon dioxide, methane and nitrous oxide. Various artificial chemicals such as halocarbons also make a small contribution to the enhanced greenhouse effect.

In addition to warming of the Earth's surface, there has been an increase in heatwaves, warming of the lower atmosphere and deep oceans, fewer frosts, retreat of glaciers and sea ice and a rise in sea level during the 20th century of about 17 cm.

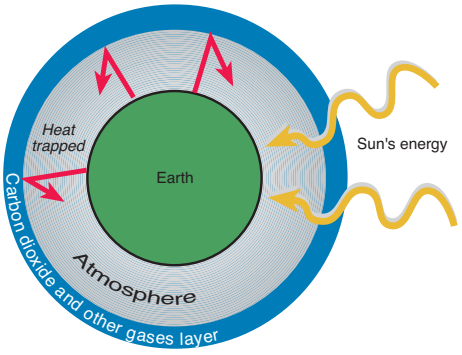


Figure 53.1 Greenhouse effect
Illustration Trent Moffatt

Global warming

During the past 100 years, global average surface temperature increased by about 0.7°C, (Figure 53.2). Tree rings and other records tell us that average Northern Hemisphere temperatures during the second half of the 20th century were likely to have been the highest in at least the past 1300 years.

How much warming is likely this century?

As the Earth's surface warms, the oceans slowly absorb heat and expand, causing the sea level to rise (see Figure 53.3). This **thermal expansion** of the ocean will be a major contributor to sea level rise during future centuries.

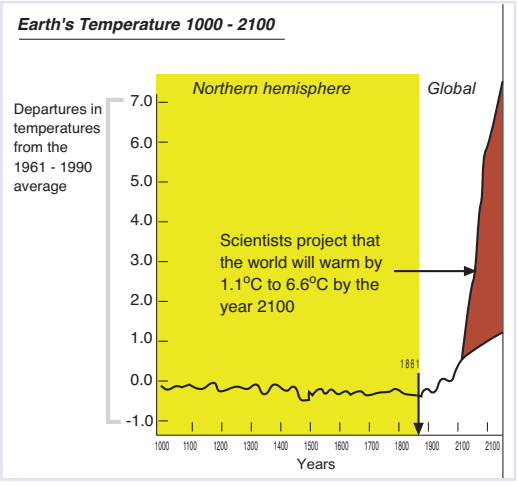


Figure 53.2 Past 100 years, global av surface temp
Bob Moffatt (After CSIRO data)

Climate change

Climate change is any long-term significant change in the "average weather" that a given region experiences. Average weather may include average temperature, precipitation and wind patterns. It involves changes in the variability or average state of the atmosphere over durations ranging from decades to millions of years. These changes can be caused by dynamic processes on Earth, external forces including variations in sunlight intensity, and more recently by human activities. The Intergovernmental Panel on Climate Change - an international body that assesses the latest science of climate change - has stated that "*Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.*"

Earth ecosystems

Many species of plants and animals have changed their location or the timing of reproductive activities in ways that provide further evidence of possible climate change. This change in timing in seasons may be a precursor to localised extinction for some species.

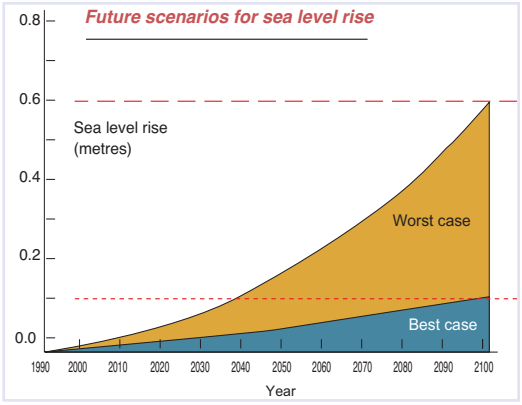


Figure 53.3 Sea level rise possibilities
Bob Moffatt (After CSIRO data)

Ocean acidification

Carbon dioxide emitted to the atmosphere by human activities is being absorbed by the oceans, making them more acidic.

Evidence indicates that emissions of carbon dioxide from human activities over the past 200 years have already led to a reduction in the average pH of surface seawater of 0.1 units and could fall by 0.5 units by the year 2100.

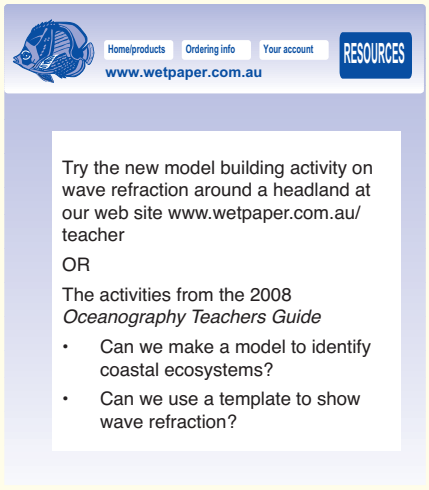
This pH is probably lower than has been experienced for hundreds of millennia and, critically, at a rate of change probably 100 times greater than at any time over this period. Impacts on oceans will be greater for some regions and ecosystems, and will be most severe for coral reefs and the Southern Ocean. The impacts of **ocean acidification** on other marine organisms and ecosystems are much less certain.

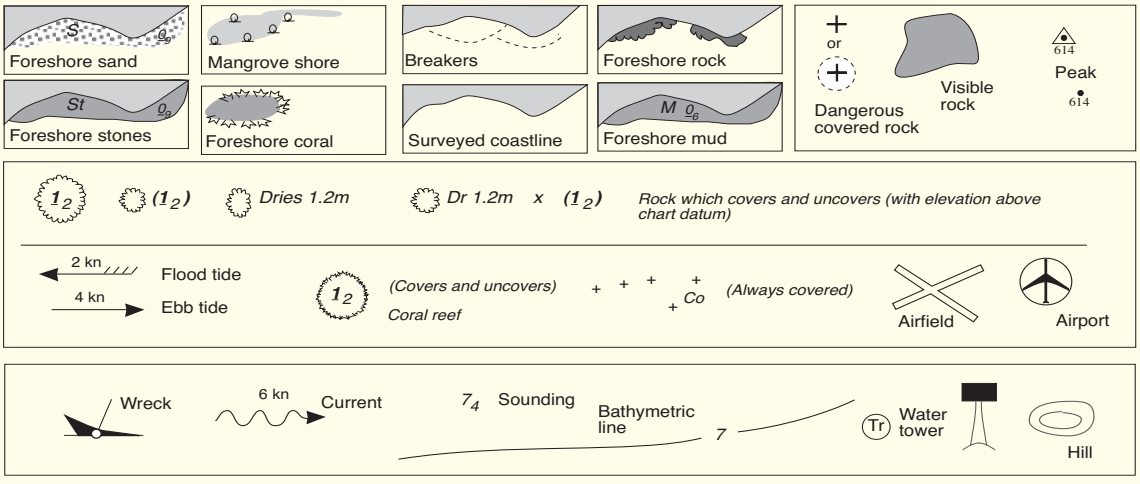
Exercise 2.6 Hypothetical Bay

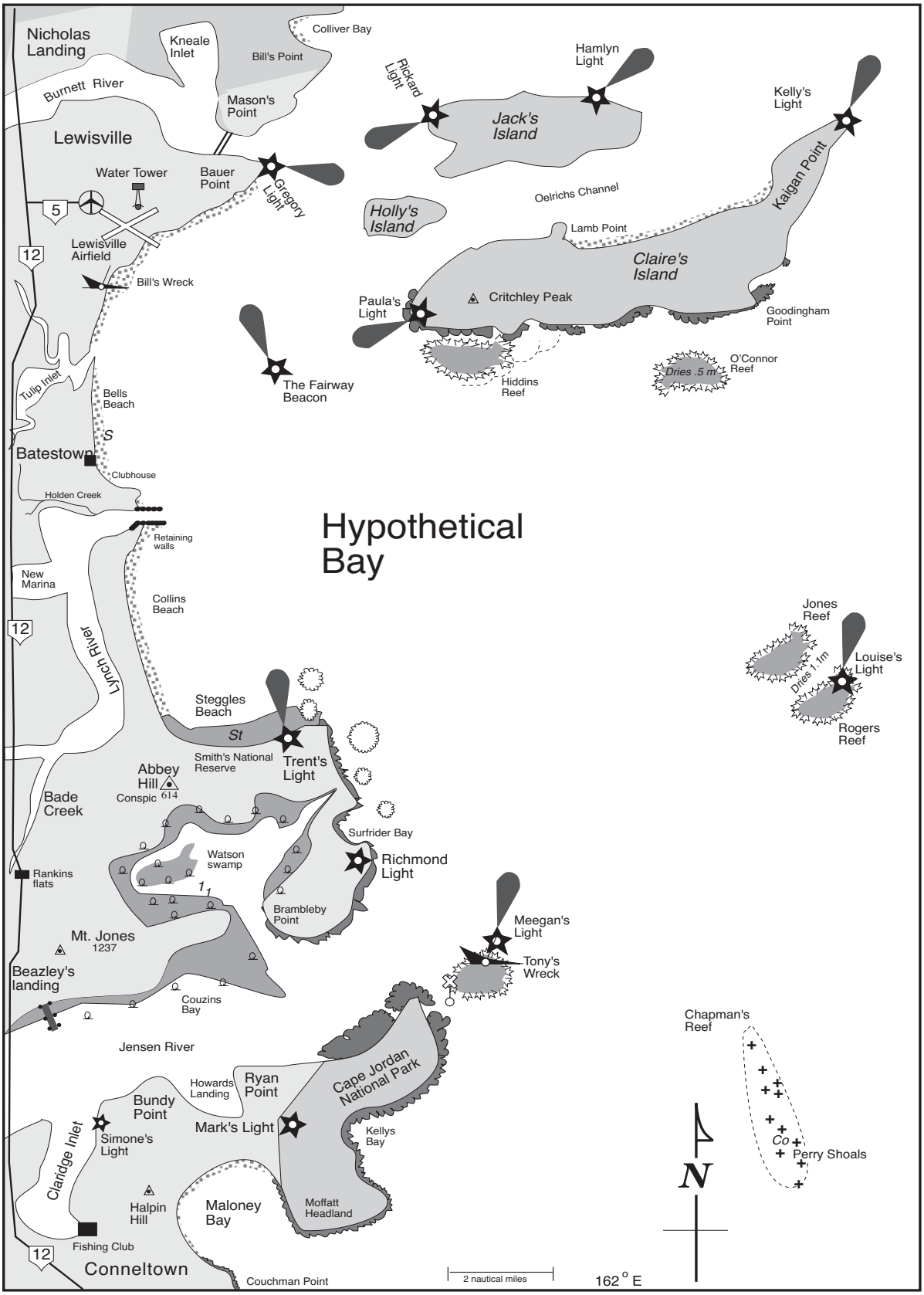
Use the chart of Hypothetical Bay and answer the following questions.

1. Maloney Bay is a famous beach for the locals from Conneltown. What would be the best prevailing winds for surfing in the bay?
2. Use the legend below to describe the sea floor on Steggles Beach, and James Beach.
3. A 25-knot northwesterly is blowing with a 2 metre southeasterly swell and you wanted to go for a surf. Is it worth the effort to drive down? Give reasons for your answer.
4. Would it be possible to surf at Perry Shoals? If so, would it be wise?
5. Surfrider Bay has a famous break. Suggest why it should have good surfing conditions.
6. James Beach near Batestown is famous for its surf carnivals with the annual iron woman and iron man races a feature event. What would be ideal surfing conditions for this beach and what type of surf conditions would force a cancellation of a surf carnival?
7. Suggest areas in Hypothetical Bay where the following will likely occur
   - Wave reflection
   - Wave diffraction
   - Wave refraction
8. Predict which areas of the bay would be especially affected by a storm surge. Explain your answer.
9. A cyclone out to sea has produced a huge swell .The swell is coming from an Easterly direction. Predict which beaches might be badly eroded?

Figure 54.1 Couchman Point
(Photo Bob Moffatt)







(Illustration Bob Moffatt - dedicated to the Marine Studies teachers of 20/21 centuries)

Exercises

From the Wet Paper Publication - *Oceanography Exercises See www.wetpaper.com.au*

A5 What is climate change and how does it affect the ocean?

A13 What causes Tsunamis?

B1 What are some characteristics of waves?

B2 How fast do waves travel?

B3 How does weather affect waves?

B7 Why do tides change over the month?

B17 Can we make a model to identify coastal ecosystems?

B18 Can we use a template to show wave refraction?

Questions

Knowledge

1. What are waves affected by as they approach the beach?
2. Name three types of wave and use drawings to illustrate your answer.
3. What is a rip? Use a drawing to illustrate your answer.
4. What is an onshore wind and what type of surf does it create?
5. Define the following terms
   - Orthagonals
   - Fetch
   - Seismic sea waves (tsunamis)
   - Storm surge
6. What is a *convergence* and how does it affect marine life on the coastline adjacent to it?
7. Where is the Leeuwin Current?

Understanding

8. Beaches with a sand sea floor have a different wave-breaking pattern than beaches with a reef or rock sea floor. Write a paragraph explaining why.
9. Why does the wave shape change with the tide?
10. How do waves affect marine life?
11. Interpret the statement that — the bigger the fetch and the stronger the wind, the bigger the waves.
12. If waves in the sea have a length of 40 metres and a velocity of 30 m/sec, calculate the wave period.
13. As waves approach the shore, sand causes them to slow down and bunch up. Illustrate this with a diagram.

Applying

14. Examine Figure 56.1 below and determine where wave refraction, diffraction and reflection are most likely to occur.
15. Use an example to show that the energy in a wave moves forward but the particles in a wave move up and down in a circular motion.

Analysing

16. Compare a high tide in a local area, with a high tide when a low pressure is just offshore.
17. What are 2 similarities and 2 differences between surging and spilling waves.
18. Distinguish between wave reflection and wave refraction.
19. Identify places in your local area or where you have been on a school excursion, where surging waves can occur.
20. Explain the concept that wind-driven continental shelf waves affect inshore currents in most Australian States.

Creating

21. Devise a formula to show that as waves approach the shore they slow down. Use wavelength and velocity.
22. Predict the effects of a cyclone on your local area. What types of precautions need to be taken by local shipping? Is there a local storm or cyclone counter disaster plan?

Evaluating

23. Argue the point that waves have a number of mathematical characteristics which can be clearly defined in physics.
24. Assess the Australian coastline for places where a wave power station could be built.
25. Decide if localised seasonal upwellings of nutrient rich water contribute to increased productivity in some Australian states. Base your decision on the fact that Australian oceans are largely nutrient poor allowing seagrasses and coral reefs to dominate.

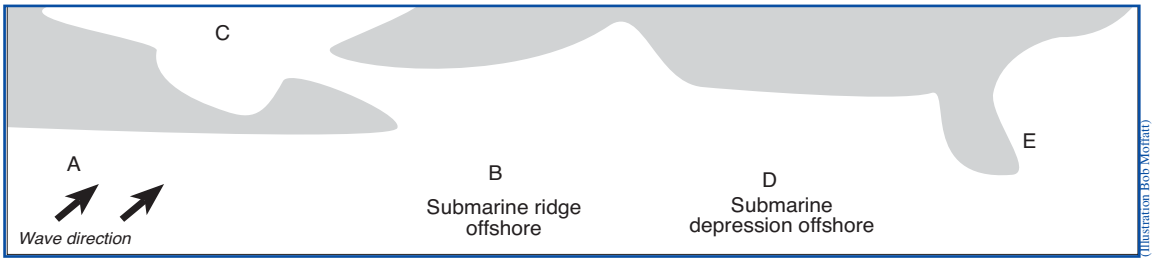
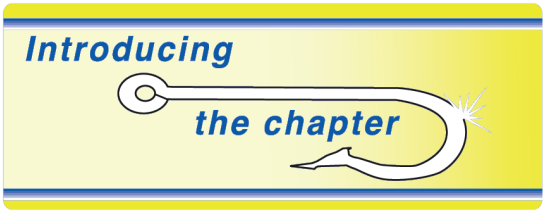


Figure 56.1 Hypothetical coastline

Chapter 3
Currents and weather

by
Bob Moffatt and Tim Ryan

Photo Bob Moffatt



Chapter hooks

- Set up a demonstration of a small aquarium filled with water with ice floating at one end and a test tube of coloured hot water in the bottom (Exercise 3.2, page 68). Add a few drops of food colouring to the ice block and see what happens. Then open the test tube and ask the questions - how do ocean currents form?
- Visit the Bureaux of Meteorology Web Site:

  www.bom.gov.au

Why study this chapter

Currents bring food for offshore fisheries, affect the movements of ships at sea, can cause drownings on our beaches and help disperse plant and animal reproductive cells.

The study of currents provides us with an increased knowledge of our oceans and in many Australian states impacts on weather.

As marine scientists it is important to study weather so that we have a way of recording the physical aspects that affect marine organisms. Marine engineers need to know also the types of weather patterns that will affect the structures they build. For example the building of offshore pipelines can cost billions of dollars. These pipelines need to be built to withstand the sea and weather conditions likely to be found in the area. A good knowledge of currents is important.

Chapter overview

Ocean currents 60
Exercise 3.1 The Australian Herring 67
Exercise 3.2 Current experiments 68
Exercise 3.3 Local currents 72
Weather and the sea 73
Weather forecasting 76
Exercise 3.4 Sea surface temperatures 77
Case study 3.1 Epic voyage ends in dumping 78
Case study 3.2 Reading the eddies 79
Exercises and questions 80

Key concepts

Currents

1. Three types of currents are ocean, coastal and local currents.
2. Ocean currents are movements of sea water caused by wind and the earth's rotation.
3. Ocean currents mix oxygen and carbon dioxide from the atmosphere into the water and, in areas called upwellings, mix in elements from the rich benthic layers deep in the sea.
4. In the eastern Pacific, a branch of the Peru current breaks off, stopping cold water from entering upper layers of oceanic water. When this happens an El Nino is said to occur.
5. As the trade winds move over the Pacific, they create areas of different pressure. The air pressure over Darwin is related to that at Tahiti. When the pressure in Darwin is high, the pressure over Tahiti is low and the pressure oscillates between the two.

   This is called the Southern Oscillation and an index called the Southern Oscillation Index (SOI) is calculated from pressure differences between the two. You may have seen this on television weather reports.
6. Local currents are found along beaches and coastlines, within river mouths and estuaries.
7. Many animals and plants use local currents to disperse their young after mating.
8. Strong tidal currents can form when large rises and falls occur in narrow channels or around headlands.
9. If waves approach a beach at an angle, they set up a longshore current close to the beach.

Weather

10. Air pressure or atmospheric pressure is the force of the earth's atmosphere.
11. Differences in temperature and pressure, along with the earth's rotation on its axis, cause the air to move over the earth's surface in large volumes called air masses.
12. Cyclones occur in tropical regions. A cyclone is a complex low pressure system which can cause great damage to coastal towns.

Ocean currents

Currents exist at all depths in the ocean; in some regions, two or more currents flow in different directions at different depths. Although the current system is complex, ocean currents are driven by two forces: the Sun and the rotation of the Earth.

The sun

The sun affects the oceans in two ways by creating density differences and wind patterns.

Wind formation

First, it heats the atmosphere, creating **winds** and moving the sea surface through friction (Figure 59.1). This tends to drag the water surface along as the wind blows over it.

Wind patterns are caused by sun's rays heating the earth unequally causing air to be heated to a higher temperature at the equator than at the poles. This causes air at the equator to rise creating areas of low pressure (Figure 59.2). When this rising hot air cools it falls, creating areas of high pressure. The spinning earth causes these systems to move.

These moving air cells are called **trade winds** and blow in one prevailing direction, depending on their latitude (Figures 59.2 and 59.3). As the wind drags on the water it causes the water to move in what we call ocean currents.

The speed of these ocean currents is approximately 5-10 kilometres per day. If these currents are confined by landforms into narrow channels or the western margin of the current meets a landform it can form stronger currents. This has happened in the formation of The Gulf Stream off California. Here the current may reach speeds of 100 kilometres per day. In the southern hemisphere these currents are weaker and are greatly affected by the Antarctic's Circumpolar Current.

Density

The second effect of the Sun is to alter the density of the ocean surface water directly by changing its temperature and/or its **salinity**.

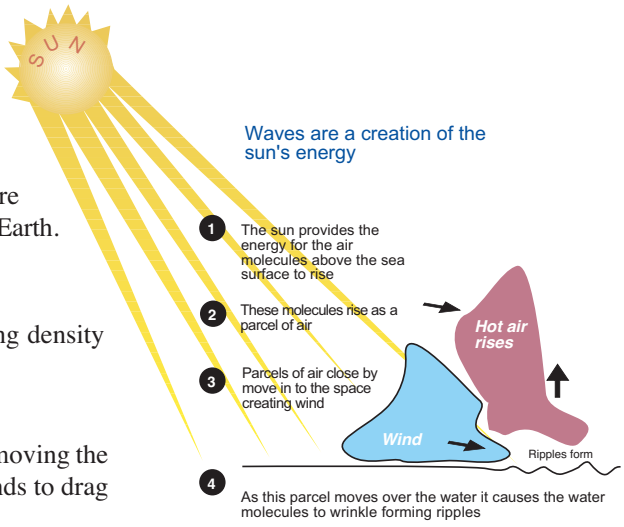


Figure 59.1 How winds form
(Illustration Bob Moffatt)

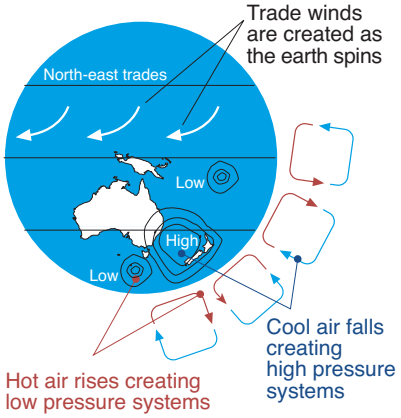


Figure 59.2 How trade winds form
(Illustration Bob Moffatt)

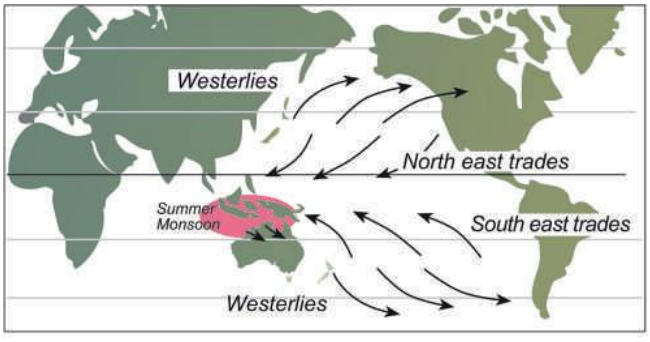


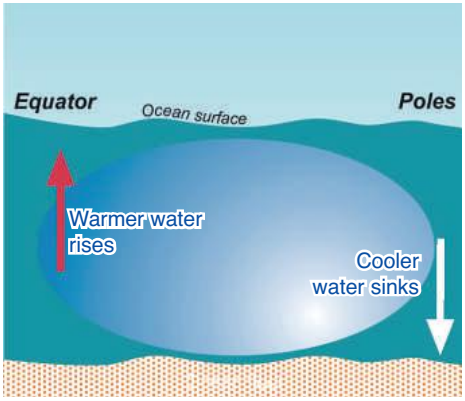
Figure 59.3 Winds of the Pacific
(Illustration Bob Moffatt)

The monsoon

During the monsoon season in northern Australia, the easterly trade winds are replaced by moist northwesterly (monsoonal) winds from the Indian Ocean and southern Asian ocean waters.

The northern Australian monsoon season generally lasts from December to March.

Locals actually refer to only two seasons - the wet and the dry



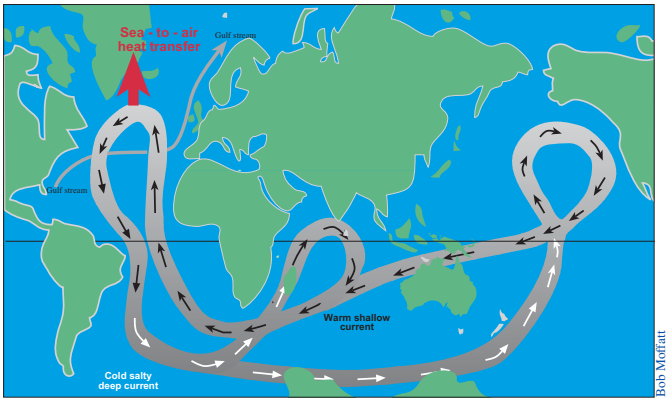


Figure 60.1 Thermohaline circulation and ocean conveyor belt

If water is cooled or becomes saltier through evaporation, it becomes denser. This can result in the water column becoming unstable, setting up density-dependent currents known as the **thermohaline circulation** (Figure 60.1). The term thermohaline circulation (THC) refers to the part of the large-scale ocean circulation that is thought to be driven by global density gradients created by surface heat and freshwater fluxes.

The thermohaline circulation is sometimes called the ocean conveyor belt, the great ocean conveyer, or the global conveyor belt (Figure 60.1)

Thermohaline circulation controls the vertical distribution of temperature and salinity in oceans, and is responsible for vertical water movements that ventilate deep ocean water masses. Rising water from the bottom of the ocean brings with it all the nutrients that have accumulated from dying animals and plants and is called **upwelling** (see page 62).

Because the oceans are neither infinitely wide nor constantly dense, complications arise at the boundaries, where water tends to "pile up." The surface of the ocean is then no longer flat, but has a slope, which sets up a horizontal pressure gradient. Just like turning on a fan at one end of the bathtub to make the water pile up at the other end, easterly trade winds push large amounts of warm water across the Pacific.

These currents caused by the sloping sea surface are called **geostrophic currents (sometimes geotrophic).**.

Because the density of the ocean varies both horizontally and vertically, scientists can use the density structure of the ocean to calculate the pressure field and hence the pressure gradient.

Definition

A geostrophic current results from the balance between gravitational forces and the Coriolis effect.
The gravitational effect is controlled by the tilt of the sea surface and water density as controlled by horizontal changes in temperature and salinity.
Geostrophic currents are zero-frequency inertial waves in the oceans. They move water horizontally, and because both heat and salinity are involved, geostrophic circulation is a type of thermohaline circulation.
Thermohaline circulation is a slightly more general term that encompasses both horizontal and vertical movement of water masses.
Thermohaline circulation controls the vertical distribution of temperature and salinity in oceans, and is responsible for vertical water movements that ventilate deep ocean water masses.

The rotation of the Earth

Because the spinning Earth is shaped like a ball, particles of water move faster as they move away from the equator. The force driving these particles faster is called the **Coriolis force** (Figure 60.2).

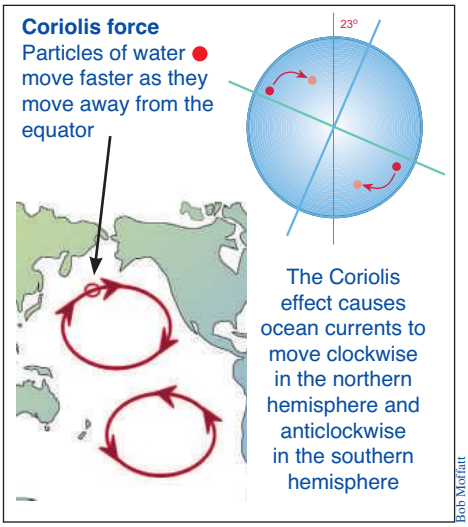


Figure 60.2 Coriolis effect on surface currents

Coriolis force is due to the Earth's rotation. This force causes moving objects (ie, water particles, air planes, birds, etc,) to deflect to the right of their motion in the Northern Hemisphere and to the left in the Southern Hemisphere. The Coriolis force is strongest near the poles and zero at the equator.

Ekman's spiral

In 1890. Valfrid Ekman suggested that the winds drove surface currents and the Coriolis force the ones beneath. He concluded that currents decreased with depth in a spiral based on surface currents moving at a 45-degree angle to the wind direction (Figure 61.1). The Coriolis force also affects the layers because they are moving.

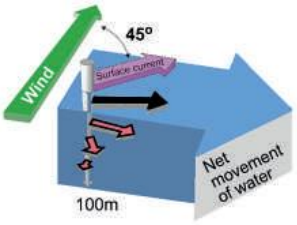


Figure 61.1 Ekman spiral
(Illustration after www.waterencyclopedia.com)

Patterns of surface currents

The general pattern of surface currents in the ocean is shown in Figures 61.2 and 61.3. This shows a series of quasi-circular **gyres**, or large eddies, in each ocean **basin**. The South Pacific gyre generates the South Equatorial, East Australian, Antarctic circumpolar and Humboldt currents.

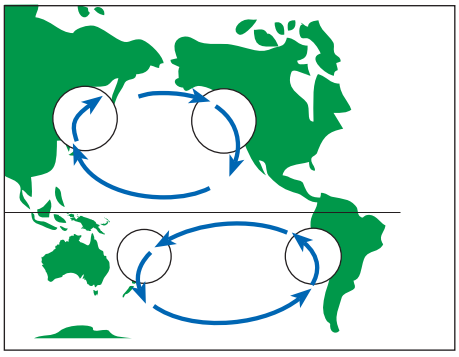


Figure 61.2 Significant world currents
(Illustration Bob Moffatt, Source Weinhaupt)

Current speeds away from the western boundaries of the gyres are generally much lower, and currents on the eastern boundaries of ocean basins are much wider. Gyres rotate clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere because of the Coriolis force.

The trade winds set up two westward-flowing currents north and south of the equator (the North and South Equatorial Currents), but because the southeast trades blow across the equator, this causes a divergence (upwelling) along the equator itself.

Gyre exceptions

In two regions of the globe surface currents do not form gyres. The Southern Ocean is a region of continuous westerly winds and is the only place on the globe where a continuous circumglobal current (the Antarctic Circumpolar Current) can form. This current therefore is a major region for mixing water between different ocean basins. It is the largest current on earth.

Gyral motion is also absent near the equator.

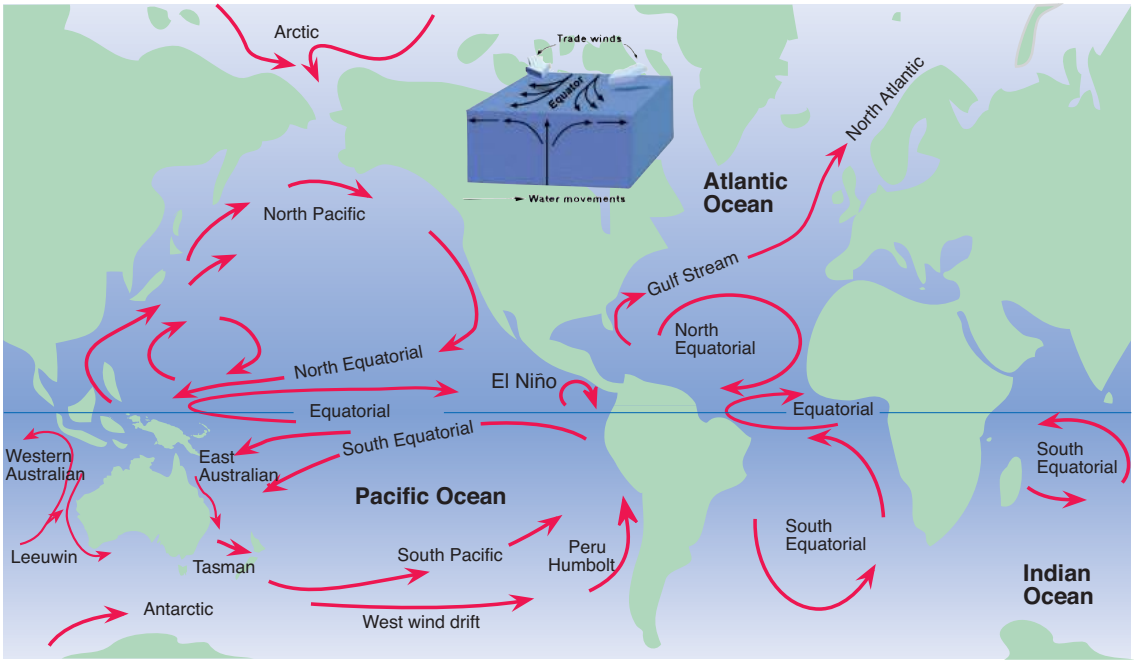


Figure 61.3 Significant world currents *(Note - El Niño is not a permanent current)*
(Illustration Bob Moffatt, Source Weinhaupt)

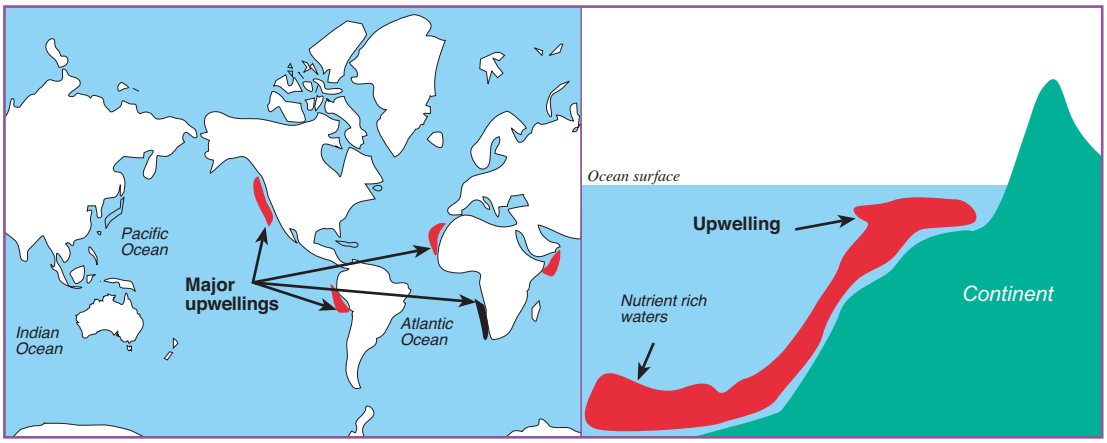


Figure 62.1 Upwellings
(Illustration Bob Moffatt)

Australian upwellings

South Australia

Localised periodic cold water, nutrient-rich upwellings have been identified off the coastal regions of the eastern Great Australian Bight (from Baird Bay to western Kangaroo Island).

These upwellings, by providing nutrients to surface waters, are sites of significant productivity.

Recent studies have indicated a close relationship between these upwellings and pilchard egg abundance in the region.

New South Wales

An oceanographical investigation of coastal waters off Laurieton, N.S.W. has shown that upwelling was a regular feature of the spring and summer season.

This upwelling is confined to a 5-mile zone against the coast, occurred at intervals between 12 and 57 days, was of short duration (9-15 days complete cycle) and originated in offshore 15-17° C waters around 125-275 m depth.

Upwellings

The rising of the water from the bottom of the oceans is called **upwelling** (Figure 62.1). Currents may also be caused by density changes due to differences in temperatures or salinity. The more dense waters sink and the less dense water rises.

The density of the water also governs current direction.

- Cooler water tends to be denser and sinks, displacing the warmer less dense equatorial waters.
- Dilution by rain, river discharges, and melting ice can affect the density of the seawater.
- The direction of the ocean current is also affected by the landmasses the current may meet.

The larger continents may deflect the currents making the direction of the current flow even more unpredictable.

Salinity also plays a role. Water tends to flow from an area of low salinity to one of a higher salinity. Ocean currents had to be studied around oil rigs following disastrous oil spills overseas.

Southern oscillation index

The **Southern Oscillation Index** (SOI) is calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin. Sustained negative values of the SOI often indicate El Niño episodes.

These negative values are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean, a decrease in the strength of the Pacific Trade Winds, and a reduction in rainfall over eastern and northern Australia. Severe droughts resulted from the weak to moderate El Niño events of 2002/03 and 2006/07.

Positive values of the SOI are associated with stronger Pacific trade winds and warmer sea temperatures to the north of Australia, popularly known as a La Niña episode. Waters in the central and eastern tropical Pacific Ocean become cooler during this time. Together these give an increased probability that eastern and northern Australia will be wetter than normal. The most recent strong La Niña was in 1988/89. A moderate La Niña developed slowly during 2007.

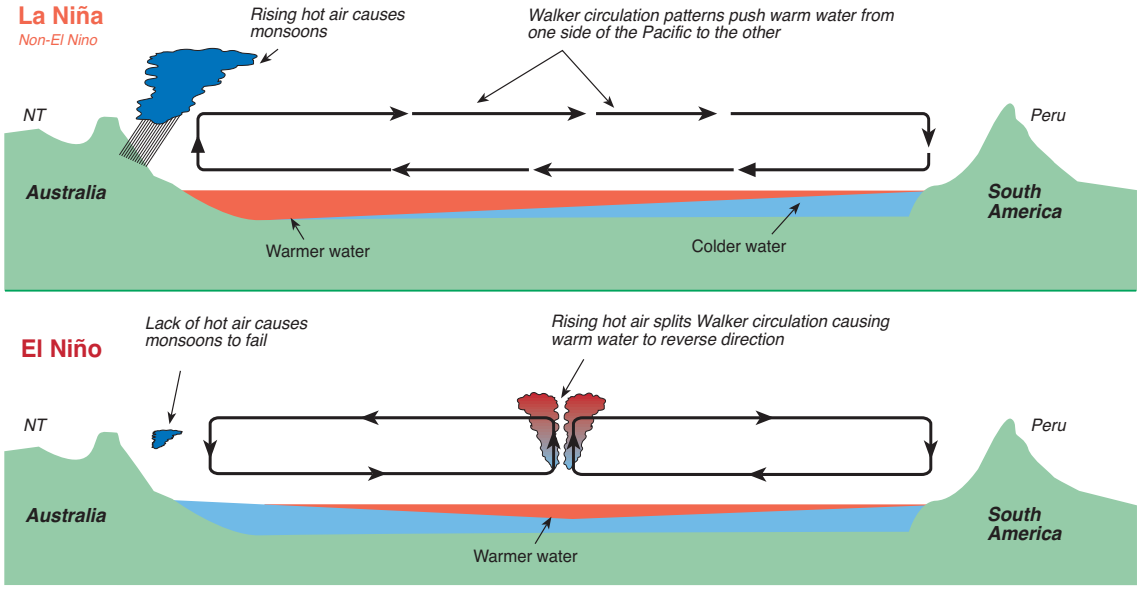


Figure 63.1 Explanation of El Nino
(Illustration Bob Moffatt)

The **Walker circulation** is the name given to the way that trade winds circulate air to and fro across the Pacific Ocean. The trade winds drive oceanic air west across the ocean to Indonesia and Australasia where the damp warm air forms monsoon rain patterns.

This warm moist air rises and, because it cannot rise over the land mass of South-east Asia, is pushed eastward by the air behind it to sink again towards the cooler water off Peru.

El Niño- a weather pattern that affects us all

Suddenly, for some reason, the push on the ocean surface falls and warm water that was once driven westward now runs back towards the central Pacific. This disrupts the ocean-atmosphere system shown in Figure 63.1 causing hot air to rise and split the Walker circulation pattern.

In the eastern Pacific, a branch of the Peru current breaks off, stopping cold water from entering upper layers of oceanic water. When this happens an El Niño is said to occur. It dramatically affects the world's climate and occurs every three to seven years.

Marine scientists have said that from a human and economic standpoint, the El Niño in 1982-83 may have affected the lives of nearly half the earth's population. The effects of El Niño are summarized below.

El Niño and fishing

Thermoclines (see page 65) off Peru are normally found about 50-200 m below the surface of the ocean (Figure 63.2). Where the nutrient-rich cold water flows so close to the surface makes ideal conditions for phytoplankton, a rich food source for larger fish.

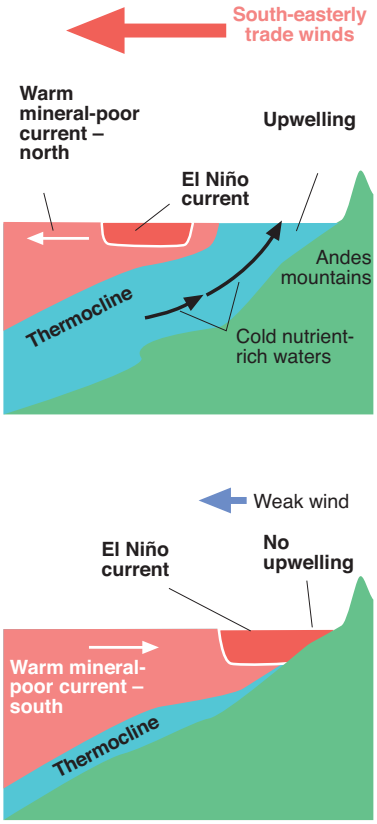


Figure 63.2 El Niño and fishing off Peru
(Illustration Bob Moffatt)

Questions

1. What are ocean currents and list the major factors that cause these currents.
2. Define the term *gyre*. In what direction do the gyres travel in the southern hemisphere?
3. How fast do the major currents flow?
   Discuss some factors that can cause their speed to increase.
4. Define the terms
   a. Corioles effect
   b. Geostrophic currents
   c. Convection currents
   d. Upwellings
   e. SOI
   f. Walker circulation
5. Discuss El Niño effects on Australia
6. Draw a diagram of a La Niña Pacific atmospheric circulation.
7. In the film - *Finding Nemo*, Marlin took three weeks to get to Sydney in the EAC. Calculate the average speed of the current based on this information.

Figure 64.1 James Cook was the first European to discover the East Australian current
(Photo Murray Waite)

However, in an El Nino event, Pacific Ocean sea levels can fall by as much as 20 cm off Indonesia and rise by up to 15 cm off South America. Warmer water drifts back towards Peru, thus cutting off the upwelling.

Plankton production drops dramatically because of the lack of food which then causes huge losses to the fishing industry and marine life in general.

El Niño and cyclones

In El Niño events, ocean temperatures can drop, changing cyclone paths so that cyclones have been recorded as far south as northern New South Wales. In normal (non-El Niño or La Niña) conditions, sea surface temperatures are about 8 degrees hotter in the west with rain and cyclones a normal part of the seasons. Marine scientists can predict that in normal times, atmospheric pressures in Darwin will be 16 times higher than in the eastern Pacific and that cyclones will have a predictable path.

We are only just beginning to understand how El Niño affects cyclones. Oceanographers from around the Pacific may one day be able to predict the paths of cyclones in all conditions.

El Nino and bushfires

During El Niño events, less wind blows across Australia, so less rain falls and summer temperatures can soar. This makes the risk of bushfires extremely high. Scientists can already predict when rainfall is going to be average or abnormal by tracking the SOI over a significant period.

Coastal currents

The film - *Finding Nemo* made the EAC world famous.

Scientists have been studying the major currents around Australia and New Zealand for many years.

Tracking instruments constantly are helping oceanographic analysts to discover many smaller local currents around our coastline.

We must understand currents to understand oceans. Oil spills in the North West Shelf can affect the tuna fishing off South Australia, pollution off Brisbane could affect the upwellings and fishing grounds in New South Wales and a study of Bass Strait oceanic sediments can reveal new resources for Australian industry.

The major Australian Currents are the

- East Australian current and eddies
- Flinders current
- West Australian current
- Leeuwin current
- South Equatorial current and
- Antarctic Circumpolar

Odd fact

Flowing south from the Coral Sea, the East Australian current carries up 10 million L of water/ second (or 10 times the amount of water in Sydney Harbour) and is up to 500 m deep and 200 km wide.

East Australian current

The East Australian current was first discovered by a European when Captain James Cook was just east of Byron Bay in 1770. An excellent navigator, Cook found that for two days he was actually sailing backwards. He realised that he had sailed into a strong current from the north.

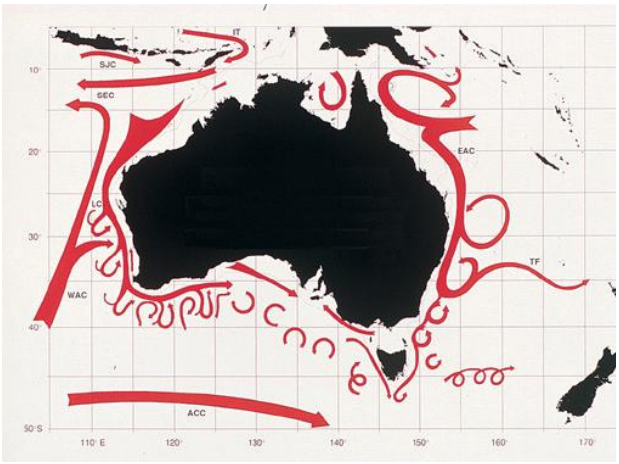
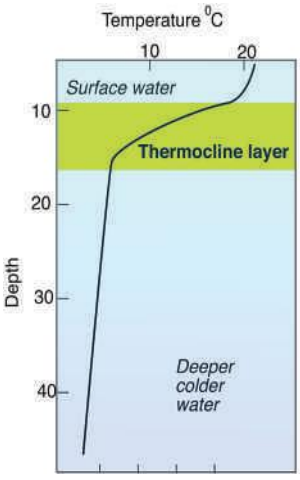


Figure 65.1 Australian currents
(Illustration Bob Moffatt Source CSIRO)



Definition
A thermocline is a layer within a body of water or air where the temperature changes rapidly with depth.

Figure 65.2 Thermocline
(Illustration Bob Moffatt Source CSIRO)

Studies by Dr Cesswell (CSIRO Marine Division) have uncovered some of the mysteries surrounding the East and West Australian currents. They used a series of tracker buoys, satellites and ships and discovered the East Australian current does not travel in one direction, but has large circulating bodies of water called eddies.

Scientists from the CSIRO have found that due to density differences the Coral Sea is almost a metre higher than Bass Strait. Because one of the seas is colder, water tends to sink.

A striking example of this can be seen in the Antarctic where the warm equatorial currents meet the cold Antarctic. As the upwelling of deep Antarctic water cools the surface water, the ocean water level sinks. Temperature differences can be up to 8°C and thermoclines develop (Figure 65.2).

But how are these eddies formed?

Dr Cresswell explains these eddies as follows, "The East Australian Current, EAC, runs over this shelf in a number of places causing the current to break up. As it does it causes eddies. In the triangle formed between the coast and the eddy, upwellings can be created, bringing up nutrients from 200 m deep.

The waters can be up to 5°C colder and the water a dirty brown." Now these eddies can last for up to a year and can drift up and down the coastline. Eddies could also be responsible for upwellings.

The eddies can last for up to a year and can drift up and down the coastline. The satellite photograph in Figure 65.4 is an image of sea-surface temperature showing an eddy pair at the eastern end of Bass Strait.

The white line is the track of the CSIRO's research vessel - The Southern Surveyor, as shown in Chapter 1.

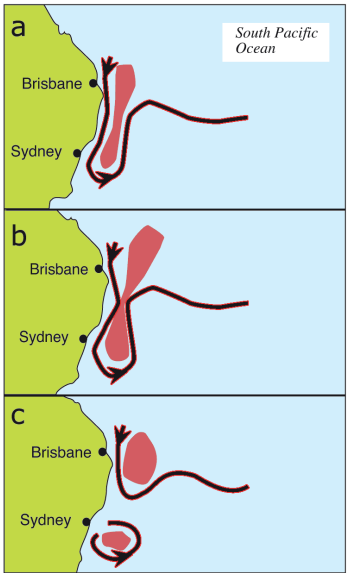


Figure 65.3 Eddies
(Illustration Bob Moffatt Source CSIRO)

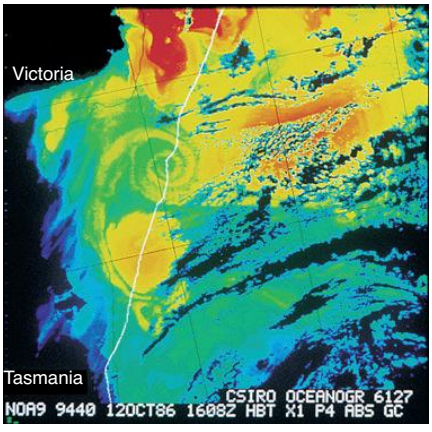


Figure 65.4 Eddies off Victoria and Tasmania
(Photo CSIRO)

Odd fact

The Southern Equatorial Current carries 50 million cubic metres of water per second which is equivalent to 50 times the volume of Sydney Harbour per second.

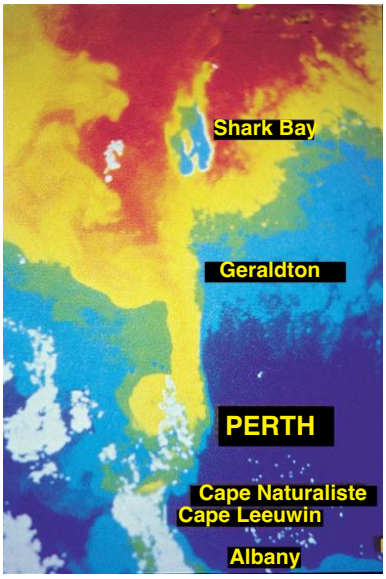


Figure 66.1 Satellite image of Leeuwin current off Western Australia
(Photograph courtesy CSIRO)

Western Australian currents

Leeuwin Current

Figure 66.1 from the Western Australian Institute of Technology, shows the Leeuwin current extending down the Western Australian coast during winter. This current is the main current influencing Western Australia and starts in the warm, low-salinity waters off the north-west coast. These less dense water causes the sea level to rise a height of 30cm. The water will then tend to flow to a lower level causing geotrophic currents. It flows southward to Cape Leeuwin and east across the Great Australian Bight.

The Leeuwin current intrudes between the coast and the south- west branch of the West Australian current. The current's movement depends on the time of year: it moves south from February to June, and is found off Perth in April.

Why fish need the Leeuwin current

Currents affect the lives of all the fish, which live in them, and thus the livelihood of everyone working in the fishing industry. The Leeuwin current, for example, brings juvenile southern blue fin tuna south along the coast of Western Australia from their spawning ground off the northwest of the continent.

Another species of fish, which depends on the Leeuwin current, is the Australian herring *Arripis georgianus* also called Tommy Ruff in South Australia and Victoria. Herring larvae grow up in the warm waters around Shark Bay and then, within a few months, are found almost one-third of the way around Australia in the ocean off Adelaide and Melbourne (Figure 66.2).

As the current slows, the larvae make their way into estuaries and bays where they grow into juveniles and feed off the rich plankton waters in the southern ocean. When they are mature, they migrate back to Western Australia. Without the Leeuwin current, *Arripis georgianus would* not be able to survive.

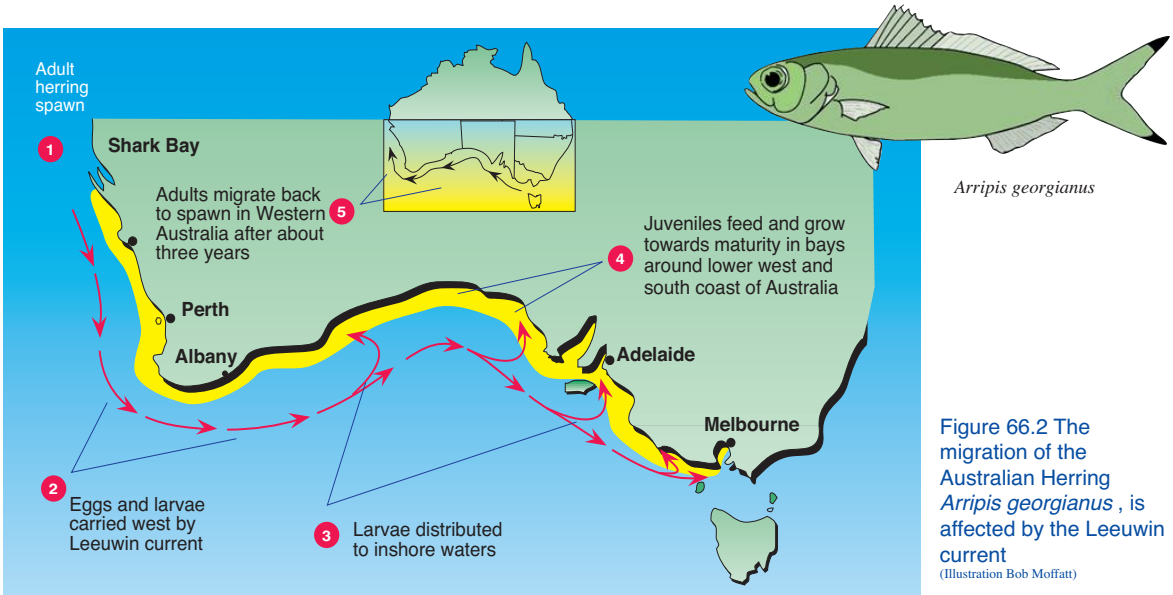


Figure 66.2 The migration of the Australian Herring *Arripis georgianus* , is affected by the Leeuwin current
(Illustration Bob Moffatt)

Western Australian current

The western Australian current is an open ocean current in the Indian Ocean and is part of the South Equatorial Current. The South Equatorial Current is a subtropical gyre called the South Indian Gyre and this forms the Western Australian Current when it encounters the landmass, Australia. This is a cold water current that moves northward up the Western Australian coast.

Flinders current

The Flinders Current is a southern current flowing from western Tasmania through the Bass Strait to South Australia between November and February. This current causes upwellings off the South Australian coast when the current interacts with the continental shelf. These upwellings bring nutrient-rich sediments from the continental shelf causing plankton blooms.

Antarctic circumpolar current

The major factor that gives rise to the Antarctic Circumpolar Current is the strong westerly winds in the Southern Ocean. This current travels at a rate of 10 km per day. The current is the only ocean current that is basically unimpeded by a land mass and it simply orbits the Antarctic. This current allows the mixing of waters of the Indian and Pacific Oceans, which is important for marine life in the area.

Deep ocean currents

Surface currents account for only 10% of the total volume of the oceans' waters and the other 90% is moved by sub-surface currents. Deep ocean currents can occur below thermoclines found in the oceans and are separate from surface ocean currents.

These currents are driven mainly by changes in water densities and ice formation. The waters at the Poles become more saline as the ice is formed. Ice contains little or no salt and effectively removes the water from the seawater. The sea floor terrain also affects these currents.

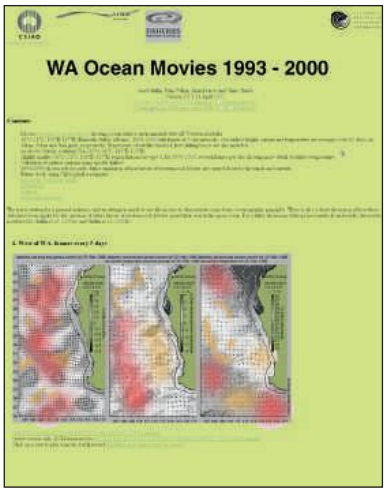


Figure 67.1 Check out movies of Western Australian currents on this site
(Photograph courtesy CSIRO)

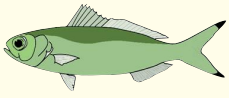
Questions

1. Define the terms
   a. Thermoclines
   b. Eddies
2. In what time of the year is a Leeuwin Current formed? Why is this current important to some marine life?
3. List the major warm currents found around Australia. How are these currents important to the ecology of those areas?

Exercise 3.1 The Australian Herring

Use the information in Figure 66.2 to answer the following questions:

1. Where do adult Australian herring live?
2. When are the commercial and recreational fishing seasons in Western Australia and South Australia? When do you think the best time would be to go fishing in Victoria?
3. Why don't the fish get to Tasmania?
4. Where do the juveniles develop? What do they feed on?
5. Why do we have to keep pollution out of our coastal waters?
6. How long does it take for a herring to grow to an adult?
7. Draw a diagram to show how a fisher would catch a school of herring from the beach with a seine net.
8. Develop a plan to protect the Australian Herring Fishing Industry. Do you believe this should be a state or commonwealth initiative? Would a closed season be part of your protection plan?



Exercise 3.2 Current experiments

Experiment A:

Aim
To determine if warm water will rise or fall.

You will need
- A small aquarium full of water (Figure 68.1), ice block, test tube and stopper, food colouring

What to do
1. Fill the vial with hot water and place a few drops of food colouring in it.
2. Now stopper it and place at the bottom of an aquarium filled with water.
3. Place an ice cube on the surface and add a few drops of food colouring. Observe what happens.
4. Now open the vial and observe what happens.
5. Write a conclusion and predict what happens to water at the poles and equator.

Questions
1. What happens to water as it cools down from the tropics to the poles?
2. What happens to water as it moves into the tropics?

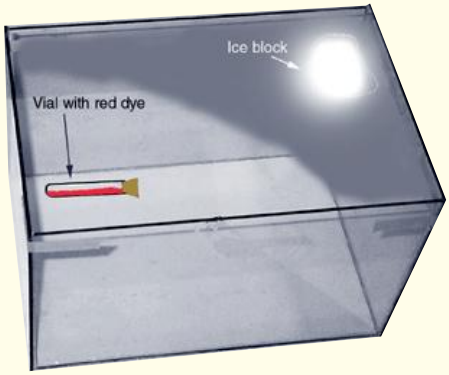


Figure 68.1 Experiment A: set up
(Photo Bob Moffatt)

Figure 68.2 Experiment B: set up
(Photo Bob Moffatt)

Experiment B:

Aim
To study longshore drift.

You will need
- A small tray filled with sand and water as shown in Figure 68.2, condys crystals, wave generator (Block of wood - see Figure 68.2).

What to do
1. Make a beach as shown in Figure 68.2 .
2. Generate some waves with the block of wood and have a partner add a few drops of Condys crystals as shown.
3. Keep generating the waves and observe what happens.

Questions
1. What happens to the dye in the tray?
2. Design an experiment to test the hypothesis that longshore drift is determined by depth.
3. Design an experiment to demonstrate refraction and diffraction (See Chapter 2).

Long shore drift field study
(Based on an original idea by Mary Lou Carle)

You will need
A straight stretch of beach, two oranges, data sheet, pencil, hard surface to write on and a watch with second hand.

What to do
1. Pace out 5 stations, 15 metres apart on the beach.
2. At a prearranged signal you cast your oranges into the sea - one close in the other as far out as you can throw and the timekeeper starts the watch. You then follow your oranges and any variations. It the orange comes in, you should throw it out again.
3. After one minute the timekeeper signals and you are to mark the position of your orange in the sand opposite where the orange is. After two, three, four and five minutes, record data accurately in the tables developed in class.
4. Draw up a data table and write a short report on your results.

Figure 69.1 Strong currents can form in narrow channels.
(Photograph Bob Moffatt)

Local currents

Tidal, overflow, long shore, rip, estuarine and river currents are found along beaches and coastlines, within mouths and estuaries.

Importance

Local currents affect the activities and safety of swimmers, sailors, surfers, snorkellers and people in boats.

Animal and plant life is also affected. Plants have special roots called holdfasts to help them stay in place and animals will have strong suction pads to stop them being washed away. Many animals and plants use local currents to disperse their young after mating. Some corals even time their reproductive cycle to coincide with tides and currents. Other animals and plants shed their reproductive cells into sea water so that the currents can help the fertilisation process by mixing the sperm and eggs.

Control

Local currents are controlled by factors such as river discharge, tides, depth of water, shape of coastline and weather.

The coastal pattern of currents also varies with the season and can even have daily fluctuations. The river flow varies with the season, with most of the rains on the east coast of Australia occurring in summer. The volume of water discharged by these rivers is enormous.

If the estuary is shallow and fan-shaped it will have a funnel effect on the current and cause strong currents.

Tidal currents

Strong tidal currents can form when large rises and falls occur in tide height in narrow channels (Figure 69.1) or around headlands (Figure 69.2). Activities in these areas should be timed for the top or bottom of the tide to avoid the full force of the tidal current. This current can be very strong when water flows through a narrow channel. These are usually well marked on local charts, which also show the speed of the current.

Research topics

1. Circulation of the Abyss
2. Power from ocean currents
3. Impact of coastal development on currents
4. How has our knowledge of the oceans increased with wars?
5. Commercial shipping routes which use ocean currents.

Odd fact

The Amazon River carries such a volume of water that water is still fresh 150 kms out to sea.

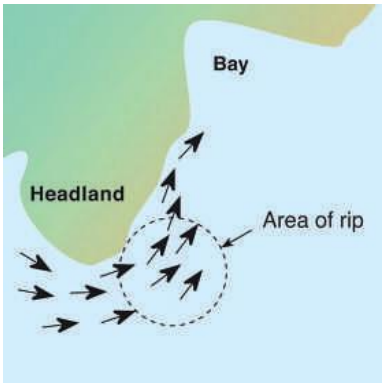


Figure 69.2 Rips can form around headlands
(Illustration Bob Moffatt)

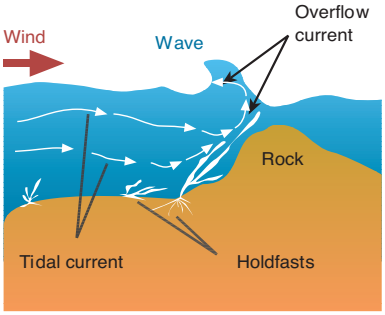


Figure 70.1 Overflow current
(Illustration Bob Moffatt)

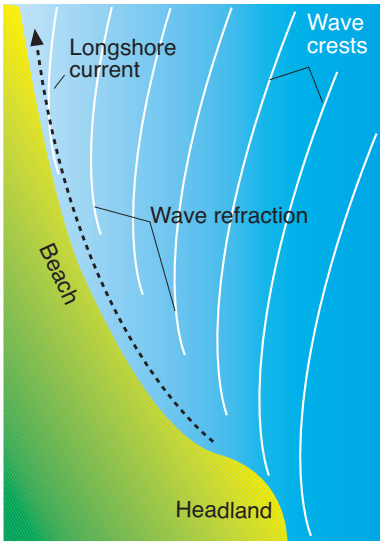


Figure 70.2 Longshore current
(Illustration Bob Moffatt)

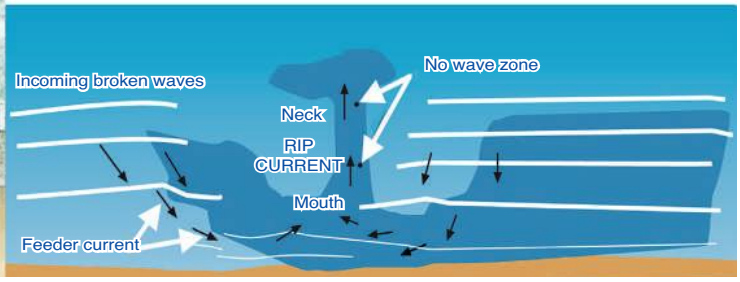


Figure 70.3 Inshore rip current
(Photo and illustration Bob Moffatt)

Overflow currents

When driving a small boat near a river mouth on a strong incoming tide, you will notice a disturbance in the water surface called a rapid. This is when the incoming tide passes over a submerged rock or reef causing the water to hump up into an overflow current as shown in Figure 70.1. If the wind blows into these humps, uneven breaking waves can form which makes boating hazardous.

Longshore currents

If waves approach a beach at an angle, as shown in Figure 70.2 they set up a longshore current close to the beach. These currents move sand along the coastline (discussed in Chapter 4).

Rip currents

The bigger the waves coming onto a beach, the bigger the backwash current away from the beach. Where the backwash finds an easy channel back out to sea, rip currents can form (Figures 70.3). Rips are areas without waves where the water runs back fast towards the open sea.

Swimmers who are caught in rips can be unexpectedly carried out beyond their depth. If caught in a rip, all you have to do is to stay calm, dive under the waves as you are taken out to sea, and attract help when you are past the breakers. Alternatively, swim sideways till you reach a sandbank and then catch the next wave in further up or down the beach.

Four types of rip include:

- permanent, where the current remains in the same place for months, even years;
- fixed, where a gutter or depression in beach sand keeps a rip in place for months;
- flash rips, where a depression suddenly occurs in a beach profile; and
- travelling, where a rip moves up the coast.

Rips are not always dangerous, they can be useful if you know what you are doing.

Surfers use rips as an easy route back to the sea after they have surfed into the shore. They enter the rip at the mouth and are quickly swept out through the neck and then past the breakers at the head of the rip as shown in the figures below.

Estuarine currents

Currents can also form in estuaries (Figure 71.1). As the tide comes in or goes out, the water currents mix rapidly causing strong rips and dangerous situations. Strong surf running at the mouth of the river causes currents so avoid river mouths if you are collecting marine samples.

River currents

River currents form when rainfall in the catchment area increases during floods. Tidal bores can also cause river currents and can reach a height of up to 5 metres in places such as Wales, the Amazon River or in the Bay of Fundy.

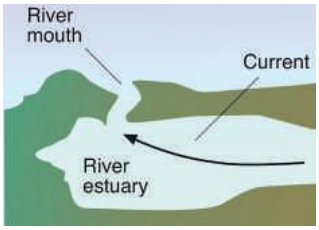


Figure 71.1 Estuarine currents
(Illustration Bob Moffatt)

Measuring currents

Oceanographers originally obtained their knowledge of the ocean currents from information supplied to them from sailing ship skippers who had becalmed in these currents. Oceanographers developed new instruments to better understand the complexities of the currents (Figure 71.2). These floating laboratories allowed the collection of data, which permitted the oceanographers to further develop their understanding of the ocean currents.

Direct measurement of these currents can be undertaken by either placing a device that floats with the current or by placing a fixed instrument to measure the current as it passes. The drifting devices can include traces, drifting buoys or drogues (which have a parachute attached). These drifting current measurers can be tracked at the surface by satellites or if submerged, by boat sonar. The fixed devices measure the direction, speed, temperature and salinity of the current as it flows past them. This information is recorded and is later downloaded by the oceanographers.

The greatest leap of understanding of the ocean currents came with the ability to gain information from space by the use of satellites. This has allowed the oceanographers to gain an overall picture of the entire system and not just fragments of information that had to be pieced together like a jigsaw puzzle. The ocean could be seen and studied as a complete system.

The satellites were able to measure infrared radiation to an accuracy of 0.1°C and show the seawater surface temperatures.

Satellites can also use a microwave radiometer that detects emissions from the sea surface allowing for the measurement of temperatures, ice cover and wind speed. Microwave radar can also be used to measure surface undulations such as waves and ship wakes with great accuracy.

Questions

1. Currents that move up rivers depend on 2 factors. What are they? How can the current's speed be calculated?
2. List the 5 major factors affecting local currents.
3. List the 6 different types of local currents.
4. Rips can be both useful and dangerous, use a diagram to explain how these rips can be formed.
5. Identify the 4 types of rips that can occur.
6. What are 2 types of current measuring devices? How has satellite imagery helped us understand the oceans?

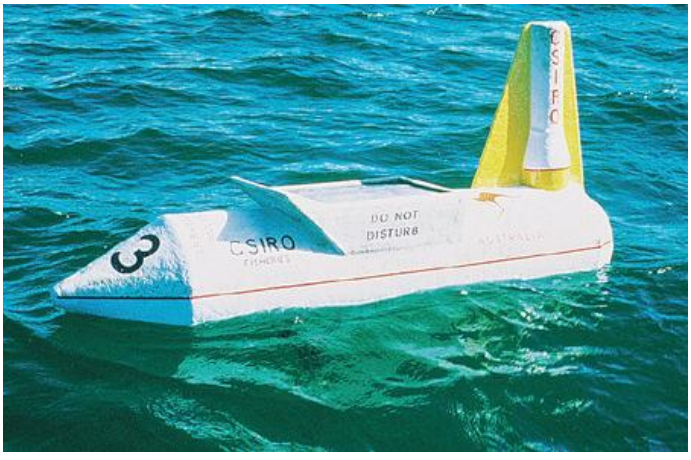


Figure 71.2 Satellite tracker buoy
(Photograph CSIRO Marine Division)

Exercise 3.3 Local currents

Method

Part A Making a drogue

1. Attach the plastic bottle to the broom stick with lots of tape and cord as shown in Figure 72.1.
2. Drill a hole in the bottom of the broom stick and tie the weight on with another piece of cord.
3. Test your drogue in a swimming pool or wheelie bin.
4. Make adjustments so that the drogue floats and add a flag.

Part B Field work

1. Tie 10 metres of cord to the drink bottle.
2. Select a place such as a jetty where the current is running and you can launch your drogue.
3. Lower the drogue into the water and tell your partner to time how long it takes for the drogue to run out to the full length of the 10 metres of rope on a prearranged signal.
4. When your partner is ready, release the drogue and observe what happens.
5. Use the hand bearing compass to determine the direction of the current.
6. Using the formula:

   Speed = distance / time

   calculate the speed of the current and record it.
7. Repeat your experiment twice and average your results.
8. Make a summary detailing how fast the current was, which direction it was flowing, the possible cause of the current and how the current may change during the day.

Extension

You may like to try to see if the current speed changes at different times in the day.

Figure 72.1 A home made drogue
(Photograph Bob Moffatt)

Figure 72.2 Tracking drogue
(Photograph Bob Moffatt)

Materials and equipment (per group)

Equipment required

- electrical tape
- empty plastic bottle
- old broom stick
- drill
- divers weight
- 11 metres venetian blind cord
- coloured materials (for flag)
- watch with second hand
- handbearing compass

Weather and the sea

Weather affects us and all other organisms. Weather maps (Figure 73.5) can be used to indicate temperatures, wave heights, wind speed and direction.

Temperature

Temperature, measured in degrees Celsius (°C), is how hot or cold a substance is. We measure temperature with a mercury thermometer.

As the temperature increases, the mercury in the bulb expands and moves up the tube. As the temperature drops, so does the mercury. The bulb of the thermometer is placed in or on the substance being measured.

Weather reports often give daily maximum and minimum temperatures, which are measured with the special thermometer shown in Figure 73.2. The pins are pushed by the mercury but stay in position in the tube when the mercury recedes. To measure either the maximum or minimum temperature for a given time period (usually 24 hours), read the scale at the bottom of each metal pin. After taking the readings, use a magnet to return the pins to the top of the liquid mercury.

Air pressure

Air pressure or atmospheric pressure is the force of the earth's atmosphere. It varies with temperature and weather. Warm air expands and rises, becomes lighter and therefore exerts less pressure.

Cold air is heavier, falls and exerts more pressure. Rapid changes in pressure produce equally rapid changes in weather: decreasing pressure is associated with wet, stormy conditions and increasing pressure with warm, fine conditions.

Air pressure, measured in hectopascals (hPa), can be measured by an **aneroid barometer** (see Figure 73.3), which connects a vacuum-filled box with a pointer (see Figure 73.4).

A small change in pressure causes the box to expand or contract, moving the pointer as shown.

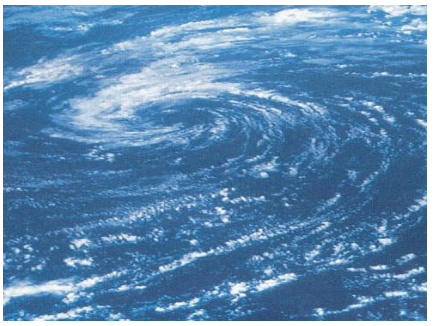


Figure 73.1 Cyclone
(Illustration courtesy Bureau of Meteorology)

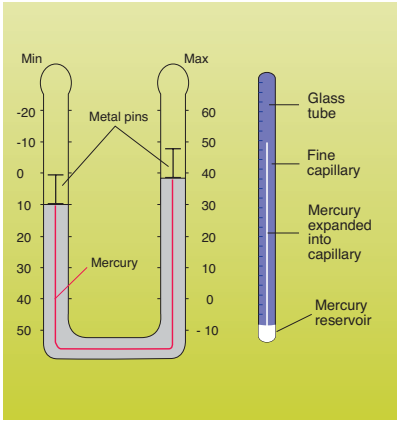


Figure 73.2 Max - Min thermometer
(Illustration Mark Moffatt)

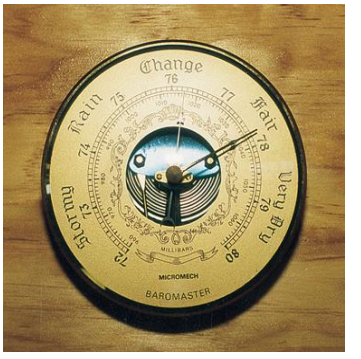


Figure 73.3 Barometer
(Photograph Bruce Heyer)

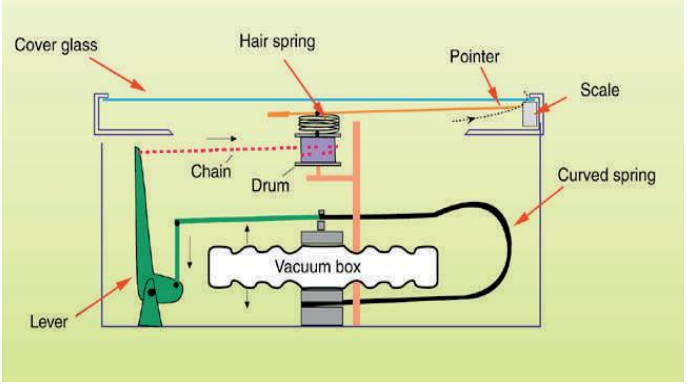


Figure 73.4 Barometer
(Illustration Mark Moffatt after an original drawing by Bruce Heyer)

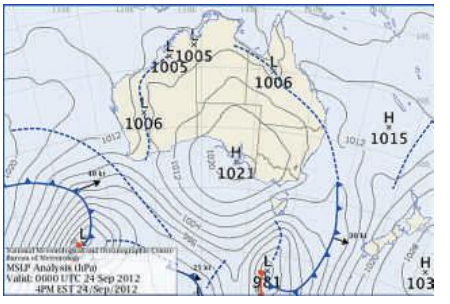


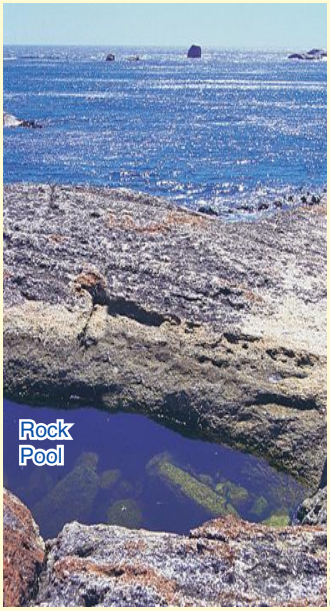
Figure 73.5 Weather map
(Illustration courtesy Bureau of Meteorology)

Temperature in rock pools

The range of temperatures marine organisms have to cope with depends also on the volume of water and tidal range in which they live.

The smaller the volume of water, the larger the range of temperatures.

Only a small amount of solar energy is needed to raise the temperature of a rock pool by 5°C, but the ocean requires a large amount of energy to cause the same temperature fluctuation.



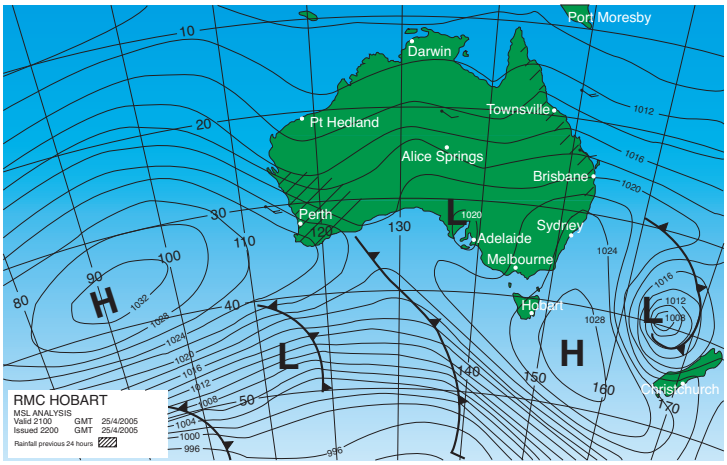


Figure 74.1 A weather map
(Illustration Mark Moffatt)

Fronts

Look at Figure 74.1. The lines connecting places of equal air pressure are called **isobars**. Low pressure areas (L) are called **lows** and high pressure areas (H) are called **highs**. The lines are drawn closer together to show steeper changes in air pressure.

Differences in temperature and pressure, along with the earth's rotation on its axis, cause the air to move over the earth's surface in large volumes called air masses.

When air masses of different temperatures meet, they produce either warm or **cold fronts**. Most changes in our weather occur at these fronts.

Cold fronts (Figure 74.2) occur when a cold air mass moves into and under a warmer air mass, usually producing colder and unsettled, sometimes stormy, weather.

When the front passes, we get colder, clearer weather. Warm fronts occur when a warm air mass moves in and over a cold air mass, usually producing cloudy wet weather followed by warmer, clear conditions when it passes. Although warm fronts do occur in Australia from time to time, they are rare. Fronts very rarely occur in Northern Australia, but control daily activities in Melbourne, and Adelaide where they are very common.

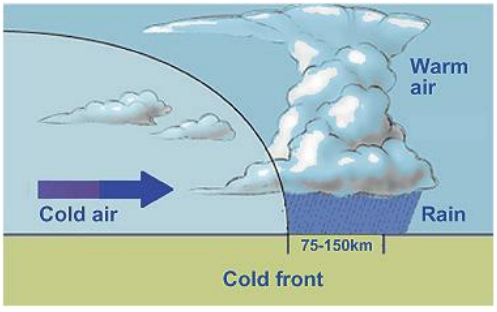


Figure 74.2 Cold front
(Illustration Mark Moffatt)

Winds

Winds are important because they:

- form waves (Chapter 2);
- control the size and direction of ocean swells;
- influence the speed and direction of currents; and
- determine our safety and comfort in the marine environment.

Winds are produced by differences in air pressure and density. Air will always move from a high pressure area to a low pressure area and the greater the pressure difference, the stronger the wind.

Offshore and onshore conditions

Land heats up and cools down much faster than water, creating pressure differences and wind as shown in Figure 75.1.

In the morning when the temperature of the sea is higher than the land, there is lower pressure over the sea than the land. Cooler air from the land replaces it, creating an **offshore breeze**. In the afternoon, when the temperature of the land is higher than the water, warm air rises to create a lower pressure region. Cooler air from the higher pressure region at sea then moves in to replace it, creating the sea or **onshore breeze**.

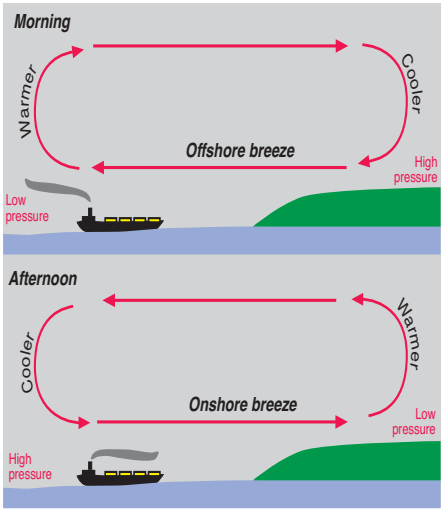


Figure 75.1 Offshore and onshore conditions
(Illustration Mark Moffatt)

Wind symbols

Weather maps show both wind speed and wind direction with the symbols shown in Figure 75.2. The angle of the tail shows wind direction. Wind speed is shown by the tail strokes. Each stroke = 10 km/hr and each short stroke = 5 km/hr. The angle of the tail stroke indicates the direction the wind is blowing. The insert shows a wind of 15 km/hr from the north-west.

An **anemometer** (Figure 75.3) can be used to measure wind speed and a weather vane is used to measure wind direction. Strong winds can produce large waves which can wash away large amounts of sand and cause beach erosion. Large apartment buildings built too close to the sea on Queensland's Gold Coast suffered a lot of damage in the early 1980s due to sinking foundations caused by erosion during heavy storms.

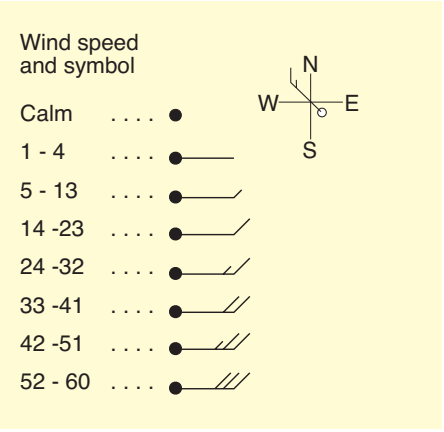


Figure 75.2 Wind speed and direction
(Illustration Mark Moffatt)

Rainfall

Rainfall or precipitation is measured in millimetres (mm) by a rain gauge. Rainfall is shown by shading on a weather map. Rainfall depends on evaporation from the oceans providing most of the water vapour that forms clouds. This is a vital link in the water cycle.

The two main rain-producing clouds are nimbostratus (middle level clouds between 2,500 and 6,000 m above sea level) and cumulonimbus (dark grey to black, low in the sky, usually below 2,000 m). Cumulonimbus clouds concern ship captains and fishing boat skippers the most because they can produce heavy rain and high winds.

Figure 75.3 Anemometer
(Photo Bob Moffatt)

Humidity

Humidity is a percentage measurement of the amount of water vapour in the air. It is measured with an instrument called a hygrometer. Humidity is important to rocky shore sea creatures as it is one method by which they can obtain water.

On humid days, some animals are able to absorb water through their skin. Days with low humidity pose a problem called desiccation or drying out. On these days animals need to keep all openings to the outside world closed to stop any moisture loss from inside the animal.

Set up a class weather station by following these steps.

1. Set up these instruments on a table or platform in a secure open area near your classroom: rain gauge, barometer, anemometer, weather vane, maximum and minimum thermometer and hygrometer.
2. Check your readings against media reports and charts.
3. When all data is collected, construct line graphs of air pressure versus time and maximum temperature versus time. Comment on any trends shown by the graphs. Compare your data with the published data.

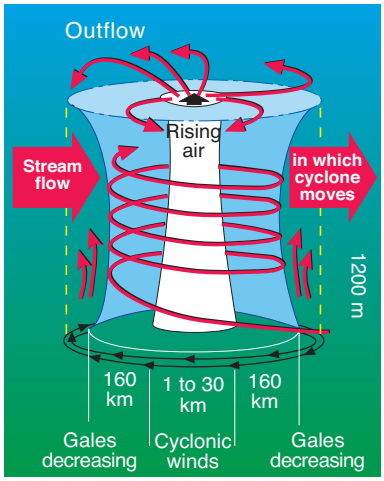


Figure 76.1 Cyclone
(After BOM web site, illustration Mark Moffatt)

Weather forecasting

Data records of these five major weather factors are sent every day to the Bureau of Meteorology in major cities from hundreds of weather recording stations from all over the world. Some of the stations are manned by amateurs, some by professional scientists called meteorologists and some stations are unattended. The unattended stations rely upon automatic recording instruments. Data is also collected from radar and satellites orbiting the earth.

Technology

Knowing weather conditions in advance is important to everyone planning outdoor events ranging from a barbecue or surfing competition to a multitude of work activities.

Professional fishers, for example, rely each day on accurate predictions of approaching wind and swell conditions at sea. This information could determine when and where to fish, or in fact whether to go at all if a storm is on the way.

In the past, people predicted weather by comparing new observations and recordings with data for similar times in the past. We still use this method but our predictions are much more accurate thanks to computer data processing technology.

Three main advances in technology have improved weather forecasting today.

- Satellites containing infra-red cameras, which can take photos at night, constantly orbit the earth and provide a continuous record of cloud cover.
- Weather balloons, containing instruments to measure temperature, pressure and humidity, are released from stations as far away as the South Pole. They can transmit this data to warn of approaching fronts.
- Radar, which can detect and accurately track the speed and direction of cyclones and storms, provides us with advance warning as to where and when they will strike.

Weather reports

Official Bureau of Meteorology weather reports in Australia and New Zealand usually include storm warnings; coastal weather forecasts on the radio; recorded boating weather reports; and weather reports on the radio, the television and in newspapers. Today inexpensive weather alert systems give up-to-date information on sea conditions. As the Bureau records changes in the weather, that information is relayed through a computer system to transmission towers, where it is beamed on VHF frequency to everyone who wants it. Weather maps can also be obtained from the internet (www.bom.gov.au) .

Cyclones

These are low pressure systems (Figure 76.1) with very high winds and waves that alter the marine environment significantly. High rainfall causes large sediment runoff which can affect reefs. Big waves can move boulders and cause severe beach erosion.

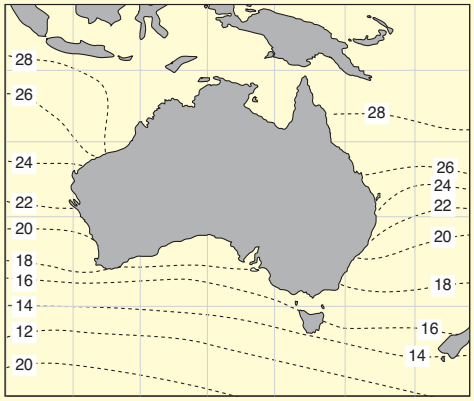
Exercise 3.4 Sea surface temperatures

By Tim Ryan

Use Figure 77.1 below to answer the following questions

1. Suggest the sea water temperatures for a position 30 km off the coast in February at the following places:
   a. Brisbane
   b. Sydney
   c. Melbourne
   d. Hobart
   e. Perth
   f. Shark Bay
   g. Broom
   h. Darwin
2. What are the coldest sea temperatures on mainland Australia in August and where were these cold waters found?
3. Suggest why the waters in the Spencer Gulf are 20^{O}C yet off the Kangaroo Island they are 18^{O} in February.
4. The lines joining sea temperatures flow southward down the Western Australian coast to Perth. Suggest a reason for this phenomenon.
5. Pure water freezes at 0^{O}C, yet some of the areas show water temperatures below this temperature. Explain these temperature readings.
6. Suggest a reason for the fact that the seawater temperatures at the same latitude are not always the same.
7. Suggest how this data may have been gathered?
8. Conduct an analysis of the data and suggest why this type of data may be useful to navigators in the Sydney – Hobart Yacht Race. If you were to complete the journey in February, what path would you take? Do you believe the current will assist you on your journey? Explain the reason for your answers.
9. Explain the change that occurred between February and August. Suggest a reason for the change.
10. How might the figures change from an El Nino pattern to a El Nina pattern? Explain your answer fully.
11. Suggest why shipwreck survivors can survive up to 40 hours in the waters off Brisbane but only 6 hours off southern Tasmania.
12. How would a plankton density map compare with this image?

Summer



Winter

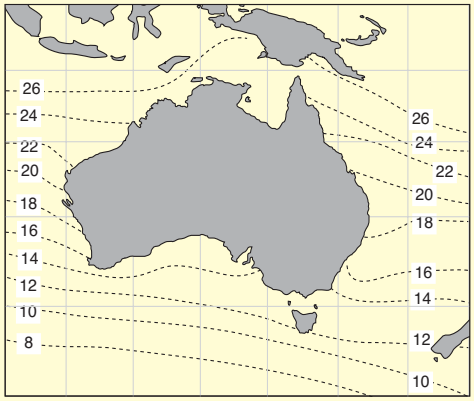


Figure 77.1 You may like to go to www.bom.gov.au to get a more up to date image
(Illustrations Trent Moffatt – source: Bureau of Meteorology)

Case study 3.1 Epic voyage ends in dumping

Text after Courier Mail, Questions by Tim Ryan

Kerry Kitzelman

After 272 days alone at sea the journey for Jim Jones, across the Pacific Ocean ended in his boat being overturned in seas off the coast of Ballina on the east coast of Australia.

On 20th December 2002 the veteran British sailor, Jim Jones became the first person to row solo across the Pacific Ocean unassisted. His non-stop crossing covered a distance of 790 nautical miles from Peru in South America to Australia. This bettered the old record of Englishmen, Peter Gull who rowed from San Francisco to the Great Barrier Reef in 1985, by 22 days.

As he waded ashore after being dumped from his boat he shouted, "Anyone would think it was a race. The boat was determined to get here before me." His 11 metre rowboat called "Le Turtle" was overturned by waves some 60 m off shore.

After 11 months at sea Mr Jones said," I can't wait for a few beers, a good meal and a good night's sleep." He said he had only been able to sleep for short periods for safety reasons as he crossed the Pacific.

The major problem he encountered was the fact that he had forgotten the tin opener and most of his meals were in tins. He did have with him fishing gear but it was not used in the entire trip. He had run out of cereal and soup a week before he landed.

After dining out at a local hotel in Ballina overnight he said that it was good to spend time with his family but he did want to get back to the beach to salvage "Le Turtle". Although stiff and sore after the pounding he took in the surf he said he was interested to get a sponsor for his next adventure.

Questions

1. What was Mr Jones's major achievement as suggested in the article?
2. Calculate the distance he travelled in kilometres on his epic journey.
3. Calculate the average speed at which he travelled on his crossing of the Pacific.
4. What do you think a typical diary entry would be for day 150 of the trip?
5. Suggest the list of gear and quantities of items he would have had to carry on 'Le Turtle'. What safety equipment do you think he would have carried?
6. It was stated that for safety reasons he only slept for a few hours at a time for the entire journey. Why do you believe this was necessary?
7. Since 1896 there have been more than 100 attempts to row across oceans with only 50 of the rowers surviving the ordeal. The British made most of these attempts. Make a list of probable causes for the failures. Rate these causes from most likely to least likely.
8. What do you believe would have been the seawater temperature changes over the journey if he had taken daily seawater temperature readings?
9. Suggest why the boat survived the high swells and strong winds of the Pacific storms but was rolled 50m from the shore of Ballina in 1.5m seas.
10. Did he row or was he pushed? Do you think he would be able to complete a return trip? Explain your reasoning.
11. Everyone has goals or dreams. Do you believe you could spend over 200 days alone? What are your goals in life? Can you visualise yourself doing this activity? What might inspire you to make such an epic journey?

Case study 3.2 Reading the eddies

Text by SOMER, Questions by Tim Ryan

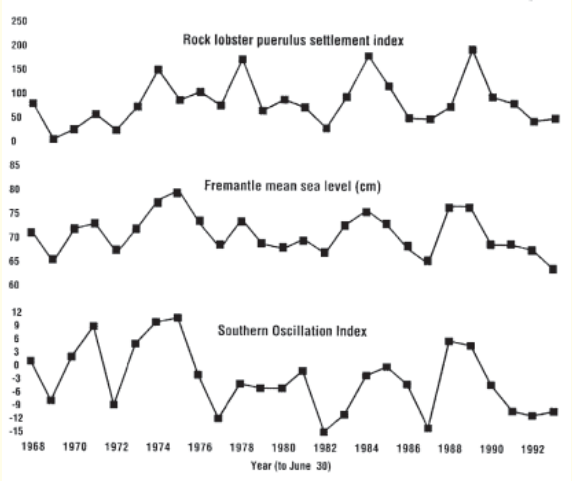
When plotted from above, the major ocean currents surrounding Australia resemble the writhings of an octopus: tapering tentacles grasping and whirling their way from warm tropical waters to sub-Antarctic seas.

To the east of the continent is the East Australian Current, stretching to 200 km wide and 500 m deep as it ferries southward about 10 million cubic metres of water per second. The current begins as a surface stream tens of metres thick on the boundary of the Coral and Tasman seas. On its snaking journey it crisscrosses the continental shelf, delivering upwellings of nutrient-rich water off Cape Byron, Smoky Cape and Sugarloaf Point.

The East Australian Current and its influence was recorded as early as 1770 by James Cook, who found himself in a southward drift off Cape Byron, despite fresh winds from the south. More than two centuries later, oceanographers at CSIRO Marine Research are developing a profile of the current, from the surface to the ocean floor, and across the continental shelf. The profile will underpin advice on the current's influence given to fishers, ocean yacht racers, and marine rescue and environmental authorities.

Alan Pearce from CSIRO's Marmion laboratory has tracked and analysed the Leeuwin Current for the past 14 years. Once a week, Pearce visits Perth's Leeuwin Centre for Remote Sensing Technologies, selecting the less cloudy sea-surface temperature images from polar-orbiting NOAA satellites. Together with more conventional oceanographic data such as coastal sea levels, these have helped him establish direct links between the Leeuwin Current and the El Nino Southern Oscillation: during El Nino events the current appears to weaken, marginally reducing its water temperature.

Pearce's work has helped answer many questions about the life cycles and sustainable management of WA fisheries. The western rock lobster (Panutirus cygnus), Australia's highest value single-species fishery, is a good example. Western rock lobsters begin life as larvae, hatched in the summer months on the ocean floor along the outer continental shelf, then float to the surface where they drift still further offshore, assisted by prevailing winds and surface currents.



Research by Alan Pearce has established direct links between the Leeuwin Current and the El Niño Southern Oscillation. These in turn affect recruitment of western rock lobster, Australia's largest single-species fishery. (Source: Australia State of the Environment, *1996)*

The voyage back to the coast can take as long as 11 months, during which the larvae undergo a series of moults.

By late spring they have changed to what is known as puerulus (tiny pre-juveniles, with the ability to swim) and settle in protected, shallow coastal waters.

Here, the Leeuwin Current has a major influence on the number of puerulus settling into the coastal reef system.

Pearce and his team, together with the Fisheries Department of WA, have shown that in years when the current is stronger, and the water warmer, the settlement is improved, resulting in a better catch when the lobsters reach legal size in three to four years time.

Conversely, when the current is weaker, (in El Nino years), settlement is not so good and the catches which follow are down. 'The difference can mean tens of millions of dollars to the industry which is partly based upon predictions of catches up to four years ahead,' Pearce says. Exactly how the Leeuwin Current affects puerulus settlement is unclear, but there are two hypotheses.

Firstly, laboratory tests indicate that the warmer waters of the current could help the growth and survival of the larvae. Secondly, the current's eddies may assist in the transport of the late larval stages and puerulus across the continental shelf into coastal reef nurseries, especially in southern areas such as Cape Mentelle.

Questions

1. How much water does the Leeuwin Current move as it heads south?
2. Who was the first person to record the effect of the Leeuwin Current?
3. Explain why the study of the Leeuwin Current is important.
4. Identify the methods that are now being used to study the Leeuwin Current.
5. Describe the life cycle of the western rock lobster.
6. Formulate an hypothesis to account for the effect of the Leeuwin Current on the number of puerulus settling.
7. In what years were the western rock lobster puerulus settlement index the highest?
8. Develop an experimental method that could be used to test the idea that western rock lobster larvae grow faster and have a higher survival rate in warmer waters.
9. Explain how the El Nino effect influences the western rock lobster catches.
10. Speculate on the effect of a mean sea level of 80 cm being recorded in Fremantle in 2020 on the settlement of the puerulus. Suggest the southern oscillation index for the sea level of 80 cm to occur.
11. Predict the trend for the settlement of puerulus over the next five years. Explain the reasoning behind your forecast.

Exercises

From the Wet Paper Publication - *Oceanography Exercises*
See www.wetpaper.com.au

A6. How do ocean currents form?
A7. How does the El Niño current affect thermoclines in the sea?
A8. What effect does El Niño cause?
A9. What is so special about the EAC?
A10. What is so special about the Leeuwin current?
A11. When do Australian ocean sea temperatures change?
B3. How does weather affect waves?
B7. Why do tides change over the month?

Questions

Knowledge

1. Describe a tracker buoy.
2. Name three types of currents discussed in this chapter.
3. List four major influences that create ocean currents.
4. Where is the Leeuwin current?
5. Name five places in the world where there are major upwellings.
6. Name the rising of the water from the bottom of the oceans.
7. State the name for the circular patterns of currents in the ocean.
8. Tell the story of Jim Jones and his rowing expedition from the case study on page 78.
9. Write a sentence describing a geotrophic current.

Understanding

10. Convert 10 km/hr to m/sec.
11. Draw a diagram to show that you can distinguish between a land and a sea breeze.
12. Describe an experiment with an aquarium, some ice and food colouring that will show the difference between warm and cold water movement in the ocean.
13. Distinguish between an eddy and a convergence.
14. Interpret today's weather map for sea conditions in your local area.
15. Explain why ocean currents of the world long influenced trade routes.
16. Draw a quick sketch of Australia and mark in the East Australian current and eddies, the Flinders current and South Equatorial currents.

Applying

17. If a constant wind of 10 km/hr over a 24 hour period will move the water approximately 5 kilometres, calculate how far water in a current will move in 4.3 months.
18. Rate the following currents from 1 (largest amount of water movement) to 5 (least amount of water movement. East Australian current; Inshore rip current; River current; Creek current; Overflow current
19. Construct a map of the world showing the Atlantic Ocean and mark in the Coriolis currents.
20. Examine the barometer in Figure 73.4 and draw a diagram to show the difference in size of the vacuum box for low and high pressures.
21. Draw a plan view of a local beach and illustrate where rips could occur as a result of wave action.
22. Record the maximum and minimum temperatures for a week and plot a graph to show the difference. (Explain why this difference with reference to the weather map).

Analysing

23. Distinguish between the West Australian current and the Leeuwin current.
24. Examine the weather map on page 74 and answer the questions below.
    a. explain why sea conditions would be ghastly in the Southern ocean;
    b. compare the weather on Queensland's Gold Coast with that of Darwin;
    c. predict the weather for Hobart in the next three days;
    d. why are Melbourne people just recovering from freezing conditions?
25. Explain why the Leeuwin current is so important to Western Australia.

Creating

26. Research the direction water spins down a plug hole in the Northern Hemisphere.
27. Propose a system for comparing ocean temperatures between your state and another in Australia.
    a. How would you implement the system?
    b. What equipment would you use?
    c. When would you deploy such equipment?
    d. Were would you put it?
    e. Why would you put it there?

Evaluating

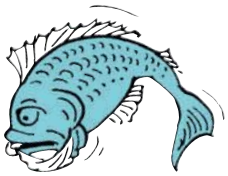
28. Argue the case for more money to be spent on oceanographic research. Give five reasons.
29. In 2002 a court at Maroubra in NSW awarded 1.7 million in damages to a man injured by waves at a local headland. Assess your local coastline and recommend to council places where you should place warning signs to prevent such public litigation for personal injury in your area. Will this solve the problem?
30. Study Figure 73.5 and decide if you would go to Margaret River (south of Perth) for a surf and justify your decision.

Chapter 4
Coastlines

by
Bob Moffatt

Photo Qld Fisheries

Introducing the chapter



Chapter hooks

- Visit a local beach and take a series of digital shots to put on the wall of your classroom.

  Watch the classic DVD — *A river of sand* available from www.classroomvideo.com.au
- Travel brochures always show places of great beauty - the Great Ocean Road, Great Barrier Reef, scenic sights. Collect a few magazines and as a group prepare a short talk on the benefits of local scenery and relate it to Chapter 1.

Why study this chapter

In chapter 1 you learnt how the shape of Australia was formed. You should have an appreciation of why there are reefs in Western Australia and Queensland and the sandstone cliffs of the Great Ocean Road. More importantly you should be gaining an understanding of your local area. This chapter concentrates on our beaches and how they were formed.

Chapter overview

Coastal landforms 83
Tropical and sub-tropical coastlines 85
Temperate coastlines 86
Forces that shape coastlines 87
Another classification 88
High energy coastlines 89
Case study 4.1 - Sand grains *90*
The sand budget 94
Exercise 4.1 Beach profiling *99*
Exercise 4.2 Sand per cent composition *100*
Exercise 4.3 Hypothetical reef *104*
Exercise 4.4 The active beach system *106*
Exercises and questions *108*

Key concepts

1. Three types of coasts are found in tropical, subtropical and temperate.
2. The coastline is made of different compositions of mud, sand, coral and rock. Apart from rock all initially are made from either the erosion of rock or the dead remains of animals and plants.
   - Mud is formed in areas with low wave energy.
   - Sand is formed in high energy coastlines.
   - Coral forms from the remains of living animals and plants.
   - Rock initially was formed from volcanic action and then changed or cemented together over long periods of time.
3. High energy coastlines contain sand which is moved in a sand system along the coastline by a longshore drift.
4. The longshore drift is caused by waves and carries sand to a series of offshore bars which protect the beach during storms. During storms this bar moves further out to sea fed by sand from sand dunes. This is called an eroding beach.
5. An analysis of sand grains gives us an insight into how high energy beach systems work.
6. In calm weather sand is moved onto the beach by wave bores which deposit layers in microridges. These are called accreting beaches.
7. These layers dry in calm weather and sand is blown up into sand dunes (Chapter 10 explores this further).
8. Sand dunes are dynamic systems which are at the mercy of storms. They erode and move and form a barrier between the land and the sea in high energy areas.
9. Low energy areas form mangrove saltmarshes and coastal lakes. These are more stable but have been developed significantly for towns, cities and agriculture.
10. Beach conservation is an expensive process because we have significantly altered the coastline with training walls and beach development. This is discussed in Chapter 5 Coastal Engineering.

Coastal landforms

How has the coastline of our great nation been shaped?

Our coastline is long and varied and encompasses some 61,700 kilometres (including nearby islands). Figures 83.1-83.5 are but a glimpse of the different types of coastal environments on our magnificent continent.

It provides a place for recreation and tourism, development, quiet recreation in sheltered waterways, a thrilling ride on a wave or a place for conservation or preservation of our fragile ecosystem. Coastlines being an important part of our natural heritage should be studied as part of any marine course. The shaping of our coastline has been a long and on-going process.

Many different coastal features have evolved as a result of the constant shaping by wind, waves and earth movements. The landforms of the Great Ocean Road (Figure 83.5) are part of a heritage which is managed in a national park. This coastline is exposed to high winds and heavy swells from the Southern Ocean driven by winds from Antarctica. The cliffs are composed of sedimentary rock of variable hardness, a feature which has lead to a remarkable diversity in shape and size.

The continental shelf is part of the ocean basin system and is a boundary between the continental slope and the Australian mainland.

It averages 200 metres in depth and was exposed during the ice ages. On one side is the coastal plain on which is settled 90% of all Australians. The other contains the ocean depths of the Pacific and Indian Oceans. Growing up from it are coral reefs and living in it is an abundance of nektonic forms that contribute to good fishing conditions. Vast parts of it are not national parks and even greater areas are totally unresearched or poorly understood. It comprises our exclusive economic zone, which is larger than the entire area of Australia and this fact alone presents us with our greatest challenge for management.

Figure 83.1 The Nut - Northern Tasmania
(Photograph Bob Moffatt)

Figure 83.2 Ballina Beach NSW
(Photograph Bob Moffatt)

Figure 83.3 Margaret River Western Australia
(Photograph Bob Moffatt)

Figure 83.4 Cape York monument
(Photograph Bob Moffatt)

Figure 83.5 Great Ocean Road Victoria
(Photograph Bob Moffatt)

Figure 84.1 drawn by G Ryan and published in the State of the Marine Environment 1996 report, distinguishes between tropical, subtropical and temperate coastlines.

Activity

Locate each of the following in the diagram and make a summary table writing a definition and a small sketch. Distinguish between tropical and temperate regions.

Coastal lakes
Coastal strip
Coral cay
Coral shoal
Current gyre
Embayment
High wave energy coast
Intertidal shore
Island fringing reef
Kelp forests
Mainland fringing reef
Platform reef
Ribbon reef
Rocky headland
Rocky reefs
Seamount
Sponge community
Submarine canyon
Temperate estuary
Temperate mangroves
Temperate seagrass
Tropical estuary
Tropical mangrove delta
Tropical rainforest
Tropical sea grass beds
Wave cut platform

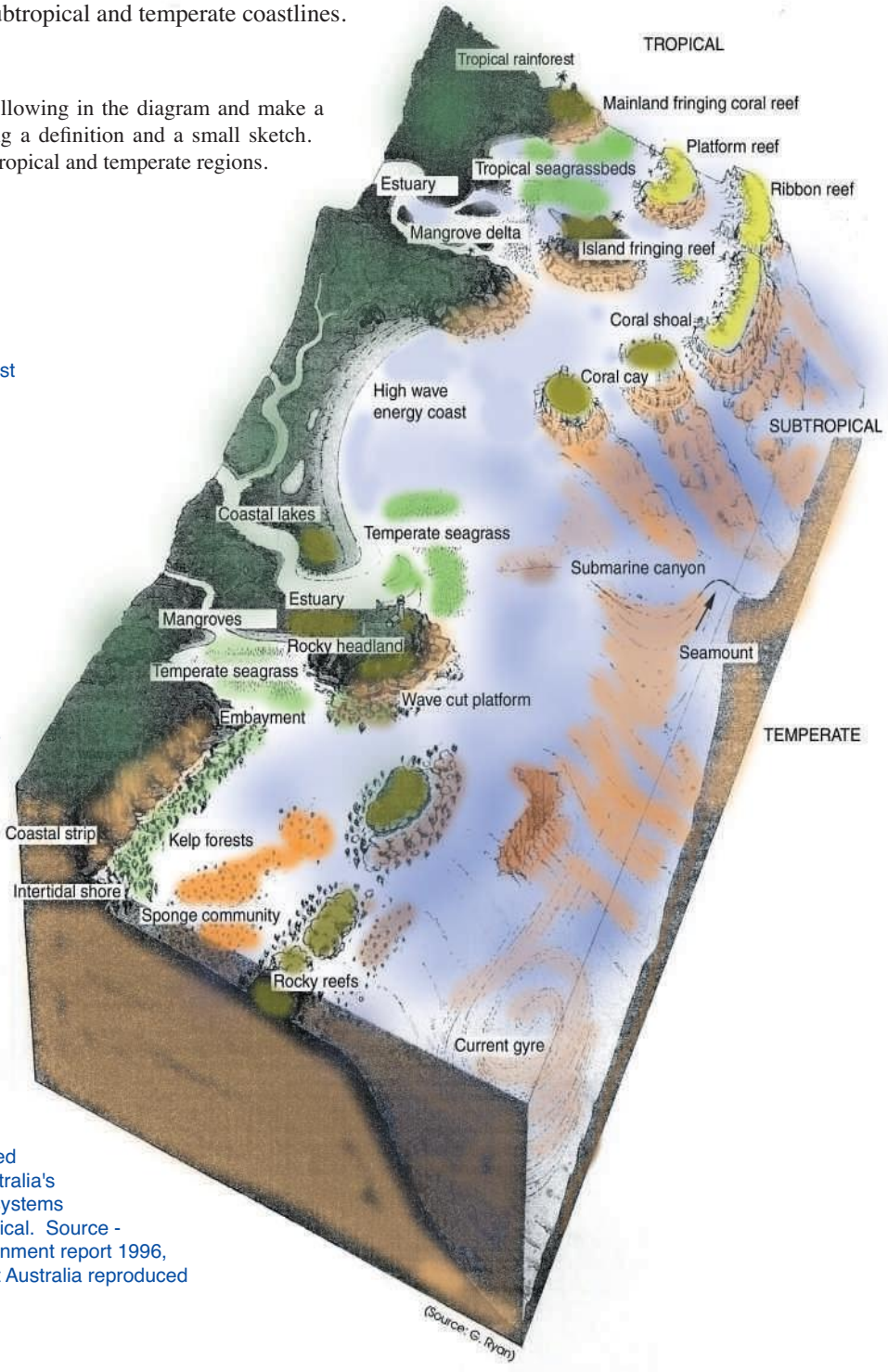


Figure 84.1 Generalised schematic view of Australia's coastal zone and ecosystems from temperate to tropical. Source - State of Marine Environment report 1996, copyright Environment Australia reproduced with permission.
(Illustration by Gavin Ryan)

Tropical and sub-tropical coastlines

We can continue this generalised schematic view of Australia by providing some examples. In many places of northern Australia these are characterised by rainforest, mangroves and reefs.

Tropical rainforest

In locations where the Great Dividing Range is close to the sea, large amount of rain fall from summer monsoons and cyclones. In pristine rainforests, rainwater is absorbed by the thick volcanic soil and dense undergrowth giving rise to a huge diversity of plants that bind the soil together. This binding minimised the amount of sediment and nutrients that enter the sea allowing corals to grow close to the coast in a number of different types of reef.

Tropical reefs and cays

Chapter 1 identified three types of reef formed as a result of ice age sea level change. These reefs vary according to where they are found on the continental shelf. Mainland and island fringing reefs are found close to the coastline. Platform reefs typically are submerged at high tide with a solid wall of corals facing the sea with lagoon behind. Ribbon reefs are found close to where the continental shelf starts.

Coral cays (small coral islands) are usually found further out on the continental shelf. Coral cay formation is discussed in Chapter 10.

Estuaries, mangroves and seagrasses

Where mangroves meet the sea in northern Australia large deltas form on which huge beds of seagrass grow, forming a rich ecosystem feeding much marine life of the tropics. Seagrasses can also form in subtropical areas.

High energy coasts

These are the areas affected by wind generated waves. They contain the sandy beaches and rocky headlands most of us love to spend our holidays on and form most of the discussion in this chapter.

Monsoon

This is a huge cloud build up in tropical regions resulting in tropical downpours each day.

A unique experience

If you have the opportunity to visit Cairns, a must see is the cable way over the tropical rainforest.

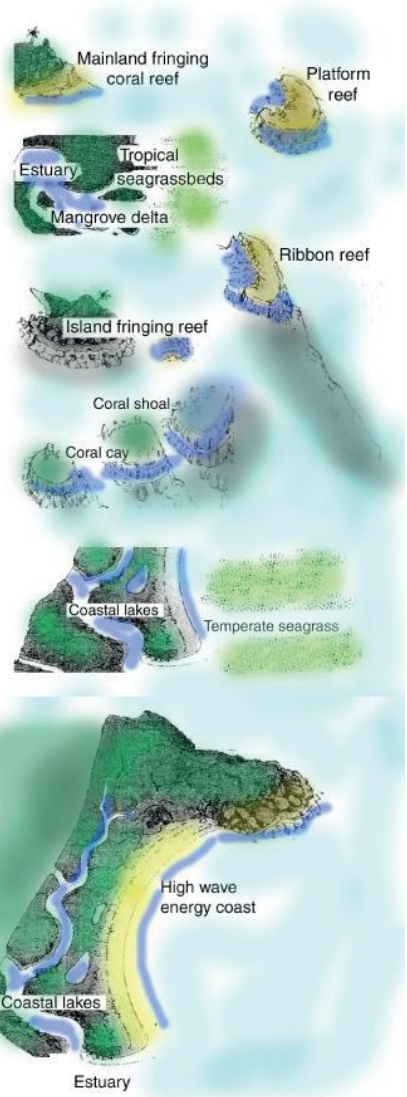
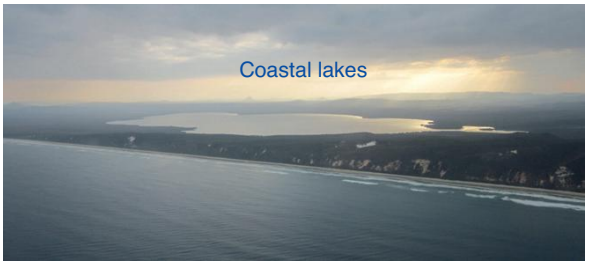
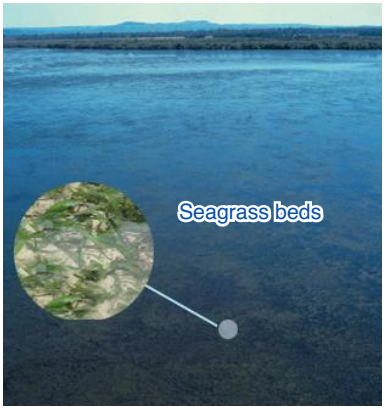


Figure 85.1 Tropical coastline summary
(Illustrations G Ryan)

Figure 85.2 Tropical mangroves and roots
(Photo Ian Morris)





Temperate coastlines

Oceanic current convergences (see Chapter 2), combine with ocean forces such as waves, wind and temperature to form temperate coastlines.

Temperate seagrasses

These form in large areas in sheltered coastal waters. Albany in Western Australia has the greatest species diversity of seagrasses in the world.

Estuaries, mangroves and coastal lakes

Where rivers enter the sea coastal lakes (Figure 86.2) can form. These areas in the main have been cleared for cities, towns and agriculture and it is very difficult to recognise pristine coastal systems today.

Kelp forests and sponge communities

Colder waters of Australia contain a fantastic community of kelps and sponges (See Figure below).

Coastal and intertidal strips

In Southern Australia huge cliffs stand guard over narrow strips of intertidal shores lined with kelp and algal communities hanging on for grim death from the large waves of the Southern Ocean.

Offshore gyres and sea mounts

As discussed in Chapters 2 and 3, these are found offshore. Gyres are currents that form offshore. Seamounts have been formed by volcanic action and are permanent structures.

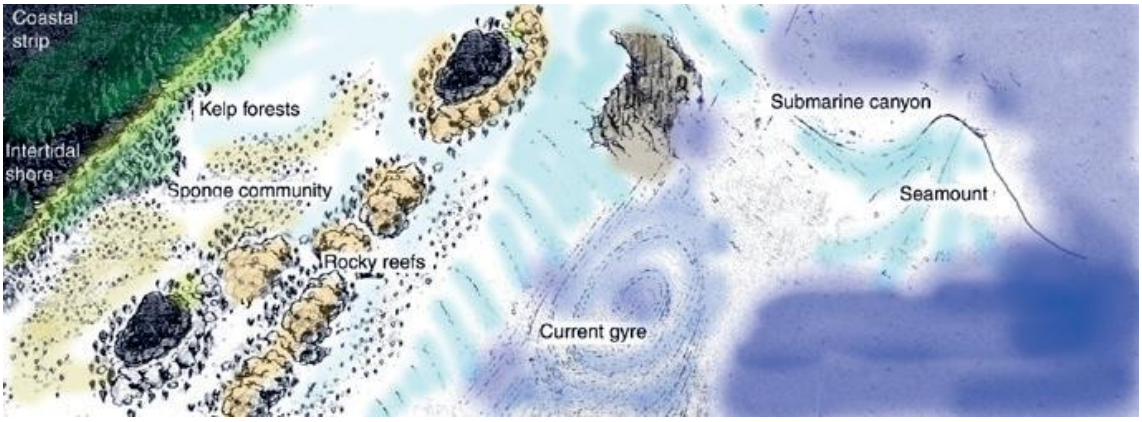


Figure 86.1 Other temperate coastlines
(Illustration G Ryan, adaptation Bob Moffatt, reproduced with permission Environment Australia)

Forces that shape coastlines

Coastlines sometimes retreat under wave action and at other times advance due to the deposition of sediments. There are many different types of coastlines but their character results from two or more of the following factors:

- wind, water and wave action,
- nature of the rocks found on the coast,
- slope of the coastline,
- changes in the level of the sea or land,
- coral formations,
- the effects of glaciers (Figures 87.1).

Weathering

The waves and currents of the sea are continually reshaping the coastline (Figure 87.3). In this re-shaping process, rock of the foreshore is being disintegrated and decomposed by the water. This is known as the process of **weathering**.

Two different types of weathering are physical and chemical.

Physical

Physical weathering is caused by the abrasive action of sand particles in the moving sea and by wave hydraulic action. The hydraulic action is the process by which waves compress air into cavities, cracks, and joints in the rocks, forcing the rocks apart. The abrasion process is the most destructive as it has been calculated that a wave can exert a pressure of 35 megapascals. To understand the force of these waves you only have to imagine the force behind a wave that can move huge boulders of 2,000 tonnes.

Normal waves are thought to generate up to one half million horse-power (400 million watts) when breaking onto a headland.

Wind can cause a sand blasting or abrasive effect on shoreline structures. Sand blasting is often used to clean corroded surfaces. If you have ever been walking along a windswept beach you would have felt the effect of sand carried by the wind.

Chemical

Chemical weathering results from the water dissolving the minerals out of the rocks. This causes billions of tonnes of dissolved minerals to be added to the oceans each year. The weathering and the removal of the debris constitute erosion.

Erosion can occur below the low water mark by biological methods. Here sea weeds, burrowing marine life (Figure 87.3) and bottom living animals move the sand and rock debris. Some of the borers weaken coral or rock and sediments so that they are more easily eroded.

The rocks of the foreshore are continually being broken down into sand. A rock of 30 centimetres in diameter can be broken down into sand in a hundred years or so under this continual weathering. The sand formed contains the fragments of the parent rock. The type of sand produced depends on the hardness and the mineral content of the parent rock.

Figure 87.1 Glaciers cut deep valleys in mountains.
(Photograph Bob Moffatt)

Figure 87.2 Waves crash on rocks
(Photograph Bob Moffatt)

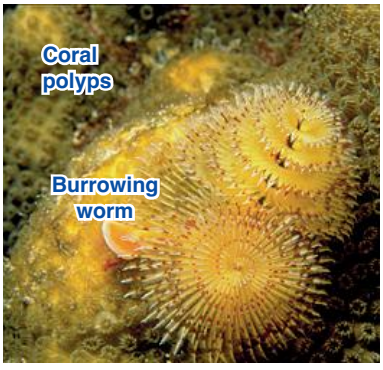


Figure 87.3 Burrowing worms
(Photograph Underwater Rhelms)

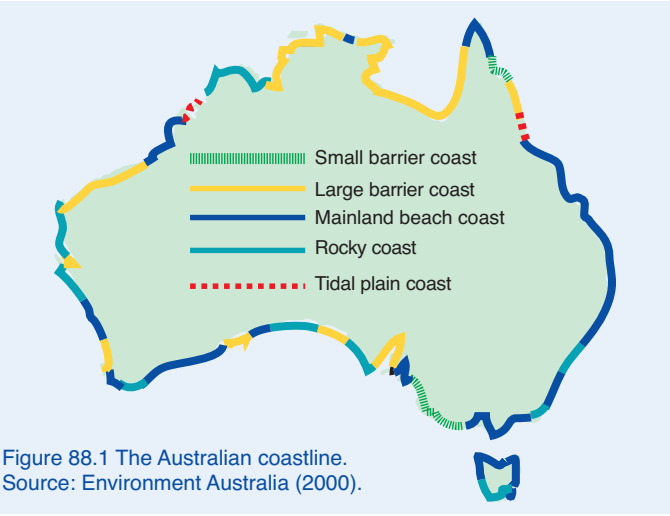


Figure 88.1 The Australian coastline.
Source: Environment Australia (2000).

Another classification

Our shores include open coasts with rocky headlands, cliffs and sandy beaches, and sheltered coasts, bays and estuaries with muddy and sandy tidal flats as shown in Figure 88.1. The predominant substrates around the coastline are sand, mud and rock. Dunes and sandy beaches feature most commonly, with tidal mud flats more evident in the tropical north. Rocky shorelines are limited, but are common along the southern margins of the continent.

Rocky coasts - an example

Waves continually wash against the coastline eroding the base of cliffs and moving rocks and sand along the coast. Where hard rocks are exposed to the forces of the sea, sheer cliffs are formed. The pounding waves at first only form a notch where the waves are hitting the headland. Eventually the material above the notch collapses and is carried away by wave action. The collapsed rock leaves a cliff face behind on the headland and the material removed forms a wave cut platform (Figure 88.2).

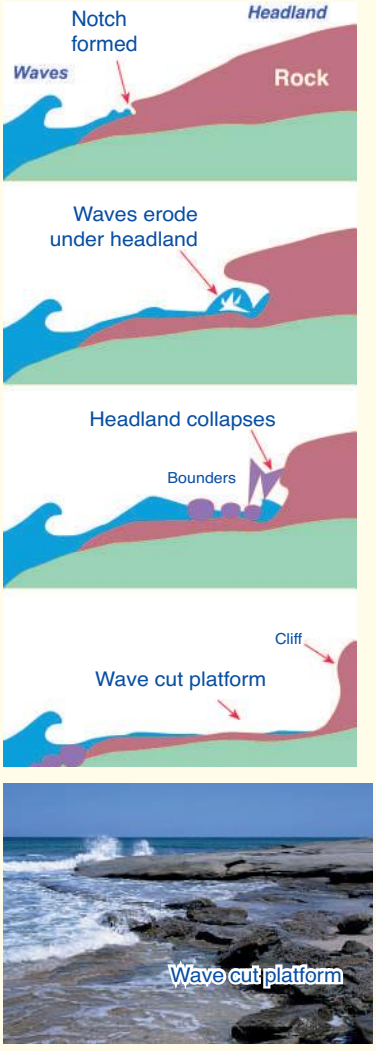


Figure 88.2 Wave cut platform formation
(Illustration Bob Moffatt)

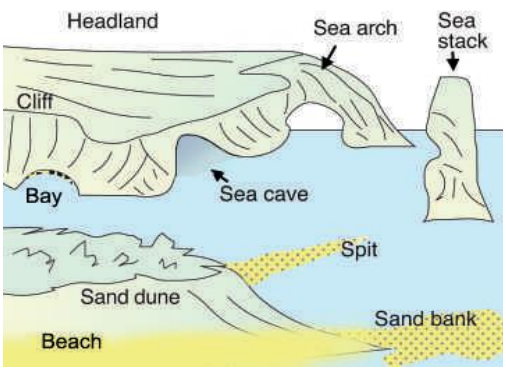


Figure 88.3 Coastal features in Victoria
(Illustration Bob Moffatt, based on ideas by David Kopelke)

Caves, arches and stacks are also features produced by wind and wave action. A cave develops in the cliff face where there is an area of softer rock that is eroded at a faster rate than the surrounding rock.

With prolonged wave action the cave may develop into an arch. The top of the arch in time may also break off and fall into the water. The new feature is called a **stack**. In the cave formation a joint of weakness may extend further up the cliff and form a blowhole.

Some soft rocks break down quickly into mud and silt, but rocks that contain quartz break down slowly and form the sand found on most Australian beaches. The type of sand formed can vary in grain size, thus affecting the type of beach.

High energy coastlines

Sand is made from weathered rock and animal remains. There are basically two types of sand –

- carbonate and
- non-carbonate.

Carbonate sands

Sands can be made from living things as well. Carbonate sands are made from the dead remains of animals that had calcium carbonate in them. On coral cays on off-shore reefs nearly all the sand is from the dead remains of coral and animals as shown in Figure 89.1.

These sands contain a high percentage of calcium carbonate. Broken-down sea urchin spines, dolphin vertebrae, fish teeth, pieces of coral, broken shells and many more animal and plant pieces go to make up the sand on a coral cay.

At the water's edge these are quite visible because they have only recently been moved to the area but at the top of the beach where they have undergone years of weathering the sand particles are very fine.

Non-carbonate sands

Non-carbonate sands are made from the minerals that were eroded in the hills long ago. Grain 3, Figure 89.2 has a sharp edge which suggest it has been cut by a glacier. Over long periods of time rocks break down into smaller fragments of either the parent rock or the individual minerals of the rock. Many minerals within the rock are fine grained and break down to form clay and silt (Figure 89.2 grains 1, 5 and 7). Other minerals like mica and feldspar are soft and breakdown to form sand over a shorter period of time. Harder minerals like quartz and silica are resistant to abrasion but gradually become smaller and rounded.

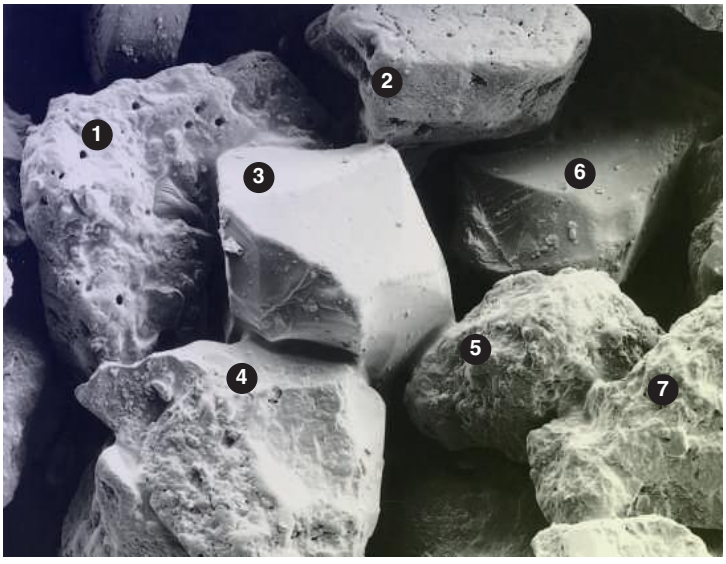


Figure 89.2 Origin of some non carbonate sands
(Photograph QUT, courtesy Sam Smith)

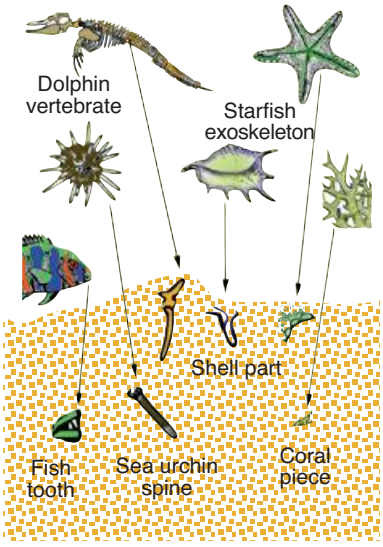


Figure 89.1 Origin of some carbonate sands
(Illustration Bob Moffatt)

Questions

1. How can erosion occur above high tide level?
2. Name the forces that can shape coastlines.
3. Explain how wave-cut platforms are formed.
4. Define the following terms:
   - weathering
   - erosion
5. Discuss the three types of weathering.
6. Suggest how the Twelve Apostles of Victoria were formed?

(Photograph courtesy Victorian Tourist Commission)

Case study 4.1 - Sand grains

To make sand, rock has to be eroded. Wind, rain, ice, earthquakes, chemicals, glaciers and temperature change are some of these forces. The photograph in Figure 89.2 (previous page) shows a sand sample taken from the sea floor at a depth of 18 metres off an Australian beach.

The photograph is from an engineer's thesis on sand grains. A close examination of sand can tell coastal-engineers where it came from. Rough angular sand means it has been blown from offshore. Round smooth sand means it has been washed down river mouths and worked in the surf zone.

In this thesis Smith (1998) identified a number of sand grain types as numbered in the photograph.

Grain 3 has been smashed by ice in a glacier and is over 200,000 years old. It was formed when Australia was separating from Antarctica. Grains 2 and 6 are rounded and have been washed down to the sea by a river. They could have entered the beach system last year. Grains 1, 4, 5 and 7 are covered with silt and contain marine borers. They have never been on a beach and have been on the continental shelf for the last 500,000 years. They were covered up by seawater as the polar ice caps melted. During the last ice age, this was exposed to wind and erosion with the sea hundreds of kilometres out from to-day's shoreline. To the south there was a land bridge between Victoria and Tasmania. In the centre of Australia, high winds blew. Extremes of cold and heat eroded rocks. As the rocks were blown about, they broke down and gradually became sand.

In Queensland Smith suggests that the strongest winds were from the north, on average 120 km / hour (Figure 90.1). "These winds blew over a large coastal plain where the Great Barrier Reef now grows. Sand that had accumulated here blew up into very high dunes creating the large sandhills of Fraser Island and Moreton Island."

Odd fact

An example occurred on July 15, 1912 at Bondi when a boulder of sandstone weighing 138 tonnes was lifted three metres and carried fifty metres by waves. This storm had its origins in the Tasman Sea.

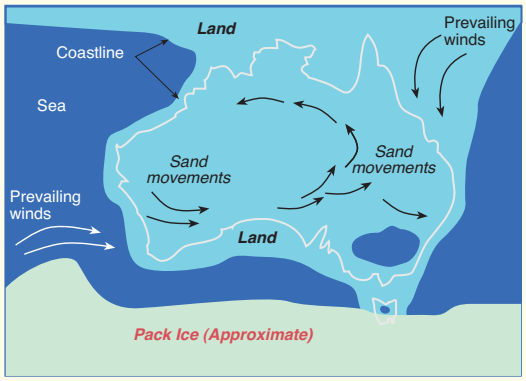


Figure 90.1 Ice age seas (After Smith)
(Illustration Bob Moffatt)

Part A

Read the paragraph below, study Figure 90.1, and answer questions 1-8

As the ice caps began to melt and with more water over the earth, different wind patterns began and wind speeds dropped. Wind speeds over the water are slower than land due to friction. Average speeds to-day are between 15 and 30 knots. The movement of the air from west to east with the characteristic high pressure – low pressure – high pressure systems became a feature of coastal Australian life.

Questions

1. If the field of view Figure 89.2 (previous page) ie the distance across the photo shown measures 1.2mm or 1200μ metres, estimate the size of grain No 3.
2. Describe the shapes of grains 2 and 3. What are the obvious differences in shape?
3. What caused the breakdown of grain 1? Describe how this breakdown occurred.
4. Use your scientific knowledge to explain how extremes of hot and cold erode rocks.
5. How does the author explain the formation of Fraser and Moreton Islands?
6. Sketch a graph showing how the sea levels may have changed over the last 500,000 years. Explain your reasoning.
7. How and when was sand grain 3 formed? If this grain was placed on a beach for a long period of time how might its shape change? Explain.
8. Propose an explanation for the strength and direction of the wind during the Ice Ages.

Part B

Read the paragraph below, study Figure 91.1, and answer questions 9-14.

The slope of the beach is largely determined by the energy events that the beach experiences. A beach exposed to continually high energy events will have a steep slope with sand of a large grain size. Mud flat beaches have little or no slope because of the low energy situation. Wind, waves, tides and currents all have the potential to affect the energy event. A bend in the river can have beach on one side and rocks on the other.

Scientific studies of beach slopes by Klemm* et al 1990 produced a table showing the average slope of the beach in degrees and the type of material found on the beach.

This is summarised in Figure 91.1.

9. Using Figure 91.1 what can gravel beaches consist of and what will be the average slope of this type of beach?
10. What is the range of size of grains of sand?
11. Organise the data on grain diameter and average slope of the beach into a graph. From the graph predict the slope of a beach if the diameter of the particles on the beach averages 100mm.
12. Explain the interrelationship between sand type and beach shape.
13. A student visiting a beach found by doing a sand analysis that the average size of grains was 1 mm yet the beach slope was measured to be 15 degrees. Propose an explanation for this result.

Classroom activities

1. Invite a guest speaker to show some slides of a trip around Australia so you can gain an appreciation of the diversity of coastal landforms.
2. Does your experience and/or knowledge of beaches fit the generalised schematic view on page 84? Explain.
3. Identify a beach near your school, identify its features and the process by which it formed. Use your knowledge from Chapters 1-3.
4. Obtain aerial photographs of beaches and identify coastal features. Make a list of how many you can see.

14. Study the sand grains A-C opposite and use the table below to classify the class of sediment.

Class	Subclass	Equiv. Diameter	Average slope of beach in degrees
Boulder		250 mm or more	*> 25 degrees*
Gravel	Cobble Pebble Granule	65-250 mm 5 - 65 mm 2 - 5 mm	*10 - 25 degrees*
Sand	Very course Course Medium	1 - 2 mm .5 - 1 mm .25 - .5 mm	*5 - 9 degrees*
Mud	Very course Course Medium	.07 - .25 mm .002 - .07 mm .002 mm or less	*< 5 degrees*

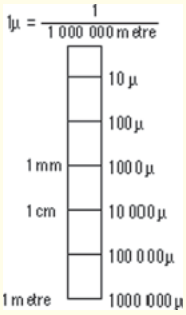


Figure 91.1 Beach slope and boulder size

(* Adapted from an activity by Barbara Klemm and Francis Pottinger, University of Hawaii)

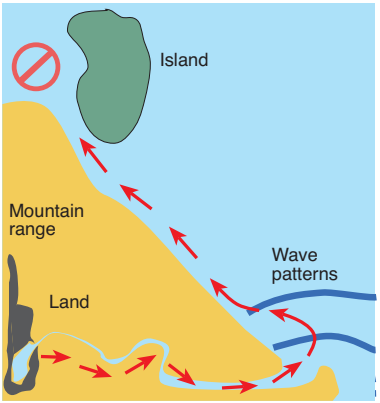


Figure 92.1 Sand introduced to the coastal sand system
(Illustration Bob Moffatt)

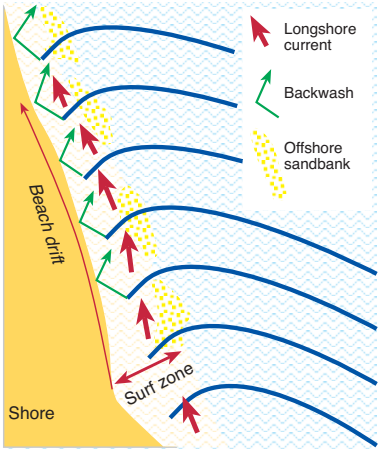


Figure 92.2 The longshore drift
(Illustration Bob Moffatt)

Transport of sand by water

Now that the sand has been made it needs to be transported to the beach. This can be done by rivers and waves.

Rivers

Large river systems deposit layers of mud and silt where they enter the sea because the water erodes the soil. These layers encourage extensive mangrove swamps to develop like those around Darwin or in the Hinchinbrook Channel (north Queensland). In New Zealand, rivers take soil from the land and quickly deposit it on coastal beaches, making them very muddy. Fast-flowing rivers turn eroded rocks into fine sand because only the toughest sand grains such as quartz and feldspar can survive (Figure 92.1).

Longshore drift and waves

Longshore drift (sometimes known as shore drift, LSD or littoral drift) is a process by which sediments such as sand or other materials, move along a beach shore. The rock and earth weathered by the wind and waves is moved is moved by this longshore drift further along the coast for deposition. Deposition of the materials occurs when the current loses its energy or when the current encounters an obstruction.

As waves approach the beach they break and carry the sand up the beach. The wave then recedes and drags the sand back into the ocean. If the wave approaches the beach at an angle, the sand grains move in a zigzag pattern along the beach. This slow movement of sand along the beach is called a beach drift.

Coastal sand structures

Spits

Spits and bars form where there is a long shore drift created by predominant wave patterns. A spit is a low lying narrow ridge of sand or pebbles joined to the land at one end and terminating at the other in deeper water. The sand is deposited where there is a change in direction of the coast. The sand continues to be carried in the direction of the current and the spit may grow across the bay.

Figure 92.3 A sand spit
Wet Paper

It may also form across a river mouth because it is constantly changing due to wave action.

A river within the system can affect the movement of sand. Sand moves in the surf zone until it reaches the deeper water caused by a river mouth. Here the waves refract, slow down and deposit the sand into a sand spit. This spit can vary dramatically because of tide, river currents, prevailing surf conditions and directions. The net effect however is a gradual lengthening of the sand spit in the direction of the predominant wave pattern. If the north shore of the river mouth erodes then the southern shore accretes. If left alone, the river mouth will keep moving north. Islands can form. New river mouths can be created.

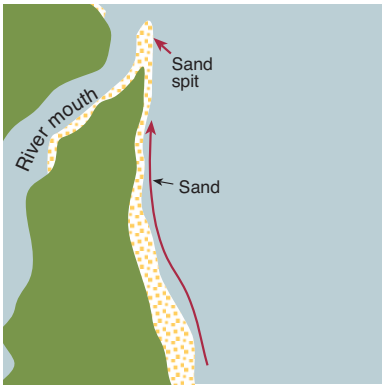


Figure 93.1 Sand spit formation
(Illustration Bob Moffatt)

Bars

A **bar** is very similar to a spit (Figure 93.2). A common type of bar is one which extends right across a bay. This starts as a spit growing out from one of the headlands and ultimately reaching the other. Many bay bars have a break in them where the tide is too fast to allow sand to be deposited. These spits may also reach far out to offshore islands to form a sand bridge to the island. When a sand spit forms between two land masses they are called tombolos.

(Photograph Qld Fisheries)

Figure 93.2 Sand spit

Sand dunes

When the beach sand dries it is often moved inland by the wind. The sand is rolled up the beach and eventually is either dropped when the wind velocity decreases or the sand hits an obstruction. The material is deposited to form a coastal dune. These dunes act like a sand reservoir that can become available to the coastal system during periods of storm.

Dunes can form enormous structures in areas that have a constant prevailing wind such as those on the east coast of Australia. Most of these dunes lie parallel to the coast. The first dune on the seaward side is called the **foredune**. It forms a protective barrier for the vegetation inland by protecting it from wave erosion, salt spray and wind.

Figure 93.3 Sand dune system
(Photograph Bob Moffatt)

Activities from our 2008 Oceanography exercises book

- How is sand made and transported in a coastal system?
- What happens to waves as they approach a beach?
  Note: This contains additional information to this textbook
- How does sand get onto a beach?
- What are sand dunes and how are they made?
- Can we classify sand grain sizes found on a beach?
- Can we determine sand per cent composition on a beach?
- How do you draw a beach profile?
- How do the dune cycles occur?
- What happens when the dune cycle is broken?

Figure 94.1 Estuary sand spit
(Photograph Qld Fisheries)

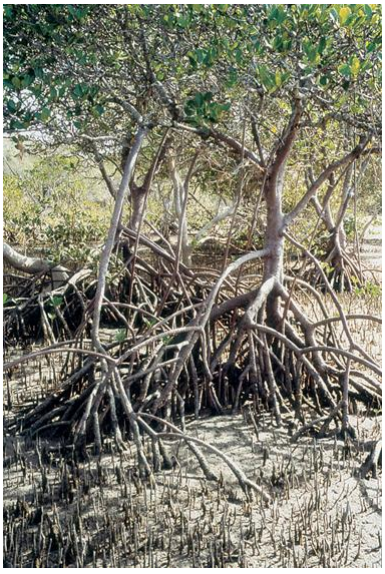


Figure 94.2 Saltmarsh mud
(Photograph Bob Moffatt)

Income	*Expense*
Rivers and streams	Damming of rivers
Cliff erosion	Mining
Longshore drift (in)	Longshore drift (out)
Wind (on shore)	Wind (offshore)
Beach nourishment	Deposition into bays and rivers
Animal and plant remains	Animal and vehicle movements

Figure 94.3 The sand budget
(Illustration Bob Moffatt)

The fore dune permits erosion during storms when sand is moved offshore.

Behind the foredune on well-developed coastlines are the secondary dunes. These dunes are mostly lower and have a more diverse range of plants. The sand in these dunes contains larger amounts of humus and thus sustains a greater variety of plants and animals. They form a secondary barrier against erosion if the fore dune has been eroded.

Dunes can be stabilized by the growth of vegetation. There is a succession of plant types as you move up the dunes. The hardier and more salt-resistant plants are the first to become established. The natural climax vegetation occurs further inland.

Estuaries

Bays can form in protected areas where rivers enter the sea in places called estuaries. A coastal plain is characteristic in some parts of the Australia's east coast. Behind this plain, mountain ranges provide the source for many of the sediments found on the coast. These were volcanic at various stages of our continent's development. Plateaus and hills provide relief on this plain and where a river has been cut off from the main stream, a swamp can form. Mangroves are the predominant species in many of these swamps in northern Australia.

Beaches, mudflats and salt marshes

Beaches lie between high and low tidemarks and are governed by the wave action they experience. Course sand allows the water to drain into it, acting as a sieve. The material carried in the water is deposited. This coarse sand normally forms a steep beach and the sand is piled up loosely on the beach. Fine sand can be packed more tightly, allowing less water to be absorbed. The material carried by the wave is moved backwards and forwards, leaving a smooth, flat hard beach with a gradual incline. High-energy beaches have tough sand particles, whereas fine-grained particles are found on mudflats and salt marshes.

The sand budget

We have looked at ways sand forms, how it is moved along the coastline and structures it forms on the coastlines.

The **sand budget** involves the net movement of sand into and out of a sand system (Figure 94.3).

Different systems will contain different types of sand but the overall principles are the same. Sand comes in, is moved around and is lost. If the sand visible on our beaches is to stay in quantities necessary for enjoyment, then engineers need to calculate the sand budget. Every budget has an income and expense. Profit or loss is what is left over after all expenses have been paid. The table opposite summarizes some of the parts to the budget. In one Australian state, studies have shown that 500,000 cubic metres of sand move in the sand system each year. The amounts will vary and depend on the energy that the beach experiences. High-energy beach systems will move more sand than low energy sand systems. Do you know how much sand moves in your local beach system?

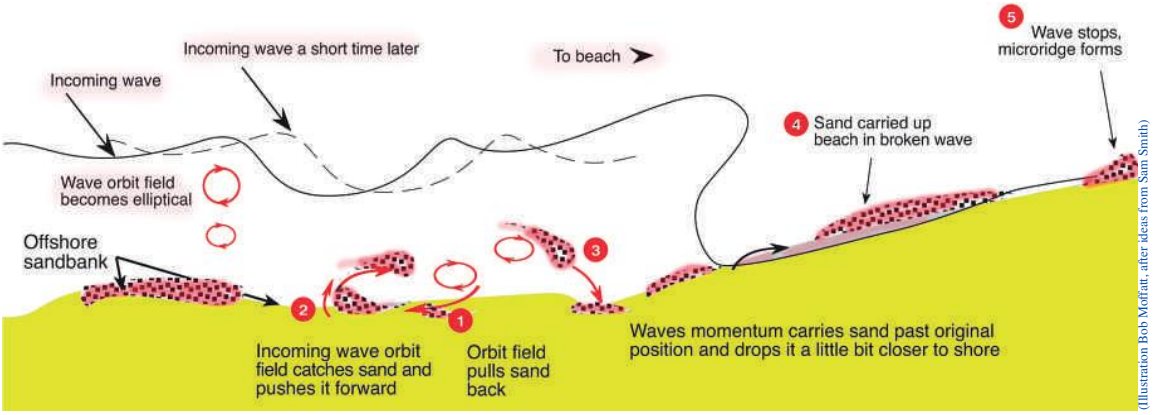


Figure 95.1 How sand gets onto a beach

How sand is introduced to the beach

Offshore deposits

During calm weather small waves pick up the sand as they pass over the offshore sandbank shown in Figure 95.1. The orbit fields interact with the sand first dragging it back and then throwing it forward. This process is repeated until the sand gets close to the beach and is picked up by the wave bore in the swash zone. A **wave bore** is the broken part of the wave in the swash zone that transports the sand up the beach into a microridge (Figures 95.2 - 95.5).

Microridges

Small waves then wash up the beach in a wave bore, slowing down and finally stopping (Figure 95.3) leaving a line of sand called a **microridge** (Figure 95.4).

In calm conditions these microridges can be many millimetres thick and result in much of the sand from offshore being deposited on the beach. Waves that deposit sand on the beach in this way are called **constructive waves**. After a wave has broken much of its energy has been released. There is however enough energy to carry sand up the beach. This is called the **swash zone** and is the maximum distance the wave bore travels up the beach. It can be identified by the wet bit found on the beach.

If wind and sea conditions are very calm the microridges can build up to form a **beach berm**. These berms are very unstable and can disappear with a rising tide in a matter of minutes. Where beach sand is moving onshore an **accreting beach** is said to occur.

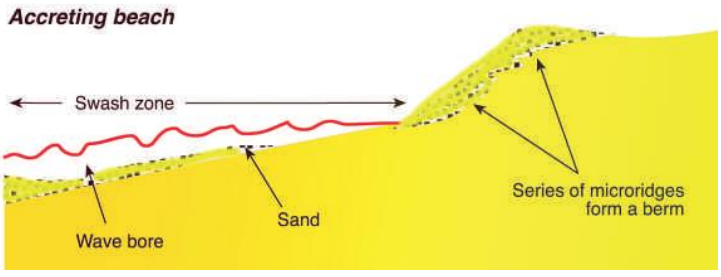


Figure 95.5 A beach berm
(Illustration Bob Moffatt)

Figure 95.2 Wave breaks on beach
(Photo Bob Moffatt)

Figure 95.3 Wave bore brings sand on beach
(Photo Bob Moffatt)

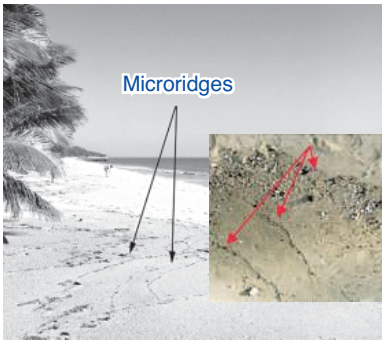


Figure 95.4 Microridge forms
(Photo Bob Moffatt)

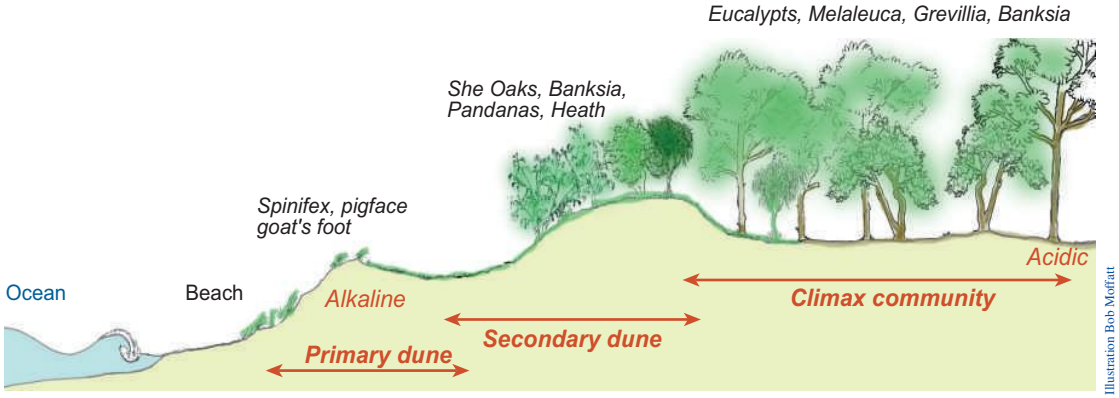


Figure 96.1 A dune system

Dune systems

On hot, sunny, windy onshore days the sand in the berm is quickly blown up the beach. Spindle-like plants called **spinifex** slow the wind carrying the sand and it deposits at the base of the dune plant. This forms the structure called a **primary dune** (Figures 96.1 and 96.2).

If the wind is strong enough, the sand continues over the primary dune where it strikes the branches, slows down and falls to accumulate under the branches of vegetation on a **secondary dune**. (Figures 96.1 and 96.3). As sand falls under she oaks, their branches fall and cover the sand allowing the dune to grow and gain fertilizer from the decaying branches. This continues until a **climax community** is formed in the hind dune (Figure 96.1).

This is an ecological term for the biological community of plants and animals which, through the process of ecological succession has reached a steady state. This equilibrium occurs because the climax community is composed of species best adapted to average conditions in the dunes. This varies all over Australia from Eucalypt forests to low heathland. Lakes can form behind dunes and even complex mangrove ecosystems. Bush fires and animal erosion often cause breaks in trees and sand can blow further to form a series of dunes. One thing is for sure - with coastal development increasing the disappearance of these valuable ecosytems will seriously affect the balance of nature and cause coastal erosion problems for developers.

Figure 96.2 Spinifex catches sand

Figure 96.3 Stronger winds build sand dunes

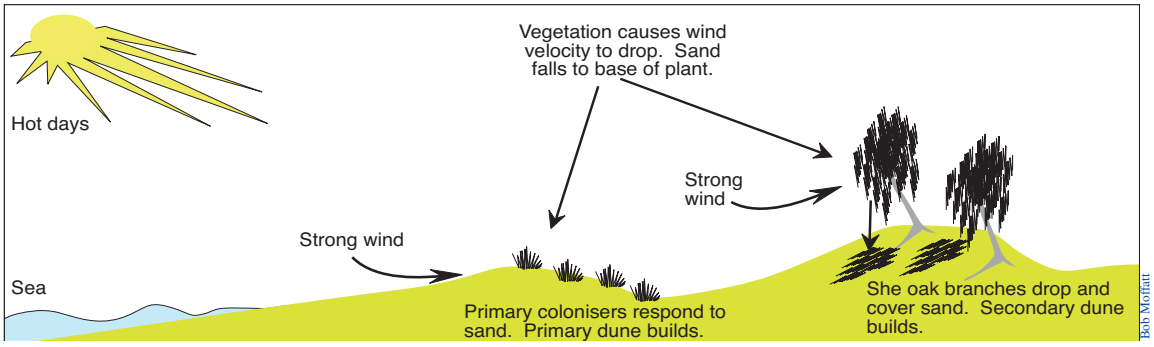


Figure 96.4 Accreting beach - wind and sun dries sand, wind blows sand up beach.

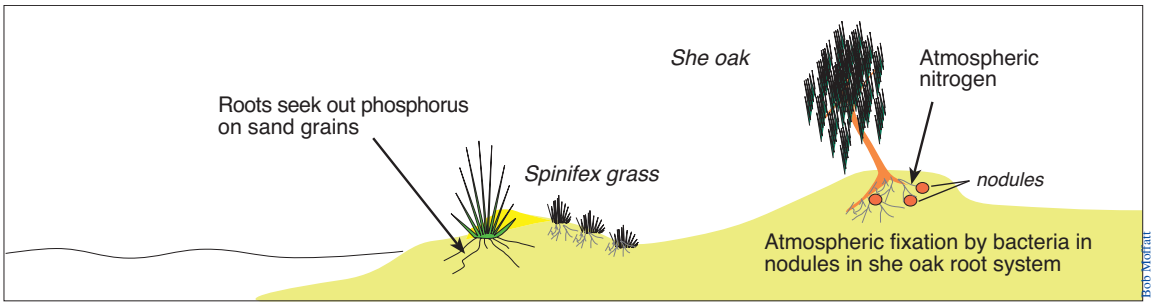


Figure 97.1 Beach vegetation fertilization

Sand fertilizer

Dune vegetation can be fertilized by nitrogen and phosphorous. Nitrogen comes from nodules in the root systems of she oaks and spinifex roots actively seek out the phosphorus in sand (Figure 97.1 and see pages 419 and 421, Chapter 16).

How sand is removed from the beach

Sand is removed from the beach in storm waves (Figure 97.2) caused by high winds created by the interaction of low and high pressure systems (Figure 97.5).

Waves that approach the shore and change shape are called **shoaling waves**. As the wave sizes increase they become storm waves and the bore frequency decreases. These waves do not have the ability to move sand forward and so sand is moved off the beach to a sand bank offshore.

This sand bank is called a **storm bar** and may stay in place for the duration of the storm and many months later. During a storm the energy in the **swash zone** increases. Large areas of sand are eroded from the beach. The size of the **active beach system** now becomes greater and a large erosion scarp forms on the beach (Figure 97.3). Erosion is a natural characteristic of beaches during storms. It can take up to 18 months for a beach to recover its original profile because many smaller storms may affect the beach during this time.

When dunes erode, the roots of the plants and shrubs are left dangling on the erosion scarp. The dangling roots are called the **fretting** (Figures 97.3 and 4) which traps sand as it is blown up the beach in calm conditions.

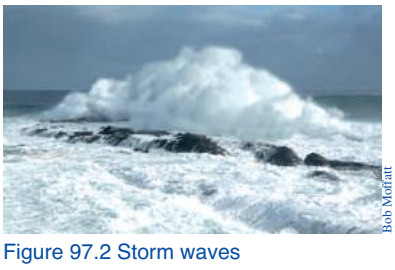


Figure 97.2 Storm waves

Figure 97.3 Erosion scarp

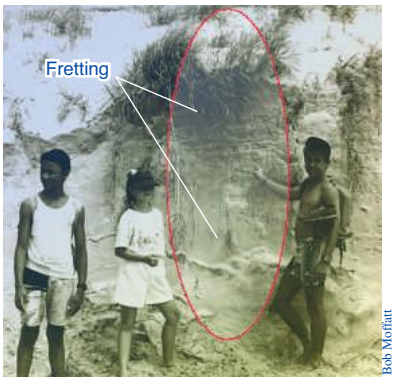


Figure 97.4 Fretting on erosion scarp

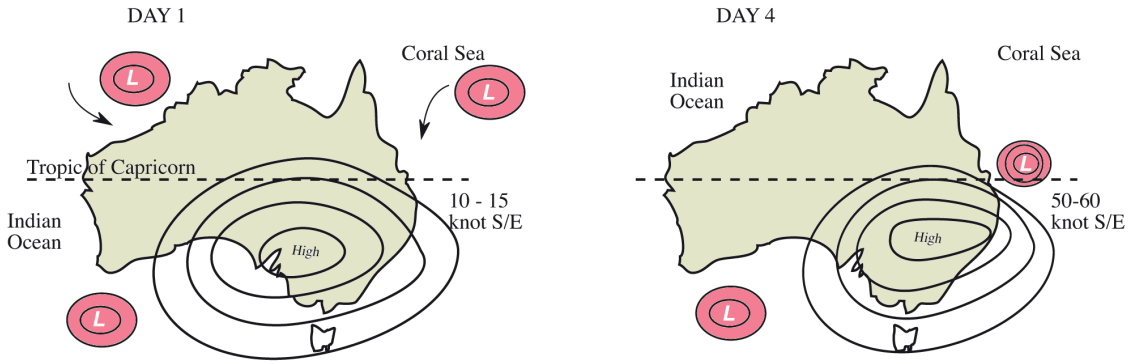


Figure 97.5 Effects of low pressure on isobars
(Illustration Bob Moffatt)

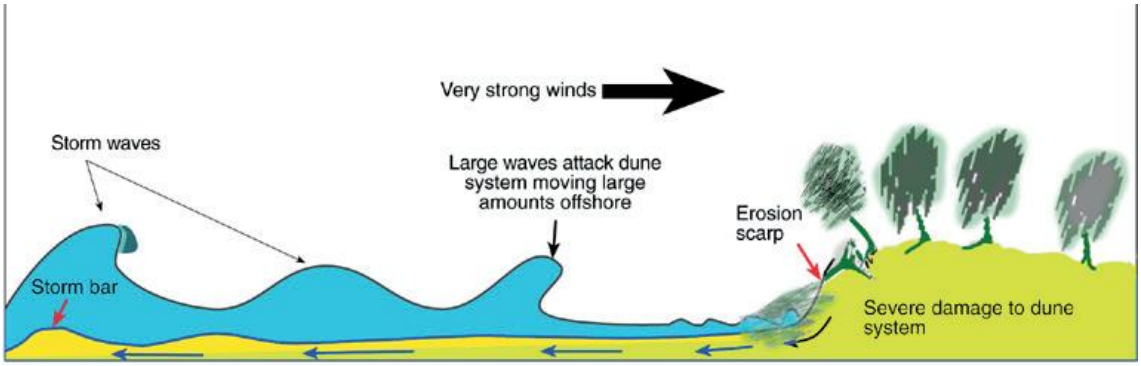


Figure 98.1 Eroding beach - wind and waves attack dunes, erosion scarping occurs and sand moves offshore.
(Illustration Bob Moffatt)

Ecological succession

"Ecological succession" is the observed process of change in the species structure of an ecological community over time.

Within any community some species may become less abundant over some time interval, or they may even vanish from the ecosystem altogether.

Similarly, over some time interval, other species within the community may become more abundant, or new species may even invade into the community from adjacent ecosystems.

This observed change over time in what is living in a particular ecosystem is "ecological succession".

In sand dunes

The change in the species structure from the primary dune system to the hind dunes would constitute ecological succession. The advantage of a dune system is that you can see the whole process at one instant in time.

The evolution of a coral cay is another example of ecological succession. Various stages can be seen on the Great Barrier Reef as you travel from coral cay to coral cay.

Again it may take up to 18 months for the original profile to be re-established and it is important that the dune vegetation is protected from damage

Dune recovery

After the storm, small waves return and the cycle begins again. The orbit fields of the smaller waves move the sand back towards the beach where it is deposited in the microridges and subsequently blown up into the dunes. These events are summarised in Figure 98.2.

Permanent coastline changes

Storms can last for as long as a week and may re-occur with a few weeks creating enormous erosion of dune systems. A series of storms can change the coastline permanently . River entrances can change, new islands form or new wetlands created by a single storm event.

Climax community in a dune systems

This is an ecological term for the biological community of plants and animals which, through the process of ecological succession has reached a steady state. This equilibrium occurs because the climax community is composed of species best adapted to average conditions in the dunes.

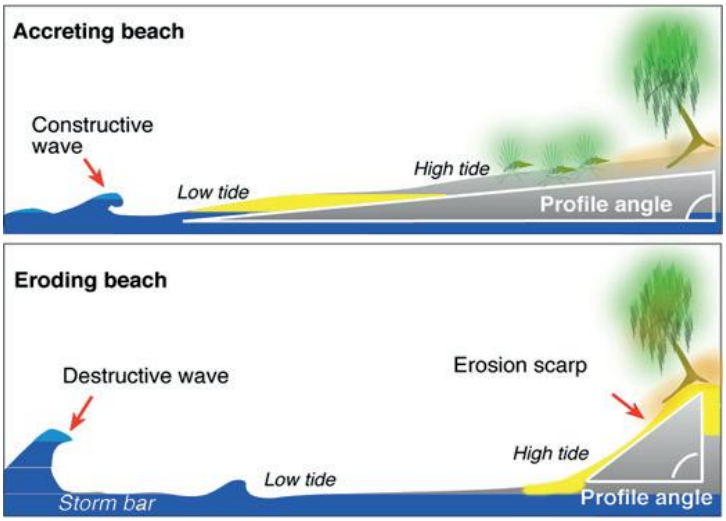


Figure 98.2 Summary of accreting and eroding beach profiles

Exercise 4.1 Beach profiling

Based on an original exercise by Ann Coopersmith and the Marine Lab at University of Hawaii

Aim

To draw a profile of the beach

Method

1. Make a profile metre rule like the one shown in Figure 99.1 and practise on a slope at school to record the change in heights down a slope or bank. Start at the top of the bank — call this your datum point. Position the metre rule so that it becomes level as shown in Figure 99.1. Pull the tape down to the ground and take a firm grip of the tape at the point it touches the sand. Then, without altering your grip, bring the tape up so that you can measure the distance from the end of the ruler and the point the tape touched the sand. This distance represents the fall over one metre. Record this in your notebook.
2. Place a stick or pencil at the place where your hand touched the sand and move the metre ruler to begin the next reading. Repeat this procedure as you go down each metre of the beach. Record ups as + and downs as –, noting distinguishing features on the beach such as dominant plants, grazing by animals, droppings, fences, walkways, erosion scarps, low or high tide marks, areas of microridges, sand waves, moving sand particles. When you get to the swash zone (that's the area where water runs up the beach), measure it. Back in class recalculate all your measurements so that you can see how far each station is below the datum point. Now plot a profile of the beach slope.

Questions

1. Is the beach eroding or accreting? How can you tell from your graph?
2. How wide was the swash zone? How will this change over time?
3. Make a prediction of how this profile will change over the year.
4. Work out the profile angle and compare it with others in your class. Are they all the same?

Figure 99.1 A beach profile stick
(Photo Bob Moffatt)

Sand grain analysis

Based on an original exercise by John Maloney, St. Augustines College, Cairns

Purpose

To identify the types of particles that make up sand.

You will need

- handful of sand
- sieves of various sizes
- sticky tape
- magnifying glass or microscope with slides

What to do

Carefully sieve the sand and separate out the particles. Now look carefully for shells, minerals and other materials.

Questions to answer

1. Look at the classification of particles on page 91. What types does your sand sample contain?
2. Draw the different materials in your sample.
3. Name any non-carbonate component and say where it came from.
4. Can you see any minerals in the sample? What do they look like?
5. Use pieces of sticky tape to collect a sample of your sieved sand and stick it into the space below giving them names.
6. Attempt to grind up your sample. How hard is your sample?
7. Design an experiment that will allow you to test chemically if a sample contains calcium carbonate.

Exercise 4.2 Sand per cent composition

Based on an original exercise by Bob Moffatt

In this experiment you are going to work out where the big sand grains are on the beach that you collected in Exercise 4.1

Materials and equipment (per group)

- Sieves — Note:

  For beaches with fine sand grains

  - sieves of sizes, 300 μ metres, 250 μ metres, 200μ metres (See Figure 100.1A)

  For beaches with larger grain sizes

  - sieves of sizes, 600 μ metres, 400 μ metres, 200μ metres
  - or larger sieves as shown in Figure 100.1B
- aluminium pie dishes labelled as follows:

  - subsample, >300 μm, 250 μm, 200 μm, < 200 μm
- 2 ice cream containers
- completely dry sand samples from top, middle and bottom of beach in plastic zip top bags
- lab balance
- 4 aluminium pie dishes or plastic jars as shown in Figure 100.2.

A. For beaches with fine sand grains

B. For beaches with larger grain sizes

Figure 100.1 Materials necessary to make sieves
(Photos Bob Moffatt - A, Geoff Jensen B)

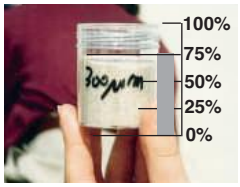
Field work hints

1. Often it is impractical to take a balance into the field.

   In this case the use of small plastic containers as shown in Figure 100.2A may be of assistance.
2. You will need a labelled container for each sieve as shown and use a rough estimation as shown in Figure 100.2B to work out the percent.
3. Use zip-top plastic bags to collect other sand samples that can be taken back to the lab and analysed if time permits.

To make sieves

1. Mesh of very fine mesh sizes is available from Swiss Screens, Randall St, Slacks Creek, Q'ld, 4127. Plastic sieves as shown are available from Hardie Iplex, in a trades pack of 10, and are called a weathering apron, 50mm, product code is VO 7450. The silk comes in widths ranging from 900 - 1200mm and a 125mm long strip will make 9 sieves of the sizes mentioned above. If you use the 50mm weathering apron, then cut the 125mm strip into nine equal squares.
2. Use a rubber band to hold down the mesh and then add bondcrete glue around the rubber band. Take the all weathering tape and bind the mesh to the sieve. Pull down the tape as you bind to make a strong seal. Allow to dry for 24 hours. Make sure you mark the sieve with the correct size.



Estimate the percent

Figure 100.2 Field analysis
(Photos Bob Moffatt)

Method

1. Take four pieces of filter paper or 4 plastic bottles and label them as shown in Figure 101.1.
2. Now weigh each and record its weight in Figure 101.3.
3. Arrange the sieves in order from 300 μm, 250 μm, 200 μm as shown in Figure 101.1 and place the ice cream container underneath.
4. Now add three level teaspoons of sand from sample A to the top sieve.
5. Carefully swirl the sieves for two minutes so that the sand moves through each sieve.
6. Separate out the sieves and carefully pour the sand from each sieve on top of its corresponding piece of filter paper or use the bottle.
7. Weigh each piece of filter paper and record the new weight.
8 Total the weights and record them at the bottom of the column.
9. Calculate the percentages using the formula:

   $$\text{Per cent} = \frac{\text{weight of sample}}{\text{total weight of sand}} \times 100$$

10. Record these in the table.

Extension exercises

- Try sand grains from different parts of the beaches and graph the differences. You will need to dry the sand first.

Figure 101.1 Sieving the sand
(Photo Bob Moffatt)

Figure 101.2 Laboratory set up to measure percent sand composition
(Photo Selbys)

Site _____

Bottle type	Bottle weight empty	Bottle weight with sample	Weight of sample	Fraction of total weight	% of total weight
Collection bottle					
300 µ m					
250 µ m					
200 µ m					
< 200 µ m					
Error					

Figure 101.3 Data table
(Illustration Bob Moffatt)

Questions

1. Sand is composed of different grain sizes. Do your results agree with this statement?
2. Why are smaller grain sizes found at the top of the beach?
3. Which type of vegetation is responsible for capturing this type of sand grain?
4. Why are dunes fenced and covered with cloth as part of dune management practices?
5. Large sand grains are found in the surf zone. Why?
6. Sand is composed of different grain sizes with the greatest percentage of large grain sizes at the bottom of the beach. (Your sieve sizes have to match the range of grain sizes you are working with. Coral Islands will have different sieves for coastal beaches with low wave action.)

Figure 102.1 Students working on a beach profile
(Photo Bob Moffatt)

a. Where was the greatest percentage of larger sand grains on your beach?
b. Is this consistent with the statement at the beginning of this section? Account for any differences.

Extension idea - Absorption (percolation) rate

Thanks Geoff Waterhouse - RIP

During your field work follow the slope operators with a bucket of water.

- At each station insert a tube into the sand and using a graduated cylinder pour a measured amount of water down the tube.
- Measure the time taken for the water to be absorbed by the beach and enter it into your data table. Now compare the absorption rates from the top and bottom of the beach.

Seive size	Site 1						Site 2						Site 3					
	Top		Middle				Top		Middle				Top		Middle			
	Wt	%	Wt	%	Wt	%	Wt	%	Wt	%	Wt	%	Wt	%	Wt	%	Wt	%
Seive 1 (300 µm)																		
Seive 2 (250 µm)																		
Seive 3 (200 µm)																		
Tailings (<200 µm)																		

Figure 102.2 Possible data table for extension activity
(Illustration Bob Moffatt)

SAMPLE DATA

Use the sample data in Figure 103.1 to plot the following graphs. Note: the datum point is the starting point.

a. Distance from datum v's height below datum

b. Distance from datum v's absorption time

c. Distance from datum v's grain size

The data was collected from James Beach at Hypothetical Bay (see map).

Now answer the following questions.

1. Is there a difference between the percent composition of sands on the beach?
2. Is the beach eroding or accreting? Give reasons for your answer.
3. Where do you think the sand has come from for James Beach?
4. Compare the absorption times for the different stations on the beach.
5. Predict the effect of the newly built training walls at the mouth of Lynch River on the beach profile during storms over say 10 years.
6. If you were a beach engineer what design would you put in place to compensate any environmental damage caused by the walls at Lynch River.
7. Predict where diffraction, refraction and reflection of waves would occur. (refer back to Chapter 3)
8. What engineering features would be necessary for the airport just north of the sample site?
9. Explain the apparent discrepancies in the data at stations 13 and 14. What may have caused this to occur?
10. Propose two reasons for there being no sand at Steggles Beach.

Refer back to page 55 for a bigger version of Hypothetical Bay.

Place: James Beach, Hypothetical Bay
Date: 12 March 2003 Time: 10am
Wind: South East Approx 10 knots
Cloud cover 20%

Station	Height (m) + or -	Absorption time (secs)	% sand grains		
			large	med	small
1	0	5	0	25	75
2	- 1	5	5	20	75
3	- 2	6	0	15	75
4	- 2	5	5	20	75
5	-.2	5	5	20	75
6	-.1	5	5	40	50
7	-.1	5	10	60	30
8	-.1	5	10	50	40
9	-.1	4	10	40	50
10	-.2	4	40	30	20
11	+.3	3	60	20	20
12	0	3	85	10	5
13	-.5	2	80	5	10
14	-.2	2	85	10	5
15	-.1	1	90	5	5
16	Swash zone	0	90	5	5

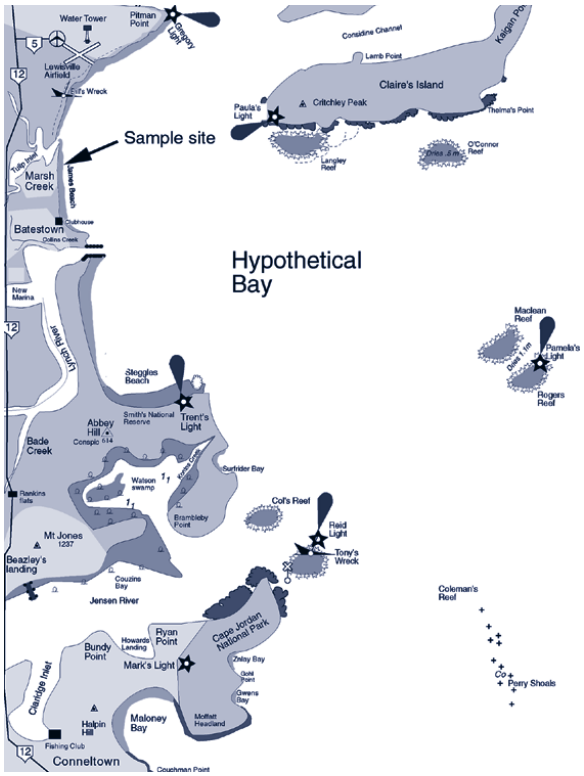


Figure 103.1
(Illustration Bob Moffatt)

Exercise 4.3 Hypothetical reef

Based on an original exercise by Bob Moffatt

Method

1. Look carefully at Figure 105.1 and identify the different water depths. Note that at -2 m, there are coral outcrops that rise above the sea floor to sea level and that there is an island 2 metres above sea level.
2. Use a coloured pencil to identify the following:
   - ocean floor (-6 m)
   - lagoon (-2 m)
   - windward side
   - inner coral zone (-1 m)
   - leeward side
   - outer coral zone (-1 m)
   - bommies (-1 m)
   - inshore gutter (-1 m)
   - reef crest (0 m)
   - coral island and beach (+1 and 0 m)
   - algal rim (0 m)
   - island vegetation (+2 m)
3. Note carefully the heights of each section and make a verbal description to your partner.
4. Build a three dimensional model of the coral island, as follows:
   a. Cut out the level between the -5 m and -6 m levels. The -6 m level represents the ocean floor and paste this onto your cardboard base.
   b. Now cut out between the -4 and -5 levels and you should be left with a thin strip that can be used as a template for the -5 m level. Use it to shape another piece of cardboard that can be glued onto the base.
   c. Continue to build your model. Note that there are pools that are set into the 0 m mark.
   d. Use colours to show the different levels of the coral island.
   e. When you have finished, clearly label the model and hand it in for marking.

Questions

1. Why is the windward side reef slope steeper than the leeward side?
2. Why do bommies, caves and gutters occur on the leeward side?
3. Why is the coral island at the northern part of the model?
4. How deep is the lagoon?
5. Could you drive a boat to the island at low tide?
6. A boat with a draft of 1.2 metres wishes to drop a camping party of 50 Marine Studies students with their equipment for a week's camping on the beach. The island in question is shown in Figure 26.2, page 26.

   What tides are necessary for this to occur assuming the loading time is 2 hours?

Materials and equipment (per group)

Equipment required

- pieces of cardboard scrap and glue
- paper artists cutting knife
- Note: Take care with knives by using a good cutting surface and by observing class safety rules

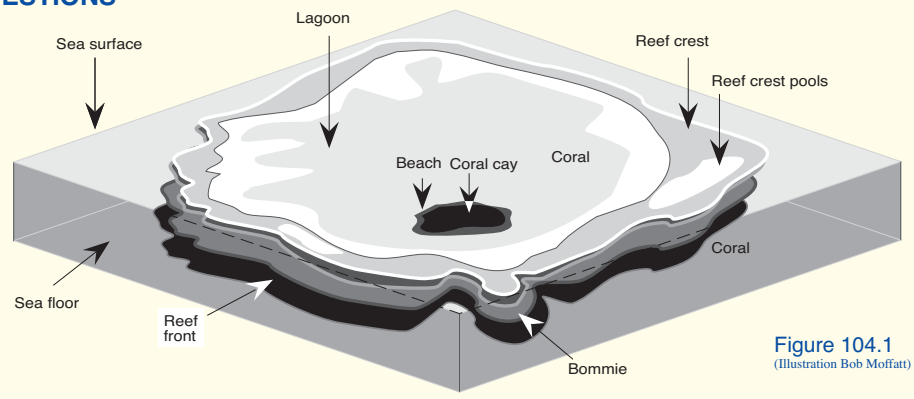


Figure 104.1
(Illustration Bob Moffatt)

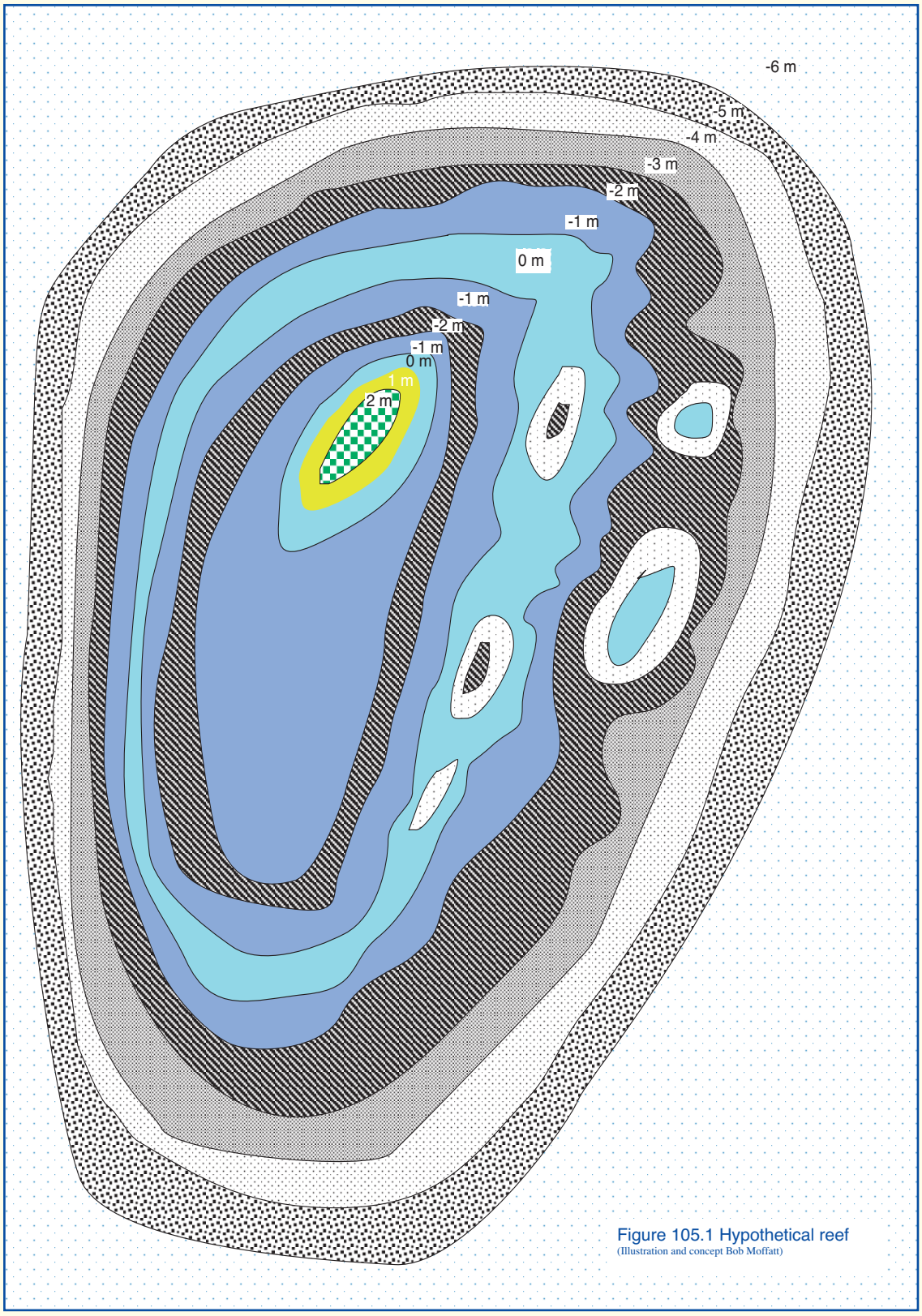


Figure 105.1 Hypothetical reef
(Illustration and concept Bob Moffatt)

Exercise 4.4 The active beach system

Based on an original exercise by Gwen Connolly, Malanda SHS

Method

1. Read the instructions to the three level guide in Figure 106.2.
2. Now read the article on page 107 and complete the following:

Level 1 Literal — reading for accuracy

a. For each of the following statements write T (true) or F (false) in the space just after the number.

b. Be able to show where these statements appear in the article.

c. Use P for paragraph and L for line.

1. ____ Beaches are made of sand from the erosion of rocks.
2. ____ A sand budget is only governed by the prevailing winds, tides and currents.
3. ____ Small broken waves predominately control the sand buildup on the beach.
4. ____ Bores drop their sand in a small ridge known as a berm.
5. ____ During storms, wave bores drag the sand offshore to form a sand bar.
6. ____ A groyne is a preventative measure against weathering.

Level 2 Interpretive — drawing conclusions

1. ____ Estuaries and bays act as sinks where sand is stored for later movement along the beach.
2. ____ Bays are areas of sand collection due to the bending of waves around headlands.
3. ____ A beach will not erode during a storm if the waves are absorbed by the storm bar.

Level 3 Applied — defending your opinion

Be able to give reasons (argue) why your answer is correct. You may draw on additional information from other sources.

1. ____ Beach conservation groups should be more active in your local area.
2. ____ Developers should be allowed to build on the waterfront.

Figure 106.1 Triggs Beach WA
(Photo Bob Moffatt)

The three level guide

A three level guide is used to impart important information. Teachers believe that in doing work and having to justify your answer, students are more likely to remember it.

The following rules are important to make this work.

1. Absolute silence for 10 – 15 minutes during which time you are to read the article and answer True (T) or False (F) to the statements in the method section.

   You also need to justify your answer by referring to the article, eg P3L2 — paragraph 3 line 2 or F106.2 — Figure 106.2.
2. The class is then divided into groups of four students and you have 15 minutes to discuss your answers and arrive at a group set of answers. Make sure that democratic discussion occurs and that the group is not dominated by one or two people.
3. Finally, re-group and as a class discuss the article.

Figure 106.2 Rules for this exercise

Beach composition

Beaches are made of sand. The sand comes from the erosion of rocks and has been washed down to the sea over many years to form the sand budget.

The sand budget moves in a sand system which is governed by the shape of the coastline, prevailing winds, tides and currents.

Sand is added to the system at one end, creeps along the coastline and is lost at the other. Estuaries and bays can act as sinks or places where the sand is lost. Moreton Bay in Queensland is a sink which absorbs the sand as it flows north.

Beach building

Small waves are the predominant force that controls the sand buildup on the beach. As a small wave breaks, it forces the sand up off the sea-bed. The broken wave is called a wave bore as shown in Figure A.

This bore carries the sand towards the beach. There are many bores at a time and the net movement is towards the beach.

When the bore stops, it loses its energy and drops this sand in a micro-ridge that can be seen on the beach. Some sand runs back, but more bores overtake the sand moving back with the net result of sand staying in the swash zone.

As the tide goes out these microridges dry and wind blows the sand up the beach into the dunes.

Sand also moves along the coast in a longshore drift current. The current moves the sand because the waves break on the beach at an angle. Where headlands occur, waves bend around and slow down dropping their sand.

Beach erosion and rebuilding

Larger waves formed during storms break down the beach as shown in Figure B below. Initially they erode the beach face dragging sand out to sea. The wave bores are very long and drag the sand offshore to a storm bar. The sand runs back forming runnels. There are not enough wave bores to keep the sand there.

The beach keeps eroding till the forces of the storm waves can be absorbed on the storm bar.

When the waves get smaller, the sand moves towards the beach again pushed by the wave bores.

Beach conservation

Some preventative measures have been offshore breakwaters, rock boulder walls, groynes, dumping sand on the beach by trucks or pumping it from offshore (or creeks and rivers).

Dune fencing and the planting of beach trees and shrubs have also been part of prevention programs. These measures are all designed to maintain beach levels.

Beach conservation involves the establishment of a program (often long term) that will allow natural movement of sand while maintaining the natural sand budget.

It is necessary for tourism, but also needs to provide aspects of the natural world which are necessary to maintain nature's balance.

Conservation intends to maintain a balance in nature in terms of human habitation, eg protection of beach front sand, maintaining beaches for locals and tourists.

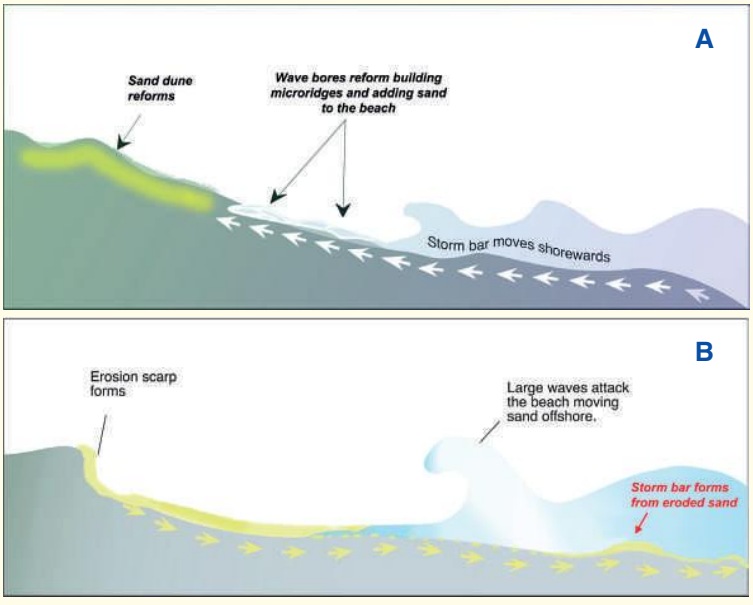


Figure 107.1
(Illustration Bob Moffatt)

Exercises

From the Wet Paper Publication - *Oceanography Exercises*
See www.wetpaper.com.au

B5. How is sand made and transported in a coastal system?

B7. What happens to waves as they approach a beach?
Note: This contains additional information to this textbook

B8. How does sand get onto a beach?

B9. What are sand dunes and how are they made?

B10. Can we classify sand grain sizes found on a beach?

B11. Can we determine the percentage composition of sand on a beach?

B12. How do you draw a beach profile?

B13. How do the dune cycles occur?

Questions

Knowledge

1. Name the types of coast found in tropical regions?
2. Describe what happen when a beach erodes.
3. Explain the meaning of the following terms: fringing reef, gyre, coastal lakes, coral cay, embayment, seamount, wave cut platform.

Understanding

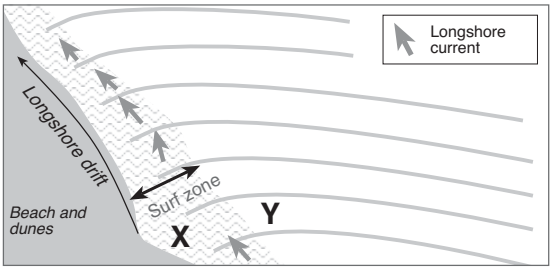
4. Give a definition for carbonate sand.
5. Provide an example of where you might find a sand spit.
6. What differences exist between carbonate and non carbonate sands?

Applying

7. Study the data table on page 103. If there were 1,250 sand grains in a sample from the wave bore, calculate the number of large sand grains in the sample.
8. Plan an experiment to show that there are more small particles in mangrove mud than in sand.
9. Draw a diagram of a coral cay or offshore island nearest your school and use the data you collected on page 104 to label it correctly
10. Identify the following is more likely to be temperate, or tropical zones - kelp beds, platform reef, sea mounts or rocky reefs. Give reasons for your answer.
11. Two dye markers were dropped at X and Y in Figure 108.1.

    Redraw the diagram in your notebook predicting where the dye would be at the following intervals - 10, 20, 30 and 60 minutes.

    Give reasons for your answer.



(Illustration Bob Moffat)

Figure 108.1

Analysing

12. A local resident group wrote a letter to their local paper complaining that the sand on the beach over the years had disappeared. They blamed sand mining and concrete construction companies for the loss of sand.
    a. Could these events have caused beach erosion?
    b. Could there be some other cause and why?
13. A marine scientist was studying a local headland. She found a series of rocks that were quite different from the ones normally found in the area and took them back to the lab. Distinguish between the types of chemical and physical weathering tests she might do.
14. A marine scientist was collecting data at a local beach and was about to have an interview with his supervising professor. Study the methods used in Exercise 4.2 and list 3 uncontrolled variables (Variables are things that change in an experiment that can affect the data).

    Having listed the three, describe how you would go about controlling these variables. For example the absorption rate for water would be determined by the diameter of the tube - how would you standardise this and is it important anyway?

Creating

15. Design a cover for a brochure for students entering a course in Coastal Physics.
16. Write a rap song about three kinds of sand grain.
17. Create a mime to show how a beach erodes.
18. Make a model of a kelp forest or some other coastal feature you like.
19. Design a wave power house.
20. Suggest ways to improve the management of beaches.

Evaluating

21. You have just been told that the variables you used in the answer to 14 are wrong. How would you defend your position in relation to the answers you have given?
22. Study Figure 89.2. Decide if there really are differences between the different sand grains identified and challenge the hypothesis that sand grain 3 was in fact cut by a glacier.

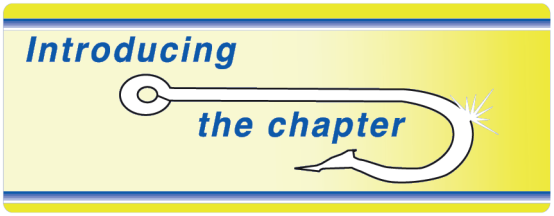
    Make a list of dot points that you would use as first speaker in a debate that sand grain 3 was not cut by a glacier but split by heating.

Chapter 5 Coastal engineering

by

Bob Moffatt

Photo Bob Moffatt



Chapter hooks

- View the CD *SAND* On the history of the Gold Coast. (Available Gold Coast City Council, Beaches and Foreshores section, PO Box 5042, Gold Coast MC 9729.)
- Visit a local coastal engineering structure making a digital photo record. Make a display of your shots around the class with a summary of the effects they have had.

  For example, a groyne with erosion on one side, a hotel and wharf complex. Identify both the positives and negatives of the feature chosen.

Why study this chapter

If you chose a career in coastal management, your knowledge and understanding of the effects of coastal development will be invaluable. Many of the examples presented here will be of use as case studies.

Key concepts

- There are many and varied coastal engineering structures established on our coastline.
- Many early structures were detrimental to the coastline because our understanding of coastal processes was inadequate.
- Now that our knowledge has increased, many of the problems caused are being addressed but at considerable cost.
- Sand by-passing of river entrances with training walls has been a coastal engineering success story.

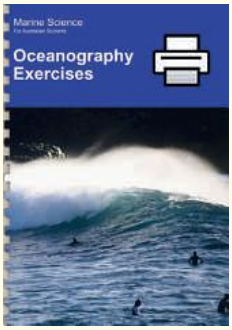
Chapter overview

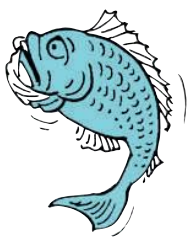
Scope 111
An example - beach erosion 111
One solution - no action 112
Engineering solutions 113
Case study 5.1 Sand bypassing *116*
Case study 5.2 Narrowneck reef *120*
Other coastal engineering structures 122
Exercise 5.1 Hypothetical bay 2010 ..... *124*
Exercise 5.2 Engineering legislation *127*
Exercises and questions *128*

Activities from our 2008 Oceanography exercises book

- When is beach nourishment a solution to coastal management?
- This activity describes the effects of the tweed river bypass system and problems created for the beach amenity
- See also

  kirrapoint.org





Scope

Coastal engineering can include all aspects of construction in, near or on the coast from houses, high-rise, marinas, groynes, underwater cabling, sand pumping jetties, aquariums, boulder walls, artificial reefs and canal estates.

In the past, coastal engineering works have created problems for our coasts (Figure 111.3) and it is only in recent years that a managed co-ordinated approach is reducing the effects. Now that our knowledge has increased, many of the problems caused are being addressed but at considerable cost.

This chapter examines some examples. Beach erosion is discussed as an example of problems which occurred when our knowledge of coastal engineering was in its infancy. Artificial reefs and sand by-passing systems are modern day examples of successful coastal engineering.

Figure 111.1 Dawsville cut in WA has been a success story (see coastal lakes - page 437)
(Photo Bob Moffatt)

An example - beach erosion

The problem

Beach erosion is a natural process as sand is continually moved along the coastline, and erosion is only considered a problem when it threatens property or tourism.

Tourism is very important to seaside communities as most of their income comes from visitors and industries set up specifically to cater for tourism.

In the past many of the foreshore dunes were built on so people could be close to the water (Figure 111.2). These fore dunes can be susceptible to erosion and the sand loss threatening to buildings.

The problem is not that beaches are being eroded but that the building took place in an area of the natural coastal system. These dunes were the reservoirs of sand that could have become available to the coastal system during severe storm damage.

The beaches and dunes can be eroded of millions of tonnes of sand in a single stormy night. When cyclones are present in the area, the beach destruction can occur over days causing massive changes to the original beach profile.

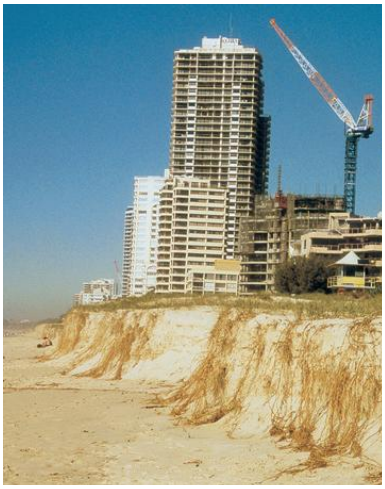


Figure 111.2 Building on sand dunes in Qld has cost residents a lot of money to repair environmental damage.
(Photo Bob Moffatt)

Sand budget

The sand budget outlined in Chapter 4 discusses the net movement of sand in and out of a natural coastal system. Engineers have estimated that on some beach systems as much as 500,000 cubic metres of sand moves along the beach in any one year.

This means billions of cubic metres of sand can be locked up in any one beach system with 500,000 leaving and 500,000 entering each year by the longshore drift.

If the amount of sand entering is reduced by coastal development or structures such as training walls (see Figure 115.1), then over a 10 year period, millions of cubic metres can be taken from the beach and never replaced. Storm waves then attack the beach with a greater force causing massive erosion as shown in Figure 111.3.

Figure 111.3 Beach erosion has long been a problem for coastal developments.
(Photo Gold Coast City Council)

Figure 112.1 Damming of rivers
(Photo Bob Moffatt)

Figure 112.2 Resident erosion issues
(Photo and article www.abc.net.au/news/2016-06-06/nsw-weather-large-waves-hit-collaroy-coast/7479846)

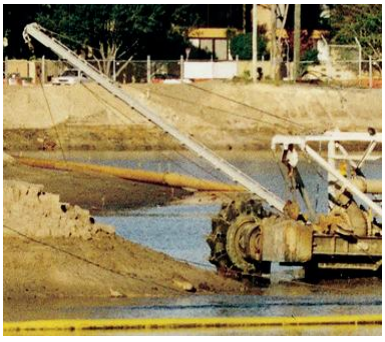


Figure 112.3 Dredging of rivers
(Photo Bob Moffatt)

One suggestion to overcome the problem of beach erosion is to take no action and allow nature to run its course.

What takes the sand

Factors contributing to this loss of sand are the damming of rivers (Figure 112.1), mining, and development of canal estates which have affected the flow of the rivers, the main source of sand. The sand budget also has incurred a loss with building on the dune system, previously a reservoir of sand.

Concrete production uses a large proportion of sand with shell grit being mined for the lime content in the production of cement.

Although most of this mining is not occurring on the beach it is however being removed from the system. River sediments are being dredged and used to reclaim land in the construction of canal estates (Figure 112.3). Most of the dredged material from river deepening is removed from the system. The total volume of this sand is significant.

Buffer zones

Sand dunes are reservoirs of sand for the beach. The sand dunes in the past were flattened to improve views from the houses and without vegetation the sand dunes just blew away. Dunes act as a buffer zone between sea and land and should be preserved and / or restored. The dunes also protect the land behind them from the sea, sea spray and strong winds.

One solution - no action

No action

One suggestion to overcome the problem of beach erosion is to take no action and allow nature to run its course (Figure 112.4).

The resulting loss of this property will cost a lot less than that incurred in trying to save the property. Residents do not want to see their property lost and will take their own action to protect their property.

This may result in cheap and nasty action (such as placing old car bodies and scrap iron on the land) to protect their property.

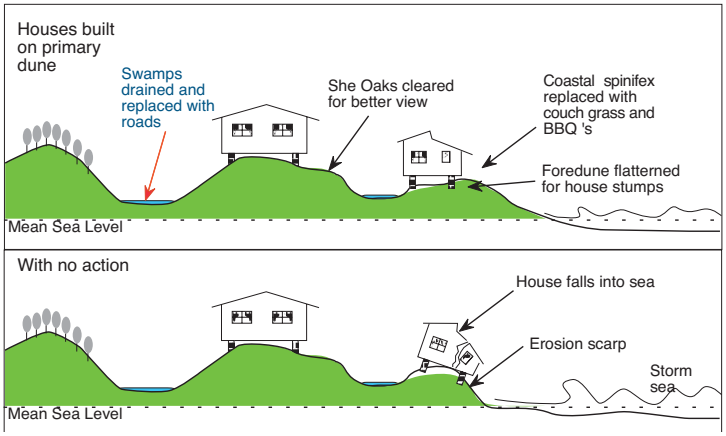


Figure 112.4 No action, allow houses to fall into the sea
(Illustration Bob Moffatt, based on original drawings by the Beach Protection Authority)

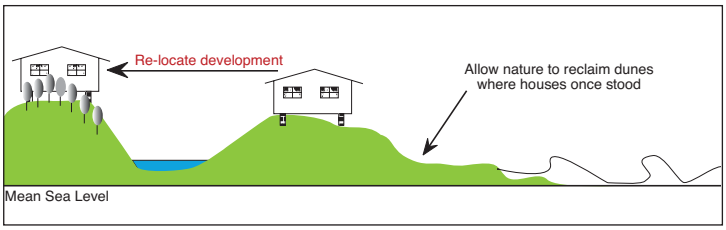


Figure 113.1 Relocation of housing
(Illustration Bob Moffatt, based on original drawings by the Beach Protection Authority)

Relocation

The property could be relocated in another area well away from the eroding sea (Figure 113.1). The public reaction to this especially the people who have beach-front property is strong. In some areas however this may be the simplest answer if such land is available.

Governments do resume land for the building of dams, road works and government projects and it is therefore reasonable for them to do it on the beach front. Towns have even been resumed where the building of a dam would have inundated them. If the buildings were relocated the resumed land would act as a buffer zone and nature could have back its sand.

Four basic engineering solutions to combating erosion are

- *the use of physical barriers,*
- *building of groynes and breakwaters,*
- sand nourishment and
- *the creation of offshore reefs.*

Engineering solutions

To minimise the effect of erosion on a particular beach is a complex issue as many of the structures have positive and negative facets. The selection of the most appropriate method for the beach concerned is not easy, as the structure has to be workable, economically viable and aesthetic. The beach needs to be maintained, as it is a valuable recreational resource.

There are four basic engineering solutions to combating erosion, any of which can be used individually or in combination. These are the use of physical barriers, building of groynes and breakwaters, sand nourishment and the creation of offshore reefs.

Figure 113.2 Building a boulder wall
(Photo Bob Moffatt)

Physical barriers

The construction of a physical barrier to the sea is one method that can be used to stop erosion of the foreshore. These physical barriers are mostly just made of rock and lie parallel to the coast. They are also known as rock revetment. This was one step that was taken by the Gold Coast City Council during a cyclone in 1967. This protective boulder wall stopped or at least hindered the erosion of the foreshore preventing damage to the buildings behind.

The impact of **boulder walls** is that they greatly restrict the rebuilding of the beach by natural means. They cause a drop in the level of the new beach because of the increase in force of the reflected waves. These reflected waves remove the sand from the beach thus reducing its width.

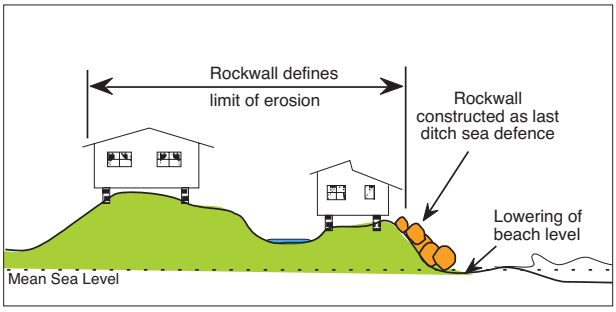


Figure 113.3 A boulder wall by itself is not a good sea defence.
(Illustration Bob Moffatt)

Figure 114.1 Boulder wall
(Photo Bob Moffatt)

Boulder walls, as shown in (Figure 114.1), are one of the most common structures used in the prevention of beach erosion and in many coastal developments is mandatory with the cost borne by the developer or home owner. The walls are very expensive costing as much as $50,000 for 100 metres of wall because the rock has to be transported sometimes large distances and heavy equipment is needed to manoeuvre the boulders into place. These structures are no sure barrier to the sea as storm surges can easily destroy these walls and houses and buildings need to have deep piles so that waves cannot erode foundations.

Groynes

Groynes are constructed to trap sand passing the eroded areas (Figure 114.2). **Groynes** are basically boulder walls, which are built at right angles to the beach. These walls need to extend far enough out to sea to form a barrier to longshore sand movements. They act as headlands trapping the moving sand. They slow down these longshore currents and cause them to deposit their load of sand against the wall.

The major impact of groynes is that they merely transfer the problem along the beach. To overcome this some beaches have a series of groynes or groyne fields. This of course will present a problem to the next beach, as it will have little or no sand arriving to replenish its own eroded sand.

Groynes do not prevent beach erosion during severe storms as they cannot prevent offshore movement, so beaches that have been built up by groynes over years can be washed away in an overnight storm. Also groynes destroy the scenic look of wide long expanses of beach.

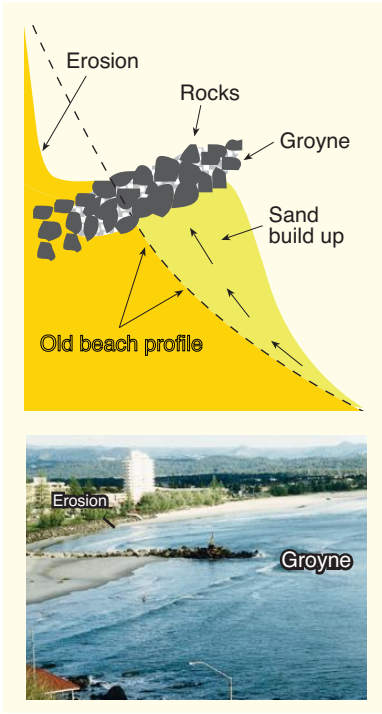


Figure 114.2 The effect of a groyne - sand on one side and enormous erosion on the other
(Photo Gold Coast City Council)

Breakwaters

A **breakwater** is similar to a groyne as it goes out at right angles to the beach for a certain distance before it veers in the direction of longshore current. Breakwaters cause accretion on the updrift side resulting in the buildup of sand on the beach. An area of protection occurs behind the breakwater and erosion occurs further along the beach. This also protects an area from the forces of the sea and thus offshore movement of the sand.

Training walls

As Australia was developed, nearly all of the trade and traffic was by sea. Towns and cities were built where there were good harbours and fresh water. Local river entrances had to be used as harbours and these entrances were not well protected, so engineers built training walls to secure a safe passage for trawlers and recreational fishers (Figure 114.3).

In many places these **training walls** created problems because they halted the natural flow of sand causing beaches on the updrift side to lose their supply of sand estimated in some places at 500,000 cubic metres of sand a year. Over time sand destined for these beaches was trapped severely affecting the dynamics of the beach (as discussed in Chapter 4).

Figure 114.3 Trawler leaves river protected by training walls.
(Photo Bob Moffatt)

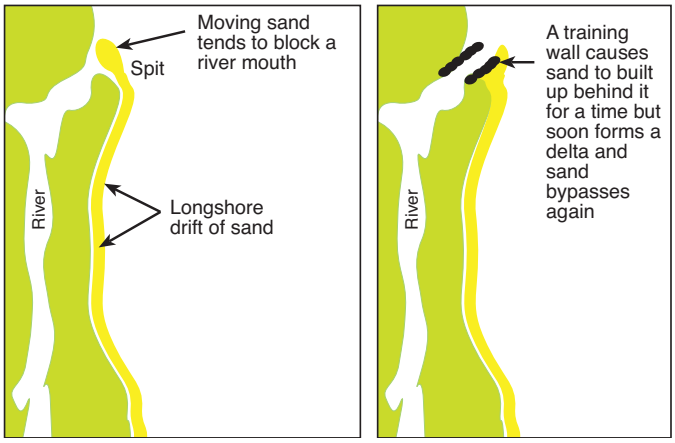


Figure 115.1 Training walls
(Illustrations and photo Bob Moffatt)

Sand bypassing systems

The solution to sand being trapped by a training wall was to build a sand by-pass system as shown in Figures 115.2 and 115.3. Here sand is picked up by a pumping jetty using a series of jet pumps, and gravity fed to a pump station on shore.

From here the sand was pumped to the other side of the river usually at night when the electricity was supplied at an off peak rate. The sand flowed out of a pipe onto the beach (Figure 115.2) which was then picked up by the long shore current on the other side of the wall. Engineers could then calculate the amount of sand required by the beach on the other side and pump the required amount of sand to stop erosion.

Figure 115.2 Sand from pumping jetty
(Photo Gold Coast City Council)

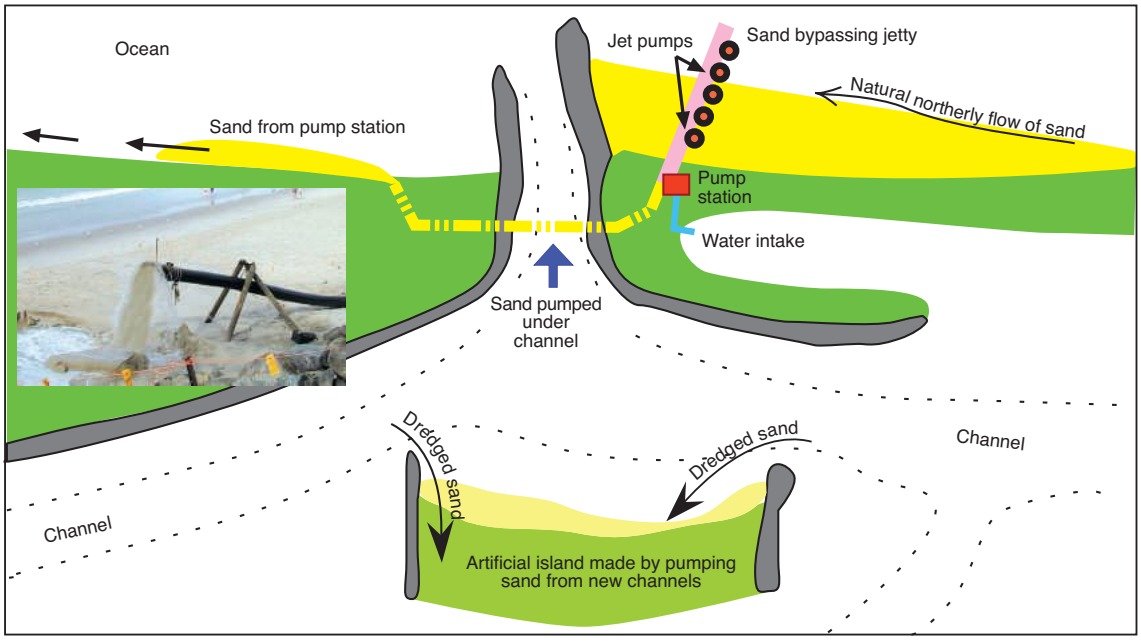


Figure 115.3 A sand by-pass system
(Illustration Bob Moffatt, after Beach Protection Authority)

Case study 5.1 Sand bypassing

Figure 116.1 Construction of the sand bypass system
(Photos courtesy Queensland Department of Harbours and Marine)

The Queensland Department of Harbours and Marine commissioned the Delft Hydraulics Laboratory in the Netherlands to investigate stabilizing the mouth of the Nerang River so that boaties on the Gold Coast could safely negotiate the mouth to access the open ocean. The Netherlands leads the world in research of coastal erosion.

With their advice and local studies by the Queensland Government Hydraulics Laboratory it was decided to construct a new entrance for the Nerang River. Training walls were constructed about 300 m apart just south of the original entrance. The southern retaining wall was constructed to extend 600 m out to sea and the northern wall 400 m out to sea. This can be seen in the general plan for the seaway.

Over one million tonnes of rock and thousands of huge concrete blocks were used in the construction of these walls. Rocks of up to 25 tonnes were used on the exposed parts of the wall so as to withstand waves of 5 to 7 metres.

To prevent the northward movement of sand silting up the entrance and forming a bar across the mouth, as well as possible erosion of South Stradbroke Island, a sand bypassing system was set up. This sand pumping consisted of 10 jet pumps located at a depth of 11 metres below mean sea level along a 500 metre pipe out to sea. These pumps were used to move an estimated 500,000 cubic metres of sand each year from the southern side of the training wall to the northern beach past the mouth of the river. This system was designed to operate in all conditions and is a permanent structure.

Dredging

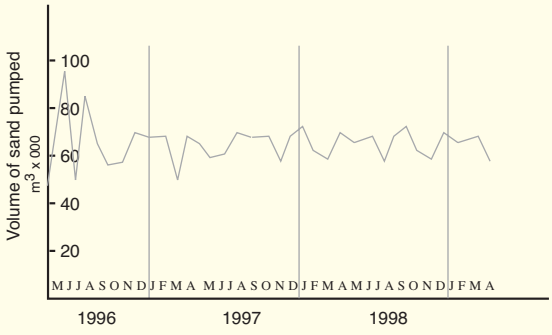
4.5 million cubic metres of sand were dredged to form new access channels within the broadwater and provide a new entrance between the training walls.

Re-vegetation

Almost 70 hectares of reclaimed areas of bare sand on Wave Break Island and on the south end of Stradbroke Island were re-vegetated with native plant species.

Questions

1. Does the graph show a cyclic pattern of sand movement ie more sand moved in the summer months than the winter months?
2. What was the highest monthly volume of sand moved by the sand bypassing system?
3. How many 10 litre buckets would a cubic metre of sand fill?
4. Why will regular surveys and aerial photography of the area need to be made?



5. Suggest why Wave Break Island was built inside the river entrance (see Figure 115.3).
6. Where are the reclaimed areas and how do you suggest these reclaimed areas could be stabilized?
7. Explain the economic importance of the Gold Coast Seaway.
8. The design was based on Australia's longest record of reliably recorded wave and other coastal data collected by the Beach Protection Authority of Queensland. Why was this data necessary for the construction for this unique feature?
9. The planning and design of the various components of the project were based on results of 4 separate model studies relating to the entrance layout, stability of training walls and wave effects. Suggest why there may be a need for these 4 model studies.
10. Explain the advantage of a quantitative approach to studying coastal processes.
11. Why is it recommended that coastal management programs be coordinated at the Federal level of government?

Dune reconstruction

There are three major methods of dune construction used to re-establish dunes. These are: importing the sand from other areas, the use of sand accumulators, stabilizing the dunes with plants and other structures.

Importing sand from other places

Sand can be pumped from offshore or estuarine dredging to construct dunes in a particular area. This is a quick but expensive method of re-establishing a dune and is mostly undertaken after storm damage. Importing the sand from other areas by truck is used in areas where rapid repair is required.

The use of sand accumulators

Sand accumulators used to re-establish coastal dunes include wooden fences to catch the sand as it blows up the beach and surface rougheners such as tree branches and bush matting which trap the wind-blown sand up the dune.

Stabilizing the dunes with plants and other structures

Healthy dunes support a wide range of plants. In any management program for coastal sand dunes it is necessary to stabilize the sand surface. Many Coastcare programs actively involve locals replanting dune vegetation (Figure 117.2). Fencing, bush matting, tree cuttings, and mulch and spray-on materials can stabilize the surface.

Most beaches now have management plans where access to the beach over the dune is restricted and dune fencing and ocean access tracks and paths have been established. Vehicle access tracks in hind dune and protected areas have been surfaced with natural substances.

Sand nourishment

Sand or **beach nourishment** refers to the replenishment of the eroded sand by pumping sand from other areas such as near-by estuaries, offshore using a dredge (Figure 117.3) or simply trucking it in from other areas. If the sand is pumped from a near-by river this may also benefit navigation of the river as well as replenishing the beach. This sand will form a buffer zone and provide a reservoir of sand against further storm damage.

The quickest method is simply pumping the sand from other areas to build up the beach. This is an expensive method but the loss of amenity from the area may be of far greater cost.

A sand pumping system may also be set up as a sand bypass system where the sand that might have built up across a river mouth is relocated up past the river mouth. This has the benefit of preventing dangerous bars from developing at the mouths of rivers.

Figure 117.1 Beach walkway
(Photo Bob Moffatt)

Figure 117.2 Planting dune vegetation
(Photo Gold Coast City Council, Coastal Engineering)

Figure 117.3 Offshore dredge pumps sand onto beach.
(Photo Bob Moffatt)

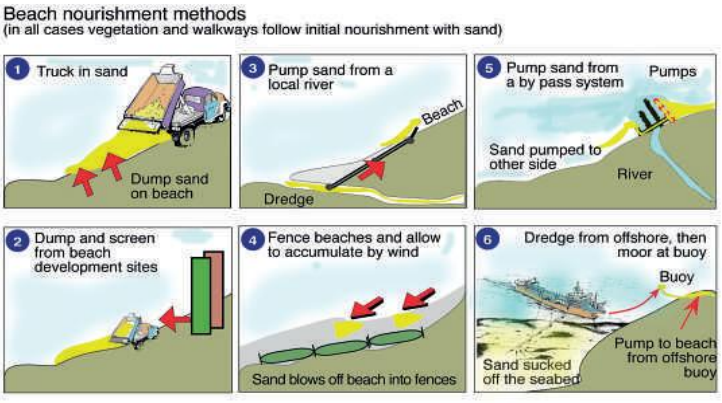
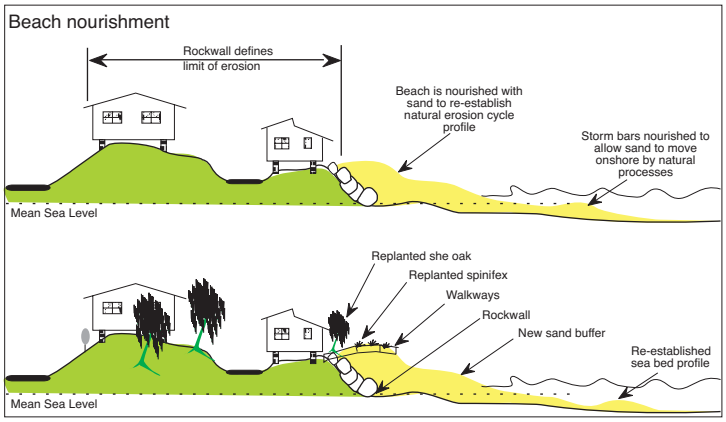


Figure 117.4 Beach nourishment methods
(Illustration Bob Moffatt, information Angus Jackson and Sam Smith)



Beach nourishment is an example of a very effective but very costly engineering solution.
Bilinga Beach in Qld has cost over $20 million to nourish and repair over the past 20 years.

Figure 118.1 Sand nourishment
(Illustration Bob Moffatt)

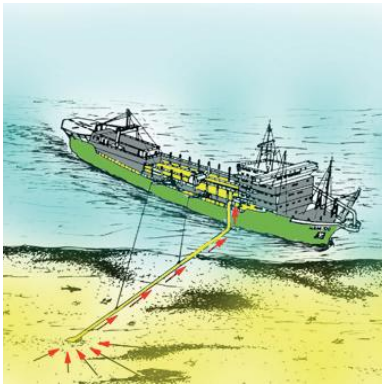


Figure 118.2 Sand for beach nourishment can often be dredged from offshore.
(Illustration Bob Moffatt)

Figure 118.3 An offshore artificial reef
(Photo courtesy Gold Coast City Council)

Use of models in coastal engineering

The coastal environment is in a delicate state of balance, and small adjustments by engineered structures can have great consequences. The future effect of engineered structures and devices on the environment is mostly evaluated by the use of models.

Two types of models, which are used in coastal engineering are the scale model, and the computer model.

The scale or physical model tries to imitate the real problems on a reduced dimension. In these reduced systems the engineers try to reproduce or replicate the environmental conditions, such as waves and currents. These scale models allow the engineers to evaluate the effects of a number of currents flowing within a system.

Computer models involve the use of mathematics to predict the effect of the artificial changes. The computer can predict the effect of the slope of the shoreline floor on the wave shape and therefore on beach erosion. The computer models can also predict the rate of sand build-up on a beach over time.

Artificial off-shore reefs

Hard reefs

Artificial off-shore barriers reduce wave action on the beach and can be constructed parallel to the beach to slow down the waves, decreasing their energy directly in front of the reef.

The lessening of wave action will decrease the longshore currents set up by the waves, thus reducing the erosion.

This is a costly method which is proving a very effective long term solution to coastal erosion and is creating a growing field of employment for coastal engineers.

It has been suggested that these offshore reefs could even be constructed of strips of plastic simulating seaweed, which would reduce the velocity of the ocean currents allowing the sand to be deposited at the desired point.

In Western Australia one artificial break at Cables (completed 1999), between Cottesloe and Leighton beaches hasn't proved as successful as it's $2 million price tag and 10 years of research might suggest.

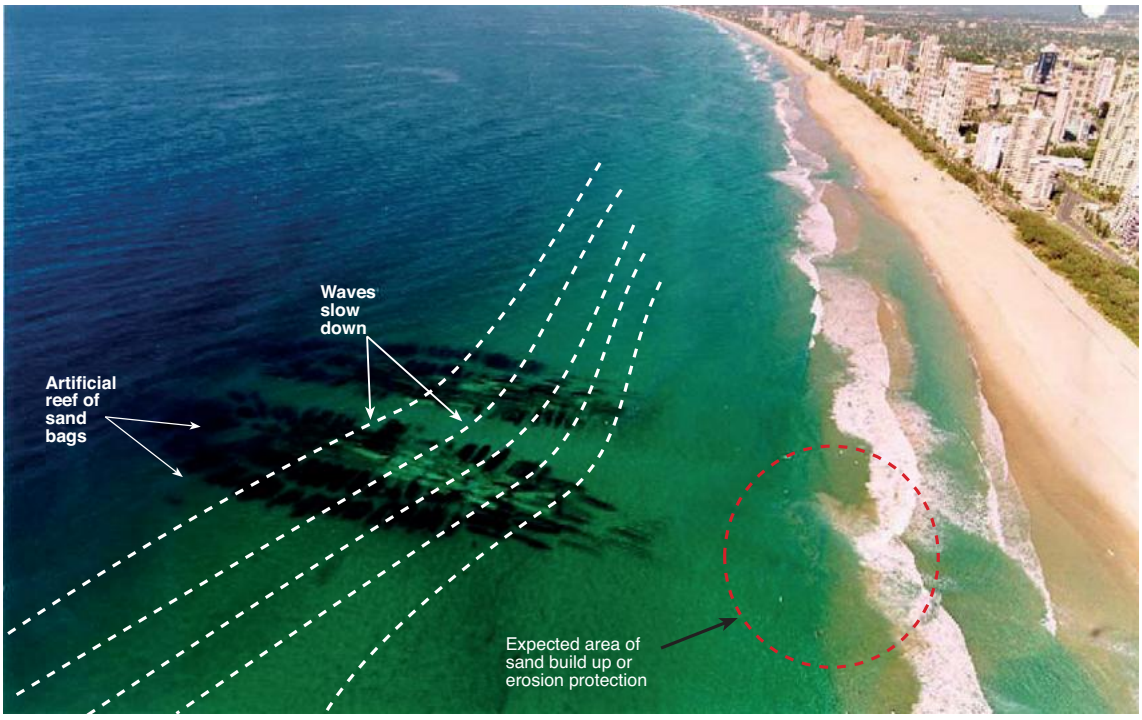


Figure 119.1 Artificial reef in high energy shore Queensland
(Photo courtesy Gold Coast City Council)

The long term effects of this reef are still being monitored as it has been placed on a shore of sheltered by an island with infrequent storm wave impact. Hard reefs however provide a great place for SCUBA diving and fishing as they allow places for fish to grow and reproduce.

Soft reefs

Artificial reefs are a new innovation in coastal engineering based on world's best practice. The reef shown above was constructed underwater to avoid the unsightly rocks of a groyne.

The problem

Incoming storm waves were causing severe erosion on the beach and threatened to damage the main highway that carried telecommunications cables and sewage pipes.

The solution

The reef was designed to slow down storm waves causing them to break further out at sea. This would slow the eroding beach cycle (see Chapter 4).

During calm weather sand could build up as shown in Figure 119.1 much the same way the groyne shown on Page 114.

The problems of unsightly rocks and permanent environmental damage was solved by having the reef made from geotextile mega bags. This meant that if the engineers were wrong or there were any problems that could not be solved, the bags could be cut open, the sand allowed to fall free and the bags removed by a dredge.

You can read more about this project on Pages 120 and 121 over.

Further information about this project can be found at:

www.coastalwatch.com

www.onthenet.com.au/~jackson/asrn/narrowneck/Index.html

www.asrltd.co.nz/projectsgoldcoast.html

Odd fact

1 million cubic metres would fill a football field to a depth of 220m.

Case study 5.2 Narrowneck reef

Article copyright Gold Coast City Council, reproduced with permission.
Photographs Angus Jackson and McQuade Marine.

The construction of the first artificial reef on the eastern seaboard is now complete and will be monitored during the next six months as the reef's 395 geotextile bags settle into position.

The $9 million Northern Gold Coast Beach Protection Strategy has these objectives:

- Widen the beach and dunes along the Surfers Paradise Esplanade to increase the volume of sand within the storm buffer; and provide additional public open space.
- Improve surf quality at Narrowneck by the construction of a submerged reef to stabilise the nourished beaches.

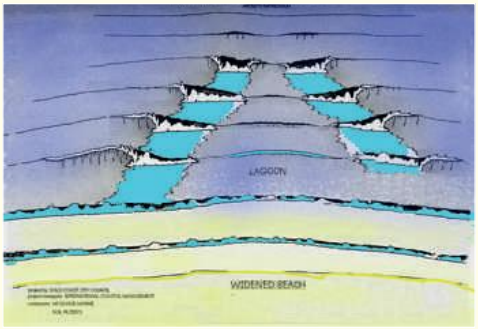
Although the shape and size of the structure was not pre-specified, the City Council wanted to maintain the amenity value of the beaches and did not want a rocky groyne or breakwater above water level to detract from the long, white-sand beach panorama at Surfers Paradise. Thus, the City Council requested that the structure should be submerged, if feasible.

Their own data indicated that the beach had a high commercial value by attracting tourists to the region, and that any increase in amenity would increase tourism. Environmental and recreational amenity value was confirmed when, after completion of the design, an economic assessment indicated that the project would return more than 60 times the project cost, some $Aust 300-500 million (Raybould and Mules, 1998).

The project took out a Queensland Earth environment award recognising the innovation and introduction of the completely new strategy. "Combining a database of world-class surfing breaks, specifically tailored computer modelling and design software, and surfing experience to incorporate high-quality surfing breaks into coastal structures."

A first for the eastern coast, the Reef has attracted the interest of scientists and marine engineers from around the world. Complex mathematics and laboratory testing of combinations of tides, wave heights and direction were used to develop the reef to enhance surfing conditions.

There were no precedents, as existing submerged, offshore reefs had been crudely rectangular and oriented longshore to maximize protection. Moreover, the potential to deliberately incorporate surfing and associated recreational amenity had not been considered previously. Thus, the novel structure had to be designed to be multi-functional. In addition, the Gold Coast



region is known to experience up to 500,000 m^3 of net longshore transport.

Any structure in this "river of sand" could have serious impacts downstream. It was necessary to trap some sand, but not all. The City was able to sustain a downstream renourishment program of around 80,000 m^3, which meant that the structure should allow free passage of more than 80% of the total littoral drift, while still providing a coastal control for the widened beach profile upstream and a "reef" for surfing. The reef, mainly intended as an off-shore defence mechanism against beach erosion, is also aiming to improve surfing conditions at Narrowneck Beach.

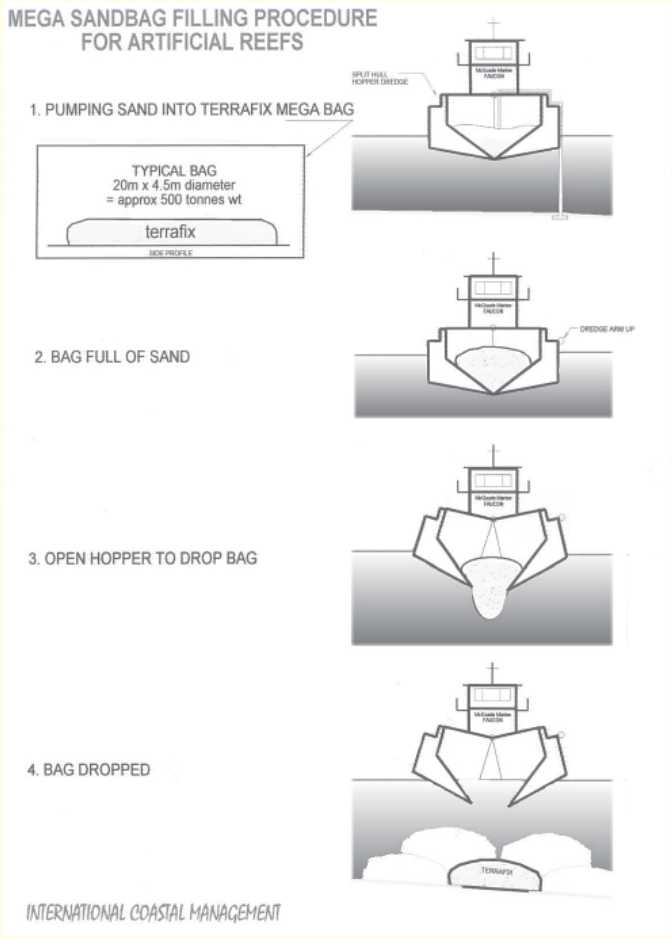
The engineer in charge of construction, Mr Angus Jackson of International Coastal Management Ltd states, "The bags are filled in a split-hull hopper dredge after being pre-sown in the supplier's factory. Once filled, bow and stern satellite positioning on the dredge is used to find the release location and the bag is dropped to the seabed. Construction is undertaken offshore and so there is minimal impact on beach users. The bags are 160-300 tonnes, being typically 20 m long and up to 5 m diameter. These are predicted to be stable in the 8-10 m waves that occur during cyclones. On the Gold Coast Reef, 300 bags are being used to make up a total reef volume of approximately 110,000 m^3."

The construction involved unrolling the geotextile bags into the hopper of the McQuade dredge; the dredge then fills the bag with sand.

When the bag is filled, it is sealed and the dredge positions itself above the site of the reef. The dredge then splits along its length and opens to allow the sand filled geotextile bag to drop to the seabed.

The long arm extends over 400 m offshore from the natural 2 m depth out to 10.4 m depth.

To develop the design, the natural bathymetry, wave breaking characteristics and peel angles of 33 (now 43) world-class surfing breaks were recorded at sites in Indonesia, Hawaii, California, Brazil, New Zealand and Australia (Mead et al., 1998). The bathometry of these reefs provided considerable insight into the characteristics of quality surfing reefs. These form a "double-sided underwater headland".



Filling bag

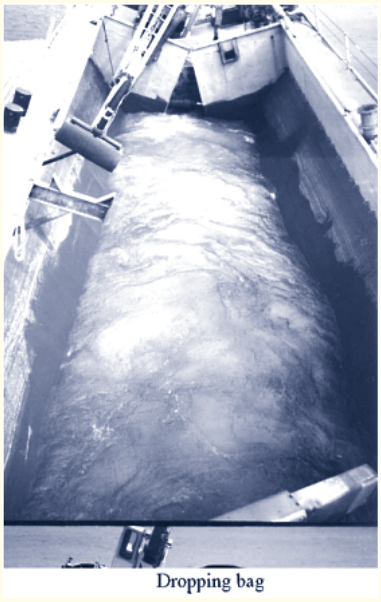

Dropping bag

Figure 121.1 Mega sandbag filling and dropping
(Illustrations on this page courtesy of Gold Coast City Council Coastal engineering and Angus Jackson)

QUESTIONS

1. How much did the Narrowneck project cost? How much do the researchers believe the asset will be worth to the community?
2. Describe the sand bags that were used to form the reef. What might you compare the size of these bags to? Describe how the bags were transported and placed into position on the sea floor. How heavy were these bags and describe the method used to find their final resting position?
3. Do you believe that this engineering structure will be safe from cyclonic forces?
4. Why do the engineers believe that the artificial reef will produce excellent surfing conditions? Describe how this artificial reef forms a double sided underwater headland.

   If a surfer was to paddle out and catch a wave produced by the structure what would be the best place to paddle out?
5. What effect will this underwater structure have on the ecology of the area?
6. Explain why collecting and analysing the data is vital for clients' projects and the establishment of numerical models.
7. Discuss the processes that were involved in the development of the project.
8. Design an investigation into geotextile bags to see if they were the most suitable material to store the sand.

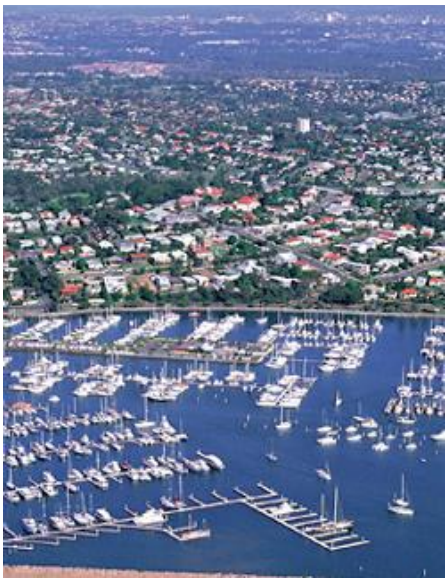


Figure 122.1 Coastal marina
(Photo Murray Waite)

Figure 122.2 Navigation markers
(Photo Qld Transport)

Figure 122.3 Pier and wharf
(Photo AMSA)

Other coastal engineering structures

There are many more engineering structures around Australia. Those described on these two pages are but a fraction of the work done by coastal engineers.

Ports, harbours and marinas

Ninety eight percent of all goods come to Australia by sea and ports, harbours and giant jetties (Figure 122.3) have been built so ships can load and unload cargo. These large structures have a marked effect on coastal infrastructure and have to be built now to strict environmental and safety guidelines.

On a smaller scale, marinas (Figure 122.1) have been built to provide the boating public places to moor their boats. These too provide engineers with environmental challenges such as sewerage disposal, electricity and water supply, storm protection as well as marina infrastructure.

Harbours require lights and markers (Figure 122.2) to guide boats in safely. Special materials and paints are necessary to withstand the severe sea conditions. Moorings are floats or places where boats and yachts are tied up for short or long periods. The anchoring mechanisms need to designed so the mooring does not move.

Piers are permanent structures that are constructed in low energy wave areas to provide an amenity for local fishers, yacht owners, divers or swimmers. Famous piers can be found dotted along the entire Australian coastline.

Canals

These were structures built in the early 1970's for a culture of home owners who wanted waterfront property. Dredges would pump up sand from coastal wetlands so residential properties could be built as shown in Figure 122.4.

Figure 122.4 Canal estate
(Photo Murray Waite)

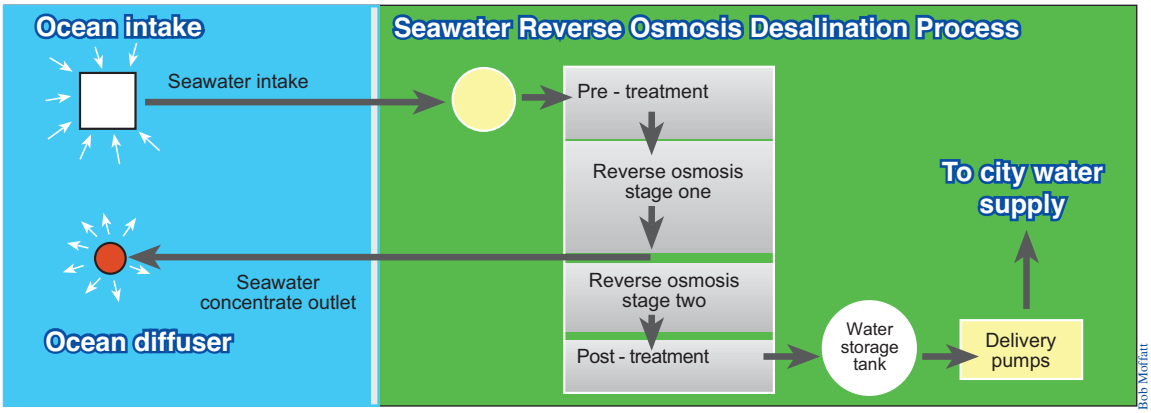


Figure 123.1 Desalination process

Desalination plants

Desalination is a technology that separates dissolved salts and other minerals from seawater or other salty water to provide clean drinking water.

Desalination technologies already exist and have been used for over 20 years. In Australia, the most common desalination process is **reverse osmosis** (Figure 123.1), which involves the removal of salts and other minerals out of the water as it moves through a membrane process (moving through a thin sheet of material) under high pressure.

Other processes include thermal distillation, which involves evaporating the salt water and collecting the purified vapour; and electrodialysis, which involves removing salts by separating and collecting their chemical components through electrolysis (using an electric current).

Lighthouses

These used to be managed by lighthouse keepers but have now been completely automated. Reliable technology needed to be developed to guarantee safety to shipping.

Oil rigs

Bass Strait and the North West Shelf are tow areas around Australia where oil and gas rigs exist. The design of these need to allow for minimal environmental impact, good living conditions for staff, safe work places for drilling to occur and supply pipelines to transport oil and gas many thousands of kilometres under the sea.

Overseas telecommunications

These were laid in the 20th century when satellite communications were not as advanced. Most tele-communications now are transmitted by digital technology.

Beach stormwater drains

New environmental legislation in most Australian states prohibits chemical discharge into the environment. Stormwater issues arise where local councils have to design gross pollution traps or catchment strategies to avoid prosecution.

Figure 123.2 Desalination plant under construction

Figure 123.3 Oil rig
(Photo Qld Transport)

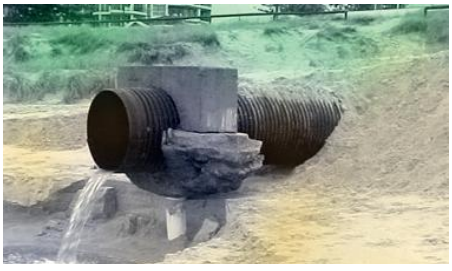


Figure 123.4 Beach drain
(Photo Bob Moffatt)

Exercise 5.1 Hypothetical bay 2015

Questions

Read the boxed section in the next column, study the information on page 126 and answer the questions below.

1. Make a comparison of Hypothetical Bay on page 55, Chapter 3 and Hypothetical Bay on page 125 opposite.

   Now describe at least 20 changes that are proposed.
2. Why did the regional government ban all development along the coastline from Steggles Beach Reserve to Farmer Beach?
3. Is it a good idea to have all the sewerage effluent from the city pumped out into the ocean at King Point?

   What could be done with the sewerage?
4. What effect will an international airport have on the proposed Watson Bay National Park?
5. If Fishers Wharf is planned, what will be the effect on the township of Holthouse Flats?
6. Massive ecotourism is set to develop in the Bay. The reefs off Steggles Beach reserve are pristine and need management.
   - What zoning or management proposals do you suggest?
   - How will you go about zoning the reef?
   - What is your vision for the reef 25 years after you draw up these management plans?
7. How will the freeway affect Mariner City?
8. How do you feel about an exclusive resort being developed in Lynch River? If the resort went ahead, what types of access do you think the general public would have to the resort?
9. Will Perry Shoals suffer from increased use and will the whole of Hypothetical Bay have to be zoned?
10. Propose a management plan for Hypothetical Bay in Figure 139.2.

Class report

1. Divide the class into nine groups.
2. Make a copy of Figure 126.1 cut the outside nine boxes up and place in a hat. Each group elects a leader who selects a topic.
3. Discuss the topic for ten minutes, make notes, elect a spokesperson and deliver a three minute summary on your notes.

Refer back to the undeveloped Hypothetical Bay on page 55, Chapter 3

Read this

Tourism is one of Hypothetical Bay's fastest growing industries with many people escaping the cold winter in the northern hemisphere to bathe in its crystal clear waters.

Steggles Beach was voted beach of the year in 2007 and has unparalleled attractions at the nearby Collins, Redden and McDonald Reefs. Watson Bay National Park is well renowned for its coastal flora and fauna including the world famous Smith Parrot.

In the 1960's Hypothetical Bay was a sleepy hollow and developed in the 70's and 80's to a stage as shown on Page 55.

In 2004 Lynch River was dredged with the approval of a new marina south of Batestown.

A proposal is before the Batestown city council for a mega city and development. It is proposed to widen Bade Creek and build a Fishers Wharf complex that will link Watson Bay by a causeway.

Watson Swamp will be dredged to create a massive foreshore development around the new Mariner City with an international airport that will take five flights from Japan each day.

The Regional Government has proclaimed that the entire foreshore from Steggles Beach be a reserve and to include Butler Beach to Farmer Beach and the Plattern Reserve.

The headland to the east of the airport is to be a national park and the sacred aboriginal sites to be managed by the local Warranda tribe requiring a permit to enter the national park.

A new breakwater is proposed as well as an artificial island offshore, the details of which are not disclosed.

To the west of Lynch River is a Harbour Town development for an expected 70,000 people and a exclusive resort opposite Wright Point is planned along the Club Med style.

A secondary sewage system is planned to discharge at King point on the new breakwater, much to the disgust of local environment groups who have taken the council to the environment court and delayed the plans.

The regional government is keen to see the proposals go ahead as they plan to develop a freeway past Richmond Hill to the new city.

The total cost of the project is 600 million dollars and is financed by a middle-eastern consortium of companies. It is the brainchild of a developer living off the coast of southern Europe.

An election is imminent with one party saying it will scrap the entire development while the other is saying it will study the proposals carefully.

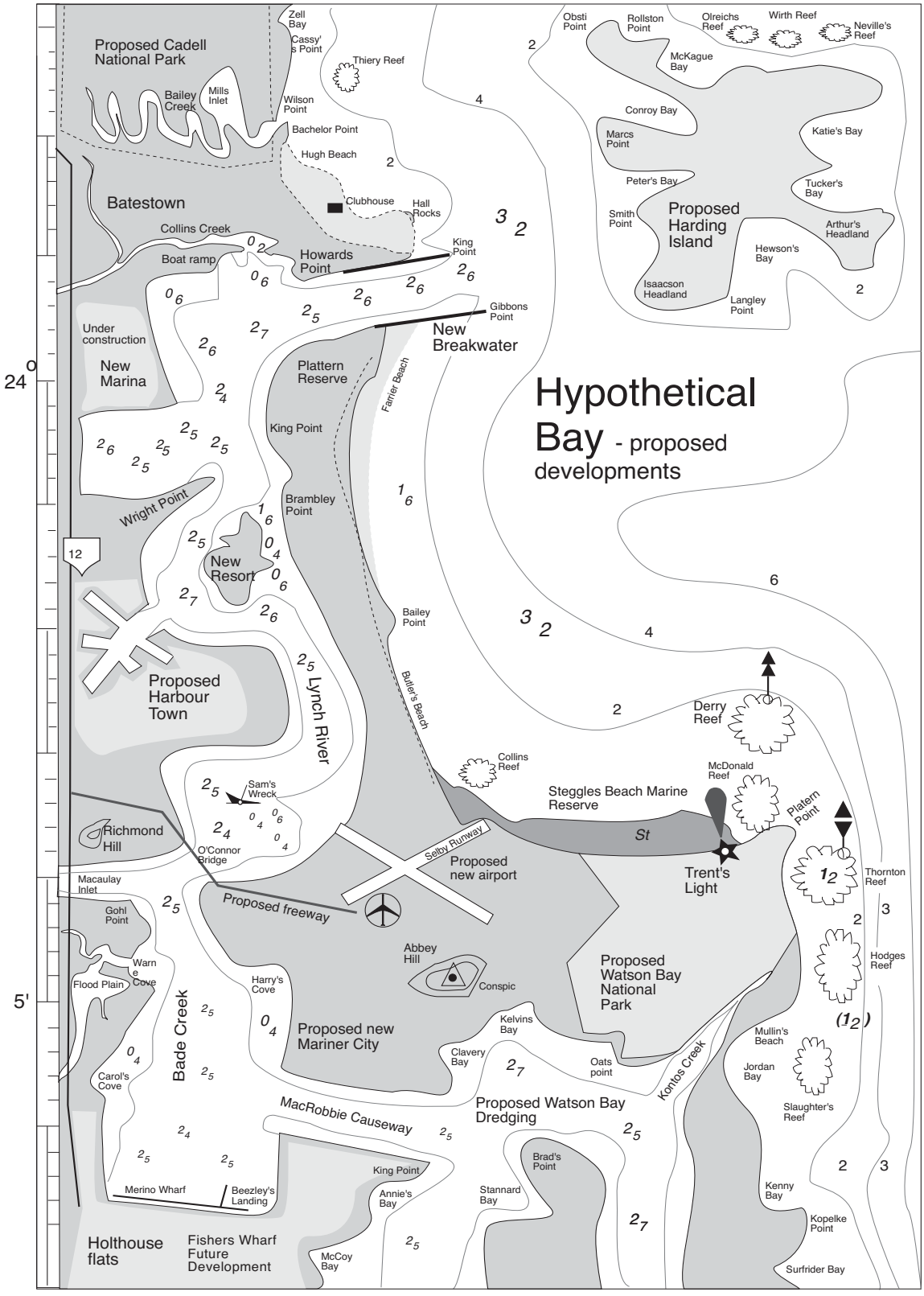


Figure 125.1 Proposed development of Hypothetical Bay
(Illustration Bob Moffatt)

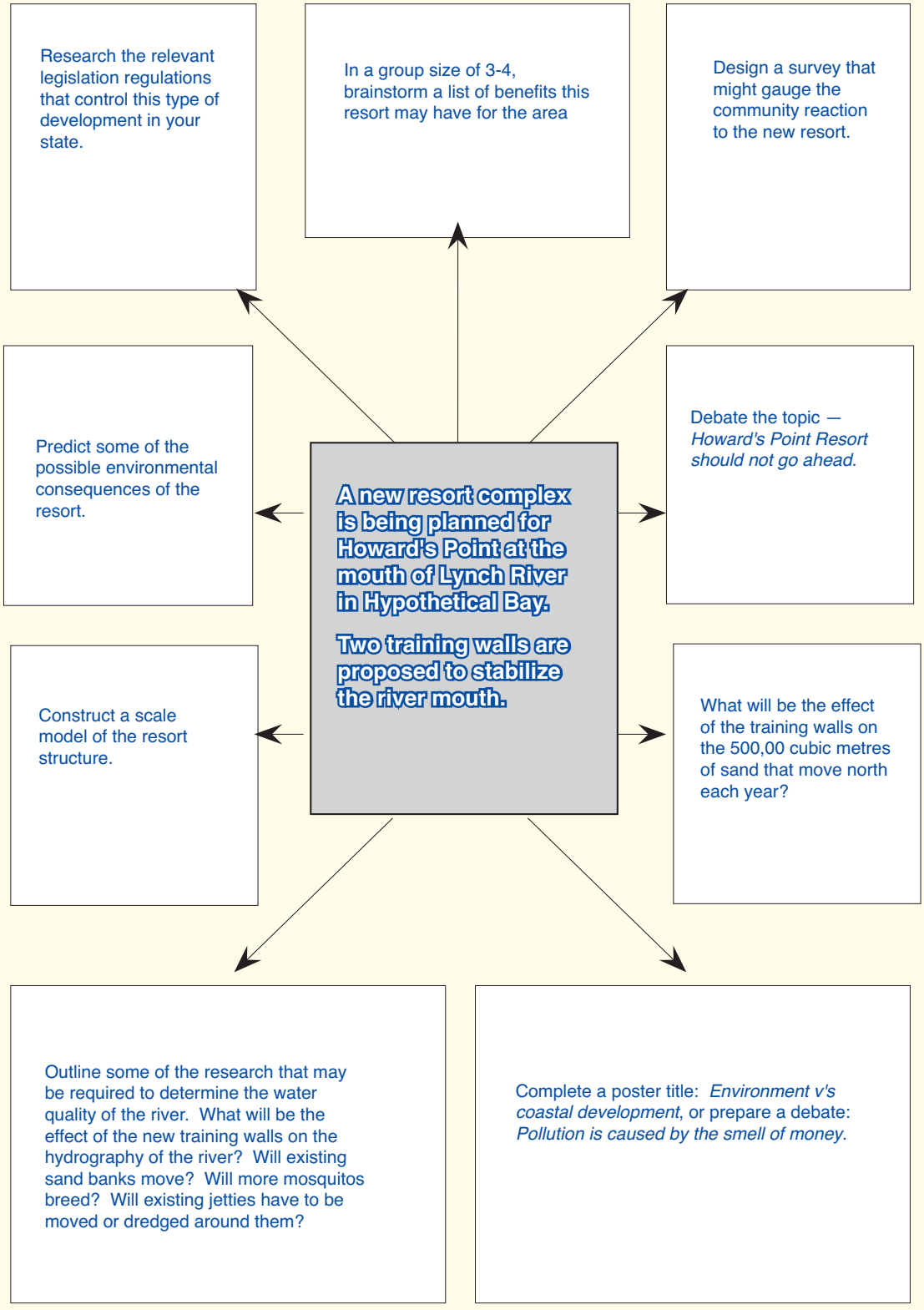


Figure 126.1 New resort data

Exercise 5.2 Engineering legislation

An original exercise by Tim Ryan

To investigate the relevant legislation or regulation controlling coastal engineering.

You will need

- A copy of a government act that manages some aspect of the coastal zone eg Beach protection acts, waterways act, beaches act, marine act. Try to choose an act that is not too long and has few amendments as it will be easier to follow (see Figure 127.1).
- To form a group of 3-5 to make a detailed study of a section.

What to do

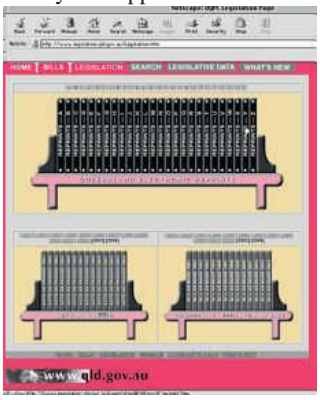
1. Find out when the act was presented to Parliament, by which political party and for what purpose. A telephone call is all that is required here to the authority that manages the act.
2. Copy down the headings of the main sections of the act and form groups of 3-5 to make a detailed study of three or four sections.
3. What authority or government department will manage the act? Find out their address and get one member of the class to write for a copy of their annual report. When this arrives, divide up into groups to make a study of the relevant sections.
4. Make a detailed summary of the sections your group has been allocated.
5. Make contact with the authority and find out if there have been any breaches under the act and, if so, what types of infringements occurred. Don't ask for names, dates and respect privacy. Make a list.
6. Present your report to the class under the following headings:
   - Section/s of act researched
   - Aspects covered and relevance to coastal zone management
   - Recorded breaches under the act
   - Your opinion on the usefulness of this section - what you think the strengths are and what are the weaknesses - what changes you would make - the reasons for the changes.
7. Compile these summaries and present them to your class.
8. Arrange an excursion to see how the members of parliament or local councillors debate aspects of coastal zone management and the processes by which coastal zone legislation is drafted .

Getting into the acts

Most states and territories have their acts on the web as pdf versions.

Try typing in the word legislation and see what comes up - for example in Queensland you will get

www.legislation.qld.gov.au and an electronic library will appear as follows:



Then select "B" for beaches and you get the Beach Protection Act 1968 (BeachProA68) [Superseded Versions] as shown below

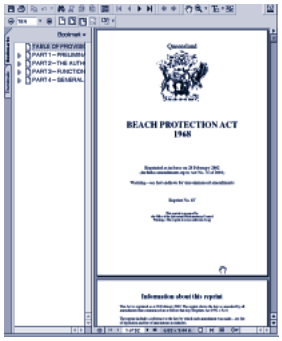


Figure 127.1

Extension

- Design a poster that tells people why we need beach protection. Make sure your poster contains a message and plenty of colour to bring life to your art work.
- Compile the summaries and present them to your local parliamentarian and find out when aspects of coastal zone management are next to be debated in parliament. Alternatively, arrange a visit to the local council or shire meeting to bear how environmental issues are debated and proposed developments are discussed. Arrange an excursion to see how the members of parliament debate.

Exercises

From the Wet Paper Publication - *Oceanography Exercises See www.wetpaper.com.au*

B14. What happens when the dune cycle is broken?

B15. When is beach nourishment a solution to coastal management?

Questions

Knowledge

1. List two types of sand accumulators used to re-establish coastal dunes.
2. Name three major methods of artificial dune construction.
3. State how coastal dunes can be stabilized.
4. Define the terms – *coastal engineering beach nourishment method*.

Understanding

5. Outline what is meant by the saying "Beach erosion is a natural process". Why is this natural process a problem on so many of our beaches?
6. Explain why training walls have been built at the mouth of so many of our rivers.
7. List any six coastal engineering structures not mentioned in this chapter.

Applying

8. How do offshore artificial reefs help beach construction?
9. Show that you understand what a groyne is and why they are they constructed. Why are they ineffective in preventing beach erosion during severe storms?
10. Explain why the building of physical barriers reduced the width of the beach.
11. Describe any two types of models which are used in coastal engineering.
12. Explain how the artificial reef in Queensland will protect Narrowneck beach from erosion.

Analysing

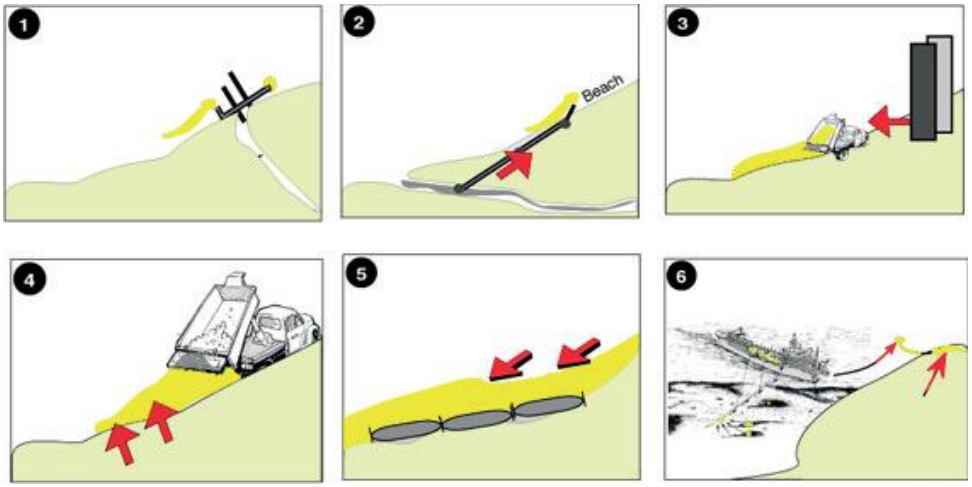
13. Name two beach erosion control measures used on your local beach.
14. What are two similarities and two differences between breakwaters and groynes? (Compare and contrast)
15. Distinguish between the beach nourishment methods shown in the figure below.
16. Explain the measures we can take to prevent dune damage.
17. Discuss the accretion and erosion processes associated with a groyne.

Creating

18. Create a sand tray model to show what a beach and sand dune system looks like on your local beach?
19. Design the perfect artificial offshore reef break.

Evaluating

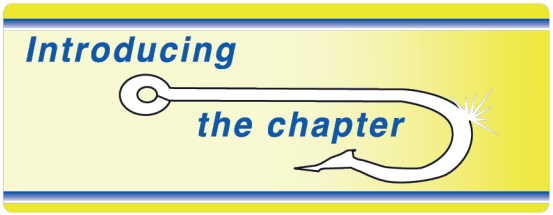
20. Two waves are approaching a beach. One is in shallow water and the other in deeper water. Compare the speeds and shapes of the waves as they break on the beach.
21. It has been suggested that the sand budget is "in the red". Assess this statement and explain why it is "in the red".
22. How might a scientist evaluate the effect of an artificial structure on the coastline?
23. Debate the use of four wheel drive vehicles on sand dunes.
24. Discuss beach erosion on the Gold Coast and decide if all the money that has been spent over the years has been worth it. Give reasons for your answer.



Chapter 6 Sea Water

by
Bob Moffatt

Photo CSIRO



Chapter hooks

1. Make a sea water iceblock.
2. Design and build a water sampling device that will collect a sample of water from .5 metre underwater that is opened and closed from the surface.
3. Set up a demonstration of Hoffman's voltameter to show that water can be separated into hydrogen and oxygen atoms.
4. Boil some sea water and collect and analyse what is left behind.

Why study this chapter

An understanding of basic sea water chemistry allows us to explain why icebergs float, oxygen circulates to the depths of our oceans and animals develop ways to regulate the amounts of salt in their bodies.

A knowledge of sea water chemistry also provides industry with new materials to prevent metal corrosion and animals and plants fouling ship hulls.

An important application of this knowledge is in the aquaculture industry where wild catch fish are grown in captivity and exported live.

Chemistry is at the heart of many solutions to the problems and opportunities created by humans.

Chapter overview

The composition of sea water 131
Exercise 6.1 Making Sea Water 132
Exercise 6.2 Sea water freezing and boiling 138
Properties of sea water 141
Exercise 6.3 Research projects 149
Exercise 6.4 Archimedes principle experiment 150
Light and sea water 153
Temperature and sea water 154
Sea water and aquaculture 155
Exercises and questions 158

Key concepts

1. Sea water's unique properties are caused by the special covalent chemical bonds called hydrogen bonds.
2. A process of titration can determine the salinity of sea water. Salinity can change due to evaporation or precipitation in coastal areas but remains fairly constant in the ocean.
3. Sea water is a unique substance having rare characteristics such as:
   - excellent solvent,
   - high heat capacity,
   - variable density and
   - light absorption
4. Dissolved gases enter the ocean from the atmosphere by a process called diffusion or are released from animals and plants that live in the ocean.

   Concentrations of oxygen and carbon dioxide are varied by biological processes such as photosynthesis and respiration. Nitrogen values remain fairly constant.

   Aerobic organisms need oxygen to extract energy from organic molecules and dissolved carbon dioxide is necessary for autotrophic nutrition.
5. Temperature gradients within the ocean determine where most animals and plants will live. The temperature controls the metabolic rate of all cold-blooded animals and controls distributions of warm blooded animals who are poorly adapted to change in temperature.
6. Light entering the ocean is absorbed and converted to heat. This warms the ocean surface. The red end of the spectrum is absorbed first with blue and violet light penetrating the furthest. Marine plants which photosynthesise are limited to the photic zone.
7. Physical, chemical and biological processes contribute to ocean water composition, eg rivers and thermal smokers.

The composition of sea water

Sea water is possibly the most unique naturally occurring substance we know. It accounts for over 85% of the mass of marine organisms and is the medium in which the chemical reactions that support life in the sea take place. It provides support in the form of buoyancy for some of the organisms that live in the sea. Water is the only substance on the earth's surface that can exist naturally in all three states as a solid, liquid and gas.

Water is less dense in its solid form than its liquid form and so it forms icebergs which float in Arctic and Antarctic waters. Figure 131. 1 shows the major elements found in sea water.

Salinity

Oceanic sea water has about 35 g of salt per litre of water with little variation world wide. This 35g/litre is made up of a variety of salts some of which are shown in Figure 131.1.

All these salts collectively go to make up the salinity of sea water.

The salt dissolved in the water is called the **solute**. The grams per litre is called its **concentration** and is expressed as 35 g/L. Sometimes it is expressed in parts per million.

The water that you add to the salt is called the solvent (that's the material the solute dissolves in). Together the solute and the solvent is called the solution. So if you had some salt from the supermarket and added it to water from the tap in a saucepan, you would have a **salt water solution**.

This would not necessarily be the same as sea water which contains other dissolved substances.

There is much debate about pollution of our seas. It is extremely important to understand what the term concentration and parts per million means when discussing pollution. World Health Authorities (WHO) talk about acceptable levels of pollution in terms of the number of parts per million or ppm.

The salts dissolved in water in the sea have a concentration of 35 g/L.

Note:

35,000 ppm

= 35 grams/litre

= 35 ppt

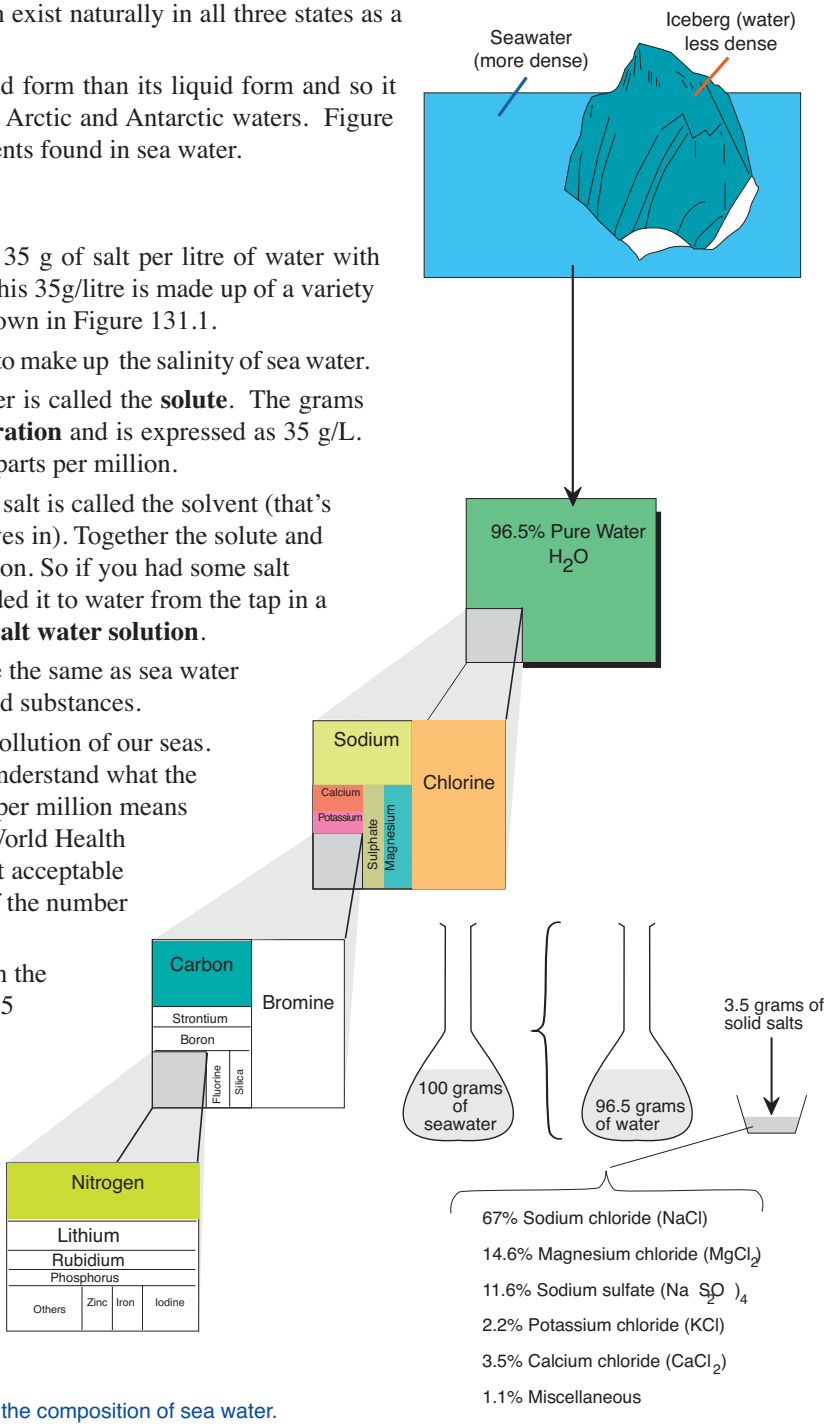


Figure 131.1 Two ways to look at the composition of sea water.
(Illustration Bob Moffatt, after Ross 1984)

Recipe for artificial sea water	
Salt	
Sodium chloride	23.48 g
Magnesium chloride	4.98 g
Magnesium sulphate	2.14 g
Calcium chloride	1.10 g
Pottasium chloride	0.66 g
Calcium carbonate	1.64 g
Magnesium bromide	0.084 g
Sodium bicarbonate	0.192 g
Sodium sulphate	3.92 g
Sodium fluriode	0.003 g
Strontium chloride	0.024 g
+ 1 litre of water	

Exercise 6.1 Making sea water

The first experiment in this chapter looks at understanding concepts of *dissolving* and *concentration*.

Aims

The aim is to make a simulated salt water solution so you can understand the terms salinity, solute, solvent and concentration. Your class is divided into groups, with each group having the responsibility of making up a sea water solution of a certain concentration.

Discussion

Suppose your group is required to make up 200 mLs of salt solution containing 35 g/L.

How much salt should you weigh out?

eg if 35g of salt make up a 1000 mL solution, then 7 grams of salt make up a 200 mL solution

Each group now needs to calculate the required amounts in column 3 as shown in the table in Figure 133.1

Copy this table and complete it to test your understanding.

Exercise 6.1 will give you a chance to measure out 35 grams of salt. This can be expressed as 35 g/L^{-1} or 35,000 ppm.

If we wish to talk about pollution - we have to be able to express our opinions on the basis of a sound understanding of the **concentration** of substances that are suspected of polluting our seas.

PPM

is the number of parts per million.

g/L

is grams per litre and a measure of pollution.

35 g of salt are to be dissolved in 1000 mLs of water from the tap

multiply

?? g of salt do I need for a 200 mL solution in my beaker?

$$? = \frac{35 \times 200}{1000} \text{ g}$$

$$? = 7 \text{ grams}$$

Simple proportion can be worked out by cross-multiplying if you have difficulty with proportion calculations.

Note

To make 200 mLs of a 7 g/L solution, add 20 mLs of distilled water to a graduated cylinder (see over)

Top up to 100 mLs by reading the meniscus, pouring this 100 mls into a 200 mL beaker, and then refilling the graduated cylinder with 100 mLs distilled water to dissolve the rest of the salt.

1	2	3	4
Sample	Weight of salt (g/L)	Weight of salt (g/200mL)	Concentratio
1	5		5 000 ppı
2	10		
3	15		15 000 ppı
4	20		20 000 ppı
5			25 000 ppı
6	30		
7	35		35 000 ppı
8			40 000 ppı

Figure 132.1 Table for your note book
(Illustration Bob Moffatt)

Figure 133.1 Top loading balance
(Photo Selbys)

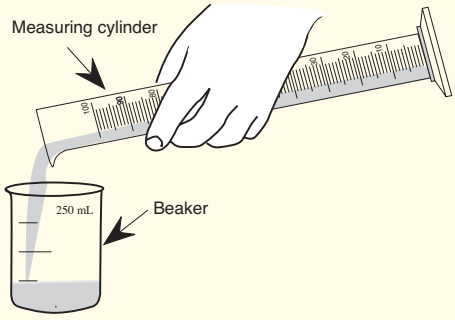


Figure 133.2 Using a measuring cylinder to mix water (solvent) and salt (solute)
(Photographs and illustration Bob Moffatt, courtesy Benowa State High School)

Parts per million

A concentration of 7 grams per 200 mL or 35 grams per litre (or 35ppt parts per thousand) is 35,000 parts per million. This is the fundamental measurement of pollution levels.

Now divide into groups and complete the experiment as set out in the method below.

Equipment required

- Top loading balance
- Some salt from the grocery store
- A piece of filter paper
- Spoon or spatula
- Safety goggles
- 100 mL measuring cylinder
- 250 mL beaker

Using an electric balance to weigh a beaker

- Locate zero adjustment (usually the TARE button) and zero the balance.
- Place the beaker on the balance and read the weight to the nearest 1/100th of a gram.

Method

Calculate the quantity of salt your group requires to make up a 200 mL solution and write it down in your notebook (see Figure 133.3).

After you weigh the salt and the filter paper you have to dissolve it in water.

1. Measure out 50 mLs of water in a measuring cylinder making sure the bottom of the meniscus is on the 50 mL mark.
2. Now carefully add the salt to measuring cylinder, swirl the cylinder and top up to the 100 mL mark.
3. Pour this solution into the 250 mL beaker or conical flask supplied and refill the 100 mL measuring cylinder, making sure you dissolve all the salt. Pour the remaining 100 mls into the beaker or conical flask.
4. Label your beaker or conical flask carefully, cover it with plastic wrap and put it aside for the experiment on salinity of sea water.

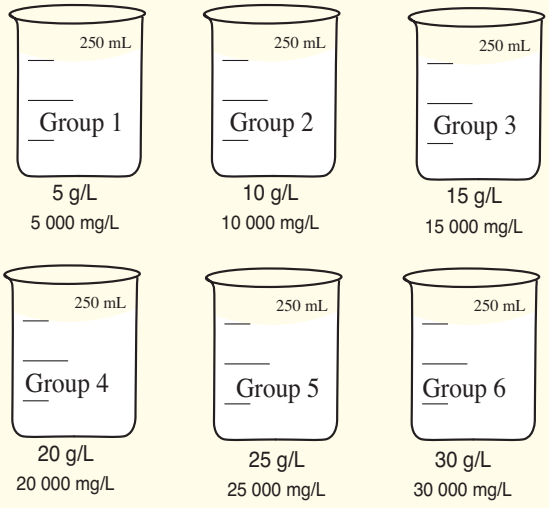


Figure 133.3 Group work on making a sea water sample - each group makes a different concentration.
(Illustration Bob Moffatt)

Establishing tests for salinity

Using light or electrical conductivity

Salinity is often measured by measuring how well electricity travels through the water.

This property of water is called conductivity. Water that has dissolved salt in it will conduct electricity better than water with no dissolved salt. The more salt that is dissolved in the water, the better the water conducts electricity.

The salt content of the water can be measured very precisely using the conductivity method (Figure 134.1).

A conductivity / TDS / Salinity Tester is used to check salt content and comes in a kit with a probe, battery, electrode soaking solution and conductivity standard solution.

The instrument gives a direct reading.

Image courtesy
Select Scientific
www.selectscientific.com.au

Figure 134.1 A conductivity / TDS / Salinity Tester

Using a refractometer

Salinity can also be measured with a hand held refractometer (Figure 134.2)

A refractometer measures the change of direction or bending of the light as it passes from air to water. Light moves slower in water than air.

The more salt in the water, the slower the light moves

A refractometer is the best choice for measuring salinity when only approximate values are needed.

Refractometers are easy to use in the field and relatively inexpensive. The salinity is read from a scale in the viewfinder (Figure 134.3)

Figure 134.2 A refractometer can also be used to measure salinity
Photo Red Sea

Figure 134.3 Salinity readings
Photo Red Sea

USING CHEMICALS

NOTE: This is an old method from the 1990's

Titration

Titration is a process of determining the amount of a certain substance present in a solution by measuring the amount of a different solution of a known concentration that must be added to complete a chemical change. The exact point of which the entire chemical has been used up during the reaction between two substances is called the end point. In most titrations chemicals are used so that a colour change is apparent when the end point is reached.

In this section we will determine the concentration of salt in a sea water solution by measuring the amount of a chemical solution containing silver nitrate and potassium dichromate required to reach an end point. This end point will be when all the chlorine has been used up.

We will have to determine the amount of chemical solution containing silver nitrate and potassium dichromate that is required to reach the end point of salt solutions of known concentrations. Students are required to make up a salt solution s of 10g/L, 20 g/L, 30 g/L and 40 g/L and carry out the experiment on page 136 Testing for Salinity.

Students may find that results are not comparable between groups, this may be due to poor techniques and errors due to spillage or the accuracy of the equipment being used.

These **experimental errors**, will prevent us from obtaining exact results and are caused by the inexpensive simple equipment we are using. The technique is called an **eye drop titration** where you count the number of drops to determine the number of grams of chloride in the salt - sodium chloride.

Now the silver in the silver nitrate reacts with the chloride in sodium chloride before it will react with chromate in the potassium dichromate. While this is happening silver chloride is being made and the solution will stay milky. You will notice that soon, small red spots will appear as the silver nitrate drops hit the milky solution. Start swirling the solution so that the red part turns back to milky.

When one drop causes the solution to stay red, the end point is reached and the silver now starts to react with the chromate to form silver chromate.

The number of drops, should approximately equal the number of grams per litre. So for a group making up a 10 g/L solution, between 7 and 13 drops should be required to reach end point.

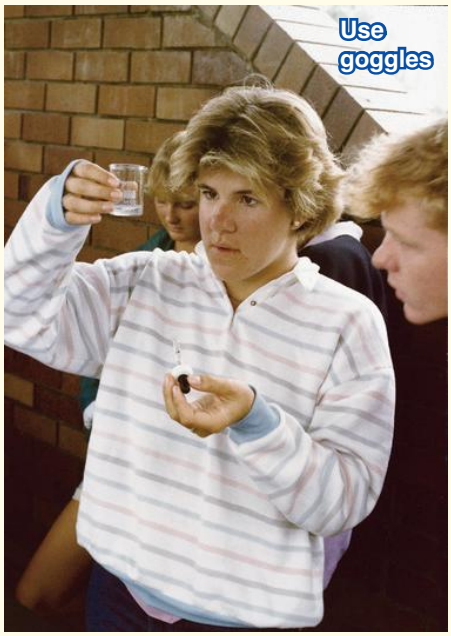
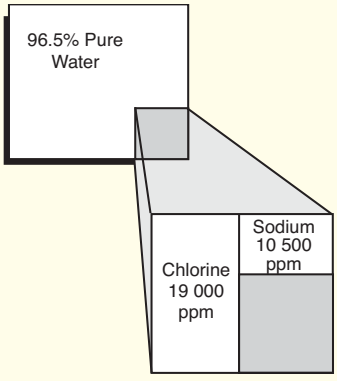
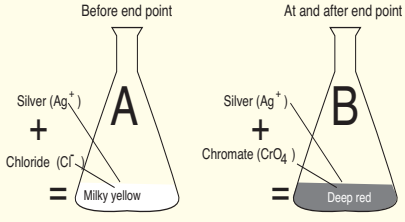


Figure 135.1 A 100 mL beaker - used with an eye dropper to establish a test for salinity. Note glasses and gloves should be worn on the instructions of your teacher.
(Photographs Bob Moffatt, courtesy Benowa State High School)





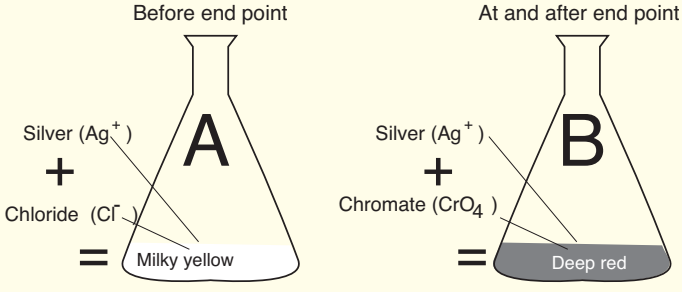


Figure 135.2 End point formula for salt water titration
(Illustrations Bob Moffatt)

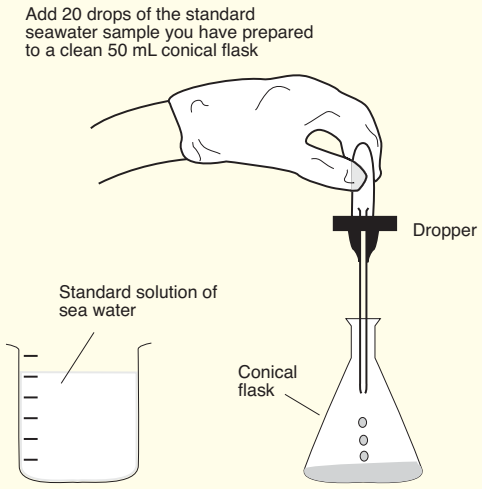


Figure 136.1 Collect 20 drops of sea water sample
(Illustrations Bob Moffatt)

Materials and equipment (per group)

Equipment required

- 10 mLs of six saltwater standard solutions:
  5,000, 10,000, 15,000, 20,000,
  25,000, 30,000 milligrams per litre
- 10 mLs of 0.5M silver nitrate solution
- salt water samples (various locations)
- potassium dichromate indicator solution
- 50 mL conical flask, **gloves and goggles**
- two eye droppers — one marked salt, the other $AgNO_3$
- sheet of graph paper

Notes

1. Because eye droppers vary from manufacturer to manufacturer, you will need to keep the same sized eye droppers for future tests.
2. The eye dropper needs to deliver about .1mL.
3. Potassium dichromate is poisonous and may be unavailable in some states.

Testing for salinity

Method

Whoever handles the silver nitrate and potassium dichromate in this part needs to wear gloves, so put them on now.

1. Collect 20 drops of the 5 gm/Litre saltwater solution and add this carefully to the 50 mL conical flask as shown in Figure 136.1.
2. Now add 3 drops of potassium dichromate indicator so as to just turn the sea water yellow as shown in Figure 136.2

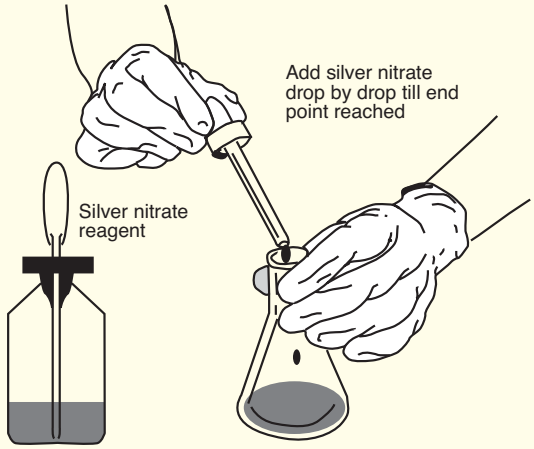


Figure 136.2
(Illustrations Bob Moffatt)

3. Add the silver nitrate drop by drop giving the conical flask a swirl after each drop as shown in Figure 136.3. Make sure someone counts each drop.

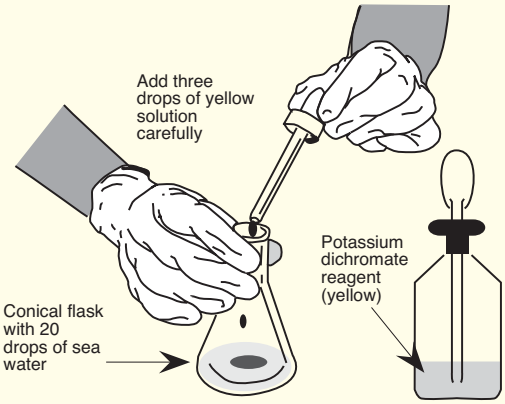


Figure 136.3
(Illustrations Bob Moffatt)

4. You will notice that a colour change appears under the drop as it falls into the sea water solution.

   When these dark red patches hang around for an increasingly longer time, start swirling after each drop.

   What is the colour under the drop?

5. When one drop turns all the sea water a reddish brown, you have reached what we call the end point.
6. Copy data table 1, Figure 137.2 into your note book and complete your section.
7. Now repeat the experiment for each of the solutions identified in Table 1 noting the number of drops to end point for each or obtain the results from other class members.
8. Now use the sheet of graph paper supplied to draw a calibration graph. (Your graph should look something like Figure 137.1) Extrapolate the graph to predict 35 and 40 g/L.
9. Paste your graph on some stiff cardboard and cover it with plastic contact. This will serve as a calibration curve for future experiments. If you use the same eye droppers, bottles and methods, experimental errors can be kept to a minimum.

Testing an unknown sample

1. Collect samples of water from an open beach and samples from a place some distance up river so that the salinity can be compared and determined using your new calibration curve.
2. Use the same technique as described above to obtain an end point.

   Record the number of drops you used in Data Table 2, Figure 137.2 and read off the salinity from your calibration curve.
3. Summarise your results from different locations giving reasons for possible changes.

Safety

1. Make sure you use gloves in this experiment.
2. Potassium dichromate is a health risk and should be used carefully and in drops only from a well marked bottle.
3. Silver nitrate is hazardous and causes staining of the hands. Fresh silver nitrate should be used for best results.
4. Samples for analysis should be done in a laboratory or desk area. The use of chemicals in the field is not recommended.

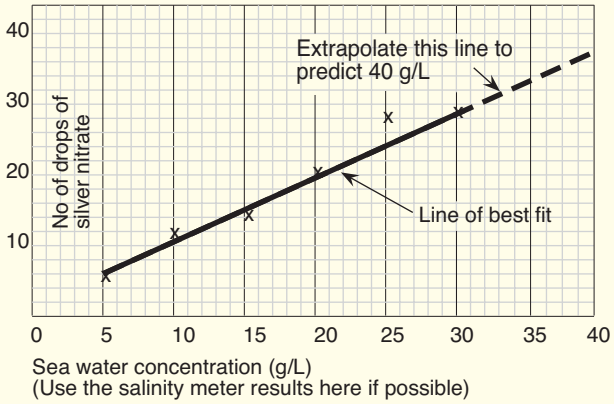


Figure 137.1 Sample calibration graph
(Illustrations Bob Moffatt)

Data table 1

Standard solution	Number of drops of silver nitrate to end point
5 g/L	
10 g/L	
15 g/L	
20 g/L	
25 g/L	
30 g/L	

Data table 2

Sample site (eg boat harbour near ramp)	Number of drops of silver nitrate to end point	Salinity in g/L

Figure 137.2 Sample data table
(Illustrations Bob Moffatt)

Exercise 6.2 Sea water freezing and boiling point

Part A Freezing point

1. Set up your materials as shown in Figure 138.1.
2. Pack the area between the beaker or jar and the outer bowl with ice.
3. Measure out 100 mLs of fresh water and pour it into the beaker.
4. Put in the thermometer and stir the water now and then with the stirring rod. Be careful!
5. When the ice starts to form in the water and not on the side of the jar, look at the temperature and write it down in your note book.

   This is the freezing temperature of fresh water.
6. Throw some salt onto the ice surrounding the beaker.
7. Make a careful observation of what happens to the temperature and record it in your note book.

Part B Icebergs

1. Take a freshwater ice block and place it in a beaker of water and work out approximately how much of the ice block is above and below the waterline. Draw the ice block in water to show how much is above and below water.
2. Repeat this for a saltwater ice block. Compare the drawings.

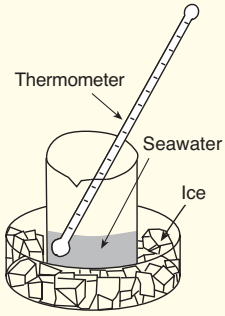


Figure 138.1 Set up
(Illustrations Bob Moffatt)

Part C Boiling point

1. Obtain four samples of saltwater labelled 10, 20, 30 and 40 g/L.
2. Set up the equipment as shown in Figure 138.1. You may have to substitute equipment if you don't have certain items. Now light the spirit burner by using the manufacturer's instructions. Adjust the burner so that a gentle flame is under the flask.
3. Put on the safety goggles and keep them on until the activity finishes.
4. Pour 10 mLs of the first sample into the 50 mL conical flask and place this on the fireproof mat.
5. Heat the flask to evaporate off all of the water. **Warning:** When the material is nearly dry, it may "spit" up. To stop this remove the flame, adjust it if possible, and gently waft it under the dish.
6. When the flask is cool and dry, use the glass stirring rod to scrape out the material that remains into a watch glass.
7. Repeat with the other sea water samples.
8. Weigh each of the four samples and record any differences in weight.

Questions

1. Describe the appearance of the dry salt.
2. Could you see a difference in the four samples? Is there a difference in weight?
3. What happened to the salt in the bottom of the flask when the liquid was almost dry?
4. How do table salt companies obtain salt from the sea?
5. Does salt affect the temperature at which water freezes?
6. Mist and ice formed on the side of the beaker above the ice. Where did this water come from?
7. Trawler operators often throw salt over the ice used for storing prawns. Why do they do this?
8. Do you think sea water will freeze at a higher or lower temperature than fresh water?
9. Which has the greater density — fresh or saltwater ice blocks? Explain your answer.

Materials and equipment (per group)

Part A

- thermometer
- ice
- fresh water
- measuring cup
- glass beaker or jar
- large glass bowl
- salt
- stirring rod

Part B

- freshwater ice block
- saltwater ice block (35g/L)

Part C

- methylated spirits burner
- safety goggles
- four 10 mL samples of sea water labelled 10, 20, 30 and 40 g/L
- fireproof mat, matches, oven mitts
- very clean 50 mL conical flask and glass stirring rod
- clean watch glass or saucer
- spring balance or equivalent balance

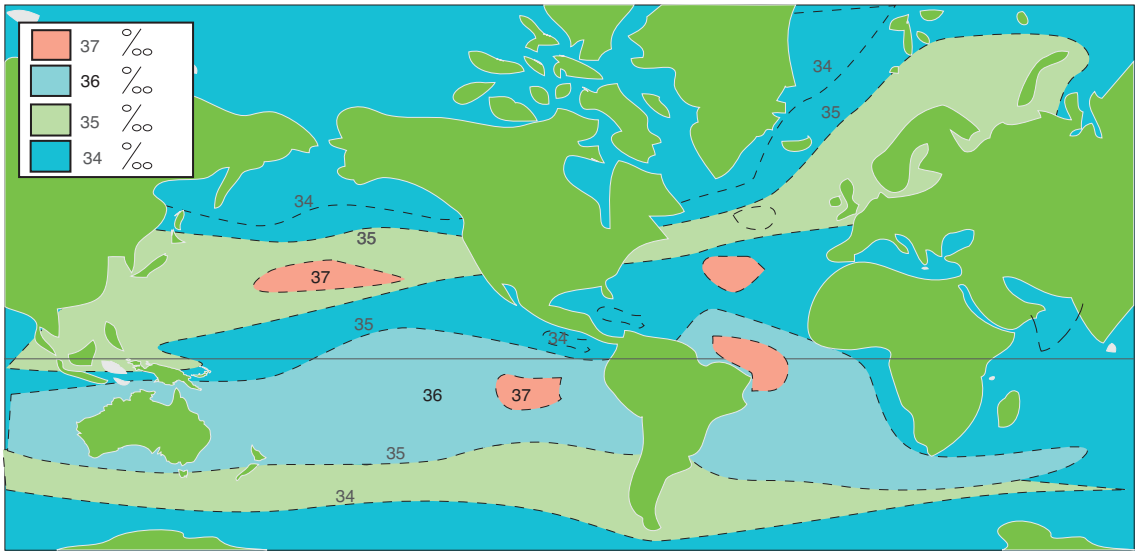


Figure 139.1 World isohalines*2002 (Source www.ngdc.noaa.gov/)
(Illustration Bob Moffatt)

Variations in salinity

The proportions of salts remains the roughly the same with 75% of all ocean water containing salt concentrations between 34.5 and 35 g/L. However the concentration of salt can change with the addition and removal of water. For example when sea water freezes the salts are left behind and high levels of rainfall can decrease salinity.

***Isohalines definition**
Isohalines are lines that join places of the same salinity.

Surface salinity

Evaporation and rainfall can greatly change the salinity of an area. In the Red Sea the salinity reaches (40g/L) due to lack of rainfall whereas the salinity of the Baltic drops to 18g/L due to a large influx of freshwater and a low rate of evaporation.

In coastal areas, salinity can also vary greatly due to rainfall, the type of parent rock close by and evaporation. Tidal pools can change in a matter of hours with salt concentrations increasing to such a point that crystals can be seen at the edge of the pool.

Latest salinity data
Check out the NOAA remote sensing site http:// www.ngdc.noaa.gov/

Figure 139.1 shows the average salinity range from 37 - 34 g/l from the equator to the poles.

Within the water column

Salinity also changes with depth as shown in Figure 139.2. The salinity in tropical waters drops quite rapidly to a depth of 200 metres then progressively falls to a steady 35 g/L at 4000 metres. The salinity of water from the poles rises slightly until it reaches the same salinity at about 4000 metres.

Rivers and estuaries

A salt water wedge can form at a river mouth as the less dense fresh water runs over the incoming sea water of higher salinity. If you collect samples of water up a river, you will be able to see a marked decrease in salinity as the concentrations of salt are gradually diluted by the fresh water off the land.

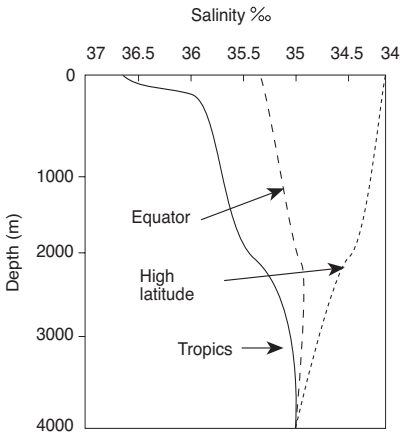


Figure 139.2 Salinity and depth - Source www.ngdc.noaa.gov
(Illustration Bob Moffatt)

The hydrological cycle

Without water all life would not exist. Many have argued that we should rename earth - water. There is over 1,350 million cubic kilometres of it and 98% of it is contained in our oceans. If the water in glaciers and ice caps is added, the earth would contain 99.35% based on recent estimates.

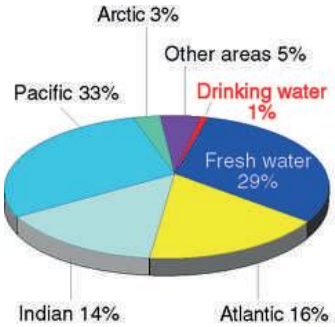


Figure 140.1 Distribution of water
(Illustration Trent Moffatt)

Approximately 71% of the earth is found beneath the sea with the mean heights of the land much smaller than the depth of the sea. The mean depth of the sea is 3.8 Km compared to 0.8 Km for land.

This three dimensional seascape provides an environment unique for animal and plant life. For us humans, only 1% of all water on the earth is available for drinking - making a great case for water conservation.

The exchange of water between the ocean and the land is called the hydrological cycle (Figure 140.2) and the shape and composition of the land determines how much absorption from the sea occurs.

Evaporation is generally higher over the ocean than is precipitation while it tends to rain more over the land. The loss from the sea is balanced by the runoff from the land. Rivers, streams, creeks and ground-water seepage return the water to the sea.

The earth is like a spaceship - nothing can enter or leave the system if life is to continue. The amount of water remains constant – only its quality can change.

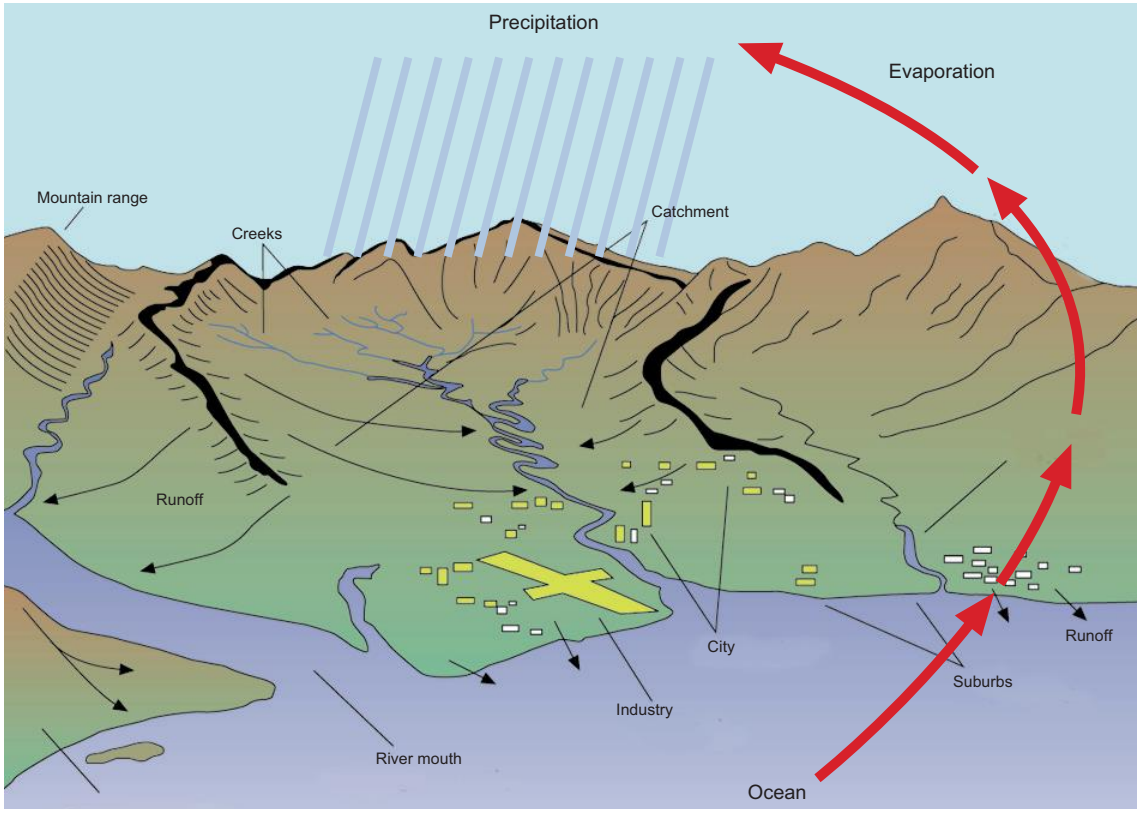


Figure 140.2 The hydrological cycle
(Illustration Bob Moffatt, clouds and ocean surface by Murray Waite)

Properties of sea water

Oceanic water enables life on earth to exist. It evaporates to give us clouds and rain and it absorbs solar radiation to stop our earth from overheating. But what makes it so special?

The following five important properties of sea water contribute to our life on earth.

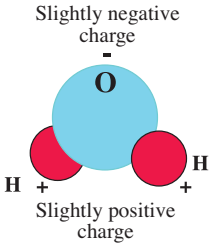
1. Physical states
2. Solvent properties
3. Heat capacity
   - Latent heat of fusion
   - Latent heat of vaporization
4. Density
5. Viscosity

Physical states

Water is made of two atoms hydrogen and oxygen (Figure 141.1).

These atoms combine in a ratio, two hydrogen and one oxygen atoms to form the water molecule H_2O.

- The atoms are held together by chemical bonds.
- These bonds form because the electrons of the atoms are shared — each hydrogen atom shares an electron with an oxygen atom.
- The resulting bond is called a covalent bond because there are two electrons shared (Figure 141.1).
- The arrangement of the hydrogen atoms and sharing of electrons results in one end of the molecule being negative and the other side positive.
- This makes the water molecule a polar molecule. The water molecule is polar because the negatively charged electrons are not shared equally in the asymmetrical molecule.



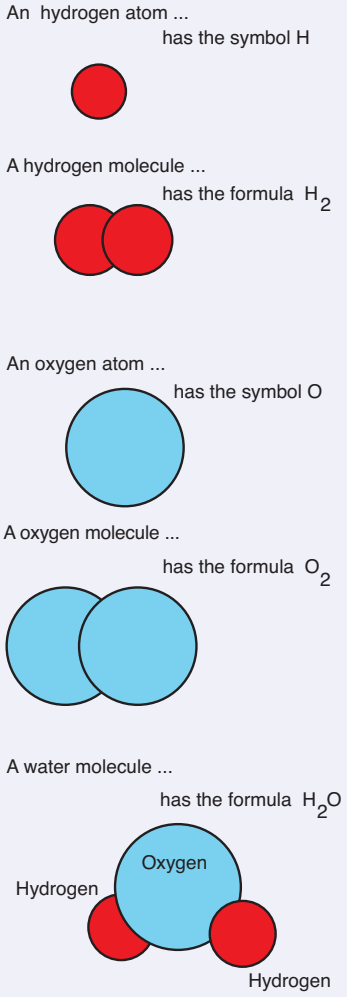


Figure 141.1 A water molecule
(Illustration Bob Moffatt)

Liquid

These different charges attract other water molecules forming weak bridges called hydrogen bonds (Figure 141.2). This results is sea water staying as a liquid right up to temperatures of 100°C.

Gas

When water heats up above 100°C, the hydrogen bonds let go and water vapour forms. Here the molecules are far apart and move freely. The process is called evaporation and occurs on any large body of water. As the water vapour rises the molecules slow down and hydrogen bonds reform. As a result clouds form.

Solid

At the poles, water temperatures plummet towards zero and some water freezes to form ice bergs and ice sheets. This is called the solid state where the molecules are very close and many more hydrogen bonds form.

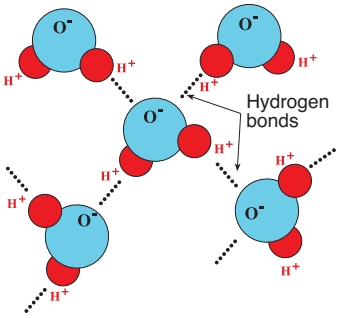


Figure 141.2 Hydrogen bonds are responsible for the unique properties of water.
(Illustration Bob Moffatt)

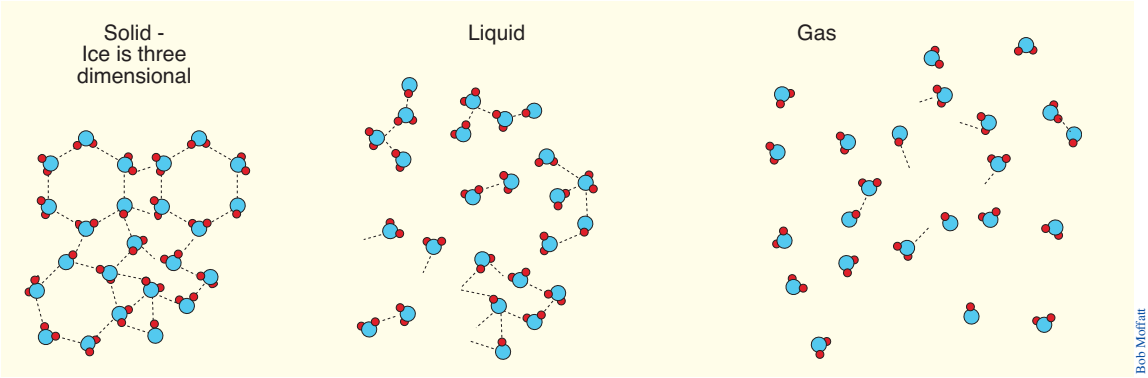


Figure 142.1 The three states of water

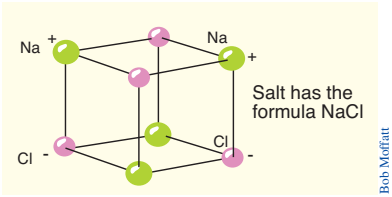
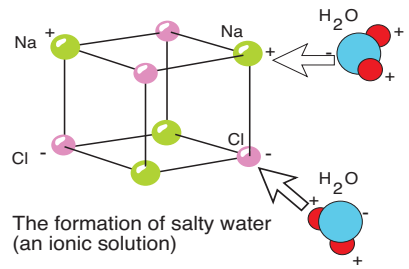
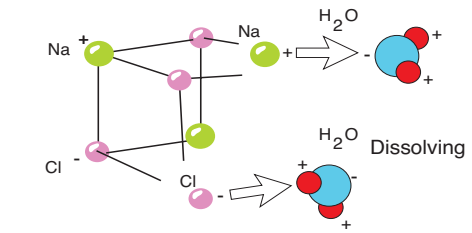


Figure 142.2 A salt crystal





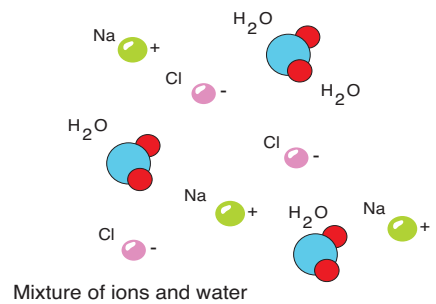


Figure 142.3 Water dissolving
(Illustration Bob Moffatt)

Solvent properties

Water has an enormous ability to dissolve substances because of its polar nature. This allows salts from the land and from the ocean floor to dissolve.

Pure water (H_20) and salt NaCl

Salt contains the elements of sodium and chlorine. Salt is therefore an inorganic material. Pure salt crystals are a combination of salt molecules held by ionic bonds as shown in Figure 142.2.

Dissolving

Water is composed of hydrogen and oxygen atoms.

Salt has sodium and chlorine atoms in a 1:1 ratio.

The chlorine is bigger because it contains more protons and electrons.

To help you understand what dissolving involves we use an operational definition, one that you put into your own words like this:

"*..The salt molecules break apart...they form positive atoms called ions*... these ions are called sodium and chlorine....

they fill up the spaces between the water molecules....

because the lattice breaks down completely, you can't see the salt any more but actually it's still there... *only as individual ions*. "

When these atoms break apart and separate, they carry with them electrical charges. These are called ions and the process of breaking apart is called ionization.

Examples of ions would be - Na^+, Cl^-

To summarise ionization we would write:

$NaCl \longrightarrow Na^+ + Cl^-$

Heat capacity

Heat capacity is the ability of water to resist temperature change. On land there are large fluctuations in temperature but the sea has a great resistance to change even a degree. Heat is a measure of molecular motion. If water temperature is to rise the molecules need to move faster but the hydrogen bonds resist this so keeping sea water at a relatively constant temperature.

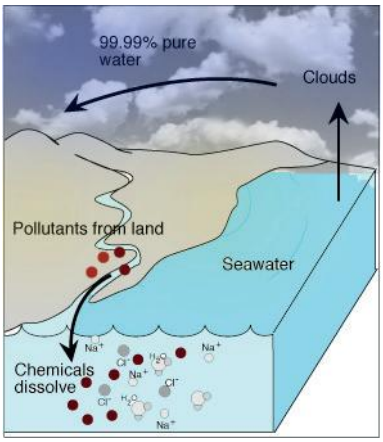


Figure 143.1 Water from the land
(Illustration Bob Moffatt)

The biological significance of heat capacity

Heat capacity is the most important moderator of climate and accounts for the narrow range of temperature change found at any location in the ocean.

Water can absorb or lose an enormous amount of heat without undergoing a large temperature change. This property makes water an insulator of life in the oceans.

Water will not freeze completely in polar regions allowing life to exist underneath, and oceans at the equator will not boil in the summer sun.

Intertidal plants can cool by releasing some of their water for evaporation however as we shall see later, this loss of water can cause problems.

Latent heat of fusion

This is the heat required to either melt or form ice and for water this is quite high.

So it takes a long time for the blood of cold blooded animals or the water in seaweeds to freeze in winter.

Latent heat of vaporization

This is the heat released when water evaporates.

Heat is continually being absorbed by the oceans each year but they do not get hotter. This is because heat is released as the hydrogen bonds break allowing water molecules to vaporise into the atmosphere.

The latent heat of vaporization is much greater than that of fusion and marine animals make use of this to cool down.

Animals on the seashore such as mussels and barnacles open slightly to allow water to evaporate to cool down. However they need to stop too much water from evaporating to avoid desiccation (drying up).

Heat

Heat is a measure of molecular motion that is measured in calories.

If temperature drops, molecular motion slows and to slow this motion heat must be taken out.

Latent heat

Heat lost or gained during cooling or evaporation is called latent heat.

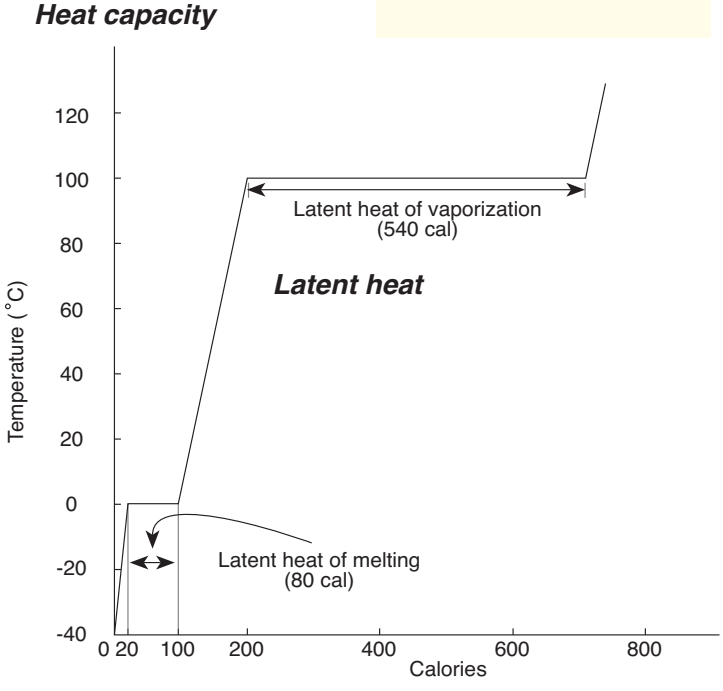


Figure 143.2 Latent heat
(Illustration Bob Moffatt)

Densities of some common substances	
Substance	Density at 25 °C (g/cm^3)
Gold	19.3
Mercury	13.5
Lead	11.4
Iron	7.87
Aluminium	2.70
Bone	1.7 - 2.0
Water	0.997
Water	1.00 (4 °C)
Ice	0.917 (0 °C)
Gasoline	0.66 - 0.69
Wood	0.11 - 1.33
Air (dry)	0.00119 (1 atm)

Figure 144.1 Densities of some common substances
(Illustration Bob Moffatt)

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Relative density} = \frac{\text{Density of substance}}{\text{Density of water}}$$

Figure 144.2 Relative density formula

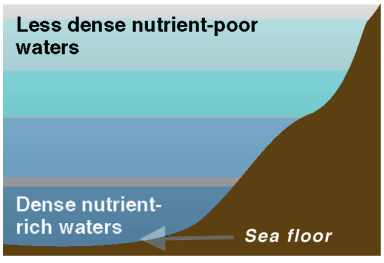


Figure 144.3 Density and water masses
(Illustration Bob Moffatt)

Density

The sea is three dimensional with depths far greater than heights on land. Water has a density 800 times greater than air which means that marine organism do not require the support mechanisms land based animals and plants require.

The blue whale weighs 150 tonnes and yet can swim gracefully through the ocean. Giant kelps reaching some 60 metres in height can be supported also by the smallest of root systems.

Density and temperature

The density of a substance is the mass per unit volume. Mass is measured in grams and volume in cm^3.

Look at the table below. Wood with a mass of 10 g and a volume of 20 cm^3 will have a density of .5.

Substance	Mass (g)	Volume (cm^3)	Density (g/cm^3)
Wood	10	20	0.50
Ice	10	10.9	.92
Water	10	10	1
Aluminium	10	3.7	2.7
Lead	10	.88	11

Wood has a density roughly half that of water and so wood floats on water. Lead is more dense and so we use a lead sinker on a fishing line to sink our bait.

As water cools more hydrogen bonds form in water and the movement of the molecules slows. The molecules are drawn closer together and the mass per unit volume increases to 4°C where its mass is equal to its volume. The density is therefore 1. As ice freezes, the volume increases. If you put a full bottle in the freezer, it will break because the water expands.

The biological significance of density

Some animals and plants can be larger but still be plant eaters (eg Manta Ray). Plankton that live near the surface in warm low dense waters must be smaller and more ornate than those living in cooler waters.

Relative density

The relative density of a substance, is the ratio of the density of that substance, to the density of pure water (see Figure 144.2).

The relative density of sea water is determined by salinity and water temperature. Dense water sinks and is found at the bottom of the oceans. Less dense water is found floating at the surface as shown in Figure 144.3. Objects that are more dense than water have a relative density greater than 1. These substances sink in pure water.

Example

Objects which have a relative density less than 1 will float. For example, the iceberg in Figure 145.1 floats because the density of the water in the iceberg is 0.92 g/cm^3 compared with the density of the sea water which is about 1.05 g/cm^3.

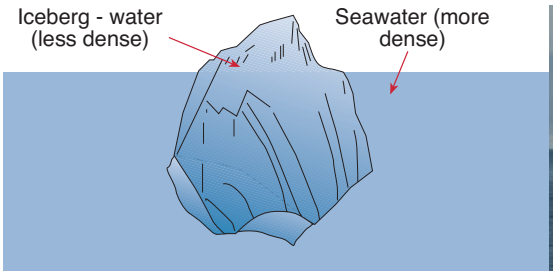


Figure 145.1 Density and icebergs
(Illustration Bob Moffatt)

Freezing point

The freezing point of water is also affected by the salt concentration. In fact, the presence of salt inhibits the formation of ice. The higher the salt concentration the lower the freezing point of the solution. Ice can be made colder if you throw some salt on it. However the salt does not become a part of the ice. In fact, Arctic ice can be melted to form pure water.

This means that as the ice forms in the oceans, the waters become even more concentrated, decreasing the freezing point of water even more. Salt water, therefore, does not completely freeze at a given temperature, as does pure water, so salt water has no fixed freezing point.

Viscosity

Defining viscosity

Viscosity is the resistance of a liquid flowing through or passing an object. Water is more viscous than air, just as syrup is more viscous than water.

Water is nearly 800 times denser than air and so it strongly resists movement. You can compare the viscosity of various liquids by measuring the time taken for a given volume of each liquid to flow through a very fine tube or funnel. A more viscous liquid will not flow as quickly as a less viscous one.

The hydrogen bonds influence the thickness of the water. Honey is very viscous and more difficult to pour than water.

Sea water viscosity increases in colder waters. It is therefore more difficult to swim in colder waters than in the tropics. Whales in their migration need to account for this. For example a 20°C decrease in temperature doubles the water's viscosity.

Biological significance of viscosity

Fish that need to move rapidly through sea water need to be more streamlined or *fusiform*..

These fish have an aerodynamic or cigar shape as shown by the tuna in Figure 145.2 . Fish that spend more time floating without moving tend to be buoyant and round.

Figure 145.2 Tuna need to be streamlined if they are to move quickly through water.
(Illustration Mark Moffatt)

Surface tension

Where the air meets the upper layers of liquid water, the hydrogen bonds are strong making a type of skin on the water called surface tension. This allows light animals to literally 'walk on water'. Only a few marine creatures take advantage of this including water fleas and some planktonic life forms.

Ocean pH

pH is a measure of the acidity or alkalinity of a solution. Aqueous solutions at 25 °C with a pH less than 7 are considered acidic, while those with a pH greater than 7 are considered basic (alkaline). Seawater used to be slightly alkaline - about 8.2.

Ocean acidification

Carbon dioxide emitted to the atmosphere by human activities is being absorbed by the oceans, making them more acidic.

Between 1751 and 1994 surface ocean pH is estimated to have decreased from approximately 8.179 to 8.104 (a change of -0.075)

This pH is probably lower than has been experienced for hundreds of millennia and, critically, at a rate of change probably 100 times greater than at any time over this period.

Impacts on oceans will be greater for some regions and ecosystems, and will be most severe for coral reefs and the Southern Ocean.

The impacts of **ocean acidification** on other marine organisms and ecosystems are much less certain as was discussed in Chapter 1.

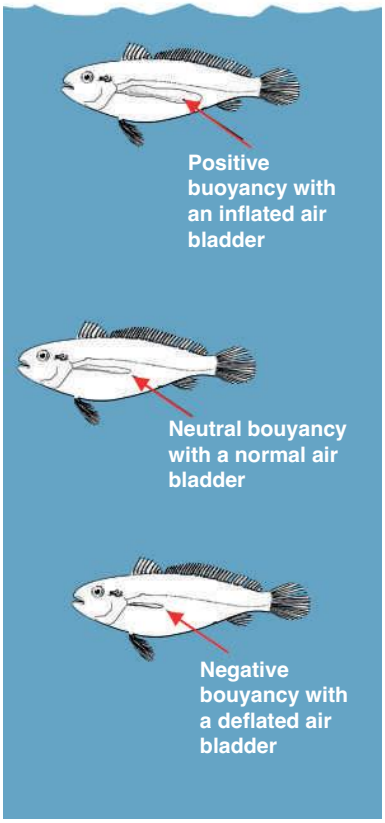


Figure 146.1 Buoyancy and upthrust in a fish with an air bladder
(Illustration Bob Moffatt)

Buoyancy

Buoyancy is the ability or tendency to float.

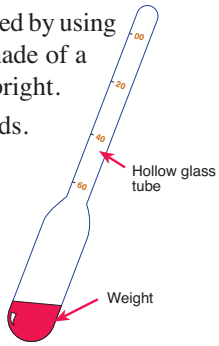
Marine organisms that have the same density as sea water tend to be neutrally buoyant; but what is the force that keeps these animals from sinking?

Measuring buoyancy

Sea water has a greater upthrust than fresh water.

This is because salt water has a greater weight than the same volume of distilled water. This can be demonstrated by using a hydrometer. A hydrometer is an instrument made of a hollow glass tube weighted at one end to float upright.

The hydrometer sinks deeper in less dense liquids.



A hydrometer
(Illustration Bob Moffatt)

Upthrust

If a fish is put into a full tank of water, the water will overflow. If we weigh that water, we find that it is equal to the volume of the fish. The mass of the water that was displaced is called the upthrust — a force acting upwards.

If the fish wants to get as deep as possible, the weight needs to be controlled. This can be done by decreasing the amount of air in its swim bladder as shown in Figure 146.1.

Figure 146.2 shows how we can also use upthrust to calculate the mass of objects. We know the density of water is 1 kg/L and the volume of water displaced by the diver is 80 L and this is the principle a famous Greek called Archimedes discovered some 2000 years ago.

So we can calculate the mass of upthrust on the diver to be 80 kg. If the upthrust is greater than the mass of the diver, the diver will float.

1 kg displaces 1 litre of water

1 kg has an upthrust of 9.8 Newtons

80kg have an upthrust of 9.8 x 80 Newtons
= 784 N (upthrust)

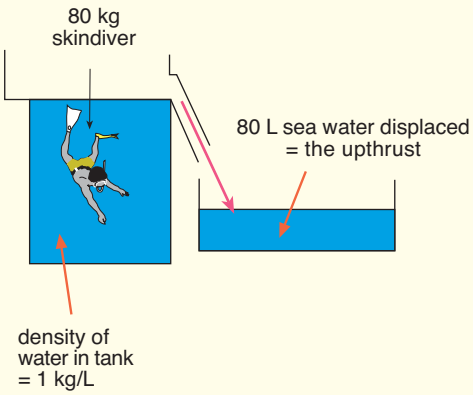


Figure 146.2 Calculation of upthrust using Archimedes principle
(Illustration Bob Moffatt)

Archimedes Principle

"An object immersed in water will displace a volume of water whose mass is equal to the upthrust".

But will it float?

Sample problem. An object has a volume of 75 L and a mass of 150 kg, when weighed in air.

a. What will the apparent mass of the object be when placed in water?

b. Will it float?

Answers

a. Volume of object = 75 L

Mass of H_2O displaced = 75 L x 1 kg/l = 75 Kg

Upthrust

Apparent mass = Mass in air - Upthrust

= 150 Kg - 75 Kg = 75 Kg

Ans: The object will appear to be half as heavy

b. The object has a mass of 150Kg. The upthrust is equal to 75 Kg. Therefore the object will sink.

If a skindiver puts on a wetsuit, the volume displaced will be greater and so will be the upthrust. The skindiver will be more buoyant.

If a skindiver puts on weights, which are small but have a high density, less water will be displaced, decreasing the upthrust and so the skindiver will sink

Worked example

A diver has a volume of 80 litres and a mass of 75 kg, when weighed in air. What will be the apparent mass when placed in water and will the person float or sink? Density of water = 1 kg/litre.

Volume of person= 80 litres, Mass of water displaced = 80 litres x 1 kg/litre = 80 Kg (UPTHRUST)

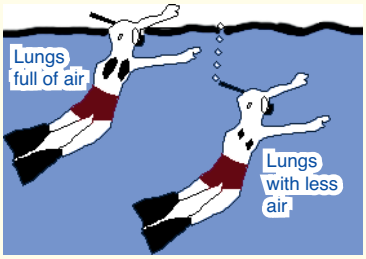
Apparent mass of diver = 75 Kg - 80 kg = -5 kg.

The diver will float because he or she weighs less in water (when the upthrust is greater than the mass of the object, the object will float).

Optional

To calculate upthrust:

= 80 x 9.8 = 784N



When you breathe in you will rise and when you breathe out you will sink because the air in your lungs adds or subtracts from the upthrust by changing the **volume** of your body.

(Illustration Bob Moffatt)

Water pressure

The pressure found in the air around the earth is called **atmospheric pressure**. The pressure in the waters of the ocean is called hydrostatic pressure.

We become aware of this pressure when we dive under the water because our ear drums are sensitive to pressure and we notice the pressure increase the deeper we dive.

These are some important facts about pressure:

- pressure increases with depth (water pressure in the bottle in Figure 147.2 is greatest at C, compared to B and A);
- pressure acts in all directions, as it does in air (see Figure 147.1);
- changing the pressure affects air spaces in the body, lungs, ears, sinuses and even in the air spaces under fillings in your teeth;
- animals that live in deep oceans need to be able to stand great pressures.

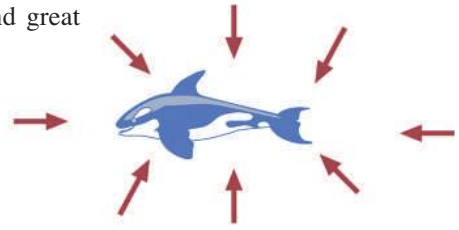


Figure 147.1 Pressure acts in all directions.
(Illustration Mark Moffatt)

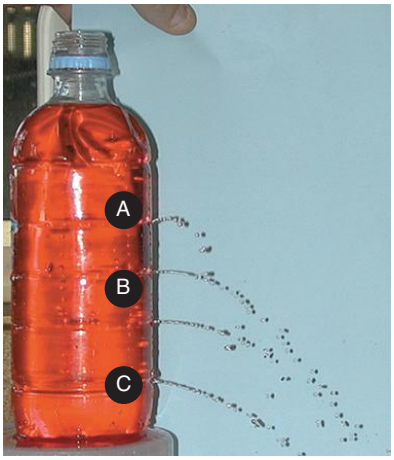


Figure 147.2 Hydrostatic pressure increases with depth.
(Photograph Bob Moffatt)

Summary of physical properties of water and biological significance

PROPERTY	BIOLOGICAL SIGNIFICANCE
Physical states Water is the only substance that occurs as a gas, liquid and solid within the temperature range found at the earth's surface.	As a gaseous (vapour) component of the atmosphere, water helps transfer heat from warm low latitudes to cold high latitudes. Liquid water runs across the continents dissolving minerals from the rocks and carrying them to the oceans. It is this form of water that accounts for over 85 per cent of the mass of most marine organisms and serves as the medium in which the chemical reactions that support life occur. Liquid water also contributes to heat transfer through ocean currents. The freezing of water into a solid (ice) during the winter season at the higher latitudes increases surface salinity and makes possible the sinking of dense surface water. This water is the only source of oxygen for the deep ocean.
Solvent property Water can dissolve more substances than any other common liquid.	Ocean water carries dissolved within it the nutrients required by marine plants and the oxygen needed by animals. It is this property that has produced the saltiness of the oceans.
Heat capacity property The quantity of heat required to change the temperature of 1 gram of a substance 1° C. Water has the highest heat capacity of all common liquids.	Heat capacity is a major factor in making water the most important moderator of climate. It accounts for the narrow range of temperature change found at any location in the ocean. Water can gain or lose a relatively great amount of heat while undergoing a much smaller temperature change than would occur in other substances. This property makes water an important insulator of life in the oceans.
Latent heat of melting The quantity of heat gained or lost per gram by a substance changing from a solid to a liquid or from a liquid to a solid without a change in temperature. The latent heat of melting for water is 80 cal, the highest of all common substances.	When ice forms, most of the heat energy lost is released to the heat-deficient atmosphere. When ice melts, the energy gained by the water is manifested as molecular energy of the liquid water. This prevents the high-latitude ocean from becoming much warmer or colder than the ocean's - 1.8°C freezing temperature.
Latent heat of vaporization The quantity of heat gained or lost per gram by a substance changing from a liquid to a gas or from a gas to a liquid without a change in temperature. The latent heat of vaporization for water is 540 calories at its boiling temperature of 100°C, the highest of all common substances. It is 585 calories at 20°C, the temperature at which much of the evaporation from the ocean surface occurs.	A great amount of excess heat energy is removed from the low-latitude ocean by evaporation and released through precipitation into the atmosphere at heat-deficient higher latitudes. This property contributes greatly to the fact that the polar regions do not get increasingly colder and the equatorial region does not get increasingly hotter.
Density Mass per unit of volume (g/cm3). Density is increased by increasing salinity and pressure and decreasing temperature. For pure water, the temperature of maximum density is 4°C.	Plankton that stay near the surface through bouyancy and frictional resistance to sinking are greatly influenced by the effect of temperature on density. In low-density warm water, plankton must be smaller or more ornate, thereby increasing the ratio of surface area to unit of body mass, in order to reduce their rate of sinking.

(from Thurman and Webber)

Exercise 6.3 Research projects

Using the sampling methods described in the next chapter on page 188, you may like to investigate a local estuary using the boating, navigating and radio skills you have learnt (Wet Paper workbooks).

Here are some working statements for you to investigate.

- Water pressure increases with depth (Figure 149.1).
- Salinity increases as you go towards the sea from the beach.
- The water is saltier nearest the shoreline at low tide.
- Pools in the crest of a reef pool are saltier than pools near the beach.
- The water one metre below the surface of the sea is saltier than at the surface.
- Water under a bommie is saltier than at the sea surface.
- As water evaporates from a pool, the salinity increases.
- The salt on trees close to the edge of the sea is greater than 100 metres inland.

Make sure you record the environmental temperature, sample site and water depth.

Use your data to calculate the density of sea water from the table below.

Set up an experiment like the one shown opposite to show that pressure increases with depth.

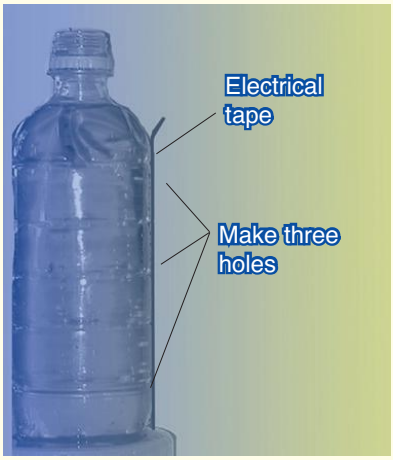


Figure 149.1
(Photograph Bob Moffatt)

Seawater density for various temperatures and salinities

		Temperature (°C)						
S (‰)		0	5	10	15	20	25	30
0	Densities	0.99987	1.00000	0.99973	0.99913	0.99813	0.99707	0.99567
5		1.00397	1.00401	1.00367	1.00301	1.00207	1.00087	0.99943
10		1.00801	1.00796	1.00756	1.00684	1.00585	1.00461	1.00314
15		1.01204	1.01191	1.01144	1.01067	1.00964	1.00836	1.00686
20		1.01606	1.01585	1.01531	1.01449	1.01341	1.01210	1.01057
25		1.02008	1.01980	1.01920	1.01832	1.01720	1.01585	1.01429
30		1.02410	1.02374	1.02308	1.02215	1.02099	1.01960	1.01801
35		1.02813	1.02770	1.02697	1.02600	1.02479	1.02337	1.02176
40		1.03216	1.03166	1.03088	1.02985	1.02860	1.02715	1.02551

Densities

Make a hydrometer

1. Sharpen two pencils to exactly the same length.
2. Now dissolve a teaspoon of salt in 100 mLs of water.
3. Place the two test tubes in the rack provided and 3/4 fill one with fresh water and the other with salt water.
4. Now place the pencils in each.
   - Can you see a difference? Which is higher?
5. Now take out one of the pencils and use a pen and ruler to mark down 0.5 cm intervals.
   - We will call this your hydrometer.
6. Fill each of the 5 test tubes with the solutions labelled 0, 10, 20, 30, and 40 grams per litre.
7. Now carefully drop the pencil into each test tube.
8. Now repeat the experiment with the other test tubes.

Questions

1. Plot a graph of the standard solution (x axis) versus the hydrometer reading (y axis).

   Describe how the graph changes.
2. What does a hydrometer measure?
3. Which is more dense, salt water or fresh water?
4. If the tide was coming into a river, would the sea water be found on the top of the fresh water or the bottom?
5. What do you think a salt water wedge is in an estuary?

Exercise 6.4 Archimedes principle experiment

Based on an original experiment by Ken Lister, Coombabah SHS.

Aim

To demonstrate the upthrust acting on a body that has been immersed in water.

Equipment and materials

- 20 N spring balance or triple beam balance.
- 1 kg mass (ideally as a cylinder of 50 mm diameter and 62 mm length)
- ruler
- large beaker (or small bucket)

Method

1. Use the 20 N spring balance to weigh the 1 kg mass in air. Note the weight of the object in air in your notebook. (approx. 9.8 N)
2. Suspend the 1 kg mass in water. Note the weight of the object in water in your notebook. (approx. 8.2 N).
3. Calculate the upthrust of the object in the water.

   Upthrust = Weight in air - weight in water

   (Approx ans. 1.6 N)

   Record the change in volume on the side of the beaker.
4. Use the ruler to find the diameter, radius and length of the cylinder.

   Diameter = 50 mm, radius = 25 mm, length = 62 mm
5. Calculate the volume of the cylinder.

   V = phi x r^2 x L (phi x radius squared x length)

   = 3.14 x 2.5 x 2.5 x 6.2 cm^3

   = 121.74 cm^3

   (Compare this with the change in volume of water in the beaker when the mass is immersed in the beaker.)
6. Hence the volume of water displaced = 121.74 cm^3

Worked example

If we know the density of water is 1 g/cm^3, find the mass of water and weight of the water displaced:

Density = Mass ÷ Volume

Mass = 1 g/cm^3 ÷ 121.74 cm^3

= 121.7 g

Mass of water displaced = 121.7 g

Weight = Mass x force of gravity (9.8N)

Weight of water displaced = 1.2 N (use W = m x g)

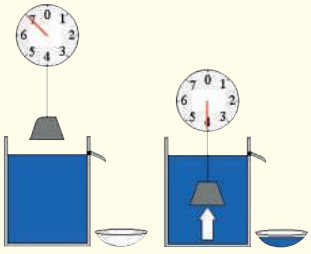


Figure 150.1 Archimedes principle
(Photo courtesy http://physics.weber.edu)

Water pressure on humans

If we have a container like a bicycle pump with a fixed amount of air and decrease the volume, the pressure increases. If you dive into a pool you notice the pressure on your ears.

Molecular motion

But how can this be explained in terms of molecules? What is the point of investigating the relationship between pressure and volume?

Pressure comes about from the molecules of a gas striking the walls of a container. It is a measure of the force with which the molecules strike a unit area of wall of the container. The molecules of a gas move about in straight lines and only change direction when they collide with the walls of the container or other molecules. Their movement ensures that they occupy the entire volume of the container.

So if the container is large (large inside surface area) and the number of gas molecules is small, then the pressure will be low. That is small numbers of molecules strike a large area of surface. Decrease the size of the container and you increase the rate at which the molecules strike the sides and so pressure increases.

SCUBA diving

The calculated values for pressure at the water surface, 10 and 20 metres are shown in Figure 151.1 and the effect on our lungs is shown is Figure 151.2.

Note that the pressure at the surface of the sea (atmospheric pressure) is = 1 atmosphere (100 kPa) and that in the first 10 metres under the water the pressure doubles.

Some examples of how pressure differences greatly affect our bodies under water are:

- cause nitrogen bubbles to come out of our blood if the pressure changes too rapidly (the bends)
- rupture our ear drums if the pressure on our ears is not compensated for when diving
- squeeze fluids in our sinuses resulting in extreme pain in our head
- release air into our body cavities

Boyle's law

This can be shown in an experiment based on Boyle's Law and is shown in Figure 152.2 on the page over.

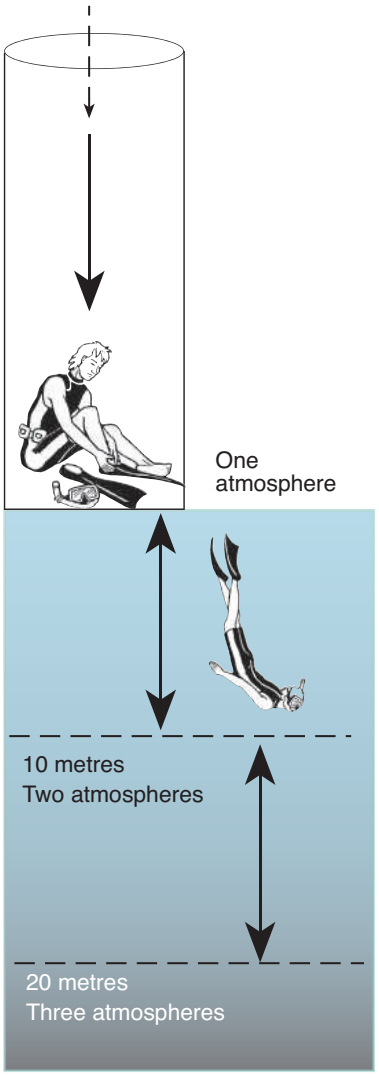


Figure 151.2 Pressure increases by 1 atmosphere for every 10 metres.
(Illustration Bob Moffatt)

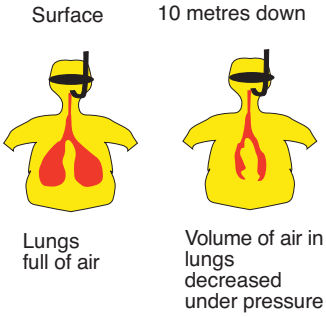


Figure 151.1 Pressure reduces the amount of air in a diver's lungs
(Illustration Bob Moffatt)

Boyle's law

Study Figure 152.1.

As the plunger is pushed in, the inside surface area is made smaller.

The pressure is seen to increase and we could expect to collect results like this.

1 Brick = 12 mls, 2 bricks = 6 mls, 3 bricks = 4 mls, 4 bricks = 3 mls

If we tabulate the results as shown in Figure 152.2 we can see that the P x V value is 12 every time

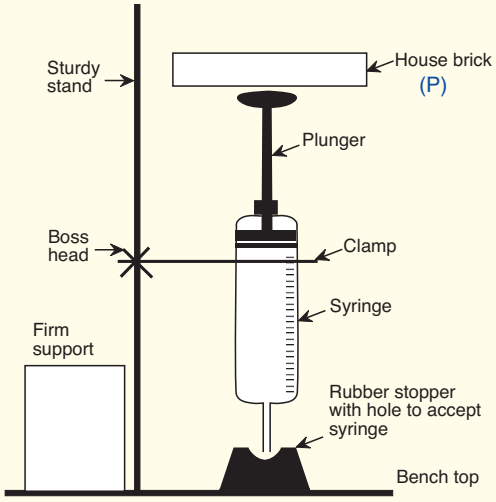


Figure 152.1 Boyle's law experimental set up
(Illustration Bob Moffatt)

Mathematical relationship

The relationship between pressure and volume can now be expressed mathematically as follows:

P x V = K (a constant value as seen in the experiment)

If K remains a constant value then we can relate these mathematically (this is what we are trying to prove by plotting PV versus P).

Because the line is straight, then PV is equal to a constant value no matter what the conditions.

So if $P_1 V_1 = K$ (a constant)

and $P_2 V_2 = K$ (the same constant in a new situation ie 2 bricks)

then $P_1 V_1 = P_2 V_2$

Worked example A

Now if we double the volume, what will be the pressure?

If $P_1 = 1$, $V_1 = 1$, $V_2 = 2$, what will $P_2 = ?$

$P_1 V_1 = P_2 V_2$

1 x 1 = ? x 2

Ans = 1/2 (the pressure has been halved)

Worked example B

If a diver has a lung volume of 4 litres at sea level calculate the volume in her lungs at 10 metres underwater?

If $P_1 = 1$, $V_1 = 4$, $V_2 = ?$, what will $P_2 = 2$

$P_1 V_1 = P_2 V_2$

1 x 4 = 2 x ?

Ans = 2 litres (the volume has been halved - Figure 152.3)

Use

The formula $P_1 V_1 = P_2 V_2$ can be used in a variety of calculations by oceanographers to calculate volumes and pressures.

Before you can enrol in a diving course you need to have your lung capacity measured by a qualified practitioner. Once you know your lung capacity you can calculate, using this Boyle's Law, how much air you will have in your lungs at 10 or even 20 metres.

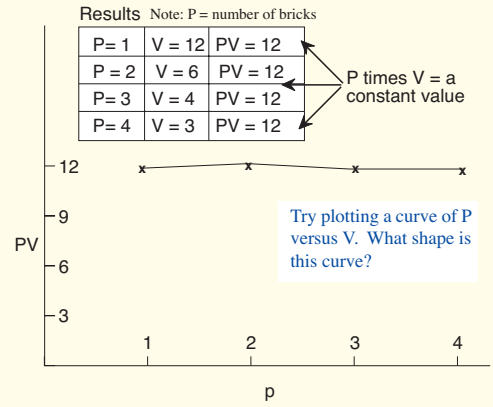


Figure 152.2 Boyle's law results
(Illustration Bob Moffatt)

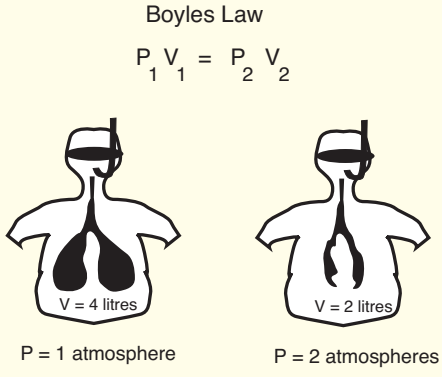


Figure 152.3 Boyle's law and lungs
(Illustration Bob Moffatt)

Light and sea water

The photic zone is the zone or depth to which light penetrates in the sea and is the zone where the plants of the sea live. A simple instrument used to measure the clarity of water is called the secchi disc (shown in Figure 153.1).

The colour of the seas

Salt water is transparent. This means it allows light to pass through it. The amount of light that penetrates the water depends on the dissolved minerals, silt and detritus material contained in it.

White light is made up of the full spectrum of colours of the rainbow. Red light is absorbed first by the water and does not penetrate as far as the blue or violet light. This is because the shorter the wavelength of light, the greater the depth it penetrates.

Since an object will be the colour of light it reflects, a red fish at a depth of 30 m will reflect no red light (see Figure 153.2). A red fish will appear black at this depth.

The colour of our seas and oceans depends on a number of factors. The two major factors are the amount of minerals and the amount of plant life in the water. Blue water indicates that the surface water contains very few minerals and so has little plant life, so it can be considered a 'desert' area.

Green sea water contains large concentrations of ions, which in turn cause an abundance of plant growth, which in turn attracts large numbers of animals.

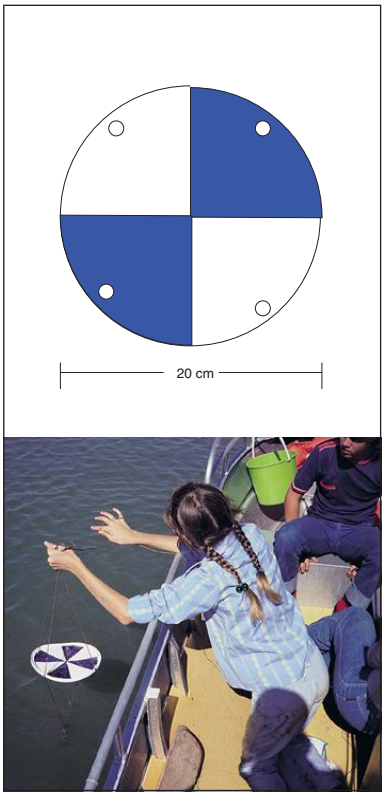
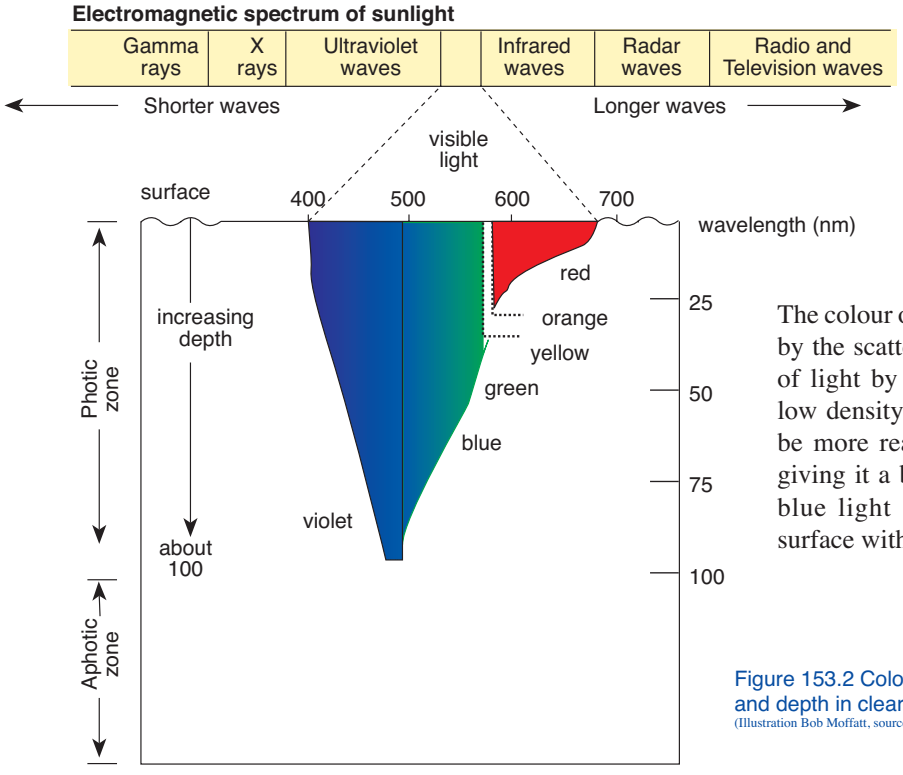


Figure 153.1 Secchi disc
(Illustration Bob Moffatt, photograph David Kopelke)



The colour of the water is caused by the scattering and absorption of light by the water. Water of low density causes blue light to be more readily scattered, thus giving it a blue colour because blue light arrives back at the surface without being absorbed.

Figure 153.2 Colour of light penetration and depth in clear sea water
(Illustration Bob Moffatt, source An introduction to marine studies)

Temperature and sea water

Ocean surface temperatures vary from 28°C in the tropics to below zero at the poles. Figure 154.1A shows the surface temperatures in the Pacific Ocean. Figure 154.1B shows the temperatures of the Pacific depths (photographs courtesy NOOA).

The ocean surface can be heated by radiation from the sun, conduction of heat from the atmosphere or condensation of water vapour. The sea surface can be cooled by radiation back from the sea to the atmosphere, conduction of heat back to the atmosphere or evaporation.

Ocean currents can also transfer heat from one place to another.

Colour references

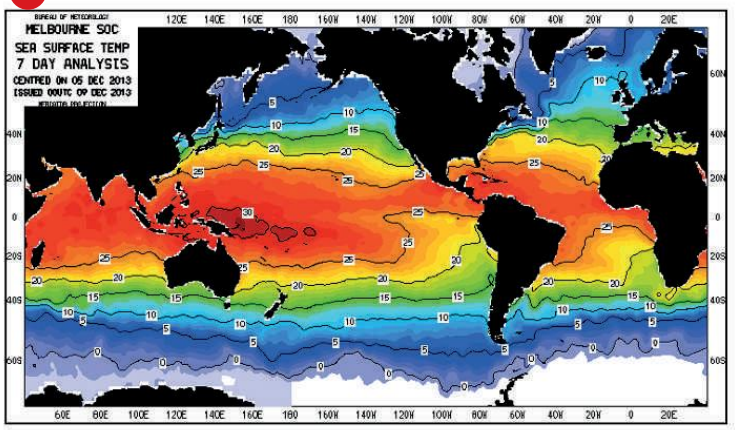
Try the following words in your search engine:
Pacific Ocean surface sea temperature

Biological significance of temperature

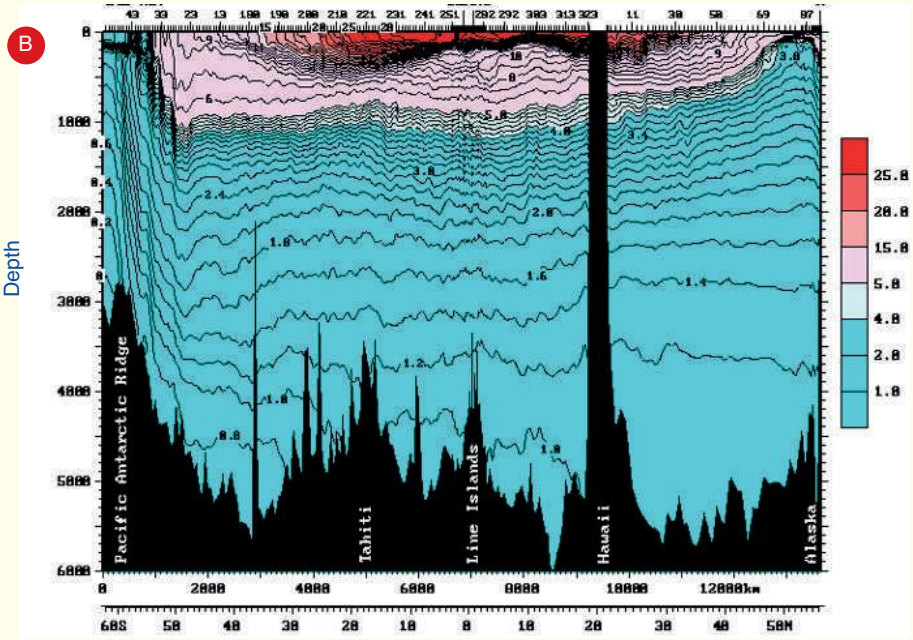
Animal migrations occur due to temperature. Whales migrate to warmer waters to calf. Corals spawn at certain temperatures and the composition and texture of marine animals and plants is governed by temperature. Animals that live on the rocky shore also develop protective coverings to compensate for temperature changes.

In recent times, coral bleaching (see Chapter 11) has been blamed on increased temperature changes.

A



B



Can you see the thermocline? See chapter 3 for more information on temperatures and currents.

Figure 154.1 Pacific Ocean potential temperatures

(Illustration A courtesy Commonwealth bureau of meteorology Illustration B courtesy NOOA)

Sea water and aquaculture

Inorganic substances

Nothing will live in pure water. Photosynthetic plants (the major autotrophic organisms) will not grow unless they have access to carbon dioxide particular mineral ions and sunlight, as well as water. All organisms require oxygen for respiration (Figure 155.1). Therefore water used in aquaculture, whether fresh or salt, must be a solution containing adequate concentrations of certain substances.

Sea water provides an abundance of mineral ions for the organisms which live in it. However, this is not always true of freshwater. Crustaceans and molluscs both require moderate levels of calcium for normal growth, for example. Carbon dioxide is very soluble in water and is not normally in short supply to photosynthesing plants. On the other hand, oxygen is only slightly soluble in water and often limits the distribution of animals. The total amount of oxygen able to be dissolved in water varies with temperature and salinity (Figure 155.3). More oxygen will dissolve in cold water than warm water. Increasing salinity reduces the amount of oxygen water can hold for a particular temperature. Therefore warm, saltwater is unable to hold as much oxygen as cold fresh water. Cold freshwater, saturated with oxygen at 1^0C. holds 25.73 mg/L whereas, hot sea water at 30^0C can only hold about 11.18 mg/L.

The oxygen levels indicated in Figure 155.3 are the maximum values possible. In many aquaculture situations oxygen levels are well below these 100% saturation figures.

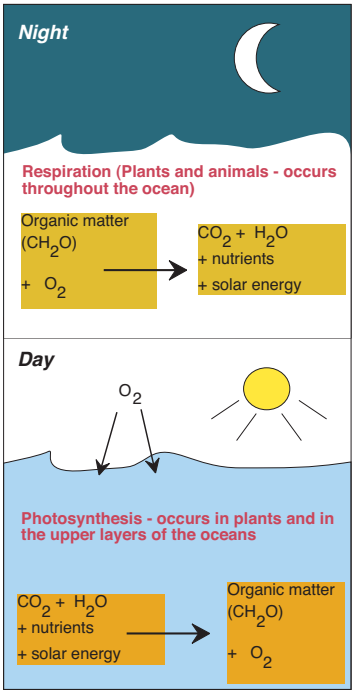


Figure 155.1 Respiration and photosynthesis
(Illustration Bob Moffatt)

Figure 155.2 Oxygen dissolves naturally in water from turbulence
(Photograph Bob Moffatt)

Cold freshwater *Cold saltwater*

Salinity (g/L)	Dissolved oxygen (mg/L)										
Temp	0	2	4	6	8	10	12	14	16	18	20
1	25.73	25.06	24.46	23.88	23.32	22.74	22.20	21.66	21.14	20.63	20.14
2	25.00	24.39	23.81	23.27	22.69	22.15	21.64	21.12	20.59	20.11	19.62
3	24.30	23.74	23.20	22.67	22.13	21.61	21.10	20.58	20.09	19.60	19.13
4	23.65	23.11	22.60	22.08	21.55	21.05	20.56	20.05	19.56	19.13	18.68
5	23.03	22.49	22.00	21.52	21.01	20.52	20.03	19.56	19.10	18.66	18.25
6	22.47	21.95	21.43	20.96	20.47	20.00	19.55	19.08	18.64	18.23	17.81
7	21.91	21.41	20.92	20.45	19.98	19.55	19.08	18.64	18.19	17.78	17.40
8	21.41	20.88	20.40	19.96	19.51	19.08	18.64	18.19	17.78	17.36	16.98
9	20.88	20.40	19.91	19.46	19.04	18.61	18.19	17.78	17.36	16.98	16.62
10	20.40	19.93	19.46	19.02	18.61	18.19	17.78	17.36	16.98	16.62	16.26
11	19.96	19.46	19.02	18.59	18.19	17.78	17.40	17.00	16.62	16.26	15.90
12	19.51	19.02	18.59	18.17	17.78	17.40	17.00	16.64	16.26	15.90	15.55
13	19.08	18.61	18.19	17.78	17.40	17.00	16.64	16.28	15.92	15.55	15.21
14	18.66	18.19	17.81	17.40	17.00	16.64	16.28	15.92	15.57	15.25	14.90
15	18.25	17.81	17.42	17.04	16.67	16.31	15.95	15.61	15.25	14.94	14.61
16	17.87	17.45	17.05	16.69	16.31	15.97	15.61	15.30	14.96	14.65	14.34
17	17.47	17.09	16.73	16.35	15.99	15.63	15.30	14.99	14.65	14.34	14.05
18	17.11	16.75	16.39	16.02	15.66	15.32	15.01	14.71	14.40	14.07	13.80
19	16.76	16.40	16.04	15.68	15.36	15.01	14.72	14.42	14.24	13.82	13.53
20	16.46	16.08	15.72	15.37	15.03	14.72	14.43	14.16	13.84	13.57	13.30
21	16.13	15.75	15.43	15.08	14.76	14.43	14.16	13.89	13.59	13.33	13.06
22	15.81	15.45	15.14	14.80	14.49	14.18	13.89	13.62	13.35	13.10	12.84
23	15.54	15.18	14.85	14.52	14.22	13.93	13.64	13.39	13.12	12.86	12.63
24	15.25	14.90	14.58	14.25	13.95	13.66	13.40	13.15	12.88	12.63	12.39
25	14.94	14.61	14.31	14.00	13.69	13.44	13.17	12.92	12.66	12.43	12.19
26	14.67	14.34	14.05	13.77	13.46	13.21	12.93	12.70	12.45	12.21	11.98
27	14.42	14.07	13.80	13.53	13.22	12.97	12.70	12.48	12.25	12.01	11.78
28	14.16	13.82	13.57	13.30	12.99	12.75	12.50	12.27	12.03	11.80	11.56
29	13.89	13.59	13.33	13.06	12.79	12.56	12.32	12.07	11.83	11.60	11.36
30	13.66	13.35	13.10	12.86	12.57	12.34	12.10	11.89	11.65	11.42	11.18

Hot freshwater *Hot saltwater*

Figure 155.3 Cold freshwater holds more oxygen than hot freshwater
(After Dave Mason, 1992 Marine Studies for Senior Students)

Question

Look at table 155.3. How much oxygen is in hot fresh water?

Eutrophic
A body of water that is rich in nutrients but periodically depleted in oxygen. The condition is often associated with polluted embayments.

Eutrophication
Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (eg phytoplankton).

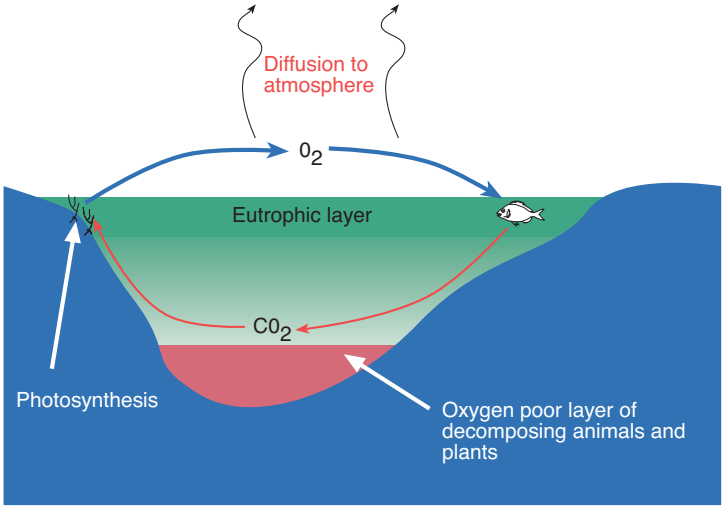


Figure 156.1 Eutropic layer in a pond
(Illustration Bob Moffatt)

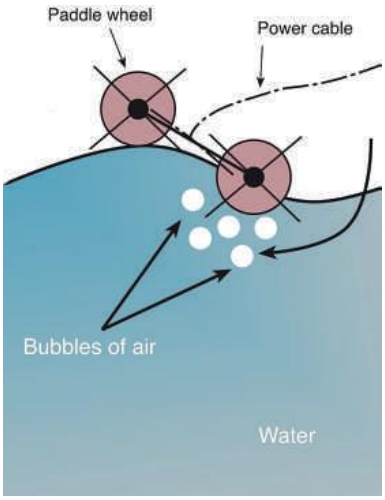


Figure 156.2 Paddle wheel aeration
(Illustration Bob Moffatt)

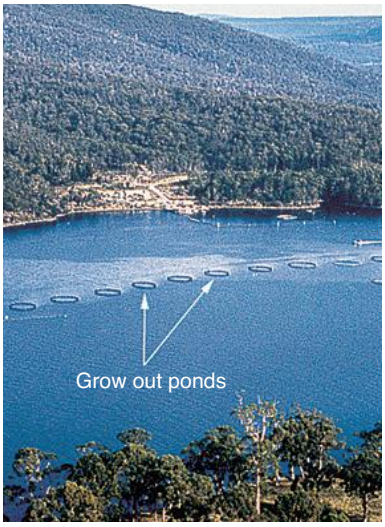


Figure 156.3 Grow out ponds Tasmania
(Photograph Tassal)

To help visualise the causes of low oxygen levels in water bodies, let us consider a pond rich in both plants and animals for a moment as shown in Figure 156.1.

During the day the plants photosynthesise releasing oxygen into the water. A significant amount of this oxygen escapes into the atmosphere. The remainder is dissolved in the water and is available for respiration. As night descends photosynthesis stops and the plants actually take oxygen from the water for respiration. Fish, crustaceans, molluscs and other animals as well as fungi and bacteria also place demands on the available oxygen.

Animals are less tolerant of low oxygen levels than the other organisms and will die if the oxygen concentration falls too far. This is most likely to occur if there is a lot of decomposing organic matter.

Aquaculture systems

In natural systems as shown in Figure 155.2, increased nutrients quickly dissolve as waves and tides dilute their concentrations.

However in an aquaculture system there is usually a much larger number of animals per unit volume of water than there is in a pond. These are growing rapidly and are continually releasing metabolic wastes into the surrounding water.

The metabolic wastes, dead animals and uneaten food are consumed by bacteria and fungi. Therefore it is essential to aerate the water so that the demand for oxygen can be met . This is done by spraying water into the air, bubbling air through water or box aeration (Figure 156.2).

Aquaculturalists are attempting reduce the effects of depleted oxygen by growing fish in growout ponds which can hold up to 5000 fish, as shown in Figure 156.3. Problems arise when the number of ponds exceeds the carrying capacity of the estuary with large amounts of algae growing killing local seagrass beds.

Temperature

Temperature has a significant effect on aquaculture production. Each species has a particular temperature range for optimal growth. The optimal temperature for the freshwater crayfish, *Cherax quadricarinatus*, is between 24^{0}C and 28^{0}C . Above or below these temperatures, growth rates are reduced as shown in Figure 157.1.

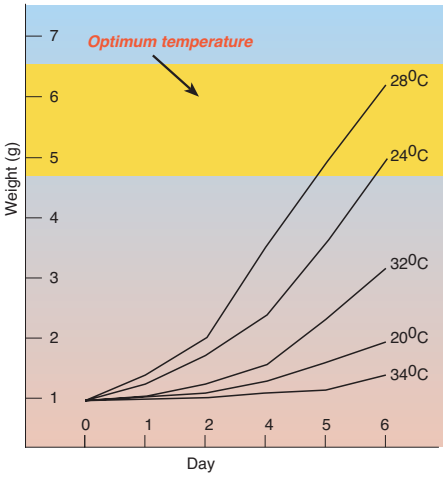


Figure 157.1 Temperature growth and crayfish
)Illustration Bob Moffatt, after Dave Mason 1992)

pH and aquaculture

pH is a measure of the degree of acidity or alkalinity of a substance on a 1 to 14 scale. One to 6 is acidic, 7 is neutral and 8 to 14 is alkaline. Factors affecting pH in aquatic systems are many and complex. Useful organisms may have different pH requirements. For example, phytoplankton in freshwater grow best when the pH is about 7 whereas zooplankton favour a slightly alkaline environment. Overall, the most desirable pH is 7 to 7.5.

Nitrate buildup (resulting from the decomposition of animal wastes and other organic matter) can acidify the water. This can be corrected by adding crushed limestone or coral or, exchanging the water.

Waste products

Fish excrete ammonia through their gills. Ammonia is soluble in water and toxic to fish in high concentrations. The decomposition of uneaten food and faeces also releases ammonia as well as a number of less important toxins. In natural waterways such as oceans, lakes and rivers there are relatively few fish in a large volume of water.

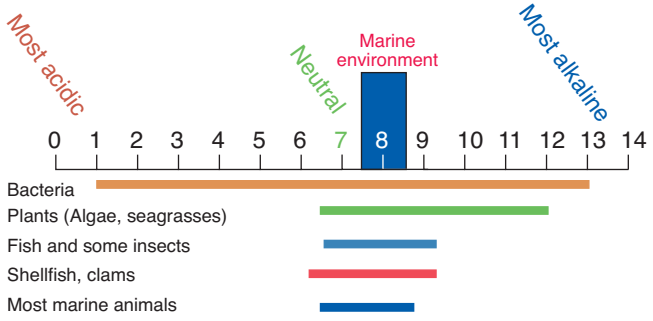


Figure 157.2 Tolerance of marine organisms to pH
(Illustration Bob Moffatt)

Under these conditions the ammonia is too dilute to affect the animals. In contrast, there are normally large concentrations of fish in small volumes of water in culture situations.

Therefore the build up of ammonia can become a serious problem in closed systems (ie where the water is recycled). An efficient filtration system such as passing well aerated water through a gravel bed (a biological filter) is one technique for removing the ammonia.

One drawback of this system is that nitrates tend to accumulate in the water. This is not a significant problem in the short term as nitrates are not very toxic to most aquatic animals. Eventually the nitrates have to be removed. This is normally done through water exchange.

Plants of various types can also be used to soak up the nitrates.

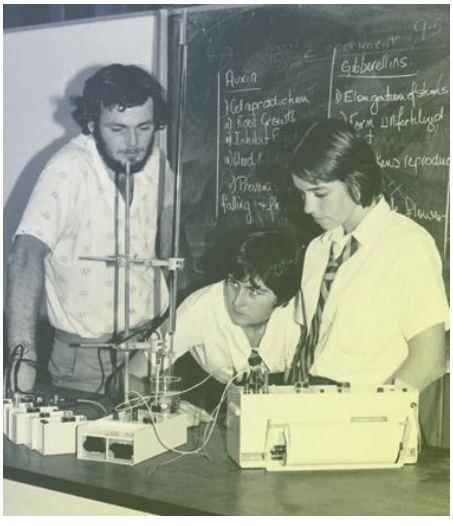


Figure 157.3 Measuring changes in pH
(Photo Bob Moffatt)

Exercises

From the Wet Paper Publication - *Oceanography Exercises See www.wetpaper.com.au*

C2. How much salt is in seawater?

C3. Can we make and establish a test for seawater?

C4. Can we determine how much oxygen there is in seawater?

Questions

Knowledge

1. Explain the meaning of the following terms:

   polar covalent water molecules, hydrogen bonding, surface tension, viscosity, density, heat capacity, salinity, evaporation, diffusion, photosynthesis, aerobic organisms, autotrophic nutrition, temperature gradient, metabolic rate, spectrum, pH, photic zone.

2. What is the formula for salt?

Understanding

3. Write the formula for photosynthesis in your own words.
4. What differences exist between the salinity at the poles compared to that of the equator? Compare also the salinities at the surface with that at 4,000 metres.
5. Draw a diagram of a water molecule to show the polar covalent bonding. What special properties does this bonding give water?
6. Write a definition for latent heat.
7. Distinguish between the biological significance of the latent heat of vaporization and melting.

Applying

8. Calculate the number of drops that would be needed to reach the end point of a silver nitrate titration on fresh water.
9. Plan an experiment to show that the density of water is higher at the bottom of an estuary compared to the surface waters.
10. Draw a diagram to show how you could measure pressure with a syringe and a house brick.
11. Examine Figure 153.2 on page 153, and explain why a coral trout appeared black when it was speared but red when it was brought out of the water.

Analysing

12. Analyse Figure 154.1 and provide evidence to support the hypothesis that water temperature decreases with depth. Justify your answer with temperature data.
13. In the experiment on Boyle's Law, are there any other possible outcomes than those described? If so, list at least one; if not say why.
14. Construct a graph to illustrate the relationship between water temperature and longitude (see page 154, Figure 154.1A).

Questions 15 and 16 refer to the table on Page 155.

15. How much oxygen can dissolve in a brackish water estuary of salinity 15.68 and temperature 19 degrees?
16. The water temperature of a mangrove swamp is 21 degrees and salinity of 15.75. Could fish survive in the swamp? Give a reason for your answer.

Creating

17. In Exercise 6.1 you worked out how to determine the salinity of a sea water sample. Can you propose how you could improve this experiment?
18. Create a powerpoint presentation to show a group of new students how to perform Boyle's Law.
19. Read about Archimedes and write a short play on how he solved the King's problem of the solid gold crown. Avoid displays of nudity as they may offend!
20. Construct a model of a salt molecule.

Evaluating

21. Assess the problem of eutrophism (page 156) and choose a better solution to paddle wheel aeration.
22. Do you believe that dilution is the solution to pollution? Justify.
23. How ineffective are secchi disks in the measurement of light penetration in sea water?
24. What is the most valuable physical property of sea water?
25. Prepare a list of equipment to be used by a marine scientist to judge if the salinity of a river changes over 24 hours.

Research projects

1. Find out about the electro-chemical series and explain how sacrificial anodes work on a boat with steel hull.
2. Explain how rust occurs using chemical equations.
3. Research modern materials that are used in marine industries to prevent corrosion.
4. Find out what osmosis is and how it affects boats.
5. The use of antifouling chemical is now carefully controlled. Find out what these strict controls are and the problems they are creating for marina operators.
6. Find out what research is currently being done by the CSIRO research vessel *Southern Surveyor.*
7. Find out about the effect ocean acidification will have on marine life.

Chapter 7
Marine pollution

By
Tim Ryan and Bob Moffatt

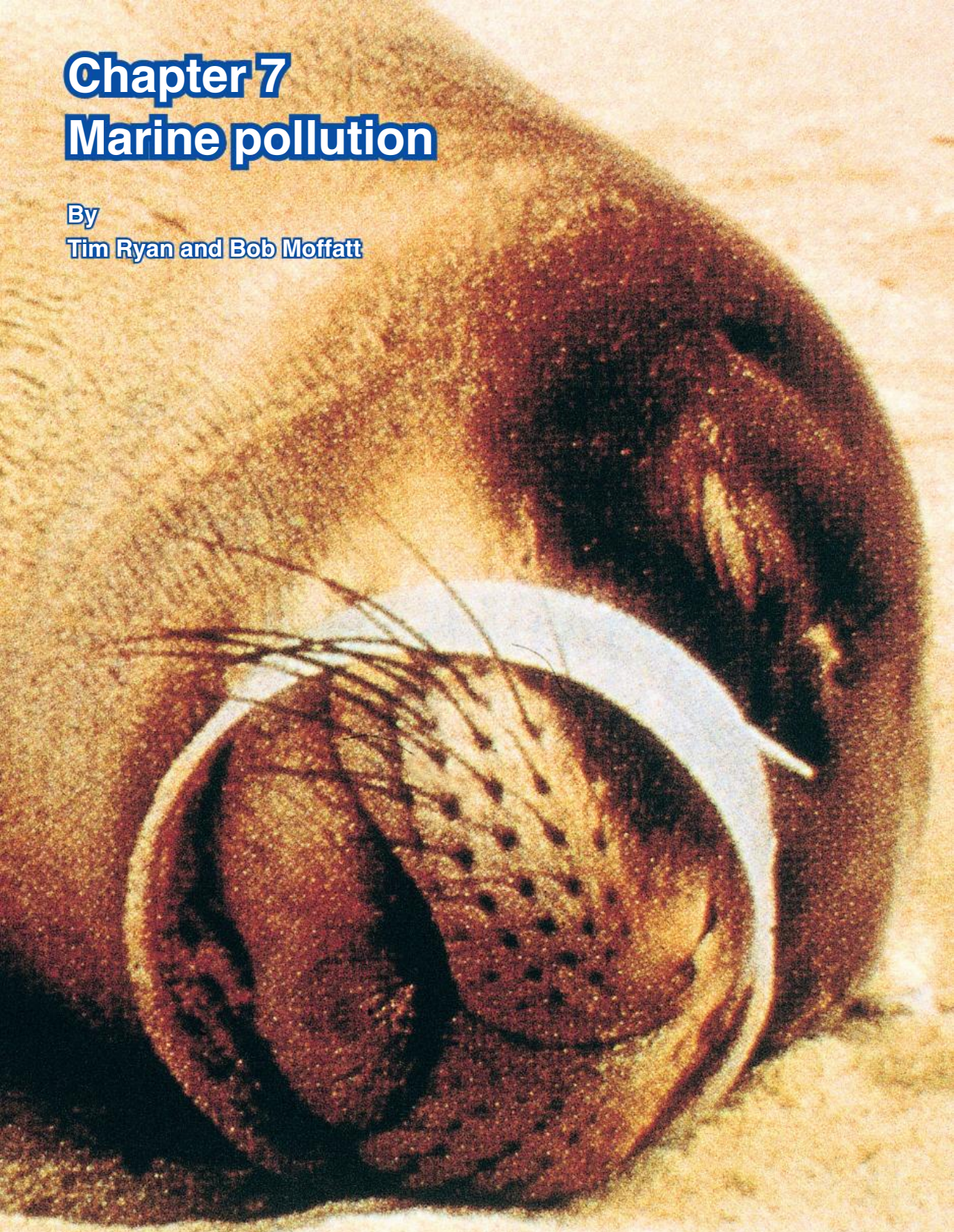


Illustration courtesy EPA Victoria.

Introducing the chapter

Chapter hooks

- Play the fatal food relay game (see oceanography exercises book Ex. C5) where the class is divided into two teams of dolphins each having to run to the end of the room to get food from a box.

  In the box are pieces of good and bad food - octopus, mullet, crabs, bream, cuttlefish (good food) and fishing line, oil, net, plastic bags, cans and cartons (bad food).

  If the team member gets the good food they stay alive, but if they get the bad food they moan and groan and die. Keep playing till everyone dies then have a discussion about the effects of pollution on marine life.
- Conduct a beach clean up classifying the types of litter collected according to the SOMER 1996 report Chapter 46 and discuss the biodegradability of each litter type.
- Discuss the statement "When the last tree is cut, the last river poisoned, and the last fish dead, we will discover that we can't eat money".

Why study this chapter

For too long the statement *the solution to pollution is dilution* has been employed by many people. The trouble was that seawater was used as the dilution and everything from heavy metals to household wastewater was emptied into the sea. In 1990 most city and town sewerage systems emptied raw or partially treated sewage in to the sea. It was the efforts of environmental activists like the Surfrider Foundation that resulted in change. In 1996 our first SOMER or State of the Marine Environment Report was released. Marine pollution has the potential to ruin our world. You need to understand how and more importantly what to do and what not to do!

Chapter overview

The need for management and conservation 161

Types of pollution 162

Case study 7.1 Sydney's beaches.....171

Exercise 7.1 Chemical tests 174

Exercise 7.2 Testing for dissolved oxygen.....178

Environmental tolerance of organisms 180

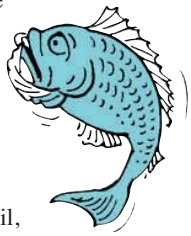
Methods used to combat pollution.....180

Exercise 7.3 Sampling methods 188

Exercise 7.4 Removal of oil from water 189

Exercises and questions 190

Key concepts



1. Our western culture has created an environmental problem because much of what is thrown away ends up in stormwater drains and then in the sea.
2. Human and domestic wastes tends to contribute to sewage and litter pollution.
3. Industry tends to contributes to oil, heavy metal and toxic chemical pollution.
4. Agriculture contributes to sediment and nutrient overload on our estuaries and oceans.
5. Land clearing for domestic, industrial and agricultural development contributes significantly to acid sulfate soils.
6. Technology for the analysis of heavy metal pollution detection is just becoming available to scientists who are frustrated by the lack of attention placed on this type of pollution.
7. A determination of the biological effect of a chemical using living organisms as indicators is termed a bio-assay.
8. Four steps to combat pollution include assessment, locating the cause, fixing the problem and education.
9. Some chemical tests that can be used by community groups in water quality monitoring include temperature differences, pH, dissolved oxygen, faecal coliform, phosphorous, nitrates, dissolved solids and turbidity.
10. Most environmental legislation now prohibits the discharge of any chemical into the environment.
11. Public interest and education in the environment will give greater emphasis into issues of sustainability and protection.
12. Environmental activism is necessary to keep environmental issues in the public eye so politicians can make laws to protect our environment.
13. Simple sampling equipment that can be made at school like water sampler bottles and plankton nets can be used to measure pollution.

Note

Chapters 17 and 18 also discuss many of the issues raised here from a management perspective.

The need for management and conservation

Today western civilizations live in a 'throw-away' society. Most of the goods we buy have specialised packaging which cannot be re-used.

Many items we buy are used once and then disposed of, such as disposable nappies and paper tissues. Manufacturers now even make disposable cameras and disposable contact lenses.

Many manufacturers are only interested in making cheap goods, which have a short life. Other manufacturers are running advertising campaigns telling us our old models are inadequate or obsolete and that we need to purchase their new improved model. But what are we going to do with our old model?

The answer - it becomes trash or gets recycled.

Our waterways are a wonderful resource to have at our disposal, but we tend to turn the inland waters into inland sewage or drainage systems and the estuaries into convenient dumpsites for a wide variety of harmful materials. Most of the waterways near our cities and ports are showing evidence of contamination.

The introduction of harmful waste substances into a natural area is termed pollution. The United Nations Organisation has defined pollution of the marine environment as: *the introduction by humans, directly or indirectly, of substances or energy into the marine environment resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of the quality of sea water and reduction of amenities*.

In many places around the world, most of the pollution occurs in coastal and estuarine waters because these are the sites of most major cities and where over 70 per cent of the population lives. Consequently, most of the waste materials and substances are released here and this area is more polluted than the open ocean.

Potential pollutants of coastal zone

Technology

Increased waste production has come with increased technology. Many wastes we produce today are full of chemical and toxic substances. Each person in our country is responsible for one tonne of rubbish each year.

The amount of garbage that a developed country throws out in a year has been estimated to contain -

- 400,000 tonnes of metal
- 600,000 tonnes of plastics
- 1,000,000 tonnes of paper (which represents 10 million trees)
- 700,000 tonnes of glass, mostly in the form of drink bottles.

Figure 161.1 Pollution trap
(Photo AMSA)

Figure 161.2 Dead fish
(Photo Tim Ryan)

Figure 161.3 Seal entangled in fishing line
(Photo Greenpeace)

Odd fact

It has been estimated that the deep sea may contain as many as 10 million species that have not yet been described or named (Grassle and Maciolek, 1992).

Figure 162.1 Bird entangled in fishing line (Photo Greenpeace)

Figure 162.2 Turtle entangled in fishing line (Photo CALM)

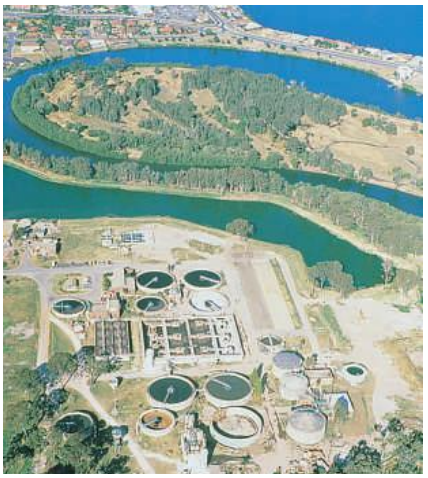


Figure 162.3 Sewerage treatment plant (Photo GCCC)

Most of these wastes are dumped in landfills around our major cities, although some finds its way into our waterways. Many landfill sites were originally unique estuarine mangrove communities located near cities that bordered coastal communities. These communities have been permanently destroyed to make way for the disposal of household waste. Many plants and animals that were once found in these areas are now becoming endangered species.

Another major problem is that technological wastes affect local fauna. Seals and turtles eat plastic bags in mistake for jellyfish. They choke on the plastic bags and eventually die. An autopsy on a sperm whale revealed more than 40 plastic bags stuck in its throat. The pelican in Figure 162.1 has tried to build a nest out of twigs trashed with fishing line. Its own nest has choked the bird. The fishing crews cut fishing nets that get tangled and let them drift in the oceans. These nets entangle turtles and seals. The end result is the collar of death shown in Figure 161.3.

There is therefore a definite need for a well managed system to save our western society from the ravages of pollution.

Types of pollution

Human and domestic wastes

Organic wastes such as animal and human excreta can become a major pollution problem. These organic materials do not constitute a problem in small quantities as they decay reasonably quickly, but the concentrations of organic wastes in waters draining large cities often reach levels which may be a threat to public health or the fish of the area. The organic wastes take longer to break down and become an unhealthy and unsightly problem.

Heavy pollution in Sydney created by an inadequate municipal system has caused many pollution problems to beaches such as Bondi and North Head.

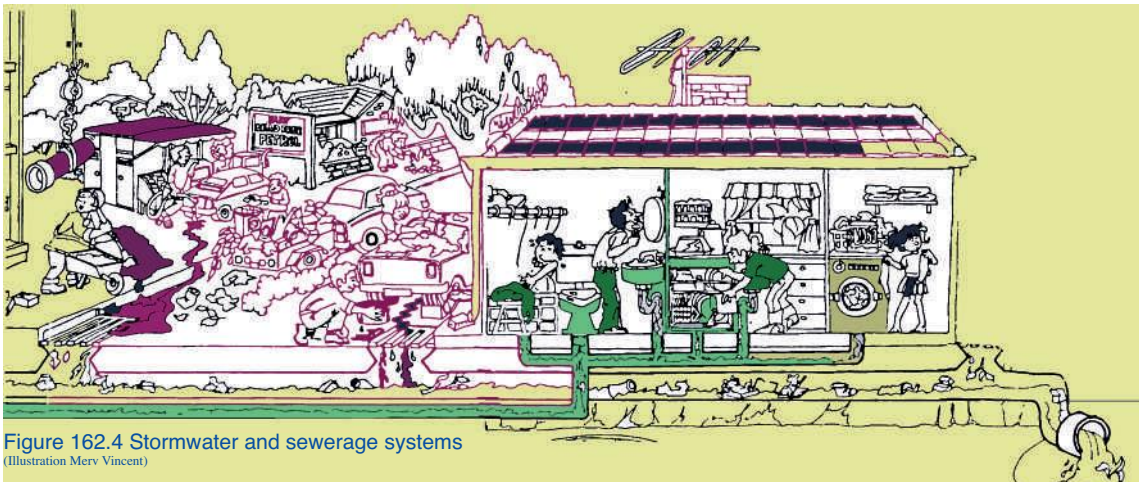


Figure 162.4 Stormwater and sewerage systems (Illustration Merv Vincent)

In nature micro-organisms such as bacteria decompose the organic material. These materials are said to be **biodegradable**.

The bacteria convert the complex organic substances into simpler compounds, but in the process use up oxygen. The large numbers of bacteria use up large amounts of oxygen that other animals such as fish may require. The amount of dissolved oxygen in the water is unable to meet the **biological oxygen demand** (BOD) of the other animals living in the water.

These wastes may also contain harmful microorganisms such as bacteria and viruses that cause diseases such as typhoid, amoebic dysentery, hepatitis and cholera. The micro-organisms that cause these diseases are called **pathogenic micro-organisms** or simply **pathogens**. Eating shellfish containing pathogens have caused typhoid and hepatitis. These shellfish have come from areas that have high faecal contamination.

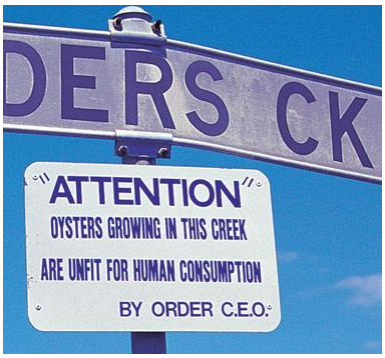


Figure 163.1 Pollution sign
(Photo Bob Moffatt)

Thermal pollution

Many industries have heavy machinery, which generate large amounts of heat. Industries such as steel manufacture and electricity-generating plants use large volumes of water as coolants. This causes thermal pollution of many streams and rivers by raising their temperatures by up to 10oC. This, of course, will have a major effect on the natural communities and the individuals living in these areas.

The behaviour patterns of many aquatic animals are influenced by water temperature. This temperature is the stimulus for many fish to spawn and migrate. Fish, being "cold blooded" animals, become more active in warm water, thereby affecting their growth rates.

Figure 163.2 Chemicals in stormwater
(Photo Qld Fisheries)

Toxic compounds

Worldwide, over 25 million tonnes of manufactured compounds are produced annually. Most of these eventually find their way into the marine environment. The chemicals that cause most concern are the non-biodegradable toxic compounds.

A **toxic compound** is defined as a substance that by its chemical action, can kill, injure or impair the functioning of an animal. These compounds are also dangerous to humans and must be handled with care.

In some areas, the levels of mercury in local fish species have been shown to be very high.

Some of these fish samples were also shown to contain selenium, arsenic, copper and zinc. Many other toxic compounds are produced in the manufacturing industries and most have no effective method of disposal. Highly toxic industrial wastes in Buenos Aires have contaminated their water supply and even closed some beaches.

Food processing industries

In the past many of the food processing industries released large amounts of organic material into the oceans eg abattoirs release blood and offal into their nearest river system. Modern environmental laws now prevent this from happening.

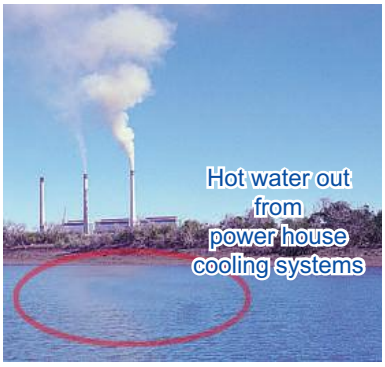


Figure 163.3 Thermal pollution
(The powerhouse uses water to make steam - Photo Bob Moffatt)

(Illustration Tim Ryan)

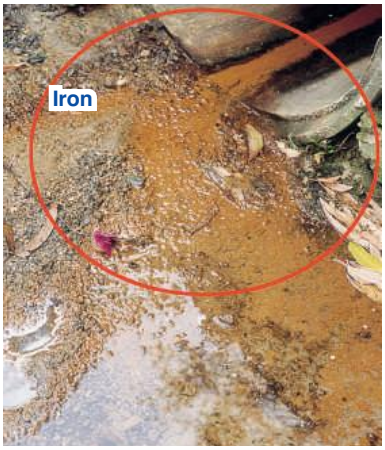


Figure 164.1 Stormwater and iron
(Photo Bob Moffatt)

Figure 164.2 Penguin and oil
(Photo AMSA)

Figure 164.3 Oil in stormwater drain
(Photo Bob Moffatt)

Figure 164.4 Oil wells in California
(Photo Bob Moffatt)

Acids

Steel rusts or corrodes in air and must be treated if it is to last for any period of time. The main method of stopping this corrosion is by coating the metal with paint. Before the metal can be painted it must be cleaned, usually with acids. The metal needs to be washed free of acid before painting. In the past these acids along with the acid baths themselves were flushed into the streams. Serious fines now apply to industries that pollute rivers and streams.

Oil pollution

Oil pollution poses a major threat to the marine environment. The sources of this pollution are industry, workshops, spillages from oil rigs and oil refineries, discharges from ships, and tanker accidents. Industry is the major source of oil pollution. Oil spillages from tankers only represent 4 per cent of the total oil pollution of the oceans.

Motor vehicle repair workshops are often sources of polluting oil that has been degreased from engines or spilled on the ground. Rain washes this oil down into the sea through the storm water pipes shown in Figure164.3. When oil spills, it spreads over the ocean's surface forming a thin layer called a **slick**. After a major oil spill, a massive area of the sea becomes covered with oil. One litre of oil can form an oil slick covering 8,000 m. This has a catastrophic effect on any coastline the slick impacts on.

The oil smothers coral reefs and mangroves. Shellfish, such as oysters and mussels, become inedible and whole fisheries may be wiped out. Animals that live on the surface, such as birds and seals, become coated with oil and die. Oil covers seabirds when they land on the surface and their feathers lose their waterproofing capacities. When the birds try to preen their feathers, they ingest the oil and die. They also die as a result of **hypothermia** (loss of body heat) because the insulating air layer around the body is lost when the oil slicks the feathers flat.

Nutrients and eutrophication

Agriculture

Deforestation

The clearing of large areas of land of their natural vegetation has increased the erosion due to water run-off. The natural vegetation in the area would have held the soil in place. The increase in ploughing and the planting of crops such as wheat, corn and sugar cane (which do not have extensive root systems) has also caused more erosion. Poor farm management in the form of over-grazing by cattle and sheep has also contributed to this problem.

The silt has an effect on structures of certain animals, such as the gills of fish. The build-up of sediments on the riverbed also limits the breeding of certain species of fish such as the catfish that builds its nest on the gravelly bottom.

This huge increase in the amounts of aquatic plants can clog up streams and rivers and deplete oxygen supplies (see Chapter 6 pages 155 - 157).

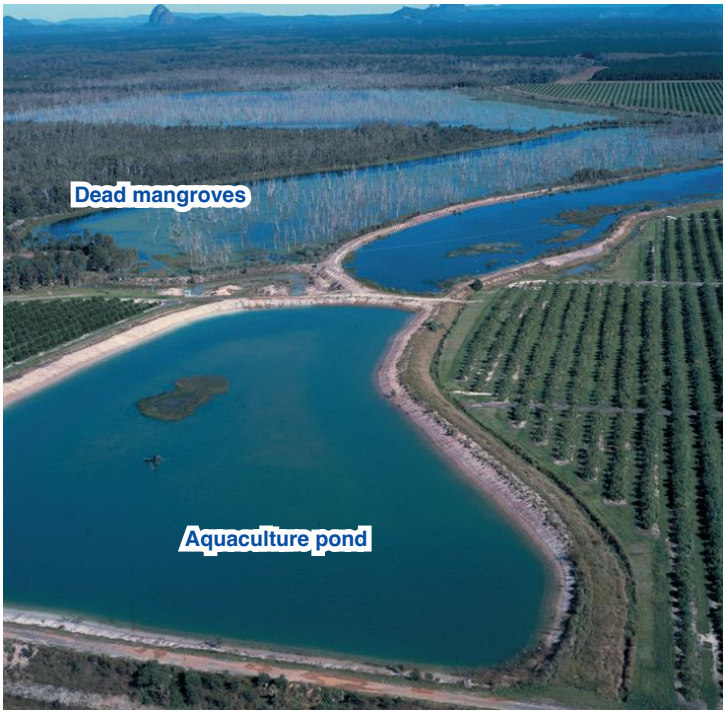


Figure 165.1 Impacts of farmland on mangroves and intertidal wetlands
(Photo Qld Transport)

Fertilizers

Most farmers, in their effort to increase production, add extra nutrients to the soil. Fertilisers such as phosphates and nitrates are washed by the rain into rivers. The nitrates and phosphates, when present in very high concentrations, cause population explosions of algae and other phytoplankton. This excessive growth of algae in the water causes the water to taste unpleasant and poisons fish with their wastes. This increase in the amounts of aquatic plants can clog up streams and rivers.

When these algae die, the bacteria that break them down use up the dissolved oxygen that is so necessary for other animal life. The process by which the waterway becomes enriched with nutrients so that it can no longer support life because of the oxygen depletion is termed **eutrophication**. The growth of red algae and other algae off Japan has choked much of the marine life found on its shores and causes a phenomenon known as red tides.

Although eutrophication is a natural process in the aging of lakes and some estuaries, human activities can greatly accelerate eutrophication by increasing the rate at which nutrients and organic substances enter aquatic ecosystems from their surrounding watersheds. Agricultural runoff, urban runoff, leaking septic systems, sewage discharges, eroded streambanks, and similar sources can increase the flow of nutrients and organic substances into aquatic systems. These substances can overstimulate the growth of algae, creating conditions that interfere with the recreational use of lakes and estuaries, and the health and diversity of indigenous fish, plant, and animal populations.

Pesticides

Farmers are constantly having problems with insect pests eating their crops and threatening the health of their animals. The cheapest and most effective way of reducing the pest numbers is by the use of insecticides and pesticides. These chemicals are produced synthetically and can be classified into two groups:

- The chlorinated hydrocarbons or organo-chlorides such as DDT and Dieldrin.
- The organo-phosphates.

It has been estimated that farmers around the world have used over 2.5 million tonnes of organo-chlorides. These chemicals are sometimes called biocides because they affect animals other than the target pest for which they were designed. They accumulate in the food chains until they reach toxic concentrations. Their full effects are not known as yet as these only show up in the third or fourth generations in 30 - 40 years time.

Figure 165.2 Sediment in stormwater can contain pesticides, heavy metals or chemical residues.
(Photo Bob Moffatt)

Bob Moffatt

Figure 166.1 Algal blooms cause loss of amenities.

Bob Moffatt

Figure 166.2 Regulations now control small business to stop pollution

Bob Moffatt

Figure 166.3 Litter on a beach washed up from the ocean.

Algal blooms

Algal blooms hurt the system in two ways.

First, they cloud the water and block sunlight, causing underwater grasses to die. Because these grasses provide food and shelter for aquatic creatures (such as the blue crab and summer flounder), spawning and nursery habitat is destroyed and waterfowl have less to eat when grasses die off. Second, when the algae die and decompose, oxygen is used up.

Dissolved oxygen in the water is essential to most organisms living in the water, such as fish and crabs. Increased eutrophication from nutrient enrichment due to human activities is one of the leading problems facing some estuaries as shown in Figure 166.1.

Organochlorides

These were commonly used pesticides in the past including such infamous products as DDT and dieldrin.

Fortunately organochlorides have been banned for several years (except under licence for termite control). Organochlorides for the most part are dangerous to aquatic life forms and bottom dwellers. They are not extremely water soluble, and tend to sink and mix with sediment in estuaries. Their chemistry often involves the release of mercury and nitrates.

Although organochlorides are recognised internationally as important contaminants of the marine environment, the SOMER report of 1996 concluded that there had been very few scientific studies undertaken to determine the magnitude of the problem.

The study also concluded that based on the available data and on the situation on the better known northern hemisphere, organochlorides occurred in their highest concentrations close to urban and industrialised centres or where run-off from rural areas had the greatest influence.

Another problem that the report identified was that the techniques for measurement and assessing chronic toxicity in waters had a long way to go and that any clear picture of the pollution of estuarine waters could not be ascertained. The authors called for a national wide monitoring program for the surveillance of organochlorides in order that a proper environmental protection program could be developed.

Organophosphates

These are common insecticides used in urban as well as rural areas to control mosquitoes, and pests around houses. Unlike organochlorides, these poisons do not accumulate in the body, but cause symptoms soon after being eaten. Again many birds can be affected due to the intake of contaminated food or water.

Ocean litter

Ocean litter is widespread and locally serious around Australia and it poses threats to whales, seabirds, turtles and seals as discussed earlier. Beach litter also reduces the beach amenities as shown in Figure 166.3.

In remote areas the problem is minor, but closer to the cities it poses a problem because it reduces the recreational and tourism values of many beaches.

The major source of land-based litter is streets, dumps and land fills where it is washed into the sea by stormwater drains. The SOMER report (Figure 167.1 and Chapter 46) concludes that while there is debate over the strategies to reduce litter - reduced packaging, education, user pays for plastic bags or better disposal practices, it is apparent that all are necessary. You can reads more on this - see Figure 167.1.

The management of ocean litter is the responsibility of MARPOL, - an international marine pollution agreement that is part of the international law of the sea convention. This international convention for the prevention of pollution from ships prevents people from throwing rubbish overboard. These regulations apply to all vessels including dinghies, yachts and fishing vessels. The basic principles of MARPOL are that no plastics are to be thrown into the sea and no garbage discharged within 12 nautical miles of the nearest land. Under international law, ports must have facilities for the disposal of waste. Special ports called ecoports are now catering for large ships.

Figure 167.1 Ocean litter
(Photo courtesy Environment Australia)

Land use

The building of industrial sites near the sea often means clearing huge tracks of mangroves and changing the flow of water in estuaries. This can lead to the death of mangroves, increased siltation and offshore altering of marine ecosystems (Figures 167.2 and 167.3).

Figure 167.2 Dead mangroves
(Photo courtesy MSQ)

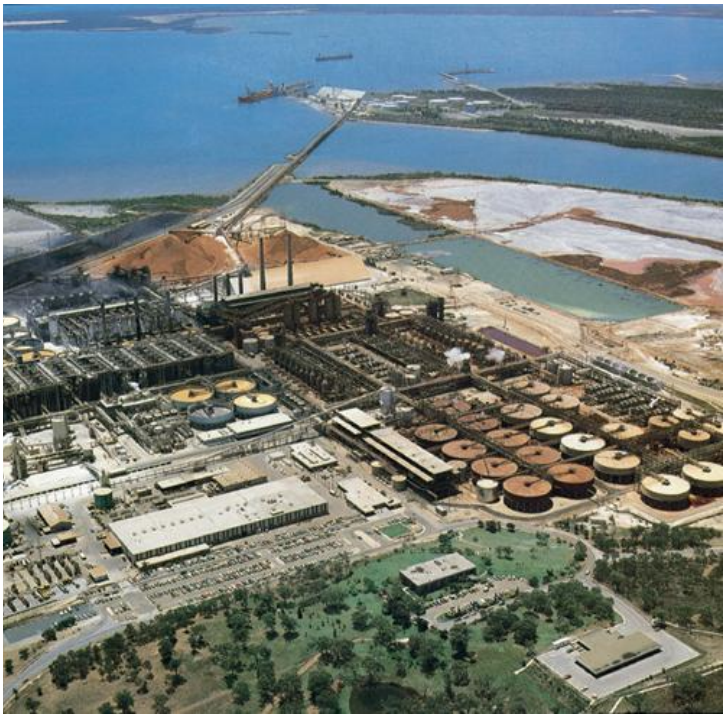


Figure 167.3 Large industrial plant next to coast
(Photo courtesy QAL)

Radioactive waste

Radioactive waste, probably the worst polluting substance ever, is dumped in many parts of the Pacific Ocean. Despite being the most dangerous substance ever to be created, it is packed into drums and dumped into the sea. The drums, which can contain highly radioactive plutonium, will eventually corrode in the seawater, allowing these substances to escape. Radioactivity will then enter food chains and eventually human bodies.

Environmental impacts of acid sulfate soils

Among the environmental impacts associated with acid sulfate soils may include the following.

- The acid and associated toxic by-products may lead to fish kills. In 1987, there was a fish kill extending over 25 km of the Tweed River due to drainage of acid sulfate soils.
- Acid drainage waters can impair the health of gilled organisms, and at worse, result in death.
- High acidity may result in nutrient deficiencies in aquatic and terrestrial plant life and increase plant's susceptibility to diseases.
- The acid generated can corrode metals such as iron and aluminium, resulting in instability of infrastructure.
- Aluminium-rich waters (as a result of low pH) may impair human health causing stunted growth, poor health and mental impairment.
- Epizootic Ulcerative Syndrome (EUS) commonly known as 'Redspot Disease' is an ulcerative disease affecting freshwater and estuarine fish in Australia, and is a result of a combination of factors - one of those being acidified water from drainage of acid sulfate soils.

Figure 168.1 Red spot
Photo courtesy Gladstone Environment Council

Acid sulfate soils

Acid sulfate soils (ASS) are the common name given to soils containing iron sulfides (principally iron pyrite) or products of the oxidation of sulfides.

These soils form when sea or brackish water mixes with sediments containing organic matter, and are part of the world's natural sulfur cycle. Those ASS of most concern are those formed in the Holocene period (within the past 10,000 years), during and after the last major sea level rise.

During the formation processes, sulfate in seawater was reduced by bacteria to iron sulfide (commonly known as iron pyrite) in waterlogged, saline sediments where there was a supply of easily decomposed organic matter, eg mangrove swamps and saltwater marshes.

The pyrite is stable under anaerobic conditions and these sediments which have potential to produce sulfuric acid but are present in an anaerobic environment are known as potential acid sulfate soils. Exposure of the pyrite to air by agricultural activities, excavation, drainage, dredging, stockpiling of sediment or drought results in oxidation of the sulfide to form sulfuric acid, often with the release of toxic aluminium when the alumino-silicate clay lattice of soil is dissolved. These are actual acid sulphate soils, and are an environmental concern in areas where they occur.

An important issue

An increased risk associated with exposure of acid sulfate soils has occurred in recent years as an increasing population places higher demands on the coastal lowlands (specifically those coastal lowland below 10 m elevation) for residential and tourism development. Disturbance of acid sulfate soils and subsequent release of acid produced from the oxidation processes represents a major environmental risk if managed inappropriately.

Significant quantities of sulfuric acid may be dispersed into the surrounding environment when oxidised pyritic layers are flushed following a dry period. The acid generated can seep into groundwater and surface waters, and if left unchecked, they can corrode steel and concrete and liberate toxic levels of aluminium, iron, and heavy metals from the breakdown of clays and silts.

Toxic levels of these metals combined with acid conditions, pose a significant risk to vegetation, concrete and steel infrastructure, and aquatic organisms.

Additional reading

You can read more about acid sulfate soils and their proposed management at: www.ahs.cqu.edu.au/humanities/geography/52208/acid_sulphate_soils.htm or

For information about acid sulfate soils follow this link to the Department of Natural Resources:-

http://www.dnr.qld.gov.au/land/lris/acidss/ass-home.html

or, you could investigate the importance of the problem by investigating the Federal government's national Strategy for the Management of Acid Sulfate Soils at:- www.affa.gov.au/armcanz/pubsinfo/ass/ass.html

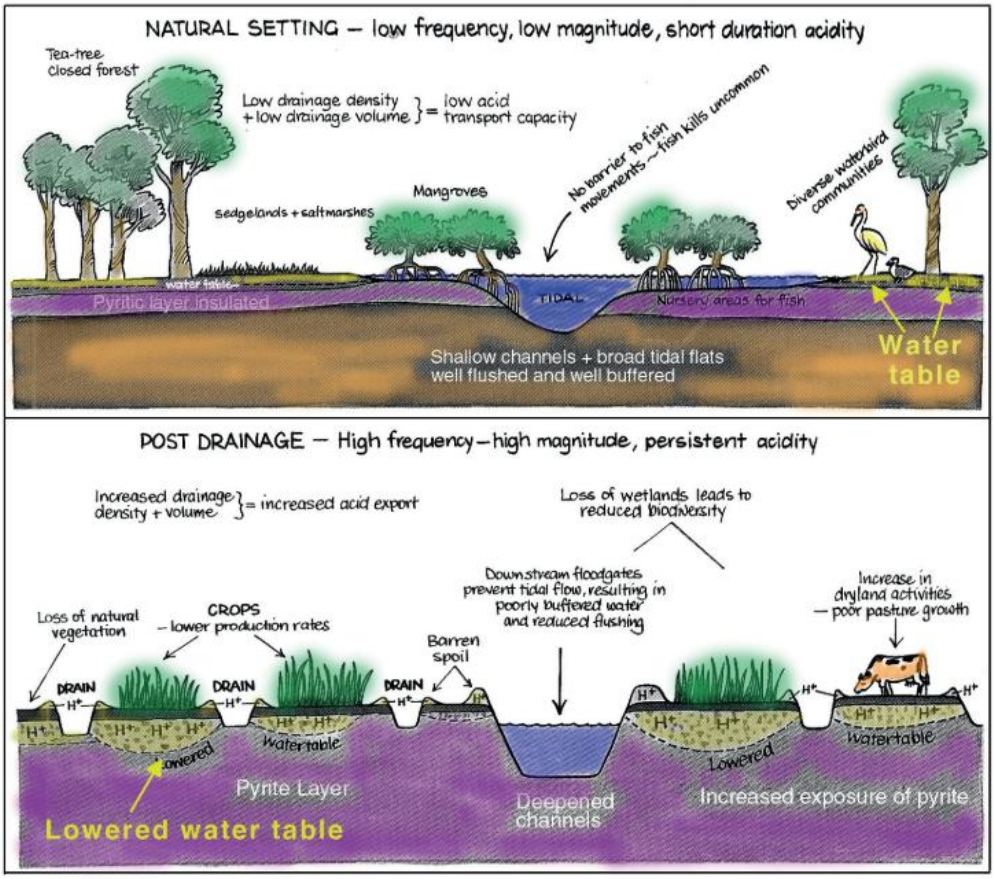


Figure 169.1 Acid sulfate soil formation. (Illustration courtesy DPI Queensland.)

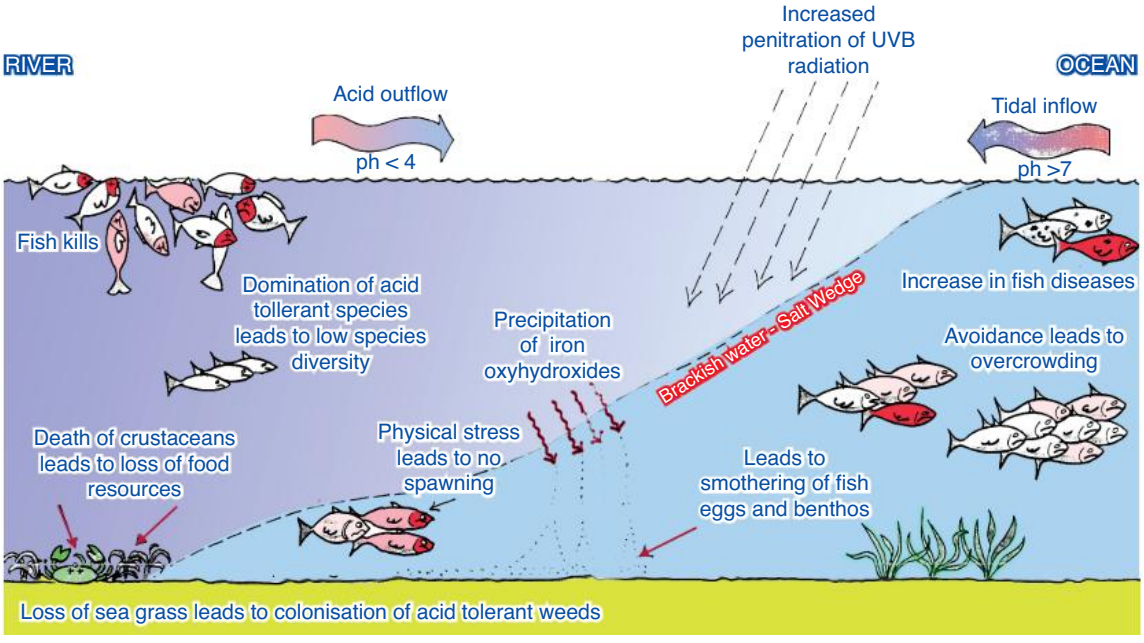


Figure 169.2 Acid sulfate soil runoff effect. (Illustration courtesy DPI Queensland.)

Figure 170.1 Reference to heavy metal pollution report in Australia
(Photo courtesy Environment Australia)

Figure 170.2 Port Kembla
(Photo Murray Waite)

Figure 170.3 Derwent River Hobart
(Photo Bob Moffatt)

Heavy metals

The following is an extract from the SOMER 1996 report on heavy metal pollution by G.E. Batley CSIRO Centre for Advanced Analytical Chemistry Menai, NSW and is reproduced with permission.

Introduction

"Heavy metals are a major contaminant of estuarine and coastal waters. Their inputs include urban run-off, industrial effluents, mining operations and atmospheric depositions, and may be in particulate or dissolved forms. Although many are essential biological elements, all have the potential to be toxic to organisms above certain threshold concentrations, and for the protection of aquatic biota it is important that these limits not be exceeded in aquatic environments.

The oceans are often mistakenly seen as a boundless sink for heavy metals and other contaminants. In shallow near-shore waters where dispersion and dilution processes are less effective, the measured concentrations of heavy metals are generally noticeably higher than in open ocean waters. Australian coastal waters are generally characterised by currents which follow the coastline and are less readily able to transport contaminants to deeper waters. In deeper waters, metal concentrations are extremely low, and there are noticeable differences between metal concentrations in surface and bottom waters, the profiles often correlating with nutrient concentrations and organic particulate matter. In near-shore waters, however, such differences are less pronounced.

Most metals ... attach to suspended particulates, and ultimately accumulate in bottom sediments. The sediment load of coastal waters is noticeably higher than open ocean waters. This is particularly so in the estuarine zone where, with increasing salinity the precipitation of iron hydrous oxides will scavenge and co-precipitate soluble metal species.

Sources

In the northern hemisphere, the higher population densities and greater urbanisation and industrialisation have led to quite high contamination of coastal waters by metals. In Australia, potential problems are restricted to less than a dozen major cities located on the coastal fringe. These include the state capitals, and a number of other highly industrialised cities, such as Wollongong and Newcastle. Because most heavy metals tend to accumulate in sediments, their presence in the water column is usually the result of recent inputs.

Metal concentrations can vary significantly over short distances and as a function of tide. Single measurements at a given site may indicate contamination, but to fully assess its magnitude a more complex sampling program which considers spatial and temporal variability is required. For this, integrating samplers, which continuously preconcentrate metals from solution over periods from hours to days, have been used."

Case study 7.1 Sydney's beaches

Activity by Tim Ryan based on a paper by Neale Philip Environment Protection Authority, 1993, copyright New South Wales EPA, reproduced with permission.

Introduction

Many major coastal cities in the world discharge their wastewaters to the ocean. Wastewater may consist of a combination of domestic, industrial and agricultural effluent. Domestic sewage contains nutrients and bacteria, whilst wastewaters from industrial processes contain trace metals and chemicals, and agricultural effluent may contain chemicals including pesticides.

Ocean conditions prevailing around the world's coastlines vary, as do effluent, discharge quality and practices. Discharges can be from multi-port diffusers in deep water, or single pipe outfalls at the shoreline. Levels of treatment of the sewage also vary.

Depending on local ocean conditions and the sewage discharge configuration, effluent may be rapidly dispersed and diluted with little visible trace in the vicinity of a discharge point.

Sydney outfall history

The ocean discharge points at North Head, Bondi and Malabar received 80% of Sydney's total sewage flow. The effluent was discharged less than 10 metres below the surface from rocky headlands, through single pipe outfalls. The remaining 20% continues to discharge from smaller coastal and inland treatment plants. In the early 1980s, after years of planning, the final decision was taken to divert the effluent of the three major sewage treatment plants from the shoreline to offshore deepwater outfalls, using multi-port diffusers in water depths of 60 to 80 metres.

Through the 1980s, public opinion had increasingly demanded action to overcome often severe pollution of bathing beaches near the outfalls. The first deepwater outfall was commissioned at Malabar in September 1990. In December 1990, the North Head deepwater outfall came on line, and the Bondi deepwater outfall commenced full operation in August 1991 (See Figure 171.2).

Trends in the state of Sydney's marine environment

Prior to 1990, monitoring results showed that the marine waters and biota off Sydney had been significantly and adversely affected by the presence of sewage from treatment plants along some forty kilometres of Sydney's coastline. The seawater at many surfing beaches was often visibly discoloured, and contained particles of grease attributed in large part to the discharged sewage (CDM 1989). Water quality at beaches, in terms of levels of bacteria, did not meet Health Department guidelines for bathing waters on many occasions.

The flesh of some species of fish caught near the major shoreline discharge points contained contaminants at levels above residue limits set by the National Health and Medical Research Council.

Figure 171.1 Bondi Beach
(Photo Murray Waite)

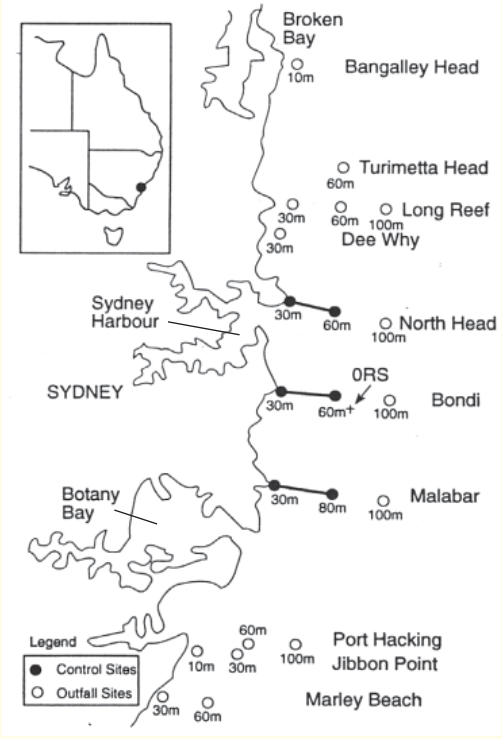


Figure 171.2 Sydney's urban coastline, showing the deepwater outfalls
(Illustration NSW EPA)

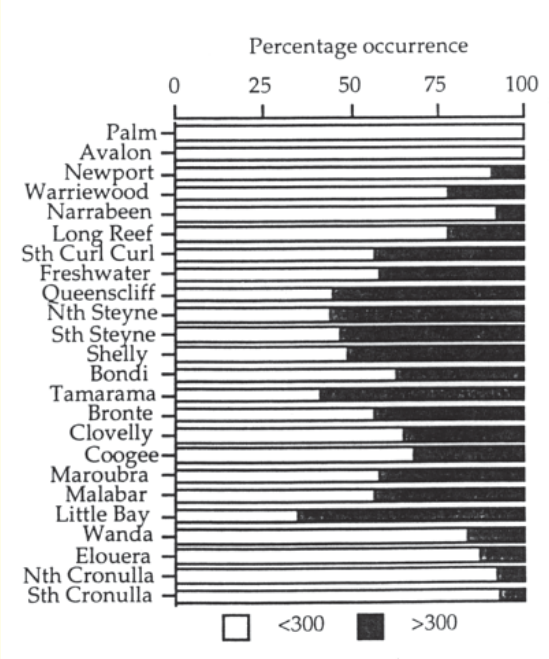


Figure 172.1 Sydney's Beach water quality December 1989 to September 1990 (categories are geometric means of colony numbers per 100 mL)
(Data courtesy EPA NSW)

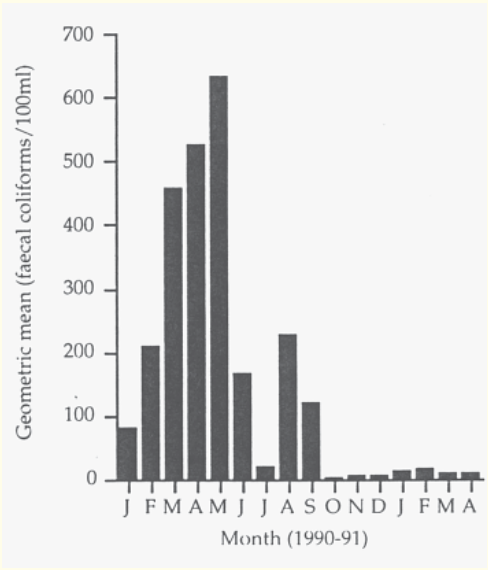


Figure 172.2 Trend in bacteria levels at Maroubra
(Data courtesy EPA NSW)

Figure 172.1 presents the distribution of two categories of faecal coliform densities at Sydney's beaches between December 1989 and September 1990. It showed that famous Sydney beaches such as South Steyne (Manly) and Bondi failed the Health Department's bathing water quality guidelines more times than they passed.

The trend from this poor environmental state to the present is reflected in Figure 172.2**.** This shows monthly coliform densities measured at Maroubra beach near the Malabar sewage treatment plant, and spans the September 1990 commissioning date of the deepwater outfall. The reduction in bacterial densities was 100-fold. Most of Sydney's beaches now pass the NSW Health Department's bathing water quality guidelines 90% of the time (Beachwatch 1993). The results from analyses of oysters deployed at the North Head and Malabar shoreline outfall sites, spanning the times of commissioning of deepwater outfalls at these sites, confirmed the pre- to post- commissioning trend observed for faecal conforms.

Figure 172.3 shows that the concentrations of technical chlordane in oysters dropped from significant levels to below the detection limit after commissioning in December 1990.

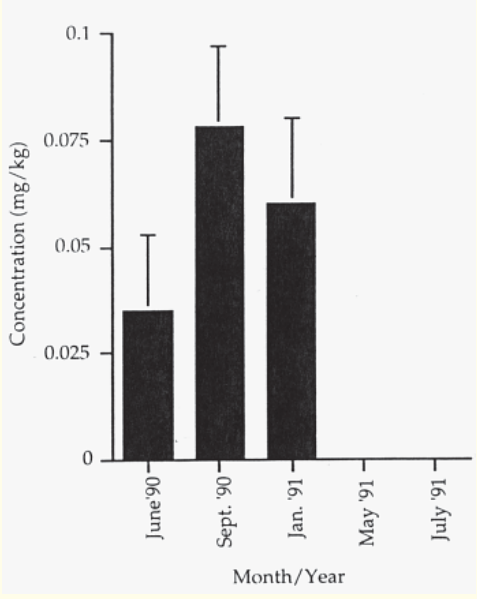


Figure 172.3 Trend in chlordane levels in oysters from North Head shoreline outfall site 1990 to 1991
(Data courtesy EPA NSW)

Note:

Since the introduction of deep sea outfalls, the data presented here is historic in nature and Sydney's beaches continue to improve due to the efforts of the EPA and local community groups such as Streamwatch.

Questions

1. How many outfalls sites exist along Sydney's urban coastline; what is the range of depths of these outfall sites?
2. The value of less than 300 Faecal Coliform per 100 millilitres is the level that has been set by the NSW department of health as a safe level for bathing waters. What was the beach worst affected by pollution by Faecal Coliforms and how many times did it fail to meet these standards? What was the cleanest beach?
3. From the data displayed in Figure 172.2 , what has been the effect of deep-water outfalls since their introduction in September 1990?
4. The number of Faecal Coliforms increased between January 1990 and May 1990. Suggest an explanation for this increase.
5. What was the effect of the deep-water outfall on the concentration of chlordane in oysters found in that area? Why do you believe that marine scientists study the contamination in oysters and not the amounts in larger animals such as whales?
6. Why will continual monitoring of the marine environment be required into the future? What should they monitor and how will they complete this monitoring?
7. Do you believe that there will be a long-term effect of deep-water outfall from the figures shown here?
8. Do you believe councils should be allowed to pump sewage that has had no treatment other than removal of the 'bits that float and sink' into the oceans?
9. Some people believe that the pumping of sewage into the ocean is a method of improving the productivity of the sea. Do you agree with this idea, suggest research that could be undertaken to see if productivity has increased.
10. How do you believe Sydney's sewage should be treated and disposed of?
11. Evaluate the data shown in the previous figures. Do you believe that one government department should be the testing body for the performance of another government body?
12. Why do you believe that the researchers used geometric means and not average results?
13. Extrapolate the effectiveness of this system being used in the year 2030.

Optional

Practice essay on beach pollution

Based on original exercise by Gwen Connolly.

Method

There is some concern about pollution of our beaches. Some have problems while others seem to be relatively free of pollution. Select one local beach and explain its present problems and how these problems are being overcome.

Then conclude your essay by recommending how protection of your beach can be achieved in the future.

1. Use the guide to construct a draft copy first, then write your final essay.
2. Both the draft copy and the final essay are to be submitted. (Show your teacher your draft copy before writing your final copy.)
3. Information for this exercise would come from:
   a. class work
   b. field trip to beaches
   c. library information on your local beach

Guide for draft copy

Define the problem in general terms. What effects does it have on the natural environment?
Describe the problem in the specific location that you have chosen.

What were the causes of the problem at this location?

Write a paragraph for each cause; tell of its effect on the environment (problem); describe the solutions which have been used to counteract this problem.

Put these causes-effect paragraphs with the attempted solutions in correct sequence.

Cause

↓

Effect (problem)

↓

Solution/s (preventative action)

↓

Next effect (pattern)

↓

Solution/s

↓

Resulted in

↓

Next effect

↓

Solution

Describe the location at present:
Which solutions have been the most effective? Why?
Conclusion:
Recommend effective prevention for the future (from evidence given in your essay).

Exercise 7.1 Chemical tests

pH

The most effective method for testing for pH is by using a pH probe (Figure 174.2) which a number of companies supply (cost is about $100). These units need some maintenance but not a lot. You can get waterproof ones and it is important that you keep the bulb moist when the unit is stored between tests.

Paper tests are available but, although cheaper, are subject to interpretation errors and inaccuracy problems).

There are some colour comparator units available which are cheaper than the probes but you should consider the degree of accuracy you require and the number of tests you are going to do before making a decision about purchasing.

Reactive phosphate

Measurement of reactive phosphate (sometimes also referred to as `orthophosphate') is important because it indicates a form of phosphorus that can be readily used by aquatic organisms.

The most effective method of testing for this component is by using a small colourimeter (Figure 174.2).

This gives an accurate reading on a digital display, is very easy to use and is portable. Colourimeters are expensive but have the capacity to do several types of tests. Normal safety issues must be addressed and there must be safe disposal of the by-product waste.

Other systems rely on visual colour comparison methods and so they are not as accurate. However, these units are still quite useable.

Total phosphorus (Total-P)

Measurement of Total-P includes all forms of phosphorus mentioned earlier, including particulate forms in unfiltered samples. Total-P also includes phosphorus bound to fine soil particles (if present), much of which is not readily released and is therefore not a potential source of phosphorus for eutrophication.

Measurement of Total-P is not easily carried out under field conditions, as it requires the 'digestion' of the sample which means that the sample has to be boiled and treated with concentrated acid to ensure that all of the bound phosphorus is released. The resulting sample is then tested as for phosphate.

Extra care should be taken with the use of the acid and the boiling water. Also take care with the disposal of waste from the reactions.

Faecal coliforms

These are the number of bacteria found in 100 mLs of water and are counted on a special plate (Figure 174.3). The number of colonies per 100 mL is used to declare if a beach or waterway is safe to swim in. Methods are specialised and you should consult with your local waterwatch or streamwatch group - see page 181 for web references.

Figure 174.1 Measuring turbidity
(Photos Bob Moffatt)

Figure 174.2 Measuring pH and nutrients
(Photos Bob Moffatt)

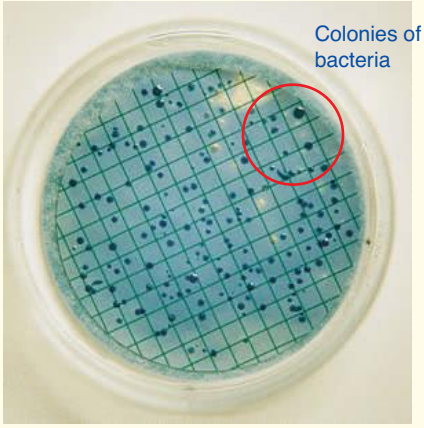


Figure 174.3 Faecal coliform plate
(Photos Bob Moffatt)

Case study 7.2 Derwent River

Reproduced with permission CSIRO ECOS magazine, 1996.

Twenty-five years ago, the people of Hobart were told the Derwent was the most polluted river in the world. Polluting practices have been curtailed since then, but much of the contamination remains buried in the river sediments. An integrated management program offers the next step towards restoration.

This article by Bryony Bennett revisits the story that CSIRO's Ecos first covered in 1974.

Figure 175.1 Zinc metal plant Derwent River 2001
(Photo Bob Moffatt)

In August 1974, the first issue of Ecos reported on the discovery of heavy metal pollution in the Derwent estuary. Four years earlier, people had become sick after eating oysters farmed in the lower estuary, at Ralph's Bay (See Figure 176.1, page over). Analysis by CSIRO's Division of Food Research confirmed that zinc and cadmium levels in the oysters were a threat to human health. Excessive mercury levels were later found in certain species of fish. Waste discharges from Electrolytic Zinc at Risdon, 15 kilometres upstream from Ralph's Bay, were blamed for the contamination. The company, now Pasminco, was established in 1917 and is one of the world's largest producers of zinc, metals and alloys. Cadmium, mercury, lead and other trace metals come as contaminants in the zinc ores.

Also implicated were effluent discharges from 13 sewage outfalls, and from the APM paper mill at Boyer in the upper estuary. The contamination of seafood in the Derwent came as a shock to the people of Hobart. It exposed how little was known about the effects of heavy metals on the estuarine ecosystem. Learning more about the problem was essential to controlling polluting practices, but there was strong opposition to the voicing of environmental concerns.

Areas of the River Derwent have higher percentages of mercury, zinc, lead and cadmium than ore bodies at Broken Hill, the Mercury reported in July 1975. The Derwent was branded the 'worst polluted river in the world' and said it would take hundreds of years, if pollution were stopped completely, for the river to clean itself through natural tidal action.

To clean up the river quickly will take considerable study and many millions of dollars, Dr Ed Butler of CSIRO Marine Research calls it a *pivotal point in Australia's environmental history*.

The Pasminco zinc refinery has undergone a series of processing upgrades since the early 1970's to reduce its impact on the Derwent estuary. An environmental services group set up by the company has been biomonitoring for heavy metals in the estuary for more than 20 years.

Some 10 years ago, most of Hobart's sewage received only primary treatment or secondary treatment without disinfection and all of it was discharged to the river or estuary. High concentrations of bacteria compounded the Derwent's pollution problems, particularly near the estuary's sewage outfalls.

According to senior environmental officers the past 10-15 years has seen a major commitment by councils up and down the Derwent to improve sewage treatment levels and reduce pollutant discharge. All the larger plants have moved to secondary treatment with disinfection, with two installing nutrient removal facilities in the past three years.

A major advance has been the move from raw sewage discharge at the Sandy Bay sewage outfall to full tertiary treatment of the sewage at the Selfs Point Treatment Plant. The ultimate goal in Tasmania is full effluent reuse and where feasible, distribute treated wastewater to water crops such as poppies, fodder and tree plantations.

Web reference

http://www.ea.gov.au/coasts/publications/somer/annex2

- *Heavy metals and tributyltin in Australian coastal and estuarine waters*

  by G E Batley

  CSIRO Centre for Advanced Analytical Chemistry, Menai, NSW 2234

Questions - Case study 7.2

Study the illustrations on this page and answer the questions below.

1. How does the concentration of mercury in sediments in 1975 compare with 1996?
2. What was the approximate zinc concentration in the sediments located at a distance of 40 kilometres from New Norfolk? (Note the graduations on the vertical axis.)
3. Evaluate the distance from New Norfolk when the concentration of mercury in the sediments was the highest. Suggest a reason why the concentration is high in this area.
4. Compare the amount of mercury in flathead in Ralph's Bay in 1995 with the amount in the same Bay in 1981. Explain the results.
5. The value of 0.5mg/kg has been accepted as the maximum value of mercury allowed in fish deemed safe for human consumption. From what areas should flathead in the Derwent River not be eaten?
6. Suggest why the amount of zinc is a lot higher in the mussels than the level of heavy metal mercury in the flathead.
7. What conclusion can you draw about the recorded levels of zinc in oysters over the 22 year period?
8. The NH&MRC suggests values over 1000mg/kg wet weight of zinc in oysters are unsafe for human consumption. In what areas of the Derwent River are oysters unsafe to eat?
9. Suggest how fish such as flathead may have absorbed the mercury into their flesh.
10. Suggest a method of decreasing the amounts of heavy metals such as mercury and zinc in the sediments. Outline an experiment that may test the method.
11. Zinc continues to be released from the sediments to the water above because the sediments are so saturated with zinc. Who should pay for the clean-up of the Derwent River? Debate this question within your class.

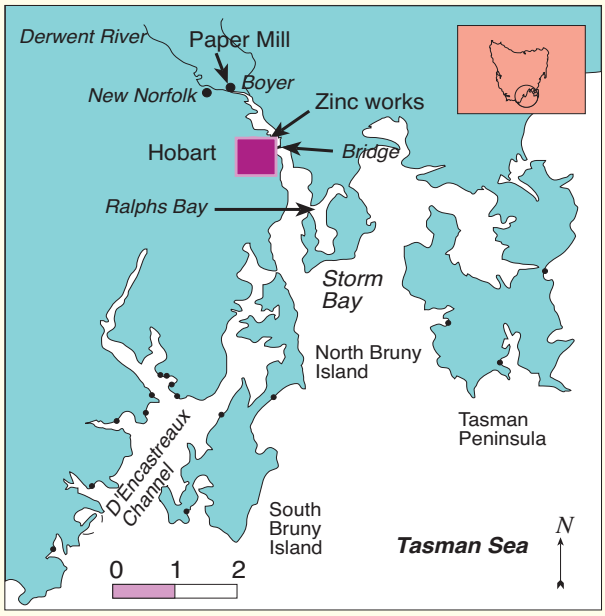


Figure 176.1 Southern Tasmania
(Illustration Bob Moffatt)

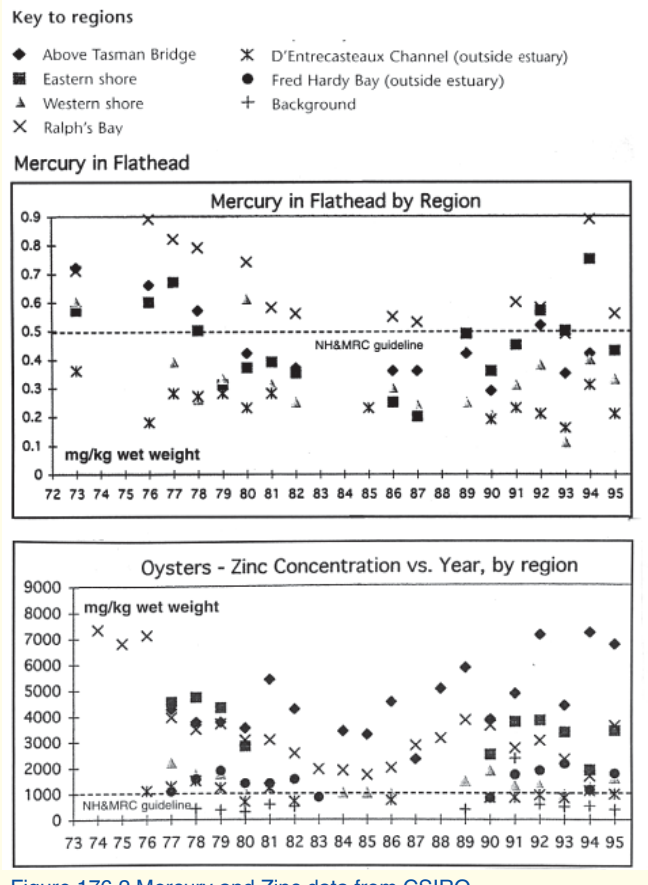


Figure 176.2 Mercury and Zinc data from CSIRO
(Illustration CSIRO)

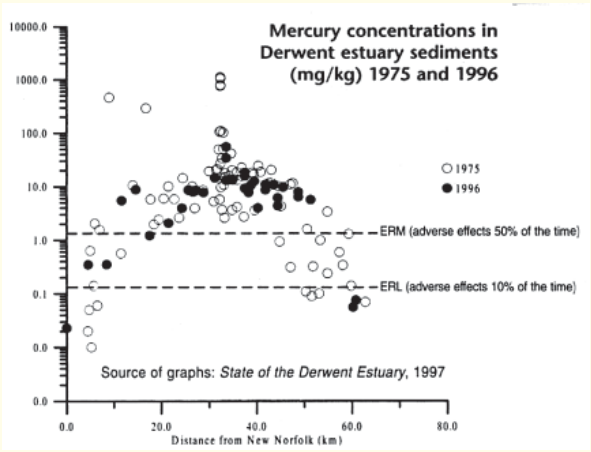


Figure 177.1

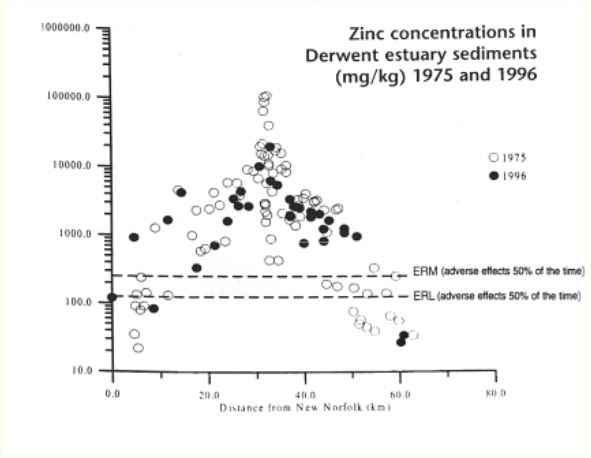


Figure 177.2

12. Study Figure 177.3 data for trace metal concentrations in marine organisms from Australian coastal areas and answer the questions below.
    a. Use an atlas to find Cockburn Sound and suggest a number of possible sources of contamination.
    b. Compare the trace elements of cadmium and zinc in fish of the Derwent River and Cockburn Sound.
    c. Calculate the median concentration of copper in plants in Cockburn Sound.
    d. What does the term ND mean in Figure 177.3?
    e. In which animal group was zinc the highest?
13. You have been asked to attend a taskforce meeting to clean up the Derwent River. Thousands of jobs are at stake if the pulp and zinc works are closed down and you are to present some suggestions at an initial taskforce meeting to save jobs but bring in new environmental guidelines.
    a. What guidelines should the taskforce bring in for the paper and zinc plant?
    b. Which would be the highest priority?
    c. When should they be implemented and why?
    d. Who should take responsibility for paying for the cleanup?

Trace metal concentrations in marine organisms from Australian coastal areas

Taxa	Location	mg/Kg (dry wt) Cadmium	Copper	Lead	Zinc
Fish	Derwent Estuary Tasmania	ND-.35	ND-29	--	3-44
	Cockburn Sound(WA)	0.1-2.9	0.2-29	0.8-22.2	6-404
Molluscs	Tasmanian Waters	ND-99	105-620	--	2430-38,350
	Townsville (Qld)	0.38-3	5-13.6	ND-10	55.7-179.6
	Cockburn Sound(WA)	.5-43.5	3.5-200.5	3.5-24	85-5950
Crustaceans	Cockburn Sound(WA)	0.5-7.5	6.5-50.5	1-15	43-161
Marine Plants	Cockburn Sound(WA)	0.2-1.6	0.6-9.3	0.2-1.7	24.7-169.4

ND - not detected

Figure 177.3 Data for Question 12.

Exercise 7.2 Testing for dissolved oxygen

Materials

- HACH dissolved oxygen kit
- Temperature and salinity meters
- safety goggles and rubber gloves
- seawater sample
- http://www.vic.waterwatch.aus.net/manual
- Follow your school safety procedure when you do this experiment and wear goggles and gloves.

Method

You must wear goggles and rubber gloves during the test.

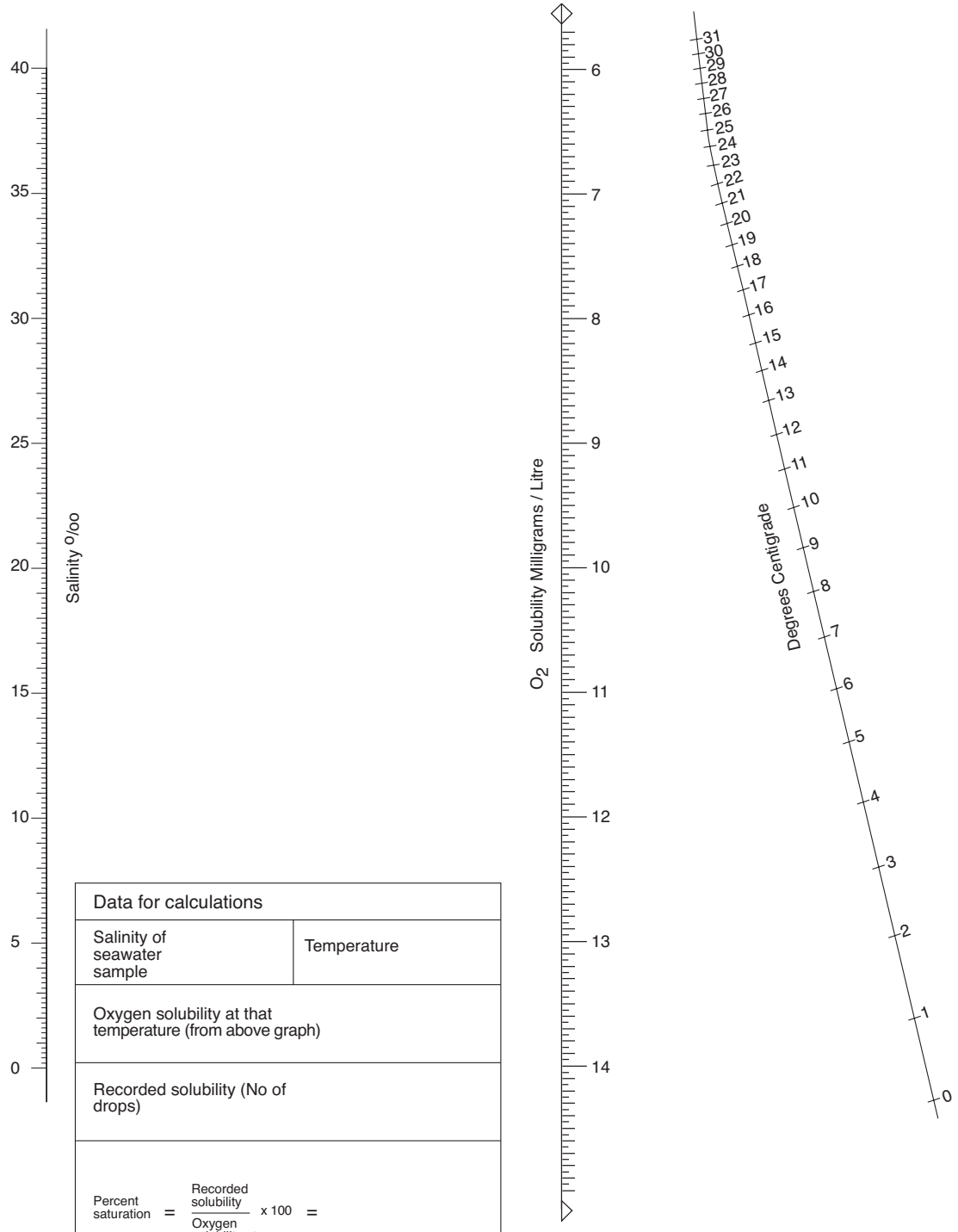
1. First collect a seawater sample in a bucket.
2. Then measure the temperature and salinity using the meters supplied.
3. Now submerge the DO bottle in the water. To avoid trapping bubbles in the bottle, incline the bottle slightly and look into the bucket to see that there is no air in the bottle. Gently stopper the bottle while it is still under the water.
4. Use the sachet or pair of scissors to tap down the chemicals in sachet number 1 and shake its contents into the DO bottle.
5. Repeat for sachet number 2 in the same bottle.
6. Collect a small amount of sample water in the square mixing bottle and use it to wash out any chemicals in the neck of the DO bottle.
7. Re-stopper the bottle carefully, tipping the small quantity which escapes into the waste bottle.
8. Hold the bottle and stopper, move away from the group and rotate the bottle 3 times to dissolve the chemicals in it.
9. Allow the sample to stand for 5 minutes.
10. Use the clippers or scissors to tap down the chemicals in sachet number 3.
    - Remove the stopper from the bottle and add the chemicals from the sachet.
    - Carefully re-stopper the bottle and rotate.
    - The floc, (this is the yucky looking yellow–brown stuff), should dissolve and a yellow colour will develop if oxygen is present. This yellow solution is called the prepared sample.
11. Fill the plastic tube with the prepared sample then empty the tube into the square mixing bottle.
12. Open the sodium thiosulphate solution by reading the instructions on the neck of the bottle.
    - Add sodium thiosulphate solution drop by drop to the bottle, swirling to mix after each drop. Hold the dropper vertically above the bottle and count each drop as it is added.
    - Continue to add drops until the sample changes from yellow to colourless. Record the number of drops on your result sheet.
    - Each drop is equal to 1 mg/L dissolved oxygen. You may like to add 1 drop more after the yellow colour goes clear. If there is no further clearing after adding this last drop, don't count it!
13. Now use the graph over on page 179 to establish the maximum oxygen solubility. Locate the level of salinity on the left-hand scale, the temperature on the right-hand scale and draw a line connecting these 2 points.
    - Record the value of maximum solubility from the centre line.
14. Now divide your measured dissolved oxygen value by this value and multiply by 100.
    - Record the value as a per cent saturation.

Figure 178.1 Dissolved oxygen meter
(Photo courtesy Hatch)

Questions

1. What values of per cent saturation did your other group members get?
2. What could cause levels of per cent saturation to fall?
3. How can we manage the marine environment to prevent decreases in oxygen levels?

After Whipple and Whipple (1911) based on measurements by Fax (1909) in American Journal of Oceanography



Data for calculations	
Salinity of seawater sample	Temperature
Oxygen solubility at that temperature (from above graph)	
Recorded solubility (No of drops)	
Percent saturation = $\frac{\text{Recorded solubility}}{\text{Oxygen solubility at that temperature}}$ x 100 =	

Figure 179.1 Dissolved oxygen conversion table and graph

Odd fact

CSIRO Marine Research has developed 'Biomarkers' to indicate the presence of a pollutant or sediment in the water and its source. Biomarkers are organic compounds that are characteristic of a pollutant. Faeces and oil are two common sources of pollution that can be tracked in this way.

Figure 180.1 Oysters
(Photo Bob Moffatt)

Figure 180.2 Stormwater pipes
(Photo Bob Moffatt)

Environmental tolerance of organisms

Ecological indicators

The population of aquatic organisms in an area also changes, as some organisms are less susceptible to pollution, while others are affected almost immediately. Biologists often use organisms that are very susceptible to pollution as ecological indicators.

Bioassays

These organisms are called indicator species as they indicate the level of pollution in the waterway. A determination of the biological effect of a chemical using living organisms as indicators is termed a bioassay.

Trout have been found to be very sensitive to pollutants. They have been used as early warning systems to indicate the presence of pollutants in urban water supplies. Scientists, by monitoring the swimming behaviour, gill movements and heart rates of trout, can detect subtle changes in water quality without completing exhaustive chemical tests. (One of the best examples of indicator species was the use of canaries in underground mining operations at the turn of the century. The canaries were very sensitive to changes in air quality and if they started to literally fall off their perches, it was time for the miners to leave the area, as dangerous gases were present. One of the major gases that the miners of the time were concerned with was methane, a poisonous and explosive gas.)

Urban waters mostly contain less flora and fauna and are sometimes a near "biological desert" with no detectable life. Introduced species such as the mosquito fish and waterweeds have become the dominating species within the food web as they are better competitors and are more tolerant of pollutants.

The animals and plants of these waters are often severely affected by pollutants and eating of fish, mussels, oysters and other marine creatures from these urban waterways is not advised.

Oysters and mussels which feed by filtering the water through their body are particularly susceptible to pollutants and are often used in bioassays.

Methods used to combat pollution

A number of steps must be taken if we are to control the pollution dilemma. These steps are:

a. Assessment of the problem - test the water quality to identify the pollutants.
b. Locate the cause and source of the problem.
c. Fix the problem - this may be difficult as the pollutants may already be in the food chain.
d. Education

Assessment

The parameters for good and bad seawater quality depend on local areas and conditions and the level of assessment required. The SOMER report of 1996 details the level of sophistication required by marine scientists to assess water quality and as mentioned earlier, many tests still have to be developed eg organochlorides.

Community groups

In recent years community groups such as Streamwatch and Waterwatch have detailed a list of parameters they use to determine water quality. The list of parameters for poor quality listed below are only generalisations based on information from their web sites (see Figure 181.1).

- Temperature- large differences in degrees in place and time (say 10 degrees).
- Dissolved oxygen - less than 60 per cent saturation and fish gasping for air or not present.
- Turbidity - one week turbid, the next clear.
- Nitrate levels - greater than 0.01 ppm.
- Phosphate levels - greater than 0.01 ppm and algal blooms occurring.
- Bacterial levels - greater than 150 colonies/100 mL and signs warning swimmers not to bathe in place.
- **Biodiversity -** would have changed. Longterm residents would tell stories of the abundance of animal and plant life in the past but current scientists would report of few species today.
- Riparian vegetation - non-existent. Polluted stormwater flows into rivers and streams and there are few or no trees or mangroves beside creeks, rivers or estuaries.

The results were often summarised in a water quality index table or report card as used by the 2002 SOMER report (http://www.ea.gov.au/soe/2001/coasts).

Locate the cause and source

The location of the source of the pollutant is fairly easy in a river or stream. Once the problem has been discovered, you then need to backtrack up the waterway, taking a series of samples to locate the source or entry point of the pollutant. If the problem is coming from a sewage outlet where many thousands of people and industries supply wastes to the plant complex, sampling from the different pumping stations can lead to the isolation of the person or industry concerned.

Pollution from agriculture and urban areas does not enter the rivers or streams at one point only. These forms of pollution are known as diffused or non-point source pollution. Discharges from sewers and drains that can be traced to their source, eg a factory, are known as point source pollution. The source of pollution problems found in ports or estuaries that have a huge number of entry points and many sources are almost impossible to locate.

The local current and wave pattern need to be understood if scientists are to locate the source of the problem.

General reference

Still the best site for a complete set of instructions
www.vic.waterwatch.org.au/fortheteacher/manual/

Streamwatch

Still one of the oldest and best programs can be found at:
www.streamwatch.org.au

Figure 181.1 Community group websites

Figure 181.2 Community group member tests for nitrates in a colour comparator
(Photo Bob Moffatt)

Water quality index

Variable	Results (Column A)	Column B	Factor (Column C)	Column D
1. Dissolved oxygen	130%	91	0.17	15.47
2. Faecal coliform	colonies 130/100ml	41	0.16	6.56
3. pH	8.8 units	58	0.11	6.38
4. B.O.D.	6.5 p.p.m.	48	0.11	4.28
5. Temperature	+0.5 Δ°C	90	0.10	9.00
6. Total Phosphorous	0.3 mg/l	82	0.10	8.20
7. Nitrates	0.62 mg/l	98	0.10	9.80
8. Turbidity	90 cm	30	0.08	2.40
9. Total solids (-salinity)	430 mg/l	42	0.07	2.94
	Overall water quality index			65.03

Figure 181.3 Water quality index table (After Bill Stapp)

Figure 182.1 Re-establishing riparian zones in estuarine creek
(Photo Bob Moffatt)

Figure 182.2 Recycling oil
(Photo Bob Moffatt)

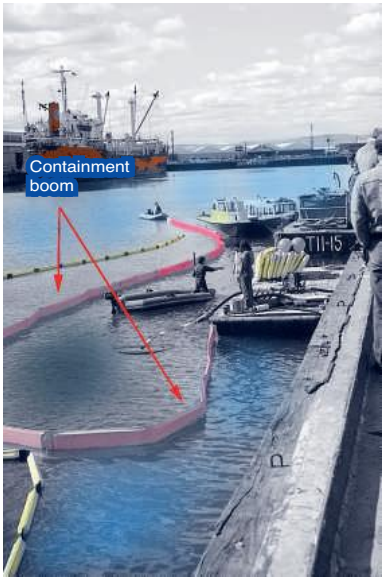


Figure 182.3 Containment boom
(Photo AMSA)

Fixing the problem

Obviously, it is better to save the sea by putting a stop to all activities that harm the marine environment. However, this is not always possible. Sometimes we have to save the sea by repairing damage already done to the environment. We can act locally to repair the damage ourselves and think globally by campaigning, to force companies that damage the environment to clean up their mess. This section discusses ways that the marine environment can be repaired.

Showcase companies

Some industrial companies are now developing ways to treat their waste before discharging it into the sea. One company that did this was ICI Olefines at Botany, NSW, which produces petroleum chemicals that are used to make plastics. Until 1994, the company was discharging significant amounts of petroleum waste straight into the sewerage system. These petroleum by-products are difficult to break down at the wastewater treatment plant and can be toxic when mixed with water.

In response to stricter controls on wastewater quality, the company designed and constructed new machinery that recycled wastewater for cooling purposes in the plant and reclaimed the petroleum by-products. This program was highly successful and resulted in a 95 per cent reduction of petroleum in the discharged wastewater which was now clean enough to irrigate company gardens and lawns. In addition, the company significantly reduced its water consumption and obtained useful by-products from the reclaimed hydrocarbons. Estimates in 1997 showed the company had saved $6.4 million in three years.

Oil spills

The biggest problem with oil spills from coastal refineries and sea-going tankers is that both crude oil and refined oil have devastating effects on marine life at sea. Refined or fuel oils, such as petrol and diesel, tend to mix with the water, especially with strong wave action. This can make them highly toxic to all marine life.

Large spills well out to sea may be sprayed from the air with chemical dispersants which break up the oil into smaller particles so that they form a bond with the water called an emulsion. In this form, they may be acted upon, broken down and made less harmful by micro-organisms. Unfortunately, dispersants are usually highly toxic and are not recommended for use in waters shallower than 20 m or within 5 km of the coast.

If a spill occurs close to the coast and is likely to come ashore, a rapid response is vital. Firstly, the oil must be contained in one area so it cannot spread further. Response teams can use containment booms (Figure 182.3) that look like long chains of floating macaroni and contain oil-absorbing material. Once contained, in calm conditions, the oil can be removed by pumping it onto tankers. Containment booms are not effective in strong waves or currents because the oil can escape over or under them.

Until the oil reaches the coast, cleaning up the spill is the responsibility of trained personnel such as Department of Transport and Sea Rescue officers. If oil does come ashore, we need to act quickly to save affected marine birds and mammals and clean up the beach. At this point everybody in the community can be involved by forming into organised action groups.

Oil on rocky shores and mangroves is best left alone. Strong wave action on rocky shores will eventually break the oil up. In mangrove swamps, oil is best left because people trampling through it can do more damage to the environment. Unfortunately, when oil pollutes mangrove communities, you cannot do much, except wait.

Riparian zone

Repairing the sea starts in the catchments, for example by replanting trees in the riparian zone Figure 182.1 or building nutrient absorbing drains Figure 183.2. Once the trees grow, they will encourage undergrowth of plants that will increase the absorbent power of the soil. Nutrient-absorbing rubble drains and dam walls made of rocks bound together with wire promote the growth of beneficial algae that remove phosphorus and nitrogen from the water as it percolates through. Rubble drains are a better drainage system than storm water pipes that speed up water flow and only pollute the sea faster.

Education

There are two ways of saving the sea - you can talk about it or you can do it. Marine Studies programs like you are doing at school go a long way to saving our sea. If you know how to look after your marine environment in simple practical ways and you pass these skills onto your friends workplace and your own children, you will save the sea.

People carry practical skills into the workplace that transfer into environmental work practices that are written down and followed as work procedures. In the future, companies will do better business and make better profits from environmentally safe work practices because we will buy their products rather than environmentally unsafe ones.

An environmentally educated population will be able to follow a path of economic development that safeguards future generations from having to pay for previous generations' environmental disasters.

Think globally, act locally

Figure 183.3 shows a group of marine educators protesting against nuclear testing in the Pacific Ocean that they fear will pollute our seas with radioactive wastes. Radioactive pollution is an example of a global issue that we must all think about. But to save our seas, we must also act locally. Recycling oil (Figure 182.2) or planting mangroves in a local creek (Figure 183.1) are ways you can act locally to save the sea. We need to educate people to change any behaviour that threatens the environment. Behaviour changes involve a combination of community group involvement, education, changed work practices and manufacturing procedures, fines and media campaigns.

Figure 183.1 Planting mangroves
(Photo Bob Moffatt)

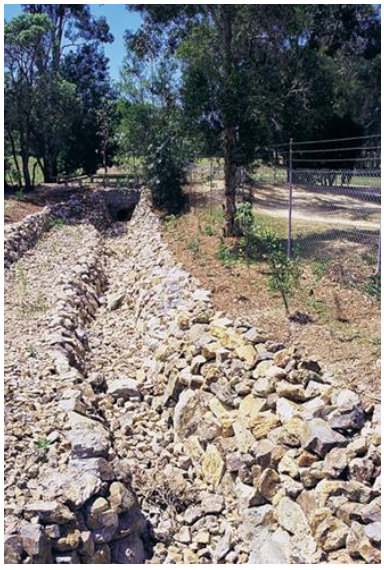


Figure 183.2 Nutrient absorbing drains
(Photo Bob Moffatt)

Figure 183.3 Surfrider no nukes rally
(Photo Surfrider Foundation)

Figure 184.1 Recycling cardboard
(Photo Bob Moffatt)

Figure 184.2 Stormwater education
(Photo Bob Moffatt)

Figure 184.3 Plastic bag for doggie do's
(Photo Bob Moffatt)

Reduce, reuse and recycle

These three R's go a long way to saving our sea because they change our relationship with our planet.

Reducing

The first and most important step is to reduce what you buy. If you don't buy it, then it can't become rubbish. Items that are over-packaged or are only used once show how we have become an over-consuming society. If you can learn to buy in bulk (but not a bigger amount than you need), to choose products with recyclable or minimal packaging and to buy quality goods that will last, then you are reducing the strain on our natural resources and the pressure on our landfills. You can also reduce the need to buy fruit and vegetables by growing your own. You can use the mulch and compost from your recycling projects as fertiliser.

Reusing

The second step is to reuse what you have bought. Before you throw a product away, think of possible ways of reusing it at home or at work. By reusing a product, you prevent it from becoming rubbish.

Recycling

The third step is to recycle as much as you can. Bottles, cans, glass and plastic containers can be recycled through local authority recycling programs. Some paper and cardboard products are also recyclable in the split bin system (check the sticker on your bin). A worm farm or compost bins are also methods of recycling materials we would otherwise throw away. Recycling enables us to reduce pollution, save natural resources, reduce the strain on landfalls and use less energy to produce new products.

Legislation

Economic cost of pollution

We live in a cost conscious age. Many people are more concerned with monetary gains than stopping pollution. Pollution, however, is costly.

Costs involved include the cost to clean up the pollutants, of losing our natural ecosystems and fisheries and of using up resources.

The three levels of government in our part of the world are national, state and local. Each has sets of laws designed to manage the sea. All we have to do is follow these rules put in place to protect the biodiversity of marine life and allow us all to enjoy the sea.

Local government action

Simple rules like keeping to common walking tracks on the way to the beach will help stop beach erosion and help local government manage coastal zones. Other practical rules put out at local authority level are as follows: take your rubbish home, keep your storm water drains clean, plan your garden so that topsoil does not get washed away in the rain, clean up after your dog by using doggie do bins, (Figure 185.1) and new building sediment containment (Figure 185.2).

Local authorities also try to stop people hosing concrete surfaces because this washes dirt, chemicals and other accumulated substances (like lead from petrol) into storm water drains. In addition, watering, a driveway is a waste of our valuable water supply. Local authorities encourage people to wash their cars on the lawn because this stops the detergent from flowing into the storm water system, and also waters the lawn.

Local authorities also often have environmental rules about running businesses. You should find out about relevant regulations dealing with environmental protection before you start any enterprise. For example, you may want to set up a dog-washing business with a car and a trailer fitted out with dog-wash equipment. Do not start until you find out how much it will cost to stop the chemicals from the dog wash entering the sea. Too often people start a business without thinking about including the costs of environmental protection.

Figure 185.1 Doggie do bin
(Photo Bob Moffatt)

State government action

State governments also have environmental rules, for example, fishing bag limits, closed seasons, net and tackle use, boating rules and regulations, marine park entry, taking of protected species, mining rights, whale-watching permits, coastal zone building applications and development control plans.

Each state government has its own set of rules and each will change over time depending on the environmental concerns of the party in power.

Commonwealth government action

National governments can make rules that affect far greater areas than rules made by lower levels of government. They can also sign international treaties and conventions on behalf of the nation as well as overrule state government decisions.

Examples of this were when the Tasmanian Government wanted to dam the Franklin River and the Queensland Government wanted to drill for oil on the Great Barrier Reef. In both cases the Federal Government of Australia passed laws to prevent this from happening.

Marine reserves

Marine reserves, parks and protected areas are controlled by cooperation between state and national governments because the sea knows no boundaries. National governments also can declare marine protected areas and set guidelines for local and state governments to ensure the sea is protected. Chapter 22 discusses marine parks in detail.

Exclusive economic zones

Other aspects of national management schemes involve the concept of the exclusive economic zone (EEZ) that takes into account national and international interests - see Chapter 18, pages 463-475. The declaration of an EEZ under the international law of the sea allows national governments to sign treaties with other countries to allow or prohibit activities such as mining of offshore reefs, longline fishing or whaling.

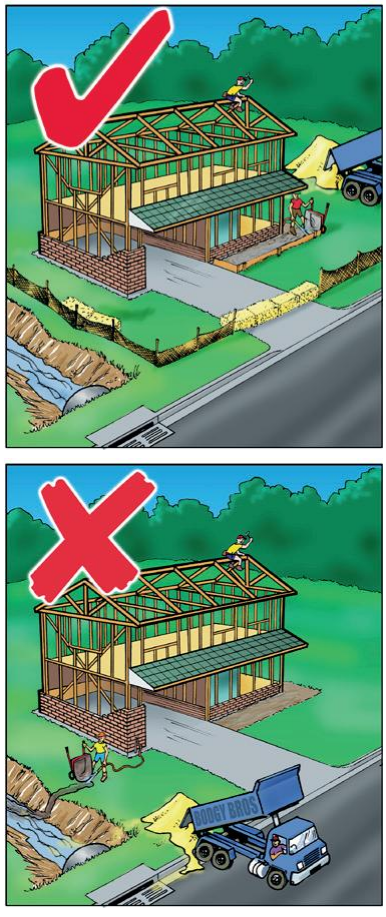


Figure 185.2 Council regulations and by laws make it compulsory to contain sediment on building sites
(Illustration Wet Paper)

Environmental activism

Greenpeace - an example

From their web page: www.greenpeace.org

"Greenpeace exists because this fragile earth deserves a voice - it needs solutions, it needs change and it needs action. Greenpeace is a non-profit organisation, with a presence in 40 countries across Europe, the Americas, Asia and the Pacific. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants. As a global organisation, Greenpeace focuses on the most crucial worldwide threats to our planet's biodiversity and environment.

The organisation campaigns to stop climate change, protect ancient forests , save the oceans, stop whaling, say no to genetic engineering, stop the nuclear threat, eliminate toxic chemicals and encourage sustainable trade.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka an area north of Alaska where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and our ships are an important part of all our campaign work." The organisation exists to expose environmental criminals, and to challenge government and corporations when they fail to live up to their mandate to safeguard our environment and our future.

In pursuing their mission, they have no permanent allies or enemies. They promote open, informed debate about society's environmental choices. They use research, lobbying, and quiet diplomacy to pursue goals, as well as high-profile, non-violent conflict to raise the level and quality of public debate. And they believe that the struggle to preserve the future of our planet is not about them — it's about you.

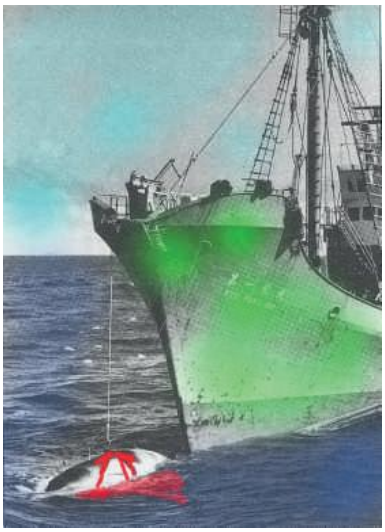


Figure 186.1 Greenpeace is well known for its relentless campaign to stop whaling.
(Photo C Greenpeace)

> "*When the last tree is cut, the last river poisoned, and the last fish dead, we will discover that we can't eat money.*"
> greenpeace.org

Surfrider Foundation - an example

From their web page: www.surfrider.org

"The Surfrider Foundation is a non-profit environmental organisation dedicated to the protection and enhancement of the world's waves and beaches through conservation, activism, research and education.

1. Surfrider recognises the biodiversity and ecological integrity of the planet's coasts are necessary and irreplaceable. Surfrider is committed to preserving natural living and non-living diversity and ecological integrity of the coastal environment.
2. Surfrider promotes the right of low-impact, free and open access to the world's waves and beaches for all people. Surfrider acts to preserve this right of access.
3. Surfrider is dedicated to enhancing wave-riding opportunities in ways which will not adversely impact nearshore ecosystems.
4. Surfrider believes environmental education is essential to the future health and well-being of the planet. Surfrider seeks to develop and utilise educational materials that are informative, factual, pro-active, synergist and fun.

Figure 186.2 Greenpeace protests against toxic waste.
(Photo C Greenpeace)

Many other groups campaign hard for the marine environment such as ACF, MESA, WWF as well as community groups, environmental lawyers, university and TAFE students as well as individuals in government and industry.

Figure 187.1 Greenpeace activists collect samples from industrial pollution.
(Figure 187.1)

5. Surfrider strives to be accurate and non-partisan in its communications with its members and the general public. In addition, Surfrider will express the unique values inherent in wave-riding: individualism, camaraderie, non materialism, and an appreciation for human kind's historic relations with the ocean.
6. Surfrider is a grassroots organisation effective through the participation of its members. Surfrider activities emphasise the value of an involved membership.
7. Surfrider encourages all commercial enterprises to adopt the valdez principles. Their determination to do so will favourably influence Surfrider's willingness to provide support. Surfrider will not permit sponsors to divert the foundation from its mission or projects undertaken.
8. Surfrider does not discriminate on the basis of race, religion, sex or national origin for any reason. Surfrider promotes the healthy enjoyment of the coastal environment for all people.
9. Surfrider and its representatives, affiliations and chapters agree to abide by these principles and all rules and regulations governing non-profit organisations.

Figure 187.2 Surfrider foundation save the whale rally
(Photo Surfrider Foundation)

Exercise 7.3 Sampling methods

Water collection

The simplest way to collect water is with a pole with a bottle attached. In many cases 200 mLs of water sample will be all that is required.

Bottle on a stick
(Photo NSW Dept of Environment)

Water samples can be collected from offshore by boat but only if you have mastered all of the necessary boating skills.

Alternatively your class can hire a boat that operates at a speed that does not require a licence.

Floating pontoons with motors
(Photo Bob Moffatt)

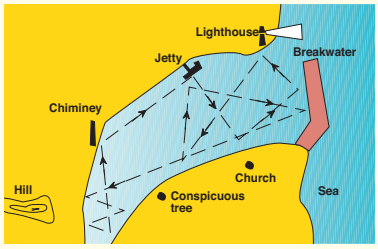
If you are sampling and then testing for oxygen, you have to be very careful not to introduce oxygen into your sample.

Some sampling suggestions are detailed below, however, don't be constrained by these and try to invent some of your own.

Bathymetric surveying

The basis requirement for an estuarine study is an adequate chart. These charts should be used with care for research purposes, however, because their quality is usually in direct relation to the importance of local shipping, if your study area is not a busy port, the charts will often be out-of date. Also, silting can be quite rapid in estuaries, and this too may invalidate the available charts.

Use your navigation skills to fix position, and your boating skills to determine depth. The simplest way to operate the survey is to run your boat at a slow constant speed on predetermined lines evenly spaced within the estuary. As a general rule in small-boat surveys, it is wise to run as slowly as possible. Your initial survey lines should be plotted on your chart using the skills you have learnt in other parts of your course. A hypothetical survey is illustrated below.



A bathymetric survey
(Illustration Bob Moffatt)

At regular time intervals (perhaps 30 seconds if you are using an echo sounder, longer if you are using a sounding lead), the depth should be measured and recorded. If you are sounding with a lead, practise a good bit before you attempt to run your survey lines. In this technique a 1 or 2 kg weight is tied to the end of a line graduated at appropriate intervals (1-metre spacing is adequate). As the boat proceeds along its track, the leadsman heaves the lead underhand ahead of the boat, pulls the line taut, and reads it as it comes vertical.

Back at the laboratory, the soundings' tracks should be transferred to an enlarged version of your base map. When all the tracks have been marked, transfer in your soundings (corrected for tidal height as necessary). Once all soundings have been recorded, the map should be contoured at an appropriate interval and then reduced to a convenient size for field use.

Water Sampling

The principle of the water collecting device is that you should be able to collect a water sample from any depth. At your sampling site, water samples are taken from a number of depths by setting the water collecting bottle and lowering it carefully over the side of the boat. The stopper knots are let through your hands, and when you are at your depth, the cork is pulled and the observer watches for bubbles to rise. When no more bubbles can be seen, the bottle is pulled on board and the sample taken. (After Marsh and Tulip). If you can't use a boat try to sample from the middle of a bridge or the end of a jetty. Samples taken from the shore are often very unrepresentative and bias can creep into your sample.

If you intend comparing data and drawing conclusions, systematic sampling methods should be used. Take many samples from the same place many times to make sure you are right.

Home made plankton net
(Photo Bob Moffatt)

Home made water sampler bottle
(Photo Mick O'Connor)

Exercise 7.4 Removal of oil from water

Note: The experiment - What effect does oil have on feathers from the earlier editions, can now be found in the Oceanography Exercises book (see below)

Aims

To investigate methods that could be used to remove oil from water and to study the effects of oil on water.

Equipment and materials

- 8 x 250 ml beakers
- Access to freezer
- Old sump oil
- Absorbent paper
- Sawdust
- Cooking oil
- Washing-up detergent
- Sand
- Syringe
- Biodegradable detergent
- Screw-top jar
- Liquid detergent

Method – Part A

1. Place 8 x 250 ml beakers on the bench. Add approximately 100 ml of water to each beaker.
2. Add 10 drops of oil (old sump oil is more effective) to each beaker.
3. Attempt to remove the oil by using each of the following methods. Use a different method for each beaker.
   a. Use absorbent paper to soak the oil from the surface.
   b. Add a teaspoon of sawdust to the beaker and stir the mixture.
   c. Add 10 drops of washing-up detergent.
   d. Sprinkle 1 teaspoon of sand onto the mixture.
   e. Add 1 teaspoon of salt to the mixture.
   f. Use a syringe to draw the oil off the surface.
   g. Freeze beaker overnight.
   h. Add half a teaspoon of biodegradable detergent and stir the mixture.
4. Record the results in table form. Evaluate the success of each method .

Method Part B

1. Half fill the jar with water and add 10 mls of oil.
2. Screw the top on, shake and let settle for 5 minutes. Note of what happens.
3. Add 5 mls of detergent, screw top on shake and let settle for 5 minutes.

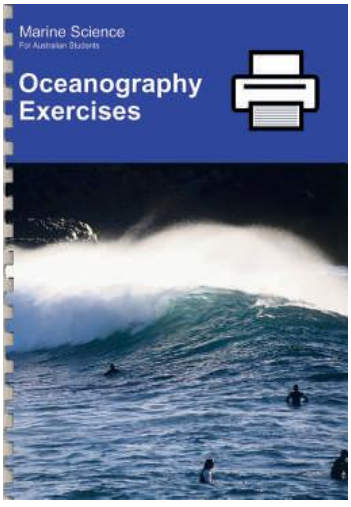
Questions

1. Which method was most successful?
2. Do you believe this method could be used to remove oil from the ocean? Could this method harm the marine environment?
3. Suggest other methods that could be used to remove the oil. You may attempt some of these methods with your teacher's approval.
4. Oil is an organic compound. Do you believe bacteria or other micro-organisms could use oil as food?
5. The detergent works the same way as a dispersant, used to deal with large oil spills at sea.
   a. What effect do you think dispersants may have on marine plants and animals?
   b. What is the danger of using detergents?

Exercises

From the Wet Paper Publication - *Oceanography Exercises*
See www.wetpaper.com.au

C1. How much plastic pollution is there in the sea?
C5. What effect does marine pollution have on dolphins?
C6. Why is DDT a problem in the marine food chain?
C7. What are some of our seas contaminated with?
C8. What effect does oil have on feathers?
C9. What happens in an oil spill?
C10. What impact do acid sulfate soils have on the sea?
C11. What effect does water quality have on the marine environment?
C12. How can impacts of coastal development be minimised?



Questions

Application

1. From the table of data in Figure 190.2, answer the following questions:
   a. Which estuaries are regarded as unpolluted and which are nitrogen enriched?
   b. Which river had the highest level of nitrogen (mg/l) and what was this value?
   c. Graph the value for the Logan River for the period of 1980/81 and 1983/4. How have the values changed? Propose a suggestion to explain these values.
   d. Attempt to explain the reason why the nitrogen levels are generally higher in the upper estuaries than the lower estuaries.
   e. Where may the sewage be entering the creek? Explain.
   f. Suggest other nutrients which may have shown similar trends to the nitrogen in the table in Figure 190.2.
2. Muswellbrook, Singleton, Maitland and Newcastle are towns situated on the Hunter River system of NSW. Each town is approximately 50 kilometres apart on the Hunter River and used the water for domestic, agricultural and industrial purposes.

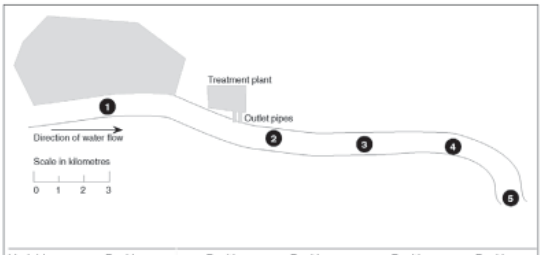
   What problems may be caused by having all four towns on the same river? Will it make the detection of the source of pollutants harder to track down?
3. Refers to Figure 190.1 for Lynch River
   a. Organisms which can only live in special environmental conditions are said to be indicator species. These organisms have a low tolerance range. Which of these species is an *indicator species*?

      a. catfish b. mullet c. yellow belly
   b. Why will the oxygen concentration decrease as you progress from position 1 to position 5?
   c. Discuss the water clarity, based on secchi disc readings, from position 1 to 5. What may have happened between position 1 and 2?
   d. What effect might the increase in mineral ion concentration have on the aquatic life from positions 3 to 5?

Creating

4. You and a group of friends are planning a peaceful protest rally against whaling (or an issue of your choice) in the Pacific, Indian or Southern ocean that has a police permit, your parents and all local government approvals.
   a. design six protest placards that you could use in the rally to get the attention of the world media;
   b. prepare a one page press release stating why you are opposed to whaling;
   c. write six chant slogans that you can give to the microphone leader to yell out during the march.

Table 1: Water quality data for Lynch River



Variable	Position 1	Position 2	Position 3	Position 4	Position 5
Water quality by Secchi disc (cm)	200cm	10cm	12cm	60cm	150cm
Temperature	22.3°C	26.2°C	25.1°C	25.0°C	24.2°C
Oxygen content	8.5 ml/l	1.0 ml/l	0.5 ml/l	3 ml/l	4 ml/l
Fish	Yellow Belly Catfish Mullet	Mullet	Nil	Catfish Mullet	Catfish Mullet
Mineral ions concentration	Low	High	High	High	High

Figure 190.1 Data for question 3

Table 2 Mean total nitrogen levels (mg/l N) in some Queensland estuaries

Estuary Description	Name of Estuary	Lower Estuary			Middle Estuary			Upper Estuary			
Unpolluted estuaries	Mooloolah	0.414	-	-	0.440	0.574	-	0.719	0.646	-	-
	Burrum	0.567	-	-	0.546	0.645	-	0.756	0.763	0.770	-
Nutrient enriched estuaries	Burnett	0.549	-	-	0.684	0.888	-	1.178	1.118	1.051	-
	Hays Inlet	0.848	0.864	-	1.136	-	-	1.270	-	-	-
	North Pine	0.568	-	-	0.972	1.630	-	1.445	-	-	-
	Caboolture	-	-	-	0.766	0.882	1.154	1.344	1.745	2.347	1.840
Nutrient enriched estuaries with significantly light limited reaches	Logan 80/81	0.590	0.935	-	1.073	1.443	1.884	2.110	1.986	-	-
	Logan 83/84	0.590	0.985	-	1.280	1.714	1.796	1.600	-	0.800	-
	Albert	1.141	1.237	-	1.212	1.093	-	0.836	0.577	-	-
	Mary	0.408	0.567	-	0.998	1.197	1.132	0.907	0.698	0.684	-
	Brisbane	0.833	0.932	1.4.08	1.771	2.177	1.944	1.793	1.546	0.726	-
	Fitzroy	-	-	-	0.978	1.179	-	1.457	1.695	1.383	-
Small creek	Petrie Creek	0.805	-	-	1.903	-	-	3.295	5.418	6.920	-

Figure 190.2
(Data supplied courtesy Dept. of Primary Industries)

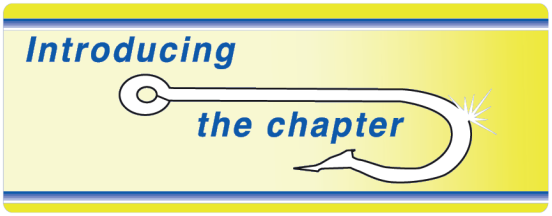
Chapter 8
Classification and marine biodiversity

by

Bob Moffatt, Tim Ryan and Mike Sugden

The authors acknowledge the work of Harry Briedahl and Nancy Tsernjavski who have given their permission to use illustrations from the ABSea and the Seaweek 1999 MESA web site with funds supplied by Environment Australia

Illustration *Trevor Ruth and Trish Hart*



Chapter hooks*

- Animal and plant roll call. Make a big marine life tree in the back of the room and add to it as you go.
- Start with a copy of Figure 207.1 and complete it for your class.

Why study this chapter

To gain an appreciation of the need for a classification systems.

For marine scientists it is important to communicate about organisms, and a universal system of naming is vital so they don't confuse one organism with another.

It also is important for the biodiversity of our planet to be maintained and as we have not yet discovered many marine species it is hard to plan for management of this diversity.

Chapter overview

Classification **193**

Scientific names 195

Taxonomy 196

Species concept **197**

Exercise 8.1 Silver gull 199

Case study 8.1 Exploring our oceans - New species 200

Identification keys 202

Exercise 8.2 Design a key 203

Exercise 8.3 Shark classification 204

Kingdom of living things **206**

Marine biodiversity **208**

Exercise 8.4 Diversity 212

Case study 8.2 Biodiversity and conservation 216

Sea habitats 218

Intertidal zone 220

Pelagic zone 223

Abyss.....223

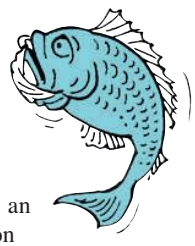
Case study 8.3 — Mangrove diversity 224

Exercises and questions 227

*Chapter 19 also discusses ways to protect biodiversity.

Key concepts

1. Naming marine organisms is based on a two name (binomial) system of genus and species.
2. The science of classification is called taxonomy and is fundamental to all scientific research. It is a means by which scientists can communicate with each other.
3. A species is defined as any group of organisms who are basically alike, and able to interbreed under natural conditions to produce fertile offspring.
4. The levels of classification are kingdom, phylum, class, order, family, genus and species.
5. Identification keys are one way of classifying marine organisms. Most keys are two part or dichotomous. This allows an easy choice when working with them.
6. In designing a key, there has to be a recognised use of well defined terms to allow the user to clearly identify the organisms mentioned in it.
7. 5 commonly recognised kingdoms are animalia, plantae, fungi, protista and monera.
8. Biodiversity in its simplest form refers to the number and variety of earth's life forms.
9. A broader definition of biodiversity goes beyond simply counting species to include genetic variety and variability within each species and the ecological complexes in which they occur.
   - Genetic diversity - refers to the genetic variety and variability within each species.
   - Species diversity - the number of different species living on earth. At present almost 1.8 million species have been discovered and described by scientists.
   - Ecosystem diversity - refers to variety in the combination of species that form ecosystems such as ponds, coral reefs, forests or grasslands.
10. Marine organisms live in a great variety of habitats ranging from deep ocean seamounts to rocky reefs
11. Australia is divided into two biogeographical regions with distinct marine organisms in each. Our ocean currents and coastal geomorphology largely controls where these regions occur.
12. The boundary between the tropical and warm temperate provinces coincides approximately with 18-20°C winter minimum surface temperature but this is variable and dependant on the influence of the East Australian Current and the Leeuwin Current.



13. Tropical northern Australia has low levels of endemicity (10%) compared to temperate waters (80-90%).
14. High biodiversity is regarded as an important attribute for the protection of our marine environment.

Classification

There are a great variety of life forms in our oceans and new ones are being discovered and described each year. Also more than 1500 new species have been discovered in Australia's waters by the CSIRO in the last ten years. So how can scientists learn to identify, name and know the biology of all these living creatures in our waters? To understand this huge array of organisms, a simple **classification system** is used to produce some order out of the chaos.

Studying marine creatures will also help us all appreciate the wonders of the sea and learn how we can conserve its beauty for future generations.

Figure 193.1 Reef and fish
(Photo Qld Fisheries)

History

There are millions of different living things in the world and since very early times people have seen the likeness between some of the creatures.

They used these likenesses to organise them into groups with similar characteristics and gave these groups names. They were concerned with such groupings as which plants or animals were edible, which were poisonous, and which could be used as medicines.

As new species were discovered, new groupings were organised. The Greek philosopher, **Aristotle** (384 - 322BC) was the first scientist to attempt to classify all living things.

Aristotle, who was the grandfather of Alexander the Great, classified many animals on the basis of their structure and behaviour. He classified animals according to whether they had red blood or not, and even realised that dolphins were mammals not fish. He classified plants using their shape and size as well as the groupings— trees, shrubs and herbs.

John Ray (1676-1705), an English naturalist, was the first scientist to develop a complex classification system. He developed keys by which animals could be identified and also improved the language used to describe animals.

His ideas were developed further by a Swedish naturalist, Carolus **Linnaeus** (1707-1778) who decided to sort plants not by how useful they were to humans, but on a basis of their flower structure.

Linnaeus invented a simple naming system for the different animals. He was also the first to apply it to the classification of plants and he even extended the idea to attempt to classify non-living things such as minerals.

Figure 193.2 Gallapagos turtle
(Photo Bob Moffatt)

Odd fact

Linnaeus was denounced as a degenerate and a corrupter of morals when, in the 18th century he proclaimed that plants reproduced sexually like animals.

Methods

Classification is a means of sorting things into groups.

The members of each group will share a certain number of characteristics with each other.

The diagram over shows how your class could be classified by using a number of different characteristics.

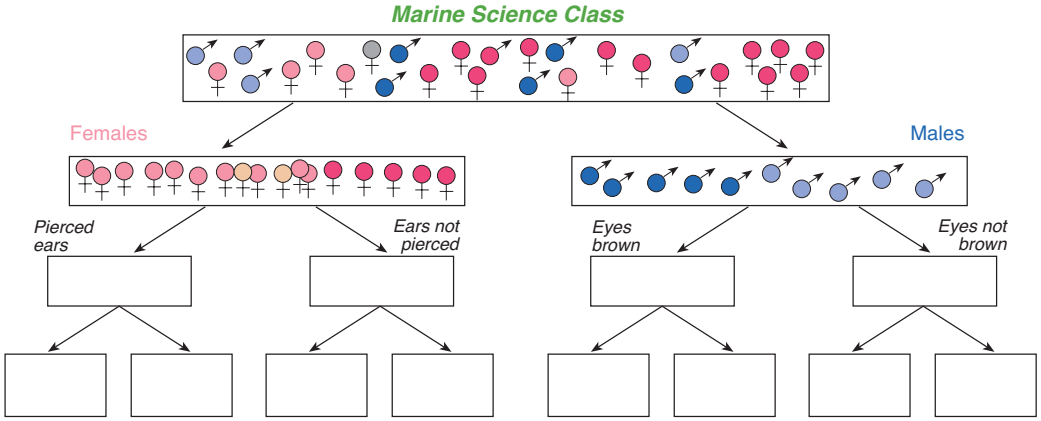


Figure 194.1 Part of the key to classify a marine science class
(Illustration Bob Moffatt)

Most of the characteristics chosen are those that will not change, eg structure and method of reproduction. Characteristics such as behaviour are seldom used as biologists are often working with dead or preserved animals. Characteristics such as colour are usually not used as the colour may change when the environmental conditions change. The colour may be the only characteristics the organisms have in common eg a blue whale and a blue gum.

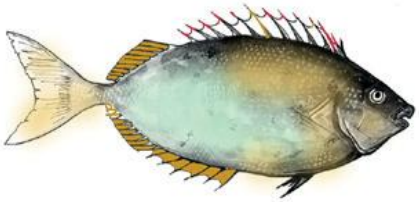


Figure 194.2 *Siganus spinus*
(Illustration Kerry Kitzelman)

Reasons for classification

Organisms are classified for the following reasons:

- to provide an acceptable scientific name to every specimen;
- to help work out relationships between the different groups of animals and plants;
- to aid in identification;
- to help to describe an individual;
- to reveal numerous interesting evolutionary phenomena;
- to enable scientists to communicate and share information about organisms; and
- to help understand patterns of development of life on earth.

It is important to have an acceptable **scientific name** for a particular species as it may otherwise be known by several different dialectal names. This would lead to confusion between scientists and poor communication. Biologists throughout the world need to use the same system for naming organisms.

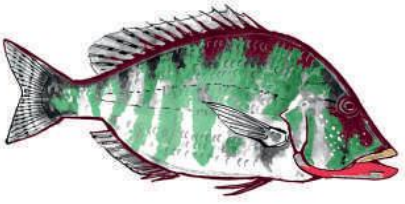


Figure 194.3 *Lethrinus fletus*
(Illustration Kerry Kitzelman)

Many individuals have a different name depending upon the region from which they came. This still occurs with some of the common names applied to fish in Australia.

- The fish, *Siganus spinus* (Figure 194.2), has the common names – black spinefoot, black trevally, blue spot trevally, mi-mi, happy moments, and the stinging bream.
- The fish *Lethrinus fletus* (Figure 194.3), has the common names - grass sweetlip, red-finned emperor, brown kelp fish, brown morwong, coral bream, piggy, red throat, and squire.

These and many others carry a variety of common names, depending upon the region from which they are taken. One species of trout, *Salmo clarki*, has been known by 70 different **common names**.

Salmo clarki

(Illustration Sharyn Madder)

Scientific names

Before Linnaeus developed the modern naming system, living things carried complicated and long-winded names.

The names were often a long Latin description of the living thing and were too cumbersome to use easily.

For example, the name that was given for the carnation plant (Figure 195.1) was —"*dianthusfloribus solitariis, squamis calcycinis, subovatis brevissimis, corollis crematis*". Can you imagine writing about organisms with such unmanageable names?

Figure 195.1 Carnations
(Photograph Bob Moffatt)

Some of the more recently discovered species carried the name of the person who first found them or first tried to describe them. The person's name had little significance to the organism being named.

Linnaeus developed a naming system called the *binominal nomenclature* that simply gives each living thing a two word scientific name.

The first word of the name is the genus name: the second part of the name is its species.

The word genus comes from the Latin language, and means "a kind". It indicates the type of organism.

The second name is often descriptive eg

- the slender elongated, sand mullet is named *Myscus elongatus,*
- the black sole is given the name *Achyopa niger,* and
- the name of the Beaked Leatherjacket with its tube-like snout is *Oxymonacanthus longirostris*.

The two names together give the species name and is either written in italics or underlined. The genus word is written with a capital letter and the species word with a small letter. The genus name can only be used once in the naming system, but the species name (descriptive name) can be used many times eg the black butterfish is named *Parastromateus niger* and the black sole's name is *Achyopa niger*.

The species name is sometimes used to indicate where an animal is normally found eg the New South Wales Port Jackson shark is called *Heterdonthus portusjacksoni* (Figure 195.2) and the Queensland school mackeral is named *Cyleium queenslandicus*.

The scientific names are normally Latin words or other words written in a Latin form. This is because the Latin words are very descriptive and are from a dead language (ie it is not used every day).

Being a dead language the meaning of the words will not change with time as our language has; eg "strike" means to hit but today it also means refusal of workers to work.

Odd Fact

The largest of the 1 600 known species of starfish found in the Gulf of Mexico was 1.4m from tip to tip.

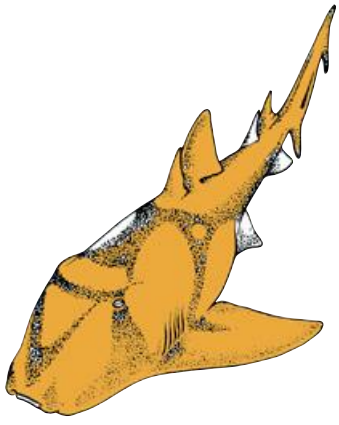


Figure 195.2 *Heterdonthus portusjacksoni*
(Illustration Sharyn Madder, from MESA ABSea)

Vocabulary

Latin		Meaning
nocti	=	at night
tri	=	three
octo	=	eight
platy	=	flat
rostra	=	beak
phaga	=	eats

You can look up more words at: www.mesa.edu.au/seaweek99/tr_11.htm

Figure 196.1
(Illustration Tim Ryan)

Figure 196.2 Taxonomist
(Photograph courtesy Qld Fisheries)

The word "rap" before the eighties meant a short, sharp blow, but today it refers to a type of modern music (in 2020 it may mean something else). Furthermore, the same things have different names in different languages eg the English "cat" is "le chat" in French and "die Katze" in German. Thus, by having a universal language, communication between scientists in different countries is not misled during translation. Interestingly, a Chinese or Japanese biology book would have the scientific names of the organisms printed in our alphabet.

This binominal naming system has now been established for over 200 years and it has remained basically unchanged. Every year many thousands of new species are discovered and named using this basic system. Today, many scientists are using English names with which most people are familiar, written in latinized form.

Mostly, when people envisage a scientific name, names like *Eleutheronema tetradactylum* (a blue salmon) spring to mind. But a number of the names are not long and are meaningful, eg the brown unicorn fish has a scientific name *Naso unicornis*.

Using scientific names is not a way of "showing off" among the educated, but is necessary for scientific exactness.

There is, however, nothing wrong with using the fish's common names when this scientific exactness is not required. The person on the street only uses scientific names to impress his or her friends.

Taxonomy

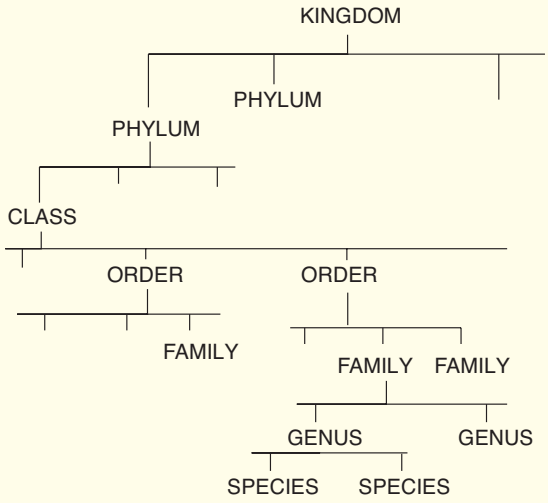
The science of classification is called **taxonomy** and a person who classifies things is called a taxonomist. This system of classifying organisms or things into groups according to the characteristics they have in common is used everywhere we go.

For example, in a food store all the pet foods are found in one area of the shop, the fruit and vegetables in another area, the milk goods in a different area and so on. In a library, the books are classified or grouped in areas according to their subject matter. The importance of this classification can be imagined if we were sent to a shop to buy some items where there was no store arrangement or if all books were simply put on any shelf in the library.

The scientists classify the living organisms in a similar way to shopkeepers. The animals are divided into a number of large groups. These groups are then divided into smaller groups. The shopkeeper makes one part of his store the bakery section, which is then divided into sections with bread, cakes, buns, biscuits, and tarts.

The categories that a scientist uses are summarised in Figure 197.1 and below. Organisms in a

- kingdom are divided into phyla.
- phylum are divided into classes.
- class are divided into orders.
- order are divided into families.
- family are divided into genera.
- genus are divided into species.



Each KINGDOM is divided into a number of phyla.
Each PHYLUM is divided into a number of classes.
Each CLASS is divided into a number of orders.
Each ORDER is divided into a number of families.
Each FAMILY is divided into a number of genera.
Each GENUS is divided into a number of species.

Figure 197.1 Classification methods
(Illustration Bob Moffatt)

These groups may be further subdivided eg the group 'family' may be subdivided into a number of groups called subfamilies.

The degree of likeness increases as one further classifies the animal. This likeness within the groupings is greatest in the classification level of species.

Definition

A species is any group of organisms who are basically alike, and able to interbreed under natural conditions to produce fertile offspring.

Species concept

The species level of classification is the final box in which similar groups of organisms are placed. So how should we define what a species is, and how do we determine which organisms belong to a particular species?

The definition needs to be simple, easily applied and universally accepted. It is also the level at which evolutionary changes can be observed and measured in our observations of groups of organisms. Hence we can observe new species evolving.

The key element in this change from one species to the next results from changes in the genetic make up of the groups of organisms. How do genetic changes occur in a population of organisms?

The answer is by mutation and natural selection. If groups of organisms can interbreed, then these changes will be passed on to future generations common to that gene pool.

Hence isolation from the common gene pool will mean that changes occurring in one population will not be passed on to the isolated population.

Therefore it was accepted that the definition of a species should take this into account. The definition became "A species is any group of organisms who are basically alike, and able to interbreed under natural conditions to produce fertile offspring".

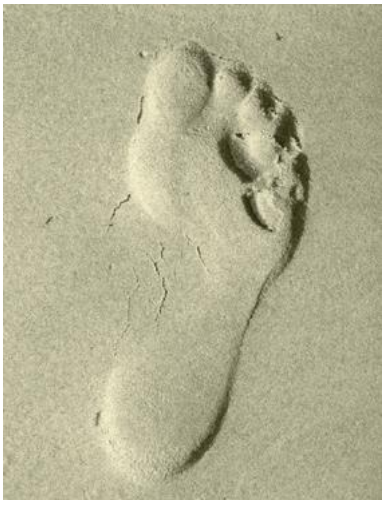


Figure 197.2 Genus and species?

Figure 198.1 *Homo sapiens*
(Murray Waite)

Therefore, a horse and a donkey are not of the same species because, although they can inter-breed to produce a mule, this mule is infertile. Horses can only inter-breed with horses to produce fertile offspring. There are a number of problems with this definition which include:

- It is often very difficult to observe or determine whether organisms can interbreed, for example deep sea organisms. When fossils are the only record of a particular group of organisms, it is difficult to determine reproductive capability.
- Within a species group there may be huge variety, for example the pet dog.
- *Canis familiaris* ranges from Great Danes to tiny Poodles or Welsh Corgis. The Great Dane and the Corgi would have great difficulty in interbreeding, but intermediate varieties exist which maintain a common gene pool.

Figure 198.2 shows how the system of classification is used to classify different invertebrate animals.

Classifying you

Kingdom	Animalia
Phylum	Chordata - animals with dorsal nerve tube
Sub Phylum	Vertebrata – animals with backbone in which is found nerve cells
Class	Mammalia – hair on body and females able to provide milk for young
Order	Primates – eyes directed forward, claws replaced by nails
Family	Hominidae – Tail absent, hind limbs longer than fore limbs, thumb able to act opposed of hand
Genus	*Homo*
species	*sapiens*

Details	American lobster	Market squid	Blue mussel	Virginia oyster	European oyster
Phylum	Arthropoda	Mollusca	Mollusca	Mollusca	Mollusca
Class	Malacostraca	Cephalopoda	Bivalvia	Bivalvia	Bivalvia
Order	Decapoda	Decapoda	Mytiloida	Pterioida	Pterioida
Family	Nephropidae	Loliginidae	Mytilidae	Ostreidae	Ostreidaer
Genus	*Homarus*	*Loligo*	*Mytilus*	*Crassostrea*	*Ostrea*
Species	*americanus*	*opalescens*	*edulis*	*virginica*	*edulis*

Figure 198.2 A comparison of the classification of different species of animals
(Illustration Bob Moffatt)

Exercise 8.1 Silver gull

Around Australia we find the silver gull *Larus novae hollandiae*. England, in the Northern Hemisphere, for a long time named two distinctly different gulls as separate species. One, the lesser black-backed gull, is found to breed in high open country in inland areas, whereas the herring gull is found on the coast nesting in cliffs. These are quite different in appearance and do not interbreed. However it has since been found that interbreeding does link these two gulls via a ring of sub species or races that encircle the North Pole. If the intermediate races or subspecies disappeared through natural disaster then these two gulls would become separate species through genetic isolation. However because these sub species in other countries around the planet (encircling the North Pole) do exist then they all belong to the one species *Larus argentatus*.

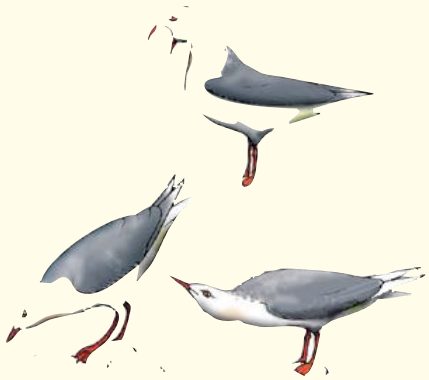
Questions

1. At what level are the following groups of organisms most alike?
   a. Order
   b. Phylum
   c. Species
   d. Class
2. Suppose that a bird such as a finch lived in six different areas around Australia. In each area the finches are quite different.
   - One population lives on Kangaroo Island in SA (Population A).
   - One population lives on Rotnest Island in WA (Population B).
   - One population lives in the Torres Strait Islands in NT (Population C).
   - One population lives on Fraser Island in Queensland (Population D).

   Suppose the following interbreeding occurs.
   - Group A can mate with Group B only.
   - Group B can mate with Group A, C, D and E.
   - Group C can only mate with Group B and likewise for group D.
   - Group E can interbreed with Groups B and F.
   - Group F can interbreed with Group E.

   a. How many species are there?
   b. If group F only died out how many species would there be?
   c. If group B only died out how many species are there?
   d. If group E only died out how many species are there?
3. Which of the following organisms are most alike?
   a. *Achyopa niger*
   b. *Haliotis rubra*
   c. *Pastromateus niger*
   d. *Haliotis laevigata*
4. A horse and a donkey, when induced to mate, produce a mule, which is infertile. Are the horse and the donkey in the same species?
5. Many organisms reproduce asexually, some with very little sexual reproduction. How do you think this might affect their chances of survival as a species?
6. Research the meaning of the following terms:
   - Mutation
   - Gene pool
   - Natural selection
   - Endemism.

7 Search the web for taxonomic classifications of "new" species.
   - What was the basis for classifying these species?
   - Who gets to name a new species?
   - Is there any check on irresponsible naming?



Case study 8.1 Exploring our oceans - New species

The following text is from CSIRO Ecos magazine April-June 1998 and reproduced courtesy CSIRO Marine Research.

Note: For information on the seamounts mentioned in this article and the research vessel - refer to Chapter 17 Pages 450-151.

Mention coral reefs, and most people picture colourful fish darting between corals, sponges and shells in the tepid waters of the tropics. Few of us envision reefs where the sun never shines. A place where, amid an inky blackness, deep-sea corals provide refuge for a host of slow-moving and often remarkable species, many of which are new to science.

But such a place does exist, founded on extinct volcanic cones known as seamounts which rise steeply from the seafloor, their summits often more than a kilometre from the ocean's surface (see Chapter 1).

In January 1997, the CSIRO team of researchers, led by Dr Tony Koslow, did their first biological survey of the newly discovered seamounts in research funded by Environment Australia and the Fisheries Research and Development Corporation. 'We feel like first explorers, travelling to unknown corners of the globe,' Koslow says. 'But this is the 1990s, and we are still discovering great areas of unexplored territory.'

Koslow says the researchers expected to find a relatively diverse deep-sea community and, if they were lucky, even a few new species. But what they discovered was more exciting than anyone had anticipated.

'We found so many new species that taxonomists around Australia, and several from overseas, are still identifying them,' Koslow says. 'There are new species in virtually every animal group that we are examining, from corals and hydroids to crabs and fish. For example, of 13 species of hydroids (Figure 200.1 - corals without skeletons - found on the seamounts), nine appear to be new to science.

Figure 200.1 A coral without a skeleton - classification unknown
(Photo CSIRO Marine Research)

Figure 200.2 Spider crab yet to be classified
(Photo CSIRO Marine Research)

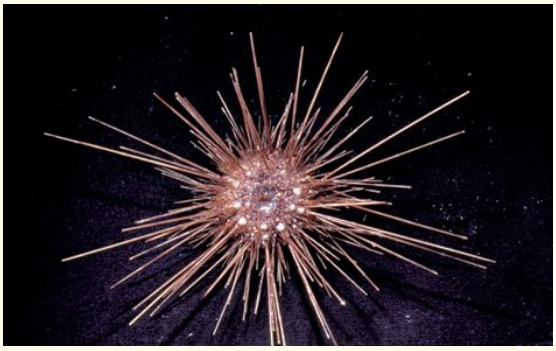


Figure 200.3 Sea urchin - unclassified
(Photo CSIRO Marine Research)

The exact number of new species found in the other groups will be known by the end of the year. But what is proving to be as interesting as the sheer number of new species is the high level of endemism. These new species are found on particular seamounts and nowhere else, not even off the coast of New Zealand. 'This is surprising because organisms in the deep sea generally have fairly wide distributions (on the order of the ambit of an ocean basin), because there are few barriers to dispersal,' Koslow says. As a result, many of these species seem to have evolved mechanisms to restrict their range to the seamounts that support them. For example, an urchin retrieved in the January samples (Figure 200.3), was found to brood its young beneath it, appearing to have bypassed the need for a larval stage altogether.

CSIRO fish biologist Dr Peter Last says the excitement of exploring unknown ecological communities is unparalleled. 'There is a general perception that the Australian seas are well-explored,' Last says. 'However an indication of how little is known about the deep-sea is that new species are being discovered faster today than the early explorers recorded fishes from our seas two centuries ago. 'It is a startling statistic, but we know more about the types of fishes living around Antarctica and Heard Island than we do about the fish species around much of Australia. And at ocean depths below 1500 m - which is more than 70% of the entire Australian marine jurisdiction - we know almost nothing.'

Life in these frigid, deep-sea waters where light no longer penetrates, and water pressure exceeds 100 atmospheres, cannot be called easy. If a person were to descend the depths in a submersible, and place a polystyrene coffee cup on the seafloor, it would shrink under the weight of water to thimble size. At these depths, extreme evolutionary adaptations are essential and creative life forms emerge.

Deep-sea life is characterised by bizarre body forms and extraordinary physiologies. Add isolation to the list, as is often the case with seamounts, and endemism emerges: evolution of unique life forms that are found nowhere else.

Taxonomist Dr Peter Last of the CSIRO is responsible for maintaining a record and specimens of all fishes around Australia.

Observations of catches of Trevalla in deep sea fisheries, indicated two distinct size groups. For a long time the smaller individuals were thought to be part of the same species. Because of the abundance of the smaller Trevalla, they were observed in greater detail.

Differences such as size of eye and other features appeared, so it was decided to do genetic analysis of the two Trevalla populations and the smaller population was found to be a new species.

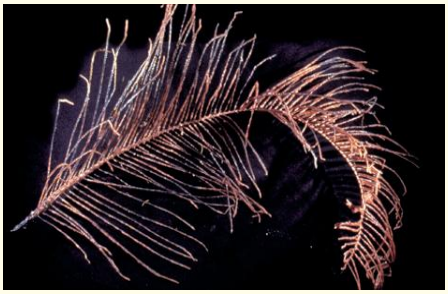


Figure 201.1 New species of black coral
(Photo CSIRO Marine Research)

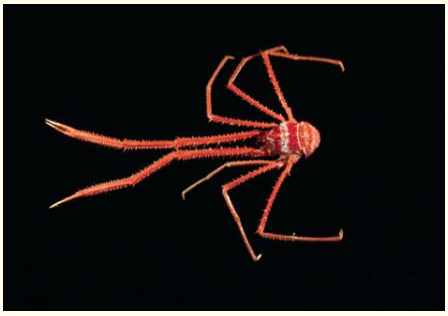


Figure 201.2 New species of lobsters
(Photo CSIRO Marine Research)

Figure 201.3 New species of cod
(Photo CSIRO Marine Research)

Questions

1. Write definitions for the following terms mentioned in the article:
   - Taxonomist
   - Endemism
   - Species
   - Seamount
   - CSIRO
   - Submersible
2. You want to dive on the reefs mentioned in the opening paragraph. Why couldn't you use conventional SCUBA gear?
3. Make a list of the different types of species referred to in the article?
4. Why is the statement "These new species are found on these particular seamounts and nowhere else, not even off the coast of New Zealand", so surprising?
5. Tropical northern Australia has low levels of endemicity (10%) compared to temperate waters (80-90%). Why do you think this is so?
6. How different genetically does an organism have to be before it is a new species?

   The fact that genetic isolation is occurring despite living together also needs to be taken into account.
7. What would happen if a polystyrene coffee cup was placed on the seafloor ?
8. The smaller Trevalla population was found to be a new species. How did the marine scientists determine this?

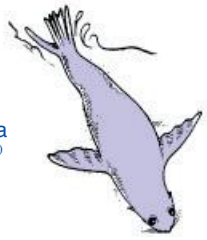
Class Chondrihthyes
(Illustration Rose Bedford)

Class Osteichthyes
(Illustration Kerry Kitzelman)

Class Amphibia
(Illustration Clip Art Explosion)

Class Reptilia
(Illustration Steven Byers)

Class Aves
(Illustration Steven Byers)



Class Mammalia
(Illustration Sharyn Madder)

Figure 202.1 Different classes of vertebrates

Identification keys

No one person could remember the names and the characteristics of all of the million or so plants and animals. Scientists use simple keys to help decide in which group the organism belongs.

The keys use certain questions on the characteristics of organisms to divide a large group into two or more subgroups. A dichotomous key is a key in which the groups are divided into only two smaller groups.

The following is a simple **dichotomous key** for classifying vertebrates into their different classes (see Figure 202.1). Vertebrates are animals that have a backbone and are discussed in Chapters 13 and 14.

1.a	The body has feathers	Class Aves
1.b	Feathers not present	go to 2
2.a	Body has hair or fur	Class Mammalia
2.b	Body has no hair or fur	go to 3
3.a	Body has fins	go to 4
3.b	Body has no fins	go to 5
4.a	Skeleton of bone	Class Osteichthyes
4b.	Skeleton of cartilage	Class Chondrichthyes
5.a	Body has scales	Class Reptilia
5.b	Body has no scales	Class Amphibia

Characteristics

The characteristics used here to " key out" will only work for the group of animals for which it was constructed. If, for example you were to attempt to classify a shellfish or an oyster using the above key, it would "key out" to Class Amphibia - an incorrect answer. Both belong, in fact, to the Phylum Mollusca. It is, therefore, important to use the correct keys.

Other keys can be used to further identify the animals. These keys are a lot more specific and a greater knowledge of descriptive terms will be required to successfully use these keys. The keys become very complicated and as the likenesses increase the characteristics used in these keys focus on minute differences between the animals.

Making a key

When choosing the characteristics to use in separating organisms in a key it is important to remember the following points.

- The characteristics used should be simple and easy to measure or see objectively. You should not use subjective terminology such as round or long. It is much better to use descriptions which can be seen or measured on one specimen. For example, rather than long, say three times longer than the width.
- For each step in the key there should be a clear choice to be made, either with or without the characteristic.
- When someone is using your key they will usually have only one type of specimen and can not compare with other types. Hence relative terms like thickest or thicker or more rounded have no meaning for the user of your key.

Exercise 8.2 Design a key

Based on an original exercise by Greg Wirth, reproduced from Marine Teachers Friend page 148 with permission.

Aim

To construct a simple key.

Materials

- Ten or more assorted buttons Figure 203.1
- Texta or small stick-on labels
- One sheet of A3 size paper

Method

1. Give each of the buttons a name or number. Write the name or number onto each button.
2. Put the buttons into a pile at the top of the sheet of paper and draw a box around them.

   Write "buttons" in this box. Draw two boxes below this box. (See example Figure 203.2)
3. Look at the buttons and find one characteristic which will divide them into two groups.

   Now write the characteristic in each box.
4. Continue doing this until there is only one button in each box. (An example, using fewer buttons is shown in Figure 203.3)
5. You have now constructed a branching diagram. Draw a smaller version in your note pad.
6. You can use your branching diagram to construct a key to "Buttons". Make a rough copy first.

   Then write your key below. (An example is shown in Figure 203.4).

Questions

1. Can anybody else use your key?
2. Can you use the keys that other students have constructed?
3. What are the best/easiest characteristics to use when constructing a key?
4. What advantages would there be for scientists using such a key for classifying animals or plants?
5. Are there any other possible outcomes to your answer? If so name one.

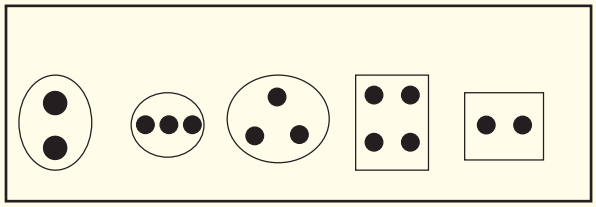


Figure 203.1 Button types

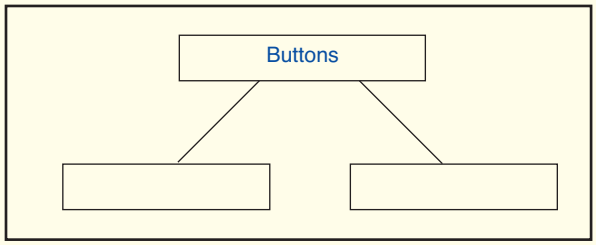


Figure 203.2 Example 1

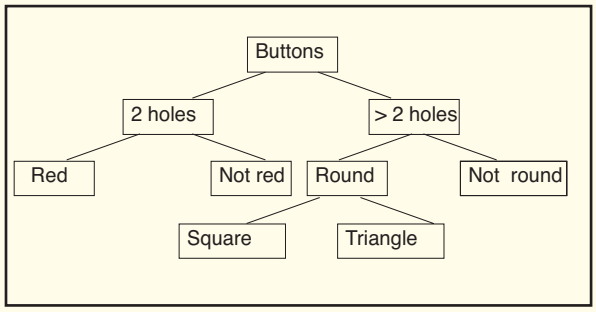


Figure 203.3 Example 2

Example button key with people

Susan, George, Barry, Bruce and Jill have all been given buttons and they have to decide how they can been identified by their button. Here is what they came up with.

1.	2 holes	go to 2
	>2 holes	go to 3
2.	red	Susan
	not red	George
3.	round	Barry
	not round	go to 4
4.	square	Bruce
	triangle	Jill

Figure 203.4 Example 3

Exercise 8.3 Shark classification

(Based on an original exercise by Mike Sugden, Hobart College, Tasmania)

Figure 205.1 shows photographs of 8 different sharks representing major shark groups (Orders).
Table 204.1 shows two ways of classifying these sharks to the order level. One is a dichotomous key, the other a chart.
Use Table 204.1 to classify each of the sharks to order level. When you have finished summarise your answer in your notebook. Try and find examples from at least three different orders.

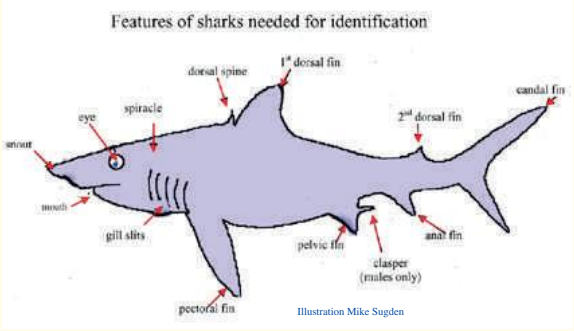
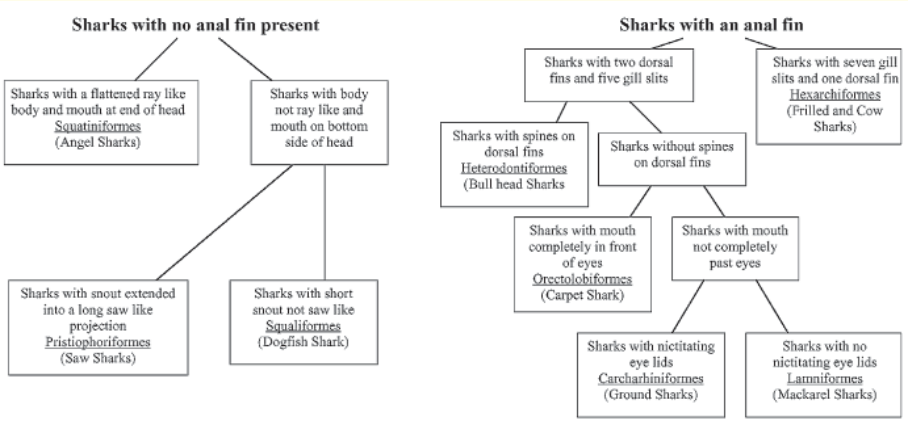


Table 204.1 Dichotomous Key for shark orders

1. a. Sharks with anal fin	4	
b. Sharks with no anal fin	2	
2. a. Sharks with flattened raylike body and mouth at end of head	*Squatiniformes* (Angel Shark)	
b. Sharks with body not raylike and mouth on bottom side of head ...	3	
3. a. Sharks with snout extended into a long saw like projection	*Pristiophoriformes* (Saw Shark)	
b. Sharks with short snout not saw like	*Squaliformes* (Dogfish Shark)	
4. a. Sharks with 6 or 7 gill slits and one dorsal fin	*Hexanchiformes* (Seven gilled Sharks)	
b. Sharks with two dorsal fins and five gill slits	5	
5. a. Sharks with spines on dorsal fins	*Heterodontiformes* (Bullhead Shark)	
b. Sharks without spines on dorsal fins	6	
6. a. Sharks with mouth completely in front of eyes	*Orectolobiformes* (Carpet Shark)	
b. Sharks with mouth not completely past eyes	7	
7. a. Sharks with nictitating eye lids	*Carcharhiniformes* (Tiger Shark)	
b. Sharks without nictitating eye lids	*Lamniformes* (Mackerel Sharks)	



Answers

A. Bullhead Sharks
B. Dogfish Sharks
C. Mackerel Sharks
D. Angel Sharks
E. Saw Sharks
F. Seven Gilled Sharks
G. Tiger Sharks
H. Carpet Sharks

Shark A

Spines on dorsal fins

Shark B

Shark C

No nictitating eye lids

Shark D

No anal fin

Shark E

No anal fin

Shark F

Shark G

Nictitating eye lids

Shark H

Figure 205.1 Shark photographs for Exercise 8.2
(Photographs courtesy Dr. Peter Last CSIRO)

You are making good progress if you can

- recognise that biodiversity includes the diversity of species and ecosystems
- determine diversity of species using indices such as: species richness, evenness (relative species abundance), percentage cover, percentage frequency, Simpson's diversity index
- use species diversity indices, species interactions (predation, competition, symbiosis, disease) and abiotic factors (climate, substrate, size/depth of area) to compare ecosystems across spatial and temporal scales
- explain how environmental factors limit the distribution and abundance of species in an ecosystem

Kingdom of living things

When Aristotle first devised his classification system he divided all living things into two kingdoms - plants and animals.

For a long time scientists have classified all living things into two kingdoms, plants and animals. However better technology and a greater understanding of the characteristics of living things have made this simplistic classification increasingly difficult to work with.

There are many living things which don't fit clearly into either kingdom. Hence today, many biologists believe there should be five kingdoms and some believe we should have even more. As technology allows us to probe deeper and deeper into the structures of living things, so our classification system should be flexible or dynamic enough to accommodate these changes in our understanding of living things.

Kingdoms

This book will use the five kingdom system for classifications. The differences between the five kingdoms are set out in Figure 206.1 and summarised in Figure 207.1 opposite.

Animalia

Organisms having cells with a distinct nucleus, no cell wall or chloroplasts. Nutrition is via ingestion of materials from an outside food source (heterotrophic). A nervous system, able to move and is multicellular.

Plantae

Organisms having cells with a distinct nucleus, a cell wall and chloroplasts. Nutrition via photosynthesis (autotrophic). No nervous system, unable to move and multicellular.

Fungi

Organisms having cells with a distinct nucleus, a cell wall and no chloroplasts. Nutrition by absorption from an outside source (heterotrophic). No nervous system or locomotion and multicellular except in yeasts.

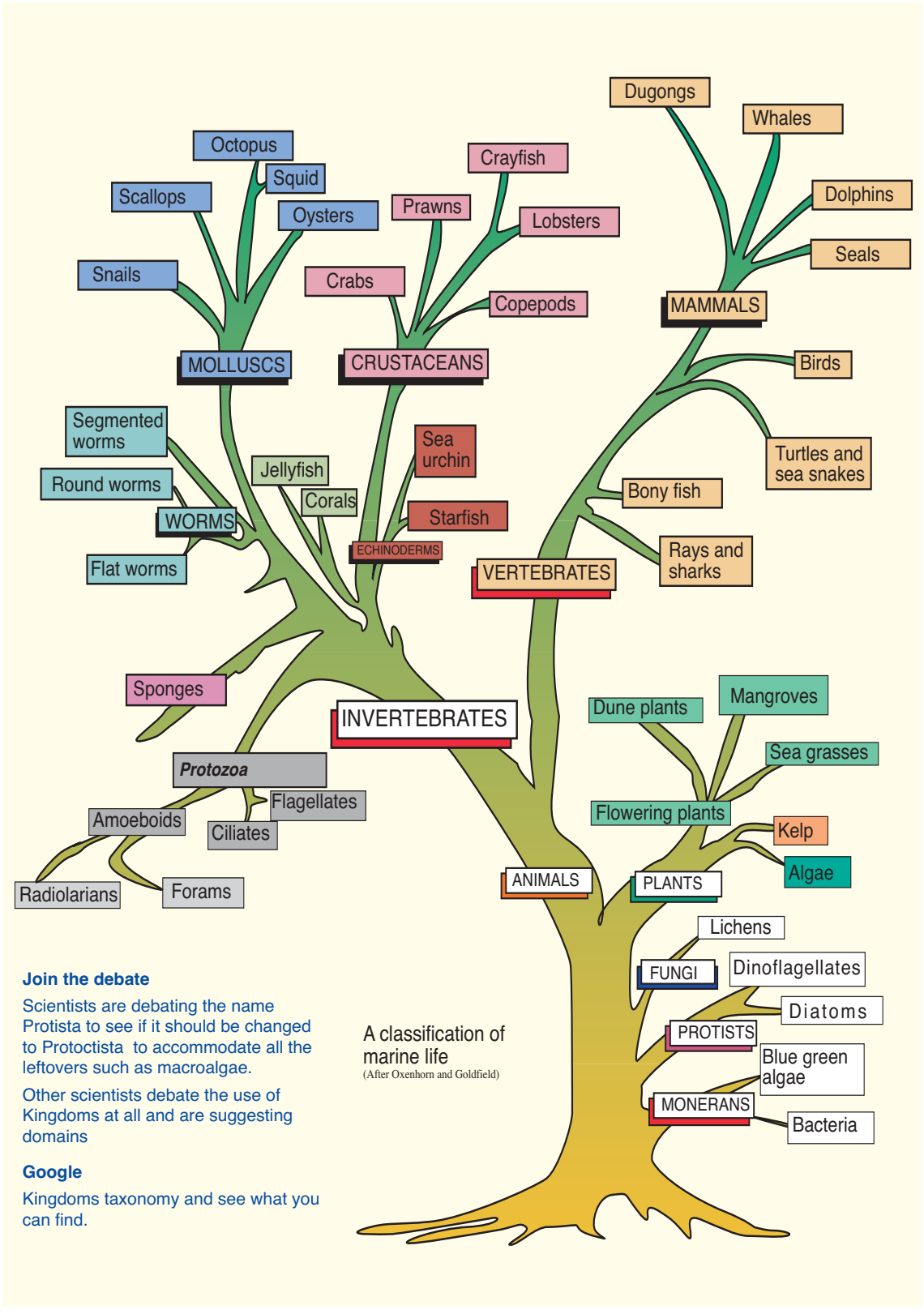
Protista

Organisms having cells with a distinct nucleus, and chloroplasts in some forms. Nutrition can be by indigestion of food materials (heterotrophic) or by photosynthesis (autotrophic). No nervous system, locomotion in some forms and mainly single celled or if multicellular lacking any transport system and having very little coordination or cooperation between cells.

Monera

Organisms having cells with no distinct nucleus or chloroplasts. Nutrition which can be either heterotrophic or autotrophic (chemosynthesis or photosynthesis). No nervous system or locomotion (in most forms) and no multicellular forms.

Figure 206.1 The five kingdoms of life on Earth



A classification of marine life
(After Oxenhorn and Goldfield)

Join the debate

Scientists are debating the name Protista to see if it should be changed to Protoctista to accommodate all the leftovers such as macroalgae.

Other scientists debate the use of Kingdoms at all and are suggesting domains

Google

Kingdoms taxonomy and see what you can find.

Figure 207.1 The tree of marine life
(Illustration Bob Moffatt)

Activities from our 2009 Marine Biology exercises book

C1. What lives in the tree of marine life?

C2. How are sharks and rays classified?

C3. Why do we need a system to classify marine life?

C4. What is the definition of a species?

C5. How are new species discovered?

C6. How are identification keys made and used?

C7. What structural characteristics separate out the Marine phyla?

The importance of biodiversity

From Exploring Biodiversity Australian Science Teachers Association 2001

In his book, *Exploring Biodiversity*, Bob Winters identified two linking views of why biodiversity is important. He says that ...

1. *People who care about the environment feel strongly that other living things have the right to survive alongside people. To them other living things do not need to benefit humanity directly to have a right to exist.*
2. *Environmental experts and others see many compelling benefits to humanity by protecting the earth's biodiversity. Among these is humanity's very own survival. As people learn more about the amazing complexity of the earth's biodiversity, they will discover more and more direct benefits.*

Marine biodiversity

Text on pages 208-211 is an adaptation of an original written by Harry Briedahl for Seaweek 1999, copyright MESA and Environment Australia and is reproduced with permission.

The word **biodiversity** is a relatively new one that is a shortened version of the term 'biological diversity'. In its simplest form, biodiversity refers to the number and variety of earth's life forms. This not only includes all of the different species (types) of familiar plants and animals but also includes less well known organisms such as bacteria and other microorganisms.

To date biologists have counted almost 1.8 million different species of living organisms. However, this count is only the tip of the iceberg and estimates of the number of different species on earth vary from 5 million to 100 million with 30 million being a widely accepted figure.

Definition

Biological diversity is the variety of living things, the genes they contain, and the ecosystems of which they are a part (after the National Strategy for the Conservation of Australia's Biological Diversity).

Three diversities

A broader definition of biodiversity goes beyond simply counting species to include genetic variety and variability within each species and the ecological complexes in which they occur.

Hence a widely accepted definition of biodiversity states that:

Biodiversity is the variety of all life forms; the different species of plants, animals and microorganisms, the genes they contain and the ecosystems of which they form a part.

As a result of this broadened definition, scientists often talk about three levels of biodiversity:

- **Genetic diversity** - refers to the genetic variety and variability within each species. Genes vary between individuals within a species. It is this variation which is genetic diversity.
- **Species diversity** - the number of different species living on earth. At present almost 1.8 million species have been discovered and described by scientists. It is the total variety of all the species in an area that makes the diversity.
- **Ecosystem diversity** - refers to variety in the combination of species that form ecosystems such as ponds, coral reefs, forests or grasslands. It is the variety of ecosystem types that is ecosystem diversity.

Biodiversity and genes

Genetic diversity refers to the variation of genes within a species. The human species makes a wonderful starting point for a discussion of genetic variability and a typical Australian classroom is a great place to commence. In a class of around 30 students you would expect to find a wide variety of body shapes and sizes, eye colour, hair colour and skin colour.

Carrying out a survey of this variability within a class, or perhaps even a whole school, would be one way to introduce the topic of genetic diversity.

The same variability of things such as shape and colour is exhibited in many marine species.

Genetic library

The underlying cause of this variability within species is to be found in the variety of genes that control each feature an individual organism displays. The value and importance of this genetic variability is best expressed in the following quotation:

In his book — *Australia's Biodiversity,* Andrew Beattie, compared biodiversity with a library. The species are the books and they contain vast amounts of genetic information. Libraries are useful because their books contain information that may be of immediate use, important in the future or simply contribute to the cultural wellbeing of society. But in the biodiversity library, vast quantities of books are hidden, others are in storage waiting to be catalogued, while only a small proportion have been read.

In an original idea, a group of authors from the Australian Academy of Science came up with a hand angle experiment to show the individual differences among species. You can do it as a class where you take a photocopy of your hand and measure the angle as shown in Figure 209.1. Draw up a table and compare the angles in your class and other classes. The angle is the indicator of genetic diversity. Unfortunately with fast foods and poor diet the hand angle could have been altered by the environment and so the never ending debate - environment or heredity emerges.

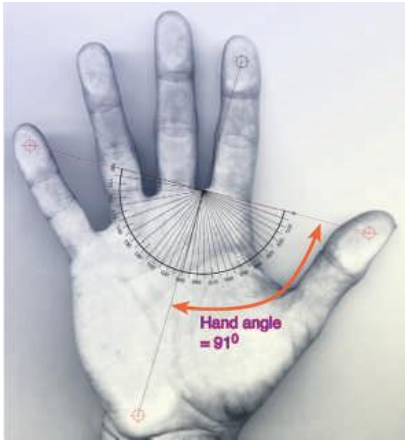


Figure 209.1 An example of genetic diversity
(Photo Bob Moffatt)

Life on earth

A brilliant site about classification, well worth exploring. Simple but comprehensive and lots of further links

www.ucmp.berkeley.edu/alllife/threedomains.html

Species level diversity

Species level diversity refers to the number of different species on earth. At present the count is approaching 1.8 million living species, with estimates of the actual count varying between 5 million and 100 million. Being able to recognise all 1.8 million species is an impossible task for a single person but getting to know some of your local marine life is achievable.

Chapters 9-14 are designed to give you a greater understanding of the variety of life forms in the sea and surrounding coastline.

Disappearing species

Over the years there has been a serious loss of diversity on our shores due to the constant collecting of marine life for food as well as increased nutrient levels caused by pollution from the land. Old timers will tell you that there used to be shells in their hundreds washing up on the beach, or large shoals of fish that would graze on invertebrates close in to shore. If you go to a local city beach or rocky shore, it will be difficult for you to appreciate what this might have looked like 25 or 50 years ago.

It is hoped that by establishing marine parks, your children will be able to see what is left!

(Illustration Sharyn Madder)

Endemic means found nowhere else in the world.

Ecosystem diversity

Ecosystem diversity is the variety of ecosystems in a given place. An **ecosystem** is a community of organisms and their physical environment interacting together. An ecosystem can cover a large area, such as a whole forest, or a small area, such as a pond.

An ecosystem may be as large as the Great Barrier Reef or as small as the back of a spider crab's shell, which provides a home for plants and other animals, such as sponges, algae and worms.

Biodiversity in the ecosystem is not just the number of different species, it is also the variation within them and the different roles they have in forming ecosystems.

Ecosystems are complex because they are formed by a variety of interactions between species.

Food webs are one important type of interaction, but species can provide an attachment base for other species, can alter current or light patterns, provide camouflage or other forms of shelter or compete for space.

Ecosystems are functional units of the marine world because they provide services beyond those performed by the individual species with which they are formed. Jellyfish, worms and sea lice can be just as vital as whales, whiting and seadragons for their role in the ecosystem.

Ecosystems are dynamic because of constantly changing physical conditions such as tides or seasons and other natural processes such as storms.

The term "ecosystem" has been applied to interactions over a range of scales from small communities spanning metres to the global marine ecosystem. In the same way that a variety of species interact to form ecosystems, smaller ecosystems interact and provide functions for larger ecosystems. For example, the fish species of a gulf ecosystem might be dependent on deep water ecosystems (for spawning habitat for adults) and mangrove ecosystems (as a nursery for juveniles) within it.

Ecosystems can be classified at different scales using parameters such as geology, coastal landforms, water temperature, salinity, currents, upwellings, wave exposure, depth, and patterns of major life form type (eg seagrass).

The proper functioning of the marine environment is dependent on its ecological integrity, which means that all ecosystem components are present, operational and ecologically viable, ie sufficiently numerous to play their ecological role.

Marine ecosystems are continually changing over periods of hours, days and seasons, but also adapt over centuries or even decades to meet changing conditions.

The variation in individual species (genetic diversity) enables them to evolve, and species diversity allows ecosystems to evolve.

Odd facts

The marine biodiversity of southern Australia evolved in isolation from the rest of the world.

Consequently, many of the species are endemic (unique to the area - found nowhere else in the world), for example:

- 75% of our red algae
- 85% of our fish
- 90% of our echinoderms
- 95% of our molluscs
- 95% of our seagrasses

In contrast, less than 15% of tropical marine fauna and flora from the same groups are endemic.

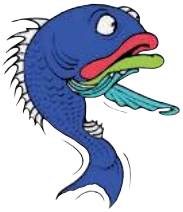
South Australia is a hot spot for endemism, with many species found only there.

Ecosystem

A dynamic complex of animals, plants and micro organisms and the associated non-living environment interacting as an ecological unit. An ecosystem may exist across a range of scales and may include several hierarchical levels (after the National Strategy for the Conservation of Australia's Biological Diversity, King, 1993).

Large Marine Ecosystem

Large Marine Ecosystems (LMEs) are relatively large regions, of the order of 200,000 km^2 or more, characterised by distinct bathymetry, hydrography, productivity, species composition and trophically inter-dependent populations (Sherman and Alexander, 1986).



(Illustration Sharyn Madder)

Ecosystems are also discussed in Chapter 16

Biogeography

Biogeography is the name given to the study of the distribution of life on earth. Biogeographers use a complex combination of the distribution of past and present life, geography and climate to currently recognise two major regions for Australia's coastline:

- The Northern Australian Region.
- The Southern Australian Region.

The boundary between the tropical and warm temperate provinces coincides approximately with 18-20ºC winter minimum surface temperature but this is variable and dependant on the influence of the East Australian Current and the Leeuwin Current.

The distribution patterns seen today are the result of evolution of marine organisms from the tertiary period (See chapter 1).

Northern Australian Region

Open shores in northern Australia are typified by extensive growths of coral reefs. Sheltered shores support over 30 species of mangrove and have little salt marsh vegetation. Northern coral reefs have a high diversity of fish and invertebrates. However, only 10% to 15 % of northern Australian marine species are endemic (found only in that part of the world).

Southern Australian Region

Rocky shores in southern Australia are typified by extensive growths of massive brown seaweeds, called kelps. Sheltered shores support extensive salt marshes and only one species of mangrove. These shores have the world's highest diversity of seaweeds and some invertebrate groups. 80% to 90% of southern Australian marine species are endemic.

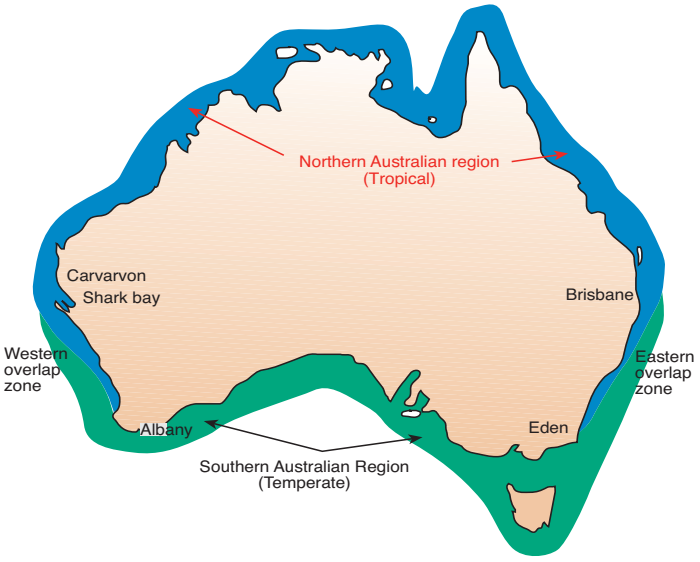


Figure 211.1 Major faunal regions of the Australian coast (after Wilson & Gillett 1971 in SOMER 1996).

A matter of definition

The two regions described here represent only one of the many schemes that research into Australian marine biogeography may uncover. Past schemes, for example, refer to as many as three tropical marine provinces and four temperate provinces around the shores of Australia.

A matter of scale

The other factor that needs to be considered is that of scale. Humans see things at one particular scale and any creature less than a millimetre or so in size is easily neglected.

As far as marine ecosystems are concerned, this is a rather unfortunate oversight because many open ecosystems depend on the microscopic life that drifts about in the sunlit upper layers of the ocean. This microscopic life, called plankton, is the starting point of most open ocean food webs and therefore a vital part of marine ecosystems.

Scale also comes into play when it comes to ecosystem diversity because whole communities of microscopic organisms live out their lives by existing on or between the sand grains in marine sediments. Meiofauna is the name given to such microscopic animals that measure between 0.5 mm and 0.062 mm while the terms microfauna and microflora refer to any such organism less than 0.062 mm.

The SOMER 1996 report suggests that tropical coasts can be divided on the basis of water turbidity: northern Western Australia, Northern Territory and Queensland where high monsoonal summer rain and dry winters result in grey mud sediments inshore and well developed mangrove creeks; and northwestern Western Australia where rainfall is low and irregular, with occasional cyclonic disturbances and flash flooding resulting in brown sediments.

Marine bioregions

For more information about marine bioregions and current work on the mapping of marine bioregions in Australia visit the Environment Australia web site at:

www.environment.gov.au/marine/coastal_atlas/index.html

Exercise 8.4 Diversity

Based on original ideas by Nancy Tsernjavski and Angela Colliver

Part A: What to do

Form groups of about 5-6 and use the poster on Page 213 as a discussion starter to answer the questions below.

Questions

1. The poster depicts a range of marine organisms in various habitats spanning coastal dune to intertidal zone, rock pool, reef and open ocean, through the zone of light and into the zone of perpetual darkness.

   What does your group think of the graphic, its characteristics and setting in attempting to explain species diversity?

   a. Make a list of the types of animals and plants you can identify.
   b. Classify them as best you can using the tree of marine life (Page 207).
   c. Make a list of the external features for each organism.
2. What is the difference between genetic, species and ecosystem diversity? Use the illustrations in the graphic to give an example of each.
3. Use the key on page 202 to devise a new key for the vertebrates shown in the graphic.
4. Draw up a two column table with temperate and tropical as headings. Now list under each heading where you think the animals and plants in the graphic would be found.
5. Study the images on pages 214 - 215 .
   a. Make a copy of each illustration and draw food webs for each.
   b. Using the tree of marine life, classify into animal and plant groups each of the marine organisms shown.
   c. Draw up a table to distinguish between the four different ecosystems shown.
   d. For each ecosystem, make a list of at least 4 individuals not shown.
6. Explain this statement:

   Food webs are one important type of interaction, but species can provide an attachment base for other species, can alter current or light patterns, provide camouflage or other forms of shelter or compete for space. (See page 210, para 5, for context).
7. What are the five kingdoms of marine life depicted and what characteristic/s separates them from each other?
8. Name one or more animals from the following groups in the illustration; Mammalia; Reptilia; Osteichthyes; Chondrichthyes; Amphibia; Mollusca; Cnidaria; Arthropoda; Mollusca; Echinodermata; Plantae.

Part B: Calculate Simpson's Biodiversity Index

A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance.

Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases.

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right)$$

n = the total number of organisms of a particular species

N = the total number of organisms of all species

The value of D ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity.

- To calculate Simpson's Index for Hypothetical Bay, two areas (natural vegetation and disturbed vegetation) were sampled using quadrats placed randomly or systematically. The number of plant species within each quadrat, as well as the number of individuals of each species should be noted. There is no necessity to be able to identify all the species, provided they can be distinguished from each other.
- As an example, let us work out the value of D for a single quadrat sample of ground vegetation in the Hypothetical Bay dunes. Of course, sampling only one quadrat would not give you a reliable estimate of the diversity of the dune flora. Several samples would have to be taken and the data pooled to give a better estimate of overall diversity.

  The method used to optimise the sampling is the Optimum Quadrat Size technique.

Species	Number (n)	n(n-1)
Spinifex	2	2
Goats foot	8	8
Sea oak	1	0
Banksia	1	0
Wattle	3	6
	N=15	∑ n(n-1) = 64

- Now put the figures into the formula for Simpson's Index above

Answer

$$D = 1 - \left(\frac{64}{15(14)} \right)$$

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right)$$

Simpson's Index of Diversity = 0.7

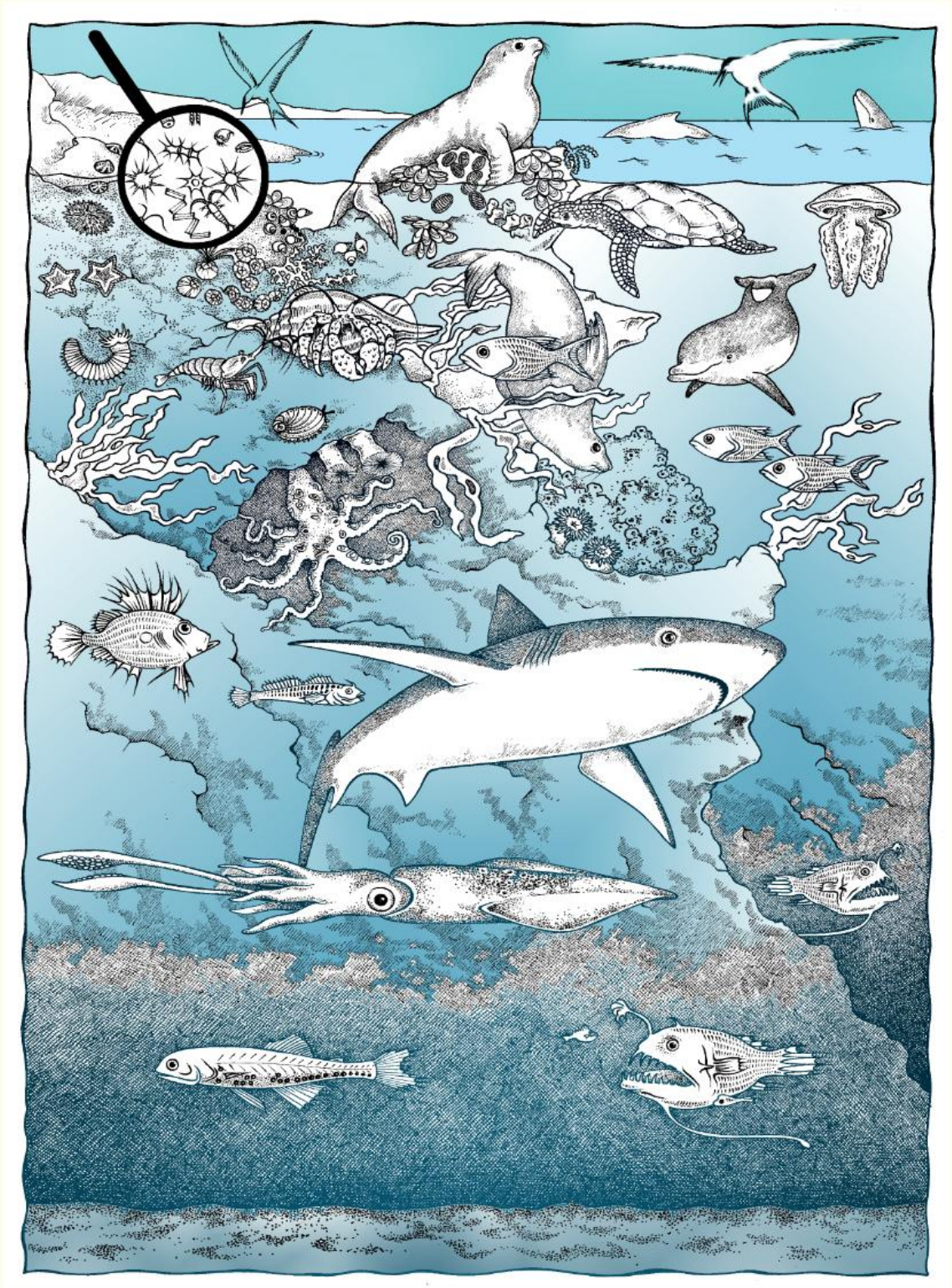


Figure 213.1 Diversity: This poster depicts a range of marine organisms in various habitats spanning coastal dune to intertidal zone, rock pool, reef and open ocean, through the zone of light and into the abyssal zone
Concept Nancy Tsernjavski, Illustration by Sharyn Madder, copyright MESA, reproduced with permission.

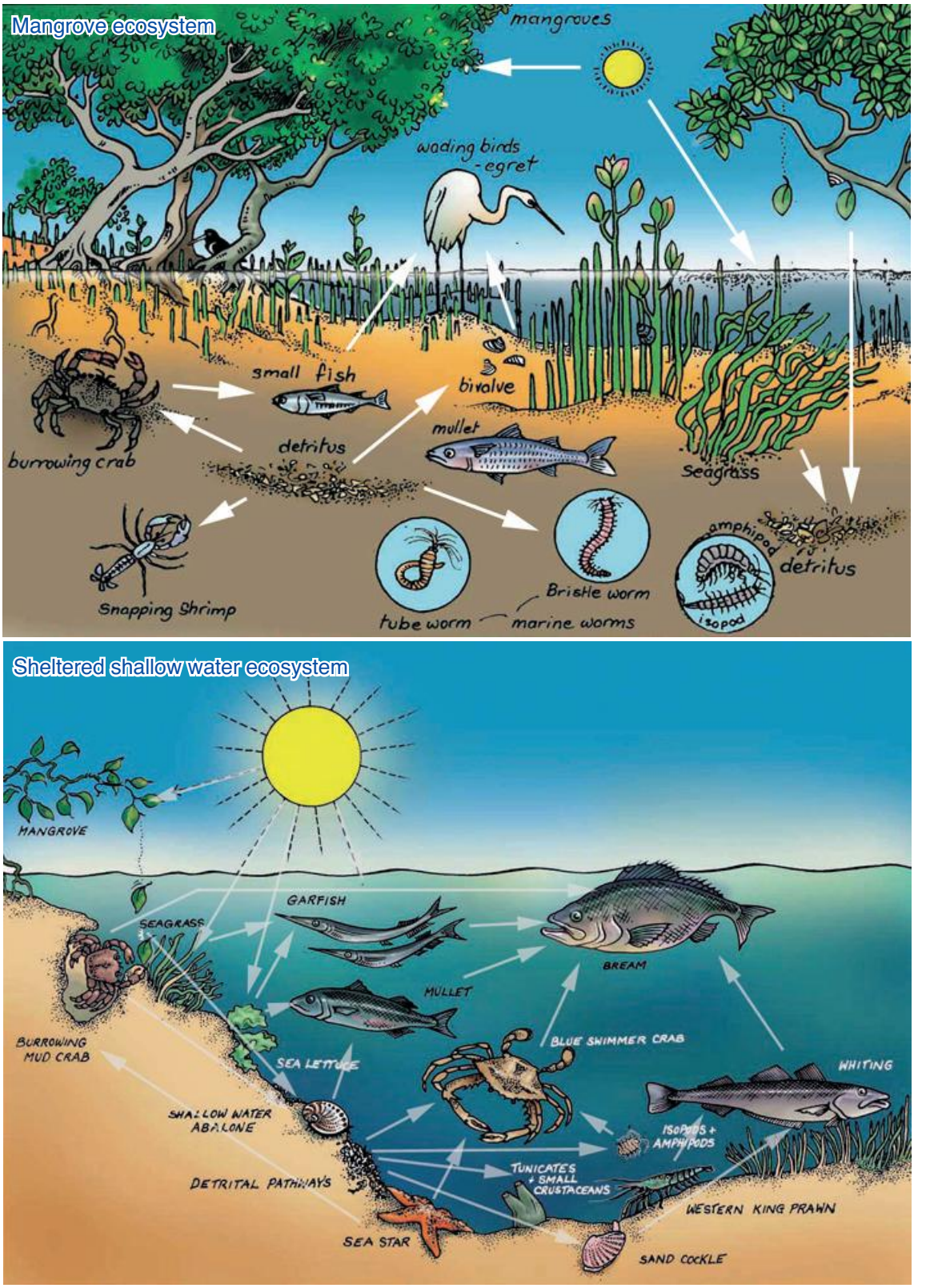


Figure 214.1 Mangrove and sheltered waters ecosytems
Concept by Nancy Tsernjavski, Illustration by Sharyn Madder, copyright MESA, reproduced with permission.

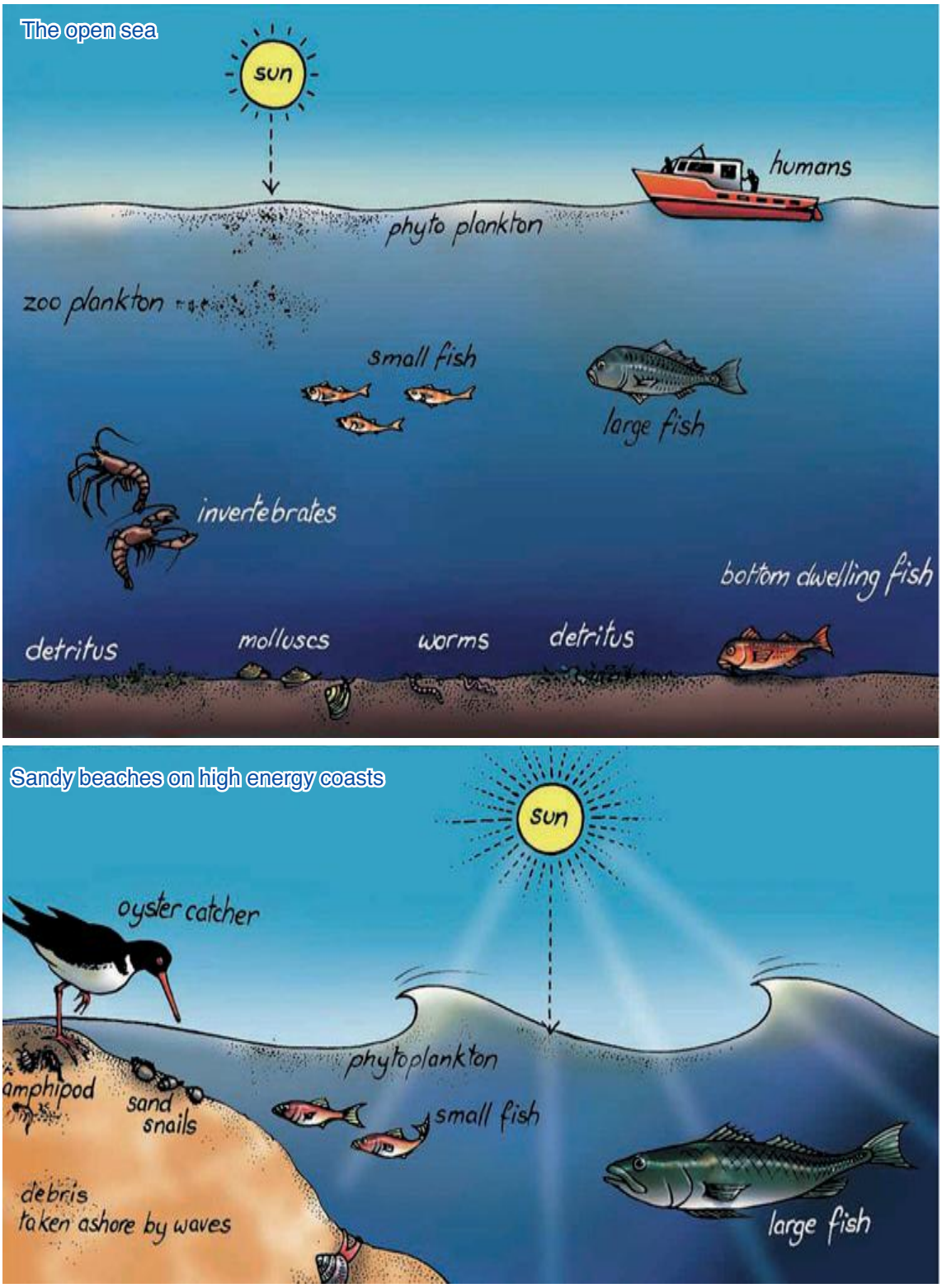


Figure 215.1 Open sea and sandy beach ecosystems
Concept by Nancy Tsernjavski, Illustration by Sharyn Madder, copyright MESA, reproduced with permission.

Case study 8.2 Biodiversity and conservation

Tropical waters

Great Barrier Reef World Heritage Area

Activity copyright Great Barrier Reef Marine Park Authority, reproduced with permission.

Ask someone what makes the Great Barrier Reef World Heritage Area (GBRWHA) so special and they will probably mention coral reefs. However, the GBRWHA is wonderfully diverse in other habitats that make up about 94% of the Area, and like the coral reefs, these areas need to be protected too.

Biodiversity of the Reef

The GBRWHA is one of the most diverse environments in the world, containing islands, coral cays, deep ocean troughs, mangroves, sands, algal and sponge gardens, seagrasses and more. It is also home to:

- over one third of the world's soft coral species;
- over 1,500 species of fish;
- six of the world's seven species of marine turtle, and the world's largest green turtle breeding area;
- one of the world's most important dugong populations; and
- breeding areas for seabirds and humpback and other whale species.

Conserving the GBRWHA's biodiversity

The Great Barrier Reef Marine Park Authority (GBRMPA) has state, national and international obligations to conserve and protect the GBRWHA's biodiversity. The GBRMPA manages conservation through:

- working in partnership with the users (like commercial fisheries and tourist operators), indigenous groups and relevant authorities;
- community education and consultation;
- identifying and protecting Representative Areas;
- promoting sustainable resource, tourism and recreational use; and
- using a 'precautionary principle'. (Sometimes, not all the information is available at the time of making decisions. However, the Authority aims to pre-empt issues and impacts, and prevent future problems, rather than waiting to see what happens and then dealing with the consequences.)

Representative Areas and zones

A Marine Park Representative Area is one that 'represents' its surrounding habitats and communities. The aim of the GBRMPA's Representative Area Program is to protect biodiversity within the GBRWHA by identifying areas that need conservation and making them green zones. Green zones are areas that are off-limits to all extractive activities, therefore conserving the biodiversity of the area and protecting rare and threatened species.

(Illustration by Sharyn Madder, copyright MESA, reproduced with permission.)

Rare and threatened species

Biodiversity is critical to the survival of the GBRWHA's rare and threatened species. The GBRMPA works to protect them by identifying threatened species and the threats to their survival, and developing and implementing management actions.

The GBRMPA uses a set of criteria to work out whether a species is' 'threatened'. Dugongs and turtles are identified as the GBRWHA's most threatened species, with seabirds and cetaceans (whales and dolphins) also of concern.

The impact of threats on the dugong and turtle species is hard to see due to their long lives and slow reproduction. Dugongs and turtles also live close to the shore, coming into regular contact with humans. Because of this, they are vulnerable to threats such as habitat destruction (linked to water quality), increased tourism, coastal development, commercial fishing like netting and trawling, and hunting.

Working together to conserve biodiversity

The GBRWHA is a beautiful, wonderful and diverse environment, which needs to be conserved for future generations to enjoy. All users have 'ownership' of the Reef, and are responsible for using it in a sustainable way. The GBRMPA works in partnership with users to ensure that their issues and needs are addressed, through formal consultation processes and ongoing discussions.

Queensland Parks and Wildlife Service (QPWS) and the GBRMPA work together to manage day-to-day use of the GBRWHA. They make sure that all activities are responsible, permitted, and occur within the right zone. The GBRMPA also works with other state, local and international authorities to protect the GBRWHA's biodiversity and threatened species.

Managing the biodiversity of the Great Barrier Reef is about deciding what we all agree on, working together towards common goals, working out what we don't agree on, and finding solutions. This way, we can all enjoy the Reef and protect its future.

IDENTIFYING AND EXPLORING BIODIVERSITY

Recording facts, feelings and opinions about the Great Barrier Reef, its biodiversity and threatened species is one way to identify the issues of biodiversity.

Many people feel that it is important to protect biodiversity and they have diverse reasons for thinking so. What reason can you give for protecting the Great Barrier Reef Marine Park's biodiversity?

YOUR TASK

Read the statements in Figure 217.1 representing many of the key reasons people have given for protecting biodiversity, and answer the question below.

Question

Read each statement, compare the ideas and choose one you feel strongly about - either because you think it is an important reason to protect biodiversity or because you disagree with it.

Now write a report or prepare a brochure which conveys detailed information about:

a Biodiversity of the Great Barrier Reef (plants, animals, fungi and micro-organisms);

b. Distribution of species;

c. Threatened species; and

d. Management actions coordinated by the Great Barrier Reef Marine Park Authority in cooperation with other government agencies, researchers and industry groups.

Statements

1. It is important to conserve the diversity of marine life on the Great Barrier Reef for medical and economic reasons. Marine plants and animals could provide us with additional medicines and foods that will save lives and benefit society.
2. It is important to protect the diversity of life because biodiversity helps maintain important ecological processes such as oxygen production, continuation of the processes of photosynthesis and respiration, cycle of natural predation and maintenance of all life forms.
3. It is important to protect the diversity of life because no generation has the right to destroy the environment and resources on which future generations depend. It is our responsibility to take care of the diversity of the plants and animals of the Great Barrier Reef Marine Park.
4. It is important to protect the diversity of life because biodiversity provides inspiration and provokes curiosity and imagination. Art, music and poetry are often inspired by the diversity of life. Many of our technological advances are often inspired by the examples found in nature.
5. It is important to conserve the diversity of life because all species have a right to exist.

Figure 217.1 Key reasons people have given for protecting biodiversity.

(Illustration by Sharyn Madder, copyright MESA, reproduced with permission.)

TEMPERATE WATERS

SOUTH AUSTRALIA'S MARINE BIODIVERSTIY

Activity by Bob Moffatt.

The southern coast of Australia is characterised by its temperate (cool) waters. South Australia has one of the longest and most varied marine and coastal environments in Australia with a wide range of coastline types (eg steep cliffs, shallow bays and sandy beaches), average temperatures (from 12 to 25 °C), wave exposures (from the full force of the Southern Ocean to the sheltered gulfs), rock and sediment types (eg limestone, granite, mud, sand).

YOUR TASK

Look up the SA gov web site (or other Tas, Vic or NSW): www.environment.sa.gov.au/coasts/marine_biodiversity.html and complete the following:

1. Write a report or prepare a brochure which conveys detailed information about the:
   - Biodiversity of the South Australian Region (plants, animals, fungi & micro-organisms);
   - Distribution of species;
   - Threatened species; and
   - Management actions coordinated by present authority who manages the coast protection act (1972). In 2003 it was the Coast Protection Board.
2. Detail some of the ways this board has
   - protected the coast from erosion, damage, deterioration, pollution or misuse;
   - restored any part of the coast which has been subject to any of the above;
   - developed any part of the coast for the purpose of aesthetic improvement, or for the purpose of rendering that part of the coast more appropriate for the use or enjoyment;
   - carried out research into matters relating to the protection, restoration or development of the coast.

Figure 218.1 Mudcrab
(Photograph courtesy Qld Fisheries)

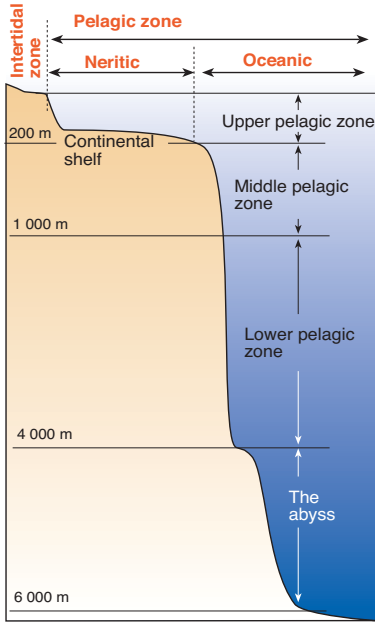


Figure 218.2 Habitats can be divided into zones.
(Illustration Bob Moffatt)

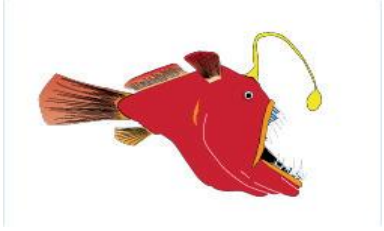


Figure 218.3 The abyss contains many strange looking animals.
(Illustration Mark Moffatt)

Sea habitats

Places where animals and plants live in the sea are called **habitats**.

Marine scientists name habitats after characteristic features such as rocks, plants or the nature of the water. For example, crabs can live in either a muddy or sandy habitat.

All organisms have become adapted to the different habitats they have grown up in over a long period of time.

For example, the only animals that will survive on a rocky shore are those that can withstand the drying effect of the sun called desiccation, wind and waves.

The mudcrab in Figure 218.1 could not live in a rocky shore because its body is too big to fit in the rock crevices so it would get smashed to pieces by the first big wave. So you do not find mud crabs on rocky shores.

As we have seen, ecosystems are a combination of habitats and can be as small as the space under a rock or as large as a barrier reef. The study of ecosystems becomes important when scientists try to get the big picture of life on this planet.

Different habitats

The sea is full of different habitats that are divided into the zones shown in Figure 218.2.

Intertidal zone

The intertidal zone is the zone closest to the shore and contains many habitats. Saltmarshes, seagrass beds, reefs, rocky pools, under rocks, mangrove swamps, muddy and sandy shores are just a few of the habitats that support a large amount of life. Living close to the land means that many coastal habitats have a direct influence on the sea.

Pelagic zone

Neritic

The continental shelf zone contains offshore islands, shallow reefs and waters to a depth of about 200 m. This zone contains the highest number and greatest diversity of marine life and because it is covered by water, it is subjected to great environmental pressures such as over-fishing or pollution.

Oceanic zone

Beyond the continental shelf is the pelagic zone, which extends over the ocean depths and on a vertical scale can be divided into three layers. The upper layer, into which light can penetrate, ranges from 0-200 m. This zone contains the phytoplankton of the sea that make oxygen for our planet. The middle and lower layers extend from twilight to perpetual darkness. These layers range from 200-4000 m.

Abyss

The amount of light in this zone is too low to support photosynthesis. The bottom of the sea is called the abyss (4000-6000 m) where strange animals such as the lantern fish live (Figure 218.3).

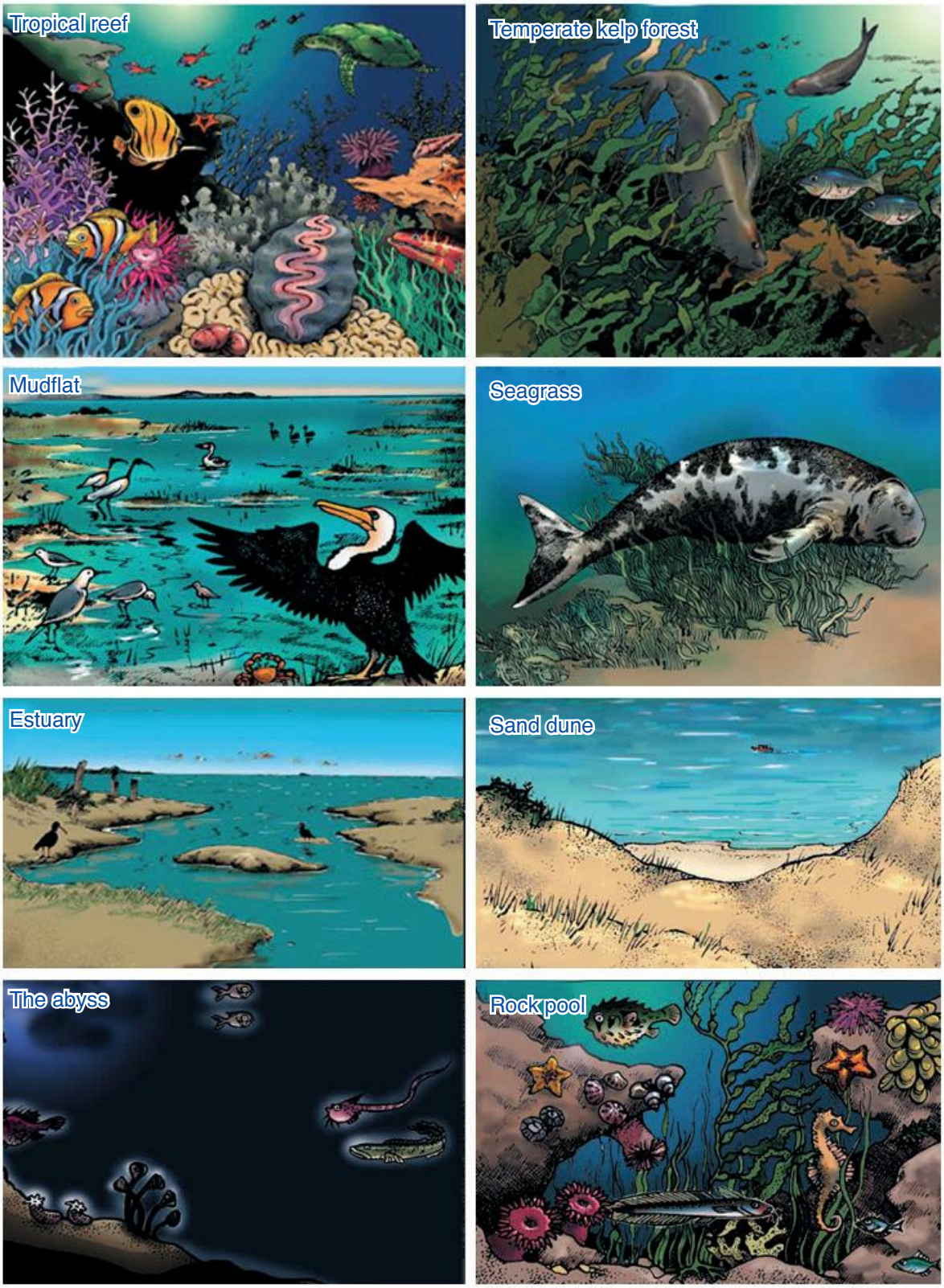


Figure 219.1 Concept by Nancy Tsernjavski, Illustration by Sharyn Madder, copyright MESA, reproduced with permission.

Figure 220.1 Kelp from temperate reef
(Illustration by Sharyn Madder, copyright MESA, reproduced with permission)

Figure 220.2 Enormous seagrass beds form in estuaries in temperate waters.
(Photograph Bob Moffatt)

Intertidal zone

Tropical reefs

The animals found in the different types of coral reef differ from reef to reef, but have the same general structure (see chapter 11). The life on the reef is complex and intriguing. There are over 1500 different species of plants and animals living on a reef. These reefs are restricted to the warmer seas of the world (temperature above 20°C).

A reef begins to form when a shallow area of the sea floor can provides suitable conditions to encourage and support benthic plant and animal colonization. Such conditions include the presence of a solid surface that is free from excessive mud and sand. Seawater must be relatively clear, warm and shallow, having sufficient movement to circulate oxygen and plankton amongst the colony's organisms. The plants and animals grow upwards and outward. They eventually die. Their skeletons and shells are cemented together by the calcareous algae (see chapter 9).

Temperate kelp beds

The diversity of life increases dramatically with colder water. Some reasons for this are that the water can hold more oxygen, there is a greater supply of nutrients and the mixing of water from convergent currents brings enormous food supplies for bigger animals up the food chain.

Temperate regions are characterised by enormous kelp beds in cold water ranging from 5-18 °C. The kelp needs to be anchored to the hard substrate by a holdfast (Figure 220.1) and moves with the currents. Kelp beds have often been called the forests of the seas because they provide a wide range of places for animals of all shapes and sizes to hide as well as places for a wide variety for plants to grow.

Seagrass meadows

Seagrass is the dominant plant and stabilises the sandy bottom, acting as a food resource and functioning as a nursery area and shelter for animals and other plants (Figure 220.2). The leaves of seagrass reduce current velocity and increase the amount of sediment that can 'settle out'.

Dense root systems bind the sediments together, reduce surface erosion and play an important part in coastal protection. Seagrasses provide food for turtles, sea urchins and dugongs while fish feed off the algae that grows on the seagrass leaves. Water birds eat seagrass at low tide and contribute to the high productivity in this type of ecosystem. The seagrass converts the sun's energy into food for the ecosystem.

Estuaries

The tidal flows in estuaries brings a constant supply of food for the animals and plants that live there. Nutrients are usually high because of the large variety of sediment and seagrasses.

Sediments are also filled with a high diversity of invertebrate including crabs, molluscs, worms and juvenile fish. At low tide birds are able to feed of this abundant food supply and return nutrients to the mud. With the incoming tide small fish feed off the smaller invertebrates. Larger predators like flathead (Figure 221.1) hide around rocks to capture the smaller fish. Estuaries are subject to large changes in temperature, water levels, salinity and sediment flows.

Figure 221.1 Flathead
(Photo Bob Moffatt)

Rocky shores

Most coastal towns of Australia would have a rocky shore somewhere nearby and it seems reasonable to use this as the first example in marine ecosystems. Rocks provide the places for the marine organisms to live and the tide brings in life giving forces.

A rocky shore has a wide variety of shapes and sizes. It could be a long, flat wave cut platform with numerous pools and boulders or a cliff face with large boulders scattered along the bottom. Whatever the case, the gaps and cracks provide places for animals to live and they must have certain features that help them survive.

The rocky shore is a hard place to live. Waves continually break with great force and the tide goes out twice a day leaving organisms exposed to heat and predators. If organisms live in a pool, the pool can dry up or the water in it becomes very saline creating great difficulties for an organism's bodily function.

Tides have a great influence on rocky shores, with some animals and plants timing their reproductive cycles to coincide with the high waters of the spring tide.

The rocky shores are usually heavily populated with a diverse group of animals. The water contains a large amount of oxygen and nutrients because of the high turbulence caused when the water crashes on the rocks.

Traditionally scientists have divided the rocky shore up into three zones as shown in Figure 221.2:

- the supralittoral or splash zone which is kept moist by waves and is usually above high water spring,
- the littoral zone, which can be divided into three subdivisions upper, middle and lower, is the area between tides; and
- the sublittoral zone.

Most of the animals found living on the rocks are filter feeders. They live on small particles of organic matter and plankton suspended in the water. Most of these filter feeders need some form of support to raise their filtering device above the ooze on the bottom. This is important as it keeps the filtering device from becoming clogged. Animals with this adaptation include sponges, sea squirts and sea anemones.

Most of the animals on the rocky shore need to be anchored, as there is little chance for them to hide in the rocks. The limpets and other shells attach themselves to the rock using a fleshy foot. Some animals even cement themselves to the rock. Animals capable of doing this include barnacles, oysters, and tube worms. Tubeworms construct limey tubes along the rocks.

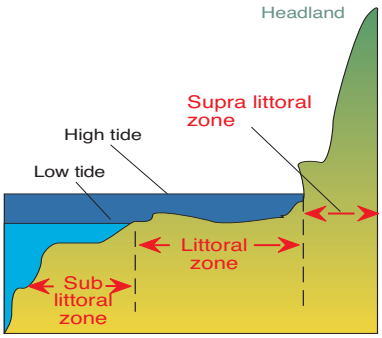


Figure 221.2 Rocky shore zones
(Illustration Bob Moffatt)

Figure 221.3 Sub littoral zone fish
(Photograph courtesy Mike Sugden)

Figure 221.4 Littoral and sub littoral zones
(Photograph courtesy Paula Moffatt)

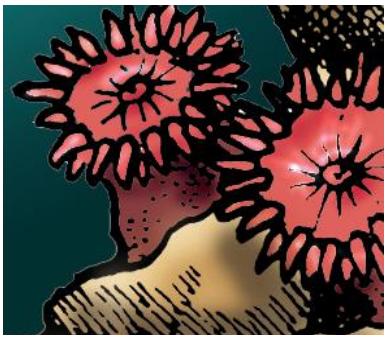


Figure 222.1 Anemones in rock pool
(Photo Bob Moffatt)

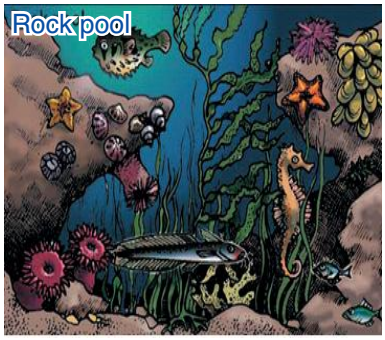


Figure 222.2 Rock pool
(Illustration concept by Nancy Tsernjavski, illustration by Sharyn Madder, copyright MESA, reproduced with permission.)

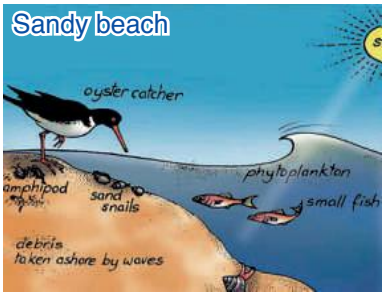


Figure 222.3 Sand shore
(Illustration concept by Nancy Tsernjavski, illustration by Sharyn Madder, copyright MESA, reproduced with permission.)

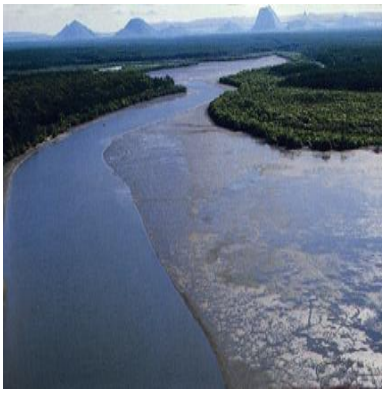


Figure 222.4 Muddy shore
(Photo Bob Moffatt)

Mussels and bivalves have developed a series of strong threads to anchor themselves to the rock. The seaweeds anchor themselves with holdfasts and allow the rest of the plant to flow back and forth in the waves. The rocky bottoms often resemble underwater gardens as seaweeds of many forms become established here (Figure 222.1). The seaweeds require a firm substrate and fail to thrive on the shifting sands of beaches. The seaweed or marine algae are primitive plants that do not have true roots, flowers, stems or leaves. The seaweeds are more prevalent in sheltered areas along our coast and here form dense beds of plants. These plants carry out photosynthesis and are the producers of the shoreline.

Sandy shores

The sandy shores have less visible life on their surface than rocky shores. This is because of the lack of solid material to attach to, and the sand is constantly moving. There are, therefore, fewer fixed plants as producers of the food chain. Most of the animals in these areas must burrow into the sand in order to withstand the wave action.

These organisms have well developed digging organs (Figure 222.3). Some animals such as soldier crabs, bristle worms and pippies find temporary refuge under the sand. Other animals such as yabbies and wriggler worms have permanent burrows under the sand. The heart urchin is well adapted to burrowing with its spines on the underside having flattened tips that act as shovels or oars. The urchin literally rows into the sand. Once under the sand it forms a small chamber and uses a mucus-like cement to stabilize the chamber. Desiccation is not as severe a problem on the sandy beaches as the sand retains the water and the animal can burrow into the sand to obtain this water.

The major problem the animals under the sand face is the lack of oxygen in the sand. The animals living in the sand have a special organ or other adaptation to gain the much-needed oxygen. The animals that form permanent burrows often create currents in their burrows to increase the oxygen supply.

The animals that live on the surface mostly have some form of protection. These include the scallops, whelks, scavenger snails and cockleshells that have hard shells. Other animals such as the starfish have hardened skin.

Muddy shores

The particles making up the bottom of the muddy shores are a lot finer than sand (Figure 222.4). The currents are less strong in the muddy areas - this is the reason the fine sediments have settled to the bottom. The animals found here therefore, need less protection and many have soft bodies. The soft-bodied animals include sea cucumbers and sea anemones.Eelgrass is the most important anchored plant on the muddy shores. These plants provide shelter and food for a number of organisms found on the muddy shores. Many animals live under the mud in order to hide from their enemies. Other animals such as mud whelks and mussels find cover on the muddy shores.

Mangroves and saltmarshes

(Mangroves are discussed in greater detail in Chapter 10.)

A saltmarsh is defined as an intertidal plant ecosystem dominated by herbs and low shrubs. Mostly saltmarshes are dominated by single species. Saltmarshes often have a zonation from low to high elevations on the shore, but are always above high tide mark.

Figure 223.1 Mangrove shore
(Photo Bob Moffatt)

Pelagic zone

This is by far the largest of all marine environments but not necessarily the most productive. The neritic zone extends from the surface waters to the continental shelf and is rich in plankton, fish, prawns, crabs, seagrasses, corals , kelps and sponges, to name but a few. The neritic zone is under extreme pressures from land based pollution and because it is hard to study, not a great deal is known. Pelagic fish include tuna and marlin which are much sought after by longline fishers. Albatross inhabit the air as they fly for enormous distances (see Chapter 14). The oceanic pelagic zone does not appear to be as productive as the neritic pelagic zone. Figure 218.2 shows three oceanic pelagic layers.

Abyss

The abyss is between 3 900 and 6 000 metres. The abyssal plains cover almost half of the deep sea floor and 90% of the ocean is in this zone. This is the soft bottom area of the sea that can range from course sand to muddy ooze. Animals living here live in total darkness, at enormous pressures, freezing temperatures and usually walk gently on the substrate or bury themselves in the mud or sand.

The shapes and sizes of fish varies and the diversity of life forms appears to be large. The Loosejaw fish shown in Figure 223.1 has large eyes and a big mouth to maximise the chances of catching food.

Deep sea animals feed mainly off the food from above. Plants have to make their own food without light and unusual worms are able to obtain chemicals from the energy they extract from deep sea **hydrothermal vents** (Figure 223.3).

These vents form in some areas along the Mid-Ocean Ridge where the gigantic plates that form the Earth's crust are moving apart, creating cracks and crevices in the ocean floor. Sea water seeps into these openings and is heated by the molten rock, or magma, that lies beneath the Earth's crust.

As the water is heated, it rises and seeks a path back out into the ocean through an opening in the seafloor spewing up super-hot, mineral-rich water that helps support a diverse community of organisms. Although most of the deep sea is sparsely populated, vent sites teem with a fascinating array of life. Tubeworms and huge clams are the most distinctive inhabitants of Pacific Ocean vent sites, while eyeless shrimp are found only at vents in the Atlantic Ocean.

Marine scientists want to learn more about hydrothermal vents because they are believed to play an important role in the ocean's temperature, chemistry, and circulation patterns.

Figure 223.2 Loosejaw - a deep sea creature
(Illustration Trevor Ruth, copyright Gould League, reproduced with permission)

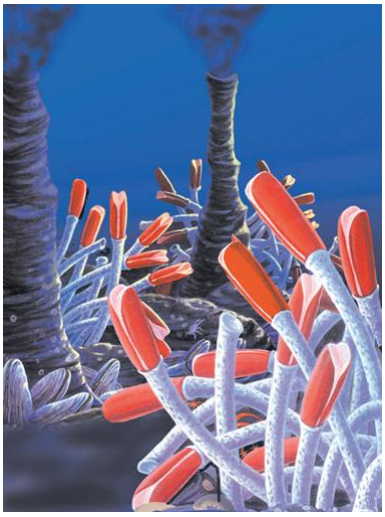


Figure 223.3 Hydrothermal vent
(Illustration Trish Hart, copyright Gould League, reproduced with permission)

Case study 8.3 — Mangrove diversity

This article from SOMER 1996 report by Robertson and Alongi, Australian Institute of Marine Science Copyright Environment Australia Reproduced with permission.

Read and study the illustrations on pages 224 to 225 and then answer the questions on page 226.

Mangrove forests are composed of unique trees and shrubs that have adapted to the extreme saline conditions between the tides. They are of major ecological and economic importance in tropical and subtropical areas. Mangroves provide habitats and nurseries for fish, including many of commercial and recreational importance. They buffer estuaries from sediments and coastlines from storm waves, are natural nutrient filters, and are critical habitats for many birds and other wildlife.

Australia's mangroves are of world significance. They are among the richest in species diversity, and rank third largest in area. Mangrove forests are also vulnerable worldwide; around 1% of the world's mangrove habitat is cleared or reclaimed each year.

Mangroves are a diverse group of largely tropical trees, shrubs, palms and ferns which have adapted for life between the tides on sheltered shores, estuaries and tidal creeks.

Australia has 39 mangrove species, of which only one species, the newly discovered *Avicennia integra*, appears endemic. They are most diverse in the wet tropics, with 35 species in some estuaries on Cape York. They are less diverse in the arid tropics, subtropics and temperate shores. Only one specie *A. marina*, occurs along the southern coastline.

The composition of mangrove communities varies with temperature, rainfall, river run-off, sediment type, tidal amplitude and geomorphology of the coast. In wet north-eastern Queensland there is a very high species diversity, the forests are very tall, to 30 metres, with closed canopies, and they are highly productive.

Ecosystem structure and function

Hydrodynamic studies in northern Australia indicate water flow is important in mangrove ecosystems. Strong tidal flows and good exchange occur in downstream creeks, and ebb tides scour deep tidal channels. Dispersion is weak in upstream creeks and in forests, and materials may be trapped for several weeks, during which oxygen concentrations may become very low. Mangrove materials washed into the sea are often entrained in the nearshore coastal boundary layer.

Recent studies of associated flora and fauna have found that bacterial standing stocks in mangrove sediments are very high and are very productive.

The microbenthos (small bottom living life forms) is dominated by low densities of nematode worms and copepods. The macrobenthos (larger bottom-dwelling animals) are dominated by crabs and molluscs. In the tropics a major role is played in the food chain by crab *Sesarma*, which consume or bury up to 80% of the annual litter fall from mangroves, retaining litter nutrients in the system.

Around 197 fish species have been recorded from northern Australian mangroves, 65 from Brisbane mangroves, and 46 from Sydney mangroves. In tropical estuaries, mangrove leaf detritus is the major source of energy, and microbial breakdown is the first step in the food chain leading to higher consumers.

State	Area (km^2)
Queensland	
tropics	4117
subtropics	485
Northern Territory	4119
Western Australia	
tropics	2507
subtropics-temperate	10
New South Wales	99
Victoria	12
South Australia	211

Figure 224.1 Area of mangrove forests in each of the Australian mainland States and their islands (after Galloway 1982)
(From SOMER 1996, copyright Environment Australia reproduced with permission)

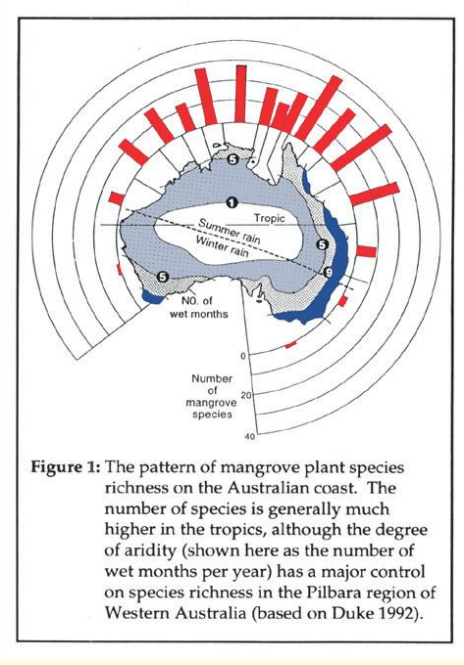


Figure 1: The pattern of mangrove plant species richness on the Australian coast. The number of species is generally much higher in the tropics, although the degree of aridity (shown here as the number of wet months per year) has a major control on species richness in the Pilbara region of Western Australia (based on Duke 1992).

Figure 224.2 Mangrove richness
(From SOMER 1996, copyright Environment Australia reproduced with permission)

Figure 225.1 Mangrove swamp
(Photo Qld Transport)

Fisheries

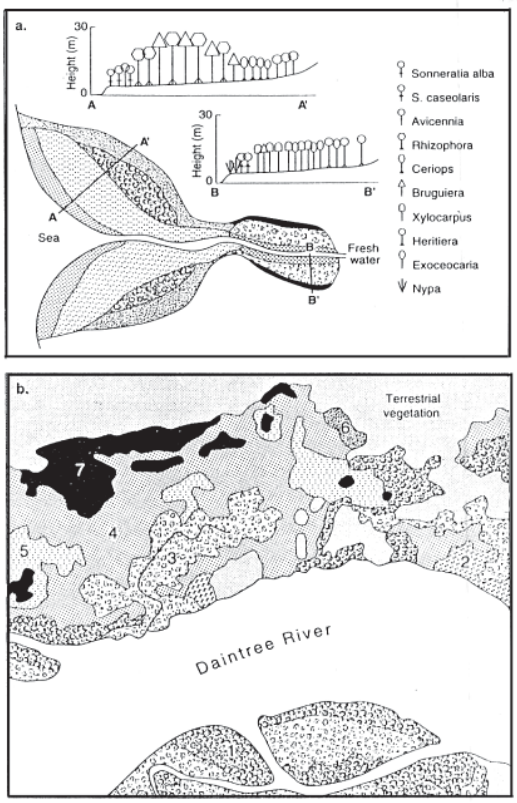
Some of Australia's most important single-species commercial fisheries are directly or indirectly linked to mangroves. The early life cycle of the banana prawn, *Penaeus merguiensis*, is confined to mangrove-lined estuaries. In the Gulf of Carpentaria, greatest catches of banana prawns are made in areas with highest concentrations of mangroves. Bait prawns (*Metapenaeus spp*), mud crabs (*Seylla serrata*) and barramundi *(Lates calcarifer*) are directly dependent on mangroves.

Many fish targeted by Australian recreational fishermen live in tropical and subtropical mangroves, including bream, grunter, mangrove jack, and barramundi. Other fauna of high conservation value are dependent on Australia's mangroves.

Major threats

Clearing and reclamation

Localised clearing and reclamation of mangroves in Australia has occurred near coastal cities such as Sydney, Newcastle, Brisbane and Cairns, but some regrowth has occurred in some of these areas. Many temperate estuaries have been extensively modified by breakwaters, channel dredging, flood mitigation and other engineering works, adversely affecting mangrove communities. A significant area of mangroves in south-east Queensland has been cleared. About 20% of the mangroves in Moreton Bay near Brisbane have been cleared.



1 = *Rhizophora* communities: total of 6 species; 2 = *Bruguiera gymnorrhiza/Osbornia* complex: total of 11 species; 3 = *Bruguiera gymnorrhiza* complex, with *Xylocarpus mekongensis, B. parviflora, Rhizophora* species and *Ceriops tagal*; 4 = *Ceriops tagal* complex with *Xylocarpus granatum, Bruguiera gymnorrhiza, Ceriops decandra* and other species; 5 = *Ceriops* open scrub; 6 = *Heritiera/Excoecaria/Bruguiera/Cynometra* terrestrial margin mangroves; 7 = saltpan.

Figure 2: a) Idealised intertidal and upstream (low salinity) — downstream (high salinity) distribution of mangrove forest community types for a high rainfall north Queensland estuary; and
b) a real situation for a small section of the Daintree River estuary (data taken from Le Cussan 1991).

Figure 225.2 Data for questions for this case study
(From SOMER 1996, copyright Environment Australia reproduced with permission)

Pollution

Oil spills have been responsible for mortality of mangroves adjacent to some ports, such as Botany Bay and Adelaide, but areas affected are relatively small in area. High nutrient levels from domestic sewage and urban run-off is a problem in localised areas of mangrove dominated estuaries in many parts of the country, particularly near Adelaide and Cairns.

Conservation and management

Around 8% of Australia's mangrove forest have some level of protection. Almost two-thirds of this area is in Queensland which has the most extensive reserve system.

Relative to other nations, Australia has a good record in mangrove conservation, mainly through protection afforded by their remoteness and a lack population and development pressures.

Significant areas lacking adequate protection include mangrove wetlands abutting the Great Barrier Reef and the Wet Tropics Rainforest World Heritage Areas and the zone communities of the Pilbara region which are some of the best representative areas of undisturbed and zone mangroves in the world.

The main problems facing future conservation and management of mangroves include the lack of coordination and overlapping responsibilities of State, Territory and Commonwealth government departments and agencies; alteration of the hydrology of catchments; and lack of knowledge on most mangrove systems in Australia. The distribution of Australian mangroves is relatively well known. Early studies were concerned largely with southern *Avicennia* communities but important advances have been made in the understanding of northern Australian mangroves through research by the Australian Institute of Marine Science in Townsville.

Figure 226.1 Dead mangroves
(Photo Qld Transport)

Case study 8.3 questions

1. Explain why mangroves are of major ecological and economic importance to an area.
2. How many species of mangroves are found in Australia?
3. Define the terms (a) meiobenthos, (b) macrobenthos. Give examples of each.
4. How many square kilometres of mangrove forest are found in Victoria? What percentage of the total area of mangroves in Australia are found in Victoria? How does this compare with Western Australia?
5. Analyse the figures showing the mangrove plant richness around Australia and estimate the number of species of mangroves found in Darwin. Repeat the exercise to predict the number of species of mangroves expected to be found in your local area.
6. Make a generalisation about the distribution of mangrove species around Australia using the information in Figure 224.2.
7. Suggest an hypothesis to explain the distribution of mangrove species.
8. How many species of mangroves are found in South Australia?
9. What are the major threats to the mangrove species and in what areas are they most likely to be lost?
10. How are mangrove communities now managed? Do you believe that this level of protection is adequate?

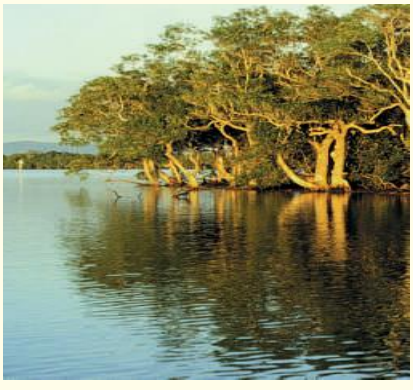


Figure 226.2 Mangroves in an estuary
(Photo Fisheries NSW)

Exercises

From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

C1. What lives in the tree of marine life?

C2. How are sharks and rays classified?

C3. Why do we need a system to classify marine life?

C4. What is the definition of a species?

C5. How are new species discovered?

C6. How are identification keys made and used?

C7. What structural characteristics separate out the Marine phyla?

Questions

Knowledge

1. List the four major reasons why biologists have developed a system of classification.
2. Name the five kingdoms of marine life and state what characteristics separates them.
3. Name the two marine bioregions in Australia and describe how they are separated.
4. Define the following terms-
   a. species
   b. taxonomy
   c. identification key
   d. biodiversity
   e. biogeography
   f. binominal naming system
   g. kingdom
   h. intertidal zone
   i. habitat
   j. ecosystem

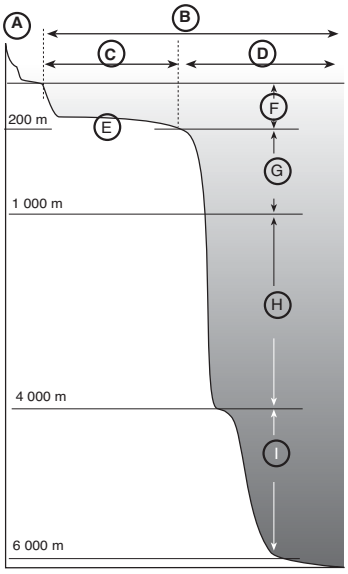


Figure 227.1
(illustration Bob Moffatt)

5. Give the names for the parts of the marine environment labelled as E, F, G, H and I in Figure 227.1.
6. Describe the colour of the abyssal zone in one word.
7. Name 8 types of habitat and list one species of marine or coastal organism found in each habitat.
8. What is a holdfast?

Understanding

9. Draw diagrams to show the differences between a sandy beach on a high energy coast and a mangrove ecosystem.
10. Why is detritus found in every ecosystem?
11. Why is the science of classification fundamental to all scientific research?
12. What is the fundamental principle in the design of a dichotomous key?
13. Biodiversity in its simplest form refers to what?
14. Why does a broader definition of biodiversity go beyond simply counting species?
15. Outline the reasons for biologists using Latin words or words written in a Latin form as scientific names, and not English or French names.
16. Why did Linnaeus develop the binominal nomenclature? Explain how this system works.
17. Name any two animals from the following classes of Vertebrates:
    - Mammalia
    - Reptilia
    - Osteichthyes
    - Chondrichthyes
    - Amphibia
18. What do the grass sweetlip, red-finned emperor, brown kelp fish, brown morwong, coral bream, piggy, red throat, and squire all have in common?
19. Distinguish between the following in Figure 227.1 to the left:
    - C and D, A and B
20. Distinguish between the following in Figure 227.2 below:
    - A, D and E
    - B and C

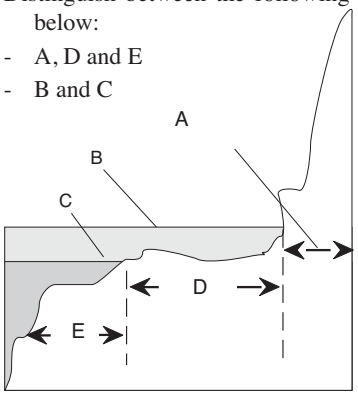


Figure 227.2
(illustration Bob Moffatt)

Applying

21. Classify the following into phylum and class levels
    - shark
    - turtle
    - penguin
22. Give an example of a species that could interact with two different ecosystems.
23. Which of the following habitats would have the highest species diversity?
    a. Temperate and tropical reefs
    b. Sand dune and estuary

    Give a reason for each of your answers.
24. Examine the illustration of mangrove distribution in Figure 228.1 and answer the following questions.
    a. Why are there no mangroves on the shores of the Great Australian Bight?
    b. How many mangrove species are found in Tasmania?
    c. Which State has the greatest number of mangrove species?
    d. What is the difference between the summer rain and winter rainfall figures?
    e. How many species are found in your State?
25. The boundary between the tropical and warm temperate provinces coincides approximately with 18-20°C winter minimum surface temperature. What significance does this have for the types of species found in your State? Give reasons for your answer.
26. Why are nutrients usually high in estuaries?

Analysing

27. Compare a system of using common names to identify a fish with that of using scientific names.

Creating

28. Design a new marine creature and classify it completely.
29. Can you imagine an ecosystem that had no decomposers? Paint or sketch a diagram.

Evaluating

30. Argue the case for the conservation of an area based on genetic diversity.
31. Decide on the boundaries of ecosystems for your next or previous field trips.
32. Evaluate the statement that "Genetic diversity is an investment in the survival of a species. It involves all the past evolutionary selection processes."
33. Justify the inclusion of macroalgae as protoctista.
34. Evaluate the statement – *high biodiversity is regarded as an important attribute for the protection of our marine environment*.
35. People who care about the environment feel strongly that other living things have the right to survive alongside people. To them other living things do not need to benefit humanity directly to have a right to exist. Discuss this statement.
36. The SOMER 1996 report suggests that tropical coasts can be divided on the basis of water turbidity: northern Western Australia, Northern Territory and Queensland where high monsoonal summer rain and dry winters result in grey mud sediments inshore and well developed mangrove creeks; and northwestern Western Australia where rainfall is low and irregular, with occasional cyclonic disturbances and flash flooding resulting in brown sediments.

    Compare this view with the methods of dividing Australia into Northern and Southern biogeographic regions shown in Figure 228.2.

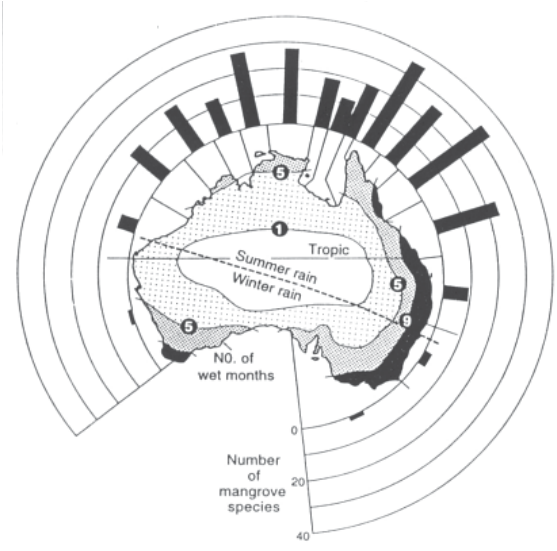


Figure 228.1 Mangrove distribution (from 1996 SOMER)

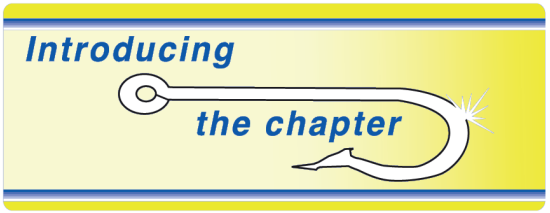
Figure 228.2 Biogeographic regions

Chapter 9
Marine Plants (1)
Protista - Algae

By

Bob Moffatt

Photo CSIRO



Chapter hooks

Arrange for all relevant permits and collect a range of marine plants to illustrate their classification. Use the tree of marine life on page 207.

Ask the class if anyone has had fish poisoning or has heard about coral bleaching.

- Plan your newspaper cuttings file for a specific timeframe.
- Discuss zooxanthellae and corals.

Why study this chapter

Two famous dinoflagellates are ciguateria (which causes fish poisoning) and zooxanthellae (found in corals as well as other invertebrates). Coral bleaching is caused when the polyps spit out their zooxanthellae.

Ecotourism guides find it useful to know how to identify the major groups of plants as well as interesting facts.

The plants that are described in this chapter form the basis of the food chain. An understanding of their structure and function is necessary if you are to understand interactions up the food chain.

Chapter overview

Monera **231**
Bacteria 231
Blue-green algae 231

Protista **233**
Diatoms 233
Dinoflagellates 234

Fungi **236**
Exercise 9.1 Phytoplankton ID 237

Where plants live **238**
Energy systems 238
Exercise 9.2 A model for where plants live 239

Plants **242**
Algae 242
Exercises and questions 246

Key concepts

1. Bacteria, blue green algae, diatoms, dinoflagellates and fungi make up primitive plant groups. True plants include algae, kelp, seagrasses, dune and mangroves .

   For a detailed discussion on classification refer to:

   http://en.wikipedia.org/wiki/Monera
2. Bacteria and blue green algae are the recyclers and molecule builders of the sea. They recycle nutrients from dead complex molecules using chemicals or light as their energy source. Examples include blue green algae and red tide.
3. Diatoms trap nitrogen from the air and fix it in seawater. They also produce over 70% of the earth's oxygen.

   Dinoflagellates are responsible for ciguateria (fish poisoning), bioluminescence and helping coral grow (zooxanthellae).
4. The process whereby plants use simple molecules and light to make complex molecules and oxygen is called photosynthesis.
5. Plants photosynthesise in the photic zone. Complex molecules can also be made using chemical energy in the absence of light. Plants in the deep sea get this chemical energy from deep sea thermal vents.
6. Fungi also help recycle dead coastal plants by using their root-like hyphae to break down complex molecules.
7. Plants that live in water include algae and kelp.

Mike Sugden

Kingdom Monera

Characteristics: Organisms having cells with no distinct nucleus or chloroplasts. Nutrition which can be either heterotrophic or autotrophic (chemosynthesis or photosynthesis). No nervous system or locomotion (in most forms) and no multicellular forms.

Bacteria

Marine bacteria perform vital processes essential to life in the sea. They decompose complex organic matter and release nutrients back into the environment that are used by photosynthetically active plants to build more complex molecules. Some bacteria in mangroves use hydrogen sulphide to make new molecules while others can use light. These can be grown in a bottle from mangrove mud (Figure 231.1).

Other types of marine bacteria from chimney vents in the deep sea provide food for entire deep sea communities.

Figure 231.1 Bacteria grown in bottle of mangrove mud
(Photo John Burnett)

Blue-green algae

Blue-green algae (Figure 231.2) are an advanced form of bacteria which have chlorophyll in their cells. In estuaries that have become polluted with sewage and stormwater runoff, these algae grow very quickly and form an algal bloom.

These blooms can cover huge areas of water, often restricting light from penetrating into the photic zone. This can reduce oxygen levels, killing fish and other marine life. Blue-green algae can also be poisonous to humans, and signs are erected during blooms to warn swimmers.

In Shark Bay in Western Australian are famous blue green algae called stromatolites (see Figure 232.1, over page).

Figure 231.2 Blue green algae
(Photo NSW Waterways)

Stromatolites - A blue green algae

The following text is from the Gardening Australia web site and was written by Dr Playford. From ABC www.abc.net.au 12/11/1999.

Dr Playford is a consultant for the Department of Minerals and Energy, and a former Director of the Geological Survey. Stromatolite fossils can be viewed at the Western Australian Museum, Perth, W.A.

In the hyper-saline water of Hamelin Pool at the base off Shark Bay in Western Australia the rocks aren't quite what they appear to be. They are living things, Stromatolites, which are the oldest living organisms on the planet. Some scientists believe they were the first living things on mother earth.

Hamelin Pool is the location of the best example in the world of living marine stromatolites. The water of Hamelin Bay is twice as saline as usual sea water because of a bar across the Bay's entrance and rapid evaporation from the shallow water. Most living animals, which feed on the bacteria and algae of which stromatolites are composed, cannot tolerate such saline conditions. As a result stromatolites can grow here successfully, undisturbed. Most stromatolites are extremely slow growing. Those in Hamelin Pool grow at a maximum of .3mm a year, so those which are up to a metre high are hundreds if not thousands of years old.

Stromatolites are formed through the activity of primitive unicellular organisms: cyanobacteria (which used to be called blue-green algae) and other algae. These grow through sediment and sand, binding the sedimentary

ACKNOWLEDGEMENTS

Web references

Hamelin Pool Stromatolites
http://www.discoverwest.com.au/hablin.html
Stromatolites
http://www.abc.net.au/gardening/stories/s69379.htm
More Results From: www.abc.net.au

Bacteria

Bacteria that infect a cut in the skin are an example of common marine bacteria. When you cut yourself on the coral on which they live, they invade the tissues of your skin with the small pieces of coral lodged in the wound. In the moist environment, the bacteria grow and cause pain. The coral therefore needs to be removed and the wound treated.

(Photo Bob Moffatt)

Figure 232.1 Boardwalk views at Hamelin Pool
(Photo Conservation and Land Management WA)

particles together, resulting in successive layers which, over a long period of time, harden to form rock. For at least three-quarters of the earth's history stromatolites were the main reef building organisms, constructing large masses of calcium carbonate.

However their most important role in the history of the earth has been that of contributing oxygen to the earth's atmosphere. The organisms which construct stromatolites are photosynthetic. They take carbon dioxide and water to produce carbohydrates, and in doing this they liberate oxygen into the atmosphere.

When stromatolites first appeared on earth about 3.5 billion years ago there was little or no oxygen in the atmosphere. It was through the oxygen-generating activity of stromatolites that other animal life on earth was able to develop. Conversely, it is believed that the decline in numbers of stromatolites is related to the evolution of animals that consumed cyanobacteria and algae.

Stromatolite fossils are evidence of the earliest life on the earth. Western Australia perhaps has the best stromatolite fossils, giving a record through the eons of time. Fossils of the earliest known stromatolites, about 3.5 billion years old, are to be found near Marble Bar in the Pilbara.

Hamelin Pool gives an indication of what the earth may have looked like 3.5 billion years ago when stromatolites were widespread. Because of their range and numbers it is a place of great interest to botanists and geologists alike. A jetty has been constructed allowing the stromatolites to be viewed without doing them irreparable damage.

It's a humbling thought that all life on this planet could have started from something so simple as the blue-green algae which created these rocks millions of years ago.

Red tide - Trichodesmium

In many reef waters, another species of cyanobacteria called *Trichodesmium* blooms during summer months and is often confused with coral spawn or oil spills.

The bloom is a rusty brown and is relatively harmless unless you swallow large amounts. *Trichodesmium* floats on the surface of the sea because parts of its cell structure are filled with gas (Figure 232.2).

Ref: www.aims.gov.au/pages/research/trichodesmium

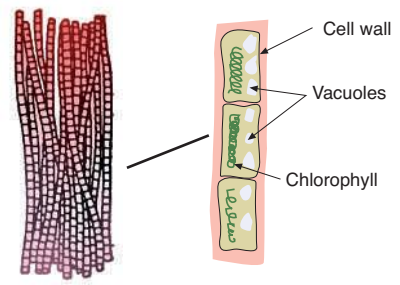
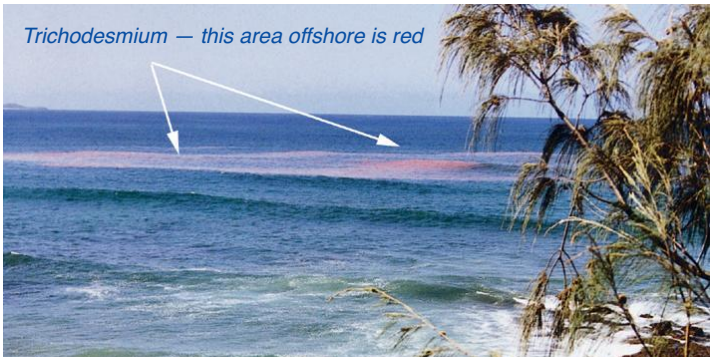


Figure 232.2 *Trichodesmium*
(Illustrations Mark Moffatt, photo Bob Moffatt)



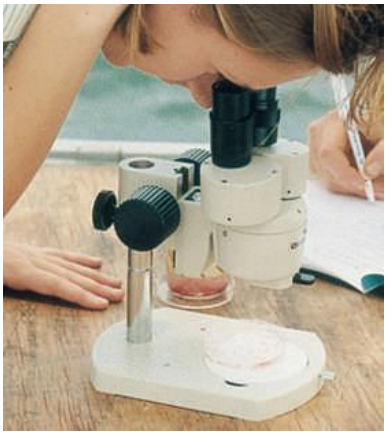


Figure 233.1 Most plankton are only visible under a microscope
(Photo Bob Moffatt)

Kingdom Protista

Characteristics: Organisms having cells with a distinct nucleus, and chloroplasts in some forms. Nutrition can be by indigestion of food materials (heterotrophic) or by photosynthesis (autotrophic). No nervous system, locomotion in some forms and mainly single celled or if multicellular lacking any transport system and having very little coordination or cooperation between cells (examples include Giguateria and Zooxanthellae).

Phytoplankton

Phytoplankton are microscopic marine plants and need light to survive. They consists of two main groups called Diatoms and Dinoflagellates.

Diatoms

Diatoms have a characteristic feature of two shells. There are four common diatoms — *Coscinodiscus*, *Rhizosolenia*, *Chaetocerus* and *Biddulphia*. (See Figure 233.2)

Diatoms are very small, about 1/1000 of a cm, and have two shells made of silica, which gives them a glassy appearance. Inside they have a structure called a chloroplast which contains the pigment chlorophyll. This pigment is used in the photosynthetic process to produce oxygen and carbohydrates (Figure 233.3).

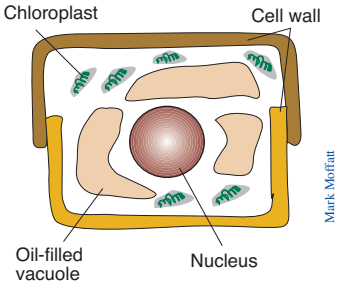


Figure 233.3 Diatom structure

Feeding

During daylight hours, water and carbon dioxide are drawn into the chromatophore and the chlorophyll reacts with the sunlight to convert this water and carbon dioxide to oxygen and sugar. The sun's energy is trapped in the sugar molecules which helps the diatom grow and reproduce.

Reproduction

The diatom grows and splits in half each half duplicating the other. This process, as shown in Figure 233.4, is called fission and it is used by many microscopic plants, animals and bacteria. At the time of reproduction, the diatom splits in half, then each half continues to duplicate the other to produce large numbers of diatoms.

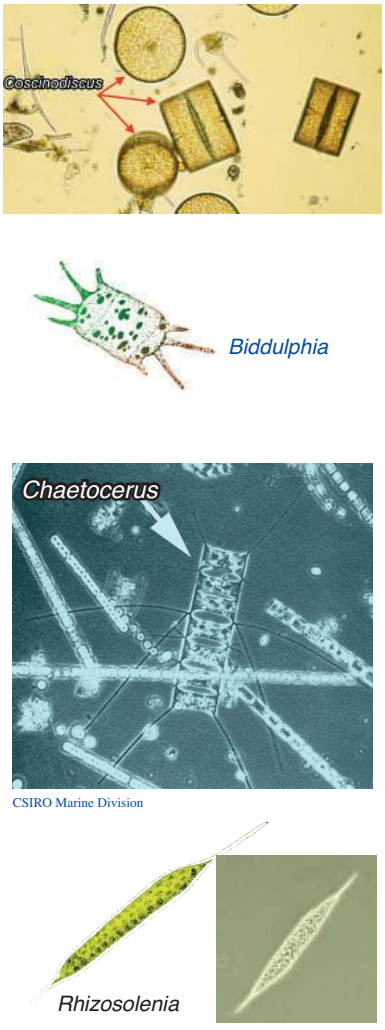


Figure 233.2 Four common diatoms
(Illustrations Dr. Jack Marsh and Dr. David Tulip, Photo CSIRO)

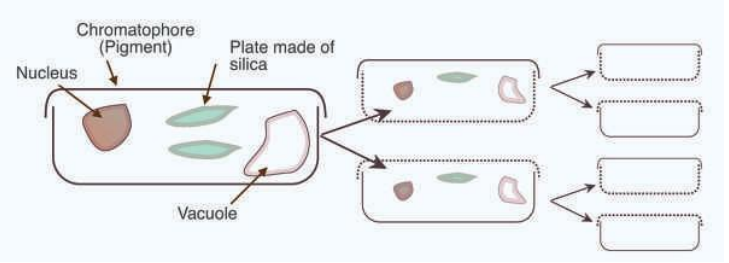


Figure 233.4 Diatom reproduction
(Illustrations Mark Moffatt)

When a diatom dies, most of it decomposes, except the shell made of silicon dioxide. These shells sink to the bottom of the ocean where they form great deposits of diatomaceous earth. Some of these deposits have been found on dry land in areas once covered by the sea millions of years ago. Diatomaceous earth is used commercially as a base for toothpaste, paint, polish and kitchen cleaners.

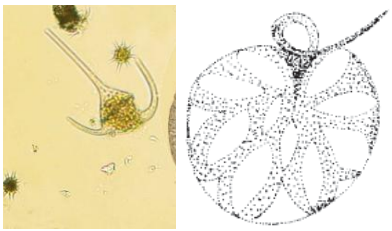


Figure 234.1 *Ceratium (L) Noctilucia (R)*
(Photo Jack Marsh Illustration David Tulip)

Ecological importance

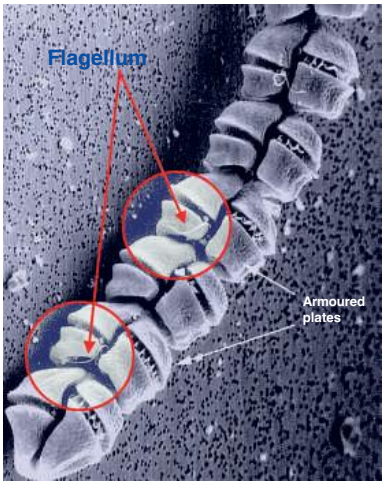
It has been estimated that up to 80 percent of all the worlds' oxygen comes from the phytoplankters in the sea. In return, they "soak up" large qualities of carbon dioxide and play a significant role in reducing greenhouse gases. Diatoms can also trap nitrogen from the air and recycle the element nitrogen in nature.

The energy trapped by these phytoplankters is passed on to all animals that eat them along the food chain. Untrapped, these nutrients would merely settle on to the ocean floor.

Some diatoms attach themselves to rocks where they form a brownish slime. Foam spilling from a wave is often coloured yellowish-brown by millions of diatoms. After the diatom plant dies, the cell walls collect on the seabed and can be mined as diatomaceous earth.

Dinoflagellates

Two of the most common Dinoflagellates are *Ceratium* and *Noctilucia* (Figures 234.1). Dinoflagellates are single-celled organisms with armoured plates containing two flagella that help the plant stay afloat (Figure 234.2).



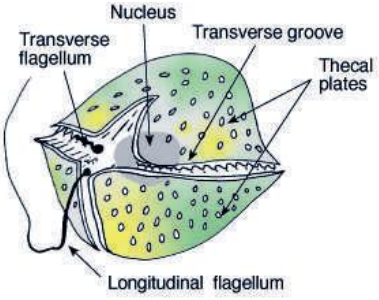


Figure 234.2 Dinoflagellate structure
(Illustration Bob Moffatt Photo Gustaqaf H Hallegraeff (Uni of Tas))

Bioluminescence

Occasionally biolumescent phytoplankton bloom in the ocean and produce a bluish-green light. *Ceratium* is one such dinoflagellate.

Ciguatera

Certain dinoflagellates can produce a toxin which kills a great number of fish. Shellfish (mussels, clams and oysters) appear to be immune to this toxin, but may pass it on to humans as well as fish.

A particular type of dinoflagellate called *Gambieriscus toxicus*, which produces a toxin called **ciguatoxin**, is responsible for fish poisoning (Figure 234.3).

Fish that cause ciguatera are moray eels, chinaman fish, red bass and paddle tails. Few problems are experienced with these as they are banned from sale, however, other known carriers are coral trout, spanish mackerel, reef cod, barracuda, emperor fish, groper, surgeon fish, travally and kingfish.

The presence of toxin, even in high concentrations, does not seem to alter the appearance, smell or taste of the fish and no known culinary method removes it.

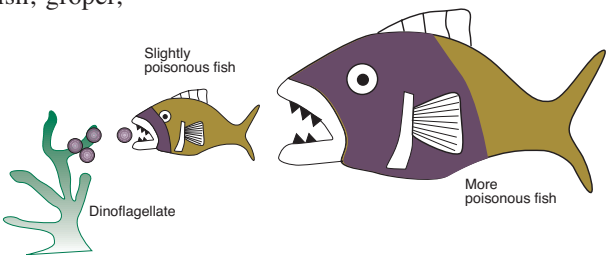


Figure 234.3 Ciguatera poisoning
(Illustration Bob Moffatt)

Zooxanthellae

Zooxanthellae are single-celled dinoflagellates which live in the tissues of marine animals such as clams and corals, taking in the sun's rays and making sugars by photosynthesis. The relationship between zooxanthellae and corals is called symbiosis.

Some dinoflagellates have the ability to give out light, known as bioluminescence, which can be quite spectacular at night.

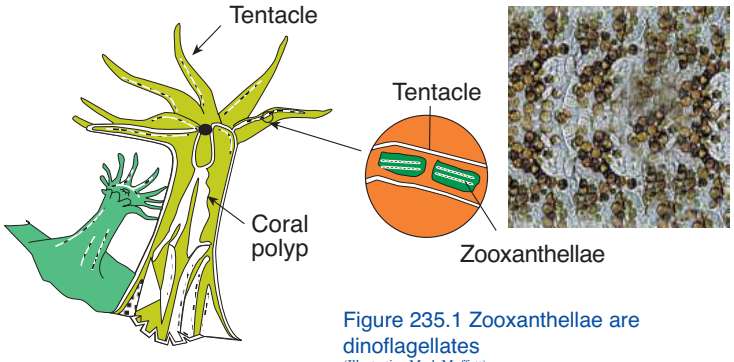


Figure 235.1 Zooxanthellae are dinoflagellates
(Illustration Mark Moffatt)

The photic zone

This zone is where the maximum amount of light can penetrate in the sea or estuary. It varies with depth according to the amount of dissolved and suspended matter present in the water.

It is also called the photosynthetic zone because it is where phytoplankton are able to carry out photosynthesis as shown in Figure 235.2.

Ocean colour

The colour of the ocean indicates whether plankton are present or not. A blue coloured ocean usually indicates a sparse population, while a green colour indicates an increase in plankton density. Phytoplankton stay in the photic zone of the sea and seldom are found more than 200 metres below the surface.

CIGUATERA

Ciguatera symptoms commence 1 - 24 hours after fish are eaten and include:

- tingling and numbness in fingers and toes but also around the lips, tongue, mouth and throat;
- burning sensation or skin pain on contact with cold water;
- joint and muscle pains with weakness and or cramps;
- nausea, vomiting, diarrhoea and or abdominal cramps;
- muscle weakness, headache, fatigue, fainting;
- extreme itchiness, often worsened by drinking alcohol and in severe cases breathing difficulties.

Ciguatera prevention includes:

- avoiding fish that cause ciguatera poisoning eg red bass, moray eels, chinaman and paddletails;
- not eating large ocean fish from warm waters;
- not eating more than 250 grams of fish at any one time;
- not eating the head, roe, liver or other viscera as the toxin concentrates in these parts.

Treatment

Ring the poisons information line in your state if suspicious symptoms appear.

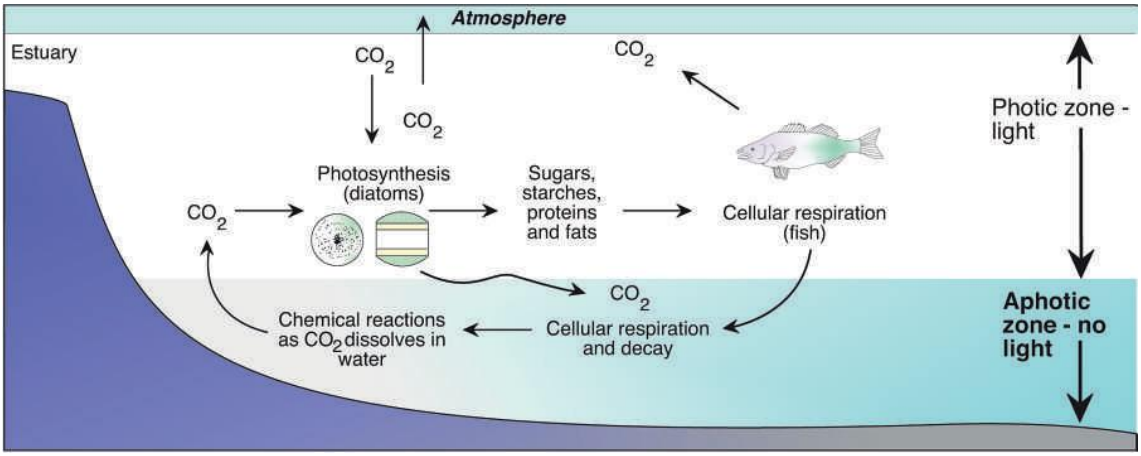


Figure 235.2 The photic zone
(Illustration Bob Moffatt)

Photosynthesis

Photosynthesis is the process by which a plant uses the sun to make its own food. Plants that use photosynthesis are called producers. So a diatom is a producer. Producers trap sunlight in a pigment called chlorophyll and use the energy to convert carbon dioxide and water into sugars and other organic compounds:

Carbon dioxide + water —> sugars + oxygen + energy

The plant uses the sugar and energy to grow and the oxygen is released into the atmosphere and into the sea where it is breathed by us and other animals on land and in the water. In some oceans of the world, diatoms are the largest producers of food and oxygen.

Kingdom Fungi

Organisms having cells with a distinct nucleus, a cell wall and no chloroplasts. Nutrition by absorption from an outside source (heterotrophic). No nervous system or locomotion and multicellular except in yeasts (example lichen).

Fungi are unicellular and multicellular plant like organisms that lack chlorophyll and are nutritionally dependant on other creatures for food. They include moulds, yeasts and fungi that live in the sea.

They resemble seaweeds because they lack roots, stems and leaves and obtain their food by decomposing dead materials such as the bark of mangroves as shown in Figure 236.1.

Fungi use a system of root-like hyphae or rhizoids that grow into the substance and digest it from within. Fungi seem to play a vital role in the decomposition of seaweeds and dead branches of mangrove or estuarine swamps.

A special relationships can exist where algae and fungi get together to form a structure known as a lichen. Here the fungi store water and support the algal cells. The algae then carry out photosyntheses thus providing food for the fungi as shown in Figure 236.2.

Figure 236.1 Lichens on a grey mangrove
(Photo Glenn Leiper)

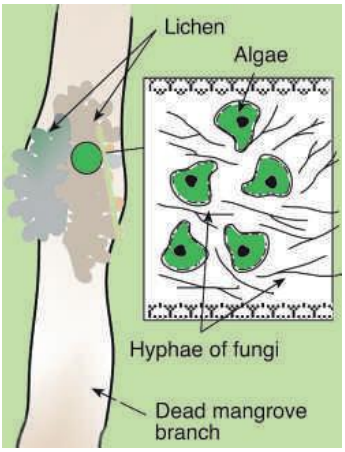


Figure 236.2 Lichens are a combination of fungi and algae and decompose dead branches of mangrove forests.
(Photo Glenn Leiper, Illustration Bob Moffatt)

Exercise 9.1 Phytoplankton ID

Algal culture

Take some aquarium water or fresh seawater and place it in a large jar in the sun for a few days.

Collect the green algae which forms on the inside of the jar. For this exercise, make a slide and view it under the monocular microscope.

Laboratory methods

1. The steromicroscope as shown in Figure 237.1 has two eyepieces, A and B.
2. Carefully remove the microscope from the case (not shown) and carry it with the stainless carry handle D to a place with light coming through a window. Place the base E, on a firm desk.
3. To focus the microscope, take some plankton (I) from your sample with an eye dropper (H) and place in a petri dish (F) that has been placed on a white stage fixed with a screw (G). Note, if you are using live plankton, you may get a better view by unscrewing G and using the black side of the stage disc.
4. Locate the fixed eye piece B and the adjustable eyepiece A. Move A_1 and B_1 apart or closer to fit your eyes.
5. Now close one eye, look through B and use the focus knob (C) to focus on your plankton. Now open your other eye and use eyepiece A to bring your plankton into perfect focus.
6. Use the identification illustrations below to identify the plankton in your sample as either diatoms or dinoflagellates. Use the Wet Paper book – *Introduction to Marine Studies 2nd Ed,* Pages 288- 289 to help you identify them further.

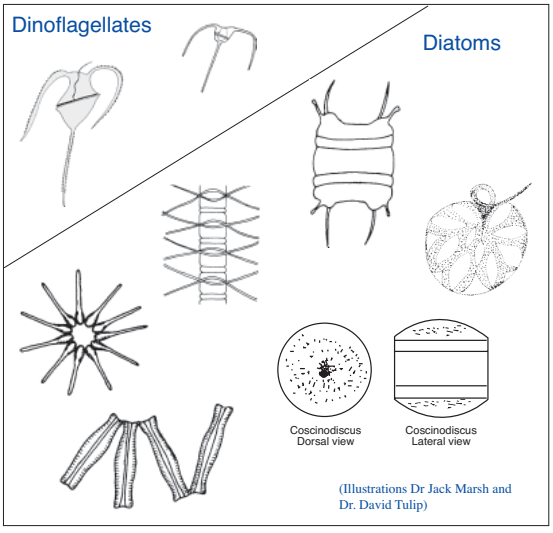


Figure 237.2 Common diatoms and dinoflagellates.

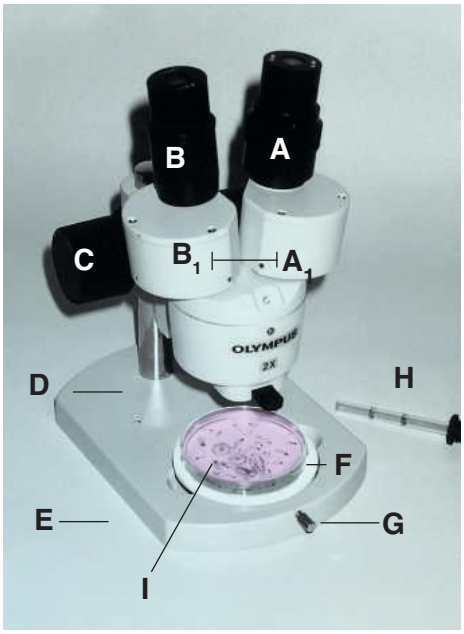


Figure 237.1 Steromicroscope for viewing live plankton
(Photo Bob Moffatt)

Digital Plankton

Digital microscopes are now available from:
Southern Biological
PO Box 57 Nunawading
Vic 3131

Digital microscope

A digital microscope transfers the image direct to your computer just like your digital camera.

This shot of a medusa was taken by a QX3 Intel students microscope at 100x.

Where plants live

Energy systems

In Australia there are high energy and low energy zones caused by prevailing weather and tides (Figure 238.1). The type of plant, its size and shape will large depend on the amount of energy in the coastal system. You will learn in the next chapter that mangroves can only grow in low energy systems where mud and silt forms, and coastal she oaks and banksias will only grow in high energy areas where they have evolved special adaptations to cope with high winds and salt.

Marine bacteria, phytoplankton and simple algae can grow almost anywhere but larger algae such as bull kelps grow in rock pools and in colder waters.

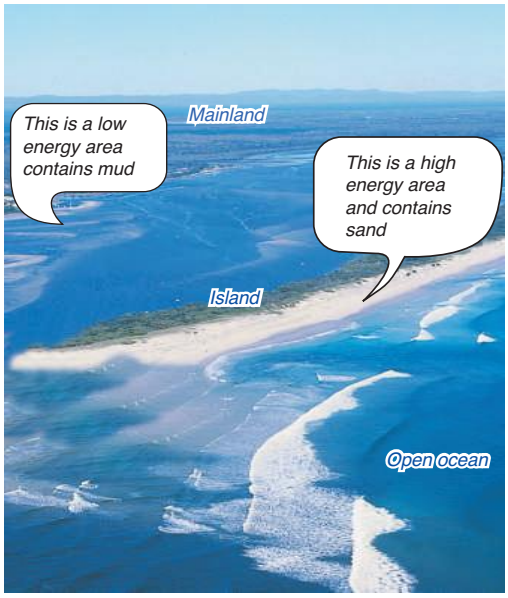


Figure 238.1 A coastal energy system
(Photo Qld Fisheries)

Making a model

The model you are about to make can provide an explanation of why certain types of plants grow in certain areas.

On the model the high energy zones would include the areas in front of the offshore island such as rocky headlands, open beaches and dune systems.

Low energy coastal zones are places where mud settles and mangroves can grow and would include:

- the landward fringe
- saltmarshes
- mangrove wetlands
- muddy shores
- seagrass beds and
- shallow water sand banks

The type of plant that grows on our model will be determined by the energy area as shown in Figure 238.1.

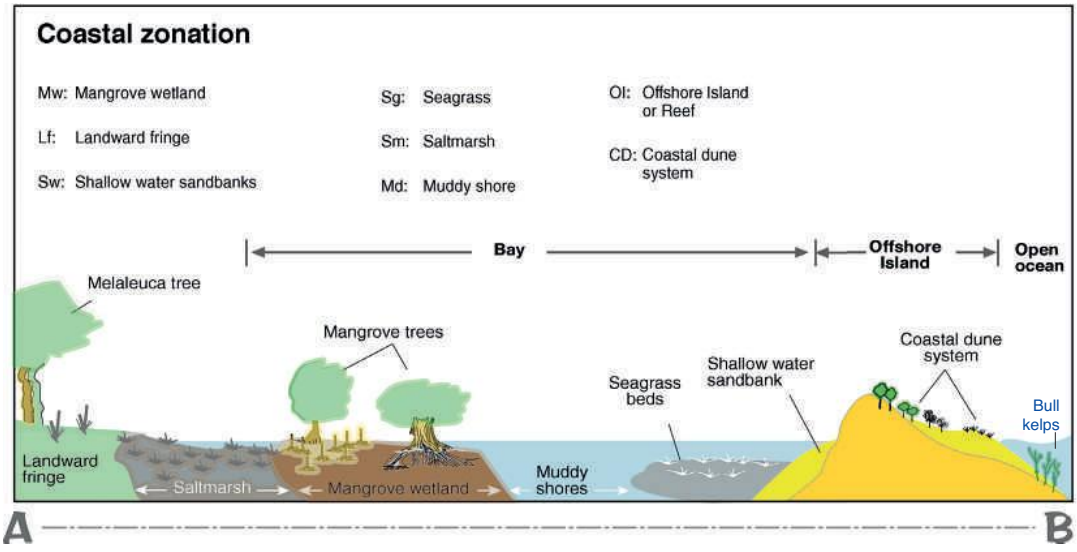


Figure 238.2 A cross section of Exercise 9.2 from Melaleuca swamp to shallow water sand banks and coastal dune system.
(Illustration Bob Moffatt)

Exercise 9.2 A model for where plants live

What to do

You are going to make a model wetland similar to the map over, to investigate the different forces in nature that shape our coastline.

The model is made up of a number of different layers of cardboard each representing different land levels. For example the bottom layer will be the sea bed, the next the mud flats and so on. Each layer will have to be cut out separately and stuck onto the next.

Now complete the following steps to make your model.

1. Take the A4 sheet of paper and design your wetland. You need to have at least areas where mangroves can grow, a melaleuca swamp, an offshore island (so that the waves from the sea don't wash away the mangroves), as well as sea and sand banks where marine animals can live.
2. Once you have your design check it is possible to cut it out into layers.
3. Cut two pieces of cardboard to A4 size. The first will be the bottom of the sea.
4. Now take a second and place it on the desk and lay the piece of carbon paper over the cardboard. Take your design and place it on top.

   Now with a pen, draw over seagrass beds, the sandbanks, the creek and the layers you think are at the same level. Ask your teacher to check.
5. Remove the carbon paper and you will see a pattern on your cardboard that you can use to cut out the first layer.

   Use the scissors to cut out the layers.
6. Now use the glue to carefully position the seagrass beds, sandbanks and foreshores on the seabed.
7. Continue cutting and gluing until your model is finished.
8. Add a compass point and label north. Add a grid and some latitude and longitude marks and then ask students to identify places on the model (eg what is the latitude and longitude of the river mouth?)
9. Optional - you may like to paint your model, and then coat it with clear varnish. You could then pour water down it to simulate water flow.

Questions

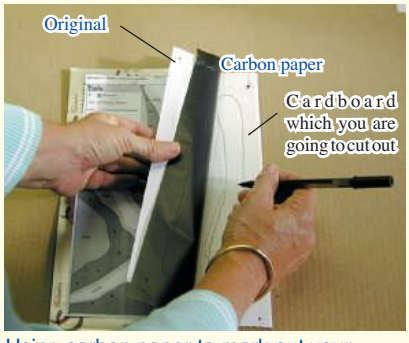
1. Scientists use the words high and low energy areas to indicate forces in nature caused by waves. On your model, what forces of nature would cause high energy areas and where would they occur?

   How does the island protect the mangroves from these high energy areas?
2. What types of weather would cause increased silting of mangrove areas?

Equipment list

- A4 sheet of paper
- Scissors
- Cardboard sheets
- Carbon paper
- Glue
- Pen
- Paints (optional)

Note: Use stanley knives with extreme care under the direction of your teacher.



Using carbon paper to mark out your cardboard

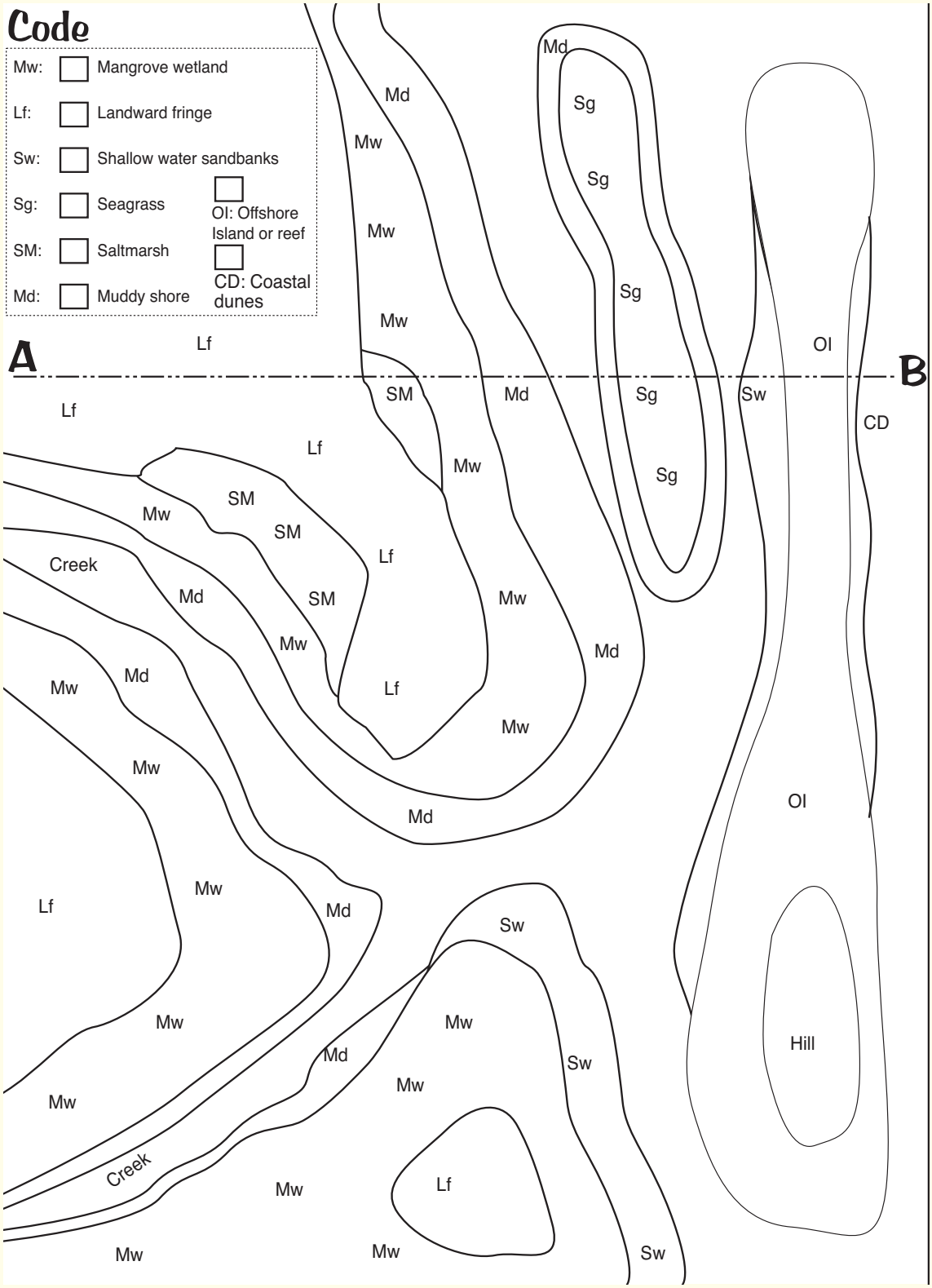
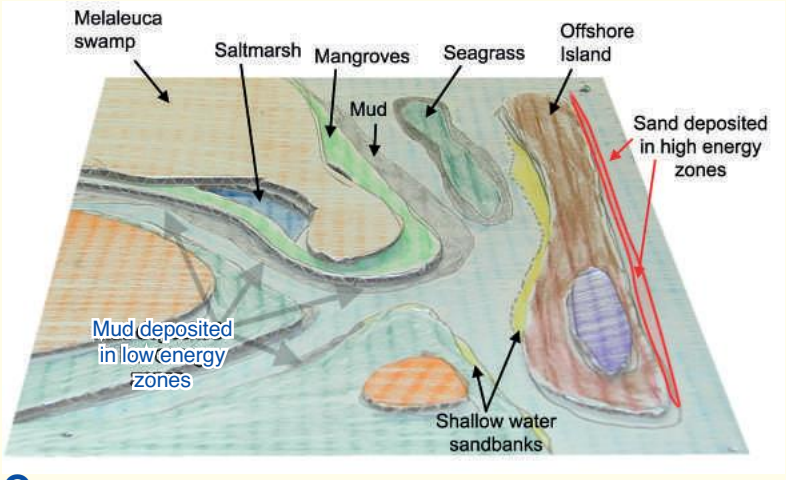
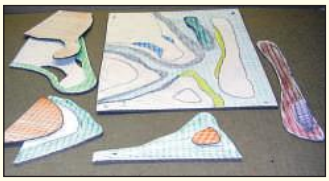


Figure 240.1 Black & white master
(Original idea and illustration Bob Moffatt)





Model ready for gluing

Finished product

Questions on your model

You may have to re-read the chapter on coastlines. Submit your answers with the model.

1. Identify the colours you have used to indicate the following habitats
   - Coastal dune plants
   - Seagrass beds
   - Mangroves
   - Saltmarshes
   - Melaleuca swamps.

   Now redraw and colour in Figure 240.1 matching the colours with the habitats.
2. Compare and contrast the formation of sand and mud. Use your model to explain your answer.
3. The seagrass beds are to the North. Identify clearly N,S,E and W on your model.
4. The offshore island has the highest sand dunes in Australia to the south. 1 million years ago the sea level was 200 nautical miles to the east. What direction would the prevailing winds have blown from and why are the dunes so high? Your answers should compare the speed that wind blows over the land with that over the sea.
5. Identify where the high tide mark is on your model. Does seagrass grow above this level?
6. Design the ideal mangrove for seagrass bed, mud and saltmarsh. You should draw your mangrove for each of the three areas and justify your design.
7. Your model needs a scale. Decide on what would be appropriate and determine the number of nautical miles or square kilometres per cm. Once you have decide this calculate:
   a. the area of the offshore island
   b. the size of the seagrass bed
   c. the total number of mangroves that could be found on the mud if the average number of adult mangroves is 1 every 3 metres.
8. Where would the following plants most likely be found on your model?
   a. Bacteria
   b. Zooxanthellae
   c. A lichen
   d. The mangrove *Avicennia sp*
   e. A seagrass
   f. A blue green algae
   g. A pandanas tree
   h. Trichodesmium
9. Discuss the role plants play in coastal ecosystems. Your discussion should include reference to the following:
   - Dune systems
   - Nitrogen fixation
   - Trees on coral cays
   - One of your choice

Reference:

http://www.reef.crc.org.au/aboutreef/coastal/seagrasswatch.html or its equivalent

Design (Optional)

You have been told that a meteor of gigantic proportions is going to hit the earth in 2 years time and you have been given the task of building an eco-ark that can:

a. withstand the impact of the Tsunamis that will follow in the Pacific Ocean; and

b. colonise this eco-dome with plants.

Use your model as a base for the design showing

a. where the best place to build the eco-ark is; and

b. the types of plants you would use to provide the greatest biodiversity for the animals you would introduce.

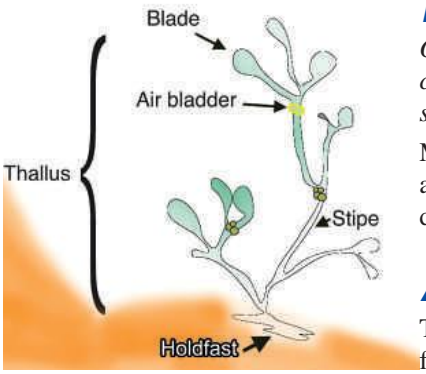
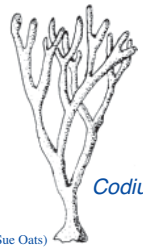


Figure 242.1 Algae are a simple plant form and have a body structure called a thallus.
(Illustration Bob Moffatt)

Figure 242.2 A green algae
(Photo Mike Sugden)

Ulva

You can check this out at http://www.ucmp.berkeley.edu/greenalgae/greenalgae.html



Codium
(Sue Oats)

(Aquarium domain)

Figure 242.3 Some common algae
(Illustrations Project Reef Ed, Sue Oats, Steven Byers)

Kingdom Plantae

Organisms having cells with a distinct nucleus, a cell wall and chloroplasts. Nutrition via photosynthesis (autotrophic). No nervous system, unable to move and multicellular.

Marine plants from this kingdom include those underwater — the algae, kelp and seagrasses, as well as those land coastal plants of the dunes, mangroves and estuaries.

Algae

The marine plants discussed so far in this chapter have been small, free-floating types. Most plants are fixed in place. Algae are a simple plant form and have a body structure called a thallus (Figure 242.1). The thallus is made up of a broad leaf-like structure called a blade which allows oxygen into the plant.

Algae that can be seen with the eye are called seaweeds and include the green, brown and red algae which are attached to the seabed or any hard surface.

The stipe of the seaweed is like a stem and is made of flexible material which allows the seaweed to bend back and forth, absorbing most of the shock from waves and ocean currents. The holdfast anchors the seaweed to rocks, corals or rubble. It varies in shape and size according to where the seaweed grows. Seaweeds found in high wave zones have large sucker-like holdfasts whereas some coralline algae have holdfasts to bore between coral polyps to get a hold.

Green algae

Green algae are a major group of marine plants that contain the green pigment chlorophyll (Figure 242.2). The most well-known of the marine green algae is the sea lettuce or *Ulva* (Figure 242.3). Other common green algae are the finger algae *Codium* and the green knobbly coralline algae *Halimeda*.

Green algae can reproduce by spores, or by eggs and sperm in a process called alternation of generations (Figure 243.1). The first sexual sporophyte generation produces a second generation of plants called the gametophyte generation.

The gametophyte generation is either a male or a female and when the time is right, they release either eggs or sperm which join up again to grow into a sporophyte generation.

Halimeda
(Steven Byers)

Chlorodesmis
(Project Reef Ed)

Lyle Vail
creativecommons.org/licenses

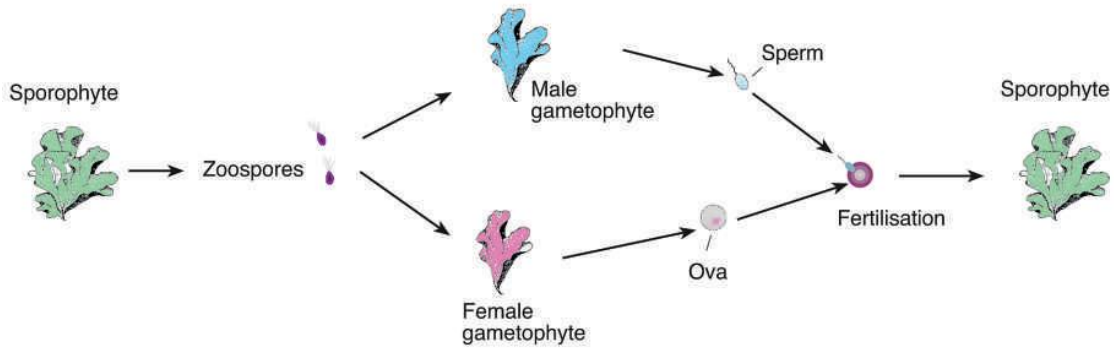


Figure 243.1 Alternation of generation in green algae
(Illustration Bob Moffatt)

Alternation of generations is a common adaptation used by plants to increase the survival of the species. Other adaptations of algae include air bladders or fluid-filled sacs which increase the surface area available for photosynthesis.

Halimeda is very important in reef building because calcium carbonate is incorporated into the cell walls and holdfasts of this plant. Many scientists refer to these types of algae as the mortar of the reef, cementing other living materials such as corals together. Some reefs may be entirely built by encrusting algae and coral polyps.

Red algae

Red algae are small, very complex algae which generally live in areas with reduced light. Most red algae is red to pink in colour although in areas with good sunlight it may be green, olive, or brown to black. This often makes red algae difficult to identify.

Red algae range from a slippery scum-like mass on rocks in southern waters to feathery weed, to coraline algae which is responsible for cementing coral reefs together.

Brown algae

Brown algae is a complex marine plant that is commonly called seaweed or incorrectly just called kelp. This type of algae contains the pigment chlorophyll and another pigment called carotene so it has a brown colour.

Brown algae lives in a variety of marine environments, and can withstand a range of conditions. The bead-like algae, neptune's necklace, Figure 243.3, lives abundantly on the rocky platforms of southern areas of New Zealand's and Australia's coastline. Also common in the southern oceans are the true kelps, some of which grow into large underwater forests.

Another brown algae, sargassum, can be found at or below low tide levels around Australia but it behaves differently in the Atlantic Ocean. Off Bermuda, sargassum grows in coastal waters. When the top part breaks, the seaweed floats out to sea and covers the ocean's surface for millions of square kilometres — an area that has come to be called the Sargasso Sea.

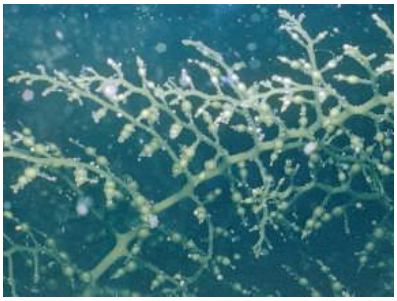


Figure 243.2 *Sargassum sp*
(Deep Voyage)

Odd fact

Seaweeds do not have flowers, the male and female propagules are borne in the tiny lumps on the surface of each bead of neptune's necklace.

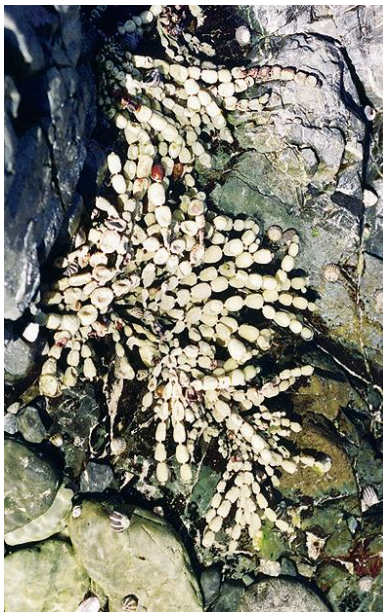


Figure 243.3 Neptunes necklace *Hormosira banksii*
(Photo Bob Moffatt)

Figure 244.1 Giant kelp
(Photo Mike Sugden)

Bull kelp, perhaps the best known of the kelps, has fronds 7 m long and up to 30 cm wide and is found in the surf zone off many southern beaches. The most distinctive of the brown algae is bubble weed, which has large irregular bladders that are often filled with water.

Brown algae has been eaten in Japan for many years in a wide range of dishes. The main seaweeds used are konbu (a kelp) used in sushi rice, nori for sushi and wakame (in soups). A useful reference can be found at http://biology-web.nmsu.edu/biology550/Algae.htm.

Some of the fleshy types of brown algae (bull kelp), are the main source of agar jelly. Agar is used for growing bacteria and moulds on agar culture plates, and for cooking in some Asian countries.

Algae as pests

Algae thrive on the nutrients nitrogen and phosphorous.

When the supply of these nutrients increases, so does the algae population.

The nutrients are found in sewage and fertilizers, many of which are washed into the sea from rivers and streams when it rains. The area in which rain falls on land is called a catchment. In natural, undeveloped catchments, the rain soaks into the ground and then drains slowly towards the sea.

This slows down the entry of the nutrients into the marine environment and thus limits the growth of the algae population. However, when we develop land, we build roads and stormwater pipes. These hard surfaces and artificial drainage systems increase the speed of draining water and thus the speed and amount of nutrients entering the sea.

This increase in food supply causes populations of some species of marine algae to grow a lot faster than normal as shown in Figure 244.3.

The increase in population size can compete for light and food with other plants. Seagrasses are one plant species which are being smothered by enormous increases in algae in South Australia. Increased algal growth can also make boat ramps and rocks slippery reducing the recreation amenity of an area.

Figure 244.2 Brown algae
(Illustration Sue Oats, Photo Mike Sugden)

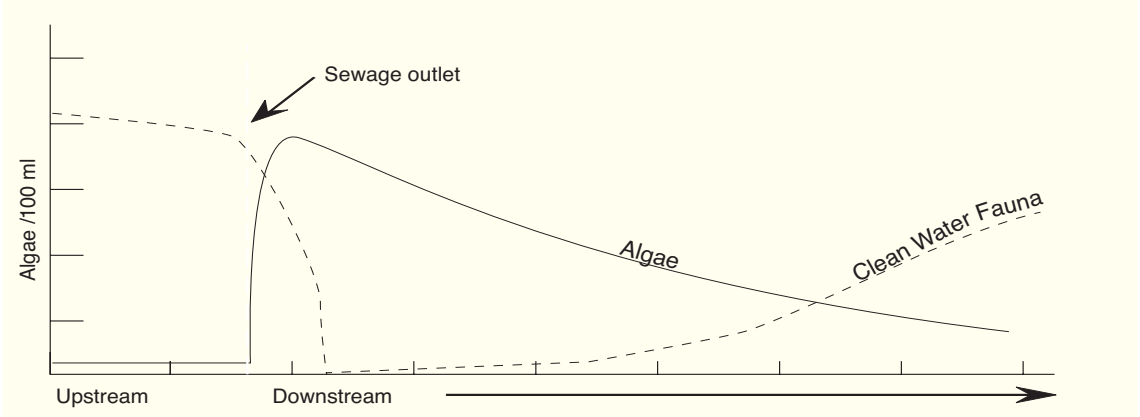


Figure 244.3 Effect of sewage in a stream - Why are the algae in such small numbers upstream?
(Illustration Bob Moffatt)

Research questions

Use the information below to answer the following questions on Phytoplankton distribution.

Based on an original exercise by Mark Rodridgue Marine Discovery Centre Queenscliffe Victoria.

Locate the colour image (Figure 245.1) from: http://seawifs.gsfc.nasa.gov/SEAWIFS/CZCS_DATA/global_full.html and answer the questions.

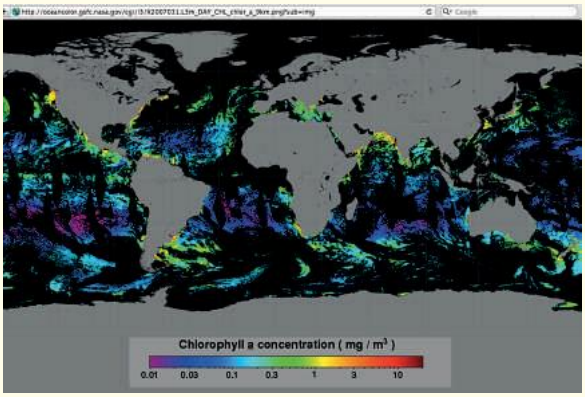


Figure 245.1 Phytoplankton data for this exercise
(Image courtesy NASA)

1. Use the map of phytoplankton distribution to answer these questions.
   a. Use the scale to determine where there are lots of phytoplankton.
   b. In general, where do you find areas with higher phytoplankton levels? In the middle of the ocean or close to the continents?
   c. Based on information you have from the satellite images predict where you would find major fisheries of the world (where there are cold water currents or cold water upwellings).
   d. Research the locations of major fisheries of the world (Peru and Chile share one of these). Compare your research findings with your predictions.
   e. In Australian summer many whales migrate to the Southern Ocean around Antarctica to feed on the plankton rich water.
   f. What reasons can you give to explain the plankton blooms that occur in Antarctic water each year?
2. Use the following information to answer the following questions.

   Obtain an Phytoplankton Density image of both the Arctic and Antarctic Waters by setting your web browser to

   http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/CZCS_DATA.html

   These images show the relative levels of phytoplankton in the oceans made as a composite of all Nimbus-7 Coastal Zone Color Scanner data acquired between **November** 1978 **-** and June 1986**.**
   a. In comparing northern and southern hemispheres which has the greater overall levels of productivity?
   b. If we translate productivity to think about fisheries which hemisphere is likely to support larger numbers of fish?
   c. What implications does this have for fisheries managers in the Southern Hemisphere?
   d. What issues of productivity have been ignored by fisheries managers in the Northern Hemisphere in the last few decades?
   e. Compare the northern and southern hemisphere. Which hemisphere has more land? Which oceans are likely to receive the most amounts of soil and nutrients coming from the land via streams and rivers?
   f. Can you think why the oceans in the Northern Hemisphere may have much larger numbers of fish than the Southern Hemisphere?
   g. Biodiversity is largely influenced by the productivity of the system. In general where productivity is lower there is greater evolutionary pressure on organisms, particularly animals, to become different to one another to take advantage of different food types. Southern Australia has some of the highest levels of biodiversity ever found on the planet. How can this be explained using the phytoplankton density data?
3. Read the article below and make a three paragraph report on the latest research.

Caulerpa taxifolia

The invasive seaweed Caulerpa taxifolia is threatening estuarine habitat across the country, with South Australia the latest state to declare war on the weed. So far, Caulerpa has invaded parts of NSW including Port Hacking, Burrill Lake, Narrawallee Inlet, Botany Bay, Careel Bay and Lake Macquarie, with Lake Conjola completely covered. The weed has caused massive problems in the Mediterranean and in California. In South Australia, the weed has been discovered in West Lakes, near Adelaide and the adjoining Port River. But unlike NSW where salt is being tried to eradicate the pest, scientists are trailing copper sulphate, which kills the weed and everything else in the vicinity as well. The Commonwealth is so far refusing to help fight the weed because it`s closely related to a native of Northern Queensland where it is neither invasive nor a threat to marine life.

Exercises

From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

A6 Where do mangroves and seagrasses live?

A13. How can I get fish poisoning?

B2. What do phytoplankton do in the photic zone?

B4. What is a red tide?

Questions

Knowledge

1. What are stromatolites?
2. Name six individuals from the kingdoms Monera and Protista.
3. What is *Halimeda* and why is it such an important plant to the reef?
4. What conditions would you predict necessary for a red tide?
5. Define the following terms:
   a. Symbiosis
   b. Bioluminescence
   c. Algal bloom
   d. Alternation of generation
   e. Producer
   f. Photosynthesis.
6. Organisms that live on the floor of the sea are called:
   a. Benthos
   b. Nekton
   c. Plankton
   d. Sessile organisms

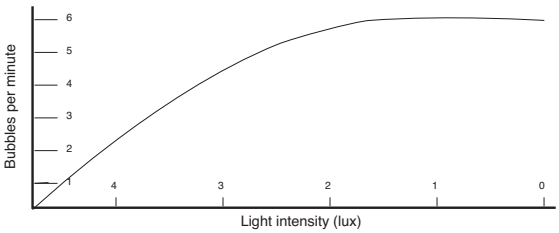
Understanding

7. Draw a generalised algae and label the following parts: holdfast, stipe, blade, thallus.
8. Describe the process of alternation of generation in green algae.
9. Distinguish between photosynthetic processes that can occur in the photic and aphotic zone.
10. Why is a lichen a fungi? Give an example and describe where you might find one.
11. What is a red tide? Outline the conditions under which it can occur.
12. Which of the following statements concerning seaweed adaptations to life on the seafloor is FALSE? Give reasons for your answer.
    a. They have a holdfast to prevent them being washed away.
    b. They have a short, thick shape to stop them being covered by mud.
    c. They have specialised floating cells to keep the shoots upright in the water.
    d. They have a reproductive cycle with both sexual and asexual stages to increase their chance of survival.

Application

13. Diatoms reproduce by a process known as fission. Why is the diatom population sensitive to its environment? (It may help to consider the process of reproduction and what it means to the diatom gene pool.)
14. *Noctiluca scintillans* has a bioluminescence ability. How might this aid in survival?

The graph below refers to the next three questions



Green algae was placed in a large test tube filled with water and illuminated with light of differing intensity. The bubbles produced by the algae were counted for one minute. The illumination was altered by moving the light source towards or away from the test tubes. The results were as follows:

Use the following key to answer the questions 15-17

A. The statement is a reasonable conclusion.
B. The statement is false according to the graph.
C. There is insufficient evidence to establish this fact.
D. The statement is not a conclusion but merely a restatement of results.

15. Light is the only limiting factor affecting the production of bubbles. Alternative -A, B, C or D
16. The temperature increases the rate of production of bubbles. Alternative -A, B, C or D
17. As the distance from the light source increased the number of bubbles produced increased. Alternative -A, B, C or D

Analysing

18. A large brown marine plant was growing in the surf zone off a southern Australian rockpool. It had long fronds. It was most probably:
    a. Algae
    b. Seagrass
    c. Lichen
    d. Bull kelp

Creating

19. Design the perfect plant for living on a rock platform.

Evaluating

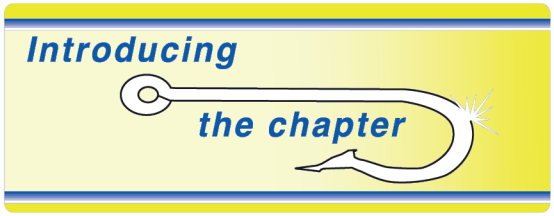
20. Engineers at the sewage plant (used for data in Figure 244.3), have developed a new method for treatment so that nitrate and phosphate levels were reduced by 60%. Redraw the graph predicting what effect this would have on the numbers of algae per 100 ml.

Chapter 10
Marine plants (2)
The flowering plants

by

Bob Moffatt

Photo Qld Fisheries



Chapter hooks

- Show one of the following videos -*Coastal dunes and management*, *Coastal processes and landforms*, *Australian ecological profiles*, *The biophysical environment* or the *Fragile ecosystem* from www.classroom video.com 1800 644 252.
- Arrange an excursion to the beach, estuary or mangroves to study the flowering plants.
- Discuss the design of a model mangrove, dune plant or seagrass that will have to withstand modern day pollution and coastal development.
- Try growing some mangrove seedlings or set up a sand dune outside your classroom.

Why study this chapter

Flowering plants are the most advanced forms of marine plant life. In dune systems they stabilize soils, in estuaries they form a diverse group of plants called mangroves and under the sea they even flower in vast seagrass beds.

What they share in common is that their habitat is under enormous threat from coastal development. Sand dune plants have been bulldozed to make way for high rises, mangroves cleared for canal developments and seagrass beds choked with algae that grows over the top of the leaves due to stormwater pollution.

From an ecotourism perspective, coastal wattles, banksia, spinifex and she oaks are found on most Australian beaches and it is useful to be able to identify them.

Detailed studies of plants from these three types of habitats is important if we are to maintain the biodiversity of our coastal zone. Environmental action is also necessary to halt the loss of habitats or our nautical nurseries may disappear for all time.

Chapter overview

Angiosperms 249
Coastal dune plants 249
Exercise 10.1 Sand dune plants 255
Seagrasses - sub-tidal plants 256
Mangroves - Intertidal plants 259
Exercise 10.2 Plant diversity 265
Exercises and questions 268

Key concepts

1. Angiosperms are flowering plants with specific reproductive features that allow for sexual or asexual reproduction.
2. The dune system acts as a buffer zone between the land and the sea and contains plants that stabilize the dune system.
3. Plants in the dune system have special adaptations to withstand low nutrient levels, high winds and salinity.
4. There is a succession of plant diversity, from low in pioneer vegetation to high in climax communities. A coral cay provides a good example of this.
5. Some dune plants can trap atmospheric nitrogen in nodules in their root systems by a process called nitrogen fixation.
6. Seagrasses are marine plants that flower underwater and contain complex ecosystems.
7. Seagrass ecosystems supply food for commercial fishing industries as well as endangered species such as dugongs.
8. Mangroves are intertidal plants that are distributed around Australia except for the Great Australian Bight and Tasmania.
9. Mangrove diversity decreases in temperate waters and is highest in tropical waters.
10. Mangroves have many adaptations to their environment including a unique root system.
11. Mangroves also show a succession from low diversity to high diversity leading up to a climax community.
12. Mangroves form ecosystems which contain an enormous variety of animals and plants and have often been classed as the world's richest ecosystems. They are under enormous threat from development and have been unappreciated as infested swamps.
13. Through education, mangroves are now being valued as nurseries supplying other ecosystems with food and shelter.

Kingdom Plantae

Angiosperms

Marine angiosperms are flowering plants with specific reproductive features and can be found in sand dunes, swamps, estuarines and seagrass beds. Generalised flower parts are shown in Figure 249.1.

The male anther produces pollen (containing sperm) which is transferred to the female ovaries (containing eggs) through a stigma.

Here the eggs are fertilized which then grow into a seed. Seeds are usually blown around and when conditions are right (eg after rain), they grow into a seedling which grows to make a new plant.

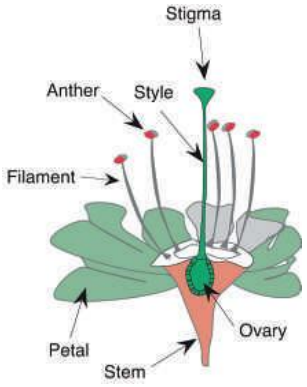


Figure 249.1 Generalised flower parts
(Illustration Bob Moffatt)

Coastal dune plants

Abiotic features

The dune system (Figure 249.2) acts as a buffer zone between the land and the sea and contains many animal and plant species specifically adapted to this harsh environment.

Abiotic features include low rainfall, high salinity, high temperatures, strong winds and stormy seas. These constantly shape the sand in the dunes which alter on an hourly basis. This is in sharp contrast to a rocky shore pool which has a degree of constancy and allows for a greater species diversity.

Adaptations

Adaptations include low-growing, wide-spreading root system and leaves that reduce water loss. Their leaves may be very small, have protective hairs, are coloured silver-grey to reflect heat, store water and have a thick waxy coating on their surface. To survive, the roots spread to obtain as much water as possible.

Dunes provide a place for pioneer vegetation to grow so that more complicated plants can establish themselves further inland. Without this buffer zone the sea would easily claim the delicate land plants which are adapted to soil, fresh water and unsalted air.

Dunes provide a place for this transition to occur.

Figure 249.2 The dune system acts as a buffer zone between the land and the sea.
(Photo Bob Moffatt)

Figure 250.1 Coastal spinifex
(PBob Moffatt)

Figure 250.2 Plants such as goats foot and spinifex are called pioneer species.
(Photo Bob Moffatt)

Coastal spinifex

Coastal spinifex is an example of a pioneer vegetation but there are other plants which perform similar functions in other parts of Australia. Usually there is a primary or fore-dune on which the primary coloniser Spinifex grows (Figure 250.2). The fore-dunes become higher and wider as the wind blows more sand up the beach. The wind sorts out the sand grains with the smallest blown further inland.

The beach is a hot, dry and salty environment with very little water. The spinifex has upright leafy sheets which enable the plant to trap sand. Its ability to grow when covered, allows quick vegetation of a dune system. Cycles of sand deposition are important to the dune building process.

Reproduction

The sand acts as a stimulus for plant growth. Long runners extend past the main body of the grass and the matted roots hold this upright plant in place. Male plants produce a terminal cluster of stalked racemes. A raceme (Figure 250.2) is an undivided axis containing the flower unit - the anther.

The anther produces the pollen which blows to fertilise the female reproductive part. This is called spikelet, which has an ovary containing eggs. The pollen fertilise the eggs to form a seed. These seeds enclose themselves in a large spine-like bract 10-15 cm long which grows to 20-30 cm and is straw coloured when mature (Figure 250.1).

The spinifex dominates the frontal dune system because of these excellent adaptations. In populated areas the frontal dune is maintained by a fencing program. This allows the vegetation to grow unhindered, allowing the dune to build.

Phosphorus cycle

Phosphorus is an important element for spinifex which has an active root system to seek out this element. When quartz and feldspar are formed, they contain a fine coating of phosphorus which sticks to the sand grain as it moves along the coast. When the sand grains are washed up on the beach, they dry and are blown towards the spinifex. The broad leaf of the plant catches the grain by reducing the wind velocity and the grains falls to the base of the plant. Fine root hairs that grow from the main plant then absorb the phosphorus coating from the sand grain.

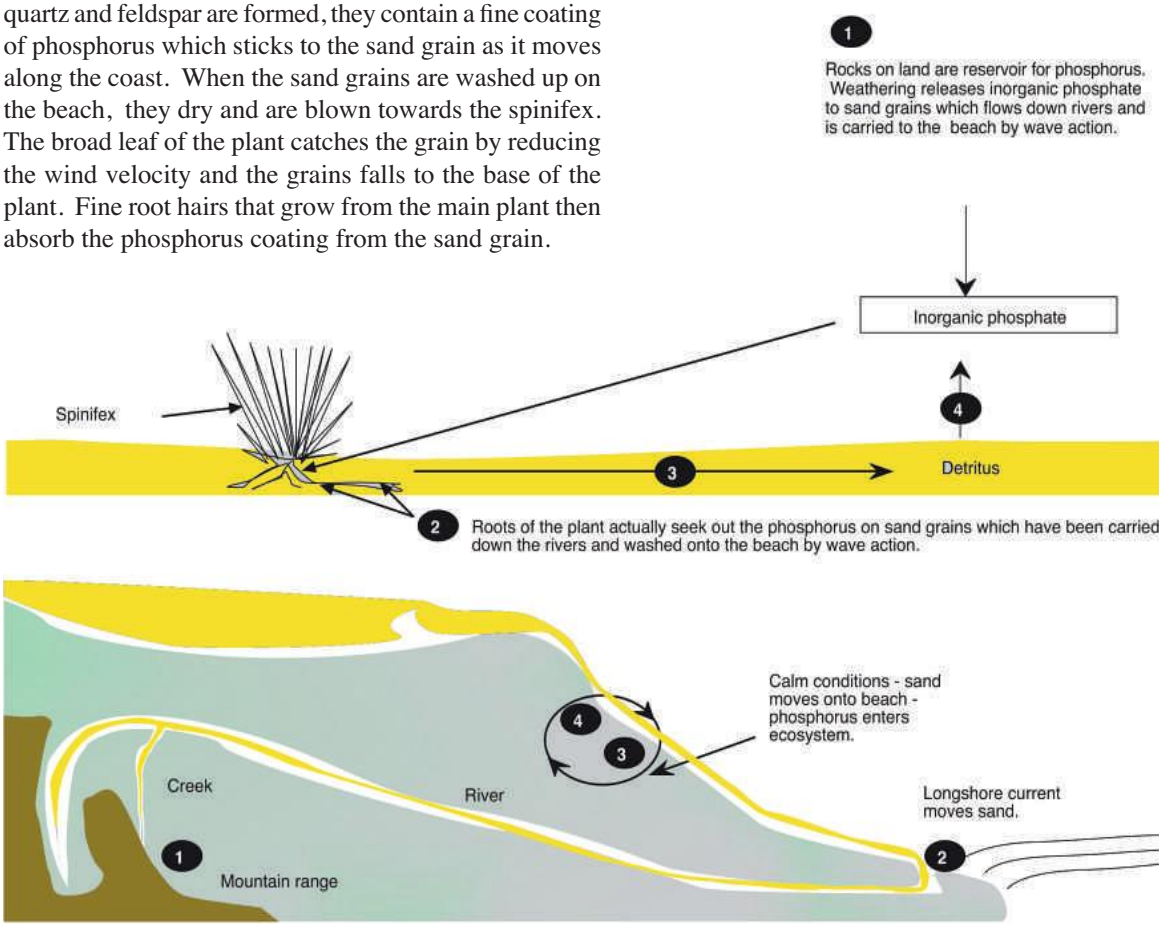


Figure 251.1 Spinifex and the phosphorus cycle
(Illustration Bob Moffatt)

Casuarina trees

The casuarina or she oak, is found just behind the frontal dune system and cleans the air of salt before it blows inland. As the salt air blows at the casuarina, the salt accumulates on the branches.

She oaks have very long branchlets which are often confused with leaves. The shape of these branchlets, and the tree itself, reduces wind velocity causing the sand to drop to the base of the plant. In some cases the salt and sand mixture sticks to these branchlets and when heavy enough, the branchlets drop with their sand load. The matting under a she oak forest can be quite thick. The buildup of sand gradually increases the height of the secondary dune system.

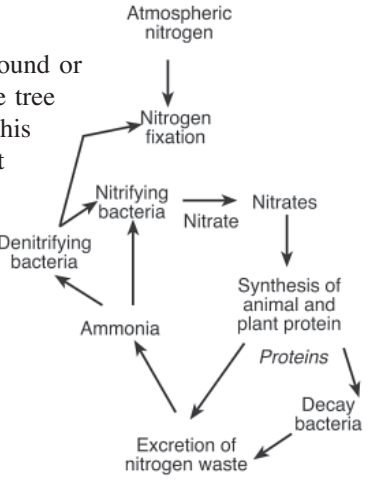
Figure 251.2 Leaf and seed
(Illustration Project Reef Ed, GBRMPA)

Nitrogen cycle

Casuarina trees are able to convert the nitrogen in the atmosphere to a solid form inside the tree. This is done by micro-organisms, called nitrogen fixing bacteria, that live in root nodules at the base of the tree.

Figure 252.1 Casuarina trees
(Photo Beach Protection Authority)

The bacteria absorb the atmospheric nitrogen and convert it to a bound or "fixed" chemical form that can be released as a fertiliser to help the tree to grow. This may be one reason why the tree grows so quickly. This process is called nitrogen fixation and is part of the nitrogen cycle that is so important to the survival of the sand dunes (Figure 252.2).



Dune care

Casuarina roots penetrate deep into the frontal dune. Out from each root is a root hair system which further helps to anchor the tree and bind together the sand. When big storms such as cyclones strike the beach, large waves break causing beach erosion. The roots of the casuarina help to hold the soil together. The branches also provide roosts for the many sea birds that come to the land to live.

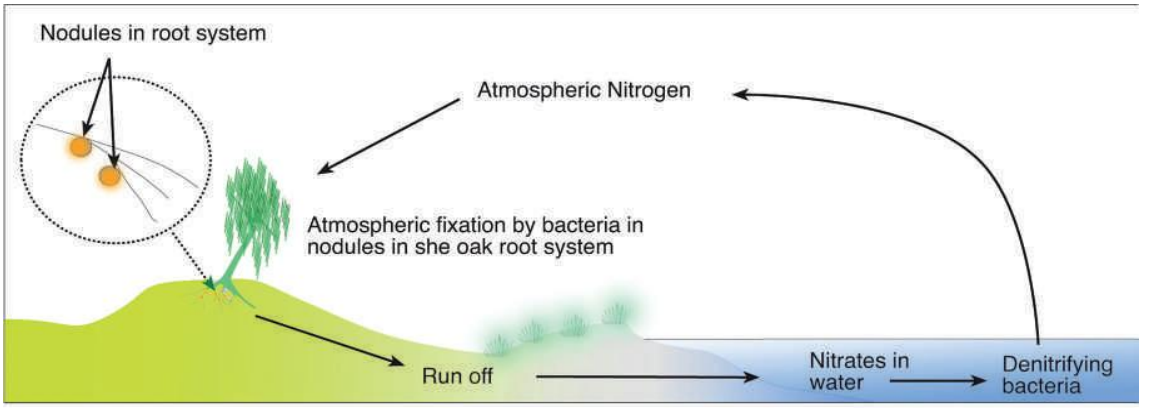


Figure 252.2 Nitrogen fixation and cycling by the she oak
(Illustration Bob Moffatt)

Other coastal plants

Other plants you may find near sand dune systems include the pandanas (Figure 253.1) banksia (Figure 253.2), paperbark, grevillia and coastal wattle.

The importance of dune plants

Changing patterns of dunes

Too much sand on dunes can be a problem also. Dunes can move inland as has happened in South Australia. Vegetation can become eroded in some places and a dune can "blow out" into the land. These blow-outs are common in higher dune systems.

Primary dunes can be lost altogether in time and the coastline can move inland. If buildings had been established on these fore-dunes they too would be lost.

Some reasons dune plants are important is that they:

- provide habitats for many animals such as birds, lizards, kangaroos;
- provide a temporary nesting site for turtles;
- stop sand blowing away providing a reservoir for sand during storms;
- fix nitrogen from the air to provide nutrients for other plants;
- sieve the salt air from the sea, providing a buffer for more complex vegetation behind.

Ecological succession

The dune system also provides an excellent example of plants that change in size from one place to another. The smallest plants (spinifex) are called the pioneer community with a succession of plants (she oak, banksia wattle and pandanas) to a climax community of paperbarks.

Island vegetation

On coral reefs and offshore islands, specialised plants such as the octopus bush and the pisonia tree can survive. These trees have a special relationship with island birds as shown in Figure 253.3.

The islands often have only a few plant species that are tolerant of beach or sand conditions (salt tolerant, resistant to desiccation) and are especially adapted to dispersal over water.

Some islands can have up to 60 different types of plants including rainforests.

If you visit a sand island you may find trees which provide homes for many species of sea bird.

Bird dung accumulates at the base of the tree, and dissolves when it rains to provide a fertiliser for tree growth.

Figure 253.1 Pandanas
(Bob Moffatt)

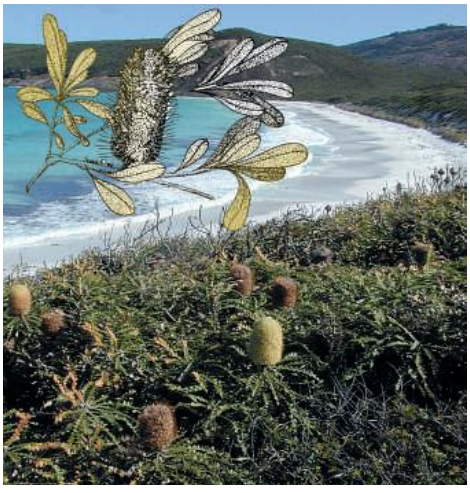


Figure 253.2 Coastal banksia
(Illustration Sue Oats, Photo Bob Moffatt)

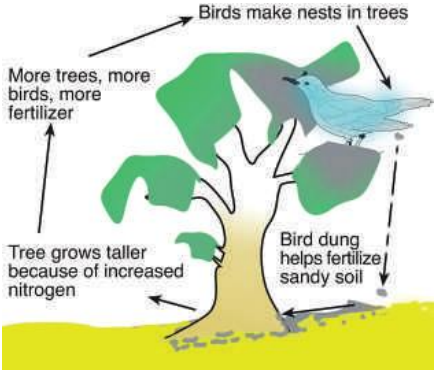
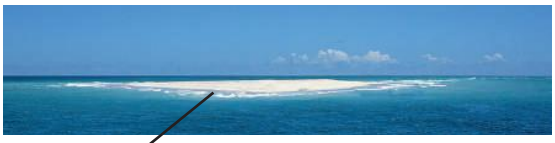
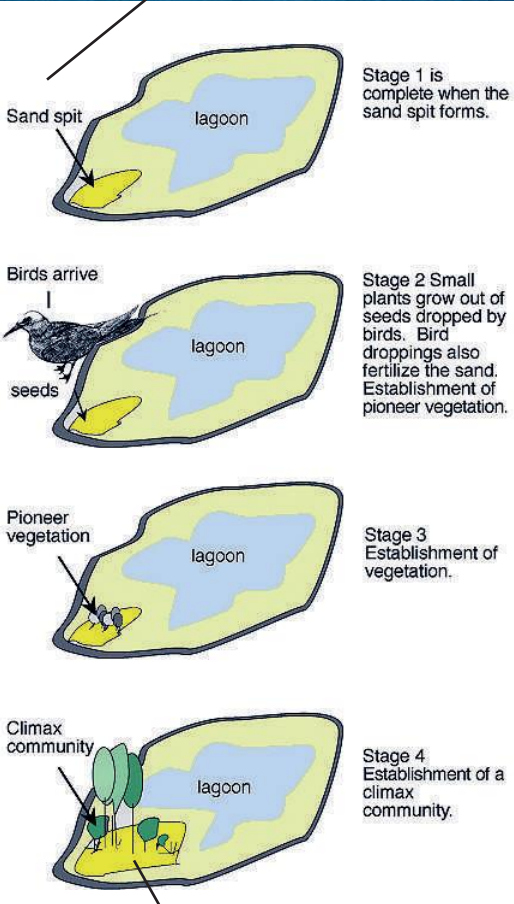


Figure 253.3 Pisonia trees and birds
(Illustration Bob Moffatt)





Ecological succession of a coral cay

A coral cay is a sand island formed at one end of a reef. The cay may begin with a sand spit which can disappear again and no further development occurs.

However if conditions are favourable and sufficient birds arrive, small plants can grow in bird dung.

A pioneer vegetation of small plants such as spinifex is established by these birds and there is a special relationship between the birds and the plants. The seeds cannot grow in pure sand and require the birds' dung from which to derive nutrient. Once established, the pioneer community then traps driftwood, dead birds, remains of crabs and other scavengers that arrive on the island.

Figure 254.1, shows the arrival of birds and the growth of pioneer grasses and shrubs. As the shrubs grow and die and as more humus develops in the newly established soil, larger trees can start growing. Insects, spiders, centipedes now arrive on the wings of birds or on driftwood. As these die, more is added to the humus.

Stage 3 is characterised by the growth of trees on the foreshore such as she oaks and larger trees inland which provide homes for the birds that characteristically inhabit the islands of the southern Barrier Reef. As more birds form nests, more dung accumulates on the ground.

A cyclone or fire may interrupt the process, calling a temporary halt to the continued growth. However the island can now consolidate the vegetation and regrowth is quick.

Figure 254.1 Ecological succession on a coral cay
(Bob Moffatt)

Exercise 10.1 Sand dune plants

Aim

To develop your skills in field planning, research, interpretation and reporting.

Method

1. Make a beach profile stick like the one shown in Figure 255.1 and use it to plot a profile of the beach.
2. Use the poster or information from your local beach protection agency to identify the plant species on the dunes, being careful not to damage sensitive plants.

   If previous year groups have made a herbarium of pressed plants that have been laminated, use these to identify specimens as well.
3. Now assign a key diagram like the one shown in Figure 255.2 and mark in your profile where these plants occur.

Questions

1. Which plant is dominant:
   a. nearest the sea?
   b nearest the land?
2. Explain the relationship between size of plant and position on the profile.
3. Which is the best plant at holding the sand together?
4. Is there any evidence of beach erosion? Give reasons for your answer.
5. Is there any evidence of pollution? Give reasons for your answer.
6. Does the amount of organic matter change as you go inland?
7. Draw a graph of your beach profile marking in clearly where each plant species is found.

Conservation hints

1. Dunes are fragile ecosystems and damage to plants can cause the dune to blowout so be careful as you do your profile.

   Take digital photographs and email them to group members to reduce the damage and analyse the photographs back at school.

2. A permit may be required to collect plant species. If you collect, do so to make a herbarium record.

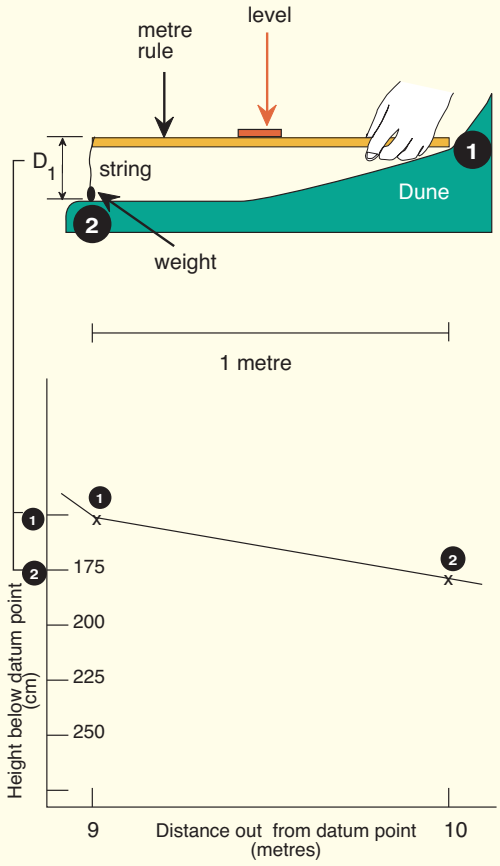


Figure 255.1 Beach profile stick and profile
(Illustrations Bob Moffatt)

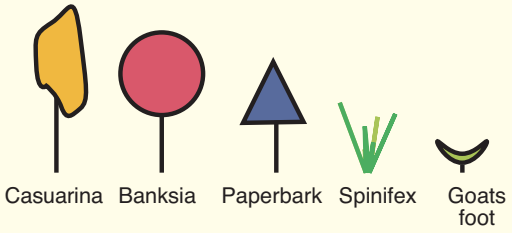


Figure 255.2 Dune key to plants
(Illustrations Bob Moffatt)

Materials and equipment (per group)

- a poster from your local Beach Protection Authority with photographs of local dune plants
- beach profile stick

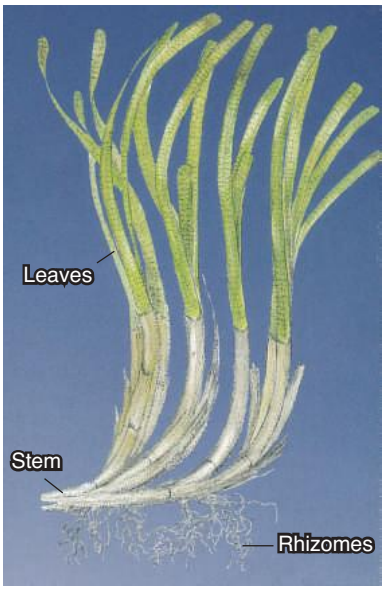


Figure 256.1 Seagrass
(Illustrations courtesy Qld Fisheries Service)

Seagrasses - sub-tidal plants

Seagrasses are plants with roots, stems, leaves and flowers that have adapted to living completely submerged in sea water. Because they have flowers, they are classified as angiosperms but they are not related to either seaweeds or true grasses. This group of plants is important because they grow into seagrass meadows that protect and hold the otherwise shifting sands of sand bars. Seagrasses are also a vital source of food and shelter for many organisms and are the nurseries for many species of fish (for example flathead).

Zostera, which is commonly called eel grass or dugong grass, has narrow grass-like leaves and stem-like rhizomes that bind the sand together.

Posidonia is a seagrass that only grows in southern waters where it helps stabilise off-shore sand areas (Figure 256.1). It has long, strap-like leaves (up to 90 cm long) and may be found in huge piles on beaches in South Australia after storms.

Reproduction

Seagrass plants reproduce like flowering land plants, needing the production of pollen which will attach itself to other flowers. The flower is then fertilised and seed is produced. The remarkable thing is that, in many cases, the whole reproductive process occurs underwater, with the released pollen drifting in the current. Some seagrasses, however, produce flowers on long stems during low tide and reproduce in much the same way as land plants.

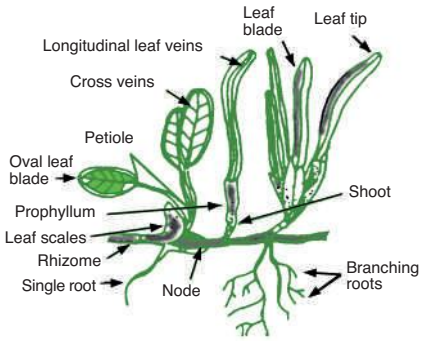
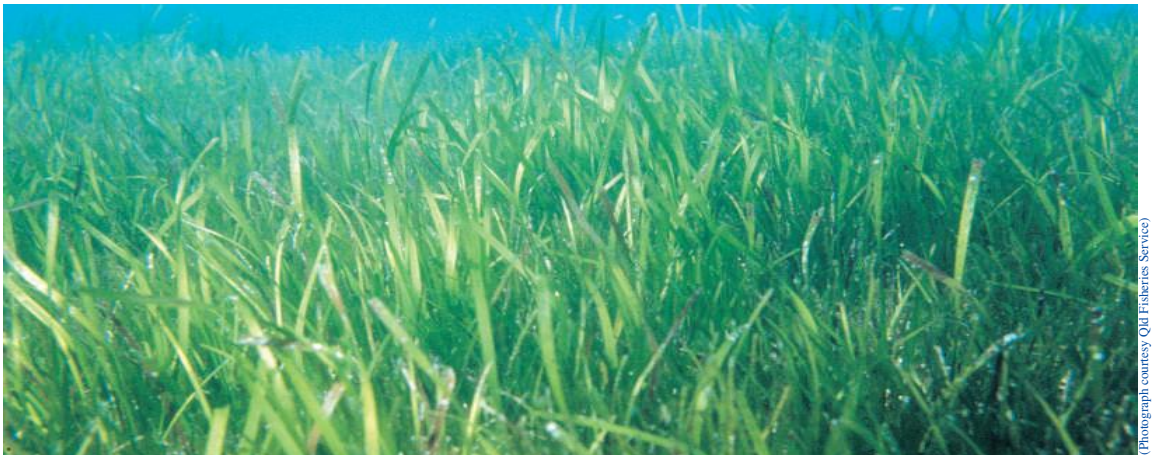


Figure 256.2 Seagrass structure
(Illustrations courtesy Qld Fisheries Service)

Significance

Seagrasses are the homes for literally thousands of animals, from the herbivorous dugong to the smallest of zooplankton. A shortlist of the animals that seagrass benefits would include fish such as flathead, snails, amphipods, jellyfish, baby prawns, bacteria, shellfish, mussels and baby fish.



(Photograph courtesy Qld Fisheries Service)

Figure 256.3 Seagrass beds

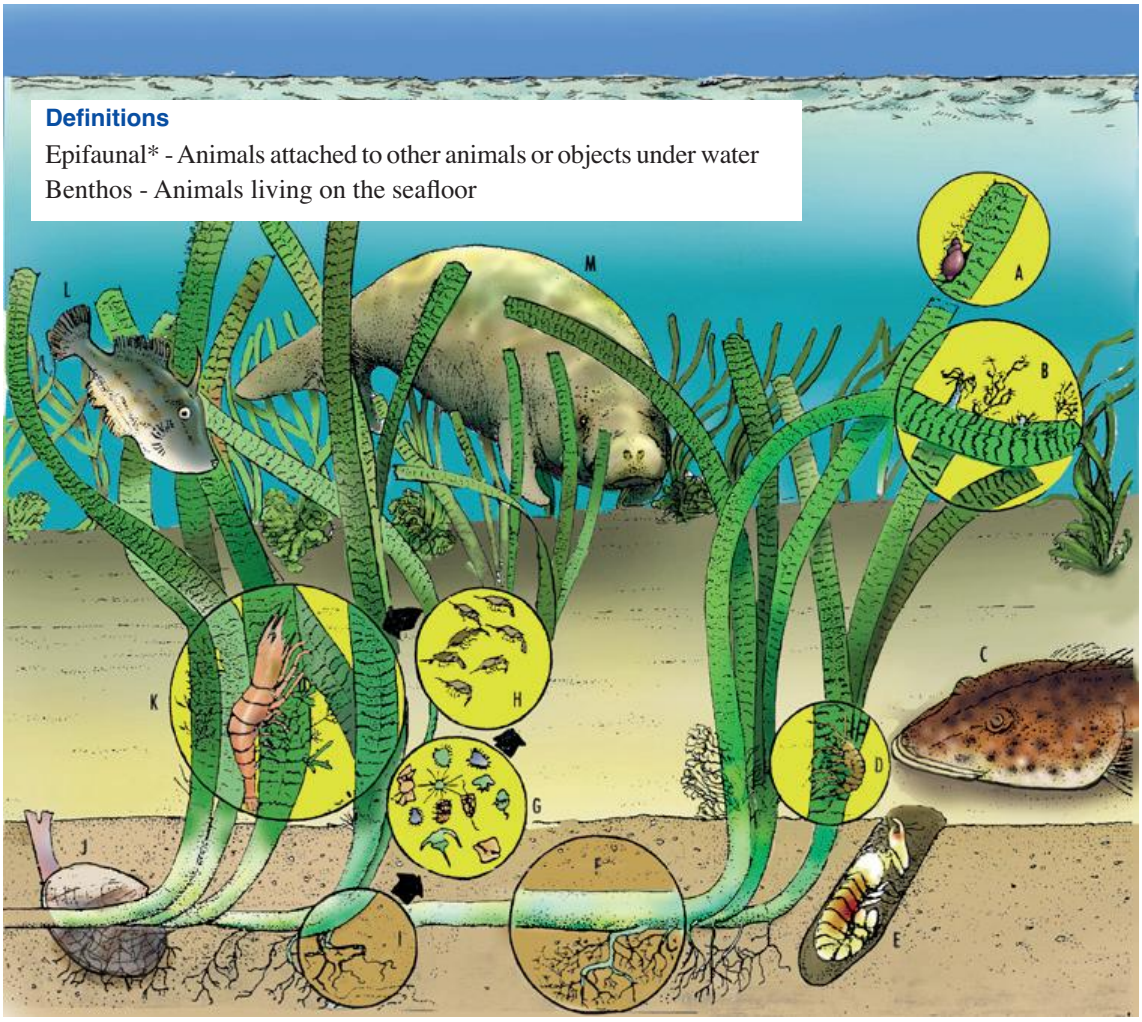


Figure 257.1 Seagrass beds are a complex ecosystem in themselves. Can you see the effect an algal bloom would have on the microfauna? Illustration courtesy WA Fisheries, reproduced with permission.
(Illustration WA Fisheries)

This is best illustrated by Figure 257.1 above. You will learn more about the animals mentioned in the next two chapters.

A. Epifaunal* grazers such as snails and amphipods live on the outside of the seagrass.
B. Epifaunal suspension feeders attached to the seagrass such as hydrozoans catch small plankters.
C. Benthic* carnivores such as flathead hide in between the seagrass waiting for small fish as prey.
D. Amphipods live on the dead remains of animals from above which accumulate on the leaf.
E. A mantis shrimp waits on the seagrass leaf to prey on other animals.
F. Bacteria live in the rhizome root system and fix nitrogen from the water. Scientists also believe they detoxify heavy metals.
G. Small protozoans – single celled marine animals live off phytoplankton.
H. Bigger crustaceans – the meiofauna feed on the single celled protozoans.
I. Bacteria decompose dead rhizomes.
J. A small clam filter feeds on plankton and detritus from above the mud.
K. A small prawn clings to the seagrass feeding on plankton.
L A herbivore fish, leather jacket feeds on the seagrass.
M. Another herbivore the dugong feeds on the seagrass.

Illustration Sharyn Madder

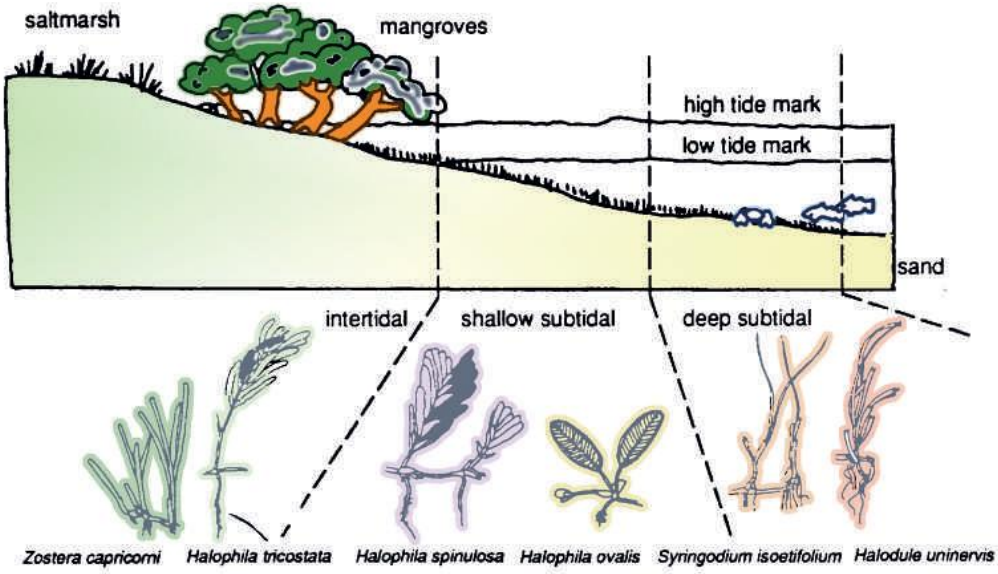


Figure 258.1 Distribution of seagrass species.
(Illustration courtesy Qld Fisheries Service, reproduced with permission)

Figure 258.2 Marine Biologist and seagrasses
(Photograph courtesy Qld Fisheries Service)

Figure 258.3 Web reference from wwwscience.murdoch.edu.au

Distribution of species

Seagrass species can be distributed as a succession underwater much the same way as plants are distributed on land (Figure 258.1).

Economic importance

Without seagrasses, our inshore seas would be like underwater deserts and would not contain the basic food supplies for our billion dollar fishing industry.

Many development companies and tourist operations are yet to learn and appreciate the importance of seagrasses. For example, the tiger prawn catch in Australia's $120 million northern prawn fishing industry is dependent on the survival of healthy seagrass beds. The juveniles of the much prized tiger prawns are found only in beds of seagrasses and algae.

In tropical waters the dugong and sea turtle graze on the seagrasses; rhizomes and western rock lobsters live off rotting dead leaves; piles of dead seagrass on the beach provide the homes for a whole community of animals on the beach.

Western Australia boasts an enormous coastline of some 12,500 km, including waters ranging from temperate to tropical. The southern coastline borders the Southern Ocean at latitudes of 32-34°S; the northern coastline is on the Timor Sea from 12-15°S, while the remainder borders the Indian Ocean. A wide variety of conditions exists along this coastline, which includes large areas of shallow soft sea bed forming an ideal habitat for seagrasses. Figure 258.3 shows the Western Australian coastline; seagrass habitats are highlighted.

Web reference

http://wwwscience.murdoch.edu.au/centres/others/seagrass/

Mangroves - Intertidal plants

The tidal zone

The term **mangrove** can be used in three ways: the trees themselves (Figure 259.2), the forest (also, but not commonly, called a mangal), and the habitat. Mangrove forests can grow over 10 metres in height in tropical Australia.

Mangroves are found growing in the intertidal areas of sheltered shores, estuaries and bays or in the lee of large islands and are most likely to grow in tropical and temperate regions shown in Figure 259.1. They grow best at river entrances and creeks where salt has been deposited to form low flat areas of mud. Here the velocity of the river is slowed which allows silt to settle out and accumulate. This mud and silt is rich in nutrients and is ideal for mangrove development. (Read back over the chapter on coastlines in Chapter 4, which discussed wave velocity and substrate type.)

Mangroves are the temporary habitats for fish populations and are in the top three of the most productive ecosystems on earth.

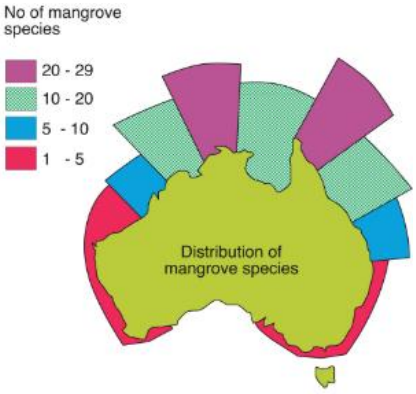


Figure 259.1 Approximate distribution of mangroves in Australia (After Hutchings and Riechter, 1987)
(Illustration Mark Moffatt)

Sheltered waters Moreton Bay Qld
(Photograph courtesy Qld Fisheries Service)

Kings Cascade WA
(Photograph Bob Moffatt)

Mangroves meet the sea NSW
(Photograph courtesy NSW Fisheries Service)

Mangroves Darwin
(Photograph Bob Moffatt)

Figure 259.2 Mangroves environments

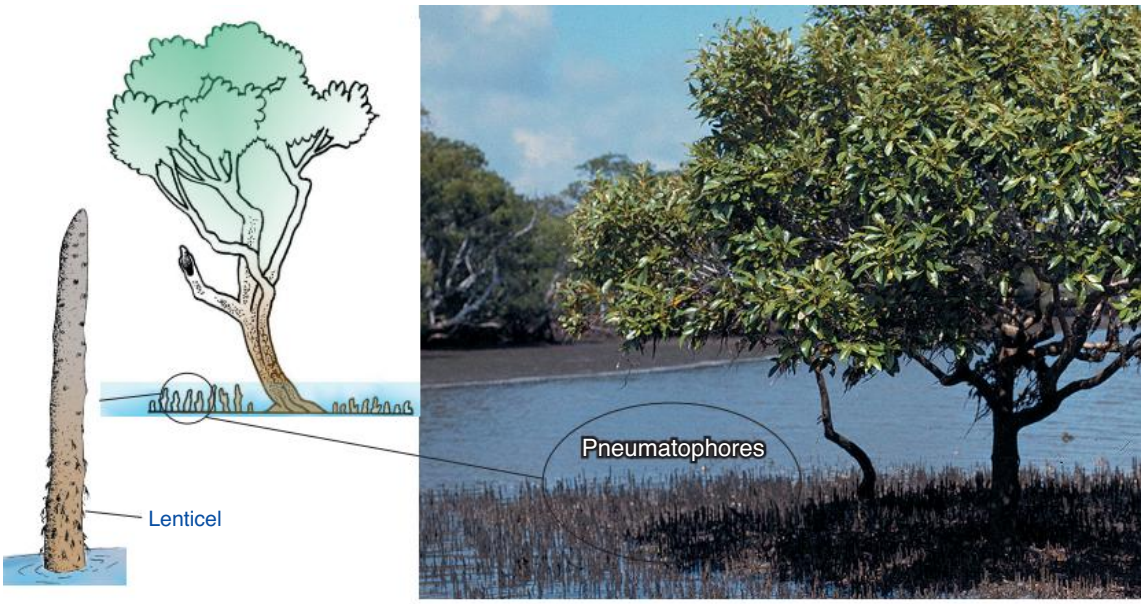


Figure 260.1 Pneumatophores allow the plant to breathe during high tide.
(Illustrations Rose Bedford, photograph Qld Fisheries Service)

Figure 260.2 Prop root system stops the mangrove from falling over.
(Photograph Qld Fisheries Service)

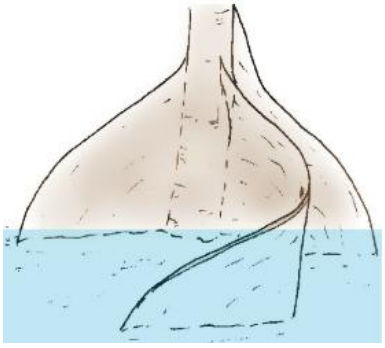


Figure 260.3 Buttress roots
(Illustration John Burnett)

Adaptations

The following text is a modification of the adaptations section written by Dave Claridge in the *Mangroves in Focus* book.

Mangroves grow in an environment where the water is very salty and the oxygen level in the muddy soil is often low.

The problem of substrate instability

All mangroves have a system of laterally spreading cable roots to which are attached the vertical anchor roots. From these go out the fine hair-like roots which extract nutrition from the soil. Mangrove root systems are invariably very shallow, and most species do not appear to have tap roots. In mangrove areas, the amount of biomass under the ground is greater to that above ground thus reducing the chance of mangroves being washed away.

The problem of aeration

Respiration takes place by diffusion through lenticels (minute openings) in the roots and stems of plants. To enable this to happen, mangroves have developed a number of specialised adaptations.

A walk through a mangrove forest will identify five different above ground root formations:

1. Pneumatophores (see Figure 260.1) are peg-like erect roots growing upwards from the cable root system.
2. Stilt roots are the distinctive curving prop roots which arch out from the trunk.
3. Buttress roots are blade like structures at the base of the trunk as shown in Figure 260.3.
4. Knee roots, which are loops in cable roots appear as knobbly knee like projections above the substrate as shown in Figure 261.1 .
5. Aerial roots, as shown in Figure 261.2, descend from the branches or from the base of the plant.

These root structures are adaptations to root aeration, because the greatest variety of root variation occurs in species which occur on lower tide levels. Those species which are found on more aerobic, less waterlogged soils near the upper tidal limit do not possess specialised root systems.

The problem of seed dispersal/establishment

The seeds of mangroves are buoyant and are adapted to dispersal by water, sometimes over considerable distances.

While the various mangrove species produce large crops of seeds each year, only a few successfully take root.

The vast majority are washed up on beaches as debris mixed with the species of seeds from littoral forests and other flotsam. Many drift into populated areas where there is little chance of survival.

Mud banks exposed at low tide are formed of river silts in sheltered areas creating an ideal environment for seedlings to develop.

When fully developed, the root network of these pioneer species firstly serves as a barrier to slow down tidal movement, secondly traps floating debris and silt during periods of inundation and thirdly maintains and builds up the level of the forest floor.

This provides the conditions which allow other mangrove species to establish and form a forest.

The problems of high salinity

The mechanism by which salt content is regulated is a function of the whole plant and not individual parts.

This involves one or a combination of the following processes—exclusion, excretion or accumulation.

Exclusion

Plants which are salt excluders have a sort of super filter, a selective absorption process which enables them to take in water and filter most of the salt out.

Excretion

This occurs by means of salt glands in the leaves as shown in Figure 261.3

Accumulation

Mangroves which accumulate excess salt, deposit it in bark or old leaves. Species which do this often have succulent or thickened leaves.

These leaves fall to the forest floor and become part of the detrital build up. For some deciduous species scientists have theorised that the leaf fall each year is a prelude to the new growing season.

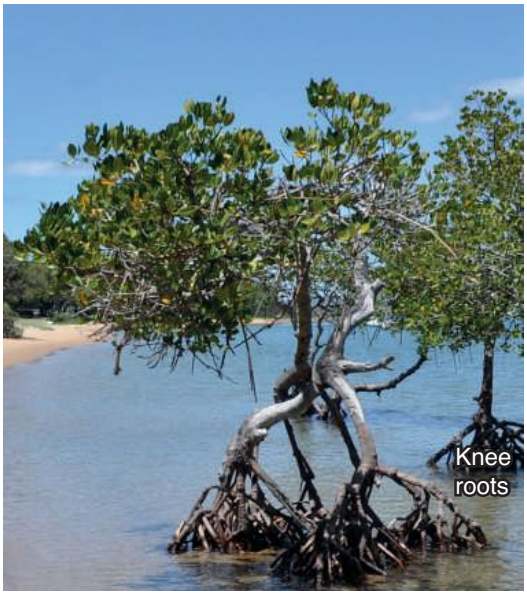


Figure 261.1 Knee roots
(Photo Bob Moffatt)

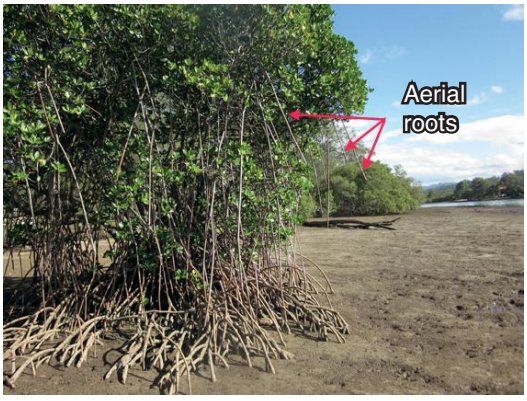


Figure 261.2 Aerial roots
(Photo Bob Moffatt)

Figure 261.3 Some leaves excrete salt
(Photograph Qld Fisheries Service)

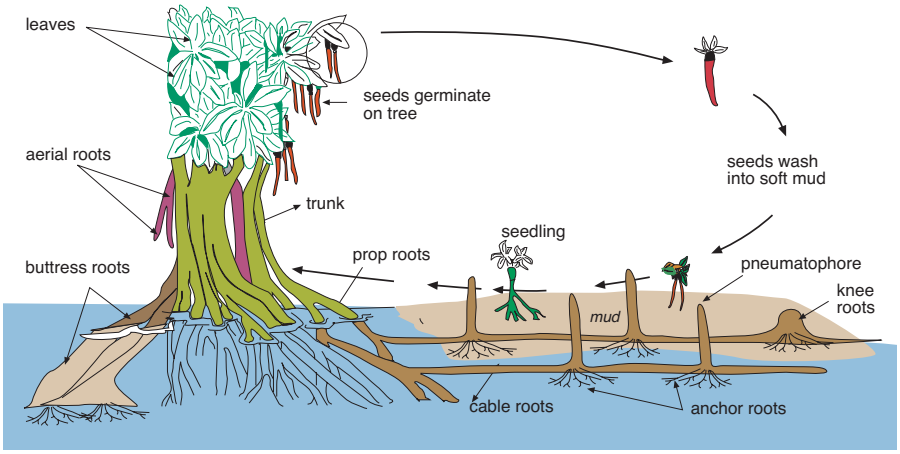


Figure 262.1 Generalised mangrove and life cycle – not all these features are on the one plant. (After Lerman 1986)
(Illustration and photo Bob Moffatt)

Reproduction

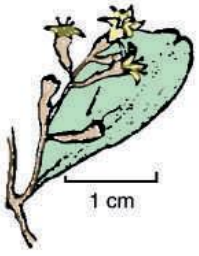
A mangrove is a tree and so has flowers, shoots, roots, stems and leaves as shown in Figures 262.1 and 262.2.

Three types of flowers include big and snowy, medium sized, or small and indistinct with different types of leaf as shown in Figure 262.2, thick and snappy, wrapped around the stem, and small (smelly when you crush them).

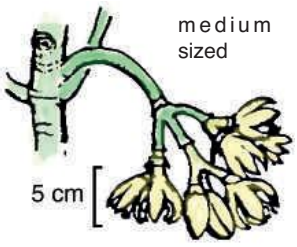
Mangroves reproduce by male and female flower parts fertilising each other and forming a seed.

In some species these seeds are specialised in that they germinate while still attached to the tree and are long and thin so that when they drop to the ground they stick in the mud.

If they fail to strike, the seed is covered by a tough sheath to prevent it from drying out and enabling it to float. Others, such as the Grey Mangrove, fall to the ground and are washed away by the tide.



small and indistinct



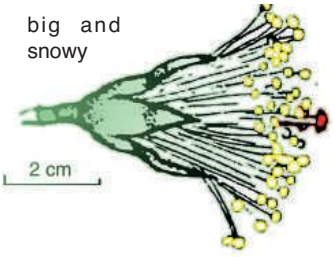


Figure 262.2 Mangrove flowers and fruit
Illustrations by Michael Mitchie and John Burnett

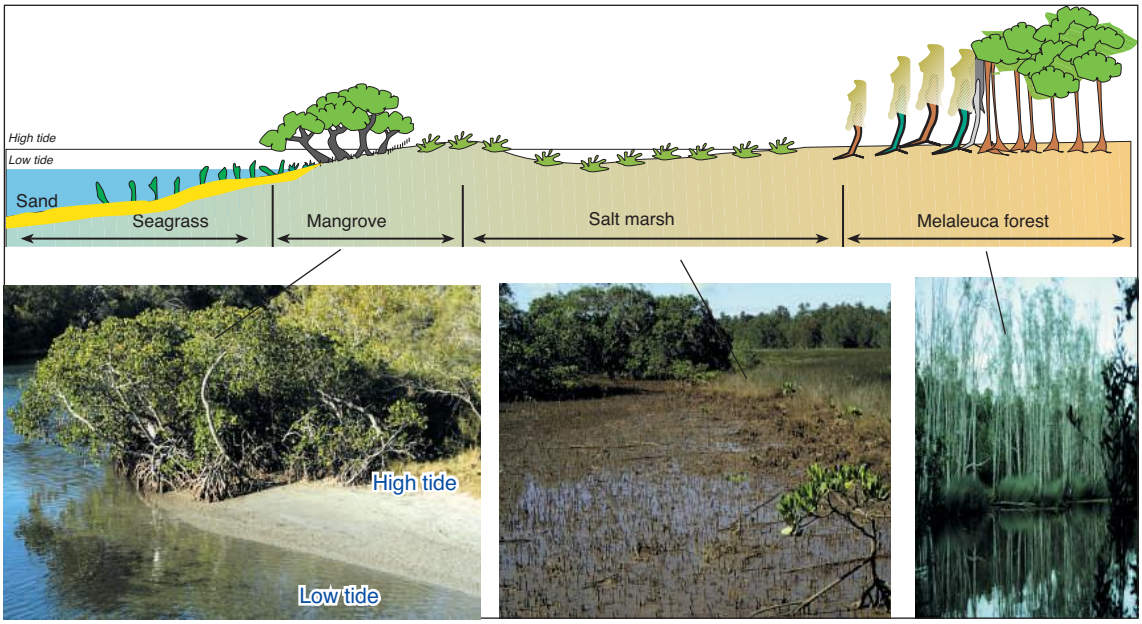


Figure 263.1 Intertidal zones
(Illustration Bob Moffatt, photographs courtesy Qld Fisheries Service and Dave Claridge)

Zonation

The typical mangrove forest of eastern Australia is divided into three zones as shown in Figure 263.1. These are the;

- outer
- middle or main zone and
- landward or littoral fringe zones.

In southern Australia, where the number of species is limited, mangroves are found in pure stands or in mixtures in which no form of zonation is able to be recognised. In Victoria and South Australia, mangrove areas are monocultures of *Avicennia marina*.

The outer zone

This is the area which is subjected to tidal inundation at least once every twenty-four hours. At the seaward edge of this region is a strip, often only one or two trees wide, of mature *Avicennia marina* (Figure 263.2). These are usually large trees and small saplings and seedlings may extend seaward of them.

The middle zone

This area is subject to less regular tidal inundation — some parts may be covered only on the four days surrounding the spring tides at new and full moon.

Landward zone

This area is above high tide mark but often has semi-saline lakes and supports a thick forest of trees. In urban Australia this has almost disappeared due to housing development.

Odd fact

One of the most unusual features of a mangrove forest is the development of bands of dominant species which run roughly parallel with the shoreline or the banks of tidal creek systems

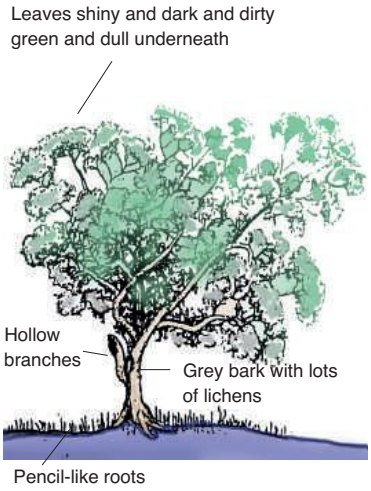


Figure 263.2 White or grey mangrove *Avicennia marina*
(Illustration Qld Littoral Society)

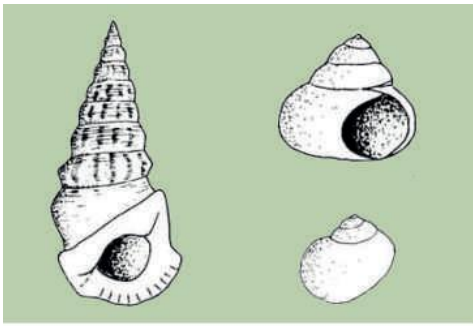


Figure 264.1 Some shells of the mangroves
(G. Leiper)

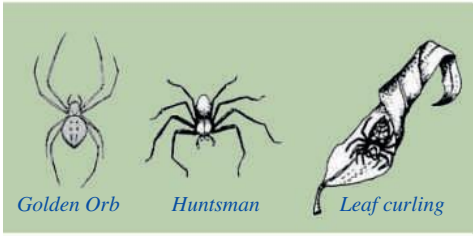


Figure 264.2 Some spiders
(G. Leiper)

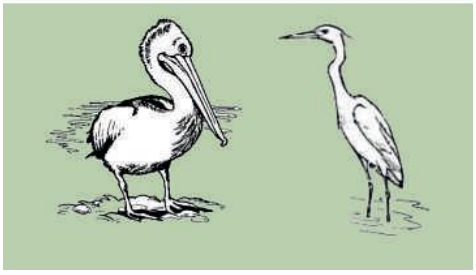


Figure 264.3 Birds Pelican (L) and Egret (R)
(Rose Bedford)

Figure 264.4 Mudcrab
(Photo Qld Fisheries Service)

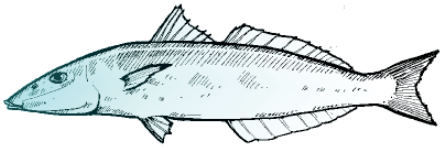


Figure 264.5 Whiting
(Illustration Kerry Kitzelman)

Mangroves as shelter

Mangroves are fundamentally important in that they offer a habitat or shelter for other plants and animals. Small fish use the tangled roots of the mangrove forest as a protection from predators.

The incredible richness of the food chains in mangroves supports a large number of commercial and recreational fish species for at least a part of their life cycles.

The most common permanent dwellers of the mangroves however are molluscs and crustacea.

Mud crabs make their homes there, even though they spawn in the open sea. Other crabs using the mangrove as a habitat include fiddlers and soldier crabs. Small fish such as whiting, mudskippers and yabbies seek shelter from predators (Figures 264.5)

Other species of molluscs include mud whelks (Figure 264.1), periwinkles, oysters and various scallop species. Spiders live in the leaves and on the branches.

Mangroves, together with associated wetlands, are important bird habitats. Both seabirds and terrestrial species are attracted to such areas.

Terrestrial species which feed on the mudflats, and in shallow water surrounding mangroves areas include, pelicans and egrets (Figure 264.3), stilts, spoonbills, ibis, jabiru and heron. Such species may also roost in mangroves.

Waders also use the areas. Mudflats with nearby seagrass beds and intertidal banks tend to attract the greatest number of wading birds.

Many of the waders are summer visitors which have migrated from the Northern Hemisphere's winter. Some of these visitors include:

- golden plovers, a migrant from the Arctic regions;
- tattlers, migrants from Siberia or North America;
- curlews and godwits, migrants from eastern Asia.

Many of these species are listed in international conservation agreements with China and Japan.

Few terrestrial animals live in or visit the mangroves. Bats and flying foxes use the mangrove forest as a roosting site during the day, and occasionally wallabies and dingoes are seen at or near the landward fringe.

Mangrove forests of northern and eastern Australia are home to the saltwater crocodile and some species of land snakes and sea snakes are found in mangroves.

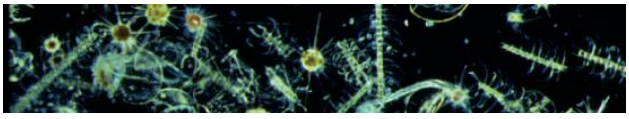


Figure 264.6 Marine Phytoplankton
(Image www.marinephytoplankton.org)

Exercise 10.2 Plant diversity

Aim

To classify a collection of plants describing some of their adaptations to where they live.

Field methods

1. Collect samples of dune plants. Note: most marine plants are now protected species and an education permit is required to collect.
2. Place all specimens in different bags noting when and where you collected specimens.

Laboratory methods

1. If necessary trim the specimen to fit onto your card.
2. Use a plant key to identify the specimens.

   Coast care or dune care groups often have identification posters.
3. To press place the specimen on waxed paper and cover in the following order:
   - cardboard
   - newspaper
   - waxed paper
   - specimen on card
   - newspaper
   - cardboard
4. Then follow steps 6-9 on the next page

   Notes:

   a. Try to collect living specimens. Dried, decaying or insect encrusted specimens are difficult to press.

   b. When removing the plant's root system make sure you remove as much sand as you can to display the roots.

She oak
(Illustration Project Reef Ed)

Digital photography plant press

Where possible use a digital camera to make your collection.

Keep your camera in a plastic bag for field work.

Print out your colour photos or arrange the original files in a power point presentation.

Pandanas
(Illustration Project Reef Ed)

Mangrove leaf
(Illustration John Burnett)

Coastal spinifex
(Photograph GCCC)

Materials and equipment (per group)

- plastic bags and ties
- labels
- shallow pans or trays
- field note book
- wax paper
- newspapers
- cellophane wrap
- dissecting needle
- scissors
- putty knife
- 10 cm x 18 cm approx. cards or herbarium sheets
- plant press
- identification keys
- two pieces of plywood and straps to make a press
- camera (optional)
- superglue (optional)

Exercise 10.3 Seaweeds and seagrasses

Field methods

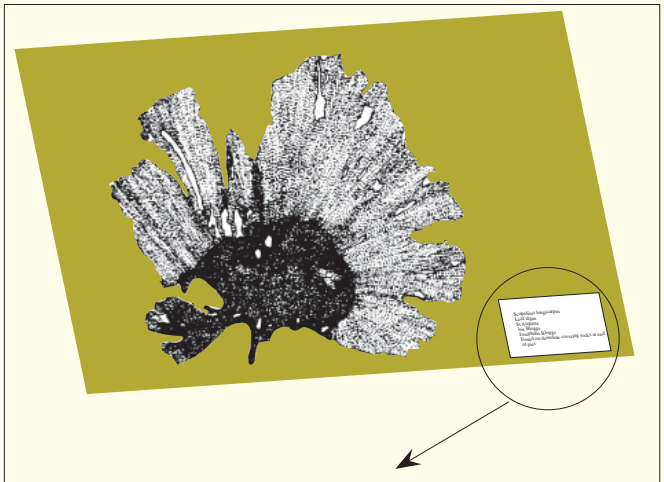
1. Collect seaweeds at low tide according to the safety suggestions in Figure 267.2)
2. Place all specimens in the same bag remembering that specimens are to fit onto a card with 8 cm left for information.
3. Number the bag and record information in your field note book detailing when and where you collected specimens (see Figure 267.1 opposite).
4. Notes:
   a. Try to collect living specimens. Dried, decaying or insect encrusted specimens are difficult to press.
   b. When removing the plant's holdfast, make sure this is carefully removed with the putty knife.

Laboratory methods

1. Wash all specimens with fresh water to remove all mud and debris. If necessary trim the specimen to fit onto your card.
2. Use a plant key to identify the specimens. If you have difficulty, take a photo and send it off to your local herbarium for identification.
3. If the specimen is rounded, it can be teased out with a dissecting needle.
4. If the specimen is delicate, it may have to be 'floated out'. Place the algae in a shallow pan filled with water.
5. Float the specimen to a natural looking position and slip the card under the algae lifting the card slowly and carefully so the water will drain.
6. Place the specimen on blotting paper with a piece of waxed paper over. Do this for all the specimens in the following order:
   - cardboard
   - newspaper
   - blotter
   - waxed paper
   - specimen on card
   - blotter
   - newspaper
   - cardboard
7. After stacking all your specimens place them between two pieces of plywood and secure with straps. Note that algae require more pressure than botanical mounts.
8. Place near a fan so that air blows through the cardboard spaces. Change blotting paper each day.
9. Most plants will "glue themselves" to the cardboard. If they don't, use a small amount of superglue to fix.

Alternatives

You could try photocopying the algae onto a card or photographing the algae in the field.



Scientific name _____

Common name _____

Locality _____

Collector _____

Identified by _____

Remarks _____

_____

_____

Research report

1. Prepare a report under the following headings.
   - Aim
   - Method
   - Classification key
2. Comment on the value of a herbarium collection and the ethics of collecting marine specimens.
3. Comment on the value of the information recorded on the label of the seaweed specimen.

Safety and conservation

1. Note in many Australian States a permit is required to collect marine specimens. Check with your local fisheries or conservation authority before collecting.
2. If you collect seaweeds on a rocky shore always wear shoes and gloves.
3. Never turn your back to the sea and don't go too close to where waves are breaking.
4. Look up the tide book before you go to make sure that you are collecting at low tide.
5. Collect only small amounts of seaweed according to your permit.

In most Australian States you need a permit from the Department of Primary Industries to collect any marine plants.

Exercise 10.4 How can we identify mangroves?

Based on an original exercise by staff at Ingham State High School.

Aim

To identify a variety of mangroves from preserved leaf specimens and photographs.

You will need

A variety of mangrove leaves and photos of the plant they came from.

What to do

- Use the key below to identify the specimens supplied.
- Use the information in Figure 267.1 to assist.

	Characteristic	*Genus / species*
1.	Stilt roots and/or knee roots present	go to 2
	Stilt roots and/or knee roots absent	go to 3
2.	Aerial prop roots	*Rhizophora* sp.
	No aerial prop roots	*Bruguiera* sp.
3.	Leaves compound	go to 4
	Leaves simple	go to 5
4.	Mid rib vein central	*Xylocarpus* sp.
	Mid rib vein slightly off centre	*Cynometra iripa*
5.	Leaves opposite	go to 6
	Leaves alternate	go to 10
6.	Underside of leaf grey	*Avicennia* sp.
	Underside of leaf not grey	go to 7
7.	Interpetiolar stipules present	*Scyphiphora* sp.
	Interpetiolar stipules absent	go to 8
8.	Leaf stalk with two glands at base	*Sonneratia* sp.
	Leaf stalk without glands at base	go to 9
9.	Leaf margin finely toothed in upper half	*Osbornia* sp.
	Leaf margin with spiny teeth	*Acanthus* sp.
	Leaf margins entire	*Ceriops* sp.
10.	Leaf underside grey	go to 11
	Leaf underside not grey	go to 12
11.	Leaf tip acuminate	*Heritiera* sp.
	Leaf tip emarginate	*Camptostemon* sp.
12	Latex (milky sap) present	*Excoecaria* sp.
	No latex	go to 13
13.	Gland at leaf apex	*Lumnitzera* sp.
	No gland at apex	go to 14
14.	Leaf stalk stem sheathed	*Aegialitis* sp.
	Leaf stalk not sheathed	*Aegiceras* sp.

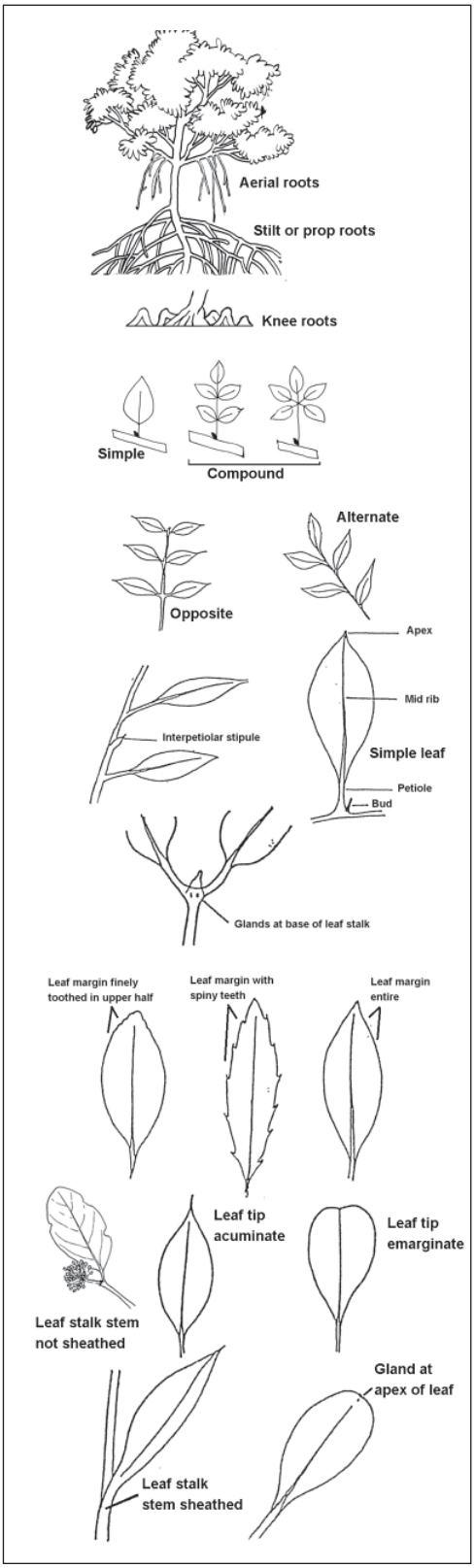


Figure 267.1 Information relevant to mangrove key

Exercises

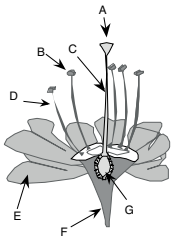
From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

A1. What do mangroves look like?
A2. Which animals use mangroves for shelter?
A3. How do mangroves grow?
A4. How do mangroves reproduce?
A5. Which animals use seagrasses for shelter?
A7. What is a marine habitat?
A8. What lives in estuarine habitats?
A9. How do mangroves overcome salt and lack of air?
A10. How can we identify mangroves?
A11. What other links are there between the sea and mangroves?
A14. Why are mangroves and seagrasses important?

Questions

Knowledge

1. Name the plant parts A-G on the diagram opposite.



2. List five abiotic features of the dune system.
3. List six animals that live in a seagrass bed.

Understanding

4. Explain the meaning of the following terms:
   - *Ecological succession; Pioneer vegetation; Nitrogen fixation; Synthesis of animal protein.*
5. Describe, with the aid of a diagram, the phosphorous cycle in a beach/dune system.
6. Draw a diagram to show the nitrogen cycle in a dune system using a she oak, sand and the atmosphere. Label your diagram.

Applying

7. Construct a diagram of a mangrove swamp using the results from a field trip.
8. Complete a diagram of a seagrass bed to show the following animals and plants.
   a. Benthic carnivores such as flathead hide in between the seagrass waiting for small fish as prey.
   b. Epifaunal suspension feeders attached to the seagrass such as hydrozoans catch small plankters.

Analysing

Read the wind velocity experiment below and answer the questions that follow.

Wind velocity experiment

Marine scientists believe that the shape of dune plants was critical to the deposition of sand in primary dune systems. A series of experiments were conducted in a wind tunnel to study the velocity of wind as it passed through a number of shaped plants. These shapes are shown in Figure 268.1. An anemometer was set up on each side of the plant to measure the effect of the plant shape on changes in wind velocity and wind velocities ranging from 5 - 40 knots were blown at the plants. The results of the experiment are shown in Figure 268.1.

9. What do you think are the names of plants A and B? Give reasons for your answer.
10. Compare the winds velocities on either sides of the plants as wind speed increases.
11. If there was sand in the wind, which plant would survive best in the sand dunes?

    Give one reason for your answer.
12. Which habitat do you think plant B is most suited to? Give two reasons for your answer.
13. A dam was placed in a fast flowing river that lead to the sea. Make a flow chart to predict possible consequences on coastal sand dune systems.
14. A sand spit formed on a coral cay, but after 10 years plants had failed to grow. Explain why.

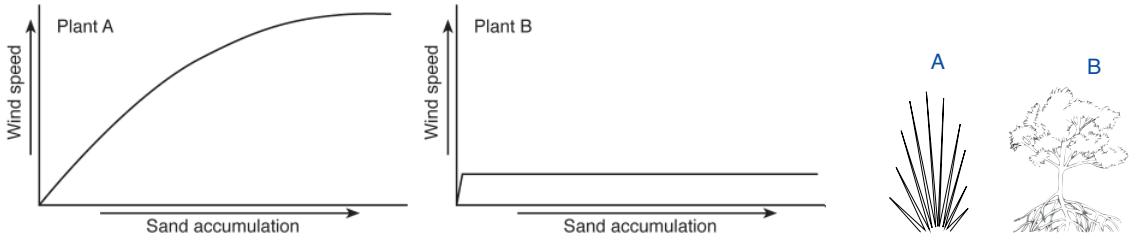
Creating

15. You have been asked to research local sand dunes. Write a series of (at least 6) questions that you may ask yourself at the beginning of the research.
16. Plan an experiment to show how you would design the perfect plant to live in the mud.

Evaluating

17. Predict 6 consequences of an algal bloom on the sea grass beds.
18. Evaluate the statement — *Without seagrasses, our inshore seas would be like underwater deserts and would not contain the basic food supplies for our billion dollar fishing industry.*

Figure 268.1 Plant velocity v's sand accumulation

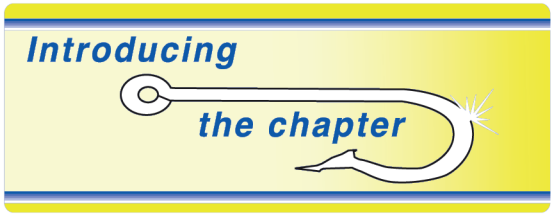


Chapter 11 Marine Invertebrates (1)

Protozoa - Molluscs

by
Bob Moffatt

Photo Murray Waite



Chapter hooks

- Use bioviewer slides (microscope like slides that have full colour photographs of marine invertebrates) in group work and then classify the slides using pages 263-290.
- Culture some paramecium or other microscopic animal to show the features of protozoa.
- Listen to earthworms as they crawl over paper to discover external features.
- Try dissecting a worm under a digital microscope.
- Play the *who am I game*. Each person takes on an animal from the chapter and pins it to the back of a partners shirt. Then you play the game of *who am I* where the person tries to guess the name that is pinned onto his/her back.

Why study this chapter

Not all marine invertebrates are dangerous, but a knowledge of the types of potentially dangerous invertebrate animals is useful for everyone who uses the sea. Some understanding of the huge array of larval forms and how they reproduce forms the basis of the food chain. If you do get the opportunity to see invertebrates in their natural world and learn a bit more about them you may appreciate the need for maintaining their biodiversity.

Chapter overview

Phylum Protozoa 271
Class Rhizopoda....271
Class Ciliata....272
Class Flagellata....272

Phylum Porifera 272
Exercise 11.1 An interview with Dr Bennett AO....274
Exercise 11.2 Using a key....275

Phylum Cnidaria 276
Class Scyphozoa....278
Class Hydrozoa....279
Class Cubozoa....279
Class Anthozoa....280

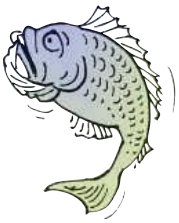
Phylum Ctenophora 284
Exercise 11.3 Coral bleaching case study....285

Phylum Annelida 287
Class Polychaeta....287
Other worms from different phyla....288

Key concepts

- The invertebrates are grouped according to their structural characteristics with each phylum sharing certain basic features. This basic design determines where the organisms live by restricting them to a particular part of the environment. eg corals to reefs.
- Animals with radial symmetry - jellyfish and corals usually have simple nervous systems consisting of a nerve net.
- Animals with bilateral symmetry have sensory structures concentrated in the head. Worms have a more complicated nervous system and associated reproductive, digestive and excretory organs.
- The evolution of the invertebrates can be traced by their increasing complexity of digestion, transportation and other body systems.
- An appreciation of biodiversity helps enhance the need for marine conservation.
- In an open circulatory blood system, moving blood flows from the vessels and into sinuses bathing the internal organs eventually seeping back to the heart. In a closed system, the blood remains in the vessels following a specific path - heart to arteries, arteries to capillaries, capillaries to veins and then back to the heart.

Phylum Mollusca 289
Class Gastropoda....292
Class Bivalvia....294
Class Amphineura....295
Class Cephalopoda....295
Exercise 11.4 Protozoans....298
Exercise 11.5 Sponge spicules....298
Exercises and questions....299



Phylum Protozoa

This is the first of four invertebrate phyla discussed in this chapter comprising single celled animals such as *Amoeba* and *Globigernia*.

Characteristics

Microscopic, single-celled animals.

Protozoans are unicellular organisms which come in many shapes and sizes depending on their specific needs and their habitat.

Like most of the other organisms in the kingdom protista, protozoans are also eukaryotes. This means that their cells contain a nucleus; a structure that encloses the cell's genetic material.

One of the most famous protozoans is *Plasmodium* which causes malaria.

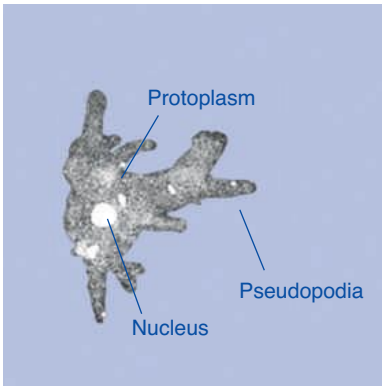


Figure 271.1 Amoeba
(Photograph courtesy Southern Biological)

Class Rhizopoda

Amoeba

The amoeboids, more commonly known as amoebas, are characterised by pseudopodia or cytoplasmic extensions (Figure 271.1).

Since the amoeboids are almost constantly moving, these pseudopodia are not completely fixed extensions, meaning that they can recede back into the main body and they can also extend whenever needed. This is achieved by extending and retreating through holes in the cell called foramina.

The ameboids consume their prey by the means of phagocytizing, which is when the pseudopodia take in the prey and then direct it to the cell's food vacuoles. Ameboids most often consume algae, bacteria, or other protozoans.

Figure 271.2 Radiolarian
(Illustration by Dr Jack Marsh and Dr Dave Tulip)

Forams and radiolarians

Marine amoebas include the formans and radiolarians have many pores (Figure 271.2) in their outer membrane through which the pseudopodia pass to extract food.

They also have chalky calcium carbonate shell (or test) on the outside of the cell which sinks to the bottom after the animals die forming fine sediments known as ooze.

Radiolarian and foraminiferan oozes cover thousands of square kilometres of ocean bottom and as parts of the sea floor was uplifted in plate tectonics (see Chapter 1); these fossilized protozoan oozes formed chalk and silicon beds. Almost all of the white cliffs of Dover are from these fossilized oozes (Figure 271.3).

Marine geologists used the fossilised remains of foram ooze to measure variations in climate. This is possible because the size and structure of the foram test changes with water temperature allowing marine scientists to determine oceanic temperatures from the past.

For example, forams living in colder waters have fewer pores than in warmer waters. Glacial and interglacial periods can therefore be determined by examining foram sediments from the ocean floor.

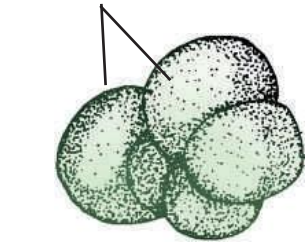
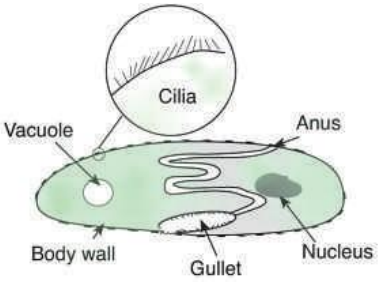


Figure 271.3 Globigerina
(Illustration by Jack Marsh and Dave Tulip, Dover photo Rosemary Andersen)



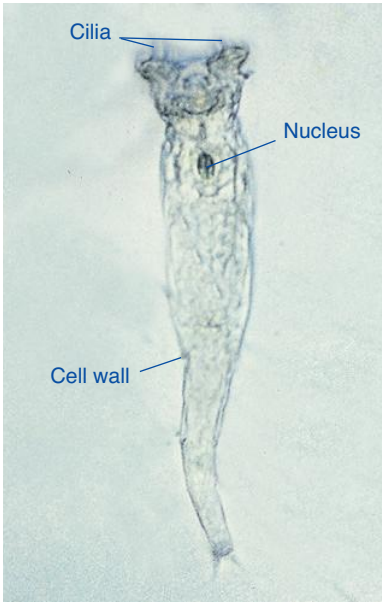


Figure 272.1 Ciliate structure
(Graham Mitchell)

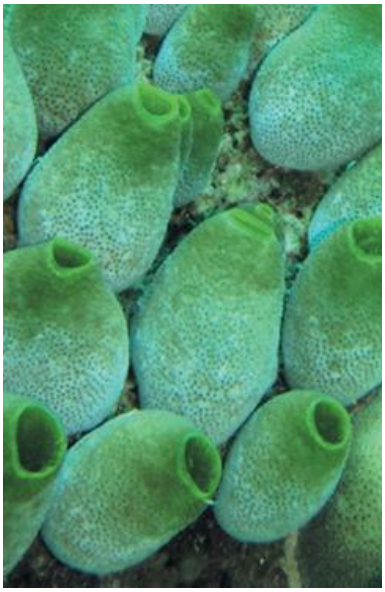


Figure 272.2 Sponge
(Underwater Rhelms)

Class Ciliata

This group of protozoans have special hairs called cilia, which beat to move food towards their cell membrane (Figure 272.1).

They have a specialized opening in the outer edge of the cell called a gullet to receive the prey.

The gullet leads the prey to the mouth, which then directs it to the food vacuoles.

Digestion of the prey takes place in the food vacuoles. All of the soluble nutrients are then absorbed into the cell, and all of the indigestible residue is eliminated through the anal pore.

Class Flagellata

Symbiosis

These creatures live through **symbiotic** (mutualistic) relationships, meaning they coexist with other sea creatures. All of these animals live in a harmonious relationship with the host where the protozoan gains its nutrition, and the host also gains something out of the relationship (see chapter 15 for a full discussion on symbiosis and other relationships between organisms).

One example of a zooflagellate is the *Trichonympha*, which lives in the gut of ship termites. *Trichonympha* contain bacteria that change the cellulose of wood to carbohydrates which are easily digested by the termite. In return for this service, the trichonympha gain nutrients from both the wood and from the host.

Phylum Porifera

Characteristics

Animals having many pores and cells but no organs. Food particles filtered from the water. Skeletal structure consists of limestone or silica spines. Attached to the sea floor.

Sponges

Adult sponges grow attached to rocks, sea plants, the shells of marine animals and to artificial structures. They can be found at all depths from the intertidal zone to the deepest parts of the sea. Live sponges are often brightly coloured.

Unlike other groups of animals, sponges show little or no symmetry. Their 'bodies' are made up of canals through which water is 'pumped' by ciliated cells. Water is pumped in through small holes and out through larger holes - the osculum (see Figure 273.1).

This water is filtered to provide the sponge with food at a remarkable speed. The water in some sponges can be changed completely in as little as 20 seconds. A sponge the size of a coffee cup could filter over 4000 L of water a day.

Feeding

The food for sponges includes dinoflagellates, bacteria and drifting particles of detritus. Water containing food and oxygen is drawn into the sponge through the pore cells (Figure 273.2). The water currents are created by the collar cells which contain long beating flagella where food particles get trapped. The food in the collar cell is then engulfed by vacuoles. Between the outer and inner walls of the sponge is a thin layer of jelly-like material called the mesenchyme which contains materials that develops into amoeboid cells. These then digest the food in the vacuoles.

Body shape and importance

In some sponges spicules (Figure 273.2) develop from the mesenchyme (tissue between cells) to give the animal structural support.

Sponges are supported by a series of small spicules, made of lime or silica, and by tough fibres. These structures are the parts of dead sponges which are washed up onto beaches. In some parts of the world, divers make a living collecting sponges. On reefs boring sponges break down coral limestone skeletons to make a home. This broken down coral forms much of the sand we see on coral reefs.

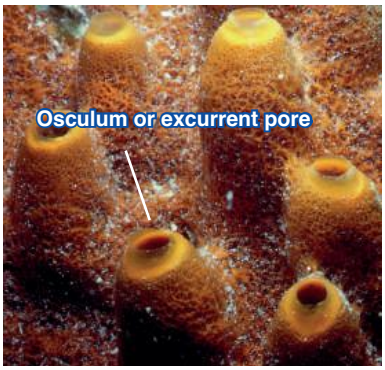


Figure 273.1 Osculum of sponge
(Photo Underwater Rhelms)

Odd fact

One of the most bizarre characteristics of sponges is that they are able to put themselves back together if they have been broken up and passed through a sieve. No other group of animals is able to do this.

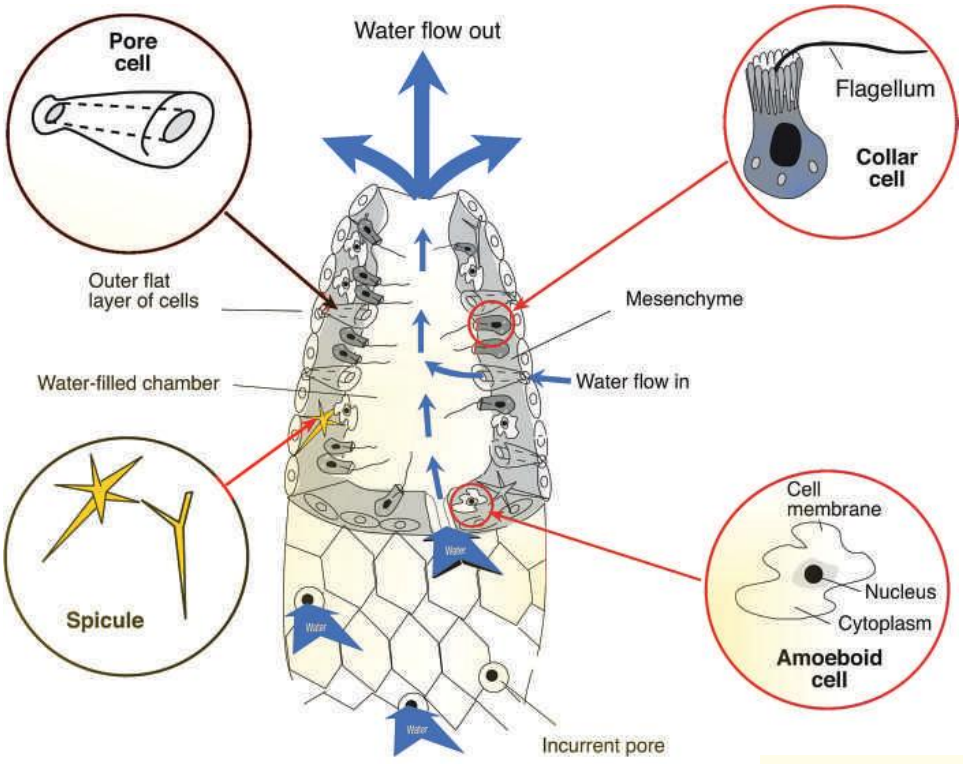


Figure 273.2 Sponge structure (After Lerman 1986)
(Illustration Bob Moffatt)

Colder waters of Australia contain fantastic communities of sponge gardens.

Exercise 11.1 An interview with Dr Isobel Bennett AO

From the Australian Academy of Science - Science education web site http://www.science.org.au/scientists/ib.htm

What to do

Read the article and answer the questions below.

Dr Isobel Bennett, marine biologist, was interviewed for the Australian Academy of Science's Video *Histories of Australian Scientists* program in May 2000. Here is an extract from the edited transcript of the interview. Note: Isobel Bennett passed away aged 98 at Seabeach Gardens Nursing Home in Mona Vale Sydney, January 12 2008 and will be sadly missed by all those who loved her work.

Introduction

Isobel Bennett is one of Australia's most distinguished and best-known marine biologists. She is unique, in that she achieved this pre-eminence without the benefit of a university degree in her discipline, and in an era when it was very rare for a woman to be a scientist at all. But to counter these drawbacks and to prevail, she was generously endowed with curiosity, tenacity of purpose and high intelligence.

Her earliest work concerned plankton, and she was involved in the first study of it to be undertaken in Australian waters. Another area which she made her own is the intertidal zone of the temperate shores. Her work here spanned nearly a lifetime of meticulous observation. Her best-known work, though, was concerned with the Great Barrier Reef. As late as 1959 it was said that knowledge of the Reef of a positive kind was far from complete or satisfactory. If this situation has been rectified, it is largely a result of the work of Isobel Bennett.

Interview extract

Isobel, could you say something about your family background?

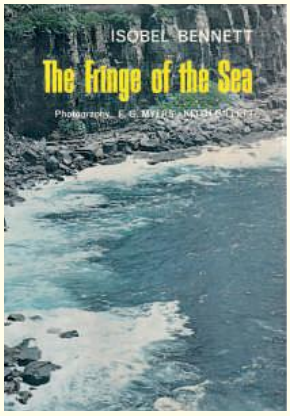
I was born in Brisbane, in 1909. I had a twin brother and sister, and another sister three years younger than myself. We lived in the suburb called Corinda, and walked about a mile and a half each way to go to the local state school.

At about 14, having passed the Scholarship exam, I was enrolled at Somerville House – a Brisbane equivalent of the PLC and MLC in New South Wales. I'm not quite sure why, but I was fascinated by the look of the biology lab and used to look at the girls doing biology. However, I was devastated to be told by my family when I was just 16 that I had to leave school, go to a business college, and then find a job.

So you never actually took science at school?

No, and I didn't know anything about it, really. After business college I obtained a position with a patent attorney's office. Then in 1928, at the beginning of the Depression, my family decided to move to Sydney and I lost all my schoolday friends. I was fortunate enough to get a position in the Sydney office of the Associated Board of the Royal Schools of Music. But at the end of 1932 the board could no longer afford to send its very high-powered examiners out to Australia from London by ship, and teachers were no longer sending children in for exams. So the board closed and I lost my job.

Dr Isobel Bennett
(Photos National Lib of Australia)



The book that inspired the author to study Marine Biology

Then came the turning-point in your life, didn't it?

Yes, it certainly did. My sister and I were able to get a cabin aboard a brand-new P&O Company ship for a five-day Christmas cruise to Norfolk Island.

This is where fate stepped in: the cabin next to ours was occupied by Professor and Mrs Dakin – we would certainly never have met them otherwise, on a ship that size – and they took us under their wing.

The Professor, discovering that I had lost my job, said he needed somebody to look up the logs of some of the old ships' whaling captains, who had a habit of drawing a little sketch of a whale whenever they sighted them. He thought that by plotting them he would get some idea of the distribution of whales around the Australian and New Zealand coasts, for the book he was writing on the history of whaling in these waters. So I did that at the Mitchell Library for two or three days a week.

In the meantime, of course, I was applying for jobs. I was actually offered a job with the CSIRO Division of Entomology, in Canberra, but my father refused point-blank to let me go and live in such a foreign city all by myself, and so I never went. (It turned out to be the kindest thing he ever did to me.) I kept on doing some work for the Professor, and offered to type the manuscript of the book he was writing. And then in May 1933 I received a surprise letter from the university offering me a temporary position in the Department of Zoology, taking my instructions from the Professor.

Questions

1. Why was it so important for Isobel to study marine invertebrates?
2. What is a ship's log and why was it important to find the sketches of whales in it?
3. Calculate how old Isobel was when she moved to Sydney.
4. Isobel is one of Australia's most distinguished and best-known marine biologists. What do you think her most valuable contributions to Marine Science have been?
5. You have been asked to introduce Isobel as guest speaker at your schools Marine Science week to which the media have been invited.
   a. Prepare a 2 minute introduction you will read to the audience.
   b. Write a one page media release about marine science at your school and three possible quotes on marine conservation that Isobel may make.
   c. What are three questions you would like to ask a world famous marine scientist? Justify your reasons for asking them.

Exercise 11.2 Using a key

Aim

To use a simple key to identify the major marine phyla.

Method

- Use the key below to identify the creatures to the right.
- Note: This is not intended to be a key to all marine animals, but will enable the identification of most of the more common members of this kingdom. You may be able to find more complete keys and you will need to use these if you are to identify some rarer marine animals.

Materials

- Photographs of marine animals or range of preserved specimens.
- Key to marine life (see below).

Method

1. Use the key to marine life below to classify the animals into Phyla.
2. When classified write down the structural characteristics particular to the animals.

Key to marine life

1a. Body with no organs or mouth. Many small openings, fewer large openings. Spicules.

Sponges (Phylum Porifera)

1b. Not as above ... Go to 2.

2a. Radially symmetrical. Tentacles with nematocysts

Jellyfish, Corals, Anemones (Phylum Cnidaria)

2b. Not as above ... Go to 3.

3a. "Wormlike" shape, body divided into segments, bilaterally symmetrical.

Segmented worms (Phylum Annelida)

3b. Not a "wormlike" shape ... Go to 4.

4a. Hard exoskeleton, jointed legs.

Crabs, Prawns, Barnacles etc (Phylum Arthropoda)

4b. No exoskeleton (May be a shell) ... Go to 5.

5a. Radially symmetrical, tough spiny outer skin may be present.

Sea Stars, Sea Urchins, Sea Cucumbers (Phylum Echinodermata)

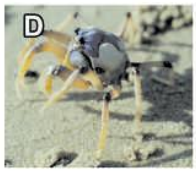
5b. Bilaterally symmetrical ... Go to 6.

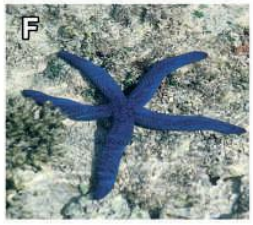
6a. Soft mucus covered body, possibly in a shell.

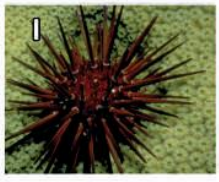
Shellfish, Snails, Slugs, Squids etc (Phylum Mollusca)

6b. Backbone present, made of bone or cartilage.

Fish, Reptiles, Birds, Mammals (Phylum Chordata)







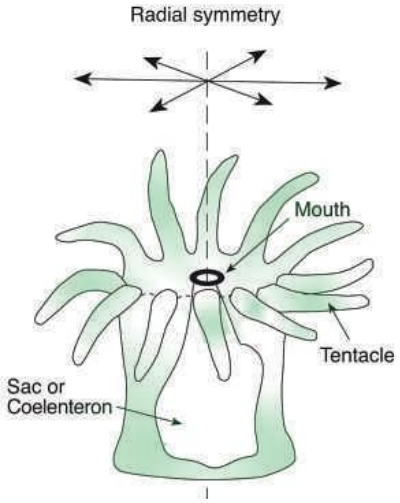


Figure 276.1 Cnidarians are radially symmetrical.
(Illustration Bob Moffatt)

Phylum Cnidaria

Sac-*like animals with body plan arranged in a circle and a sac at one end, two cell layers, stinging cells. Includes animals such as corals and sea jellies.*

External features

These animals are radially symmetrical, with a simple body in the form of a sac or coelenteron with one opening or mouth as shown in Figure 276.1.

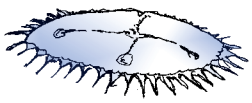
Animals can be either attached by means of a basal disc to form a polyp (eg corals) or may drift in the water as a free swimming medusa such as sea jelly (Figure 276.2).

Medusae have a bell with balance organs known as statocysts and tentacles located below the bell Figure 276.2.

Attached

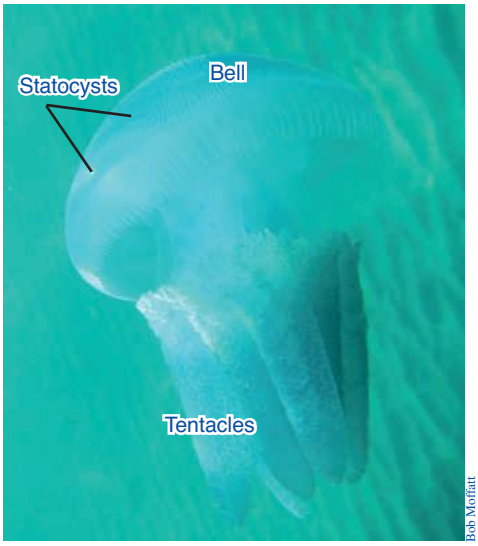
(Steven Byers)

Free swimming



(Sue Oats)

(Sue Oats)



Bob Moffatt

Figure 276.2 Animals can be either free swimming or attached.

Feeding

The mouth is surrounded by a ring of tentacles (Figure 277.1) on which special stinging cells called nematocysts are found. Nematocysts are for feeding and defence and are the characteristic which gives the phylum its name.

Figure 277.2 a and b shows how these specialised cells fire. The venom from the nematocysts of the sea wasp box jellyfish are extremely painful and fatal in many cases.

Figure 277.1 Mouth and tentacles
(Murray Waite)

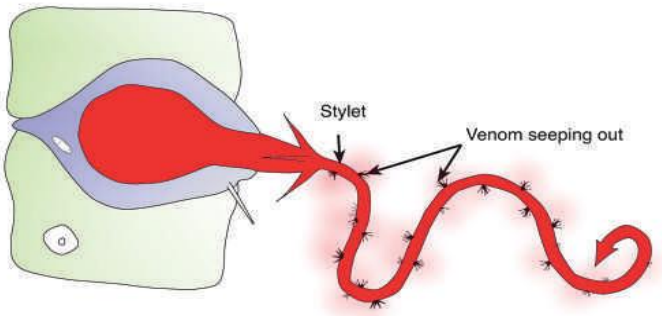


Figure 277.2a Nematocyst discharged
(Bob Moffatt)

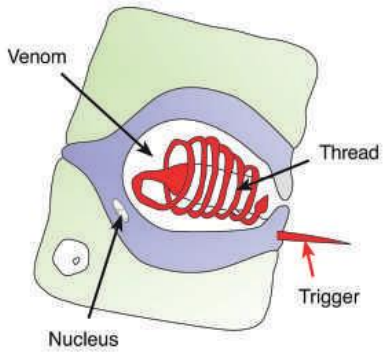


Figure 277.2b Nematocyst undischarged
(Bob Moffatt)

Reproduction

Reproduction is complex among Cnidarians with both asexual and sexual forms. In corals, the most common asexual means is by budding where another coral polyp grows as bud from the parent polyp resulting in a new animal that is genetical identical to the parent.

For genetic diversity, sexual reproduction is needed and in corals this is a spectacular event in November each year.

Inside the polyp the male and female sex organs develop which produce sperm and egg (Figure 277.3). Fertilization in some corals is internal producing an egg bundle which is released through the mouth. These fertilized eggs disperse and grown into a planula which settles to the ocean floor to grow into a juvenile and finally back into an adult.

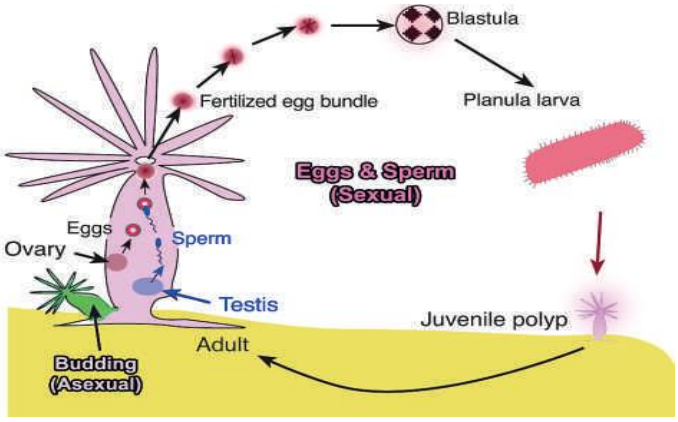


Figure 277.3 Coral reproduction
(Illustration Bob Moffatt)

(Photo courtesy Peter Harrison JCU 1988 Reproduced with permission.)

Bob Moffatt

Figure 278.1 Jellyfish featured as part of the Sydney Olympics opening ceremony.

Class Scyphozoa

Jellyfish (Sea jellies)

Two forms of cnidarians are the polyp and the medusa.

In sea jellies, the medusa stage occupies the main part of the life cycle but still develops from a polyp.

In reproduction sex cells develop in the bell to produce sperm and eggs. After fertilization the zygote grows into a planula which settles on the bottom of the sea. From here budding occurs and new polyps are produced. To make a new jellyfish a specialized process called strobalization occurs at the mouth of the polyp. After strobalization the new medusa jelly fish is set free to swim the sea.

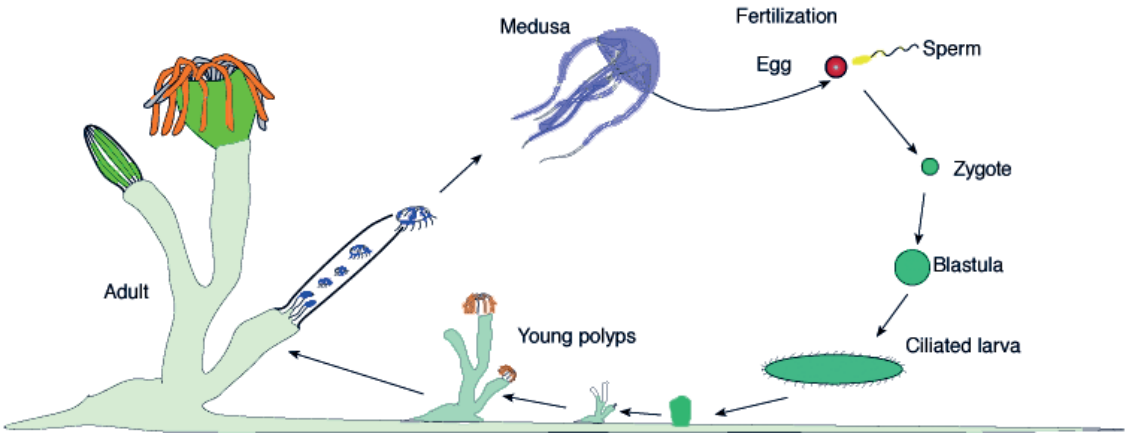


Figure 278.2 Life cycle of a sea jelly. Where does strobalization occur?
(Illustration Bob Moffatt)

Class Hydrozoa

Bluebottle

Blue bottles form colonies of specialised individual cells as shown in Figure 279.1 and are often confused as jellyfish. Each group of cells performs a different function: feeding, digestion of food, reproduction. Even the float is a group of cells designed for floating.

The bluebottle gets its name from the colour and shape of its body which looks like a blue, sail-shaped balloon up to 25 cm long. The trailing tentacles are up to 10 m long (over 30 feet), which makes them hard to avoid especially in strong currents or large waves. Although not fatal in most cases, the sting causes severe pain and welts on the skin. *Vinegar should not be used on blue bottle stings as it increases irritation - use only cold water and ice to relieve the pain.*

Other hydrozoans include the fireweed and stinging hydroids.

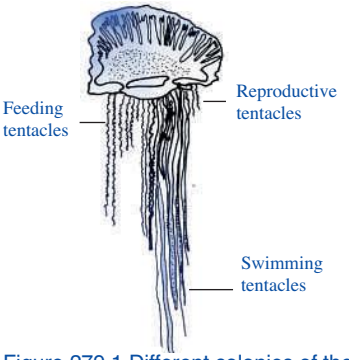


Figure 279.1 Different colonies of the blue bottle
(Illustration Bob Moffatt)

Figure 279.2 Blue bottle
(Photo Neville Coleman)

Class Cubozoa

Box jellyfish

Box jellyfish, also known as sea wasps, are the deadliest stinging jellyfish in the world and have killed swimmers, adults and children, off northern Australian beaches. They have large, transparent, bell-shaped bodies up to 30 cm across, each with a large, trailing clump of tentacles up to 4 m long, containing millions of nematocysts.

Preferring warmer waters, they are found only in the tropical waters of Australia's far northern beaches between December and March. Beaches from Cairns around to Broome are closed for swimming during this period.

Victims, especially children, usually die within minutes of being stung after suffering intense pain followed by paralysis (caused by the poison shocking the heart) followed by breathing failure. The poison also attacks the red blood cells in the victim's skin upon contact and produces large, purple, whip-like marks.

Figure 279.3 Box jellyfish
(Photo Neville Coleman)

Irukandji

These are small members of the box jellyfish family with a bell size of about 2 cm. This means they can pass through stinger nets. Although the sting is very minor the pain which develops later can be excruciating. *If stung in Northern Australia, flood the area with vinegar and get to hospital within 20 minutes for pain killers.*

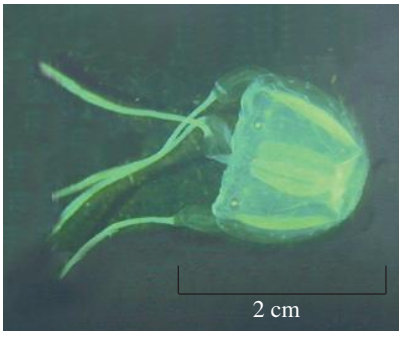


Figure 279.4 Irukandji
(Photo Jamie Seymour)

Treatment for box jellyfish and Irukandji

1. Flood the area stung with vinegar.
2. Seek medical assistance as fast as you can.

Web: Search engine word — Irukandji
http://www.reef.crc.org.au/aboutreef/coastal/irukandji.html
http://cnsfse01.jcu.edu.au/schools/tropbio/cubozoan.html

Figure 280.1 A sea anemone
(Photo Mike Sugden)

Class Anthozoa

Sea anemones

Sea anemones illustrate some of the features of the phylum Cnidaria. The body plan is arranged in a circle with two cell layers and stinging cells on the tentacles (see Figure 280.1).

The tentacles are connected to a mouth which leads down to a hollow gut (the coelenteron) which is where food is digested (Figure 280.2). Wastes are then ejected out of the mouth. Sea anemones can move by sliding on their basal disc or by somersaulting from place to place. They reproduce by growing small buds on their sides or by producing eggs and sperm from inside their gut.

They can also retract during low tide or to eat their prey using strong retractor muscles located in the body wall.

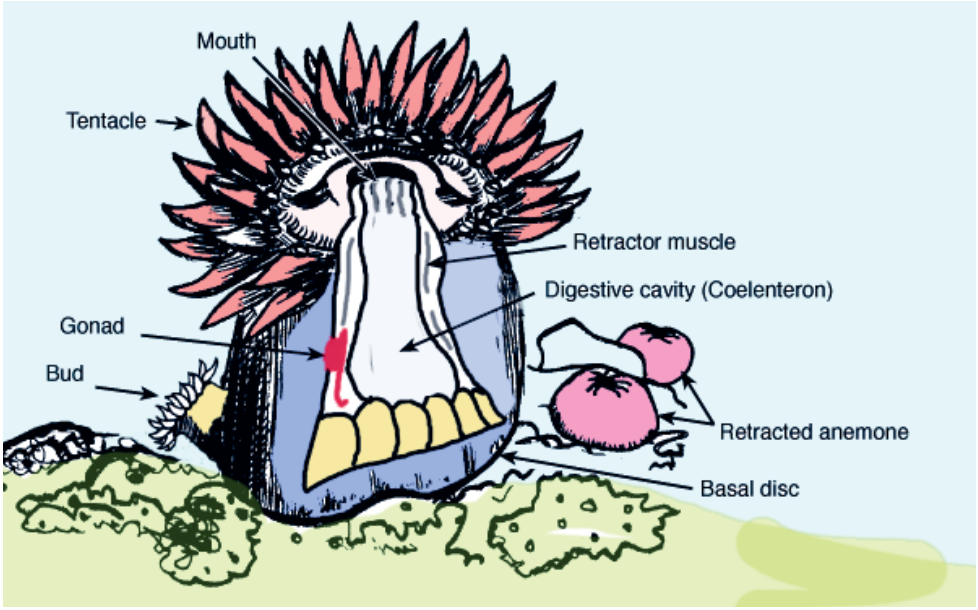


Figure 280.2 Sea anemone internal structure

A special relationship

Some anemones have a symbiotic relationship with clownfish. These fish hide amongst the tentacles to avoid predators.

They can do this because a coating of mucous protects them against the nematocysts of the anemone.

The fish benefit by having a safe place to hide and in return the clownfish chases away fish which feed on the anemone eg butterfly fish. This type of symbiosis is called mutualism and is discussed further in Chapter 15.

Figure 280.3 The anemone and the clownfish form a symbiotic relationship called mutualism.
(Photo Murray Waite)

Corals

The only living thing that can be seen from outer space is the Great Barrier Reef. This reef is made by individual coral polyps that secrete a calcium carbonate base when they grow. When the animal dies, this is left behind for new coral polyps to grow on, so coral reefs are made of dead coral with a thin veneer of living corals and animals on the outside.

Corals need specific requirements for growth and scientists from the Great Barrier Reef Marine Park Authority have identified the following four main requirements:

- clear water so they can get necessary light,
- low nutrients,
- stable salinity and
- hard surface to grow on.

Few reefs grow next to the mainland because the water quality is too poor caused by high sediment runoff and other pollutants from land.

There are two types of coral — hard and soft.

Soft corals and sea fans

Soft corals lack a hard skeleton and protect themselves by secreting chemicals called terpenes. These make them toxic to predators.

Soft corals have eight fringing tentacles with each tentacle having side branches giving it a feathery appearance (Figure 281.1).

Sea fans

Sea fans are like soft corals but the coral polyps are supported by an substance called gorgonium. They often protrude out from coral bommies like the ones shown in Figure 281.2.

Hard corals

Tourist operators commonly classify hard corals by their appearance as either boulder, branching, plate, table, vase, or solitary — see Figures 282.1 - 7 over.

Figure 281.1 Soft coral
Bob Moffatt

Figure 281.2 Hard coral
Bob Moffatt

Figure 281.3 Sea fan
(Murray Waite)

Questions

1. Make a table of the structural characteristics that separate the protozoa, porifera and cnidaria.
2. Give example of animals from each of the phyla mentioned above.
3. Distinguish between corals and sea anemones.
4. Describe the life cycle of an animal from the class scyphozoa.
5. How does a sponge get its food?
6. Describe the special relationship between the clownfish and the anemone.
7. What's the treatment for a box jelly fish sting?
8. What's the signs and symptoms of an Irukandji sting and what treatment would you recommend to a tourist if stung?
9. How do corals reproduce?
10. Draw a diagram of a cross-section of a sponge showing the relationships between the various cellular layers.
11. Distinguish between the medusa and polyp stage of a cnidarian giving an example.
12. Discuss possible reasons for considering the Protozoa as the most basic form of life.
13. What is phagocytosis and how is it important to the Protozoa?
14. Compare and contrast the digestive processes of sponges and jellyfish.
15. Mutualism is one form of symbiosis - name two others (see chapter 15).

Figure 282.1 Soft coral
(Photo Bob Moffatt)

Figure 282.2 Branching coral
(Photo Bob Moffatt)

Figure 282.3 Boulder coral
(Photo Underwater Realms)

Figure 282.4 Table coral
(Photo Murray Waite)

Figure 282.5 Solitary coral
(Photo Bob Moffatt)

Figure 282.6 Vase coral
(Photo Murray Waite)

Figure 282.7 Plate coral
(Photo Murray Waite)

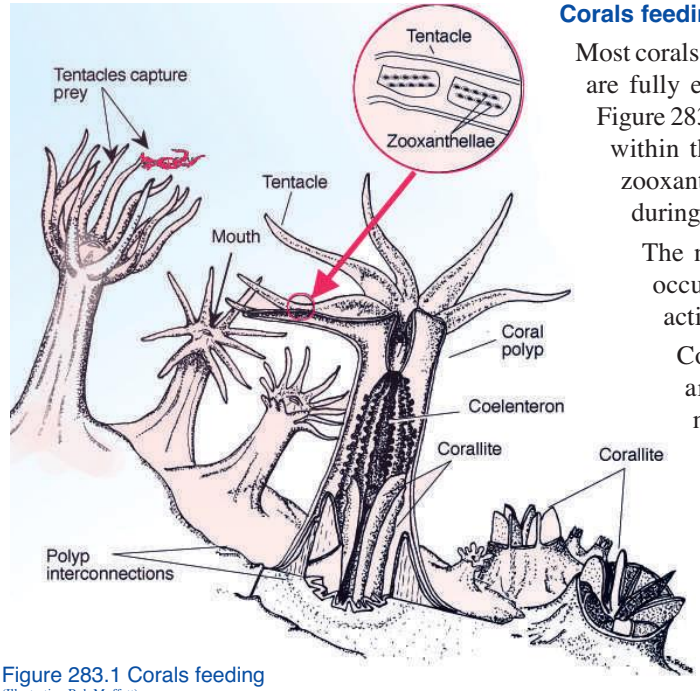


Figure 283.1 Corals feeding
(Illustration Bob Moffatt)

Corals feeding

Most corals feed at night, and at this time their polyps are fully extended in search of food as shown in Figure 283.1. During the daytime they are retracted within their corallites. This maybe because the zooxanthellae produce enough food for the coral during the day, or they retract to avoid predators.

The night feeding pattern of corals probably occurs because zooplankton reefs are most active at night.

Corals feed by extending their tentacles armed with nematocysts and catching microscopic plankton that pass by (Figure 283.1). When the tentacle encounters an animal such as a shrimp, the barbed darts of the stinging cell are fired into the flesh of the prey, killing it instantly. The prey is then forced into the animal's mouth and into the coelenteron where it is digested. Once the food has been broken down and absorbed into the polyp's tissue, some of the nutrients are passed to other polyps by the interconnections that join with other polyps.

The limestone base is added slowly as a result of the polyp absorbing calcium carbonate from the seawater as shown in Figure 283.2.

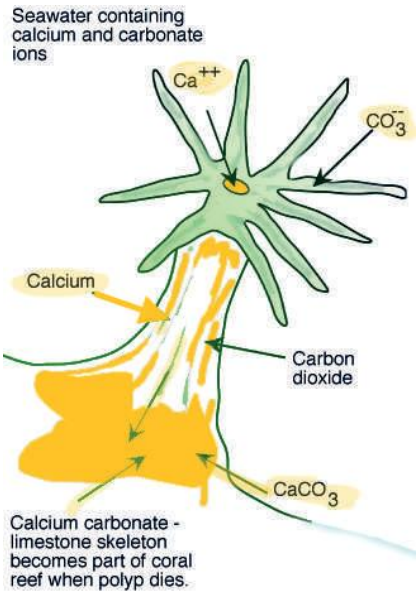


Figure 283.2 Coral colonies secrete a limestone skeleton as they grow by extracting calcium and carbonate ions from seawater.

$Ca^{++} + C0_3^{--} \rightarrow CaC0_3$

(Illustration Bob Moffatt)

Algae and corals

Reefs are not made entirely of coral. Algae play a very important role in the production of hard calcareous (calcium type) materials, which helps cement sand, coral pieces as well as living and dead material together to form the reef.

Algae also play another important role in promoting coral growth. Corals are carnivorous animals, but they also obtain some nourishment from the plant cells embedded in their tissues. The success of corals as reef builders is due in part to the remarkable association with these tiny single-celled algae called zooxanthellae as shown in Figure 283.1.

Symbiosis - mutualism + + *(see also page 406)*

The relationship is one of mutual benefit or symbiosis. The plant cells gain a suitable place to live, (like other plants they harness energy from sunlight to manufacture materials necessary for their own nutrition and reproduction). They also use the waste products of the coral polyp for nutrition and growth. The polyp gains oxygen, and between 70-90% of body sugars from the zooxanthellae.

During the day, reef-building corals usually have their polyps retracted into their limy skeletons. This allows the microscopic plants to absorb as much light as possible.

Reef-building corals flourish in shallow tropical waters, rarely being found below depths of 60 metres, and with water temperatures ranging between 20°C and 30°C.

Since all plants require sunlight it is considered that the presence of the zooxanthellae is a determining factor for the depths at which reef building corals flourish.

Recent scientific research has begun to explore the question of how much nutrition the coral obtains from zooplankton on the one hand, and from its zooxanthellae on the other.

Some scientists believe that coral obtains most, if not all of their nutrient from the zooxanthellae, while others seem to think zooxanthellae play only a minor role in providing basic nutrition.

Coral bleaching

The following text is from the GBRMPA web site and is reproduced with permission.

"Coral bleaching is a stress condition in reef corals which involves a breakdown of the symbiotic relationship between corals and unicellular algae (zooxanthellae). These microscopic plants live within the coral tissue and provide the coral with food for growth and their normal healthy colour.

The symptoms of bleaching include a gradual loss of colour as zooxanthellae are expelled from the coral tissue, sometimes leaving corals bone white.

Bleaching stress is also exhibited by other reef animals that have a symbiotic relationship with zooxanthellae such as soft corals, giant clams and some sponges."

Further information on coral bleaching:

http://www.gbrmpa.gov.au

Coral bleaching web reference

www.gbrmpa.gov.au/
Hot issues, coral bleaching

Research diver from GBRMPA inspects coral bleaching

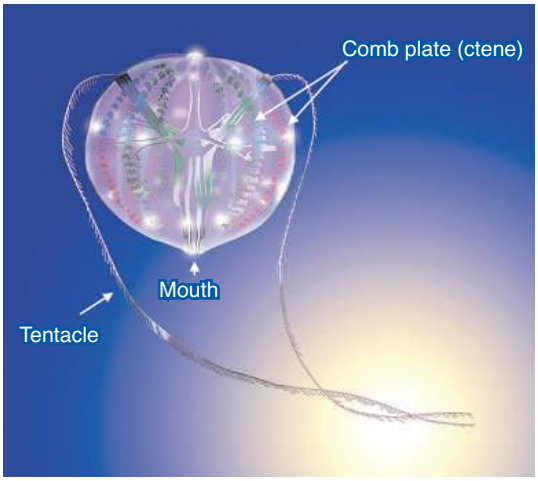


Figure 284.1 Comb jelly (After Lerman)

Phylum Ctenophora

Comb Jellies

Radially symmetrical, similar to jellyfish with eight rows of comb plates called ctenes.

These animals are similar to jellyfish but have rows of cilia which beat in a comb-like manner as shown in Figure 284.1. They are free swimming, are part of the plankton family and are very common in tropical waters.

Comb jellies feed on plankton that are trapped by a special glue made by the tentacles.

The tentacles then draw the food to their mouths. The tentacles do not have nematocysts and so are a separate Phylum. Some species of comb jellies are bioluminescent.

Why not order some bioviewer slides from Southern Biological - these are microscope like slides that have full colour photographs of marine invertebrates
Southern Biological
PO Box 57 Nunawading
Vic 3131

Exercise 11.3 Coral bleaching case study

The following is an extract of an article on coral bleaching
© GBRMPA Reproduced with the permission of the Great Barrier Reef Marine Park Authority and Dr Paul Marshall.

In the summer of 2001-2002, north Queensland experienced unusually hot and still weather, leading to increased sea temperatures and stressful conditions for the Great Barrier Reef (GBR). These conditions resulted in another mass bleaching event in the Great Barrier Reef Marine Park. Until recently, the worst coral bleaching event ever recorded on the GBR occurred in 1998. However, the recent bleaching event has affected a greater area of reef than the 1998 event, making 2002 the worst bleaching event on record for the GBR.

Increased stress detected in January 2002

The AIMS/GBRMPA sea temperature monitoring program provided real-time updates of actual sea temperatures at key reef sites. Hourly data were transmitted from weather stations on the reef to GBRMPA and AIMS offices via satellite link. At several locations, temperatures quickly rose 1.5-2°C above the long term seasonal average, exceeding those recorded during the bleaching event of 1998.

The two "hot spells" of exceptionally warm weather, interspersed with a cooler period, can also be seen in the temperature data for Agincourt Reef in Table 1 below.

Table 1: Comparison data for sea temperatures Agincourt Reef January - March 2002

Date	Av Temp	2002 Temperature
1/1/02	27.8 °C	29.1 °C
7/1/02	27.9 °C	29.7 °C
14/1/02	28.2 °C	30.1 °C
21/1/02	28.4 °C	28.8 °C
28/1/02	28.6 °C	29.2 °C
7/2/02	28.8 °C	29.8 °C
14/2/02	28.8 °C	30.4 °C
21/2/02	28.7 °C	28.6 °C
28/2/02	28.6 °C	29.2 °C
7/3/02	28.5 °C	29.5 °C
14/3/02	28.3 °C	29.1 °C
21/3/02	28.2 °C	28.3 °C
28/3/02	28.1 °C	28.2 °C

(Project Reef Ed)

(Sue Oats)

Aerial surveys

GBRMPA and the CRC Reef surveyed bleaching from the air. Severe bleaching, especially on shallow reefs with high coral cover, can readily be observed from the air.

GBRMPA and the CRC Reef conducted surveys from light airplane at the peak of the bleaching event to determine the spatial extent of bleaching on the GBR.

Aerial surveys assessed 641 reefs during March-April 2002, representing 22% of all reefs in the GBRMP. The surveys confirmed that bleaching was extremely widespread, spanning 1450 km and including inshore, mid-shelf and outer-shelf reefs. Almost 60% of all reefs surveyed from the air showed some signs of bleaching. Among the bleached reefs, however, the intensity of bleaching was highly variable. In total:

- 43% of reefs had low to negligible levels of bleaching (less than 1% of the reef affected);
- 36% of reefs had moderate levels of bleaching (1-30% of reef affected); and
- 21% of reefs had high levels of bleaching (30% or greater of the reef affected).

Inshore reefs were worst affected

As in 1998, the worst affected reefs were those closest to the mainland. In 2002, almost 50% of inshore reefs were bleached to high or very high levels, with only 30% unaffected. Many offshore reefs were also affected with over 50% of reefs bleached to some extent.

Underwater surveys provided detailed information on impacts of bleaching.

Aerial surveys provided a rapid, broad-scale picture of the spatial extent of bleaching. However, detailed underwater surveys were required to determine the extent of bleaching on the reef slope, measure the amount of coral death on a reef, and therefore assess the ecological implications of this coral-bleaching event.

GBRMPA conducted detailed underwater surveys of coral reefs to assess the ecological consequences of this year's coral bleaching event. Corals that recover from bleaching are likely to suffer sub-lethal effects such as reduced growth rates, lower reproduction and possible decreased resistance to disease. Comprehensive, longer-term research programs are required to determine the long-term effects of these sub-lethal impacts of coral bleaching on coral reef communities. However, the most important and immediate ecological impacts arise when bleaching leads to death of corals.

The major goal of our underwater survey program is to assess the proportion of corals that die versus those that survive the 2002 coral bleaching event. Further surveys are planned for later in 2002 when the fate of corals that bleached during the Summer will be studied further.

Range of bleaching

Our underwater surveys found that the immediate ecological consequences of bleaching varied from negligible to severe. The coral communities at some survey sites, such as the inshore reefs of the Frankland Islands, were almost completely unaffected by bleaching. In contrast, some other inshore reefs were devastated, with the proportion of dead corals ranging from 50% to 90% on reefs around Bowen. In general, however, most reefs appear to be likely to recover from bleaching with minimal mortality. Further surveys are planned to ascertain

the final fate of corals that were still bleached at the time of the underwater surveys. Among the offshore reefs in particular, even sites recorded as extensively bleached are likely to suffer very little mortality, such as Thetford Reef on the mid-shelf out from Cairns.

Bleaching intensity varied between reefs: (a) unaffected reef, (b) moderately bleached offshore reef and (c) severely bleached inshore reef.

Inshore reefs were most severely affected

Inshore reefs were the most severely affected during this recent bleaching event. Extensive mortality was not seen on any of the offshore reefs surveyed, while several inshore reefs had suffered the loss of over 80% of corals.

Interestingly, some of the few reefs surveyed in detail that were completely unaffected by bleaching were also inshore reefs, specifically those between Townsville and Cairns, including Pandora Reef and the Frankland Islands.

The inshore reefs most damaged in 2002 are different from those affected in 1998. While inshore reefs between Townsville and Cairns were least affected in 2002, they were the most severely affected during 1998. Similarly, the Whitsunday Islands and associated inshore reefs were relatively unaffected by bleaching in 1998, but severely affected in 2002.

Coral species differ in their susceptibility to bleaching

Coral species are known to differ substantially in their susceptibility to bleaching, and these patterns of susceptibility were seen in the underwater surveys. At all sites surveyed, Pocilloporid (needle and clumping corals) and Acroporid (staghorn and plate corals) were the most severely affected. Poritid and Faviid (massive, hemispherical and brain) corals were generally the least affected by bleaching, although at some sites even these more resistant corals were bleached, with many showing signs of partial mortality on their upper surfaces. Invariably, reefs that were observed to have the most intense bleaching were those that had high abundances of the more susceptible species.

Bleaching severity varied with depth

The severity of bleaching also showed strong variability with depth at most reefs. Corals in shallower water tend to be exposed to warmer water and more intense sunlight, both of which combine to be the key causative stresses in mass bleaching events. Predictably, corals in the shallower waters of the reef flat and crest were more likely to be bleached than those in deeper water. However, bleached corals were seen on the lower reef slope down to 10-15 m at most reefs.

Questions

Part A Understanding the article

1. Coral bleaching involves stress leading to the death of the coral polyp. How does this occur?
2. What were the criteria used to report low, moderate and high levels of bleaching from aerial surveys?
3. Draw a graph of the change in temperatures on Agincourt Reef. Express as a percentage how much the above average temperatures were for the 11 January and 11 February.
4. What was the major goal of the underwater survey program?
5. Suggest a possible reason for high rates of coral bleaching in shallow depths.
6. The rate of calcium carbonate deposition may be affected by temperature. How could this kill the coral polyp?
7. In 1998 and 2002 the worst affected reefs were those closest to the mainland. Suggest two possible reasons for this.
8. Are coral species known to differ substantially in their susceptibility to bleaching? If so list the corals that are most affected/least affected.
9. Design an experiment to show the effect of increasing water temperature on the different species of corals you have just described.

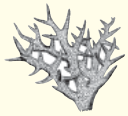
Optional (web access needed)

Make a summary of the NOAA data presented in the web images of sea temperature.

Part B Communications assignment

Make a poster called *coral bleaching* to be used in a display to explain to the general public how this occurs. Your poster should include:

1. A drawing of a coral polyp to indicate the process by which coral bleaching occurs. The diagram should show
   - the structure of a coral polyp;
   - the method by which corals take up calcium carbonate;
   - where zooxanthellae occur and what happens to them;
   - a list of possible stresses on coral polyps.
2. A summary graph in colour showing the temperature changes on Agincourt Reef.
3. A recommendation for new strategies to be adopted by Australia to reduce global warming.



(Steven Byers)

Phylum Annelida

Worm shape, segments mostly with bristle appendages, distinct head with eyes and tentacles which are reduced in tube-dwelling forms.

Figure 287.1 Sand worm
(Photo Qld Fisheries)

Class Polychaeta

External features

Annelids are segmented worms because their bodies are made up of many sections. These animals have four distinct parts: the anterior (front), posterior (back), dorsal (top) and bottom (ventral).

Segments allow simple animals to have specialised areas in their bodies. The anterior end has mouth and sensory parts, middle regions have digestive and reproductive parts with posterior segments for excretion. The polychaetes (meaning many bristles - parapodia), are marine worms and live in and under rocks, corals, shells and even on the backs of other animals. They are usually free swimming as the one shown in Figure 287.1 or secrete tubes that are covered with shells and grit, or grow in association with corals like the one shown in Figure 287.3.

In free swimming worms the head is distinct and has eyes. Often the pharynx can be everted to catch prey and teeth can be seen.

Most marine annelids have leg-like bristles along their length. They may be free swimming, live in burrows in the mud or they may construct tubes to live in (see Figure 288.1 over).

A common worm without a reduced head is the Christmas tree worm (Figure 287.3). Larvae of this worm settle among coral polyps and stimulate the coral to grow around them as the worms grow to maturity. A favourite trick with divers is to put a hand close to them and snap the fingers. This causes the worm to retract into their tubes with lightning speed.

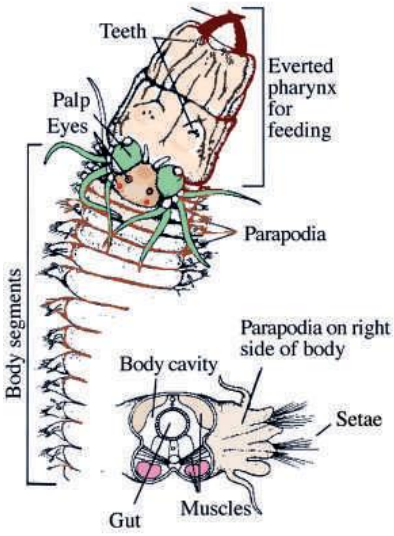


Figure 287.2 A free swimming polychaete worm
(From Qld Museum article 83/14, reproduced with permission)

Biological importance

Worms form an integral part of the benthic ecosystem because they process dead and decaying matter, aerate the mud and filter food. They are the source of food for mud flat birds such as spoonbills and herons. Because they spend most of their time burrowed in the mud they have a specialised way of life.

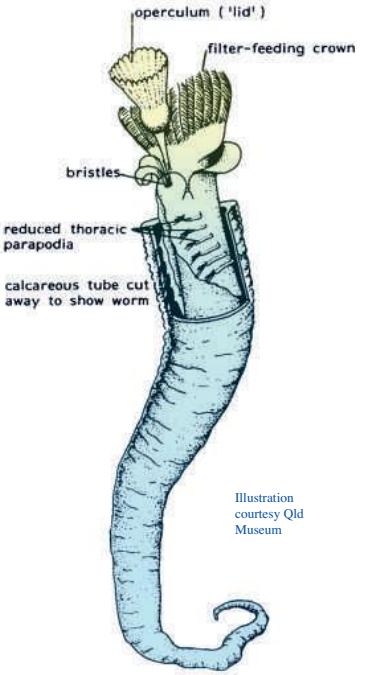
Figure 287.4 Annelid larvae
(Illustrations by Dr. Dave Tulip and Dr. Jack Marsh)

Reproduction

Worms can have separate sexes or be hermaphroditic. Once fertilized the eggs change into free swimming larvae like the ones shown in Figure 287.4 and drift in the plankton until they grow back into adults and settle on the sea floor.

Figure 287.3 Christmas tree worms on brain coral
(Photo Neville Coleman)

Figure 288.1 Tube worm and structure
(Photo Neville Coleman)



Other worms from different phyla

Ribbon worms

These are similar to Polychaete worms but have a straight through digestive track with a mouth with a long proboscis developed digestive track and anus.

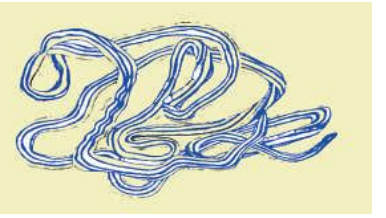


Figure 288.2 Ribbon worm
Illustrations Qld Museum (top) Sue Oats (bottom)

Flatworms and round worms

Flatworms are unsegmented worms that are either free swimming or parasitic on fish and other marine animals.

Their simple structure is characterised by having a sucker like mouth which is used to attach itself to the host organism where the animals continually feed on tissue or partially digested food. Many roundworms live in the intestinal track of the larger marine animals and have specialised hooks around their mouth to stay attached.

Deep sea worms

Discovered in 1977, these giant tube worms were found near deep thermal vents in the eastern Pacific Ocean. They have no mouth or digestive tubes and absorb food through their skin. Their survival depends on a symbiotic relationship with the billions of bacteria that live inside of them. These bacteria convert the chemicals that shoot out of the hydrothermal vents into food for the worm. This chemical-based food-making process is referred to as **chemosynthesis**.

Check out the deep sea worms and a short movie at:
www.ocean.udel.edu/deepsea/level-2/creature/tube.html

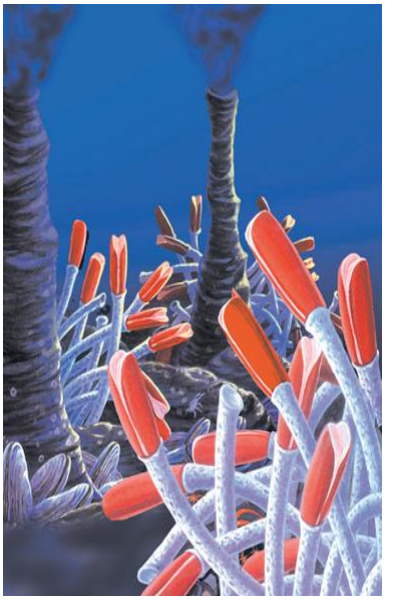


Figure 288.3 Deep sea worms
(Illustration Trish Hart)

Phylum Mollusca

Characteristics: Most have a soft skin, bilateral symmetry, mantle with gills, most types protected by a shell, no segmentation. Most have a large foot and some posses a specialized feeding organ known as a radula.

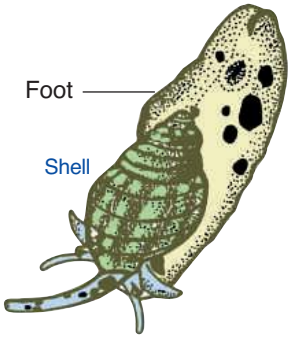


Figure 289.1 Most molluscs have a foot and a shell.
(Illustration Gould League)

External features

Molluscs have a soft body, usually covered with a hard outer shell or shells and have a strong foot to fix themselves to rocks for protection (Figure 289.1). The limpet in Figure 289.3 is a good example of this phylum because if we carefully prize it off the rocks and turn it over we can see the head, foot and mantle cavity.

Feeding

Some molluscs also have a modified mouth piece called a **radula** which scrapes food off rocks (Figure 289.2). Food is then passed to a digestive tract and anus. This radula can be modified further in carnivorous molluscs to bore into other animals such as the oyster borer (Figure 290.1). Other molluscs such as clams, filter feed by drawing water into their bodies through a series of siphons.

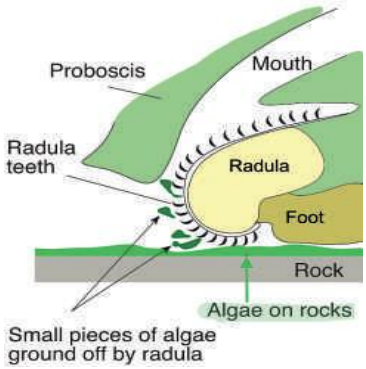


Figure 289.2 Limpet radula
(Illustration Bob Moffatt, after Lerman)

Breathing*

Molluscs breathe through gills located in a mantle cavity located on top of the foot. Water is sucked in by muscular contractions and is drawn over the gills' surfaces where oxygen is extracted and carbon dioxide released. (Figure 291.1, shows the gills under the mantle cavity.)

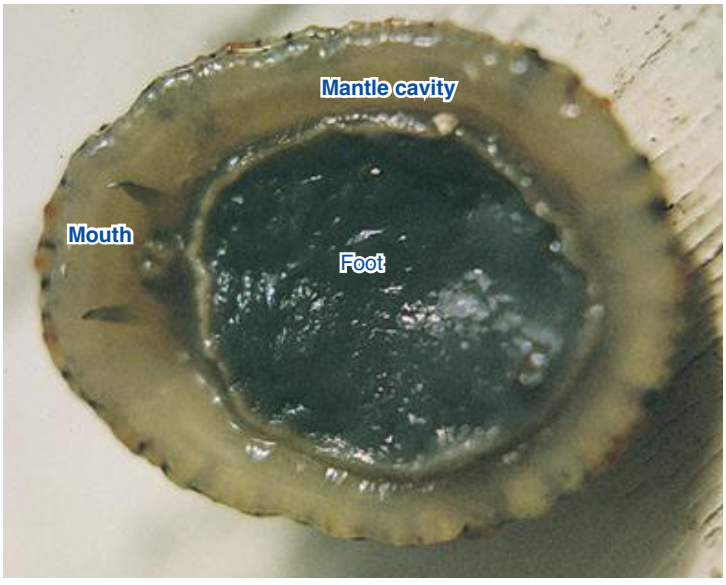
Breathing note*

Scientists talk about respiration, tourists talk about breathing.

Respiration by a mollusc is the use of oxygen for the production of carbon dioxide and energy.

Breathing is the mechanical ventilation of the mantle cavity.

Figure 289.3 Limpet — a Gastropod
(Illustration and photo Bob Moffatt)



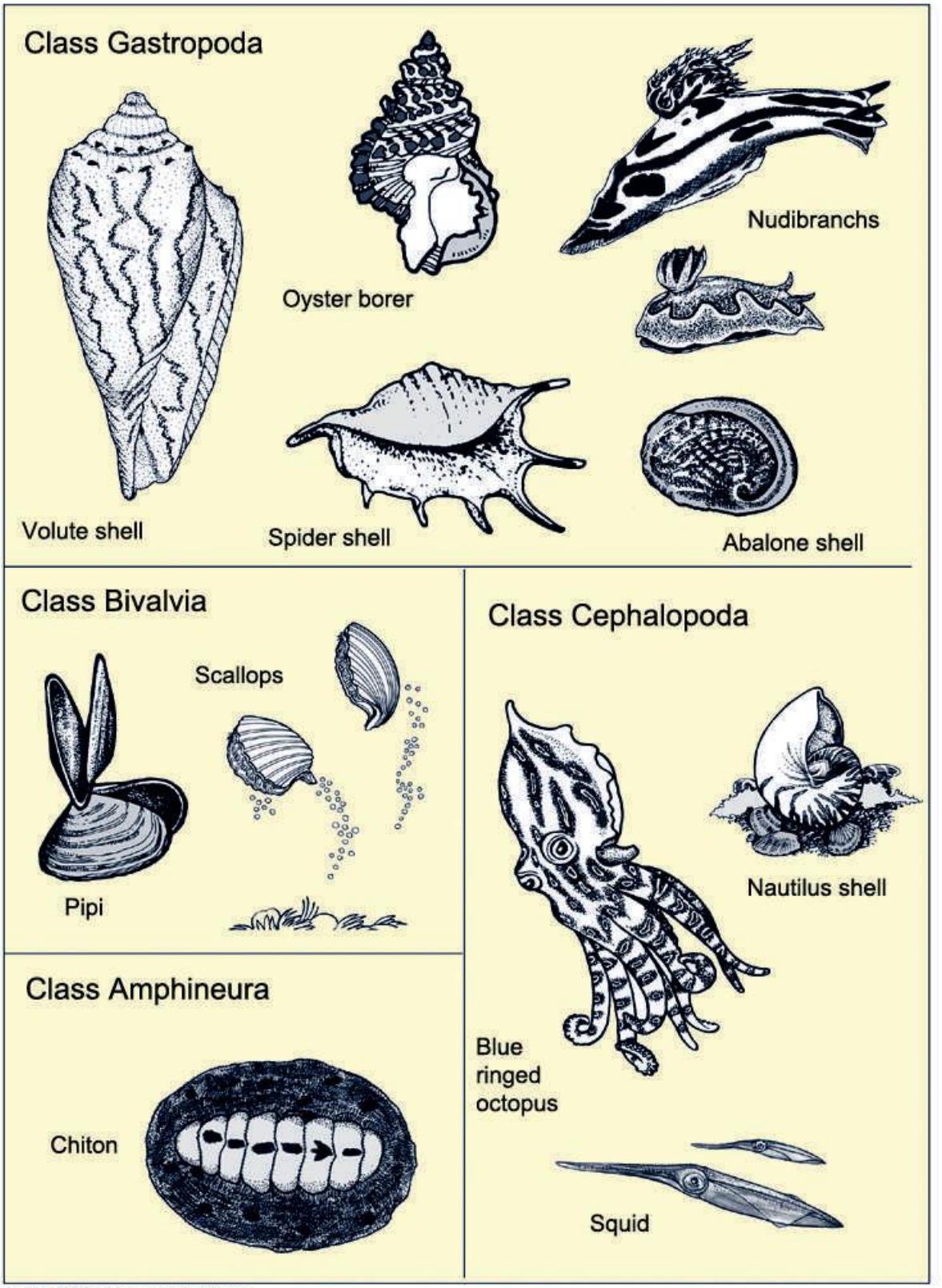


Figure 290.1 Common Molluscs
(Illustrations by Steven Byers, Sue Oats, Rose Bedford, Sharon Madder)

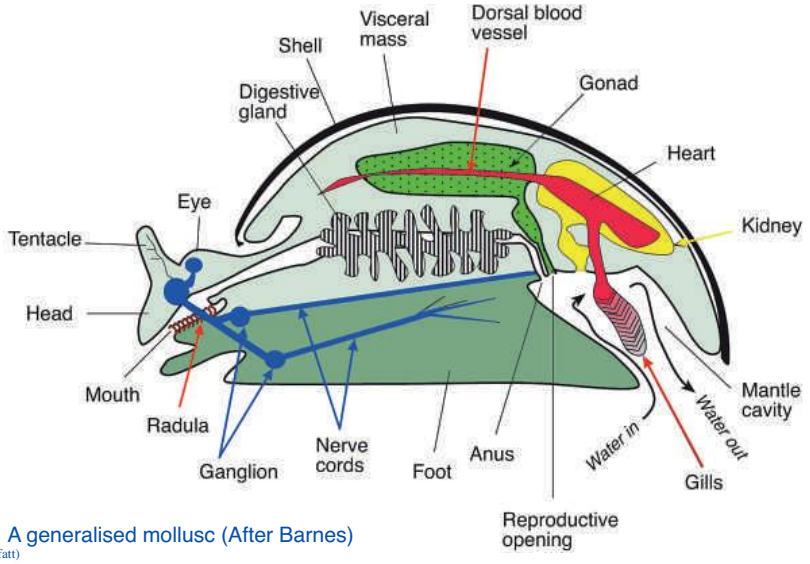


Figure 291.1 A generalised mollusc (After Barnes)
(Illustration Bob Moffatt)

Circulation

A two chambered heart (Figure 291.1), pumps oxygen rich blood from the gills forward into a single aorta which branches into smaller blood vessels. Blood carrying oxygen then leaks out into the rest of the animal's body. Blood is then returned to the gills and back to the heart. This is called an open blood system.

Excretion

Cellular wastes that end up in the blood stream are removed by a kidney that excretes them into the mantle cavity - see figure 291.1 above.

The nervous system

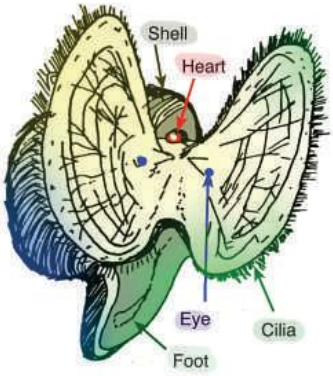
This consists of a nerve ring around the oesophagus with two pairs of nerve cords that run backwards. The ventral (bottom) cords operate the foot and the dorsal (top) cords operate the organs inside the mollusc. Sense organs consist of tentacles, eye spots and statocysts (balance) in the foot and osphradia which are located in the gill to detect grit. In the octopus, the eye is well developed.

Reproduction

Male and female molluscs occur or as in the case of the giant clam, have both sexes in the one animal (hermaphroditic). In either case sperm and eggs are produced from the gonads and in some cases deposited in a protective case.

A planktonic stage called a veliger (Figure 291.2) emerges from the eggs. This feeds by rows of cilia which move food to a food groove by mucous.

At some stage the veliger needs to twist (in a process called **torsion**) to form the shape of the adult and after this stage ceases to swim and sinks to the bottom where it can feed and move with its foot.



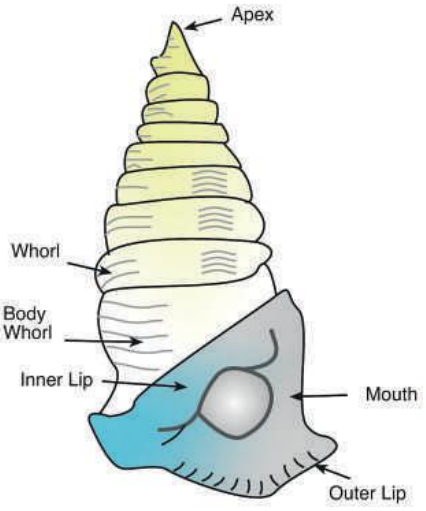
Veliger larvae

Gastropod larvae

Bivalve larvae

Figure 291.2 Molluscan larvae
(Illustrations by Dr Jack Marsh and Dr Dave Tulip)

Figure 292.1 Limpet and periwinkles
(Photo Bob Moffatt)



Class Gastropoda

This is the largest class and is characterised in nearly all cases by a spiral shell. Gastropods include whelks, limpets, nudibranchs and periwinkles.

The most commercially important Gastropod is the abalone which is harvested for the Asian export market.

Drupella

In Western Australia, coral-eating snails called Drupella (Figure 292.3) have killed many thousands of kilometres of reef. The snail eats the coral polyps, leaving a white trail of destruction through the entire reef system.

Mud whelks

Living in mangrove swamps and other muddy areas is the mud whelk. These feed on plankton and debris from the dead remains of other animals and plants.

The mouth is ventral and is surrounded by an outer and inner lip which can be closed with a cap called an operculum.

This happens as a mechanism to stop predators entering the shell and to prevent drying out in harsh conditions (Figure 292.4).

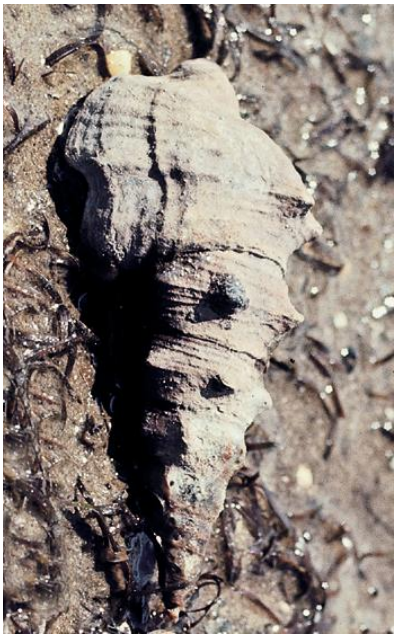


Figure 292.2 Mud whelk ventral and dorsal views
(Photo Neville Coleman)

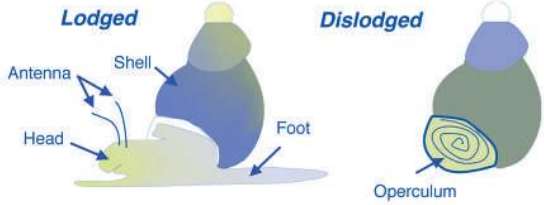


Figure 292.4 Periwinkle lodged and dislodged
(Illustration Bob Moffatt)

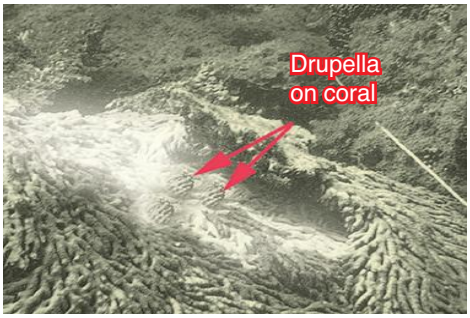


Figure 292.3 Drupella
(Photo Alan Wolfe)

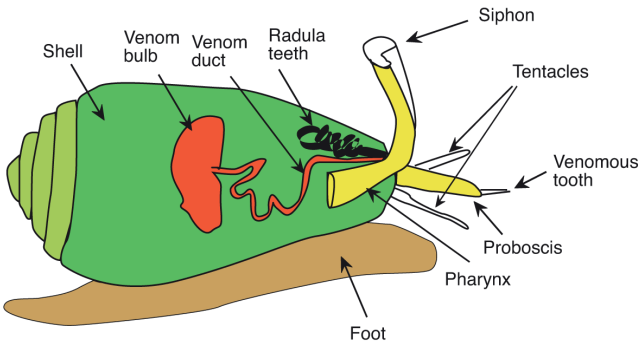


Figure 293.1 Cone shell with siphon and tentacles
(Photo Neville Coleman, Illustration Bob Moffatt)

Figure 293.2 Never pick up a cone shell like this.
(Illustration Rose Bedford)

Cone shells

Many cone shells are very dangerous to humans and should never be picked up by the methods as shown in Figure 293.2. The venom of the cone shell is produced in a venom gland inside the body of the cone shell. It is believed that prior to stinging, the radula teeth are released into the pharynx and from there into the proboscus which has a venomous tooth. The venom is then forced under pressure down the venom duct and into the pharynx under pressure. Prey are instantly killed, swallowed, and then eaten away at with the radula.

Very few people have ever died in Australia from a cone shell envenomation.

Nudibranchs

Text from the web page of Phil Slosberg (Check out his excellent photos)
http://www.cybereef.com/nudiroundup/Pages/nudie_text.htm

"The name *nudibranch* means naked gills and the tail end of most sport a tuft of feathery objects that are the exposed gills that allow oxygen exchange. The front end is set off by a pair of tentacles that are called rhinophores and are exquisitely sensitive chemical receptors for prey, dangers or potential mates.

Nudibranchs have perfected the technique of making themselves unpalatable to any potential predator. Their bodies are often covered on top by small projections called papillae that can secrete a number of noxious chemicals, including sulphuric acid! Studies have shown that predator fish have an intense aversion to anything with an acidic taste.

Certain nudibranchs feed on hydroids that contain stinging cells called nematocysts. They have the ability to separate the stinging cells from the digestible hydroid in their digestive tract and actually move the stinging cells into their own skin for protection!

Nudibranchs have a residual shell when young and shed it during adulthood. Beautiful coloration is their most striking feature and serves either as camouflage or a warning to potential predators that they are poisonous."

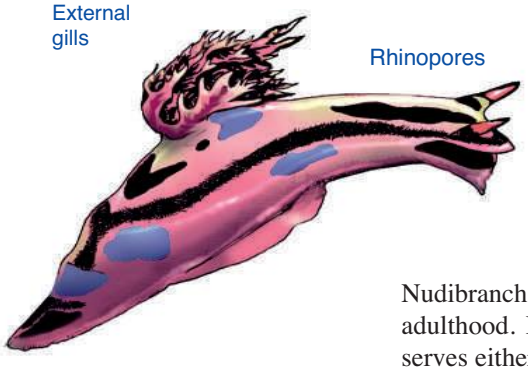


Figure 293.3 Nudibranch
(Illustration Steven Byers and Kerry Kitzelman)

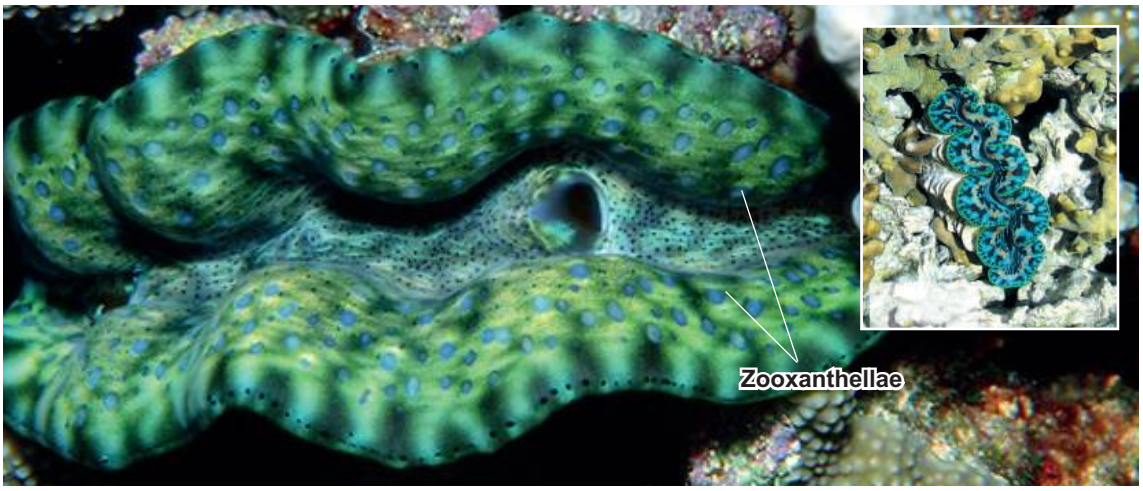


Figure 294.1 The giant clam is a bivalve
(Photo Bob Moffatt)

Class Bivalvia

Molluscs with two shells are known as Bivalvia (or sometimes as Pelecypoda).

The two shells are hinged and can be opened and closed by muscles attached to the shell. The giant clam has a unique relationships with zooxanthellae, which are the bright green growths surrounding the opening of the two shells shown in Figure 294.1. These zooxanthellae actually make the food for the clam because they are microscopic plants which make sugars from sunlight energy as they photosynthesise.

Other bivalves attach themselves to rocks (such as oysters), or burrow into the sand, like cockles and pippies. Many bivalves are commercially important. Oysters, mussels, scallops (Figure 294.2), cockles and razor fish are all harvested for human food.

Oysters are grown on sticks attached to rafts as shown in Figure 294.3. When mature they are removed and sold.

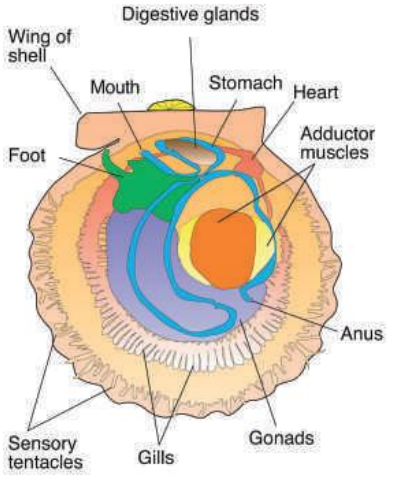


Figure 294.2 A scallop broken in half
(Illustration Steven Byers and Mark Moffatt)

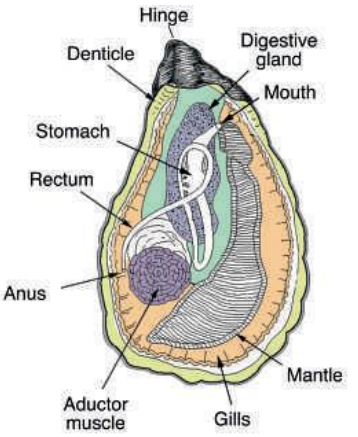


Figure 294.3 Oysters and an oyster lease
(Photograph Bob Moffatt)

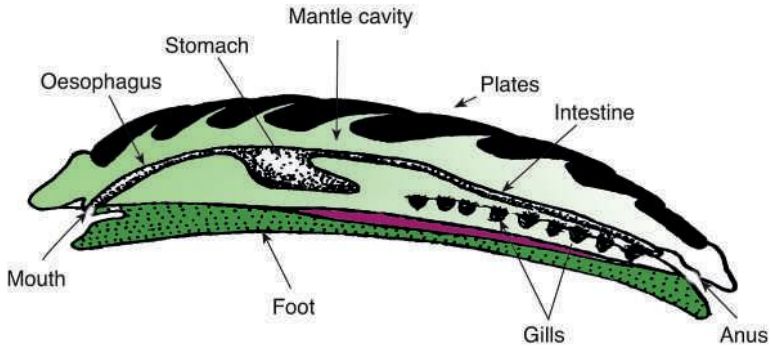


Figure 295.1 Chiton internals
(Illustration Steven Byers)

Figure 295.2 A chiton
Bob Moffatt

Class Amphineura

These are a little like long limpets (Figure 295.1 and 2 with eight sections to their shells. They are found clinging to rocks, often in the surf zone. Chitons are slow moving herbivores who graze on algae found on rocks in the intertidal zone.

There are only male and female chitons with sperm and eggs released into the water. Fertilization is at sea and laval chitons drift with the plankton. After a time they return to hard surfaces to grow to adults.

Class Cephalopoda

The most spectacular group of molluscs is probably the cephalopods. This is the class which contains the squids, octopuses (Figure 295.3), cuttlefish and nautiluses. In this class, the foot is modified into a group of tentacles surrounding the mouth.

Cephalopods have highly developed eyes and a relatively large brain. The blue-ringed octopus can be a very dangerous animal if handled incorrectly. Generally, humans are more danger to cephalopods than the other way around. Squid, octopus and cuttlefish are all captured and eaten by humans in large quantities.

Figure 295.3 Octopus
(Photo Neville Coleman)

Octopuses

Octopuses live in rock pools and use eight long arms to move around. Because they are flatter from side to side they can squeeze into very small crevices and holes.

When disturbed, they squirt ink and water out of a siphon making them rocket backwards and providing a smoke screen. Octopi eat crabs, which they break up with their strong beaks.

Cuttlefish

Cuttlefish (Figure 295.4 and 296.1) are related to octopuses. Some cuttlefish can be trapped in rock pools as the tide goes out. They are hard to see because they hide among the seaweed.

The cuttlefish shells found on the beach were once inside the bodies of the larger cuttlefish that live in the ocean. Like octopuses and squid, cuttlefish can change colour very quickly.

Figure 295.4 Cuttlefish
(Photo Below H_2O)

Figure 296.1 Cuttlefish and shell
Photos - Marine Education Society of Australia (top) Bob Moffatt (Bottom)

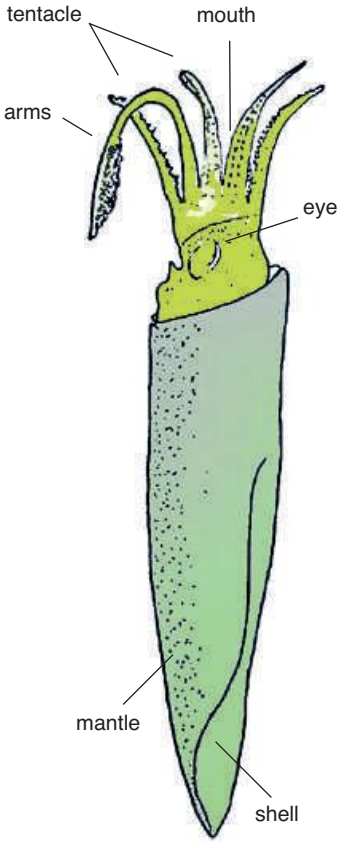
Squid

The largest of the invertebrate animals is the giant squid, which can grow to at least 18 m long. It is found in the open ocean at depths of 300 m or more and is prey for sperm whales. The giant squid is sometimes washed onto beaches or found dead floating on the sea surface. It is probably this creature which gave rise to myths of sea monsters which were supposed to devour ships and seafarers.

Squid live on the continental shelf and have a long elongated body with triangular fins extending along a quarter of the body (Figure 296.1). Some squid can grow up to .75 of a metre and weigh up to 1.5 kg.

The common Pacific Squid congregate and mate in large groups. Males approach a prospective female with arms and legs ablaze with red and white markings changing generally to solid maroon when actual copulation ensues.

- The animals mate either head on or with the male grasping the female from under the left side (Figure 296.2). Using one of the tentacles, the male picks up sperm in a packet called a **spermatophore**, delivered from his penis and transfers it to the females mantle cavity. He holds the tentacle there until the sperm from the spermatophore are released into the female body. The sperm swim inside the mantle to fertilize the eggs of the female.
- Copulation lasts about 10 seconds. Following mating the female produces long cases containing the fertilized eggs. The cases swell and become firm when in contact with sea water. The young squid develop inside the cases and emerge as juveniles (see Figure 296.3).



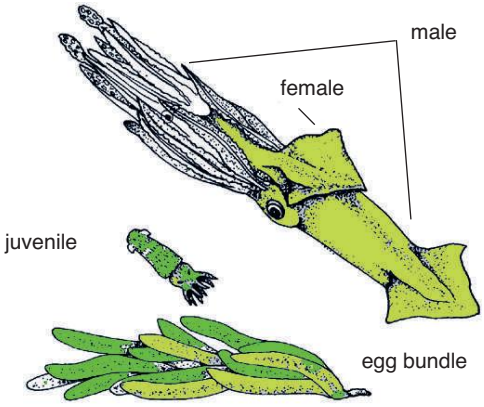


Figure 296.2 Squid reproduction
(After Nielsen 1982)
(Illustration Steven Byers)

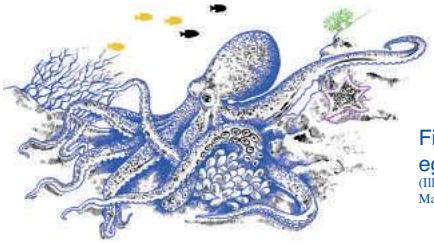


Figure 296.3 Octopus and egg bundles
(Illustration courtesy MESA - ABSea by Sharyn Madder)

Blue ringed octopus

The octopus should never be picked up as it can inflict a severe bite.

These are inflicted from the mouth of the animal.

In most cases the mouth is located in the front.

Halstead records the following death of a diver in Darwin.

"... a diver captured a small blue-ringed octopus...which had a span of about 20 cm. The diver permitted the octopus to crawl over his arms and shoulders, and finally to the back of his neck where it remained for a few moments.

During the period that the octopus was on his neck, a small bite was inflicted, producing a trickle of blood.

A few minutes after the bite the victim complained of sensation of dryness in the mouth and of difficulty in swallowing.

After walking a short distance up the beach the diver began to vomit, developed a loss of muscular control, and finally suffered from respiratory distress and was unable to speak. Even though he had been rushed to hospital and placed in a respirator, the victim died about two hours after being bitten."

This animal will display iridescent blue rings on its body and tentacles when agitated.

First-Aid for Blue Ringed Octopus

- A rescuer must be prepared for ECC.
- Apply a broad pressure bandage as high up the limb as possible.
- Immobilise the limb with a splint and seek medical aid as quickly as possible.

Legend of the deep

www.pbs.org/wnet/nature/octopus

- Read about some amazing examples of octopus ingenuity. Find out how an octopus can be a master of disguise.
- Discover how much you know about these sea creatures by taking the web page quiz.

Photo Neville Coleman

Squid dissection

Acknowledgment

Adapted from LaRosa, E. (2000). Middle school science. from www. middleschoolscience.com

Part A: Dissection

1. Identify the tentacles, head, eye, siphon, mantle and fins.
2. Open the mouth and look at the *radula* (the squid's tongue). Remove the *beak* then draw and label the squid's mouth parts.
3. Using tweezers grasp the *brain* by going through the mouth and the long nerve attached to it. Carefully remove and examine them.
4. Make sure the squid is siphon-side up. Cut carefully through the *mantle* only with scissors. Lay the mantle flat in the dissection tray.
5. Find and examine the following
   - *intestine, liver* (pale brown), *stomach* (glistening white), *gill* (feathery), and *3 hearts*.

   Draw and label these parts.
6. Find the silvery, black *ink sac*.
7. Locate the hard *pen* near the squid's fin. Grasp it and pull it out. Now use this to pierce the ink sac, and write your name in the squid's ink.
8. Remove and examine the *eye*.
9. Remove the *cornea* (film like), and the *lens* (hard, silvery pearl-like structure). Sketch and label it.

Part B: Questions

1. Identify the differences between the tentacles and arms. Explain why they are different.
2. Compare and contrast the differences and similarities between squid and human mouths.
3. Explain how the squid uses the funnel and mantle for locomotion.
4. Analyse how squid get oxygen from water.
5. Explain how squid reproduce.
6. Analyse the importance of chromatophores to squid.
7. Recall who the squid's relatives are and why?
8. Explain the function of the fins.
9. Imagine you are Poseidon (or Neptune), and are designing a new improved version of a squid.

   Draw your updated squid, and explain the improvements you have made.

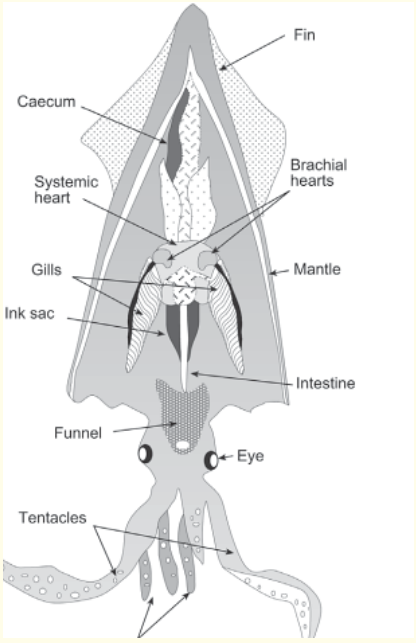


Illustration by Bob Moffatt

Exercise 11.4 Protozoans

Aim

To find single celled animals under the microscope.

Materials

- microscope
- slides and coverslips
- pond water

Amoeba
(Jack Marsh)

Method

1. Place a drop of pond water on the microscope slide and examine it under low power.
2. When you find and animal that looks like it has a single cell switch to high power and record its shape, how it moves and any other interesting features of the animal.

Questions

1. What do all protozoans have in common?
2. What different shapes of protozoans did you see?

Exercise 11.5 Sponge spicules

Aim

To examine the internal supporting structures of sponges.

Materials and equipment (per group)

- microscope, slides and coverslips
- mounted needles, scissors and paper towel
- bleach
- dead sponge (several types if possible)

Method

1. Cut small pieces of sponge (about 2 mm cubes).
2. Place on microscope and add 3-4 drops of bleach.
3. Tease and "mash" with mounted needle for 2-3 minutes.
4. Add 5-6 drops of water. Remove excess water with paper towel. Add cover slip.
5. Examine under low power (40 - 50 X), then under higher power (100 -200 X).
6. Draw diagrams of any structures you find. Remember the rules of scientific drawing. (Label your diagram, show magnifications, use a sharp pencil, make your diagrams large.)
7. Repeat this procedure for as many other types of sponge as you can.

Questions

1. Why do you think the sponges would have structures such as these?
2. Did all of the sponges have the same shaped spicules?
3. What do you think the spicules are made of?
4. Did all of the sponge spicules seem to be made of the same sort of material?

Sponge spicules
(Illustration Bob Moffatt)

Nautilus

The pearly nautilus (Figure 298.1) is active at night and rests during the day. Whether it is swimming or resting its gas filled chambers keep the shell buoyant and upright. A pearly nautilis can dive to depths greater than 600 metres and uses this gas to regulate its depth.

Swimming relies on the ejection of water through a siphon by the contraction of muscles in the mantle.

An unusual feature of the pearly nautilis is that it can retract into its shell and seal itself with its hood. No other cephalopod can do this.

Pearly nautili eat crabs and fish.

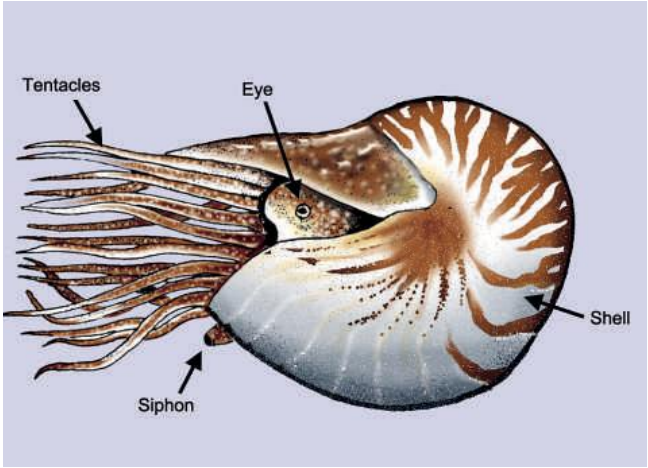


Figure 298.1 Pearly nautilus
(Illustration Rose Bedford)

Exercises

From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

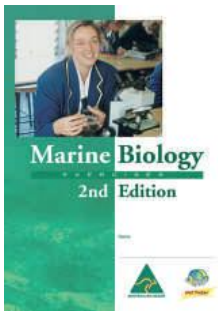
B3. What lives in the intertidal zone of an exposed shore?

B5. How do corals feed and reproduce?

B6. What is coral bleaching?

B7. How do molluscs feed, breathe* and kill?

E5. Can you dissect a squid?



Teacher's Guide

There are extra exercises, field work, experiments and activities in the Marine Biology exercises book

Questions

Knowledge

1. Describe the structural characteristics for each of the following Phyla:
   - Cnidaria, Annelida and Mollusca.
2. List the internal organs of a generalised mollusc.
3. What dangers could you face if you picked up a cone shell?
4. Name a polychaete.
5. Retell the story of a diver who captured a small blue-ringed octopus in Darwin in your own words.
6. State the first aid procedure if stung by a sea jelly. Compare this with the procedure if stung by a box jelly.
7. What is the technique nudibranchs have perfected to make themselves unpalatable to any potential predator?
8. Write a paragraph on the reproductive cycle of a mollusc.
9. How do free swimming marine worms feed?
10. What is a radula and how is it used?

Understanding

11. Draw a diagram of a cone shell showing the following parts: venom bulb and duct, radula teeth, siphon, tentacles, proboscus, foot and pharynx.
12. Draw a diagram to show you can distinguish between the terms *radial* and *bilateral symmetry*.
13. Describe the role zooxanthellae play in the life of a coral and outline what happens when temperature rises.
14. Distinguish between the classes Rhizopoda, Ciliata and Flagellata.
15. Draw a diagram of a sponge showing different types of cells. Indicate how water gets in and out and describe how a sponge gets its food.
16. A surfer paddled out through a group of jellyfish-like animals but did not get stung. Which Phyla do you think they were from and why?
17. Identify the animals A-F in Figure 299.1
18. Outline why worms form an integral part of the benthic ecosystem.

Applying

19. Classify the animals A-F in Figure 299.1 as far as you can and make a dichotomous key.
20. Construct a diagram for the life cycle of a sea anemone.
21. Explain how retractor muscles help an anemone.
22. To make a new jellyfish a specialized process called strobalization occurs. Examine the photo of the sea jelly in Figure 279.2 and draw a diagram to explain how this process applies to this animal.
23. Write two similarities and two differences between the tentacles of the animals in A and B.
24. Describe how animal D feeds.
25. Write two similarities and two differences between the shells of the animals in D and E.

    Which could hang on to rocks better? Give reasons for your answer.
26. Describe how animal B feeds.
27. How does animal F reproduce?

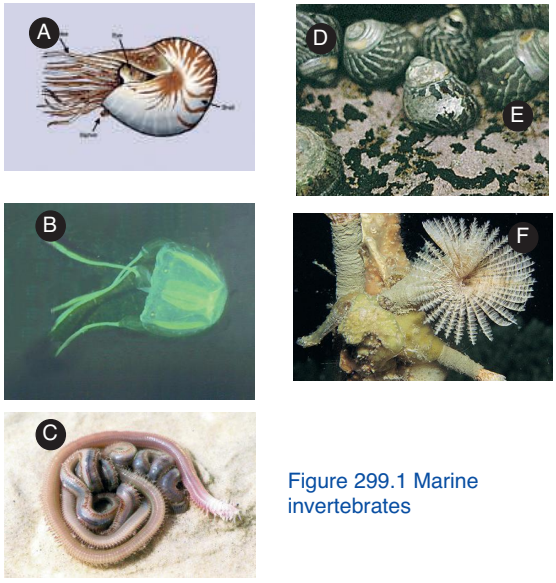


Figure 299.1 Marine invertebrates

Questions (cont'd)

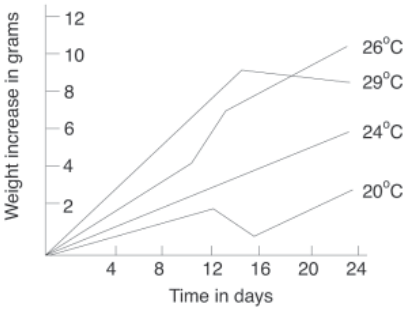
Application

Information for questions 28 and 29.

Reef building corals flourish in shallow tropical waters, rarely being found below depths of 60 metres. An experiment was conducted to determine the optimum temperature for coral growth.

Coral of the same species were placed in similar aquariums and the temperature in each was regulated. The weight of the coral was determined every four days.

The results are as shown below.



Choose the correct answer.

28. The results indicate:
    a. Temperature had no effect on growth.
    b. The growth rate was most rapid at 29 degrees centigrade for the first 12 days.
    c. A disease affected the aquarium at 20 degrees on the 12th day.
    d. Light, not temperature, affects growth.
29. The coral was then placed in the dark and the experiment was repeated. The expected results would be:
    a. No change as corals are animals and are not affected by light.
    b. The corals would lose weight at a constant rate because of respiration.
    c. The water would become dark and murky.
    d. Growth rates would increase for the first few nights as corals normally feed at night.
30. Organisms such as limpets and other molluscs that live on a rocky shore live in a harsh environment.
    a. What differences would there be between the environments of a limpet on a rock on a hot summers day when the tide is in, compared to when the tide is out?
    b. How could a shower of rain affect the living conditions on the rock?
31. Compare the processes of ingestion and digestion in Porifera and Cnidaria. Identify polyp and medusa.
32. What are the advantages of the molluscan shell? What are the disadvantages? Identify radula, mantle and foot.

Creating

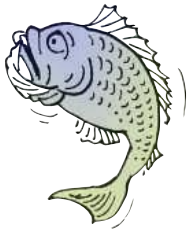
33. Design a marketing brochure for a touch tank in a marine aquarium using the invertebrates in this chapter. Which animals would you have difficulty displaying?
34. Estimate the amount of food you would need for an aquarium of octopus in a display aquarium.
35. Plan a display of marine sea jellies. What material would you use and where would you put them in a public aquarium?
36. Predict what would happen if you were bitten on the hand by a blue ringed octopus. Describe how you would create a makeshift splint from snorkelling gear.
37. Propose a conservation strategy for people who love collecting shells.
38. Conduct a survey of people in class who have been stung by a sea jelly. Write a short story about the accident.
39. Create a dichotomous key for the corals on page 282.

Evaluating

40. Evaluate the statement that the invertebrates are grouped according to their structural characteristics with each phylum sharing certain basic features. Give examples of the basic design of any three animals which determines where the organisms live by restricting them to a particular part of the environment.
41. Choose any phyla in this chapter and make a list of what extra information would be relevant to you if you were to become a tour guide.
42. In an open circulatory blood system, moving blood flows from the vessels and into sinuses bathing the internal organs eventually seeping back to the heart. Decide if a closed system could work in this way.
43. Determine if the animals in this chapter with bilateral symmetry have sensory organs concentrated in the head. List the phyla.
44. Justify with examples, the statement *that the evolution of the invertebrates can be traced by their increasing complexity of digestion, transportation and other body systems*.

Activity

Make a dichotomous key for the mollusc shells illustrated in this chapter.



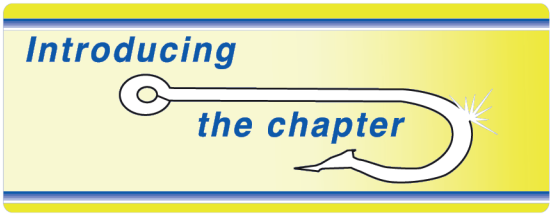
Chapters 12
Marine Invertebrates (2)

Arthropods and Echinoderms

by

Bob Moffatt

Photo Qld Fisheries



Chapter hooks

- Hatch some sea monkeys.
- Buy a class set of school prawns (small ones) and have students pull off all the appendages and arrange them in order from anterior to posterior. Take a photocopy of their sheets and then discuss the adaptations of each.
- Arrange for someone to come and show students how to tie up a mudcrab, or peel a prawn, or how to cook crustaceans.
- Collect a sample of live plankton and place in the fridge until class. Then have students examine it in a test tube with a hand lens and describe the movements.
- If you are able to set up a marine tank, students can describe the movements of crabs, prawns, lobsters.
- Go on an excursion to see the invertebrates at low tide.

Why study this chapter

The higher invertebrates provide a valuable food source for many people in our world. Crustaceans such a as prawns and crayfish form an essential part of the restaurant trade however the methods used to fish these species are often destructive. It is essential marine scientists research their biology and ecology to develop aquaculture methods that can sustain the seafood market.

Chapter overview

Phylum Arthropoda **303**

Class Crustacea 303

Exercise 12.1 Artemia life cycle 305

Exercise 12.2 Mick's Prawn dissection 312

Phylum Echinodermata **319**

Class Crinoidea 320

Class Stelleroidea 320

Class Echinoidea 321

Class Holothuroidea 322

Exercise 12.3 Research 323

Exercises and questions 325

Key concepts

- The invertebrates are grouped according to their structural characteristics with each phylum sharing certain basic features. This basic design determines where the organisms live, by restricting them to a particular part of the environment; eg the Echinoderms are all marine.
- Crustaceans play an important role in the food chain because they scavenge for dead and decaying matter. They clean up the sea floor, keeping bacterial and algal growth to a minimum.
- The Arthropods and Echinoderms have a more complicated nervous system and associated reproductive, digestive and excretory organs.
- Diurnal migration refers to the daily migration of plankton towards the surface at night.
- Arthropods are bilaterally symmetrical and Echinoderms pentamerous radially symmetrical.
- The evolution of the invertebrates can be traced by their increasing complexity of digestion, transportation and other body systems.
- Echinoderms have a unique water vascular system to assist in locomotion and feeding.
- Arthropods contain commercial species and are often referred to as part of the fishing industry.
- An appreciation of biodiversity helps enhance the need for marine conservation and sustainability.
- Artemia are brine shrimp and are easy to use in experiments.

Phylum Arthropoda

Characteristics: Segmented animals with an external skeleton called an exoskeleton. Bilaterally symmetrical with an open circulatory system, a one-way digestive tract and a ventral nerve cord. Examples include crabs, prawns and barnacles.

This phylum is by far the largest animal phylum. The number of arthropod species outnumbers all of the others put together. All arthropods have an exoskeleton made of a substance called chitin, which must be shed by the animal as it grows. Arthropods are bilaterally symmetrical which means that if you cut one in half, one side looks like the other. For example, if you cut the crab in Figure 303.1 in half, one side would be the same as the other. All arthropods have jointed legs (Figure 303.2) which are adapted for functions such as digging, sensing, grasping, mating or egg carrying.

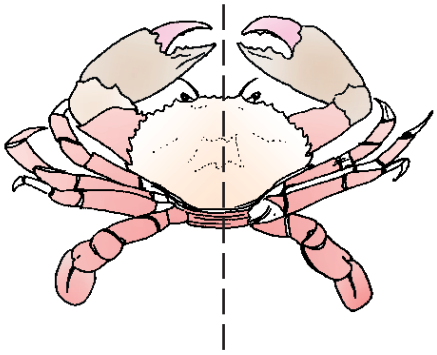


Figure 303.1 Bilateral symmetry divides an animal in half
(Illustration Ed Fish)

Importance

Crustaceans play an important role in the food chain because they scavenge for dead and decaying matter. They clean up the sea floor, keeping bacterial and algal growth to a minimum.

Figure 303.2 Soldier crabs have jointed appendages to allow flexibility of movement
(Photo Qld Fisheries)

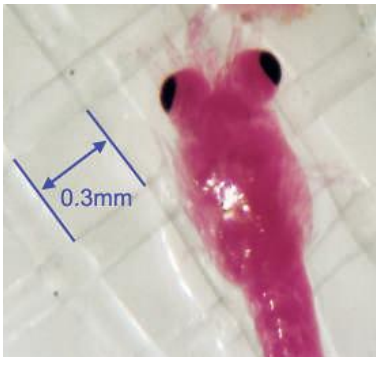
Class Crustacea

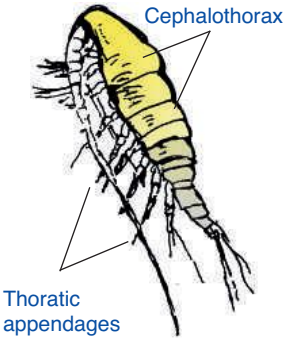
See page 306 for a definition of microscopic size

Sub class Copepoda

Copepods

These are microscopic free living arthropods found in the plankton with a simple structure as shown in Figure 303.3. The body is divided into a cephalothorax, abdomen and telson. Copepods swim by means of their beating antennae or thoratic appendages where present. Their principal food is phytoplankton which are filtered out by specialized mouth parts. However some copepods are carnivorous and able to catch small fish.





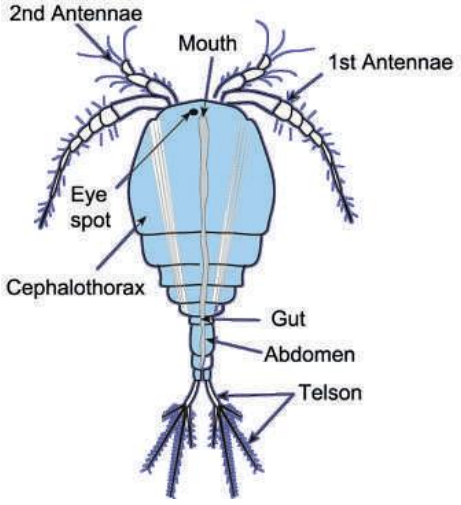


Figure 303.3 Copepod size and structure
(Illustrations and photography Wet Paper)

A simple food tract starts with a mouth and finishes with an anus at the end of the abdomen.

There are male and females copepods which produce sperm and eggs from gonads within the body cavity. Males have a copulatory organ associated with one of the appendages.

In some species males actively pursue females and once caught the male clasps the female with his antennae while depositing a sperm package to the base of one of her legs.

Copepod eggs may be stored for some time before fertilization but once release change into a larvae (Figure 304.1). To grow bigger, the copepod must shed its chitinous skin (moulting). After a series of moults, the copepod reaches the adult stage.

Copepods form part of a group of animals called the plankton which are continually swimming in the surface layers of the sea and form the prime source of food for billions of sea creatures.

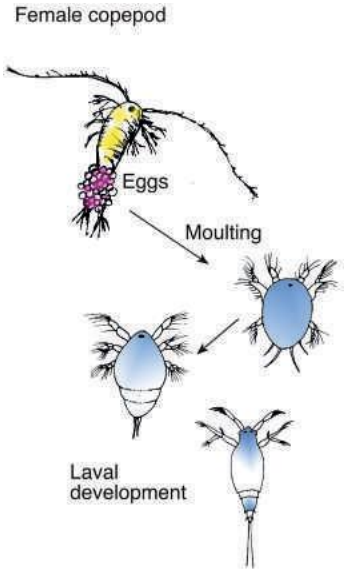


Figure 304.1 Copepod reproduction
(Illustrations Merran Kilgour)

Planktonic adaptations

An adaptation is something which helps the animal or plant survive. It is a characteristic of all life on earth because organisms that are poorly adapted die before they can reproduce.

Plankton are no exception and have developed a number of adaptations to help them stay floating and drifting.

Colour - Nearly all plankton are clear which makes them very difficult to see. Others are blue, so they blend in with the sky when viewed from below and other deep sea plankton are red making them invisible at depth.

This protective camouflage helps them avoid being eaten by predators.

Take a closer look at copepods with drawings by Elke Willen at: www.uni-oldenburg.de/zoomorphology/Biology.html

Figure 304.2 Copepod external features
(Photo Jack Marsh)

Size - Most plankton are small which helps them float and makes them difficult to see. Figure 306.1 on page 306, shows a prawn larva on a piece of plankton net with a mesh width of only 0.25 mm. Many plankton are even smaller.

Small size also means that larvae can ingest and excrete straight through their body wall so they do not need a complicated digestive system which would add weight to the body.

Shape - Many plankton make use of their shape to stay afloat.

A long, flat, copepod can glide through the water using its winged shape. A bell-shaped copepod can fill its bell with air or a buoyant material to help it float. By adjusting the air, it can control its movement up or down to make the most of the weather conditions.

Swimming - Copepods use long swimming appendages outside the body to stay afloat.

Vertical migration - Many plankton in the top 100 m of water spend their daylight hours in deeper water and move towards the surface at night in a process called vertical migration (Figure 304.3).

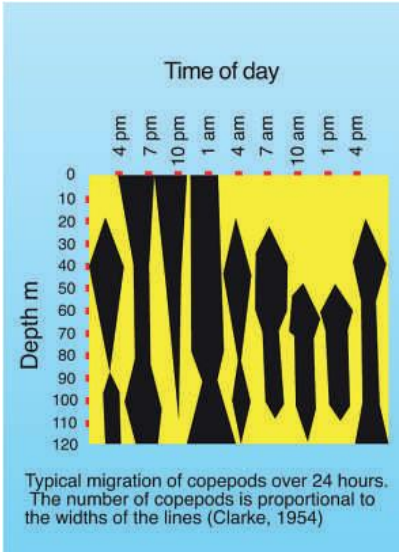


Figure 304.3 Copepod vertical migration
(Illustration Mark Moffatt)

Exercise 12.1 Artemia life cycle

Based on an original exercise by Alan Wolfe, South Fremantle High, with slide by Geoff Jensen and Bob Moffatt.

Note

Artemia are also called sea monkeys or brine shrimp.

Aim

To grow brine shrimp from eggs as either a food source for marine aquaria or for pollution experiments.

Methods

If you are using aquarium artemia, read carefully the instructions on the packet. If they are different from those below, use the packet instructions.

Part A Your experiment

1. Weigh 4 g of Artemia eggs and add to 200 mL seawater at 23 °C in a 400 mL beaker.
2. Place above in a water bath also at a temperature of 23 °C .
3. Use an aerator to hydrate eggs gently for 36 hours under an artificial light source at 23 °C to encapsulate the eggs.
4. After 36 hours, draw 3 to 5 mLs of sample into a 10 mL pipette and quickly release 1 mL onto a plankton net slide (see Figure 306.2).
5. Count the number of larval Artemia (including those partially hatched) per square cm with the plankton net slide and steromicroscope. Study Figure 305.1 to determine which stage the larvae are at.
6. Repeat steps 4 and 5 twice more to get an average count and record this in Figure 306.3.

   Note: Some artemia eggs require a different encapsulation process and this is usually described on the packet in which they came.

Materials and equipment (per class)

- small aquarium
- brine shrimp eggs (from pet shop)
- laboratory balance and watch glass
- artificial light source
- water bath
- 10 mL pipette
- filter paper
- counting slide (see Figure 306.2 over page)

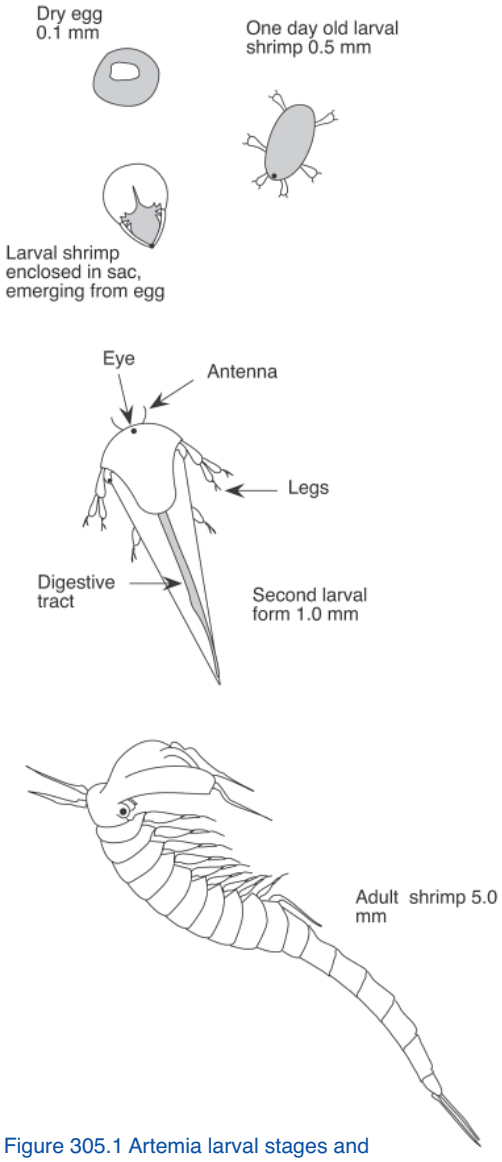


Figure 305.1 Artemia larval stages and adult (Wolfe 1995)
(Illustrations Mark Moffatt)

Instructions on how to make a plankton net slide

1. Collect a plastic photo slide frame, a piece of 3 mm clear plastic sheet, one 200 mm square of plankton net, an overhead transparency sheet that has had .5 or 1cm squares photocopied onto it and tube of 5 minute Araldite glue.
2. Cut all sheets to size.
3. Glue together as shown in steps 1 - 4 below.
4. Try making other sized counting grids using 250 m and 300 m squares of plankton net offcuts.

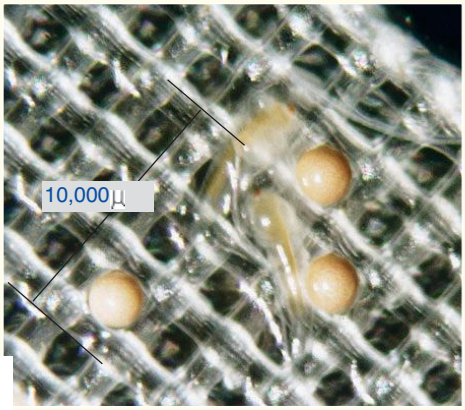


Figure 306.1 Artemia on plankton net
(Photo Bob Moffatt)

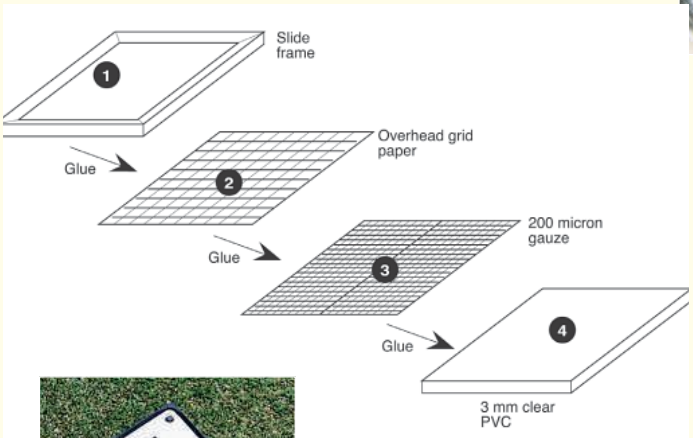


Figure 306.2 Plankton net slide and construction details
(Concept Geoff Jensen, photo Bob Moffatt)

Artemia count / sq cm				
Life cycle stages	**Count 1**	**Count 2**	**Count 3**	**Average**
Eggs				
One day old larvae				
Second laval stages				
Adults				

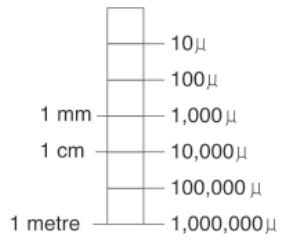
Figure 306.3 Part A results

Microscopic size

Plankton are classified according to the following sizes:-
"Ultraplankton - below 5 m
Nannoplankton between 5 - 60 m
Microplankton between 60 - 1000 m
Mesoplankton between 1 - 5 mm
Macroplankton above 5 mm
Megaplankton - very large forms"

The mesh size of the bolting silk in Figure 306.1 will determine what type of plankton is caught. For large forms, the size of the bridle will also determine which forms are caught.

$$1\,\mu = \frac{1}{1\,000\,000\ \text{Metre}}$$



Part B Your report

1. Read the information in Figure 307.1.
2. Elect a class co-ordinator who is to divide the class into six mixed groups.
3. One of the groups is to be the control group while the other five are to select controlling factors.
4. Each group is to discuss and design a method to test their factor by modification of the standard procedure.
5. Write out your group's method and add your results when they become available.
6. Combine your results into a class data table like the one shown in Figure 307.2.
7. Formulate and write a conclusion on all the factors that have been tested in your final report.

Factors that affect the production of artemia

1. Salinity. Normal seawater is 35 g/L but can rise in shallow pools that are heated or fall as freshwater dissolves from runoff from the land.
2. Temperature. Ambient temperature is about 23ºC however this can rise to as high as 30ºC or fall to as low as 8 ºC in Australian waters.
3. pH. Seawater has a pH of about 8 but can be lowered by the addition of freshwater or acids from marine plants to pH 4. It can be raised by the addition of basic materials from shellfish or urban runoff to as high as 10.
4. Overcrowding. As the number of artemia increases in a given volume of water, competition for food, space and available oxygen can decrease the chance of survival. Is 4 g/ 200 mL an ideal population density?
5. Premature chemical removal of eggs (cysts). It has been shown that the following bleaching can affect population densities.
   a. Three hours after gentle hydration in part A (step 1), drain and then mix hydrated cysts with 50 mL of 4% bleach solution.
   b. Stir every 20 seconds for 15 minutes then rinse through a 200 micron sieve with fresh water.
   c. Add the decapsulated cysts to 200 mL of fresh sea water, return to water bath and follow part A (steps 3 - 6).

Figure 307.1 Factors affecting artemia

Group's results

Factor	Variations	Artemia count / sq cm			
		Count 1	Count 2	Count 3	Average

Class results

Factor	Variations with average artemia counts / sq cm
Factor	

Figure 307.2 Suggested data tables

Figure 308.1 Barnacles
Bob Moffatt

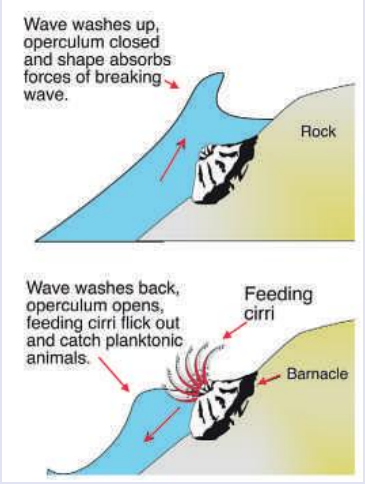


Figure 308.2 Barnacles feeding
(Illustrations Rose Bedford and Bob Moffatt)

Sub class Cirripedia

Barnacles

External features

Shore barnacles live on rocks (Figure 308.1) or places like pylons within the tidal zone and can be found attached to most hard surfaces in the sea because the shell has been modified into a protective coating that helps to anchor the barnacle to a surface.

Barnacles can also attach to boats as they move from one port to another. The goose or stalked barnacle is most often found in the open ocean attached to driftwood.

Feeding

A barnacle uses modified legs called cirri to wash food into its mouth. The top of the barnacles opens and closes at about 140 times per minute so the cirri can "grab" at small planktonic animals as they pass by. Food then passes through the mouth to a stomach where it is digested before being passed out of the anus.

Circulation, excretion and respiration

A heart and arteries are absent but blood flow is helped by a blood pump behind the oesophagus. No gills are present and gas exchange is most likely in the cirri. Excretion of wastes is by the maxillary glands located behind the stomach.

Reproduction

To reproduce, each barnacle has a male reproductive organ called a testis which makes sperm and a female reproductive organ called an ovary to make eggs (Figure 309.1).

Because both male and female organs are found in the one animal, the barnacle is called an hermaphrodite. Sperm and eggs are called the reproductive cells of the adult stage of an animal and fertilisation is where sperm and eggs join to form a fertilised egg.

Even though they have both female and male organs, barnacles do not fertilise themselves. Each barnacle has a penis that transfers its sperm to the eggs of its neighbour barnacle.

When tide and time are right, the fertilised eggs are released from the ovaries and float to the surface of the sea to become plankton. The fertilised barnacle eggs quickly divide to form many more cells.

This is called a larval stage. A larval stage is the baby stage of an animal. To distinguish between the different stages, marine scientists call them different terms.

The first larval stage of a barnacle is called the nauplius and is shown in Figures 309.2. It is characterised by its microscopic size, two horns and external feeding arms or cirri. The barnacle grows rapidly and changes into a cypris larvae (Figure 309.3).

This larva finds its way to shore or onto a solid object by using a remarkable chemical sensory organ which guides it back towards land even though at this stage it is less than 1 mm long and has no eyes.

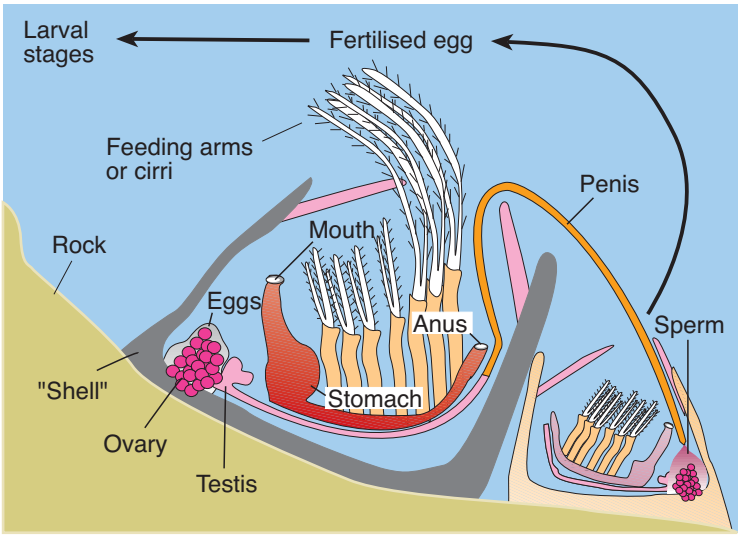


Figure 309.1 Barnacle structure
Bob Moffatt

Amazing facts

Reproduction

A barnacle's penis can be up to 20 mm long - the largest in the animal kingdom in terms of body proportion (equivalent to 4 times that of humans).

Barnacle's importance

These animals colonise rocks and surfaces worldwide and contribute significant amounts of food to higher order consumers. They also provide habitats for other animals and plants.

Shortly before settling on to a solid object, the barnacle changes again, this time into a post-larval stage called a juvenile larvae (Figure 309.3).

This juvenile stage lands on the rocks and crawls around until it finds other barnacles. Its stalk then helps it attach itself to the rocks and grow to the adult stage.

Distribution

Barnacles are found worldwide and can even attach to sea jellies, sharks, whales, sharks, fish, turtles crabs and many other marine species.

Figure 309.2 Nauplius
Jack Marsh UK

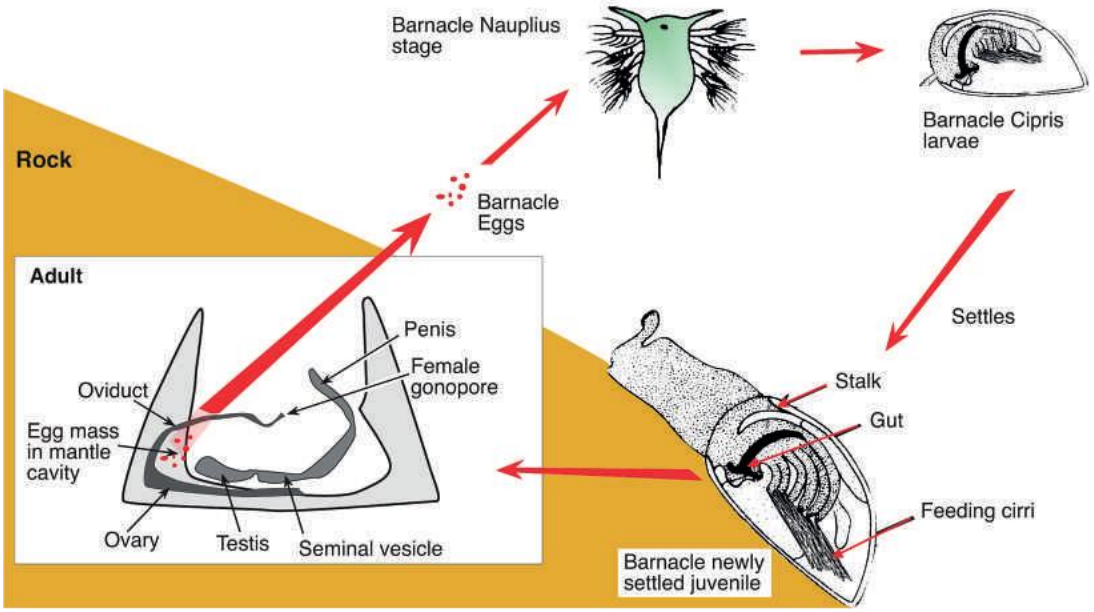


Figure 309.3 Barnacle reproduction and life cycle
Bob Moffatt

Subclass Malacostraca

This subclass is represented by prawns, crabs, shrimps and lobsters.

Order Decapoda

External features

Decapod crustaceans are made up of nineteen body segments grouped into the **cephalothorax** and **abdomen**. Each segment may possess one pair of appendages, although in various groups these may be reduced or missing. Figures 310.2 and 311.1 summarise these segments.

Cephalothorax

- The **cephalothorax** is covered by a carapace which protects the internal organs and the gills; the section of the carapace that projects in front of the eyes is called the rostrum.
- The head has **antennules**, **antennae**, **mandibles**, first and second **maxillae**. The head also bears the (usually stalked) compound **eyes**.
- The thorax has first, second and third **maxillipeds**, followed by five **pereiopods**.
  - Maxillipeds are appendages modified to function as mouthparts. Each appendage from the second maxilla to the fifth pereiopod also bears a gill.
  - Pereiopods are primarily walking legs but can also gather food. Some pereiopods are armed with a claw. Pereiopods bear the sexual organs, which are the *third pereiopod* in the female and the *fifth pereiopod* in the male (Figure 310.1).

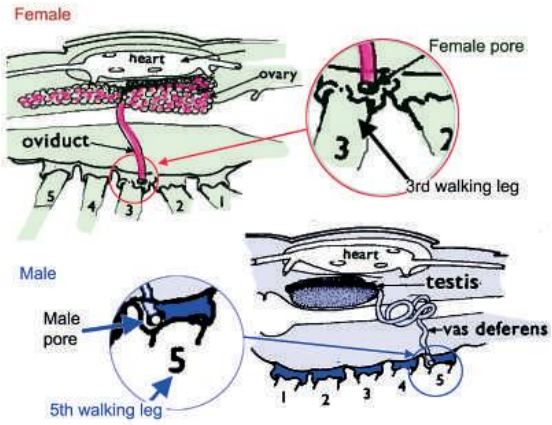


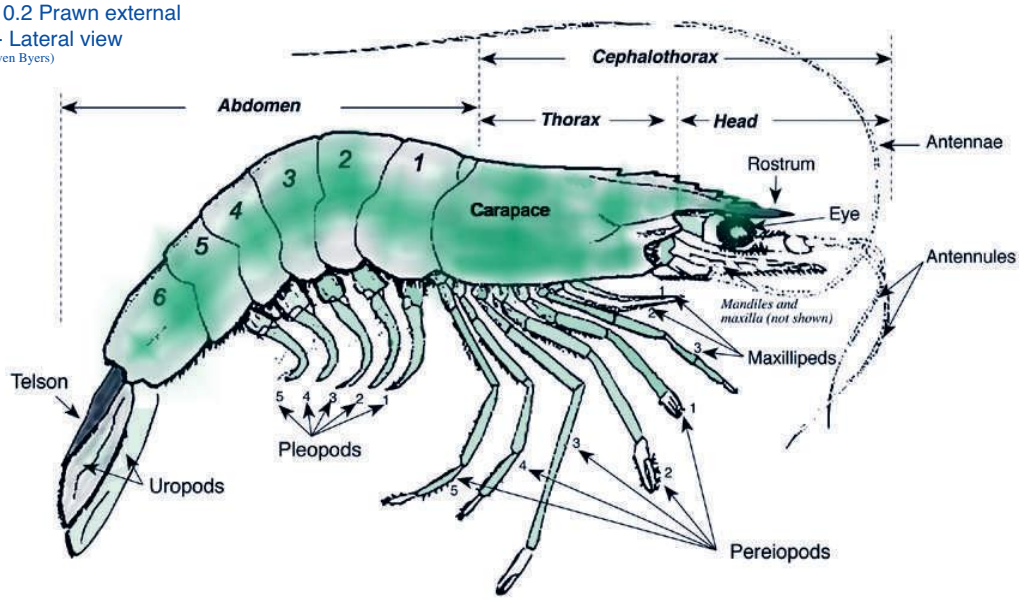
Figure 310.1 Prawn reproductive
(Illustration Dr. Tom Hailstone)

- Sperm are produced in a **gonopore** from the base of the 5th walking leg. From here they are picked up by a tubular organ called the **petasma** located on the first swimming leg and transferred to a female opening called at **thelycum** located in the mid section of abdomen opposite the 5th walking leg where they are fertilized (Figure 311.1).

Abdomen

- This has five **pleopods** and two pairs of **uropods**. Pleopods are primarily swimming legs, but can also brood eggs (except in prawns) and catch food. In some groups, the first one or two pairs of pleopods are specialised in the males for fertilisation.
- At the end of the abdomen is the tail fan, comprising a pair of uropods and the **telson**, which bears the anus. Together, they are used for steering while swimming and escaping prey.

Figure 310.2 Prawn external features - Lateral view
(Illustration Steven Byers)



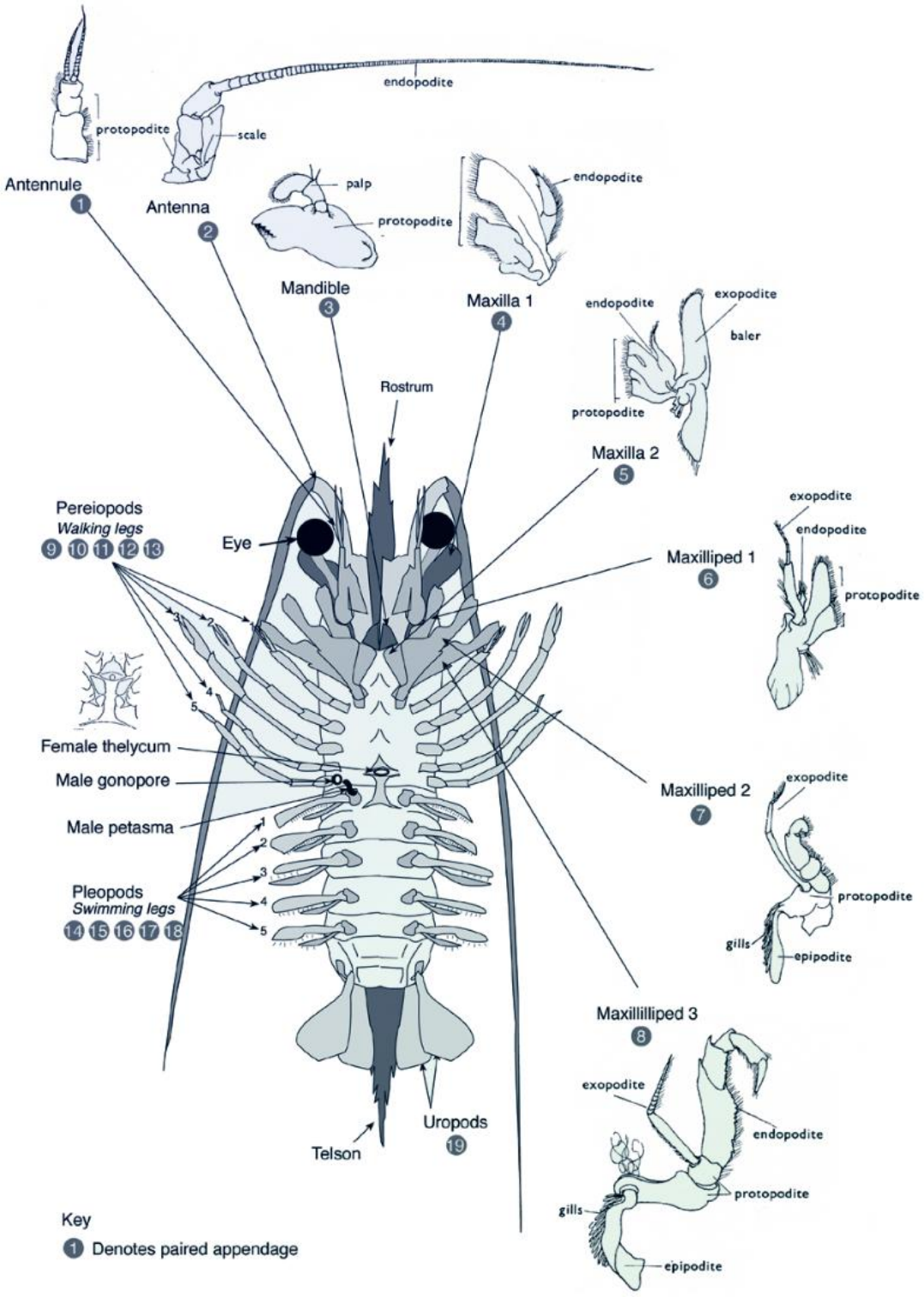


Figure 311.1 External features of a prawn - ventral view
(Stylised illustration Mark Moffatt, Mouthparts by Dr. Tom Hailstone 1967)

Exercise 12.2 Prawn dissection

Based on an original exercise by Mick O'Connor, with editing by Katie Gill and Tony Courtney.

Aim

To dissect a prawn and show external and internal features of an invertebrate from the Phylum Arthropoda.

External anatomy

Note the following regions of the body as outlined on pages 310 and 311. The paired appendages numbered [1] -[19] in Figure 311.1 are used to clarify the dissection.

a. Abdomen

b. Thorax

c. Head

d. Draw a diagram identifying these 3 regions.

1. Abdomen

a. Look at the abdominal region. There are 6 individual segments. The appendages of the 6th segment have been adapted for rapid backward propulsion. The telson and uropods [19] form a paddle which, with the large flexor muscle (the edible part of the prawn) provides an effective method of escape.

b. Look at the appendages of the 5th, 4th, 3rd, 2nd abdominal segments [18-15]. They are flattened like small oars and have been adapted for swimming.

c. Study the 1st abdominal segment [14]. The appendages on this segment have been modified as sex organs. Locate the appendages and using Figure 310.2 and 311.1 determine the sex of your specimen.

d. Label the 6 abdominal segments onto your diagram.

2. Cephalothorax

a. Locate the cephalothorax; note the carapace which covers the head and thorax regions. These may be difficult to distinguish. There are 13 segments in the cephalothorax - 8 of these are in the thorax [6] - [13] and 5 in the head [1] - [5]. Look at Figure 311.1 to identify these.

b. Label the cephalothorax on your diagram.

3. Thorax

a. There are 8 segments in the thorax. 5 of these 8 can be easily seen.

- The 8th and 7th pairs have been modified for walking. The 6th, 5th and 4th pairs are used for walking, food capture and defence.
- They have small 'nippers' called chela, on their extremities.

b. Turn the prawn on its back and find the 3rd, 2nd and 1st pair of appendages (Figure 311.1). These are called maxillipeds I, II and III. Maxillipeds III hold the food while it is shredded and strained by the maxillipeds II and I.

c. Locate these and label them on your diagram.

4. Head

a. There are 5 appendages left to identify. These are located in the head. The appendages (cephalic pairs) of this region are heavily modified.

b. The 5th cephalic pair forms a large flattened plate called the 'bailer'. It vibrates to produce respiratory water currents over the gills. Identify the 'bailer'.

c. The 4th pair are flattened bristled appendages used to manipulate food. Identify this.

d. The 3rd cephalic pair which forms the jaw or mandible. Locate the mouth opening.

e. The remaining 2 pairs of appendages have been modified as sensory organs.

- The 2nd pair form the large feelers.
- The 1st pair forms a shorter sensory organ which acts as a balance, auditory smell and chemical sensor.
- They also have depression in which the eye ball can rest. A small eye brush occurs in the inner edges.

f. Label the 5 cephalic appendages on your diagram.

Internal Anatomy

1. Respiratory System

a. Lay the prawn on its left side. The gills are located on each side of the thoracic region and are covered by an extension of the carapace.

b. Locate this region and observe the bailer

c. Using fine pointed scissors, place one blade under the back lower edge of the carapace, lift up the carapace and cut away the section covering the gill region.

d. Observe the gills.

e. Draw a separate diagram showing the gills and bailer.

2. Removal of the Exoskeleton

a. Hold the prawn with the dorsal side facing you then go to the rear of the carapace and with a sharp scalpel carefully cut down the dorsal mid line to the telson. Do this by placing the point of the scalpel under the first abdominal plate and cut with shallow upward movement.

b. Free the lower section and sides of the plates carefully with a scalpel. The chromatophores can be used as a depth guide here. The skin with the chromatophores should be left behind, i.e. the scalpel blade should be placed between the abdominal plate and the tissue containing chromatophores.

c. Remove all appendages (snip off at their origins with scissors). Remove remaining carapace from right side of the cephalothorax by starting to cut forward from the rear dorsal end of the carapace, using the same technique as when cutting down the abdominal dorsal mid-line.

d. Use the scissors to cut forward freeing this section. Place the scalpel under the lower edge and lift off the remainder of the right side of the carapace.

e. Now the whole right hand side of the prawn should be free of the exoskeleton and is ready for internal examination.

3. Nervous System

a. The main nerve cord is on the ventral side of the prawn and is easily recognised by the ganglia along its length

b. Locate and note the ganglia

4. Digestive System

a. Prawns eat small annelids and small molluscs. The mandibles have strong teeth which grind, tear and finally force food into the mouth.

Digestion continues in the anterior section of the hind gut – absorption takes place along the remainder of the hind gut.

b. From the mouth, using a scalpel and fine tweezers carefully remove the overlying tissue from the oesophagus and trace the hind gut as far as possible to locate the anus

5. Circulatory System

a. The prawn has an open circulatory system with a heart, blood and respiration pigment. The blood is pale blue in colour due to the respiratory pigment hemocyanin. The heart lies under the dorsal rear section of the carapace. The heart pumps blood along the dorsal artery shown in figure 314.1.

b. As the arteries branch, blood leaves the vessels and flows through the tissues to a system of ventral sinuses. The blood flows from the sinuses to the gills where it is oxygenated and then via blood vessels back to the heart

c. Locate the heart.

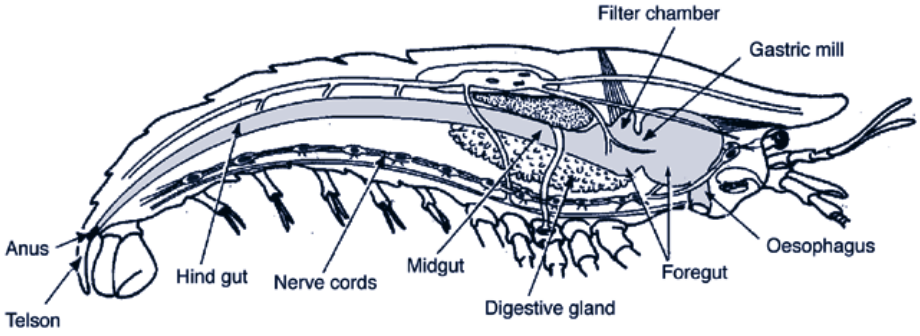


Figure 313.1 Digestive and nervous systems
(Illustration Dr. Tom Hailstone)

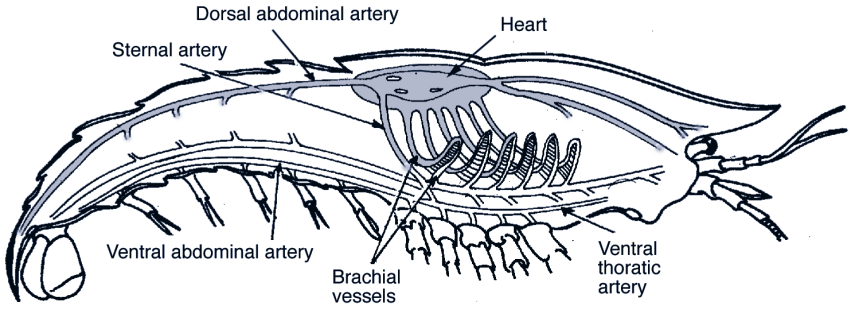


Figure 313.2 Circulation system
(Illustration Dr. Tom Hailstone)

6. Excretory System

a. The prawn gets rid of its products of the metabolism using a structure called the green gland. These are the prawn's kidneys.

b. The green glands are found in the head region and open into a pore at the base of the antennules (see Figure 314.1)

c. Locate the excretory pore of the right side green gland and carefully, using a scalpel and tweezers, expose the bladder of the green gland.

d. Draw a diagram identifying the heart, mouth, digestive tract, anus and green gland.

7. Muscular System

a. Cut a cross section through the abdomen.

b. Identify the flexor and extensor muscles as shown in Figure 314.3.

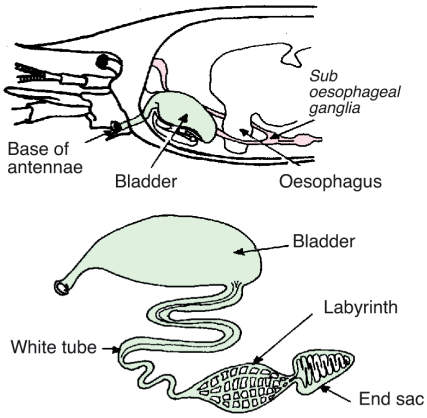


Figure 314.1 Green gland and excretory system
(Illustration Dr. Tom Hailstone)

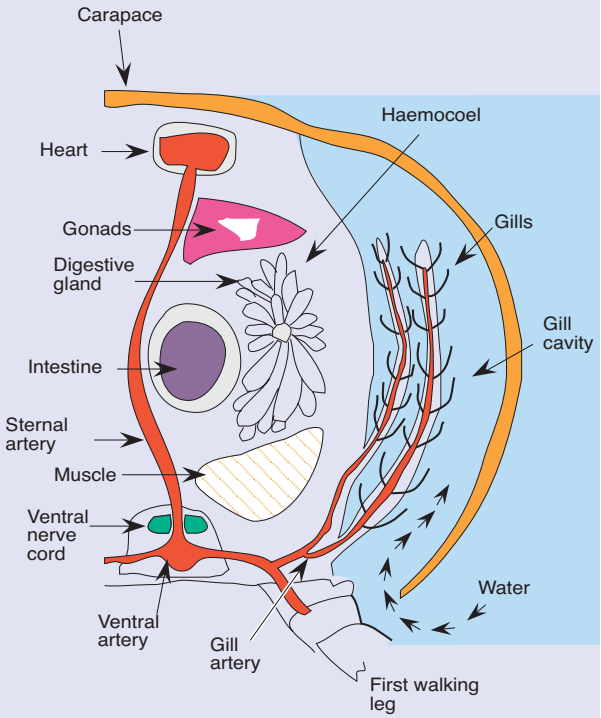


Figure 314.2 Transverse section (TS) of prawn to show blood vascular, digestive, respiratory, reproductive system elements of cepahalothorax.
(Illustration Mark Moffatt)

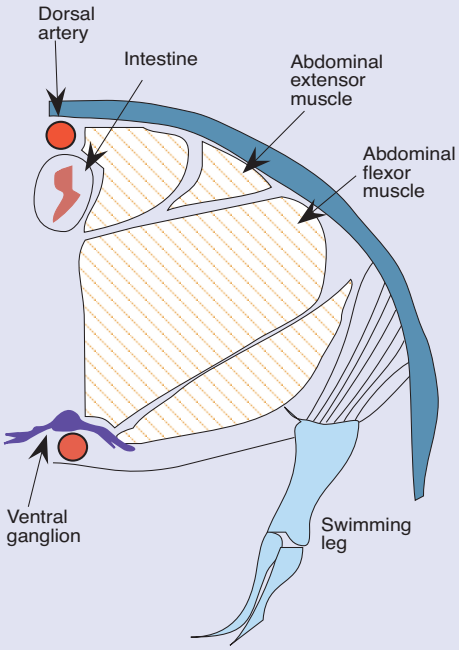


Figure 314.3 Transverse section (TS) of prawn to show muscular, digestive, circulatory and nervous system elements of abdomen.
(Illustration Mark Moffatt)

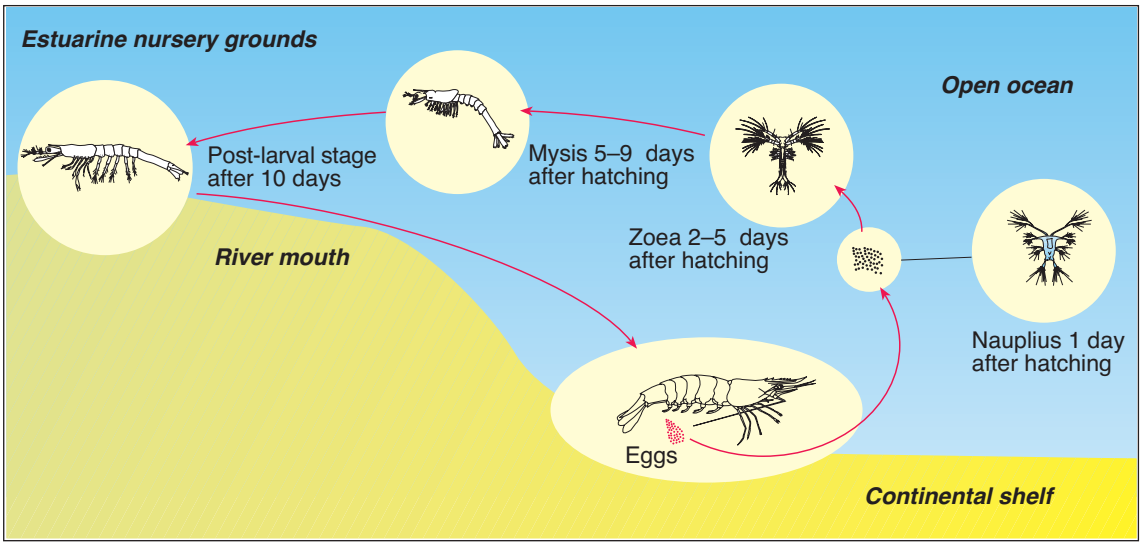


Figure 315.1 Prawn life cycle
(Illustration after Ed Fish, drawn by Mark Moffatt)

Reproduction

Mature prawns live on the continental shelf close to river entrances as shown in Figure 315.1.

The fertilised eggs shown in Figure 315.2 are released into the sea by female prawns, float to the surface and start their lives as plankton. Within 24 hours, they hatch to become the first larval stage called a nauplius, which is very similar to the barnacle.

After two days, the larva moves into a second larval stage called a zoea (Figure 315.3), an animal about 1.5 mm long. This larval stage changes yet again after 59 days to a final larval stage called a mysis.

This mysis has legs and has developed swimmers so that it can migrate quickly through the river mouth to the estuarine nursery grounds (Figure 315.4).

After 10 days in this nursery, it has grown to about 4 mm long and becomes a post-larval stage or baby prawn.

The prawn now changes its planktonic habits and takes up a bottom-dwelling life in the mangroves for a few months. Young adults then migrate to the open ocean to grow to maturity.

Prawns pass through the nauplius, zoea and mysis stages quickly to make sure as many survive as possible because death rates among plankton are very high.

Research by marine scientists into understanding these stages and behaviour patterns has allowed the aquaculture industry to develop rapidly.

The prawn is an excellent example of an animal which has a planktonic part to its life cycle.

Large prawns sell for up to $200 each in some Asian countries and culturing prawns for export is a fast-growing industry.

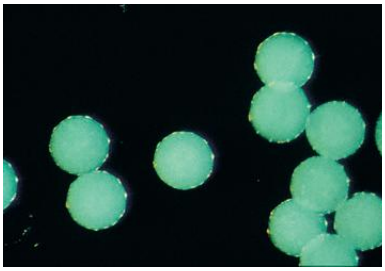


Figure 315.2 Eggs of prawn
(Qld Fisheries)

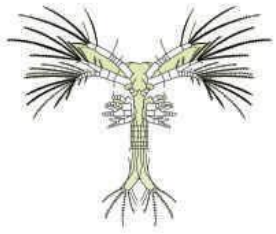


Figure 315.3 Zoe of prawn
(Illustration Mark Moffatt)

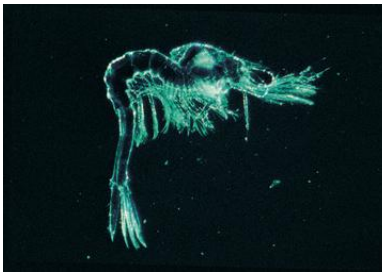


Figure 315.4 Mysis of prawn
(Qld Fisheries)

Figure 316.1 Coral shrimp
(Underwater rhelms)

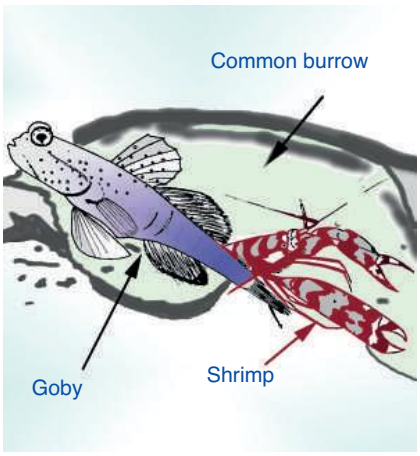


Figure 316.2 Goby and Alpheid shrimp
(Illustration Steven Byers, Photo Wet Paper)

Order Decapoda — Coral shrimp

The banded coral shrimp (Figure 316.1) performs an important role in the marine ecosystem by using its feeding appendages to clean mucous and parasites off fish. This is not the only shrimp to live in a relationship with fish. The Alpheid shrimp (Figure 316.2) shares a common burrow with the gobie fish. The shrimp excavates the burrow while the fish stands guard. If there is danger the fish warns the shrimp and both duck for cover.

Order Decapoda — Rock lobsters

Crustaceans have many forms of defence but none more impressive than the lobster (Figure 316.3). Their spiny armour, rostrum and antennae are all sharp and the lobster uses them to ward off predators.

Female lobsters and crayfish hold their fertilised eggs in their abdomen before they hatch into small larvae (Figure 163.4). These larvae are planktonic and can drift for many months over thousands of kilometres during which time most of them are eaten by predators.

Figure 316.3 Rock lobster and larvae
(Mike Sugden)

Those left, sink to the bottom and grow to be adults. Of the 80,000 eggs produced by each adult female, only about two will grow to maturity.

Figure 163.4 Larval rock lobster
(Russel Bradford from MESA)

Order Decapoda — Crabs

Crabs are bottom-living animals and are dorso-ventrally flattened (ie squashed). This allows them to squeeze into small places like cracks in rocks. Others live in mud.

In male crabs, the abdomen is reduced to a small flap tucked away under the cephalothorax as shown in Figure 317.1. In females, the abdomen has special appendages that enable her to carry eggs. This rounded abdominal flap makes it easy to sex crabs. Female crabs should not be taken for food.

Figures 317.3 - 317.5 show other types of crabs as an example of the huge diversity and adaptations in nature.

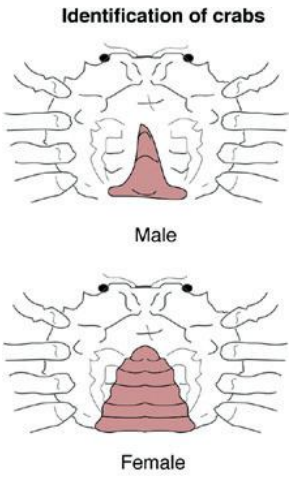


Figure 317.1 Male and female crabs
(Illustration courtesy Qld Fisheries)

(Qld Fisheries)

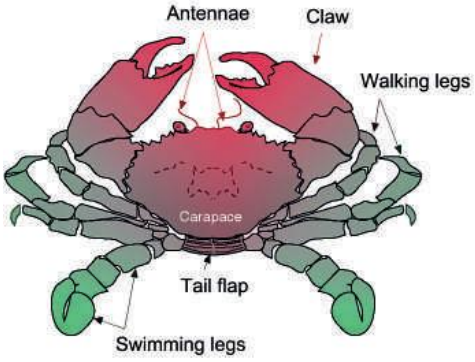


Figure 317.2 Mud crab
(Illustration courtesy Qld Fisheries)

Figure 317.4 Decorator crab
(Illustration courtesy Sharyn Madder)

Figure 317.3 Sand crab
(Photograph Bob Moffatt)

Figure 317.5 Hermit crab
(Jack Williams)

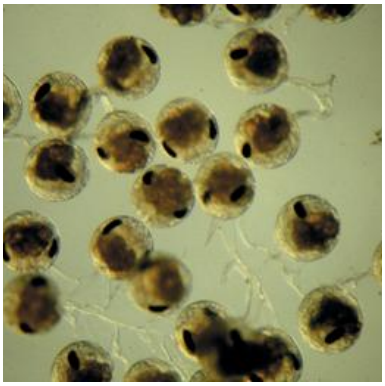


Figure 318.1 Crab eggs
(Photo Qld Fisheries)

Figure 318.2 Crab zoe
(Illustration Meran Kilgour)

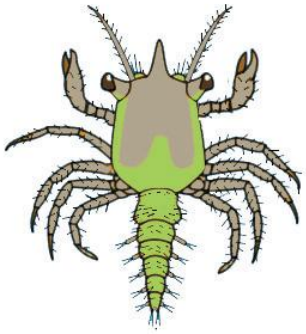


Figure 318.3 Crab megalopus
(Illustration Meran Kilgour)

Reproduction

One problem with having a hard exoskeleton is that it is difficult to mate and crabs like many crustaceans have to wait till the females moult or shed their skin. The male then only has a few days to inseminate the female generally in a face to face position.

A short time after mating, the female crab lays an egg mass which is held and protected beneath her abdominal flap until hatching takes place (Figure 318.1). After this the larvae are released into the water column as part of the plankton.

Most crustaceans hold their eggs beneath their bodies until they hatch and young larvae called zoe (Figure 318.2) are released into the plankton before returning to a bottom-dwelling existence first as juveniles (Figure 318.3) which grow into adults.

Order Stomatopoda

Mantis Schrimps

These feed on other crustaceans and small fish. The claws can strike at incredible speed with power. They not only crush but pierce their prey making them a formidable predator.

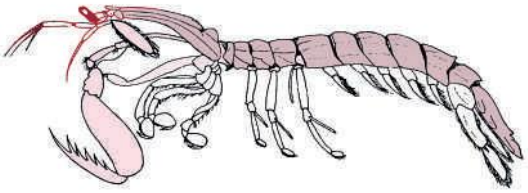


Figure 318.4 Mantis Shrimp
(After Hyman, illustration Steven Byers)

Order Euphausiacea

Krill

These are found in colder waters and are the staple food of whales in Antarctica. A whale may consume up to 2-3 tons of krill in one mouthful.

Krill are high in protein because they consume large amounts of phytoplankton which grow in areas of high nutrient upwellings. One school of krill (tracked near Elephant Island) was 3 square kilometres and 200 metres deep and weighed an estimated 10,000 metric tonnes (1/7th of that year's total world catch of all fish species).

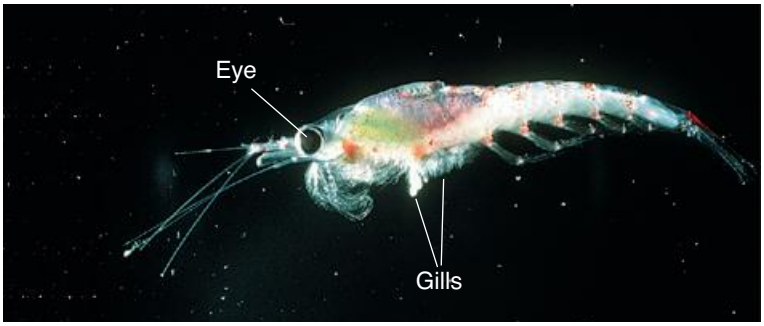


Figure 318.5 Krill
(Photo Australian Antarctic Division)

Check out Antarctica at:
http://www.antdiv.gov.au/
Check out the Krill page on:
http://www.ecoscope.com/krill4u.htm

Phylum Echinodermata

Characteristics: Radially symmetrical, water vascular system characterised by tubed feet, skeleton of calcareous plates with no distinct head or brain.

This is a large and diverse group of animals which includes sea stars, sea urchins and sea cucumbers (Figure 319.1). The echinoderms are the only major group of animals that are confined to the marine world. Among the 5000 species of echinoderms, sea stars are the most common and are found in abundance on our rocky shores and offshore reefs.

Most echinoderms have a rough, spiny outer skin and a supporting skeleton within the skin called an endoskeleton. This consists of plates of calcium carbonate called ossicles (Figure 319.1). Sea cucumbers are the exception to the rule and have very small ossicles that are embedded in the skin.

One of the most distinctive characteristics of the echinoderms is the way they move. The organ system is called the **water vascular system** - a unique system of water filled tubes under pressure. Water enters through a madreporite and passes down a stone canal to a ring of tissue. The radial canal delivers water to ampulla and finally to hundreds of tubed feet (Figure 319.2). Its is the ampulla which fill or empty the tubed foot. The expanded tube foot is moved by muscles which control the arm movements.

Tubed feet help echinoderms move and feed. If enough tubed feet attach to an object they can exert constant force which accounts for the ability of sea star to pull apart clams or oysters.

Echinoderms show remarkable powers of regeneration because new body parts can be created from old ones. For example, if a sea star loses one of its arms, it can grow another. This is called a comet and is shown in figure 319.3 below.

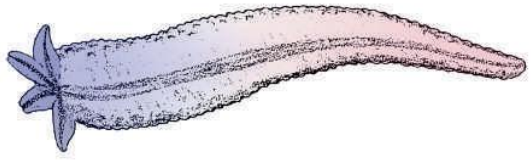


Figure 319.3 Sea star comet (After Hyman)
(Illustration Steven Byers)

This is a form of asexual reproduction which is used also by brittle stars where in some cases the leg of a sea star will simply walk away from the rest of the body. Sexual reproduction usually involves mass spawning. Scientists from the Great Barrier Reef Marine Park Authority report that, " many sea cucumbers rear up like snakes and sway in the water as eggs and sperm are released from a pore in the head. The crown of thorns starfish is one of the ocean's most productive spawners releasing over 100 million eggs each year. Prior to reproduction almost the entire body cavity of sea stars, sea urchins and sea cucumbers is filled with gonads".

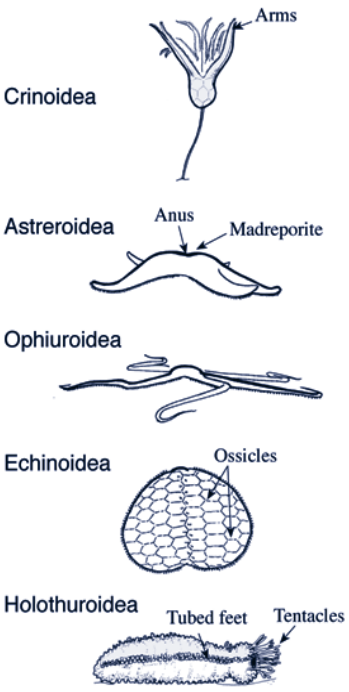
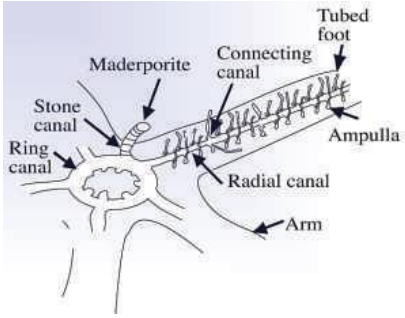


Figure 319.1 Echinoderm structure
(Illustrations Steven Byers)



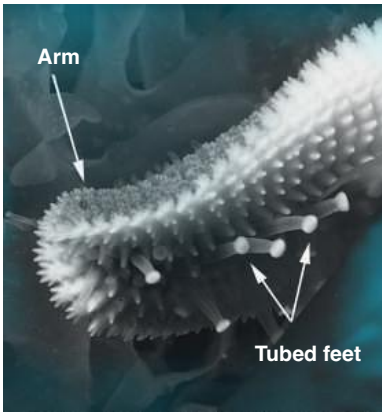


Figure 319.2 Echinoderms have a hydraulically operated tubed feet in their arms.
(Photo Mike Sugden)

Class Crinoidea

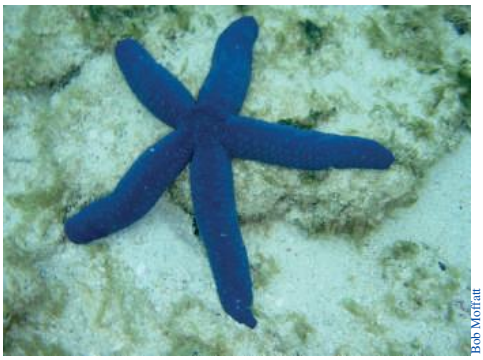
Feather stars

Feather stars or sea lilies attach themselves using their legs to reefs or rocks and extend their arms outwards to filter feed (Figure 320.1A). They look a bit like upside down sea stars and filter out food which travels down a groove to the arms and mouth. Sometimes a specialized shrimp lives in the grooves which steals the food as it passes down the grooves.

Figure 320.1A
Bob Moffatt

Most feather stars are free living (Figure 320.1B) and use their arms for feeding and in some cases swimming.

Figure 320.1B Feather star
Below H_20



Bob Moffatt

Figure 320.2 Sea star on the Barrier reef

Bob Moffatt

Figure 320.3 Sea star Moreton Bay

Figure 320.4 Starfish eats snail
(Photo Mike Sugden)

Class Stelleroidea

Subclass Asteroidea

Sea stars usually have five arms (Figure 320.2) but can have more. These are continuous with the central body section.

Japanese sea star

The Japanese sea star in Figure 320.3 came from the Northern Hemisphere in the ballast water of ships (See *Read this* box opposite). The sea star was first recorded in Tasmania in 1986 and the larvae has been carried across the Tasman Sea and Bass Strait to the mainland of Australia and New Zealand.

Sea stars eat bivalve molluscs by wrapping their arms around their prey and pulling them apart (Figure 320.4). In large numbers, they can wipe out entire populations of bivalve molluscs in a matter of months and in doing so can threaten commercial industries eg scallop farming.

Read this

When ships travel the oceans they either carry cargo or some form of ballast to keep them low in the water and thus stable. Up until the late 1870s, ships carried solid ballast. Then it became cheaper and more efficient to use the water close to or in the port the ship was leaving, and deposit it on entering the new port to take on cargo.

Ballast water is therefore sea water taken on in overseas ports to balance large ships sailing to Australia and New Zealand with limited cargo. This water can contain pests from the country in which that water was taken on board. The potential to carry pest organisms into a country is called a marine threat.

Figure 321.1 Crown of thorns starfish
(GBRMPA)

Crown of thorns starfish

The crown of thorns starfish or COT (Figure 321.1), is found on offshore reefs and increase in numbers from time to time causing massive destruction to coral.

Many methods have been used to control the crown of thorns starfish, such as injecting them with a poison or physically collecting them. However, neither method has achieved much success to date. In the Indian and Pacific Oceans, the crown of thorns starfish causes great damage to reefs. When population numbers increase, the animal is declared a marine pest and often attracts media attention.

Coral reefs affected by COT attacks often show large areas of dead and broken coral. This widespread damage reduces the number of habitats available for marine life and this reduces the food supply for the community. The effects can be long lasting. Animals move away or their numbers drop and the reef loses it tourism potential.

You can read more about COTS by typing *Acanthaster planci* into your web search engine.

Search engine words

Acanthaster planci

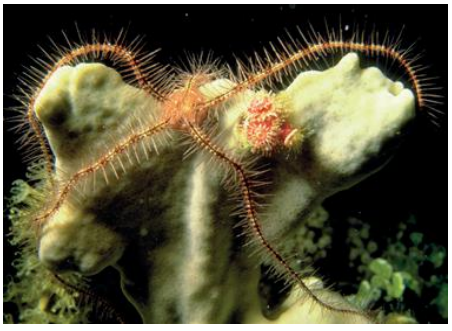


Figure 321.2 A brittle star
(Underwater rhelms)

Sub Class Ophiuroidea

Brittle Stars

Brittle stars have a distinct central disc with usually five arms growing from it (Figure 321.2). They are usually smaller than sea stars and the arms are much thinner.

Class Echinoidea

Sea Urchins

Sea urchins are more or less spherical and have no arms. The body can be flattened in the case of the sand dollar (Figure 321.4). They are covered in long, brittle spines that can make them dangerous to touch (Figure 321.3). Body plates are fused together into a shell called a test and rapid movement can be achieved by using the spines as levers.

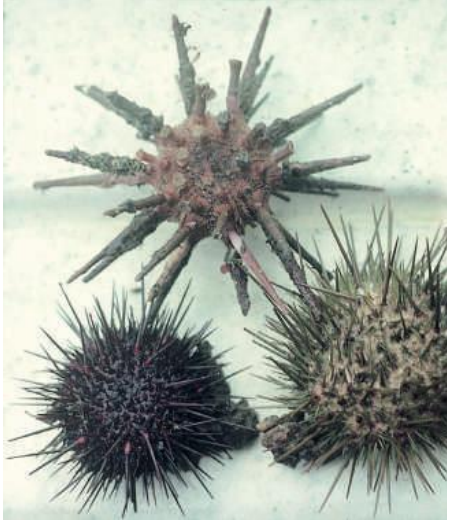


Figure 321.3 Sea urchins
(Illustrations by Steven Byers)

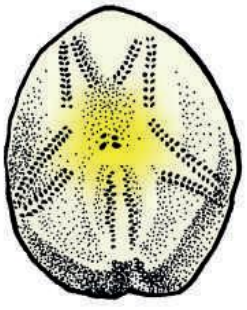


Figure 321.4 Sand dollar
(Illustration by Rose Bedford, Photo Quality Shells.com)

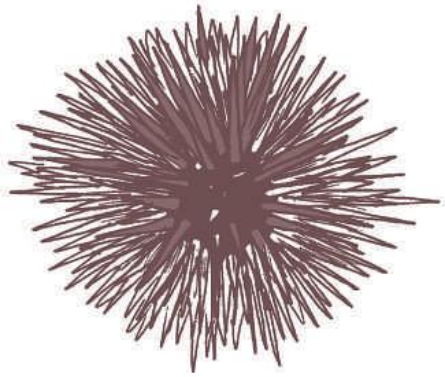


Figure 322.1 Sea urchin
(Illustration Steven Byers)

Sea urchins have diverse feeding habits. Some sea urchins feed on algae and seaweeds in the intertidal areas using a remarkable set of jaws called Aristotle's lanten. This consists of five plates of calcium carbonate that is moved by sets of muscles. Other sea urchins do not have jaws and feed on dead and decaying materials on the sea floor.

Class Holothuroidea

Sea cucumbers

These animals have a soft fleshy body resulting from a huge reduction in the size of the ossicles embedded in the skin.

The tubed feet are greatly enlarged at the mouth where food and sand grit are taken in and digested. Clean sand is then expelled through the anus. This feature has lead to them being called the vacuum cleaners of the sea.

The powers of regeneration are high in sea cucumbers because they can escape their prey by throwing up their stomach and other digestive organs in front of their predator and fleeing. They can then regenerate their digestive organs at a later date.

In addition they take water in through their anus to breathe and can expel a mass of sticky white threads called cuvier's organ (Figure 322.2). Sometimes they can secrete a toxin to make them unpalatable to predators. If you put a sea cucumber in a aquarium tank, you can find everything dead in the morning because of this toxin.

Finally, if you thought the cucumbers were a weird lot, there is a fish (called a pearlfish) which lives inside their anus during the day emerging at night to feed. When it wishes to re-enter, it waits for the cucumber to start breathing through its anus and then swims back inside.

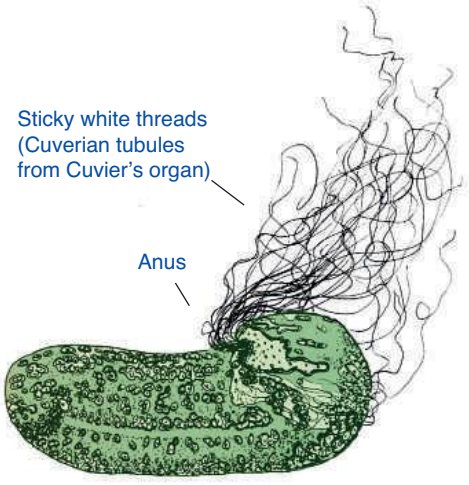
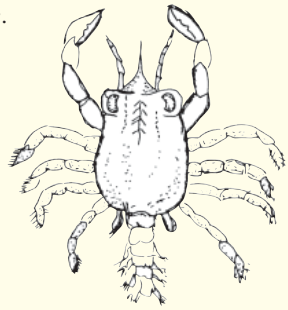


Figure 322.2 Sea cucumber defence mechanism
(Illustrations Steven Byers Photo Bob Moffatt

Exercise 12.3 Research



Based in part on an original set of questions by Ward Nicholas, Heatley Secondary College.
Use the text or other sources to find the answers to the following questions. If using the internet, quote web reference and indicate which sentences and paragraphs have been written by the author compared to those that have been written by you. Remember it is OK to use others people's work to illustrate your point of view provided you quote the work . The more widely read you become the more references you will use.

1. Barnacles live near the surface in what could be considered a harsh environment. What adaptations has enabled the barnacle to survive and discuss these in relation to their feeding habits.
2. Sea grass beds are considered to be of great ecological importance. Many crab and prawn species spend considerable time in these beds. How could a major change to the environment, such as a marine development, affect the life cycles of seagrasses and prawns?
3. Some echinoderms undergo an unusual process when they lose a portion of their body. Outline this process and discuss its significance to medicine.
4. Distinguish between bilateral and radial symmetry indicating where it occurs on the tree of marine life.
5. Distinguish between the sac like digestive system of the lower invertebrates and the one way tube of the higher invertebrates.
6. Why have invertebrates with three cell layers had to develop organs as part of their body plan?
7. Compare segmentation in worms and crustaceans noting similarities and differences.
8. Why are all echinoderms marine?
9. What is an open blood vascular system and how is oxygen transported to cells in it?
10. Distinguish between molting and metamorphosis in crustaceans.
11. Why are barnacles classified as arthropods?
12. Sand crabs and mud crabs are alike in many ways.
    a. In what ways are they alike? b. What features distinguish the two crabs from each other?
13. Why does a sea cucumber get rid of its stomach when attacked?
14. Discuss ways a barnacle larvae could get back to shore from its planktonic existence.
15. Check out the virtual rock pool: http://www.mesa.edu.au/friends/seashores/page1.html or visit a real one as shown in Figure 323.1.
16. Research the development and use of the box jellyfish antivenom (Figure 323.2).

Figure 323.1 Rock pool Sydney Aquarium
(Photo Bob Moffatt)

Figure 323.2 Box jellyfish antivenom
(Photo Bob Moffatt)

Diving deeper

1 Visit a fish shop and buy a selection of local crustaceans such as prawns or crabs. Find out where they live and how to cook them.

2. Visit a fishing boat and ask the skipper to describe how crustaceans are caught.

   Suggestion:

   Find a parent who fishes and ask them.

3. Arrange an excursion to a rocky shore to identify the different zones and identify some of the animals that live there. The aim is to see the animals, so do not collect any and be careful as rocks are slippery.

   Suggestion:

   Make sure you plan the excursion around the tide. Low tides are best for excursions.

   Check out the excursions on the Wet Paper web page www.wetpaper.com.au/teacher

4. Many videos describe animal marine life. Visit your library and borrow four. Make a report on some of the animals discussed in the video.

   Suggestion:

   See your librarian for advice.

Australian Government
Great Barrier Reef Marine Park Authority

Visit the GBRMPA website www.gbrmpa.gov.au and enter biodiversity in the search field

Visit the Reef Ed website
www.reefED.edu.au

Marine tour guide — Amazing invertebrate facts

Aim

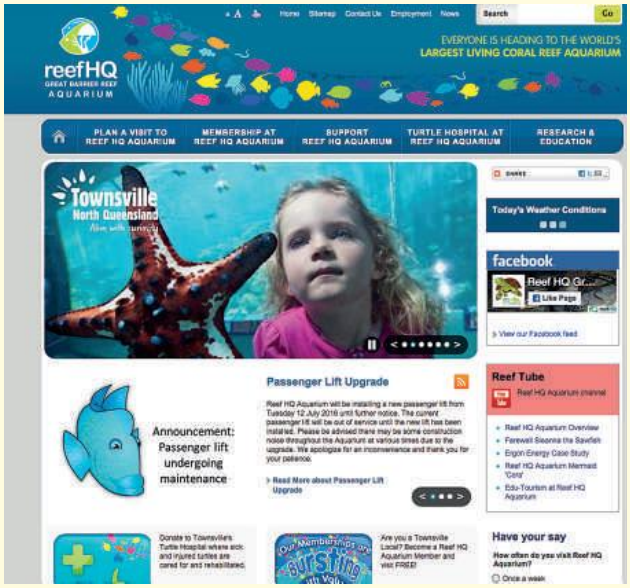
- To make a list of amazing facts that can be used if you were to become an underwater or aquarium tour guide.

You will need

- A copy of The Great Barrier Tourist Operators Handbook (see Figure 324.1)

Method

- Make a list of interesting marine invertebrate animals.
- Use the reference books supplied and the internet to find out interesting facts.
- Add to these facts as you read through the pages of this chapter.
- Present your information in a class talk using the class members as the tour group as if you were a tour operator



Exercises

From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

B2. What are copepods?

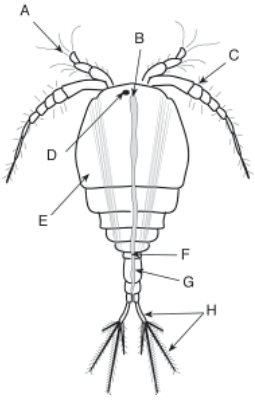
B8. What's so unusual about spiky skinned animals?

E3. External features of a crayfish.

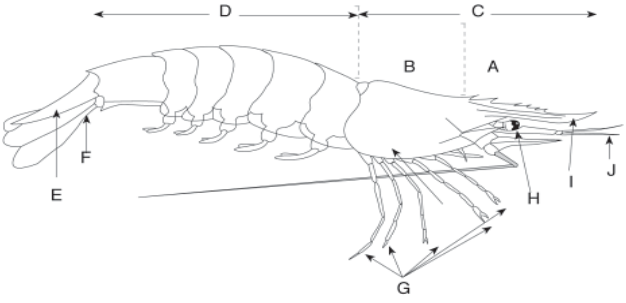
Questions

Knowledge

1. Describe the life cycle of a crab.
2. What is an exoskeleton?
3. List the characteristic features of the Phylum Echinodermata.
4. Locate the external features labelled A-H on the copepod drawn opposite.



5. Name the parts of the prawn labelled A-J below:



Understanding

6. Sketch the difference between male and female crabs.
7. Draw the life cycle of a barnacle.
8. Describe how a barnacle feeds.
9. Distinguish between the function of the telson and the uropod in a prawn.
10. Express 150 µ in mm.
11. Outline the steps you would take to grow artemia shrimp.
12. Why are the cucumbers said to be a weird lot?
13. What are filter feeders and how can they be affected by sediments from the land?
14. Why is ballast water a problem?
15. What is an *introduced species* and why are they a problem?

Applying

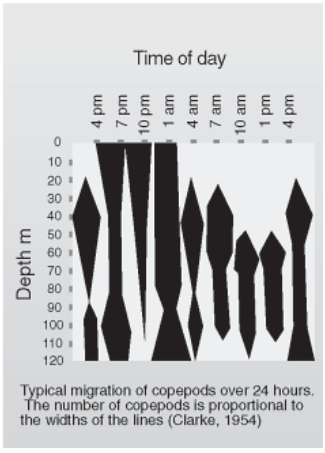
16. Calculate the size of a copepod in mm that was measured at 1,000 µ.
17. Classify the animals A and B into their phylum and class and if possible, order.

A

B

• 18. Interpret this diagram

Hint: Small sea creatures do it.



Typical migration of copepods over 24 hours. The number of copepods is proportional to the widths of the lines (Clarke, 1954)

Continued over/326

Questions

Continued

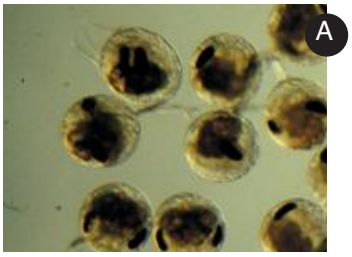
Analysing

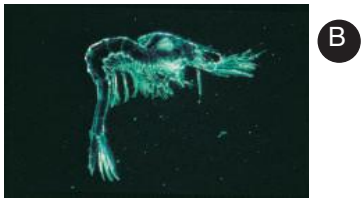
19. A marine biologist conducted a growth study on an intertidal species of crab over a 9 month period. Her measurements of carapace width through time are shown below:

Time (months)	1	2	3	4	5	6	7	8	9	10
(after start of experiment) Carapace width (mm)	10	15	15	29	42	42	52	52	57	57

    a. Draw a line graph of these results. Axes should be labelled and the graph titled.
    b. According to your graph, when is the greatest rate of growth?
    c. Bearing in mind the type of animal that was being investigated in this growth study, give an explanation for the shape of your graph.

20. Write two similarities and two differences between each of the following pairs of animals:
    a. prawn and crab;
    b. sea urchin and sea star;
    c. feather star and barnacle;
    d. sea cucumber and brittle star;
    e. soldier crab and Japanese sea star;
    f. crayfish and prawn.
21. Explain how the water vascular system of an echinoderm works.
22. Explain how to make a microscope slide that can be used to measure plankton size.
23. Distinguish between a metre and a mu (μ).
24. Compare the shell of a crab with the shell of a limpet.
25. Compare the different habitats of krill and prawns.
26. Identify the species below and predict what they will turn into.



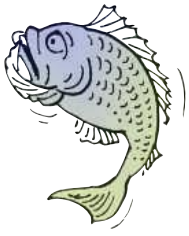


Creating

27. Compose two verses of how a barnacle feeds.
28. Research ballast water on the internet.
29. Create a new arthropod.
30. Design a new mollusc.
31. Devise a new method for measuring size under the microscope.
32. Estimate the number of brine shrimp that could be cultured from a teaspoon of eggs.
33. Formulate a plan to grow prawns in a pond.
34. Imagine you had an unlimited budget and were asked to design a house with invertebrate art. Draw a floor plan of what you would do.
35. Invent a device to peel prawns.
36. Plan an excursion to a rocky shore to study marine life.
37. Predict what would happen if all the krill died in the Antarctica.
38. Propose a solution to people taking undersized crabs.
39. Conduct a survey in your class to see who likes various types of seafood.

Evaluating

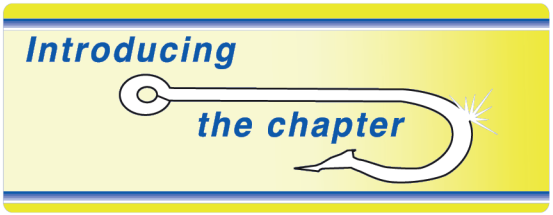
40. Argue a case for a national plan to fund marine aquariums in schools.
41. How can we assess the damage caused by people over collecting shells.
42. Choose an invertebrate from this chapter and write a short talk for a year 5 class at your local primary school.
43. Decide if ships entering ports in Australia should have their ballast water decontaminated.
44. Determine if your local council has any plan to protect invertebrates in your local area.
45. Evaluate this chapter in terms of things you need to know if you were to become an ecotourism guide.
46. Justify the study of crustaceans in a course on aquaculture.
47. You are charged with saving the world. Prioritise which invertebrates in the chapter for which you would collect and harvest DNA samples.
48. Rate your beach in terms of species biodiversity.
49. Recommend the types of signs that should be placed to stop people over collecting invertebrates from rock platforms.



Chapter 13
Marine Vertebrates (1)
Fish

by
Bob Moffatt

Photo Murray Waite



Chapter hooks

- Go to a fish market and see what is available.
- Plan a visit to an aquarium that displays sharks.
- Set up your room with fish nets and make paper fish and sharks.
- Design a model shark and build it to size.
- Plan the fibreglass fish exercise.
- Design a fish based on a set of environmental parameters provided by your teacher.
- Arrange a trip to a trawler base and find out how fish are caught.
- Use paints to do fish printing to hang around the classroom wall. Make some model fish/sharks.

Why study this chapter

- The anatomy and physiology of marine vertebrates provides valuable insight into ways marine animals use their world. This insight may help us develop new technology. For example sharks can detect minute electrical impulses with their neuromast system, whales can withstand huge changes in pressure and the venom of sea snakes may be used for new drugs.
- Fish provide a valuable food source for many people of the world and aquaculture is a growing field.
- Ecotourism creates interest in whales and dolphins as well as turtles, crocodiles and sharks.

Chapter overview

Phylum Chordata **329**
Class Ascidacea....329
Class Chondrichthyes....330
Class Osteichthyes (bony fish)....338
Exercise 13.1 Fish gut analysis....*344*
Exercise 13.2 Osmosis....*347*
Exercise 13.3 Streamlining....*347*
Exercise 13.4 Fish classification key....*348*
Exercise 13.5 Excursion to a trawler....*350*
Exercises and questions....*352*

Key concepts

- All chordates have a stiff rod or notochord and gill slits in the pharynx at some stage of their life history.
- A coordinated nervous system has allowed for the development of highly specialised organs which perform specialised functions to extend the life of the animal into many decades and allow it to grow a lot bigger than invertebrates.
- Variation in body form among fish reflects adaptations to the environment or to a special behaviour pattern such as speed or bottom feeding.
- The skeletal and muscular systems of fish are designed primarily to provide locomotion as the surrounding water provides support.
- Buoyancy is regulated by a swim bladder in most bony fish.
- Saltwater fish actively maintain osmotic balance by drinking seawater and excreting excess salt. Without this mechanism they would dehydrate and die.
- Fish have a variety of sensory organs including eyes, ears, lateral line and chemoreceptors for taste and smell.
- The skin of fish is made of living cells called scales, protected by mucous and containing pigmented cells to allow for colour change.
- The larger the animal the more food is necessary to support it.
- Sexual reproduction is highly variable. The sexes are usually separate and many fish have developed breeding patterns which allow for courtship behaviours to ensure fertilization and survival of the zygote. Some species can change sex to ensure breeding while others can undergo long migrations between feeding and breeding grounds.
- Marine predators are important to weed out the sick and weaker species making the sea a place where only the fittest survive.
- The famous biologist Charles Darwin recognised this and proposed a theory of evolution based on the fact that only the fittest of a species survive.

Phylum Chordata

Characteristics: Bilaterally symmetrical with a hollow dorsal nerve tube and stiff notochord beneath it. Gill slits in the pharynx. The notochord and gill slits may be lost as the embryo or larvae develops into an adult. Some segmentation especially in the arrangement of muscles and nerves. Sea squirts are chordates because they have a notochord.

Class Ascidacea

Sea squirts

Hollow body with two openings, no head, gill slits in the pharynx, notochord in larval stage.

This class links the invertebrates to the vertebrates because of the appearance of a stiff dorsal "backbone" called a notochord in the larval stages of development.

Associated with this notochord is a hollow dorsal nerve cord that extends the length of the larval stage and gill-like openings associated with the pharynx (Figure 329.3).

Sea squirts live in colonies or as single individuals feeding by drawing water though a siphon. Food is passed to the stomach and then waste voided with the aid of the ex-current siphon (Figures 329.1 and 2).

Both male and female sex cells are found in the one animal and in some species the eggs are held inside the animal. In solitary animals, eggs and sperm are released into the sea through the ex-current siphon. After fertilization a tadpole larvae is produced (less than 6 hours in solitary forms).

The larvae then settles, losses its notochord and develops into an adult. Sometimes sea squirts are used for bait by fishers. They create problems when they foul ship's hulls.

Defence

To defend itself against predators the sea squirt

- has a tough outer skin (tunic).
- is cemented to the substrate.

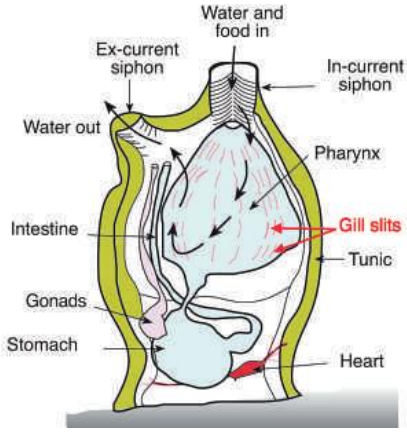


Figure 329.1 Sea squirt internal structure
Bob Moffatt

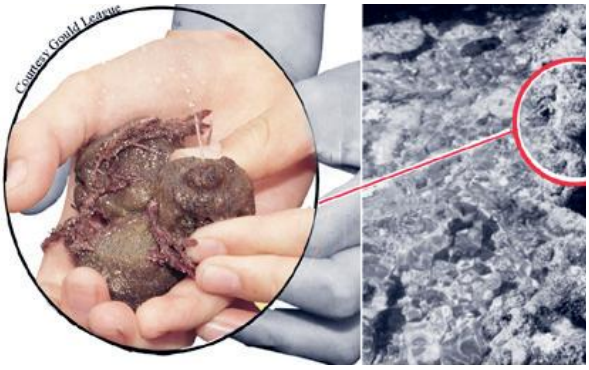
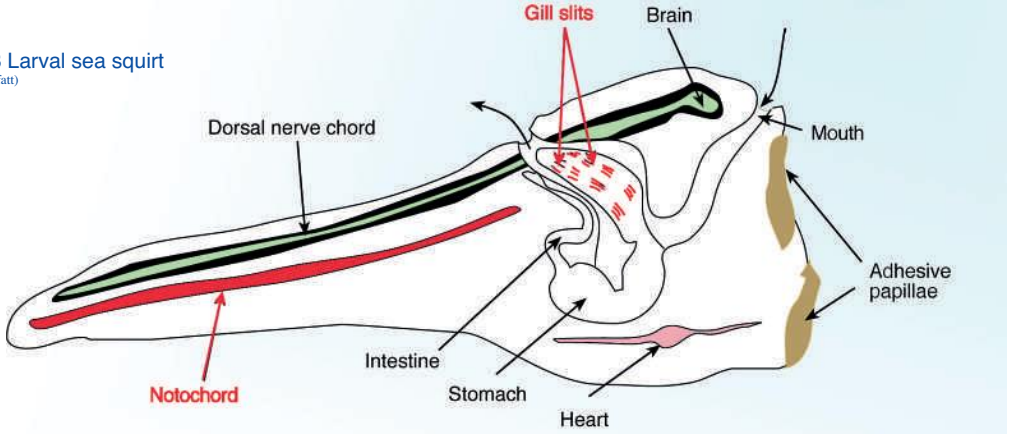


Figure 329.2 Sea squirt external feature
(Photos Gould League and Bob Moffatt)

Figure 329.3 Larval sea squirt
(Illustration Bob Moffatt)



Class Chondrichthyes

Skeleton of cartilage, 5 or more pharyngeal slits usually visible from the outside, 2 chambered heart, mouth and nostril usually ventral.

This class contains the sharks and rays. They have a skeleton composed of cartilage rather than bone — cartilage is a type of gristle similar to that found in your nose.

Sharks and rays also do not have typical fish scales. If you run your hand one way along a shark's skin it will feel smooth, but try to run it back the other way and you soon realise that the skin is sharp (see Figure 331.1A).

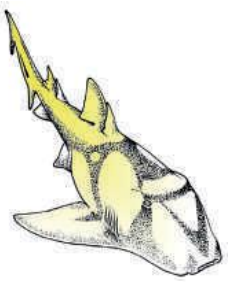


Figure 330.1 Port Jackson shark
(Illustration Sharyn Madder courtesy MESA)

Sharks

There are about 350 different species of sharks, ranging in size from less than a metre (the Port Jackson shark Figure 330.1) to the giant whale sharks with average length of over 12 m – longer than two school buses. The whale shark (Figure 330.2), despite its large size (up to 15 metres), is non-aggressive and feeds only on plankton.

Figure 330.2 Whale shark
(Photo Below H_2O)

Only two species, the great white and, to a lesser extent, the tiger shark are responsible for nearly all attacks on humans resulting in death or serious injury. However divers and swimmers should take care whenever any species of shark is close by.

Great white sharks

These large, efficient predators are responsible for most fatal attacks on humans throughout the world. Also called white pointers due to their cone-shaped heads and pointed snouts, as shown in Figure 330.3, these creatures fully deserve our utmost respect.

Figure 330.3 Great white shark
(Photos Barry Bruce)

Most adult great white sharks are about 5 m long, the same length as the average family car however there have been recorded sightings of these sharks up to 10 m long.

Great whites have a large girth up to 1.3 m and are capable of very fast speeds. A diver in waters off South Australia who saw his buddy taken by a great white said that the attack resembled being hit by a train in both speed and intensity.

Great whites live worldwide from the warm waters of the tropics to the almost-frozen ocean near the poles and like most sharks, have excellent eyesight being able to see much better in water that humans.

They spend considerable time circling and studying prey before attacking. The great white is the only shark that can hold its head vertically out of the water enabling them to observe prey on the surface or on shore, such as seals on rocks. These creatures are not mindless eating machines. Their mouths and teeth are perfectly adapted for their role as predator as shown in Figure 330.3.

During attacks, their entire head changes shape. Both jaws extend to the front and the snout bends upwards and out of the way. They have rows of sharp, triangular teeth which bite with a sawing action. Their jaws open to give them a large bite radius of up to 0.5 m which would enclose two adult humans.

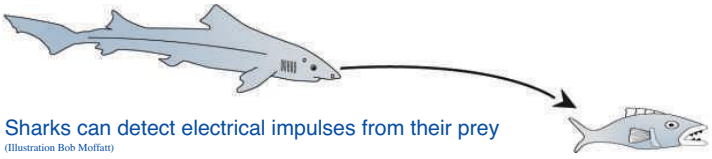
External features

The surface of the body is covered with denticles or **placoid scales** (Figure 331.1A). These progressively grow into teeth in the mouth region and are continually replaced (Figure 331.1B).

A shark's body is elongated with a depressed head and rounded trunk with an upswept tail which carries the caudal fin. There are two dorsal fins and two pairs of pectoral and pelvic fins and a single ventral fin Figure 331.3. An opening called a **cloaca,** leads to both reproductive and excretory organs, is found between the pelvic fins (Figure 331.2). In males this develops further to form two scroll like **claspers** to assist copulation.

The head region is made up of eyes and nostrils and in some sharks a spiracle. In front of the pectoral fins are 5-7 **gill slits** which serve as valves to let water out. Over the surface of the snout are numerous jelly-filled canals leading to ampullae. These lead to the lateral line system which can be seen at the junction of dark and light areas of the skin.

The lateral line and ampullae make up the neuromast system which is connected to the ear. Sharks detect electrical impulses from their prey with this system.



Sharks can detect electrical impulses from their prey
(Illustration Bob Moffatt)

Ampullae are electro-receptive jelly-filled organs whose function was not discovered until fairly recently (see page 334).

New shark repellent devices seek to disrupt this **neuromast system** and some say that if a shark attacks — try to kick it in the nose.

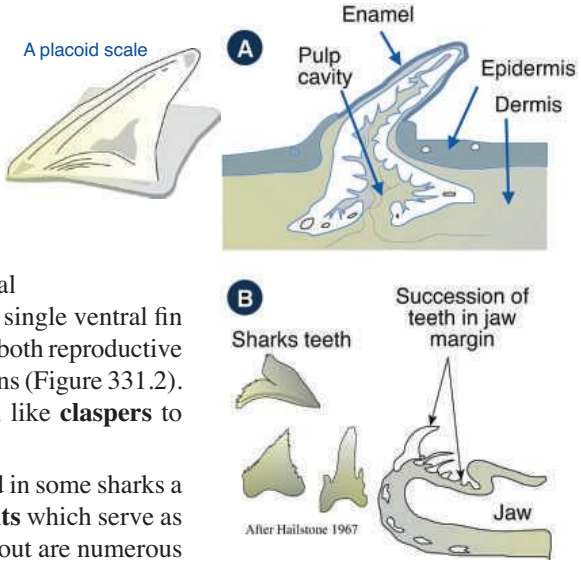


Figure 331.1 Shark skin — (A) denticle, (B) sharks teeth and jaw structure
(Illustrations Bob Moffatt)

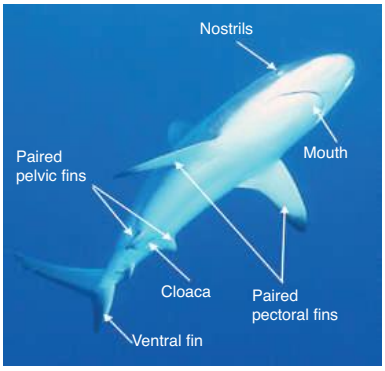


Figure 331.2 Shark ventral
(Photo Murray Waite)

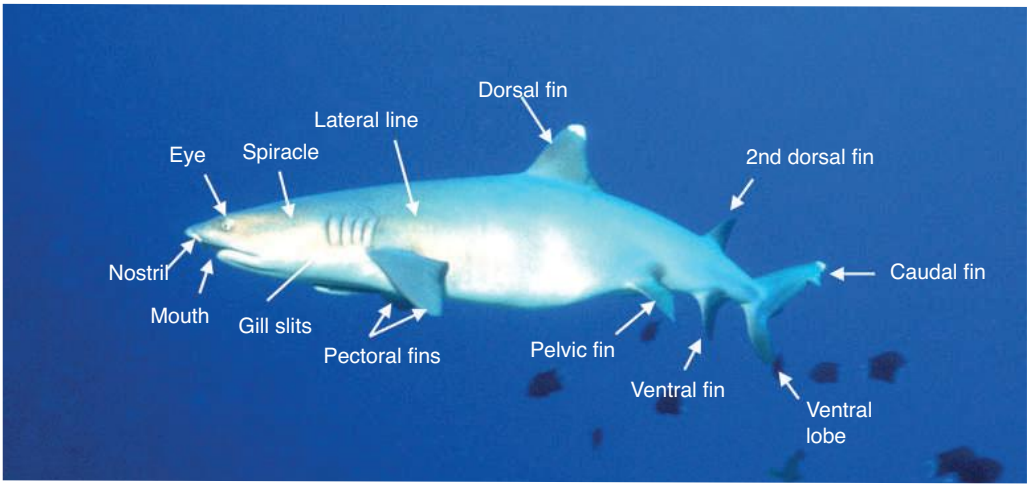
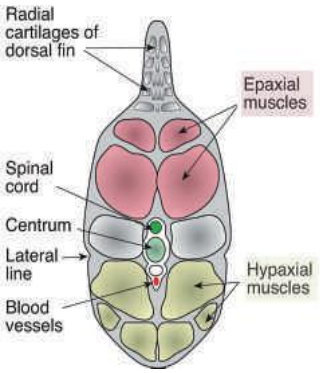


Figure 331.3 White tip shark external features
(Photo Murray Waite)



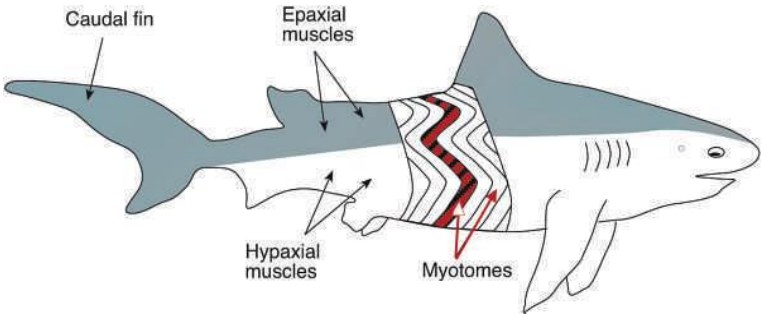


Figure 332.1 Shark muscles
(Illustration by Mark Moffatt)

Reference on shark swimming
http://www.reefquest.com/white_shark/body_shape.htm

Muscles and movement

Peel back the skin and a shark's swimming muscles can be seen as a series of v shaped blocks (Figure 332.1).

These blocks called "**myotomes**", contract and expand to produce a body wave that moves smoothly along the body (Figure 332.2).

The vast majority of a shark's propulsion is from the caudal fin force. In cross section, shark swimming muscles form bundles of concentric rings that meet at the midline of the body underneath the lateral line (Figure 332.1).

Those muscle bundles above the lateral line are termed "epaxial" those below "hypaxial". Opposing contractions of these two sets of muscles allows huge variations in movement.

Other muscles control sharks' fins, raising, lowering and flexing these foils to control every aspect of swimming. In conditions under which it is difficult to breathe, some sharks flare or rhythmically pump their gill slits to move oxygen-bearing water over their gill membranes.

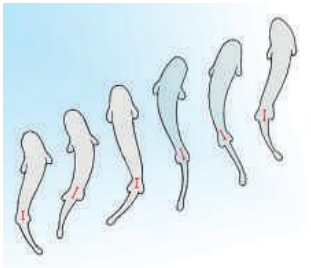


Figure 332.2 The body wave of contraction of the myotomes produces a free flowing swimming patterns driven by the caudal fin.
(Illustration by Kerry Kitzelman)

Nutrition

Sharks eat almost anything from plankton (whale and basking sharks), to fish of all shapes and sizes and even take on whales.

Apart from the great white shark, the jaws of most sharks have limited movement and speed is used to kill prey ripping and tearing it with their teeth.

This is why teeth are continually replaced because many are lost during the process of striking the prey.

Food passes through the pharynx with its characteristic gill slits and then down the oesophagus and into the stomach.

The stomach is either U or J shaped and divided into two parts where acids kill the food and mechanical digestion takes place.

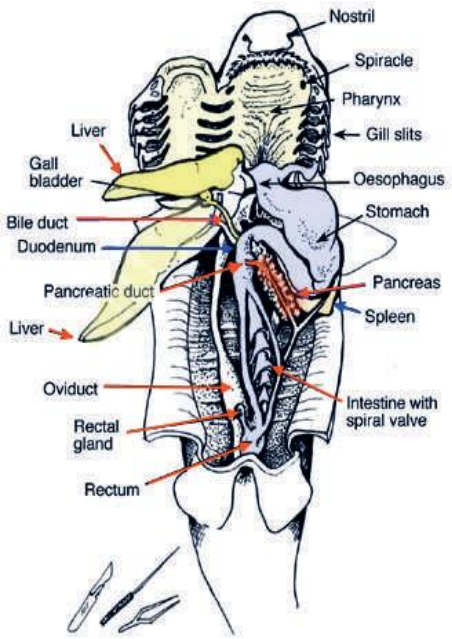


Figure 332.3 Shark nutrition (After Hailstone 1967)
(Illustration by Kerry Kitzelman)

Food then passes to an intestine containing a spiral valve to increase absorption into the blood stream. In front of this spiral is the duodenum into which opens the pancreatic duct from the pancreas and the bile duct from the gall bladder. Bile contains bicarbonate to neutralize the stomach acid and salts to help digest fat. Pancreatic enzymes are released into the duodenum to further digest food. Undigested food passes to the rectum and then out the cloaca.

Liver

Many shark's livers contain fatty acids and oils that are not only useful as energy storage, but greatly assists with providing buoyancy.

Respiration and circulation

Breathing and respiration

Oxygen is found in sea water and is required by the shark's tissues for growth. Carbon dioxide is a by-product of this cellular process and has to be removed or it will poison the shark's cells. Food from the blood stream is also required for growth and the process whereby oxygen combines with this food to release energy and produce waste is called respiration . Breathing is a process of bringing in the oxygen.

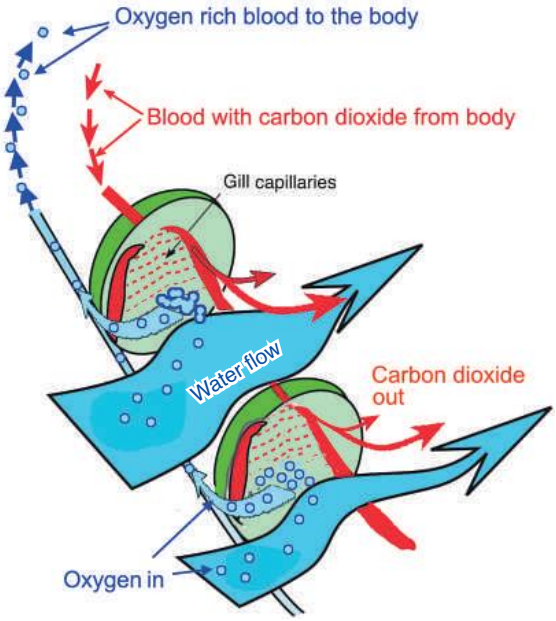


Figure 333.1 Counter current gas exchange system at the gills
(Illustration by Mark Moffatt)

The shark takes in water through its mouth or spiracle and then over the gills to the outside. Oxygen and carbon dioxide are exchanged across the gill surface (Figure 333.1). Most sharks have five gill slits, although a few have six or seven.

Sharks lack air bladders (sacs filled with air that help keep fish buoyant). Because sharks don't have air bladders, they have to continuously swim or they will sink, which many of them do when they are resting.

Circulation

The most important feature is that blood is forced through the gills before it is distributed to the rest of the body as shown in Figure 333.2.

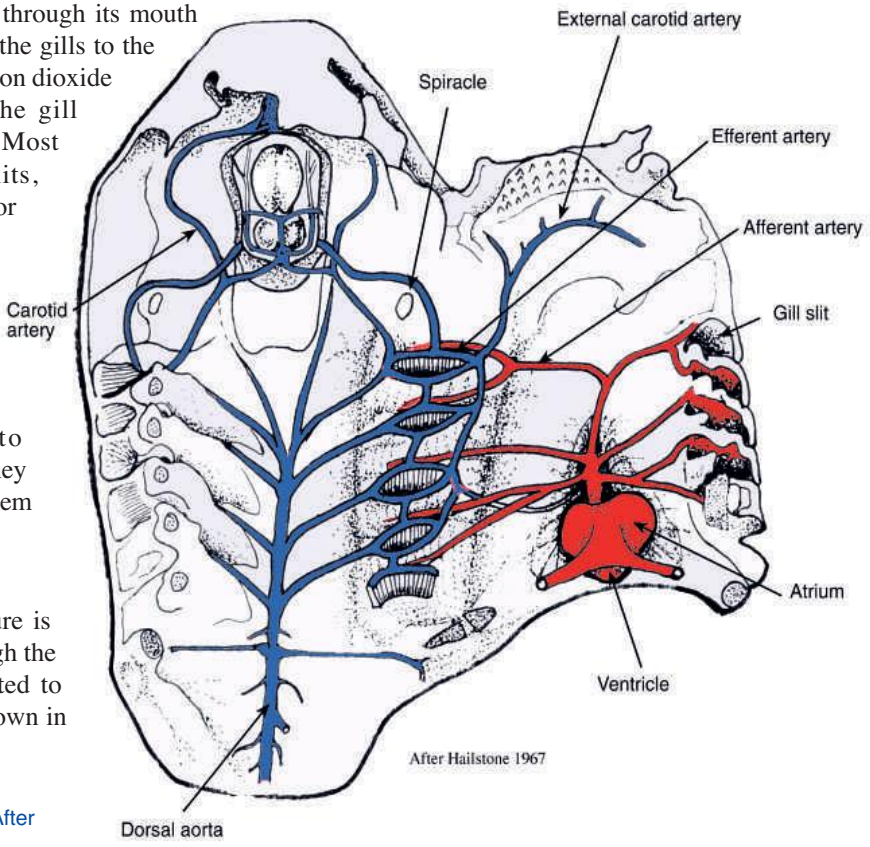


Figure 333.2 Blood system (After Hailstone 1967)
(Illustration by Kerry Kitzelman)

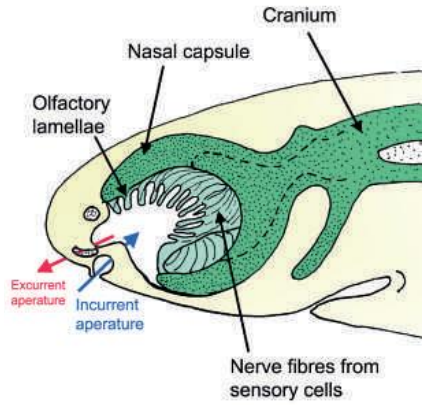


Figure 334.1 Olfactory system
(Illustration by Kerry Kitzelman)

Figure 334.2 Shark repellent scuba unit
(Photo Bob Moffatt)

Nervous system

The olfactory system

Sharks have an incredible sense of smell that lets them detect the blood of an animal more than half a kilometre away, or the body fluids of a dead tuna although it is diluted to one part in the half million. The inner surface of their organ of smell, called the olfactory pit, has many thin folds. These leaf-like folds, called **lamellae** (Figure 334.1), are constructed so that the water from the outside constantly flows over this sensitive surface. As a shark gets closer to its prey, its sense of hearing takes over.

The neuromast system

Located around the front of a shark's head is an extremely sensitive system of sensors, which scientists believe help sharks to locate prey and to navigate in response to the earth's electro-magnetic fields. These bio-electrical sensors, known as the **ampullae of Lorenzini**, are jelly-filled pores, which can detect extremely faint electrical currents generated by the earth's magnetic field and by other living creatures.

The ampullae seem to function like an internal compass, helping sharks to orient themselves in relation to north-south (the strongest electro-magnetic fields) and east-west (weaker) electrical fields. Scientists have found that the **ampullae of Lorenzini** (Figure 334.4) are so sensitive that great white sharks are able to detect the heartbeat of a perfectly still mammal from a distance of 3 metres, just by sensing electrical currents the heartbeat sends out into the water! Modern shark repellent devices (Figure 334.2 and 334.3) employ an electrical field which is said to disrupt the function of the neuromast system.

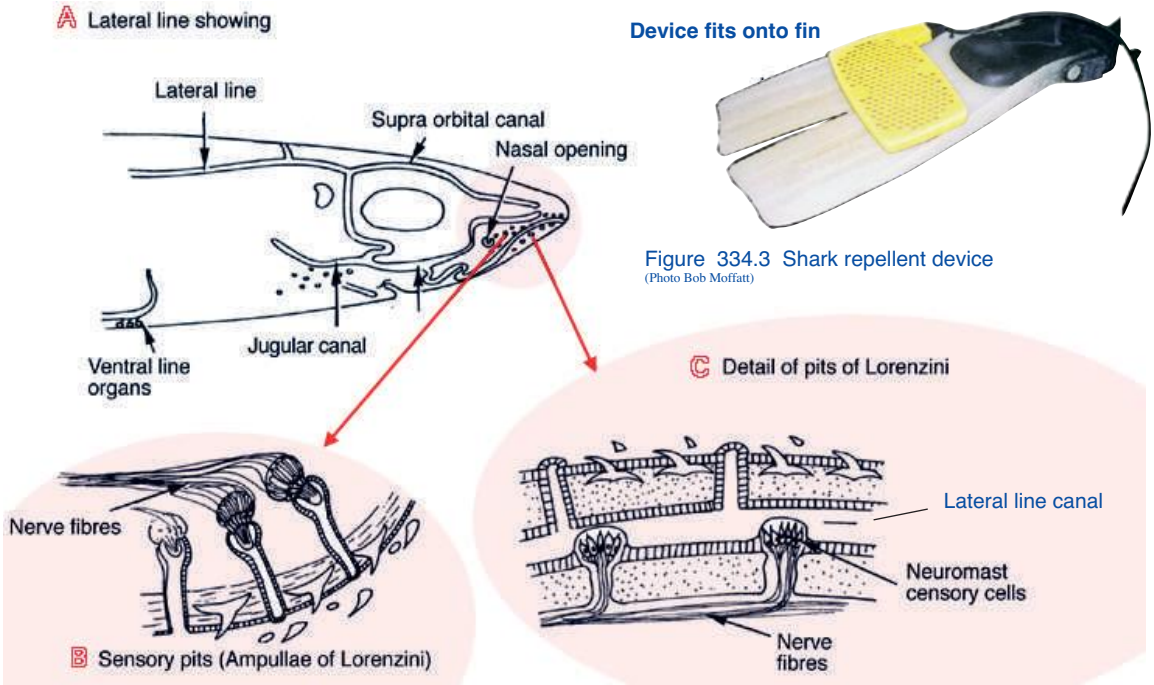


Figure 334.4 Neuromast system of the shark
(Illustration by Kerry Kitzelman)

Figure 334.3 Shark repellent device
(Photo Bob Moffatt)

The eye

Finally, when a shark gets within 15 metres of its prey, it can see what it has been smelling and feeling. The structure of the eye is shown in Figure 335.1.

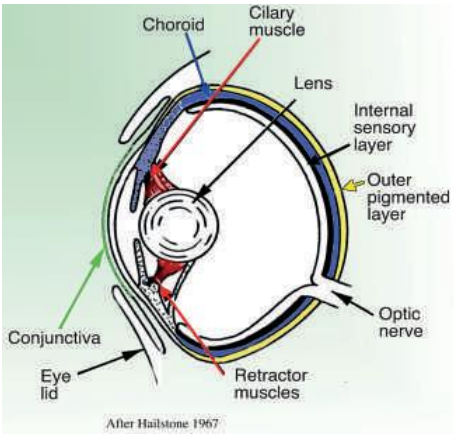


Figure 335.1 A shark's eye
(Illustration Bob Moffatt)

Urinogenital system

In sharks the reproductive and excretory systems are joined and exit the body from the cloaca in the urino genital system.

Excretory system

Excretion is the process whereby toxic by-products of respiration in cells are removed as waste from the body. The kidneys play a vital role in this process and extract wastes from the blood as it passes through them.

Reproductive system

Sharks and rays have varied breeding habits. Unlike bony fish, they reproduce by internal fertilization. Some sharks and rays lay eggs which are covered by hard cases that protect them while they develop (see Figure 336.2 over). In others, the eggs hatch within the mother and the young are born live.

Sperm are produced in the testis which pass to the seminal vesicle and sperm sac. During copulation (Figure 336.1 see over) the claspers are inserted into the female cloaca and guide sperm which are flushed into the female with water from a siphon. Fertilization is internal with eggs taking up to 10 months to develop. Reproductive organs are shown in Figure 335.2.

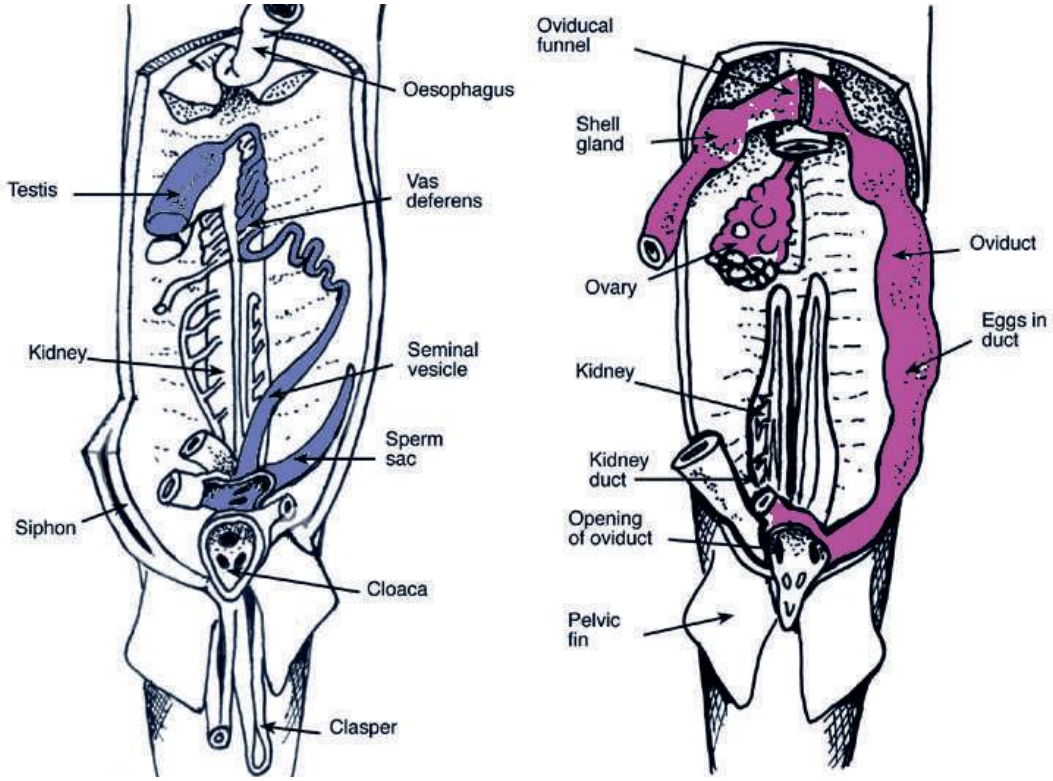
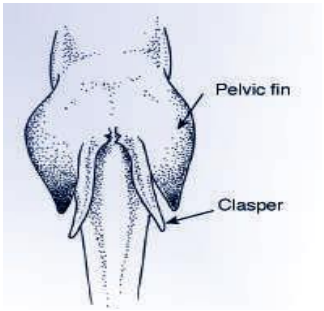


Figure 335.2 Urinogenital system of shark (male left, female right)
(Illustration by Kerry Kitzelman)



Defence

Big sharks have few predators however all animals need to develop some defensive strategy. It could be argued that to defend itself against predators the shark:

- has a tough outer skin (placoid scales)
- incredible speed, ventral mouth and replaceable teeth
- a well developed neuromast system
- a highly co-ordinated neuromuscular system
- internal development of eggs or a protective egg case
- counter-shading — dark on the top and light on the bottom.

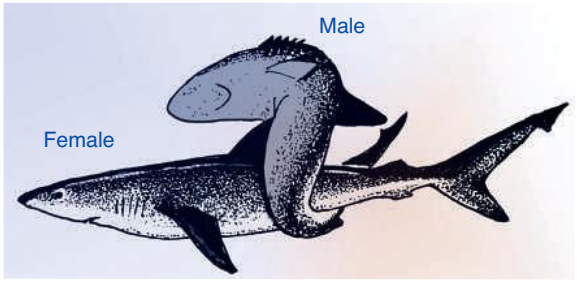


Figure 336.1 Copulation in sharks (After Thurman and Webber)
(Illustration by Kerry Kitzelman)

Figure 336.2 A shark's egg case
(Photo Bob Moffatt)

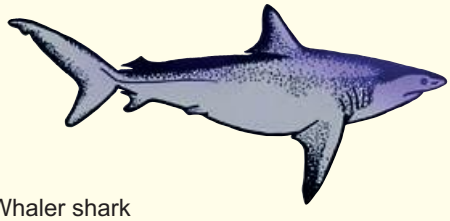
Questions/research

1. Set up an aquarium and keep some fish for a term.
2. Visit a local marine aquarium or zoo and study marine life there.
3. Write a poem or song about life in the sea.

   Suggestions: Read the *Rhyme of the Ancient Mariner,* a poem by Coleridge. Download *The Simpsons* 'Under the sea' song from the Internet.
4. Invite a marine scientist to your class. Ask for a discussion on the research he or she is doing into the marine world. Suggestions: Ask parents for help or ask your local aquarium, sea life park or education advisor.
5. Run a marine photographic competition. Use a digital camera to capture images and make a web page.
6. Use the library to compare drawings of fish scales and shark teeth.
7. How do sharks reproduce?
8. What impacts have humans had on shark numbers worldwide? Suggestions: Locate a fisheries officer, shark contractor or search the internet for information on sharks.
9. Compare and contrast the behaviours of the grey nurse and whaler sharks. Use http://www.oceanstar.com/shark/ to research your answer.
10. Use the following reference to make a power point presentation on fish nurseries:

    http://www.dpi.qld.gov.au/extra/nnn/default.html

Grey nurse chark
(Illustration by Rose Bedford)



Whaler shark
(Illustration by Rose Bedford)

11. Make a wall chart of shark anatomy from the following web site:

    www.ucmp.berkeley.edu/vertebrates
12. Write two letters to the editor. One saying shark nets should be removed to protect the by-catch and the other from the government defending their placement for the tourist industries. Organise a class debate in your English class.

Rays

Rays have their mouth and gills on the ventral surface as shown in Figure 337.1 whereas sharks have their gills on the side and spiracle in the head.

Rays are well adapted to a dual life. For feeding on the bottom (Figure 337.2), they have a ventral mouth and dorsal eye.

They are light underneath and dark on the surface so that when viewed from above they appear like the bottom and viewed from underneath - look like the surface waters.

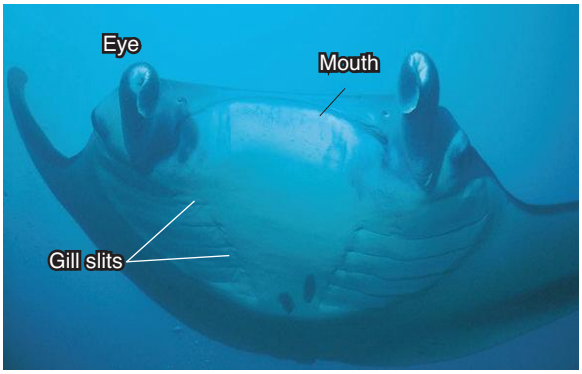


Figure 337.1 Manta ray
(Photo Underwater Realms)

Manta rays

Manta rays are the largest type of rays and can have a wing span of up to 7 metres and can weigh over 3 tonnes.

These rays get their name from the Spanish word "Manta" or blanket, describing the unique spherical body shape of this animal. Similar to sharks, the skeleton of this ray is made out of cartilage; and some people characterize these rays as simply "flattened out sharks".

Manta rays are known to be one of the most gentle creatures in the sea. The horns on their head herd plankton into their mouth, and they can also eat small fish and crustaceans.

Female manta rays give birth to one or two individuals per litter. Fortunately most baby rays do not face many predators learning to evade them by spending much of their time on the sandy bottom, flapping their pectoral fins to throw sand on their body.

Some predators include sharks or killer whales. The most threatening are net trawlers which scoop up rays with prawns causing them great stress while on board the vessel as they are man handled and gutted before they are thrown back into the ocean.

Figure 337.2 Sting ray
(Photo Neville Coleman)

Stingrays

Similar in structure to manta rays they feed on molluscs and crustaceans. Stingrays have a barb which they can thrust into your leg if stepped on.

One way to avoid being stung is to shuffle your feet when you walk into reef waters at low tide.

First aid

Immerse your foot in hot 50^{0}C water for about an hour or until pain stops and seek medical advice.

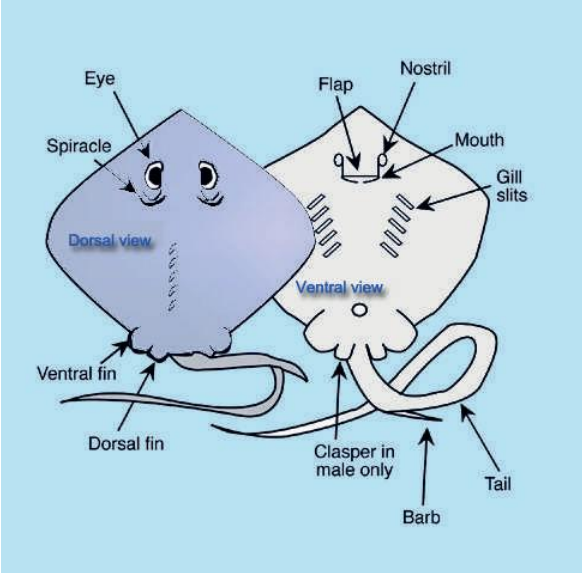


Figure 337.3 Sting ray external features
(Illustration by Bob Moffatt)

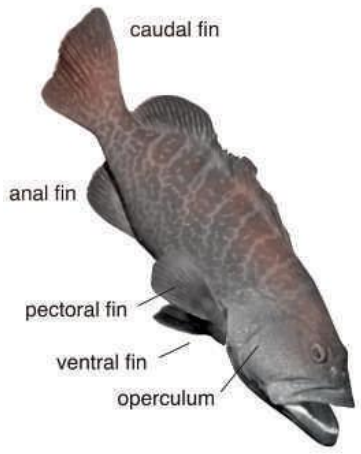


Figure 338.1 Fish external features
(Photograph courtesy Qld Fisheries)

Class Osteichthyes (bony fish)

Bony fish have true scales, a bony skeleton, a single pair of gill openings and an operculum which covers the gills (see Figures 338.1). Fish have a lateral line system which enables them to sense vibrations in the water and their eyes and sense of smell are also well developed.

Rays or spines stiffen these fins because they are mostly used for swimming. Some fish have fins modified into feelers or suckers. Other types of fish, such as the moray eel live in burrows where they can dart out and catch passing fish. The burrow also gives the moray eel protection from predators.

Some fish inflate their bodies to protect themselves from their enemies (for example, the puffer fish in Figure 338.2) whereas others disguise themselves as plants, for example, the sea dragon in Figure 338.3. Colour has become an important part of fish anatomy. Some fish even disguise their heads with stripes so that predators cannot distinguish them from the homes where they live.

Fish are the world's main source of animal protein for humans.

Figure 338.2 Scorpion fish
Bob Moffatt

Figure 338.3 Reef fish
Bob Moffatt

Bony fish

The bony fish include up to 40 thousand species of fish. These include cod, whiting, flathead, perch, bream and many, many more. The fish of this group have bony internal skeletons and a single pair of external gill openings. Fertilization may be internal, but usually is external.

External features

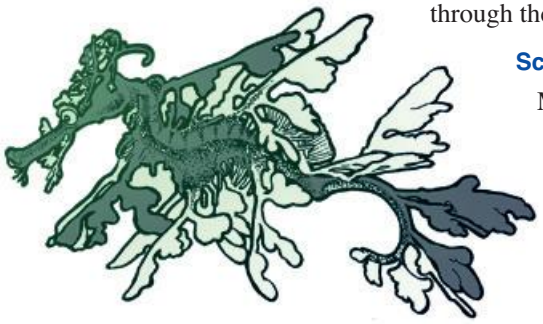
See Figure 339.1

Fish have fins to assist movement through the water. The pectoral fins can be used individually to turn the fish in either direction or control the up and down movement.

Together, these fins act as brakes, or when used in a reversing motion, they allow the fish to swim backwards. The ventral fins are used for braking and steering.

The pectoral and ventral fins are paired but fish also have three unpaired fins- the dorsal, anal and caudal. The dorsal (back) fin may consist of two parts, the first spiny, and the second one soft, or the entire fin may be composed of soft rays.

The number of rays in a fin are often used to identify fish. Also the dorsal and anal fins are used like a keel or rudder to stabilise the fish. The caudal fin or the tail fin is used to give the fish power to move through the water.



Scales

Most fish have scales. Fish are usually scaleless when they hatch but develop scales in the first year. Scales serve as a protective covering and provide further protection against bacterial infection. All fish secrete a slimy coating.

Figure 338.4 Leafy sea dragon
(Illustration Sharyn Madder)

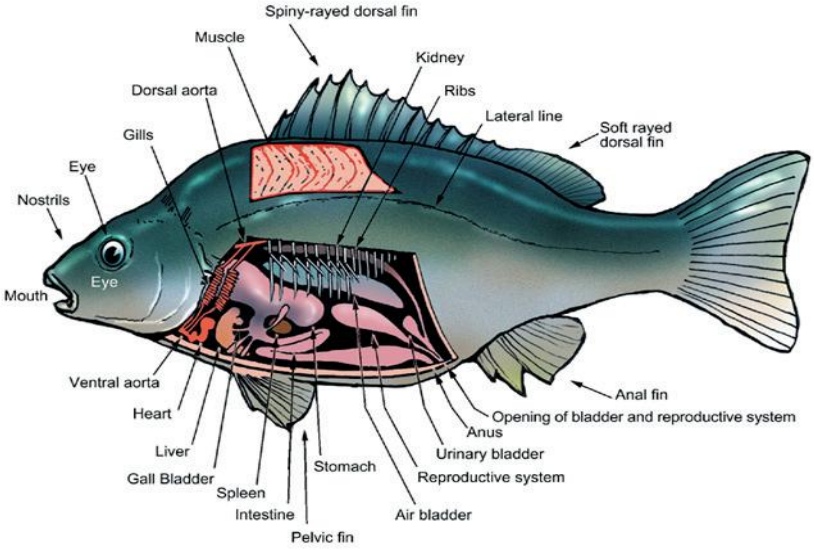


Figure 339.1 Silver pearch
(Illustration Bob Moffatt)

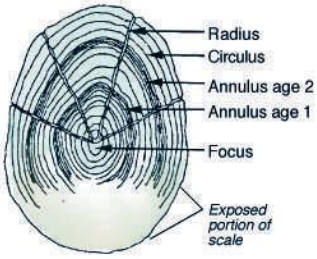


Figure 339.2 Fish scale features
(Illustration Bob Moffatt)

There are three types of bony fish scales (Figure 339.3 - *Placoid scales are the type found on sharks and rays*). Ganoid scales, found on gars are shiny and plate-like. Cycloid scales are found on sole, and are over-lapping scales. Ctenoid scales are found on most bony fish and have comb-like edges.

Scales grow from pockets in the skin with growth being marked in rings as shown in Figure 339.2. In winter, growth is usually less and rings are closer together, forming annulus or annual rings. These can be counted like a tree, and the number of rings tell the age of the fish.

Skeleton

Fish have three skeletal parts: the skull (cranium), vertebral column and the fin skeleton (Figure 339.4). The skeleton provides support to the body, protection to the brain and an attachment place for muscles.

Fish with large mouths and long, sharp teeth are carnivorous. Some deep ocean carnivorous fish have a large enough mouth to swallow fish almost as large or larger than themselves. This is an adaptation for survival in a habitat where food is scarce.

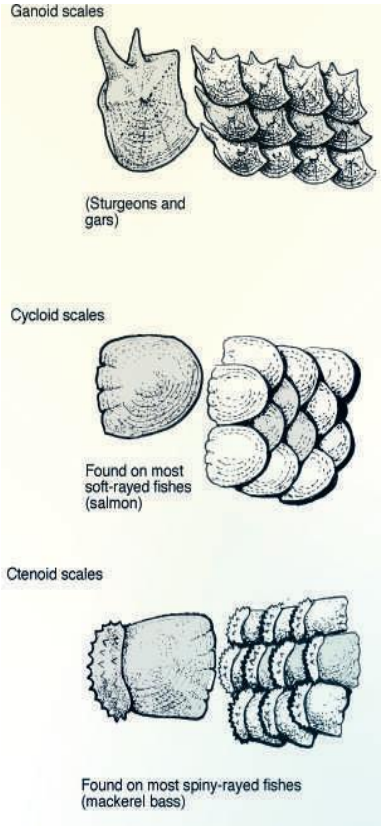


Figure 339.3 Three types of fish scales

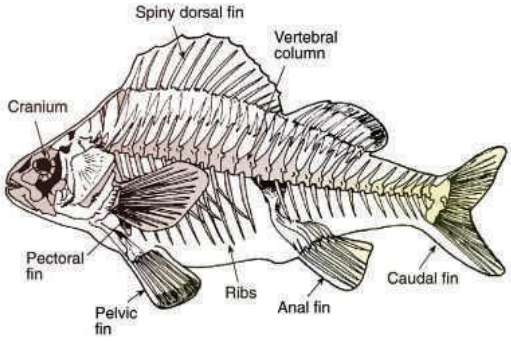


Figure 339.4 Fish skeleton (After Thurman and Webber)

Odd fact

Fish with smaller mouths and cutting teeth are generally plant eaters (Figure 340.2). Those with molar teeth eat shell fish. Those with large lips and toothless mouths are suckers and suck up their food.

Fish with toothless mouths and well developed gill rakers are plankton feeders, taking in water through their gills and straining plankton out. Sardines and anchovies are well known examples of plankton feeders.

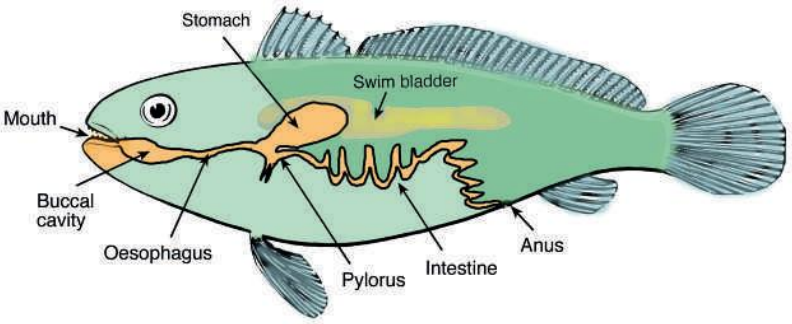


Figure 340.1 Fish internals
(Illustration Jack Marsh)

Figure 340.2 Fish feeding on algae
(Photo Murray Waite)

Feeding and nutrition

Like sharks, fish have a one way digestive system. Food enters the mouth and buccal cavity and passes by muscular contraction to the oesophagus located in the gill region. It connects the mouth to the stomach as shown in Figure 340.1. The stomach (or gullet) is the place where much of the digestive process takes place.

The pylorus is a constriction between the stomach and intestines. It opens to let the food pass into the intestine for further digestion.

As a general rule, fish with short intestines are carnivorous and those with long intestines are herbivorous. Digested wastes are then eliminated from the intestine through the anus.

Circulation

Bony fish breathe through gills, which are best observed by lifting the gill cover, the operculum, and peering under it, but can also be seen from the mouth.

Water passes through the mouth and over the gills where some of the oxygen dissolved in it is removed.

Blood is circulated by a two-chambered heart as shown in Figure 340.3, and passes through the gills, where it receives a fresh supply of oxygen before coursing through the remainder of the body.

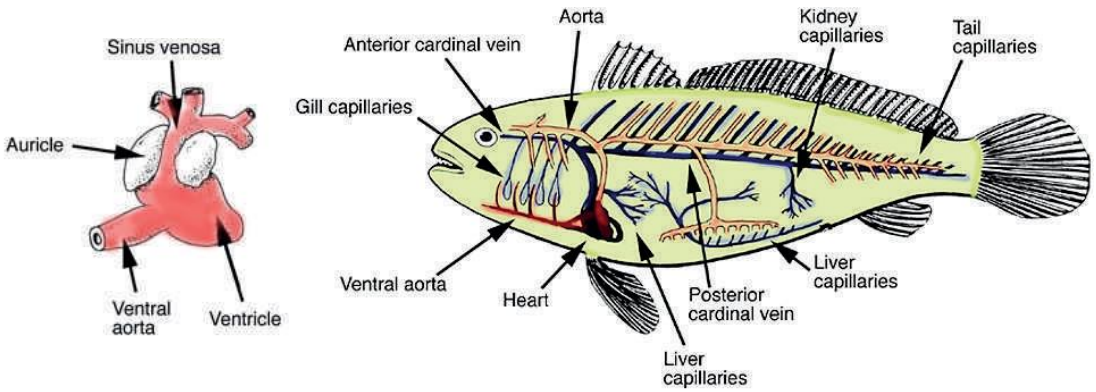


Figure 340.3 Fish circulation (After Lerman and Marsh)
(Illustration Jack Marsh)

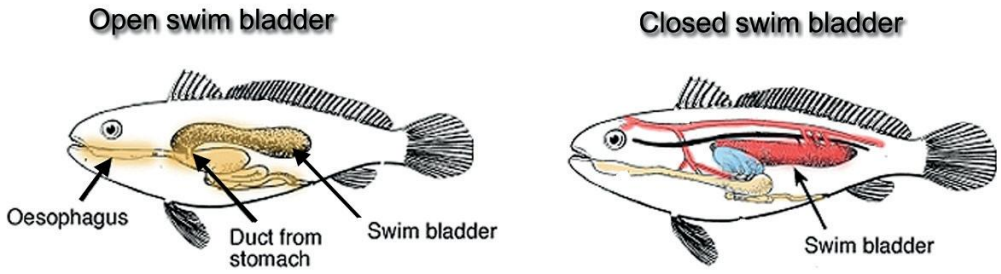


Figure 341.1 Fish swim bladders (After Lerman)
(Illustrations by Kerry Kitzelman and Jack Marsh)

The swim bladder

The swim bladder, a thin-walled sac, also aids breathing in some fish as well as keeping the fish buoyant. In some cases the air bladder is connected to the oesophagus and in others it is a separate organ (see Figure 341.1).

Osmoregulation

Excretion and water salt balance

In order for water to enter cells, it has to pass through a cell membrane and the mechanism which regulates this is called **osmosis** (Figure 341.2).

The membrane through which the water moves is semipermeable and allows some substances through while inhibiting others, eg water can pass through easily but not salt.

The diffusion of water will depend on there being a difference in concentrations on either side of the semipermeable membrane as shown in figure 341.2.

Applying the laws of diffusion, water will diffuse from an area of low salt concentration to an area of high salt concentration presumably in an effort to dilute the salt.

Salt balance

Salts are actively excreted by the gills of salt water fish so marine fish produce very little urine.

However freshwater fish do not drink water because the water in their blood has high concentrations of salts causing water to be taken up automatically in the gills by osmosis as shown in Figure 341.2.

This water has to be removed by the urinary system and excreted as part of the urine.

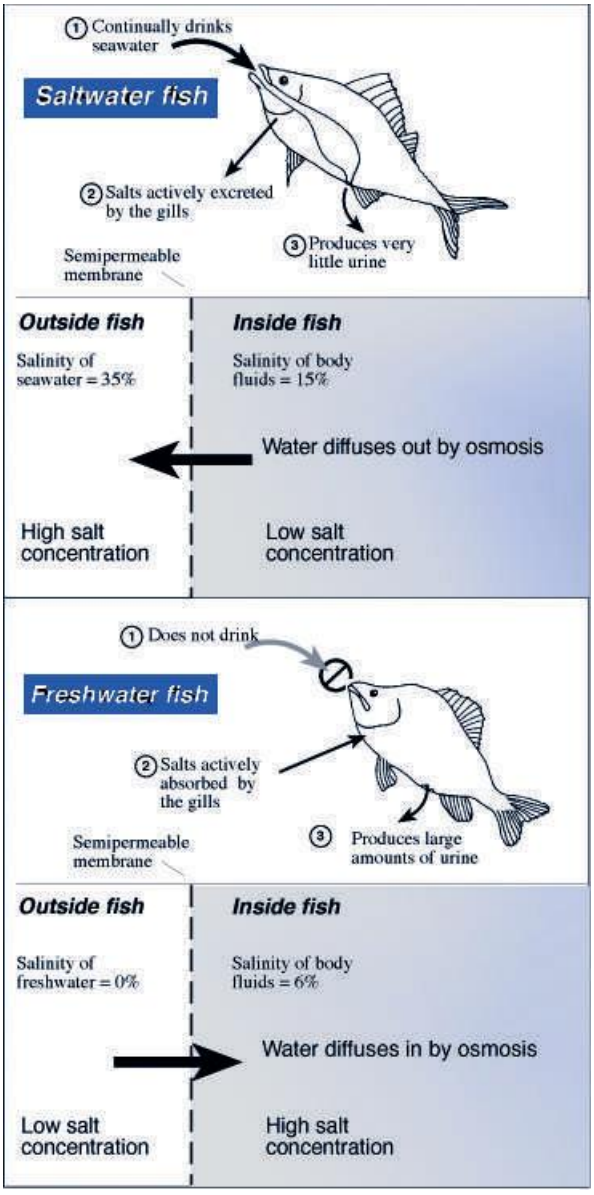


Figure 341.2 Comparison of physiological adaptations of fresh and salt water fish

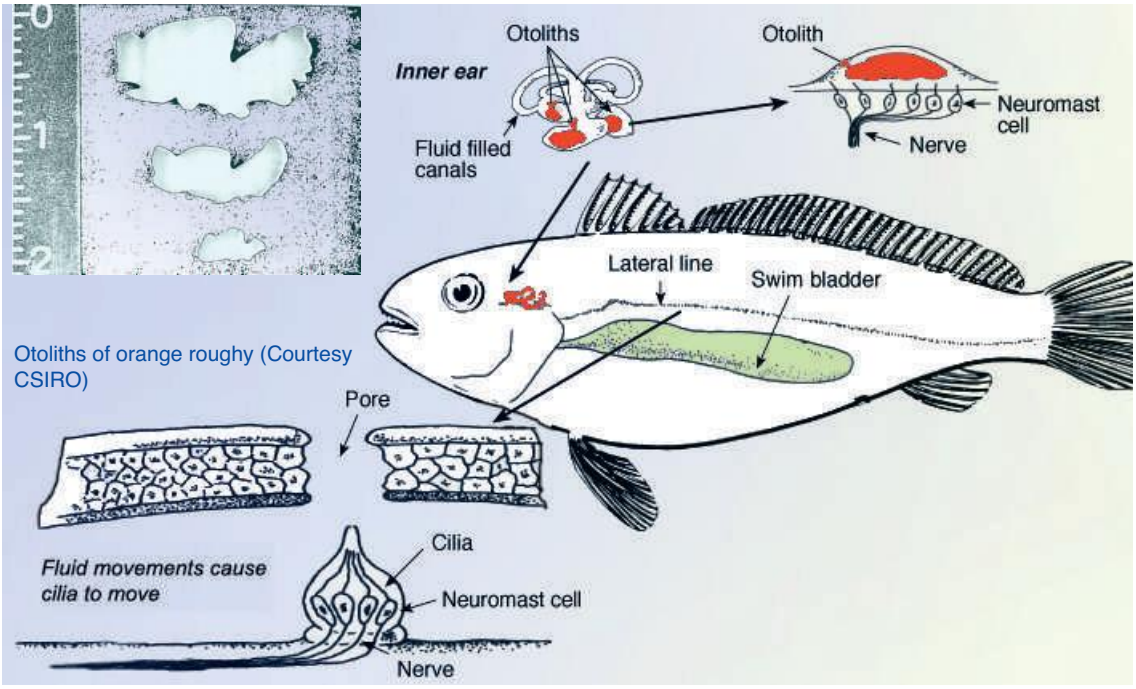


Figure 342.1 Hearing and balance (After Lerman)
(Illustration Mark Moffatt, otholiths courtesy CSIRO Marine Division)

Odd fact

Fish aging:

search engine words

Otoliths Orange roughy

or try

http://www.marine.csiro.au/LeafletsFolder/pdfsheets/38oroughy.pdf

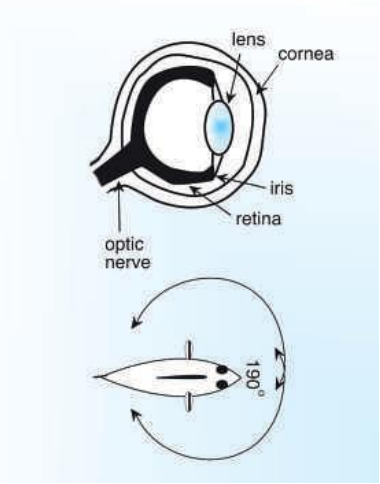


Figure 342.2 Fish vision
(Illustration Mark Moffatt)

Vision, hearing and balance

Hearing and balance in fish is controlled by the interaction of inner ear, lateral line and **swim bladder** (Figure 342.1).

The cells which translate vibrations in the water into nerve impulses are the neuromast cells. Fluid movements in the lateral line system cause cilia to fire off nerve endings which are connected to the brain. Neuromast cells are located in the inner ear and in the canals of the lateral line system. The swim bladder acts as a transducer to amplify sounds as the swim bladder vibrates.

A well developed eye with an almost 360° vision, is one of the adaptations that help the fish survive (Figure 342.2).

Smell and taste

Smell and taste are controlled by specialised cells called **chemoreceptors**.

Receptors associated with smell are located in the olfactory pit in the nostrils while taste receptors are located in the skin and around the mouth. Chemical senses are responsible for a wide range of behaviours in courtship, schooling, sexual identification, migration and mating.

Like sharks, bony fish are able to detect weak electric currents by the process of electro-perception. Some fish even make their own electric fields — the African electric catfish can generate several hundred volts using specifically modified muscle tissue. When it finds a school of fish it simply swims through the school electrifying its prey.

Fish reproduction

There is extreme variation in reproduction of fish. Sexual reproduction involves the production of sperm and eggs from gonads. Masses of sperm called milt comes from the testis and masses of eggs or roe come from the ovaries. Fertilization can be external or internal in fish but all results in an embryo.

Breeding

The gonads of fish can produce hormones to produce secondary sexual characteristics and control courtship activities. Breeding can also be controlled by water temperature, daylight length, salinity or tide heights. The timing of reproduction is important to enhance the chance of fertilization.

Courtship

Many fish engage in elaborate courtship activity. Reef fish may change colour, build nests or perform ritual dances or displays to attract members of the opposite sex. In all species it is important to identify mating between sexes of the right species. Courtship activities ensure this occurring.

Fertilization and development

In most fish fertilization is external (Figure 343.1) with sperm and eggs fusing and dividing many times to form an embryo. In some cases (see box to right), males develop into females.

The larval stages contain the yolk sac and are known as fish fry. They feed on this yolk until they are able to find their own food, which is usually other plankton. In some fish species, it is often hard to tell the difference between males and females.

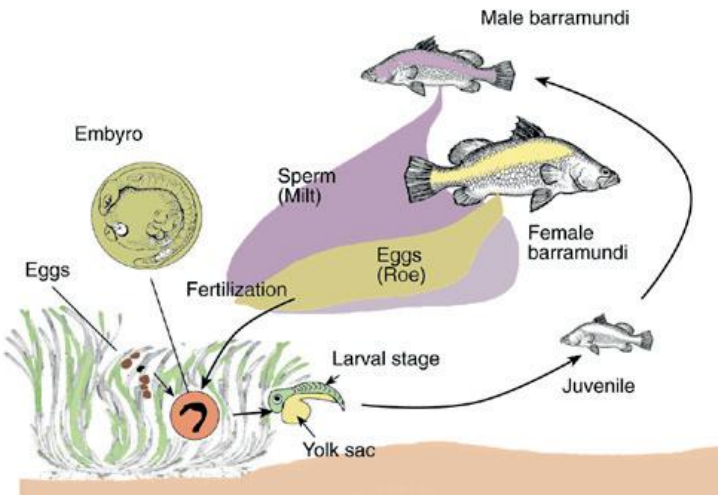


Figure 343.1 Fish reproduction in Barramundi
(Illustration Bob Moffatt with fish by Rose Bedford)

Odd fact

The amazing seahorse

Reproduction in fish varies a great deal. Some fish lay eggs, others bear live young.

Some fish can change sex as they mature, others change from female to male if there are no males available.

Male seahorses have a pouch where the female deposits her eggs to mature.

Sex change

Barramundi for example mature as males from 3 to 5 years, at which time they are about 700 mm long. After spending several years as a breeding male, the fish changes sex to become a fully functioning female. This is known as sex inversion and occurs when the fish is 6 - 8 years old and about 800 mm long. Large barramundi are nearly always female. During the breeding season adult barramundi move downstream into the salt water reaches of rivers, creeks and coastal shallows. The fish often breed in shallow water on incoming tides during evenings of a full or new moon. Males and females come together to spawn. The male produces sperm in his testis and releases it into the water in the vicinity of the female.

Some fish spend part of their life in fresh water and part in salt water. These are the *andromous* fish.

Salmon are the best known fish which travel hundreds of kilometres to spawn. These fish must have the ability to regulate their salt intake.

Exercise 13.1 Fish gut analysis

By Dr Jack A Marsh (Published STAQ Journal, reproduced with permission).

Introduction

The marine food chain as a sequence of organisms associated with one another, of who eats whom, can be determined by direct gut analysis of some marine animals such as fish. The examination of fish gut contents can be used to establish the basis of a food chain and energy flow pattern for a complex marine food web. The analysis of fish gut contents teaches students:

- the skill of dissecting a marine animal to display and identify the internal features,
- the structure and function of the digestive system,
- the design and construction of a food chain for a food web and
- indirectly, fish external characters by using a key for identification.

The following exercise outlines a procedure, report technique and discussions which can be adopted to use for fish gut studies and determine the position of a fish in a food chain.

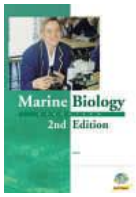
Fish Gut Analysis

Aim

1. To dissect, draw and identify the digestive system of a fish.
2. To determine the gut contents in the digestive system.
3. To determine the feeding habits of the fish.
4. To relate the position of the fish and energy flow in a good chain and food web.

Sea mullet dissection

See Marine Biology Exercise book



Materials

1. Fish sample
2. Dissection Tray
3. Scissors
4. Scalpel
5. Forceps
6. Probe
7. Petri dish
8. Stereo and / or monocular microscope
9. Paper towel
10. Surgical gloves

Part A Procedure

1. Place the fish on its side (right or left) and locate the general position of the digestive system by observation (normally between and just above the pelvic and anal fins) (Figure 344.1).
2. Locate the anal opening, then using scissors or scalpel (see step 1 to 3 Figure 344.1)
   - Dissect open the fish mid-ventrally from the anus to between the base of pelvic fins. Continue to base of the lower jaw.
   - Dissect (right or left side of the fish) towards the dorsal region by cutting posterior to the operculum, anterior to the pectoral fin and stopping at the level of the eye.
   - Continue to dissect back down towards the anus.
3. Remove this "side flap" of skin and muscle to expose the digestive system.

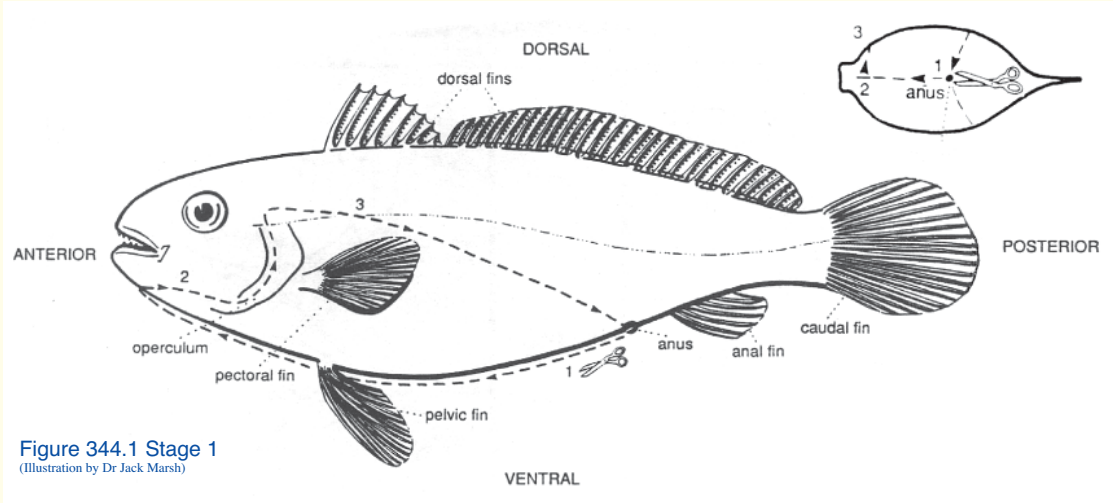
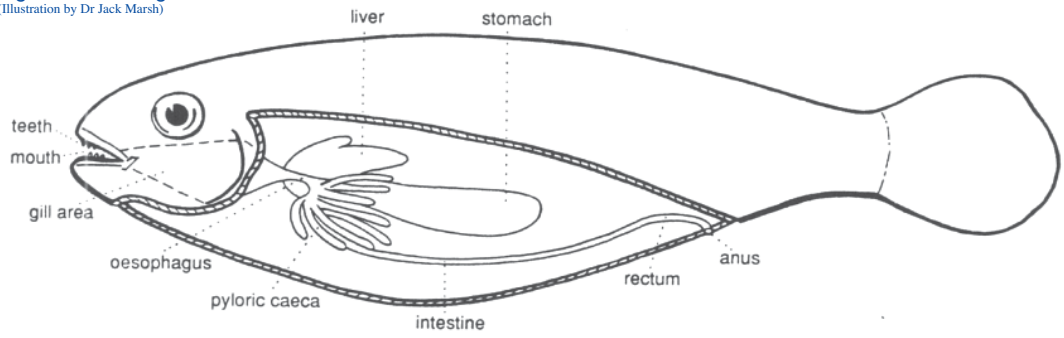


Figure 344.1 Stage 1
(Illustration by Dr Jack Marsh)

Figure 345.1 Stage 2
(Illustration by Dr Jack Marsh)



4. Identify the parts of the digestive system (Figure 345.1).
5. **Draw** and label a diagram of the digestive system *in situ*.
6. Remove the digestive system by cutting through the base of the oesophagus and rectum near the anus, keeping the organs intact.
7. Spread the digestive out either on the dissecting tray or in a petri dish (depending on its size and/or length).
8. Identify, draw and label the digestive system.
9. Measure and record the length of the digestive system.
10. Locate the base of the oesophagus, then using scissors or scalpel cut open the stomach and intestine.
11. Place the gut contents in a petri dish or on a slide.
12. Identify the gut contents macroscopically and/or microscopically.
13. Complete the fish gut analysis report and table.
14. If the gut contents do not give a clear indication of the type of food eaten, it should be recorded as food absent.

Note:

Tabulated information recorded from student studies over the years could also be used as a source of reference.

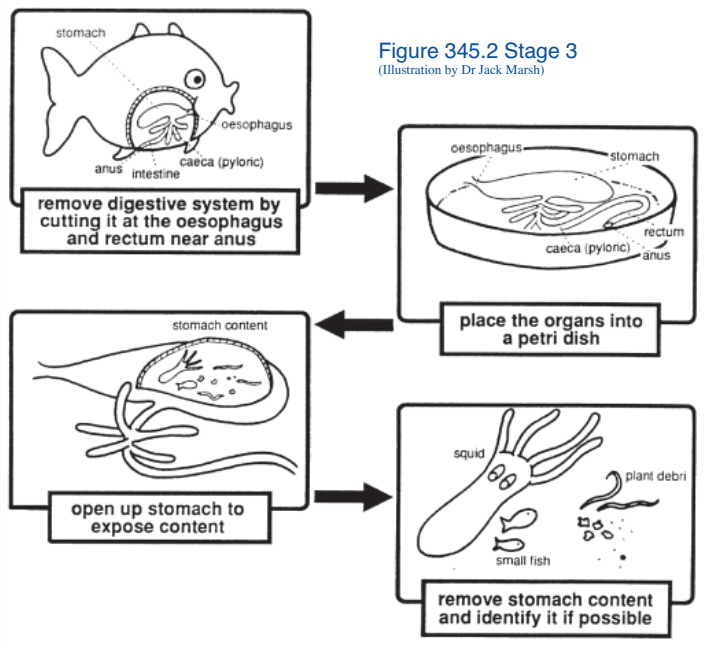
Part B Procedure Fish Gut Analysis

For each fish - record the following data in fish gut analysis report.

1. Indicate fish location.
2. Give date and time.
3. Draw the shape of the fish tail (for classification purposes).
4. Give a brief description of fish - using main identification points (ID).
5. Key out and identify family, genus/species and common name of fish.
6. Record length and weight of fish.

Turn over ...../346

Figure 345.2 Stage 3
(Illustration by Dr Jack Marsh)



7. Identify if male or female.
8. Identify if diurnal or nocturnal.
9. Describe teeth pattern such as type, shape, numbers above and below the mouth.
10. Dissect, draw and label the gut (digestive system)
    - in situ
    - spread out (refer to dissection procedure).
11. Measure the length of the gut.
12. Dissect the gut and determine the food contents at each area.
13. Complete fish gut analysis table.
14. Identify any parasites present. Give genus/species and common name of these parasites.
15. Mention where parasites are found in/on fish.
16. Relate teeth pattern to food type and their function.
17. Draw a food chain for the fish.

Work underlined is to be done separately from information of fish gut analysis report and table.

Part C Fish Gut Analysis Report

1. Location
2. Date/Time
3. Tail Shape
4. ID
5. Family
6. Genus/Species
7. Common Name
8. Length (cm)
9. Weight (gm)
10. Sex
11. Niche
12. Teeth
13. Gut length (cm)
14. Food/site
15. Feeding habit
16. Parasite/site

FISH	FH	PC	CPL	CPR	CCR	GP	BV	SQ	EC	PP	PR	SG	MD
1.													
2.													
3.													
4.													
5.													
6.													
7.													
8.													
9.													
10.													
11.													
12.													
13.													
14.													
15.													
16.													
17.													
18.													
19.													
20.													

FH	-	*Fish*	SQ	-	*Squid*
PC	-	*Polychaete*	EC	-	*Echinoderm*
CPL	-	*Crustacea, Plankton*	PP	-	*Phytoplankton*
CCR	-	*Crustacea, Crab*	PR	-	*Plant remains*
GP	-	*Gastropod*	SG	-	*Shell Grit*
BV	-	*Bivalve*	MD	-	*Mud*

Notes:

- ID - key identification characters
- Niche - diurnal or nocturnal
- Feeding habit - carnivore, herbivore or omnivore

Part D Questions

Write a paragraphs on any of the following:

1. Discuss general fish feeding habits - whether herbivorous, carnivorous or omnivorous, diurnal or nocturnal and a comparison between male and female species.
2. Discuss the position of the fish in relation to the food chain, energy flow and food web.
3. Compare and contrast fish digestive systems, including teeth patterns.

Research

1. Discuss evolutionary trends in fish feeding habits.
2. Describe the feeding patterns of fish families.

Exercise 13.2 Osmosis

Based on an original exercise by Tim Ryan, Maryborough State High School.

Method

1. Open the cellulose tubing by wetting it and then rubbing it between your fingers. Cut off a 20 cm section.
2. Tie a knot in one end of the tubing.
3. Use a filter funnel to fill the bag with a starch solution.
4. Tie off the end with a rubber band to make a sausage like "organism".
5. Record its length and circumference.
6. Place it into a large beaker of water.
7. Add some iodine solution to the water in the beaker.
8. Record the colour changes after 50 minutes.
9. Repeat steps 1 to 7 but use a sugar solution instead of a starch solution.
10. Allow the bag to sit in the beaker for 50 minutes.
11. Record the size change in the bag and add a piece of Testape to the water in the beaker and record its colour.

Questions

1. What is the chemical test for starch?
2. What colour did the bag turn in step 8?
3. Describe the change in size of the bags in both cases.
4. What substances can pass through a cellulose membrane?
5. What is a "differentially permeable membrane"?

Materials and equipment (per group)

- distilled water
- cellulose tubing (dialysis tubing)
- starch solution
- sugar solution
- iodine solution
- test tape
- scissors
- filter funnel
- 2 beakers

Exercise 13.3 Streamlining

Part A

1. Three-quarters fill the graduated cylinder with water.
2. Drop each of three shapes as shown in Figure 347.1 down through the water column.
3. Make careful observations and record which shape travels the fastest through water.

Figure 347.1

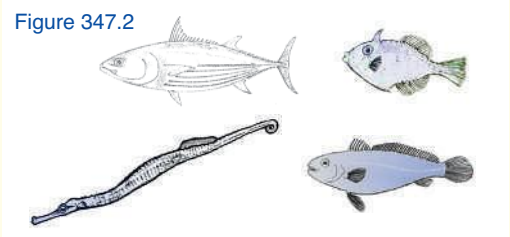
Part B

1. Set up a streamlining tray as shown in Figure 347.3.
2. Run water through the tray.
3. Make careful observations and record which object appears to create the greatest drag.

Questions

1. Which shape is the best for swimming through water quickly?
2. Name any four fish that are shaped this way.
3. Fast swimmers usually have forked caudal fins. Why is this?
4. Make up a table for the fish in Figure 347.2 below showing where the fish could live and which would swim the fastest.

Figure 347.2



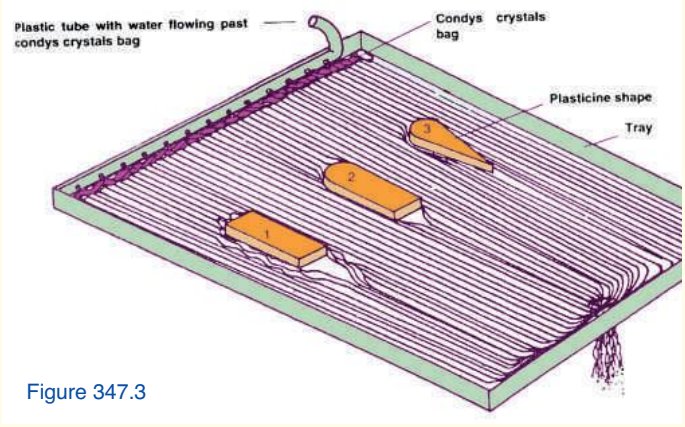


Figure 347.3

Exercise 13.4 Fish classification key

Based on an original exercise by Tim Ryan, Maryborough State High School.

Study the fish A - I in Figure 348.1 and answer the questions below.

Questions

1. Classify each of the fish in Figure 348.1 by using the key on Page 349.

   To use the key, select a fish.

   Start at number 1a and read the statement. If it applies then go to the number allocated.

   Continue down the key until you reach the species name.

2. When you finish, write out the steps you used in your notebook.

   Example:

   This fish has scales that are fairly large. The body is compressed, long and slender. The dorsal fin is single and situated near the caudal fin of the fish. This fish has very large eyes and large scales. The mouth is hinged in front of the eye. The mouth has a long slender beak. The upper jaw is much broader than it is long. It has a slightly forked tail.

Creativity activity

Make a fibreglass fish

The aim of this activity is to make a series of fish you can use to create your own classification key

Follow the instructions on page 349.

Safety

1. Catalyst used in fibreglassing can cause blindness so wear safety goggles and use a well ventilated area such as under a tree or fume cupboard.
2. If you are in doubt ask your manual arts teachers who will be up to date with current workplace health and safety guidelines.

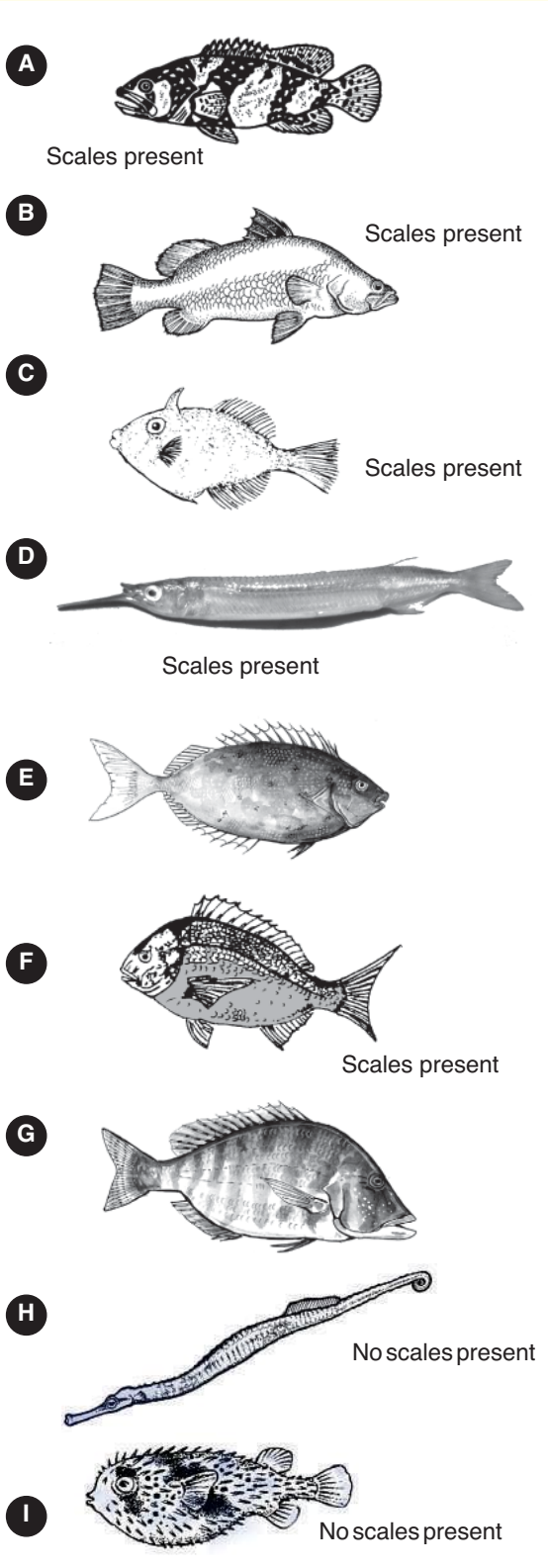


Figure 348.1 Fish A - I

Classification key for certain fish

1. a.	Body covered with scales	Go to 2
1. b.	Body lacking true scales	Go to 8
2. a.	Caudal fin concave in shape	Go to 5
2. b.	Caudal fin rounded	Go to 3
3. a.	Two separate dorsal fins	Go to 4
3. b.	Dorsal fins joined	Estuary Cod
4. a,	Large hinged mouth	Barramundi
4. b.	Small mouth	Trigger Fish
5. a.	Head has a pointed beak	Garfish
5. b.	No beak present	Go to 6
6. a.	Anal fin covers over one-third of body length	Happy Moment
6. b.	Anal fin covers less than one-third of body length	Go to 7
7. a.	Body has even coloration	Bream
7. b.	6-7 coloured vertical bands on body	Grass Sweetlip
8. a.	Body long and narrow	Pipe Fish
8. b.	Body less than 4 times as long as broad	Porcupine fish

Answers

A Estuary Cod
B Barramundi
C Trigger Fish
D Garfish
E Happy moment
F Bream
G Grass Sweetlip
H Pipe fish
I Porcupine fish

Extension exercise — The fibreglass fish

Based on an original idea by Perry Kaigan, with photographs by Geoff Jensen.

Plaster work

1. Wash the fish with sponge and detergent.
2. Rinse off detergent.
3. Wipe dry with cloth or paper towelling to remove all slime.
4. Place fish on side half buried in sand.
5. Fill mouth cavity with clay.
6. Place fins in realistic position.
7. Mix some plaster of Paris – enough to cover whole side and to overlap the sides by 2-3 cm.
8. Pour plaster over fish, gently quivering plaster into all parts.
9. Allow to dry.
10. Remove fish from mould as shown in Figure 349.1
11. If you like, you can now clean, fillet and cook your fish.

Fibreglassing

1. Clean mould of any bits and pieces adhering — wash and let dry thoroughly.
2. Brush on a **thin** layer of release agent.
3. Using a brush, paint on a layer of resin.
4. Allow this layer to dry.
5. Mix more resin.
6. Brush on more resin and work in fibreglass matting — work in well to remove bubbles.
7. Allow to dry.
8. Remove from mould.
9. Trim and paint (Figure 349.2).

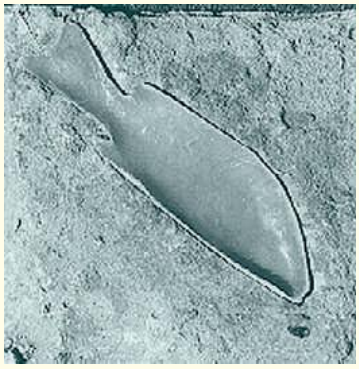


Figure 349.1 Fish mould in plaster of Paris
(Photo Bob Moffatt)

Figure 349.2 Final fish
(Photo Bob Moffatt)

Exercise 13.5 Excursion to the fish board/trawler

Aim

At the conclusion of the excursion students should be able to:

1. Name the parts of a trawler from an outline drawing identifying the types of nets used by the vessel and their operating depth.
2. List the types of fish caught using the vessel's rigging and describe how the rigging works.
3. Describe where the catch is cooked and stored.
4. Describe what happens to the catch and the methods used to prevent spoilage.
5. Describe how the catch is marketed and recall the sale prices for different parts of the catch.

Five things to focus on are the technology of the vessel, how that technology works, what the technology produces, what the catch is worth and how the catch is marketed.

Your report

Answer the following questions

1. Make a drawing of the trawler naming the following parts: *bow, stern, deck, winch, gantry, sorting tray, wheelhouse, net, cod end, tickler chain, otter boards, warp, storage*.
2. How does the trawler rig work?
3. Draw a diagram showing how the net operates under water and how the net can catch fish, prawns. You may like to ask the skipper how this happens.
4. What is the name of the fishing method used.
5. What fish are caught and when?
6. What was the trawler fishing on its most recent trip?
7. What was caught ?
8. What was the catch worth?
9. What price did the fisherman receive for the catch?
10. Did the catch cover the costs of the trip?
11. What is the trawler worth?
12. How is the catch marketed?
13. What methods are used to prevent the catch from spoiling?
14. How are prawns cooked?
15. What is added to prevent spoilage?
16. How are fish stored before marketing? What happens to the fish at the wharf and then in the fish processing rooms?
17. How are the fish prepared for sale. What fish are for sale and how much are they per kilogram ? How does this compare with the price of a "big mac"?

Qld Fisheries

Extension exercise: Graphing population densities

Aim

This is an exercise where sample population data is given and students are to graph population changes over time and answer a series of questions about habitat changes. Students are to propose hypothesis and solutions.

Procedure

Go to the following web site, download the graphs and complete the exercise below.

http://www.dpi.qld.gov.au/extra/nnn/activity_graphing.html

1. Read the annual reports from the Queensland Fish Board from 1936 to 1980. These pages are available in PDF format:

   Download (14 kb)
2. Study the data in the table Table 1: Millions of tons fish caught.
3. Study the graph in Figure 1: Fish population changes from 1998-2000.
4. Draw a graph similar to the one on the web site.
5. Answer questions 1-5 from the web site.

Questions

1. Which fish population appears to be most stable?
2. What natural and human events may have accounted for the decrease in fish #2's catch between years 2 and 4, and 16 and 18?
3. What effect did the introduction of fish #4 appear to have on the other fish species?
4. What actions did the regulating body take to maintain the catch size of fish #2?
5. What natural and or human events may have caused all the fish species to die in year 2000?

Shark meshing

How sharks are caught

Major beaches in some Australian States are protected by shark nets and drum lines as shown in Figures 351.2 and 351.3.

Drum lines are made up of a baited shark hook on a chain running up to a float on the surface. The float is attached by a rope to a heavy anchor on the sea-bed so it remains in place. The hooks are baited and sharks are attracted and caught as they bite at the bait. Drum lines are checked for sharks on a regular basis and are baited if required.

Nets are anchored to the sea floor by tow anchors at either end of the net. Marker buoys identify the end of the net and a series of white floats keeps the net hanging on the surface.

Sharks are caught as they swim into the net and are hauled on board a special shark boat (Figure 351.1) usually under contract to the government.

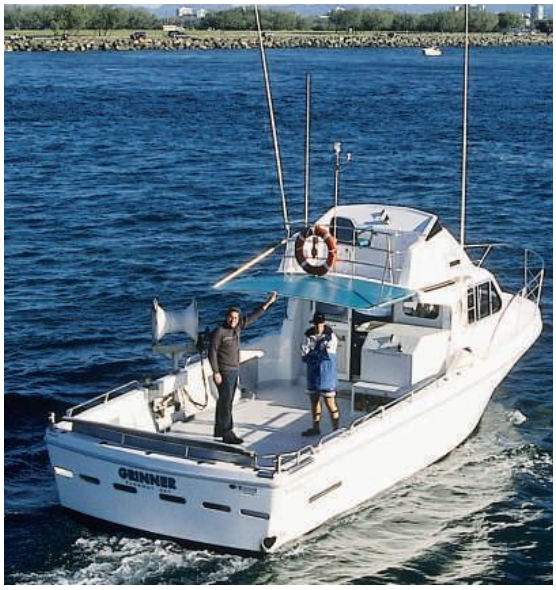


Figure 351.1 Shark boat contractor
(Photo Bob Moffatt)

The debate over nets

Each year during whale migrations, there is much debate over the practice of catching sharks using nets. Some whales are caught in these nets and have to be rescued creating much media attention.

The fact that there has never been a shark attack on a beach since shark meshing has been introduced tends to swing the argument in favour for keeping them in place.

However there are some who call for the nets to be removed at certain times of the year to allow whales safe passage on their swim back to Antarctica. One thing is for certain the debate will continue and politics will decide the shark's fate.

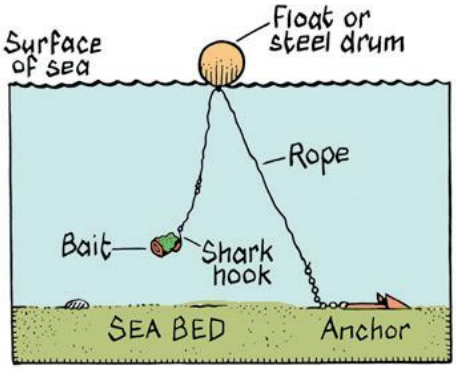


Figure 351.2 Drum line
(Illustration Paul Lennon, Courtesy Qld Fisheries, reproduced with permission)

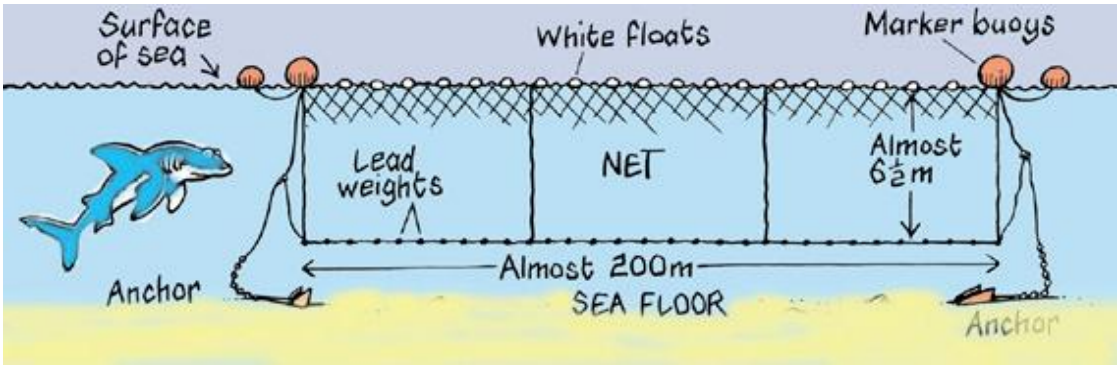


Figure 351.3 Shark net
(Illustration Paul Lennon, Courtesy Qld Fisheries, reproduced with permission)

Exercises

From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

C2. How are sharks and rays classified?
B10. How do turtles feed and reproduce?
B11. How do sharks move?
D7. How do sharks navigate and locate their prey?
E1. External features of a bony fish
E2. A sea mullet dissection

Questions

Knowledge

1. Draw a labelled diagram of an ascidian showing the following parts - pharynx, gill slits, tunic, heart, intestine, gonads, stomach, in-current and ex-current siphons.
2. What is a denticle and what makes them different from human teeth?
3. How do shark repellent devices work?

Understanding

4. Draw a diagram to show the difference between a drum line and a shark net.
5. What type of bait would be used on a drum line?
6. What differences exist between sharks and rays?
7. Outline the main reasons for classifying sharks and fish in different classes.
8. Describe the role of capillaries in a shark's respiration cycle.
9. Describe how a shark's neuromast system works.
10. Describe how a saltwater fish osmoregulates.
11. Describe how a barramundi reproduces.

Applying

12. Prepare a flow chart of the steps involved in a molecule of oxygen getting from the gills of a shark to the pectoral fin. Then draw a flow chart to show how a molecule of carbon dioxide gets back to the gills.
13. Draw pictures to show you can distinguish between gannoid, ctenoid and cycloid scales.
14. Distinguish between the afferent and efferent arteries in sharks.
15. Draw diagrams comparing the male and female urinogenital systems.

Analysing

16. What type of sharks do you think shark nets and drum lines should catch? Give reasons for your answer.
17. Discuss the problems a shark may experience when attempting to feed in a low visibility environment.
18. Consider the various commercial fishing techniques that make use of nets. These nets may cause environmental damage. Discuss the advantages of each method and outline procedures which could be implemented to protect the environment.
19. Many dolphins are killed each year by the accidental trapping in nets even though they have the ability to easily locate objects as small as 1 mm in diameter. Dolphins are generally regarded as intelligent so explain why they fail to jump clear of the fishing nets?
20. Discuss the following statements about Coral trout and their relationship with reefs:
    - Adult Coral trout are non-nomadic and overall, do not range far.
    - Coral trout spawn (ie release eggs and sperm) in early summer on the southern Great Barrier Reef.
21. Write an essay on Electro-reception in Elasmobranchs (sharks, skates, and rays).
22. To the fishery biologist, the fish scale represents a valuable tool in the investigative process. The biologist can choose to use the scale to determine the age of the fish. This information can be used as an interpretation on the life history of some fish. In addition, scientists use scales in the identification classification of fish. It should be mentioned, however, that not all fish have scales, and those having scales do not all have the same type. Scales are not exclusive to fish.

    Collect some fish scales and use them to determine the age of a fish by counting scale rings.

Creating

23. Are you afraid of sharks? Devise a simple questionnaire with six questions to see if you and your class mates are afraid of sharks and to test some understanding of shark behaviour. You might like to use questions like - are all sharks dangerous?

    Calculate percentages from your survey and illustrate them either in a graph or as a table.

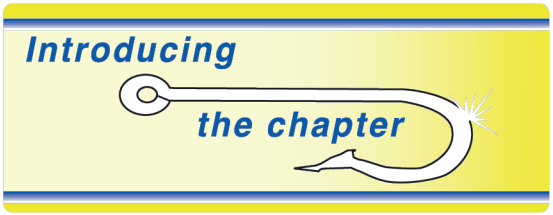
Evaluating

24. Recommend new strategies to be adopted by the government of your state based on your strategic plan to review shark meshing.
25. Write a letter to the editor of the local newspaper complaining about the number of dolphins caught in shark nets. Then write a response from the local minister justifying the shark nets.
26. Justify the inclusion of sea squirts in the Phylum Chordata. Use a diagram of a larval sea squirt to support your argument comparing it with that of a fish.
27. Evaluate the statement about chordates that "a coordinated nervous system has allowed for the development of highly specialised organs which perform specialised functions to extend the life of the animal into many decades and allow it to grow a lot bigger than invertebrates".

Chapter 14
Marine Vertebrates (2)
The higher vertebrates

by
Bob Moffatt

Photo Neville Coleman's World of Water



Chapter hooks

- Check out and download the crocodile education kit from the mesa web site:

  www.mesa.edu.au/friends/croc_kit/croc_facts.htm
- Arrange a visit to a marine theme park so you can see dolphins, seals or whales.
- Go bird watching and record the differences in bird behaviour between low and high tides.
- Build a model whale and hang it in the room.

Why study this chapter

Dolphins and whales are mammals and seem to be the sea creatures we relate to the most.

However reptiles, birds and mammals include species who play a vital role as predators at the top of the food chain.

The role involves the removal of the sick and dying in a population. This ensures only the fittest survive and the world can continue to evolve with the best adapted species.

Bird watching is a century old tradition and the establishment of RAMSAR migratory bird treaties and their management is an emerging field.

Chapter overview

Class Reptilia **355**

Crocodiles 355

Turtles 356

Sea-snakes 358

Case study 14.1 Dean the Green 359

Class Aves **360**

Class Mammalia **372**

Order Sirenia 372

Order Carnivora 373

Order Cetacea 375

Exercises and questions 382

Key concepts

- Reptiles include salt water crocodiles which are dangerous marine creatures causing many deaths in Northern Australian waters.
- Reptiles are cold blooded animals and require behavioural adaptations to control their body temperatures.
- The turtle life cycle has taken years of painstaking research to unravel. Only in recent years has technology been used to answer some questions about turtle migrations.
- Four groups of birds include tubenoses; pelicans, boobies, frigates and related species; gull-like birds and penguins.
- There is a huge diversity in bird behaviours which is well documented by ornithologists. This diversity includes courtship and feeding behaviours.
- Some birds migrate for thousands of kilometres and have to be protected by RAMSAR sites.
- The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 133 Contracting Parties to the Convention, with 1229 wetland sites, totalling 105.9 million hectares, designated for inclusion.
- Seabirds play a vital role in coast and ocean ecology. For example, as scavengers of dead fish they remove dead and dying animals from the genetic biodiversity equation. They are responsible for transferring seeds from island to island and provide a way for plants to reproduce. Their droppings are important for plants because they heap fertiliser on island soils which would otherwise be very poor in nutrients.
- Mammals have four-chambered hearts, are warm blooded and have hair or fur at some stage of their lives. In some parts of the world, all marine mammals are protected however in other parts they are still hunted for food or killed for research.
- Three orders of marine mammals are Sirenia, Carnivora and Cetacea.

Class Reptilia

Most reptiles lay eggs that, unlike the eggs of fish and amphibians, resist drying out. Reptile hearts have three chambers, though the crocodile heart is almost completely divided into four chambers just like the hearts of mammals and birds.

Reptiles breathe with lungs but, because they do not have diaphragms, they can only inflate their lungs by moving their ribs. Reptiles have scaly, waterproof skin and are equipped with salt glands which remove excess salts.

Figure 355.1 Croc at night
(Photo Michael Mitchie)

Crocodiles

Crocodiles are found in the northern-most parts of Australia. The Australian saltwater crocodile is the largest of all reptiles, at least 9m long, and is an extremely dangerous "cold-blooded" animal. Crocodile jaws are designed to grab prey and powerful muscles snap the jaw closed.

To get warm they bask in the sun and to cool off, they lie in the shade or water, sometimes with their mouths wide open (Figure 355.2). They have the ability to control the blood flow inside their bodies and can shut down blood flow or speed it up. The skin is scaly and waterproof and for extra protection it has bony scales and ridges along its back which has lots of blood vessels to collect the sun's warmth.

Crocodiles can move very quickly. To swim, the croc swings its tail from side to side with the legs held against the body. It can swim long distances and stay underwater for up to 4-5 hours. On land, they can move quickly for short periods of time but they also tire quickly.

Crocodiles are aged by counting the rings on their scales and scientists now know that male crocodiles can live up to 70 - 100 years old.

You can read more on the mesa web site: www.mesa.edu.au

An excellent resource kit for schools is available on line from MESA at: http://www.mesa.edu.au/friends/croc_kit/croc_facts.htm

Some Do's and Don'ts

Obey crocodile warning signs. Just because you don't see any crocs doesn't mean they aren't there.

Don't go swimming, paddling or wading in areas where there are likely to be crocs. This includes coastal areas and beaches in some places.

Keep well away from the water's edge in croc country. Avoid washing dishes and gutting fish on river/billabong banks and be very cautious when collecting water.

Don't be complacent. Large crocs rarely show themselves and approach very stealthily.

Figure 355.2 Croc basking during day
(Photo Mike Sugden)

Courtesy Qld Marine Parks and MESA

Figure 356.1 Green turtle
(Photos Bob Moffatt

Turtles

Marine turtles can live for 60 years or more and are well adapted to life in the sea. They can spend up to half an hour underwater, before coming to the surface to breathe. Turtles have a mouth with strong jaws and feed on jellyfish, sponges, sea grasses, crabs and many other benthic animals. Their forelimbs are strong paddle shaped flippers, with which they flap bird-like as they cruise (Figure 356.1). Turtles drink salt water, but excrete the excess salt through glands next to their eyes.

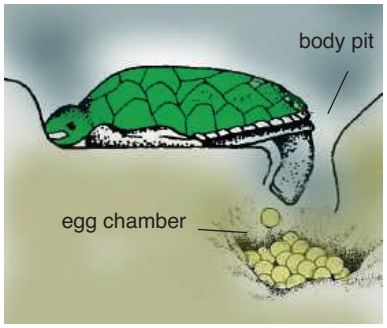
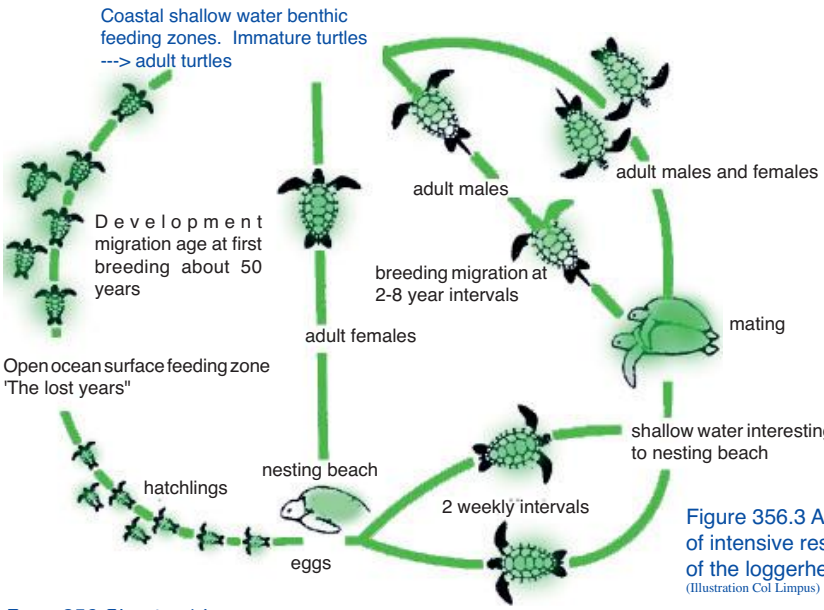


Figure 356.2 Turtle laying eggs
(Illustration Steven Byers)

Sea turtles use flippers to move through the water and are protected by a hard shell. Fatty deposits and very light spongy bones also increase buoyancy enabling turtles to float easily.

Turtles are 30 years old or more before they start to breed. Males and females migrate from feeding grounds to breeding grounds during the summer breeding season. Turtles mate in the water; the male mounting the female and holding on to her carapace with spurs on his flippers (Figure 356.3). A female can mate with several males and store sperm for successive batches of eggs. Having mated, the males return to their feeding grounds.



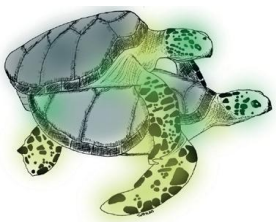


Figure 356.3 As a result of more than 20 years of intensive research, the story of the lifecycle of the loggerhead turtle is becoming known.
(Illustration Col Limpus)

A female green turtle lays hundreds of eggs in a summer, in clutches at regular intervals. The eggs hatch about two months later and the baby turtles make straight for the sea and do not stop swimming to rest or feed for several days.

By the time this initial frenzy is over they could be over 200 N miles away from their birthplace . They remain at sea until they are about one year old.

During this time many are taken by predators and it has been estimated only one percent survive to return to the shallow waters at the beginning of the second year. By rearing baby turtles in captivity the huge losses from predators are avoided.

Research

An Australian researcher Dr Col Limpus has made the study of turtles a lifetime quest. Initially researchers began tagging turtles in the mid 70's at Heron Island off the Queensland coast. These turtles carry the tag through life. One turtle X2757, has been studied for 24 years because she comes back to Heron Island each year. Dr Limpus recently has developed a technique used on humans, to study the reproductive organs with a laparoscope.

This is a fine tube with a camera at one end, which is inserted through the body wall of the turtle. With this instrument, the turtle's reproductive organs can be viewed (as shown in Figure 357.1), and changes recorded without having to kill the animal.

Previously it was impossible to tell a small turtle's sex and whether they were adults or at puberty. The instrument allows the researchers to tell if the turtle is breeding, whether it bred last year or the year before. Such data is collected and logged in a database so that over the years the life cycle of this remarkable animal can at last be recorded.

Conservation

Because marine turtles are migratory animals that regularly cross international boundaries, no one country has total control of a population. They are a shared international resource that needs international cooperation in their management. While governments must cooperate, individuals must also help. Street and house lights can be turned off adjacent to turtle rookeries to minimise hatchling disorientation. Dogs, foxes and pigs can be prevented from destroying turtle nests and hatchlings. Turtle mortality can be kept to a minimum in the fishing industry.

When turtles are caught in trawl nets they could be gently removed and returned to the sea after a period of convalescing on deck. Plastics are a real problem for turtles and they choke on bags and bottles thrown into the sea. International travellers can refrain from buying turtle products such as tortoise shell jewellery, stuffed turtles, turtle soup, shoes or handbags made from turtle or other products from endangered species.

Turtle conservation is important today so that our grand children will enjoy the things we see today, tomorrow.

Figure 357.1 Col Limpus, Jan Taylor and the laparoscope
(Photo Sea World)

Conservation

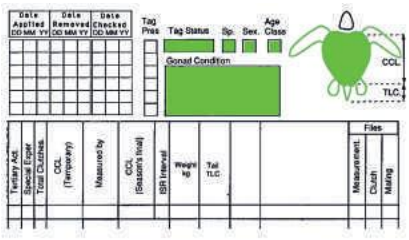
www.reef.crc.org.au/aboutreef/wildlife/marineturtlesspecies.html

- Refuse to buy sea turtle products (tortoiseshell jewellery, souvenirs, meat and eggs).
- Turn off street lights and screen house lights adjacent to sea turtle rookeries.
- Keep dogs away from nesting beaches.
- Do not throw plastic bags, fishing line and other rubbish into the sea or onto the beach.
- Support international conservation agencies that are trying to reduce turtle harvests to ecologically sustainable levels.
- Assist turtle research and conservation by reporting dead or injured turtles to the turtle hotline

  Australia phone:

  008 801 500

(Illustration Sharyn Madder)



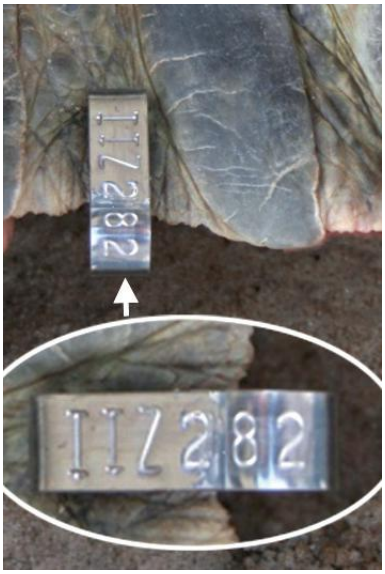


Figure 358.1 Turtle tag and data sheet
(Illustration Col Limpus)

Figure 358.2 Sea snake
Neville Coleman

Turtle watching and tagging

There are now hundreds of tagged turtles in the Pacific and here are some hints for turtle watching:

- If you find a turtle with a tag, record the date and location and anything else you may think relevant and send the information to the address on the tag.
- Keep the use of lights to a minimum while walking along the beach.
- Do not approach closely or shine lights on turtles leaving the surf or moving up the beach as they may return to the sea and not lay again till next year.
- Wait till the turtle is laying before shining lights on her or taking photographs.
- Avoid excess noise or sudden movements and keep dogs away from nesting turtles.

Turtle survival

Less than 1 per cent of newborn turtles will survive their first year. Most are taken by predators soon after they hatch.

Domestic dogs and cats and feral animals like foxes are also a threat. Because watching turtles lay their eggs is a popular tourist attraction, steps are taken around turtle breeding beaches to prevent problems.

Turtles have been exploited for their meat and shells in many parts of the world so some species are becoming rare or endangered.

All marine reptiles, including turtles, are totally protected in Australia but turtles cross international boundaries and are exploited in other countries where they may be turned into soup, jewellery, shoes or handbags.

The Australian Customs Service imposes heavy fines on people importing turtle products from other countries.

Turtles are also threatened by litter such as plastic bags that are thrown into the sea. Turtles eat jellyfish and often mistake plastic bags for food. When they eat plastic bags they die a slow, painful death.

Sea-snakes

Sea snakes are found primarily in tropical waters. They are marine reptiles and comprise about 86% of living marine reptiles species. Many species can spend long periods underwater because they have an elongate right lung that extends for almost the entire length of their body. Sea snakes have to return to land to lay their eggs.

Sea snakes avoid accumulating excess salt from seawater by using a salt excreting gland - the posterior sublingual gland that sits under the tongue.

The major threat to sea snake populations is probably the impact of the commercial trawl fishing industry. The trawl fishing industry across the north of Australia may inadvertently catch tens of thousands of sea snakes each year.

Case study 14.1 Dean the Green

Figure 359.1 Dean the Green
(Photograph from http://www.env.qld.gov.au Qld Gov Copyright)

Reproduced with permission from the www.env.qld.gov.au web site, copyright Queensland Government.

A satellite-tracked turtle nicknamed "Dean the Green" surprised QPWS researchers in July by suddenly heading out of Moreton Bay and across the Pacific at a fast clip, then meandering around the ocean.

The public joined in the excitement by logging onto the turtle's web page, encouraged by daily coverage in The Courier-Mail newspaper. Wearing a radio transmitter, the adult male green turtle was released at the southern tip of Moreton Island by Environment Minister Dean Wells on 6 June, during the annual Moreton Bay turtle survey by QPWS.

The signals stopped in early August and the EPA has now offered a $500 reward for the first confirmed sighting of Dean the Green.

Minister Dean Wells (right) announces the reward for finding his namesake to The Courier-Mail's Michael Madigan and a freshwater relative of Dean the Green, an unnamed Mary River turtle.

QPWS Senior Principal Conservation Officer Dr Col Limpus, who heads Queensland's turtle research program, said Dean's departure from Moreton Bay during winter was completely unexpected.

"We expected Dean the Green to stay in the Bay foraging on seagrass beds until moving north to his breeding grounds in spring, but after five weeks, he suddenly headed out of the Bay, across the continental shelf and into the Pacific Ocean," Col said.

"On 16 July he was 264km east of Moreton Island and heading to the north. At times he was swimming about 70km a day.

"He swam in a big arc back towards the coast, staying in deep ocean waters, then did a series of slow loops, headed north again then west, tracing a giant '3' in the ocean. The last signals came just off Fraser Island.

"More tracking data may have clarified what Dean the Green was up to. He might have made an early start on a breeding migration to a courtship area yet to be identified, or he might have moved out of the bay because waters were getting too cold or food too scarce, or his foraging area is much larger than just Moreton Bay."

One of 194 turtles of three species captured in the annual survey, the radio-tagged green turtle is a massive animal with a shell measuring more than 105cm across. It is likely to be more than 40 years old.

"We had hoped to discover such facts as the home range for a green turtle foraging over the Bay's seagrass pastures, the path and time it takes migrating from feeding area to courtship area, and where it goes after breeding," Col said.

"Now Dean the Green's trek is expanding our knowledge of migration paths — we can look at how these animals' movements intersect with areas where they face high risk of mortality, such as trawling and long-line fisheries known to impact on turtles.

"We hope to see Dean again, in his courtship area or in Moreton Bay."

To track Dean the Green's progress, and for details of the reward and conditions, log on to:

www.env.qld.gov.au

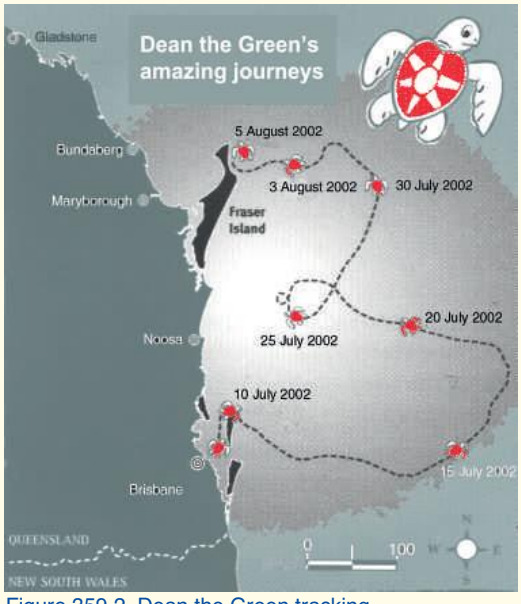


Figure 359.2 Dean the Green tracking
(Illustration from http://www.env.qld.gov.au Qld Gov Copyright)

Class Aves

The Class Aves comprises seabirds who have a four-chambered heart almost identical in structure to that of mammals. They lay eggs and unlike reptiles, are warm blooded. Birds are covered with feathers that protect them from the environment and insulate them from the cold. Birds also have wings that may allow them to fly or may be modified for swimming.

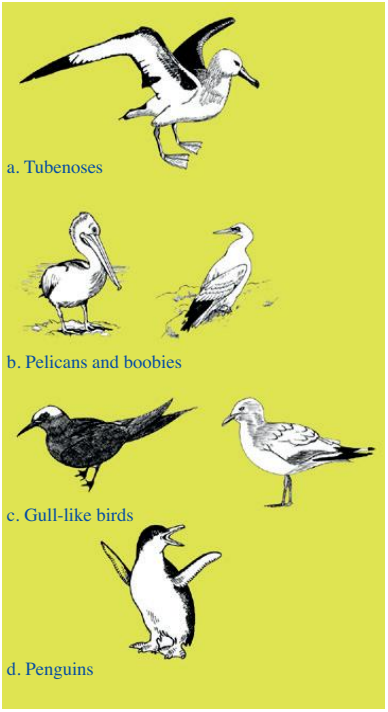


Figure 360.1 Four groups of birds
(Illustrations Steven Byers and Sharyn Madder)

Water conservation

Seabirds have to have different body systems from land birds because they need to conserve water. They drink salt water and process it into drinking water by getting rid of the excess salt through their nostrils and excreting a water-free and very white waste called uric acid. This is often seen on shoreline structures as a white paste and is very hard to clean off.

Staying afloat — buoyancy

Seabirds have light bones to help them take flight and to float on the water when they land on the sea. Their bodies contain a lot of fat and oil and have special glands near their tails which secrete an oil known as preen. Seabirds constantly apply this preen to the rest of their body by rubbing their beaks in the oil and spreading it over their feathers. The preen coats the feathers and traps a layer of air against the birds' bodies which helps them float.

Keeping warm

Birds are warm blooded and their temperature ranges between 39–41°C. To maintain this temperature, they need to insulate their bodies from the cold. Birds trap air beneath their feathers in the same way that a doona keeps you warm on cold nights. Preening is also a good insulator. Penguins need fat to stay warm in Antarctic winters where temperatures fall below -69°C. They have a thick layer of fat under the skin called blubber which protects them from the cold.

Sight

Seabirds must be able to see well both in air and under the water. Birds that see well in air have binocular vision to help them dive from great heights to pounce on fish under the surface.

Other seabirds swim on the surface and dive for long periods to hunt their prey. To help them, many have developed an extra eyelid which is semi-transparent to help them focus and catch fish underwater.

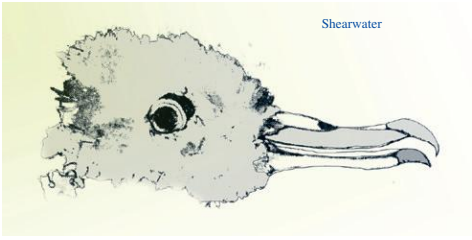


Figure 360.2 Tubenoses
(Illustrations Steven Byers, Photo ANARE)

Four groups of birds shown in Figure 360.1 a-d are commonly recognised as:

a. Tubenoses

b. Pelicans, boobies, frigates and related species

c. Gull-like birds

d. Penguins.

Bob Moffatt

Figure 361.1 Albatros

Tubenoses

Albatross, petrels, storm petrels, diving petrels and shearwaters.

Tubenoses get their name from their development of external nostrils used for detecting odours and measuring the speed of passing air. This unique adaptations allows them to soar over the oceans for enormous distances.

All birds keep their feathers in good order by preening. Most birds squeeze a droplet of oil from a gland near their tails and wipe it through their feathers.

Albatross

The albatross is mostly confined to the southern hemisphere and is the largest seabird with a wingspan of up to 4 metres. They use their noses to glide for hours with very little or no energy, allowing them to circle the globe. They feed on the offal and other fish wastes discarded after processing. They are also capable of shallow dives to catch fish swimming close to the surface.

You can see albatrosses in New Zealand's South Island where a world heritage area at Portobello has been declared. Here they build nests and teach their young to fly, then migrate to South America each year.

Shearwaters

The short-tailed shearwaters migrate annually from the northern hemisphere to their breeding grounds in southern Australia - a remarkable journey of 11,000 km. The birds return to breed in late September and in early April the parents leave the colony taking about seven weeks to arrive back in the feeding grounds in the Arctic. The chicks follow later and the birds spend all their time at sea before returning south. Short-tailed shearwaters can live for up to 36 years and complete this amazing journey several times in their life time.

Short-tailed shearwaters usually occupy the same burrow each year with the same mate - not bad since they flew over 11,000 km.

Tasmanian Aborigines collected shearwaters and their eggs as long as 6,600 years ago and later the birds became food for early settlers. Today the shearwater chicks are harvested during a short season from March to April for their flesh, down and oil. The short-tailed shearwater breeds only in Australia and Tasmania is the home for 80% of the entire population.

Shearwaters are also found around Australia in tropical regions where they spend most of their day fishing at sea, leaving early in the morning from large groups called colonies. Many offshore islands have distinct tracks made by these birds as they line up in runways to take off each morning (Figure 361.2).

Petrels

Although most species of birds travel extensively and have definite migration paths, some migrate amazing distances in the face of the most hostile weather conditions. One such bird is Wilson's storm petrel. This small bird, only about 15 cm long, migrates over a huge area, from the Antarctic Ocean in the south and Pacific Ocean in the east to the Indian and Atlantic Oceans in the north and west. Tagged petrels have been recorded up to 15 000 km away from their breeding grounds in Antarctica.

Stormy petrels are one of the smallest seabirds and millions congregate on Antarctic ice packs in summer to feed on zooplankton and occasionally dive for small fish such as pilchards.

Some birds fly over the water, skimming the surface for fish. When they touch a fish, they use their wings to brake as their head turns backwards, and they swallow their fish whole.

Some petrels are also good divers. In fact, the white-bellied storm petrels are often considered a nuisance by people fishing because they dive to take bait from lines.

Photo Len Zell

Figure 361.2 Mutton bird runway North West Island

Pelicans, boobies, frigates and relatives

Pelicans, gannets, boobies, cormorants, darters and frigate birds.

The pelican is a popular bird, found all over Australia and lives in estuaries (Figure 362.1). They can be seen diving for fish, filling their beaks and then returning to their nest to feed the young chicks from their mouth.

Bob Moffatt

Figure 362.1 Pelicans

Bob Moffatt

Figure 362.3 Ganet colony

Gannets and boobies

Gannets

Bob Moffatt

Figure 362.2 Masked boobie

Gannets are large seabirds whose distribution ranges across the Tasman Sea to New Zealand. Large colonies of gannets can be found on the west coast of New Zealand on high cliffs where they can launch themselves into the air from rocky outcrops in high winds. They soar out over the Tasman Sea in search of food, torpedoing down on schools of fish at recorded speeds of up to 140 km/hr (Figure 362.3).

Gannets seem to be able to detect changes in weather pressure systems. When the wind is blowing a westerly on an incoming high pressure system, gannets will leave their colony using the offshore winds to carry them out to sea. When the weather patterns change as the low pressure system moves over the country, they will then use the easterly winds of a low pressure system to help them return to shore.

Boobies

The name may originate from the Spanish "bobo," meaning clown.

The booby's distinctive feet play an important role in their famous courtship ritual. The male advertises himself with a special skypointing display (Figure 362.4) and, once he has attracted a female, alternately raises one foot and then the other. Next, the female and the male take turns posing in either the skypointing or "bill-up-face-away" posture, until their actions become simultaneous. After mating, one to three eggs (Figure 362.5) are laid and incubated alternately by both parents for about 46 days.

Bob Moffatt

Figure 362.4 Courtship display - blue footed boobie

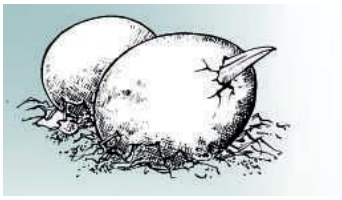


Figure 362.5 Eggs
(Illustration Sharyn Madder)

Even more peculiar is a ring of faeces that is squirted around the nest area. Marine scientists believe this circle marks a nesting territory. Should a chick wander outside this area, or be purposefully "pushed" out by an older sibling (known as "opportunistic sibling murder"), it will no longer be treated as offspring by the parents. This behaviour could have developed to prevent parents from raising another's young.

Figure 362.6 Nesting to young bird
(Illustration Sharyn Madder, Photos Bob Moffatt)

Boobies like gannets are also known for their spectacular hunting, which involves dive bombing - stopping in mid-flight and hurling themselves in a headlong dive into the ocean from heights up to 30 metres. They hit the water at breakneck speed and reappear at the surface about 2 to 3 metres away.

Gull like birds

Gulls, auks, terns, egrets and skuas.

Bob Moffatt

Figure 363.2 Egret

Few gulls are oceanic and a number of species can be found far inland. Graceful flyers, they use their legs for paddling and are buoyant birds who seldom dive beneath the surface.

Probably one of the most familiar seabirds of this group is the silver gull, commonly called seagull (Figure 363.1). These birds, with white/light grey feathers and black tips, orange beak and legs, can be found in flocks on any beach and many inland areas.

Bob Moffatt

Figure 363.1 Silver gulls

Flocks of gulls are interesting to watch, especially during feeding, because they display a large number of obvious behaviours, including a distinct pecking order which forces weaker birds to feed last.

Seagulls form pairs in the breeding season and develop an elaborate recognition system of head bows and squarks so they can identify each other (Figure 363.3).

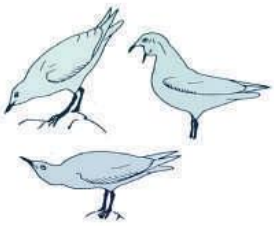

Mark Moffatt

Figure 363.3 Silver gull breeding pair recognition display

Paired birds often preen themselves and do not fight during the recognition process. After a considerable period of courtship, mating occurs when the male jumps on the female back and lowers his tail. The female then raises her tail so that an exchange of sperm can be achieved. A nest is then built and the 1-3 eggs laid. Both parents take turns in rolling the eggs and keeping them warm and after about 3 weeks the eggs hatch. The young chick has a coat of down and they remain in the nest for about another six weeks. The hungry chick begs for food that the parents regurgitate.

Mikle Stugden

Figure 363.4 Tern

After 4 weeks the first adult feathers begin to show and flying commences at about 7 weeks. It takes about 15-18 months for the young to loose their grey colour and dark legs.

They are certainly not shy of humans and have adapted to living around humans almost too well. They have become scavengers, easily feeding on our leftovers and garbage rather than hunting for their traditional food of beach worms and small crustaceans. This has led to an overpopulation of gulls in most coastal cities resulting in government culling programs to reduce their numbers. Seagulls cause problems to planes at airports.

Bob Moffatt

Figure 363.5 Noddy tern

Terns (Figure 363.4 and 363.5) are more marine and may travel the ocean for long periods in search of food. They feed on plankton and small fish catching them with their characteristic plunge dive. Auks are poor flyers and live in the Northern Hemisphere.

Skuas (Figure 363.6) are large birds breeding in Antarctic waters, excellent flyers and feed on other birds such as penguins. Another method is to harass a smaller bird until it regurgitates its food; it can even upend another bird by grabbing its tail.

Bob Moffatt

Figure 363.6 Skua

Check out
www.ramsar.org

Figure 364.1 Bird entangled in fishing line
(Photo Greenpeace)

Figure 364.2 Fairy penguins
(Photo Gould League)

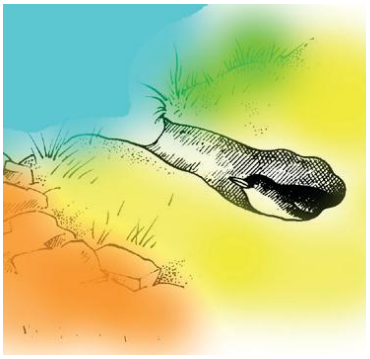


Figure 364.3 Penguin burrow
(Illustration Sharyn Madder)

Controlling troublesome behaviour

In some place in Australia, gulls have become a pest because they compete with terns for food and nesting space.

Gulls can be controlled simply by not feeding them, by taking your rubbish home from the beach and by separating out food from rubbish before you send it to the dump. Try using a compost bin at home, so that the waste that you do send to the tip does not encourage gull numbers to increase.

Dangers to birds

Spilt oil and fuel from wrecked and unseaworthy tankers as well as fishing line have killed countless seabirds (see Figure 364.1).

Birds also suffer when relaxed quarantine laws result in the death of fish they depend on for food. The gill virus wiped out millions of pilchards from Fremantle in Western Australia to the North Island of New Zealand in 1995. Pilchards are an important food source for many seabirds and the loss of this food starved wild bird colonies.

Ground-nesting birds also need protection from people. Many seabirds either build their nests directly on the ground or raise their young in shallow burrows. Both these types of nest are at risk from unwary walkers blundering into nesting sites and damaging nests, eggs and young birds.

Penguins

Penguins are a group of flightless birds that have adapted to living in cold climates. On the land (Figure 364.2), they walk with difficulty but are great underwater swimmers when they tuck their wings and legs in close to their bodies to become streamlined. Penguins can spend up to two years at sea before returning to land. They feed on krill and small fish. Their greatest enemies are killer whales and leopard seals.

Blue penguin

The blue penguin can be found in many places around New Zealand and southern Australia and is the world's smallest penguin. They only come ashore under the cover of darkness and live underground in burrows. Although quite common, its small size and unusual habits make it rarely seen.

The blue penguin stands about 25 cm tall and weighs about 1 kilogram. Plumage is slate-blue with a bright white belly and juveniles are indistinguishable from adults.

Blue penguins make a variety of calls. For example to:

- keep in contact at sea they bark,
- declare territory and advertise for mates they bray,
- let the neighbours know they are home they croon,
- get food, chicks make a high pitch peeping .

Blue penguins breed underground in burrows or natural holes (Figure 364.3). Near human habitation it is not uncommon to find them nesting under buildings, stacks of timber or even railway tracks.

A series of courtship displays (Figure 365.1) ensures pair bonding and after mating (Figure 365.2) one or two clutches of eggs are laid and incubated.

During this time both parents share the incubation and feeding duties. The chicks are guarded by one parent for the first 2-3 weeks, after which both parents must go to sea to keep up the supply of fish. Chick growth is rapid, with adult weight (1000 g) being achieved in 4-5 weeks. Chicks usually leave at 8 weeks and are independent from then on.

Blue penguins usually breed for the first time at 2-3 years of age. Long term partnerships are the norm, but divorce is not uncommon. There is a high rate of juvenile mortality, but individuals can reach up to 25 years of age.

Blue penguins are very faithful to their home site. Chicks will often return to within a few metres of where they were raised and once settled in an area never move away. Less than 1% of juveniles disperse to other breeding sites.

Penguins feed on a variety of surface schooling fish, squid and crustaceans up to 25 km offshore with a daily round trip of about 75 km (not bad for an animal weighing in at a kilogram and 25 cm tall!)

Long winter feeding trips of up to 750 km (one way) have been recorded and blue penguins can reach speeds of up to 6 km/hr underwater.

Bob Moffatt

Figure 365.1 Courtship

Bob Moffatt

Figure 365.2 Nesting

Adélie penguins

The Adélie (Figure 365.4) is a medium-sized penguin that stands about 0.7 m tall and feeds mainly on krill. Males and females are about the same size and spend their whole life in Antarctica. They breed in spring and summer in rocky areas free from melting snow and make their nests out of small stones. Like other birds, the Adélie penguins feed their young by regurgitating food from their stomachs. The stomachs of Adélie penguins contain antibiotics to sterilise the food while it is stored there which allows the parents to feed the chicks small portions of krill each day. These antibiotics preserve the food for several weeks.

(Photo Nick Mooney)

Figure 365.4 Adelie penguin

Emperor penguins

Emperor penguins (Figure 365.5) are migratory birds that build their nests from rocks in a rookery with thousands of other birds. After each pair's single egg is laid, the male takes over the incubation while the female leaves the nest to fish at sea. The males then keep the eggs between their legs and on top of their feet for about 70 days until they hatch. The females return to feed the young while the males, having lost considerable weight during the nursing period, struggle to the sea to feed.

An amazing feat of nature is how these penguins find each other after so long and among so many other penguins.

Marine scientists believe that they do this through voice communication in which they call to each other when they complete their journey over the ice and snow.

(Photo CSIRO Antarctic Division)

Figure 365.5 Emperor penguins

Figure 366.1 Osprey
(Bob Moffatt)

Birds of prey

Family Pandionidae

Bob Moffatt

Figure 366.2 Sea eagle

Two of the most efficient hunters among the seabirds are the sea eagles and ospreys that are found all around our coastline. White-breasted sea eagles are white underneath and charcoal grey black on the back and on the top of their wings.

Larger than ospreys (Figure 366.1), they grow to nearly 1 m long with a wingspan of about 1.5 m. These birds, like other eagles, are magnificent fliers, soaring to great heights with the slow beat of their broad wings then descending very rapidly and accurately upon unsuspecting prey that they have pinpointed with their superior vision. The sea eagles' diet includes fish and sea snakes, and occasionally the prey of other hunters, including ospreys, that they chased and hassled until they have dropped what they were carrying.

Observing birds

People who study birds are called ornithologists and birds have been watched and studied since recorded history. Perhaps our fascination for birds comes from our own inability to fly and we marvel at the skills birds have achieved to become the sole masters of the skies.

Birds can be observed with binoculars or by listening to the whole range of songs each makes. In the morning there is the dawn chorus where each bird gets up and makes its first call at a different time. You can make a tape recording of this dawn chorus from first light (well before sunrise).

Features

Birds have a number of distinct features as shown in Figure 367.1. If you are describing a bird, you often describe some or all of these features. Birds can also be described by their flight patterns or how they hold their wings in flight. Fast-flighted birds have long pointed wings, soarers have broader wings and feather tips, and fishing birds (such as pelicans) have large wings to help manoeuvre them during landing.

Where birds live is often reflected in their features. For example mud flats will attract waders with long legs and bills adapted for hunting local available food. Spoonbills and herons are good examples.

Wading birds are possibly the easiest to observe but the hardest to identify because some species look alike. Look for differences in bill and wing shape, leg length and feather colour. A good reference book is an invaluable tool.

Behaviour

Gulls are great birds to watch in a group. Some birds are more dominant than others and will chase or put on displays of aggressive behaviour as previously described. Other activities to watch for (Figures 366.3) include submissive behaviours, being alert, hovering, courtship displays or the birds may huddle together just to keep warm.

Alarm call

Keeping warm

Being aggressive

Figure 366.3 Sea gull behaviours
(Illustrations Mark Moffatt)

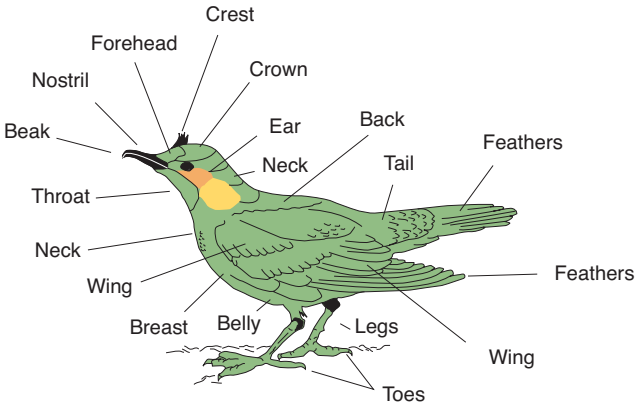


Figure 367.1 Common bird features (After Vernon)
(Illustrations Kerry Kitzelman and Bob Moffatt)

Flight

Some birds fly with their necks tucked in (Figure367.2) while others cannot tuck their necks in (Figure 367.3).

Light

The best way to observe birds is with the sun behind you. Mornings are best in Western Australia or western New Zealand. Evenings are best in eastern states. In southern states, you can pick a spot at any time of the day, however, birds are most active in the early morning.

Tides

As the tide goes out so do the birds therefore at high tide they will congregate closer to you. A pair of binoculars will help you get a close look at some of the behaviour patterns associated with animal space and territory.

Ground nesting birds

(A real case for careful management)

These birds leave the island and fish for the best part of a day. Each night they return in very large numbers to rest, build a nest, court, mate, or feed their young. Some birds, like the mutton bird, live on the ground in burrows. Here they reproduce and raise their young.

Humans walking around can collapse these burrows, killing the chicks in the process (Figure 367.4). If you have the chance to visit a sand island and are there when the mutton birds are, you will have a chance to witness a most amazing event each morning.

Thousands of mutton birds wake up early and line up on specially created “runways” prior to taking off for the day's fishing (look back to Figure 361.1). If you are unlucky and pitch your tent in the runway, then you will get a rude awakening in the morning. This also happens when visitors play loud music, run generators, operate speed boats at excessive speeds or generally move about the island. Usually once a bird is forced to leave its nest it may not return, leaving the chicks to die.

Figure 367.2 Some birds fly with their necks tucked in.
(Photo Bob Moffatt)

Figure 367.3 Some birds fly with their necks straight.
(Photo Bob Moffatt)

Figure 367.4 Ground nesting birds need special management plans.
(Illustration Qld Marine Parks)

Figure 367.5 The mutton bird is a ground nesting bird.
(Photo Wet Paper)

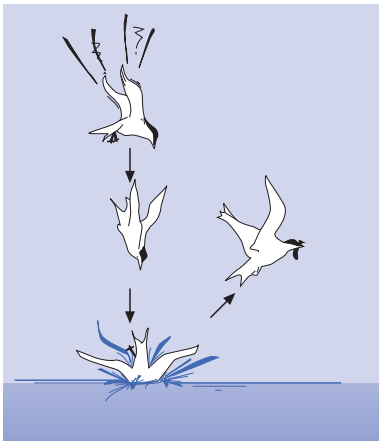


Figure 368.1 Tern feeding
(Illustration Mark Moffatt)

Figure 368.2 Cormorant feeding
(Illustration Mark Moffatt)

Figure 368.3 Regurgitation from the parents crop is one of many methods used to feed their young.
(Illustration Brady Moffatt)

Feeding

The sea is a three-dimensional space which makes hunting for food difficult. On land, a prey can only move along one plane, however a fish can move up, down and sideways. Seabirds must be adapted to flying in the air and hunting under the water.

Adaptations

Birds must be able to reduce their buoyancy when they dive underwater. To do this, they exhale air from their lungs, squeeze air out from under their skin with their wings, tuck their feathers in close to streamline their bodies, slow their heart rates and squeeze oxygen out of their blood to supply their brains.

Feeding methods

Plunge diving is one method of feeding. If you get a chance, watch a tern feeding. It selects its prey while hovering, bomb dives using its wings for entry speed, closes the wings at the last moment before entering the water and re-emerges with a fish (Figure 368.1).

Cormorants locate schools of fish from the air and then settle on the water, diving and swimming to catch fish as shown in Figure 368.2. Their long necks can even probe rock crevices underwater. Their skills are used by humans to catch food. Fishermen in parts of Asia fish with trained cormorants by placing a ring around the bird's neck and attaching a line. They set the bird free to catch a fish and regurgitate it for its owner.

Surface dipping is another method of feeding used by skuas, gulls, terns, pelicans terns and petrels. A pelican feeds by dipping its bill into the water then throwing its head back, bringing the bill full of water forward and upward.

Once out of the water, it presses its bill against its chest, pushing all the water out through its bottom jaw. Food trapped in the bill is then swallowed. Food can be stored in the bird's digestive system and regurgitated later to feed its young back at the nesting site. Groups of pelicans have also been observed encircling and herding fish to a specific area where the birds cooperatively take turns to fish.

Except for penguins and auks which use their wings to swim underwater, most birds feed from the surface.

A variety of methods have been identified as shown in Figure 369.1 including:

- surface plunging - the bomb dive
- chase prey underwater
- surface seizing
- surface dipping
- skimming
- surface filtering
- aerial pursuit
- pattering
- scavenging.

(Illustration Kerry Kitzelman)

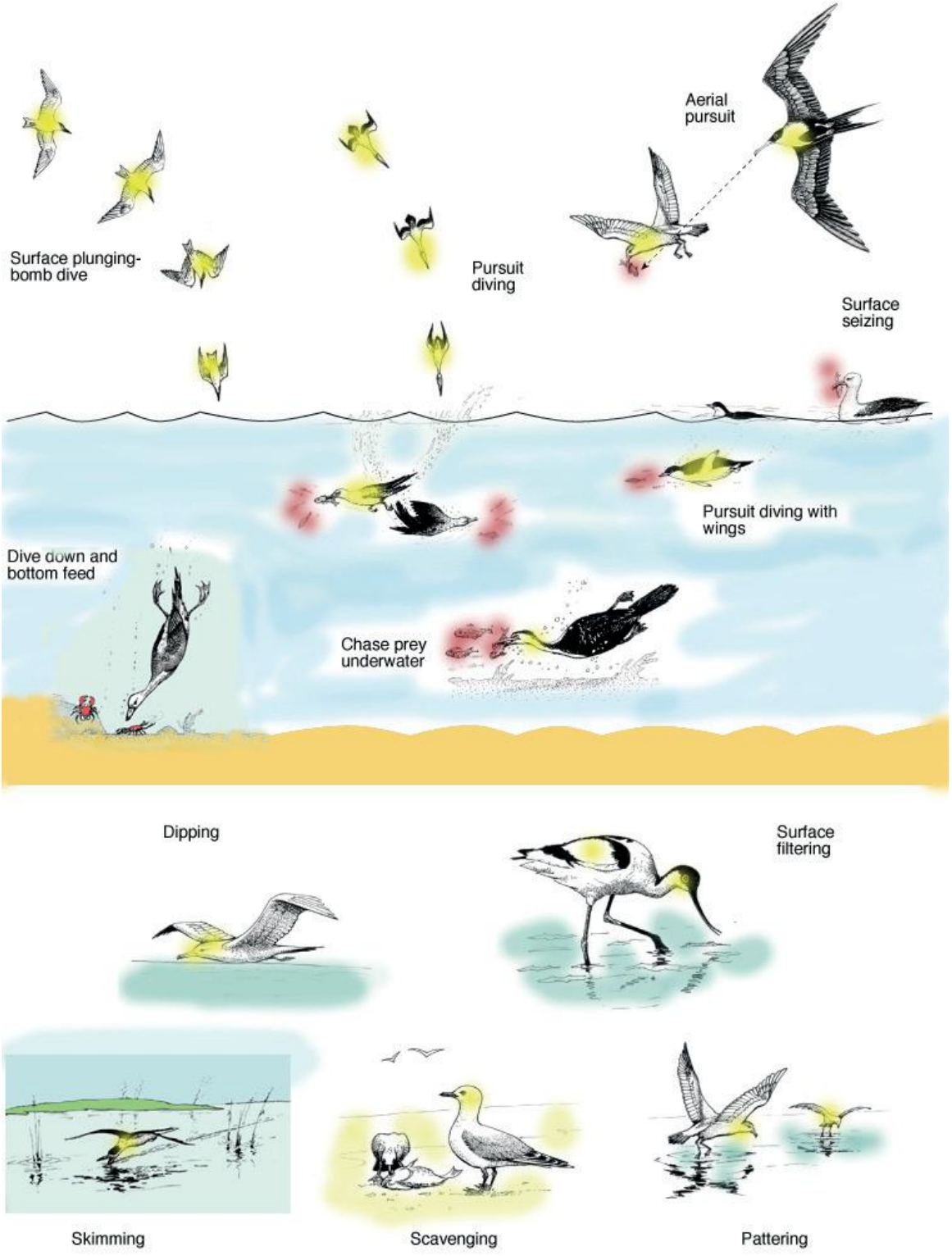


Figure 369.1 Some feeding patterns of birds
(Illustrations Kerry Kitzelman)

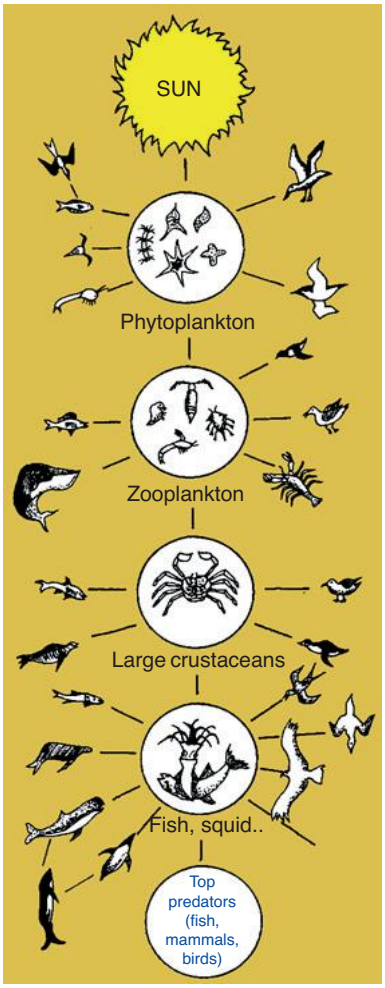


Figure 370.2 Food sources for sea birds (After Thurman and Webber)
(Illustration Brady Moffatt)

Figure 370.3 Pied cormorants
(Bob Moffatt)

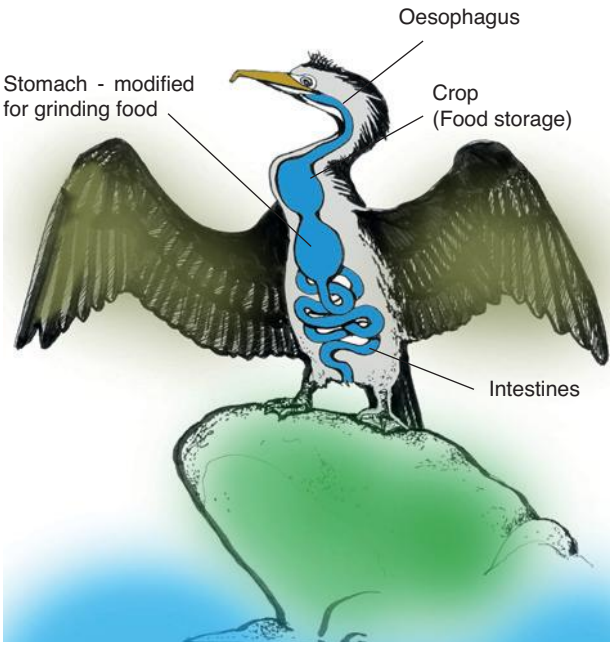


Figure 370.1 Cormorant (After Lerman)
(Illustration Kerry Kitzelman)

Food sources

Birds feed on a wide variety of animals and plants ranging from phytoplankton and zooplankton to small fish and crustaceans. A summary of food sources is shown in Figure 370.2.

Importance of seabirds

Birds form an integral part of the coastal ecosystem and are usually the highest order consumer in the food chain. Any change lower in the food chain usually shows up in birds. They are well adapted with light skeletons and feathers and have keen eyesight and are excellent at catching fish.

Seabirds are scavengers of dead fish, predators of squid and fish, or feeders on plankton.

They are responsible for transferring seeds from island to island and provide a way for plants to reproduce. Their droppings are important for plants because they heap fertiliser on island soils which would otherwise be very poor in nutrients.

Seabird nesting sites in the same parts of the world have been in use for millions of years and, in places where rainfall is low, the accumulated wastes (called guano) build up into thick layers of super concentrated phosphate. Some guano deposits on rocky islands in the Pacific Ocean are up to 18 m thick. It is mined by many countries as a source of fertiliser.

Some coastal African countries also have set up offshore wooden platforms as artificial guano islands. These have become profitable sources of fertiliser for export markets and local industries. However, some scientists believe that mining guano interferes with the nesting patterns of seabirds.

Life at sea and migration

Most seabirds feed on small squid, fish, krill, egg masses and the dead remains of other animals. Many can migrate for long distances and travel from one hemisphere to another. Migratory birds cannot nest at sea but must return to land to breed and raise their young.

The places where they breed are therefore special places and require careful management. This is why island national parks have been created and international conventions agreed to secure breeding places for migratory birds. One such convention is the Ramsar convention which protects places in different countries where birds can rest or breed.

Some species fly non-stop for 12 days over 25,000 km to migrate from Siberia in Russia to rest and feed on the mangrove lined flats of Hervey Bay. These birds need undisturbed rest before their migration return journey so coastal development and planning needs to take into account resting sites.

Birds that breed in the northern hemisphere, especially those in regions with definite seasonal differences tend to migrate, even travelling down into the southern hemisphere. The Arctic Tern makes the longest journey, migrating from the North Pole in autumn down to the South Pole and then back again in the spring. Birds who breed in the southern hemisphere also migrate. However very few, except perhaps sea birds, migrate from the southern to the northern hemisphere. The warm temperatures close to the Equator are the wintering home of many birds (although many will choose a spot that is not as far, but still warmer, and has more food than where they left).

When migration occurs

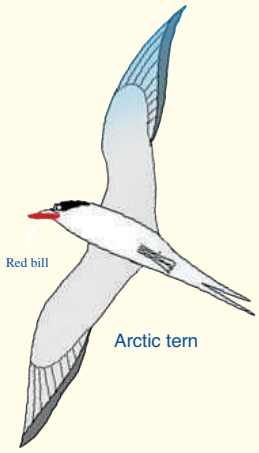
The winds must be blowing in the direction that the birds want to go. Birds will usually wait until the most favourable weather conditions then set off on their journey.

Ornithologists watch the weather to help predict when large numbers of birds will be passing through their area. A strong wind in the right direction will speed the birds on their way. If there are strong headwinds, the birds' speed will be greatly reduced, therefore it will need more fat reserves to travel the same distance. Many birds that encounter storms and strong headwinds perish in the seas. If these weary birds are over land, they will drop down and land, find food and rest before continuing.

Odd fact

Flight record

The longest flight recorded was by an Arctic tern which nested in the Arctic and then flew to within sight of the Antarctic for the winter (summer in the Southern Hemisphere) a round trip of 38 000 km!



Web reference

http://birding.about.com/library/weekly

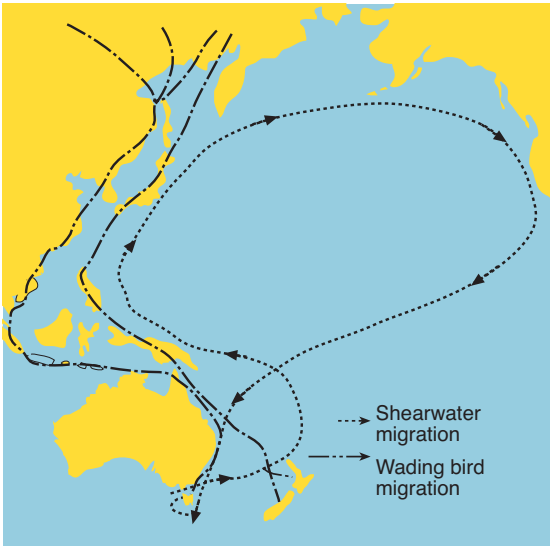


Figure 371.1 Short-tailed shearwater migration - where would you declare RAMSAR sites?
(Jim Kneale)

http://www.cetacea.org/watch.htm

Class Mammalia

The word 'mammal' comes from the Latin word for breast because all mammals suckle their young.

Mammals have four-chambered hearts, are warm blooded and have hair or fur at some stage of their lives. In some parts of the world, all marine mammals are protected however in other parts they are still hunted for food or killed for scientific research (although this is often disputed). Three orders of marine mammals are Sirenia, Carnivora and Cetacea.

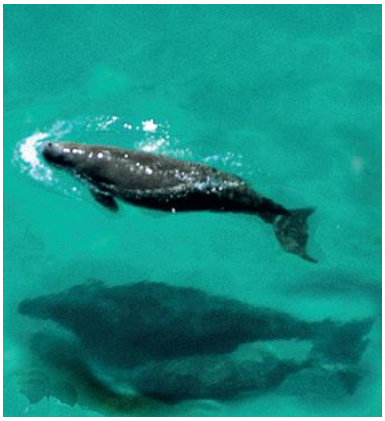


Figure 372.1 Dugongs
(Photo Qld Fisheries)

Figure 372.2 Dugong feeds on seagrass.
(Illustrations Sharyn Madder)

Order Sirenia

Manatees, sea cows or dugongs were named after the sirens, singing mermaids of Greek mythology who lured sailors to their doom on rocks and reefs.

Dugongs feed off seagrass, sometimes eating more than 40 kg a day, and so have been called the lawn mowers of the sea. Much of their time is spent grazing on these seagrass beds mainly close to shore from latitudes at Shark Bay WA to Moreton Bay Qld.

They also play an important role in the traditions and culture of Aboriginal and Torres Strait Islander peoples. Dugongs have existed for more than 60 million years which means that they were around at the same time as the dinosaurs! Unfortunately one of their close relatives Steller's sea cow was hunted by fishers to extinction.

While manatees have a paddle-shaped tail, dugongs have a tail that is pointed on the ends, very much like a whale's (Figures 372.2 and 372.3). Although dugongs have very small eyes and no external ears, they can still see and hear underwater.

Behaviour

Dugongs rest in the deep water during the day and move towards the shoreline at night to feed. The dugong uses its flippers for balance and moving along the ocean floor as it grazes. They can hold their breath for about 20 minutes, however they usually come up to breathe every three to five minutes.

Figure 372.3 A dugong (Courtesy Queensland Transport)

Feeding

The upper lip is split down the middle and each side can move independently. The lower lip and jaw have horny pads that help it grasp plants. Its teeth are broad and flat, well suited for grinding up plants.

Reproduction

Dugongs give birth to only one calf every three to five years. The gestation period, or time it takes the calf to develop inside the mother, is about thirteen months. Once born, a calf immediately swims to the surface for its first breath of air. Sometimes a calf clings or rests on its mother's back as she feeds or sleeps and comes up to the surface for air when she does. The calf drinks milk from its mother's teats which are under her flipper and although the calf is able to graze on plants soon after birth, it nurses and stays with its mother for up to two years. The father does not participate in the care of the calf, and the mother and father do not stay together as a pair.

Dugongs can live up to 70 years old and breed from as early as nine years.

Order Carnivora

These are seals (Figure 373.2), sea lions and walruses which are closely related to dogs and cats. All possess paddle-like flippers and hind limbs for swimming and moving on land.

Seals and their relatives must leave the water to breed. Their young are raised in colonies on rocky shores (Figure 373.1) found around the southern coasts of Australia, New Zealand and Antarctica.

They are well adapted to a cold environment having a sleek coating of hair on a tough skin with numerous oil glands. Under the skin seals have a thick layer of fat called blubber which insulates them from the cold.

Bob Moffatt

Figure 373.1 Seal and pup

Australian fur seals

Australian Fur Seals are found mainly in Bass Strait between Victoria and Tasmania and small patches off the coasts of New South Wales and South Australia. Breeding now occurs at only 9 sites, all in Bass Strait. These sites are all "rocky" eg rock slopes, ledges, pebble beaches reefs and caves. Population size is hard to determine but estimates suggest between 35,000 and 60,000.

Australian Fur Seals dive deep in Bass Strait to feed on small squid, octopuses, fish, crustaceans and rock lobsters. Their preferred prey are squid and small fish, such as schools of pilchards or mackerel.

It seems probable that it finds some prey by echolocation. Australian Fur Seals have very keen sight.

The fur seal is an extremely good swimmer and diver and moves eloquently through its marine environment. The same can not be said for its movement across land where it uses its four flippers in a variety of gaits and waddles to move at speeds from a slow walk to a fast gallop.

You can read more at:
http://home.mira.net/~areadman/aussie.htm

Figure 373.2 Seal Galapagos Islands
(Photo Bob Moffatt)

Figure 374.1 Weddell seal and pup
(Photo Australian Antarctic Division)

Weddell seals

The Weddell seals live under the stable inshore ice that surrounds the continent.

They are quite large (about 3m long) and breathe air through cracks in the ice. This is difficult in winter.

During this time they use their teeth to keep open small holes in the ice and must use their remarkable powers of navigation to find these underwater holes in the darkness of the Antarctic winter.

During the summer months, the seals climb out of their holes in a process called hauling out.

While on the ice females also give birth to young seals called pups.

Pups grow rapidly and learn to swim, feed and haul-out in their first week.

During the breeding season, males defend their underwater territory and breathing holes from other males.

Weddell seals hauling out
(Photo Australian Antarctic Division)

Breeding

Breeding of the Australian fur seal occurs on exposed sites such as rock slopes, ledges, pebble beaches and reefs. Adult breeding males (bulls) arrive at the breeding sites in late October (spring) and establish their territories (resolved through fighting).

Pregnant females (cows) mostly arrive in late November and generally give birth to a single pup about 2 days later, virtually a year since copulation, (though gestation actually begins 3 to 4 months after copulation). After giving birth, the fur seal female will remain ashore for 6 days and then re-mate. They then go to sea to feed for a few days at a time, returning for 2 to 3 days to nurse their pups. This pattern continues for about 10 -11 months until the pups are weaned.

Weddell seals

Weddell seals have no natural predators when on fast ice. At sea or on pack ice, they become prey for killer whales and leopard seals, which prey primarily on juveniles and pups.

Crabeater seals

The crabeater seal does not eat crabs but krill and has specially adapted teeth with extra projections to strain out the krill after gulping a mouthful of sea water. Marine scientists estimate crabeater seal populations consume over 100 million tonnes of krill a year, possibly making them the world's largest consumer of this food source.

Elephant seals

Elephant seals are named for the trunk-like projection over the male's mouth (Figure 374.2). They have a thick layer of blubber and for many years they were hunted and their carcasses boiled down to make oil. Elephant seals can dive to depths of more than 1500 m and can stay submerged for up to 2 hours while they hunt for squid and fish.

Elephant seals breed in groups called harems in which a single dominant male can control up to 50 females. In groups larger than this, other males are allowed into the group. ANARE scientists have estimated that harems can grow to include 1000 females and more than 30 males.

Figure 374.2 Male elephant seal
(Photo Australian Antarctic Division)

Order Cetacea

The cetaceans are almost certainly one of the best-loved groups of animals in the sea. Dolphins and whales are highly intelligent animals and at times, even seem to enjoy human company.

Communication

Cetaceans have highly developed sonar systems for navigation and for finding food, as well as sound communication systems to communicate with each other. Dolphins can locate fish (Figure 375.1) and whales can dive to great depths to find large squid (Figure 375.2).

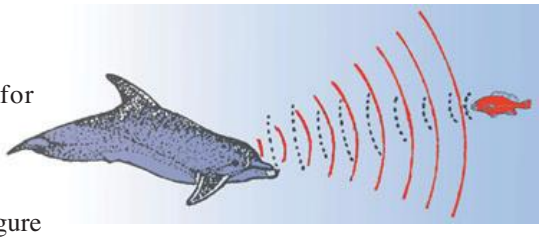


Figure 375.1 Dolphin echolocation
(Illustration Steven Byers)

Echolocation

Cetacenas are carnivorous and feed by a special adaptation called echolocation. They can hold their breath while underwater and dive to great depths. Smell, taste and touch are poorly developed so they rely on vision and hearing for most daily activities.

As sound travels further and more clearly underwater, cetaceans have exploited this to the fullest. Sounds are also used in daily communication, location of food and navigation.

Figure 375.2 Whale echolocation
(Illustration Steven Byers)

Making sound

Sound is made in the nasal cavity and is amplified by the melon and head region including the upper jaw (Figure 375.3). Sound waves are sent out at a variety of frequencies and bounce back off objects in front like radar or sonar. The returning sound waves strike the lower jaw which then transmits the vibration to the inner ear located just below the brain where analysis takes place.

Whales are thought to be able to communicate over hundreds of kilometres using very low frequency sound. They have the largest brain of any animal — the brains of some whale species can weigh as much as 7 kg (a human brain weighs about 1.3 kg).

The two main groups of cetaceans are the toothed whales and the baleen whales.

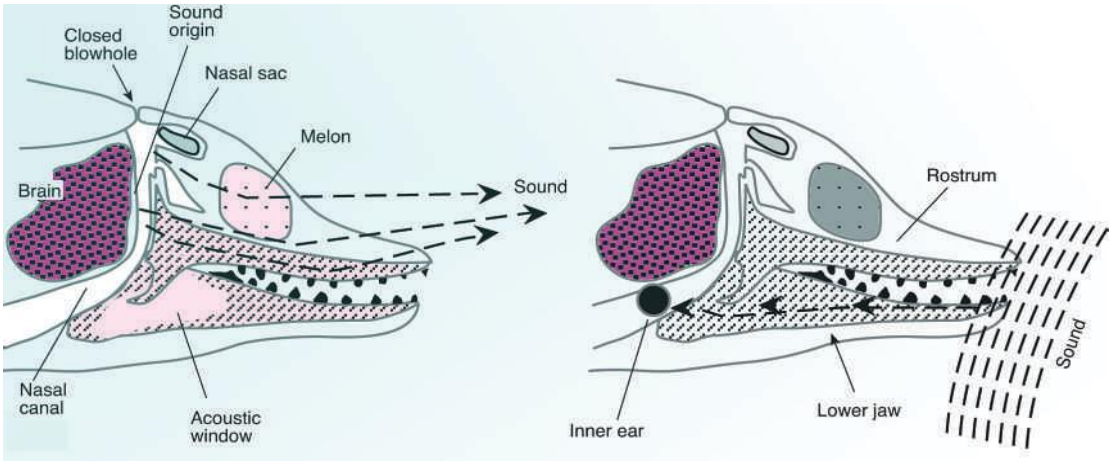


Figure 375.3 Echolocation in cetaceans (After Lerman)
(Illustration Bob Moffatt)

Figure 376.1 Killer whales
(Albany historical society)

Figure 376.2 Killer whale
(Photo Chantel Latter)

Figure 376.3 Dolphin
(Neville Coleman)

Toothed whales

These include dolphins, porpoises, sperm whales, killer whales and narwhals. This group has many peg-like teeth with which they grasp their prey, usually fish or squid. Toothed whales often hunt in highly organised packs. Killer whales for example, will actually beach themselves to catch seals lying on the shore. They have also been observed breaking through solid ice to catch seals and penguins.

Killer whales

Killer whales (Figure 376.1) are the largest predators of mammals averaging 5 metres in size and inhabiting all oceans of the world. Although killer whales can be found in both the open ocean and coastal waters, they primarily inhabit the continental shelf in waters less than 200 m deep. In cold water areas, their distribution is limited by seasonal pack ice.

Because of their wide distribution, the worldwide population of killer whales is unknown but population estimates in the Antarctic range from 70,000 to 180,000. There is extensive information about killer whales at http://www.seaworld.org/infobooks/KillerWhale/home.html

Dolphins

Dolphins are one of the best known marine mammals because of their relationship to humans and their roles in movies such as *Flipper* and *Dolphin Cove*. They have all the internal features of humans and are physiologically very similar.

Diving and breathing

As humans, we can only wonder at the diving ability of dolphins considering the effects pressure has on our bodies. Dolphins breath at the surface by opening their blow hole and filling their lungs. This very efficient mechanism removes over 90% of air in the lungs in less than a second which accounts for the water spout seen at times.

This blow hole closes and any water trapped is prevented from entering the lungs by the tongue. The dolphin exhales before diving; the alveoli in the lungs collapse and any air is forced into the trachea. Because there is no air during the dive, nitrogen does not become a problem.

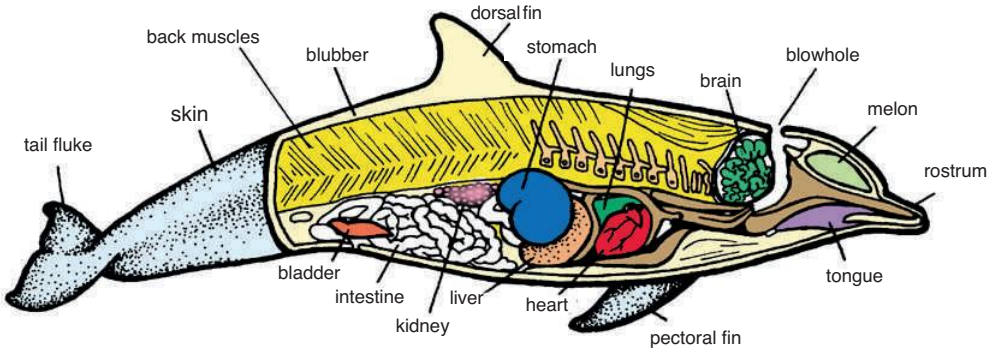


Figure 377.1 Dolphin internal anatomy (After Sea Word Dolphin Project 1988)
(Illustration Rose Bedford)

First breath

Baby dolphins are born underwater and need to he pushed to the surface by the mother at birth (Figure 377.2). It then feeds underwater from milk squeezed from the mothers nipples as they swim close by.

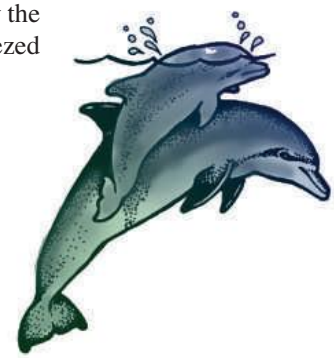


Figure 377.2 Mother pushes calf to the surface for first breath.
(Illustration Rose Bedford)

Physiological adaptations to diving

To prolong diving time, all marine mammals have large amounts of blood and a high concentration of red blood cells allowing the animal to carry more oxygen. In additional to this extra blood, muscle tissues contain a substance called myoglobin which can store oxygen in tissues. Considering a blue whale can dive for up to 90 minutes, this stored oxygen comes in handy for basic metabolic activities.

The blood also contains glucose (blood sugar) which provides the energy for muscles during diving. Ratios of blood sugar are similar for land mammals but because there is more blood, this gives the animal more available energy for continuous swimming (the swim from Antarctica to the tropics and back each year is a long way).

Marine mammals are also able to modify the amount of oxygen they need to metabolise food and use glucose in a mixed anaerobic/aerobic way (if you can use glucose without oxygen in your metabolism, you can conserve it for other vital purposes such as heart and lung maintenance). During the dive the blood is shunted to the brain, heart, muscles and lungs and away from nonessential organs such as stomach and kidneys (Figure 377.1). These adjustments in circulation effectively conserve the supplies of oxygen during the dive. The heart rate also slows.

Other structural adaptations include a flexible skeleton which allows the ribs to be compressed during diving (Figure 377.3).

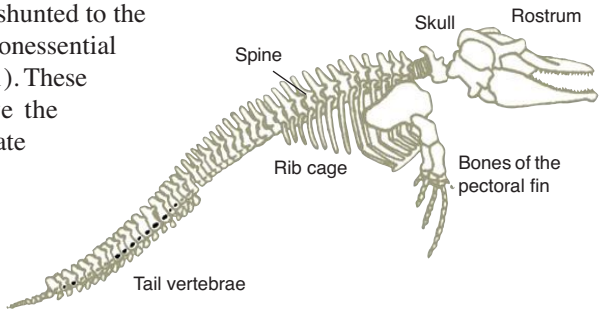


Figure 377.3 Flexible skeleton allow cetaceans to dive to great depths.
(Illustration Rose Bedford)

Baleen whales

These are whales with no teeth and include right whales, humpback whales and blue whales. Instead of teeth they have a filtering mechanism. This mechanism consists of a series of plates that hang down from the gum region of the upper jaw (Figure 378.1). The plates are not teeth but actual outgrowths of the palate made of keratin, the structural protein that in other mammals forms hair, fingernails and claws.

While feeding, they gulp large amounts of sea water and small planktonic animals. They can circle a large quantity of krill and fish and use a method called bubble netting where the whale comes up from below the food source and gradually encircles it by sending a steady stream of bubbles up from the blow hole. The bubbles concentrate the food which is then gulped by taking in a vast amount of water.

The tongue drops and the mouth closes. The tongue then comes up forcing water out through the baleen and trapping the food. The whale then swallows the food.

Many of the baleen whales were hunted to the point of extinction. The right whale was even given its name because it was the 'right' whale to catch. They floated when shot which made them easy to haul on board the whaling ship supplying a good yield of oil and meat. Australia did not stop whaling until the mid –1970s (see Chapter 18).

Some countries, including Norway and Japan, still insist on hunting whales despite bans on this practice by the International Whaling Commission.

The largest of the dinosaurs was probably *Diplodocus* or *Brachiosaurus*. They were as long as 30 m and weighed as much as 50 tonnes. Blue whales have been captured that were 30.5 m long and weighed 135 tonnes.

The blue whale is almost certainly the largest animal which has ever lived.

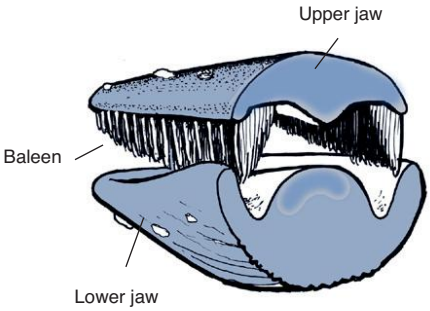


Figure 378.1 Baleen whale cross sectional view of mouth
(Illustration Kerry Kitzelman)

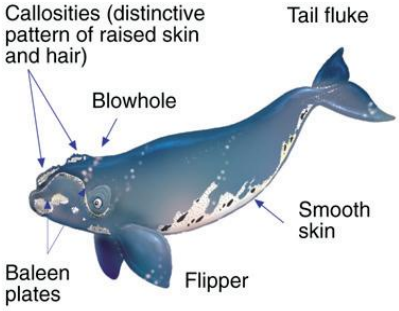
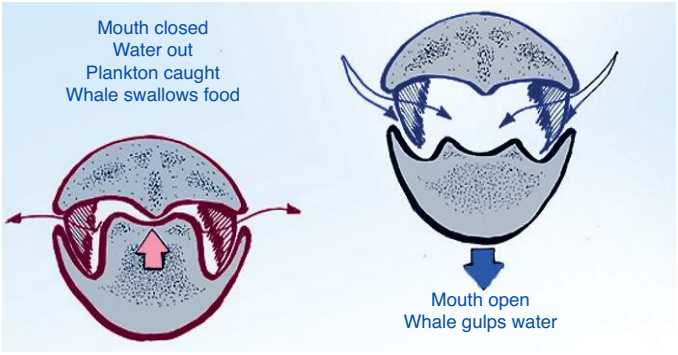


Figure 378.2 Southern right whale
(Illustrations Rose Bedford, Kerry Kitzelman, Mark Moffatt)



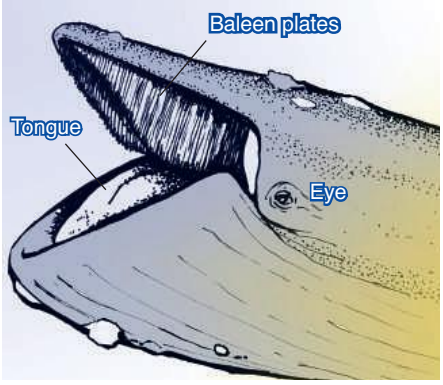


Figure 378.3 Whale feeding (After Thurman and Webber 1984)
(Illustration Kerry Kitzelman)

Although whales were still hunted off the Australian coast just over 30 years ago, whale watching is now an important tourist industry. Whale watching can be from the shore or from a boat. People travel from all over the world to see whales off our coastline.

When whales are migrating along the New Zealand and Australian coasts, cruise boats take tourists out on daily outings sometimes with spotter planes used to direct the vessels to where the whales are. Strict rules now govern whale watching.

Numbers of some whales are certainly increasing. Unfortunately, the largest of the whales, the blue whale, may still become extinct because there may be too few of them left to breed the next generation.

Figure 379.1 Humpback whale diving sequence - whales are identified by the way they dive and by their tail flukes.
(Illustration Steven Byers)

Humpback whales

The following information is from the Humpback Whale brochure — Queensland National Parks and Wildlife Service, reproduced with permission.

The humpback whale Megaptera novaeangliae is named from the Greek 'megas' meaning great and 'pteron', a wing, because of its huge wing-like flippers. It is the fifth largest of the great whales. Adult females grow to 15 m, slightly longer than males. A mature humpback can weigh 40 tonnes.

Humpbacks are generally blackish with white under and at the sides. The flippers or pectoral fins often carry large barnacles. Golf ball-sized protuberances on the head are called tubercles. A long coarse hair which grows from the centre of each tubercle is believed to act as a sensor.

Each year humpback whales migrate from Antarctic to the sub-tropical coastal waters of western and eastern Australia and South Pacific islands where they give birth and mate during winter and spring.

At least 2000 humpbacks migrate approximately 6000 km to Australia's eastern coast. Groups (or 'pods') of whales start to arrive in southern Great Barrier Reef waters in mid-June and in the following weeks might move further along the Reef.

Around September, the whales migrate south back to Antarctic waters, many stopping for a period of time in bay and inlets along the Australian East and West coasts but by October most humpbacks have left these waters.

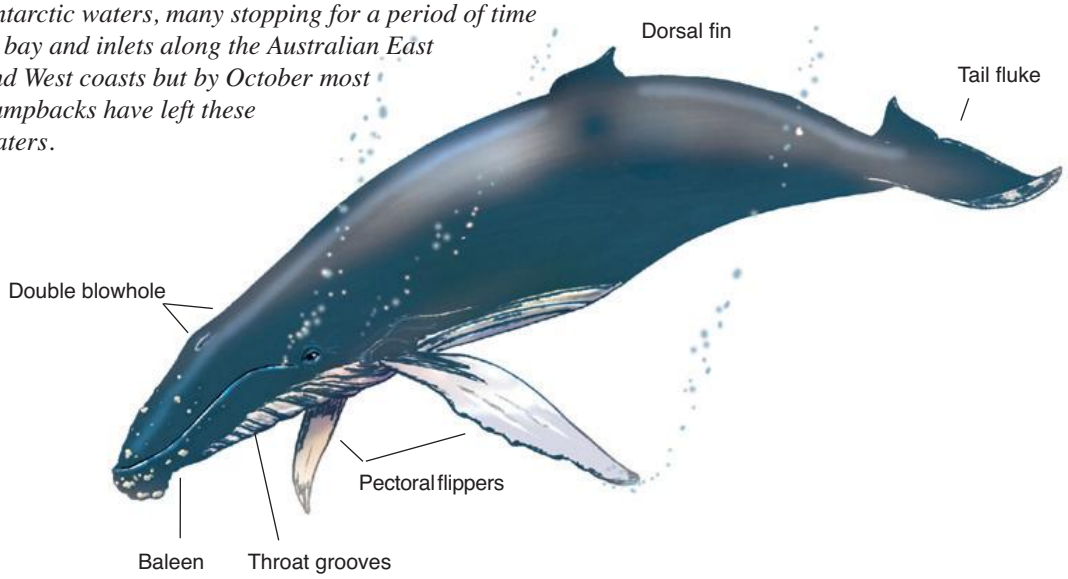


Figure 379.2 Humpback whale external features
(Illustration Steven Byers)

Figure 380.1 Breaching - humpback whale
(Photo Nevile Coleman)

Figure 380.2 Mating
(Illustration by Steven Byers)

Behaviour

The most obvious humpback behaviour is that which occurs above water (see page opposite Figures 381.1 - 381.5). We do not know why humpbacks behave in some of these ways and little is known of their underwater behaviour patterns or how these relate to the more obvious above-water patterns.

Breaching

A humpback's grace and vigour is well demonstrated with the breach. Propelling most of its body from the water, the whale then turns to crash spectacularly onto the water.

Pectoral slapping

Humpbacks can come to the surface and show their pectoral fins, lying on the water to slap one or both fins.

Blowing

Look for a blow when whale watching. Adult humpbacks have two lungs, each the size of a small car. As it surfaces, the whale exhales forcefully through two blowholes on top of its head. A distinctive cloud is formed from vapour condensation and water collected around the blow hole. Unlike the drawings of ancient map-makers, the whale does not blow a stream of water.

Spy hopping

Cetaceans use many senses for orientation and navigation, one of which is vision. A humpback will rise almost straight out of the water so its eyes are just clear of the water, before slipping back into its aquatic world.

Tail slapping

While submerged near vertically, a humpback can slap its flukes on the surface of the water.

Possibly a threat signal, tail slapping might continue for long periods of time.

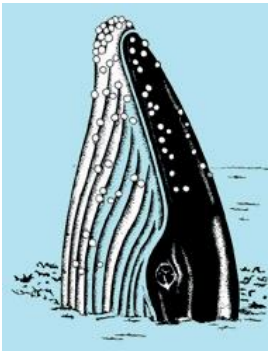


Figure 381.1 Spy hopping
(Illustration by Steven Byers)

Breeding

Antarctic waters provide whales with their richest food source, but the cold water is thought to be too harsh for newborn calves which have no protective blubber layer. So humpbacks mate and give birth in warmer waters.

Gestation takes 11-12 months. At birth, calves are about 4-5 metres long and weigh more than one tonne. A cow feeds her calf milk with an unusually high fat content (35 percent compared with 2 percent for human milk). Hundreds of litres are drunk daily.

Calves are nursed until they are one year old and about 8 metres long. Humpback whales mature in less than 10 years. Pods of mothers and calves are often escorted by an adult male. Successful reproduction and nurturing is critical to continuing recovery so minimising human impacts is important.

Feeding

One of the world's largest whales, the humpback's bulk is supported by a diet of krill (shrimp-like crustaceans up to 5 cm long), plankton and small fish. Humpbacks sieve food from huge volumes of water using specialised fringed mouth-plates. These mouth-plates or baleen are made of keratin, like our fingernails. Bristle edges form a mesh to filter food from water. These bristles gave the baleen whales their scientific name Mysticetes, Greek for 'moustached whale'.

Humpbacks feed in the Antarctic where food is plentiful in preparation for their lengthy northern migration. Anecdotal evidence suggests opportunistic feeding of small bait fish may occur along the migration path. Blubber reserves provide the bulk of their sustenance during migration.

Songs

Humpback whales produce the longest and most varied 'songs' in the animal world. Their intricate vocalisation range from high squeaks to low, guttural growls. Songs are produced by moving air back and forth through body passages.

While all whales vocalise, only males are believed to sing. The song might function as a sexual display, advertising the presence of a breeding male and keeping a family group together.

Analysis shows the sounds produced are organised into long sequences. Each sequence normally lasts 10-15 minutes and can be repeated without a pause for hours.

Whale song sequences are arranged into cycles characteristic of a particular whale population. Songs evolve over time and occasionally within a season, but eventually the changes are incorporated into the current sequence.

These haunting sounds can travel kilometres under water and can be heard above the surface through the hulls of vessels.

Bob Mollatt

Figure 381.2 Other behaviours

Exercises

From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

B9. Can you prepare some answers to whale questions asked by tourists?

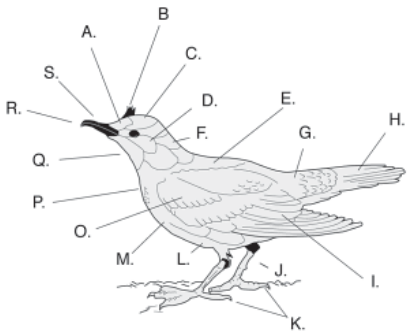
B10. How do turtles feed and reproduce?

D2. How do sea birds survive?

Questions

Knowledge

1. A bird has a crop and a stomach. What are these used for?
2. Birds can feed on prey in the water in 12 different ways. Name any ten ways and describe how the bird catches the food.
3. How are whales and dolphins protected under Australian law?
4. What is baleen?
5. How do dolphins breathe?
6. Name the parts of the bird labelled A-S below.



Application

7. Which is more closely related: an octopus and a scallop, or a bony fish and a bird? Give reasons for your answer.
8. A saltwater fish was swimming up a river. What problems would it experience and why?
9. Why should you not frighten birds resting on a beach?
10. How can you tell the age of a crocodile?
11. Describe the features which make the crocodile such an efficient predator.
12. Describe ways to avoid a crocodile attack.
13. Explain why sea-snakes are not regarded as a serious threat to humans.
14. Explain how a baleen whale feeds.
15. How is a laparoscope used in turtle research?
16. Draw a flow chart to explain turtle reproductive cycles.
17. If you are walking around a beach with a torch and see a turtle coming up the beach, what should you do? Why?
18. Why is turtle conservation important?
19. Suggest possible reasons for bird migration.
20. What practical conservation steps must you follow if you were the skipper of a boat approaching a whale?
21. What is *echolocation* and how is it used to locate food?
22. Why can't dolphins breathe underwater?
23. How do dolphins communicate with each other underwater? Use a diagram to explain your answer.

Analysing

24. One year no turtles came to nest on a beach. Which events could have happened to cause this and why?
25. Distinguish between dugongs, seals and dolphins. Draw up a table to show similarities and differences.
26. Make a flow chart to show the food sources for sea birds.

Creating

27. Propose a design solution to turtles being caught in prawn nets.
28 Develop a proposal which will keep conservationists and shark contractors happy.
29. Predict what might happen if some countries continue taking whales for scientific research.
30. Create a new product for farmed crocodiles and plan a marketing campaign renaming the meat and how it would be advertised in restaurants.
31. Design a turtle or bird tag. Describe what materials you would use and how it would be fitted.
32. Suggest ways to improve the management of RAMSAR sites (these are international bird protected areas).

Evaluating

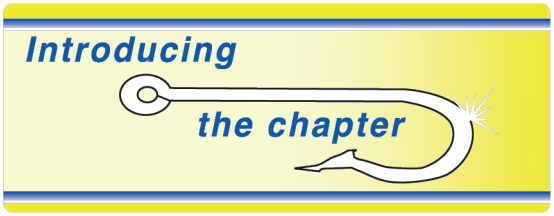
33. Plan and conduct an experiment to test echolocation in dolphins.
34. How would you defend your position in relation to a ban on all world whaling?
35. Choose a better solution to prawn trawling.
36. Do you believe that whales should be killed for scientific purposes? Explain.
37. How would you feel if you were a commercial fisher who had to sell his business to protect a marine park?
38. What are the pros and cons of Marine Parks?
39. Why do whales breach?
40. Seagrasses are important to dugongs. Excessive nutrients cause algae to grow on the seagrass and kill it. Why can't dugongs just change their diet and eat the algae?

Chapter 15
How they survive

by

Bob Moffatt and Tim Ryan

Photograph Mike Sugden



Chapter hooks

Read the story below and have students draw a killer prawn.

Mantis shrimp *Odontodactylus scyllarus*

Also known as killer prawn, mantis shrimps are voracious predators feeding on other crustaceans and small fish. They live amongst the coral and in burrows in the sand. The claws of these creatures are quite formidable and come in two forms: clubs or spears. Their claws are 'cocked' back, ready to shoot forward at passing prey. Those mantis shrimps that possess clubs, use them to smash the legs off other crustaceans and to crack open their shell. They can also break snail and clam shells to feed off the soft tissue inside. Those with spear-like claws can strike and kill fish and other animals at the speed of a 0.22 calibre bullet. In captivity, mantis shrimp have been known to smash glass aquariums.

Why study this chapter

A knowledge of these adaptations and factors affecting survival is important before we can study the ecosystem in which they live.

Chapter overview

Environment of marine organisms 385

Biotic environment.....385

Abiotic environment 386

Problems of survival 390

Exercise 15.1 Rocky shore transect.....391

Adaptations 394

Structural adaptations 394

Functional or physiological adaptations 398

Behavioural adaptations 400

Relationships 403

Exercise 15.2 Fish adaptation 404

Exercise 15.3 Writing definitions 408

Case study 15.1 The Australian herring 409

Exercises and questions 410

Key concepts

1. The *abiotic* refers to chemical and physical factors. *Biotic* refers to other animals and plants.
2. The biotic part of the environment is composed of populations of similar organisms or communities that exist in habitats and ecosystems.
3. Within the biotic environment each organism exists in a particular habitat and performs a specific role - its niche. Defining the limits of the niche is a crucial part of marine ecology because the niche defines the relationship of an organism with the marine world.
4. The abiotic environment includes the non-living or physical and chemical factors that impinge on organisms such as light, buoyancy, pressure, temperature, viscosity, sound, silt and salinity.
5. Abiotic and biotic factors determine the limits of tolerance of an organism.
6. An adaptation is a characteristic that helps an organism survive. These types of adaptations include structural (body form), functional (physiological) and behavioural.
7. To survive in the marine environment, marine organisms often engage in a variety of relationships with other organisms. The principal type of relationship is one that involves food. Three categories among organisms in the food chain are predator - prey, scavenger and symbiosis.

   Other relationships such as competition between species for space, or dominance hierarchies may also impact on the food chain.

Acknowledgement

Parts of the text in this chapter are adapted from the writings of Nancy Tsernjavski from the ABSea — a MESA publication and have been used with her permission.

Environment of marine organisms

The environment of an organism consists of all the factors that affect its chances of survival. The factors that influence these organisms may be abiotic or biotic.

The biotic factors are the living components of the environment, including the animals and the plants living with that organism.

The abiotic factors are the non-living or physical factors and include light, pressure, temperature, viscosity, dissolved gases and salinity.

Biotic environment

These are the living organisms and their interactions. For example, the populations of plants and animals in a penguin colony will make up the biotic community (Figure 385.1).

From the photo it is obvious that the individuals that constitute this community depend on other factors such as food, living space, removal of waste or places to hide.

The most common species in a community are called the dominant species and in most communities these are photosynthetic plants. For example the open ocean adjacent to rocky shores will have as its most dominant life form the phytoplankton which forms the basis of food chains for the ocean and the rocky shore.

Seagrasses would be the dominant life form in a shallow water ecosystem and beach grasses the dominant form in sand dunes.

The dominant population will exert a powerful influence on other members of the community and if affected, can cause a community to change significantly. Seagrasses for example support a high diversity of life by providing food, hiding places and places to grow — see pages 256 - 257, Chapter 10.

Figure 385.1 The biotic environment: the living organisms and the interactions among living organisms.
(Photo courtesy ANARE)

Biotic factors include

- food
- predators
- other animals taking up space
- competition from other animals
- animals with disease or parasites

Living places

The place where an organism lives is its **habitat**. Some examples are given in the table below. A **community** is often named after the most dominant species in that community — for example a mangrove, seagrass or coral reef community.

Marine scientists use the term ecological niche to describe an organism's function or job in a community.

Types of habitats	Page in this book	Types of habitats	Page in this book
Sand dunes	219	Ocean bed	215
Sandy beaches	222	Kelp beds	219
Rocky shores	221	Seagrass meadows	219
Rock pools	219	Mud flats	222
Coral reefs	220	Mangroves	214
Open ocean	215	Estuaries	220

Figure 386.1 The barnacle and limpet share the same habitat but occupy different niches.
(Photos Bob Moffatt)

Competition example

The barnacle and limpet in Figure 386.1 will compete for food.

Each species interacts in a slightly different way with the environment and so occupies a slightly different niche. For example, barnacles and limpets occupy the same environment but obtain food in different ways (Figure 386.1). The barnacle (Ch 12, page 309) obtains its food by filter feeding, whereas a limpet (Ch 11, page 289) uses its radula to scrape food of the rocks. They may live side by side, but are said to occupy different niches.

Abiotic environment

These are the non-living or physical and chemical factors that impinge on organisms such as light, buoyancy, pressure, temperature, viscosity, sound, silt and salinity.

Light availability

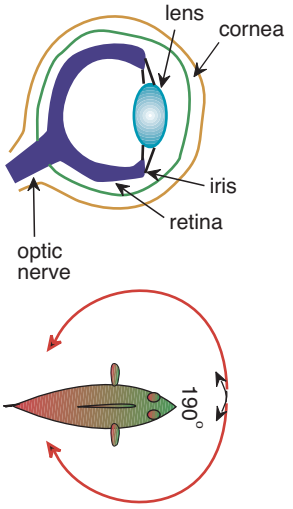
Animals

Most fish have well developed eyes to detect light penetrating the water. The lens of the eye of the fish is spherical and protrudes out of the iris, giving the fish a good peripheral vision. It is possible for the light to enter the eye from wide angles. This allows the fish to have nearly 360° or total field of view.

This is especially helpful for fish because the prey or the predators can be seen above, below, in front of or behind their body. The eye of the fish varies from the eye of land mammals in that the lens does not change shape but changes position. The lens moves in and out to focus rather than change shape as it does in humans.

Fish must be able to see colour because of their own colouration and courtship behaviour. It has also been shown that they can respond to different coloured discs behind which food reserves have been placed. Some fish are believed to be able to distinguish colours according to the brightness of the objects.

The fish of the deep can only detect the intensity of the light. Their eyes are well developed with a large pupil and a special golden pigment that is sensitive to blue light. Some of the species found in the deep have tubular eyes that can concentrate or better focus the light.



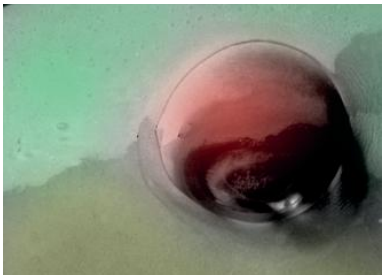


Figure 386.2 Fish eye and vision
(Illustration Bob Moffatt, photo Underwater Rhelms)

The fish that live below 1000 m have small eyes or no eyes. The exception being the angler fish which uses its eyes to find its mate. The male anglerfish has an organ that can produce light to attract the female (Figure 387.1). There are over 600 different species of fish living below 1000 m that possess light producing organs.

Plants

Since plants need light to carry out photosynthesis the plants can only be found to a depth light can penetrate in the water column (usually the top 100 m of the ocean).

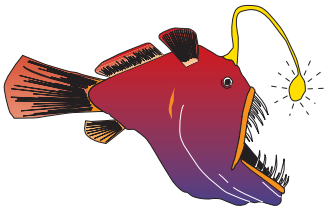


Figure 387.1 Male angler fish
(Illustration Mark Moffatt)

Buoyancy

Since density increases with depth, a fish will tend to float back to a depth where its density equals that of the water.

The effect of the buoyancy can be beneficial to aquatic plants and animals. Aquatic organisms require fewer supporting structures in their bodies. An aquatic plant does not require a stem made of tough cells cemented together to hold it upright. If an aquatic plant such as algae (slime) is removed from water it forms a claggy mess, but in water it is supported and has a feathery appearance.

The gill structures of fish and amphibians also need little support in water but would collapse if placed in air.

Figure 387.2 shows a cloth in and out of water which is similar to how gills would behave. The aquatic fish also require fewer interlocking structures on the vertebrae of the dorsal backbone. This allows a greater flexibility of the backbone permitting the wave-like swimming motions that most fish exhibit.

Figure 387.2 Buoyancy in water
(Photos Bob Moffatt, thanks for the idea Jim Thompson)

Another example of how the water supports the aquatic animals is seen when large marine animals such as whales and dolphins are beached. These animals often suffer broken rib bones, as the water no longer supports their weight.

The bones in the skeletons of aquatic animals are very different from those in terrestrial (land-living) animals. The terrestrial animals need to have hollow bones to keep their weight to a minimum. Aquatic animals mostly have solid bones as they have the water's upthrust reducing their weight.

Pressure

Creatures such as jellyfish are able to adjust the pressure in their tissues to that of the water outside their body. Fish of the great depths have very dense bony bodies and lack air-bladders to increase the density of their bodies.

Whales have special adaptations to allow them to dive to great depths. The whales have lungs and because these will collapse at great depths, they have a special network of blood vessels that carry extra oxygen. Whales also have fatty emulsions that carry extra oxygen.

These same fatty emulsions absorb nitrogen from the blood stream. This nitrogen would otherwise cause symptoms similar to the "bends" suffered by human divers.

Figure 387.3 Water depth and pressure
(Photos Bob Moffatt)

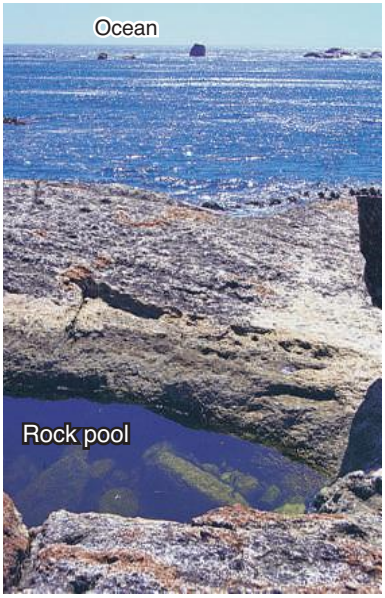


Figure 388.1 Rock pools are subject to large temperature fluctuations.
(Photo Bob Moffatt)

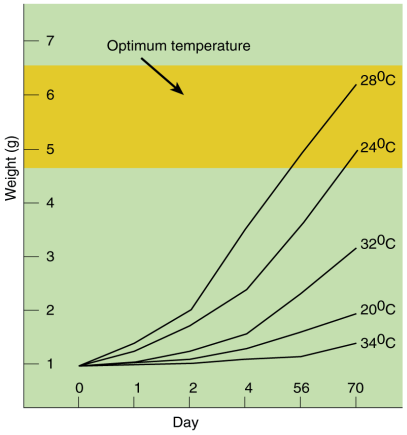


Figure 388.2 Temperature and growth rate
(Illustration Bob Moffatt, source Dave Mason)

Figure 388.3 Body shape and viscosity
(Photo Wet Paper)

Temperature

The range of temperatures a marine organism has to endure depends also on the volume of water in which it is found - the smaller the volume of water the larger the range of temperatures. A rock pool will only require a small amount of energy from the sun to cause a temperature fluctuation of 10°C, but a lake or ocean requires a large amount of energy to cause the same temperature fluctuation (Figure 388.1).

The fish can detect these changes in temperatures with receptors that are located all over their body. Fish are also cold-blooded or **poikilothermic**, which means that their body temperature varies in response to the temperature of their environment. As a result their activity tends to become sluggish if the water temperature drops. The change in temperature also causes the chemical reactions that take place in their body to speed up or slow down. Many scientists believe that the stimulus for breeding of many species of fish is a change in water temperature. Some fish migrate to areas that have different water temperatures to breed.

Water temperature also exerts a major control over the distribution of marine organisms. Figure 388.2 shows how temperature can affect growth rates in fish.

Temperature tolerances differ widely between species. Some species can withstand a wide range of temperatures and these are called **eurythermic**. These eurytherms are mostly found in the shallower waters that have a greater temperature range. The organisms that can only survive within a small temperature variance are called **stenothermic**. These organisms are mostly restricted to the deep oceans.

Fish are found in all waters, but are more abundant in the tropics where the temperatures vary from 6°C to 20°C. Most fish can withstand a range or fluctuation of 7°C to 9°C if the change is not sudden.

Viscosity

Another of the rather formidable problems aquatic organisms have to face in their watery environment is viscosity. Water is more viscous than air, just as syrup is more viscous than water. Water is nearly 800 times the density of air and this offers considerable resistance to movement. Some creatures of the sea need to move more rapidly through the water to survive need to be streamlined. These fish have an aerodynamic or cigar shape. In the bony fish the snout is pointed, the body tapers, and there are no projections which would act as sails to slow down their movement.

This has lead to a bewildering and bizarre array of shapes. Fish in Figure 388.3 have narrow bodies, so are well adapted to swimming through rocky crevices. Some fish can reach amazing speeds. Minnows and pikes can cover the first ten centimetres they have to swim with an acceleration of 40 m/sec. Sailfish can reach speeds of 65 km/hr and sharks reach speeds of 40 km/hr (viscosity is also discussed on page 145).

Sound

Another effect of the viscosity or density of the water is that sound travels almost five times faster in water than in air, and vibrations are more easily detected. Fish have an acute sense of hearing and can respond to sound waves up to 7000 Hertz.

The greatest range of hearing is found in catfish and carps. Many people, especially skin-divers and swimmers, believe that the watery world is a silent world. In fact, the under-water world has a multitude of sounds.

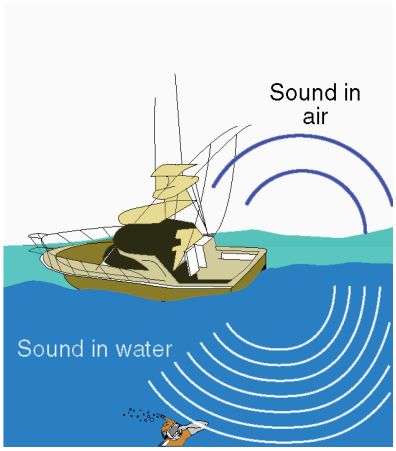


Figure 389.1 Sound travels faster in water
(Illustration Bob Moffatt)

Salinity

The most obvious problem caused by the salinity of the ocean is the osmotic effect. Osmosis occurs if a thin membrane separates two solutions with different concentrations of ions.

There will be a nett movement of water from areas of low ion concentration to areas of high concentration (Figure 389.2)

Areas that contain limestone have streams that contain high concentrations of calcium ions. These waters are said to be "hard" and contain large numbers of molluscs (shellfish). This is because these animals need calcium to make their shells.

See also page osmoregulation page 341.

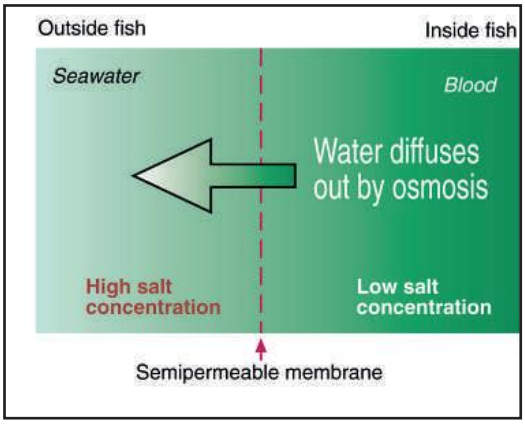


Figure 389.2 Osmosis
(Illustration Bob Moffatt)

Sediments

Water from the land carries huge amounts of sediments which can greatly affect local marine habitats. Figure 389.3 shows a sediment plume flowing out of a coastal river. This has great consequences for filter feeding animals.

As the silt moves over the continental shelf, it will gradually flow down the continental slope till it reaches the deep sea. Animals and plants that live here will need to cope with these layers of deep sea ooze.

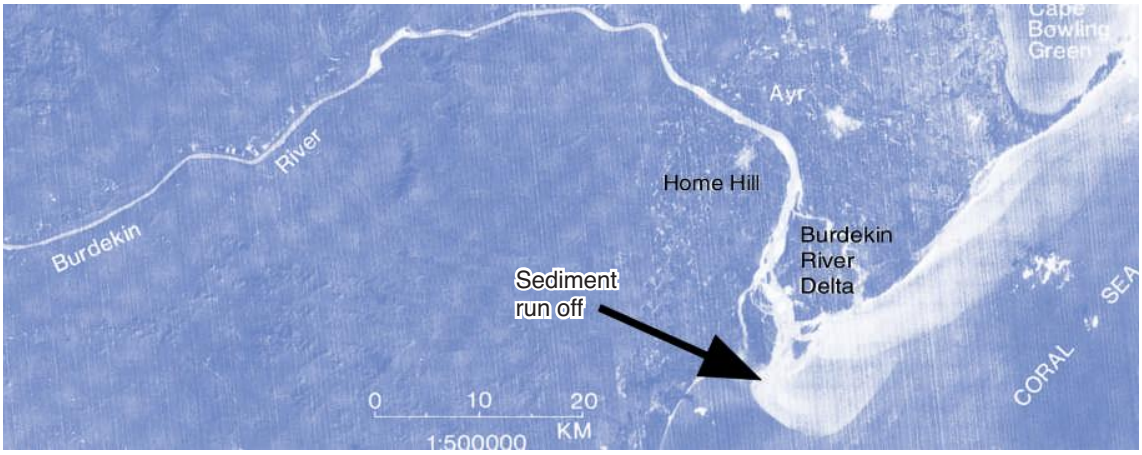


Figure 389.3 Sediments create huge problems for filter feeding animals.
(Photo Beach protection Authority)

Problems of survival

Figure 390.1 Barnacle
(Photo Jack Marsh, Illustration Rose Bedford)

Figure 390.2 Limpet and periwinkles
(Photo Bob Moffatt)

The barnacle and the limpet in Figures 390.1 and 390.2 , share similar problems in a rocky pool and are subject to biotic and abiotic influences. Some examples of this are:

Abiotic influences

- Wind, waves and tides
- Temperature
- Sediments from stormwater drains
- Acidity or alkalinity

Biotic influences

- Seagulls as predators
- Lack of algae
- Competition from other limpets or periwinkles
- DDT polluted algae
- Lack of other limpets to mate with

Tolerance limits

Both the barnacle and the limpets will have tolerance limits to survival and past these limits the animals will die. For example, if the rocks get covered by sand from a sand bypass system for a long time (see chapter 5, page 116) they will both die due to lack of food, available light, inability to obtain oxygen or a combination of all three.

In Chapter 11, page 285, you learnt that corals were affected by temperature where the increase caused the polyps to expel their zooxanthellae.

If salmon are subjected to cooler temperatures and reduced food intake, body fats will be metabolized and DDT released from storage leading to acute toxic response. This will lead to health issues for fishers of salmon. Similarly oysters can also be affected by levels of bacteria from time to time and often pose a health issue for restaurants.

Figure 390.3 shows some of the tolerance ranges for organisms and pH. While bacteria have a wide range of tolerance, most marine animals are greatly affected by changes in the acidity or alkalinity of sea water.

This is why *acid sulfate* soils are such a danger to marine creatures (see Chapter 7, page 168).

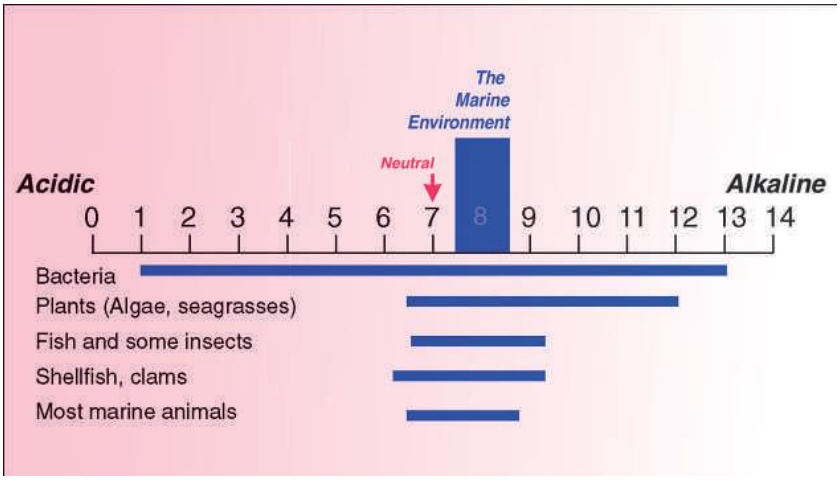


Figure 390.3 Some animal and plant tolerance to pH (after Mitchell and Stapp)
(Illustration Bob Moffatt, thanks Bill)

Exercise 15.1 Rocky shore transect

(Based on an original exercise by Bob Moffatt)

A low tide rocky shore profile from Moffatt Headland in Hypothetical Bay (Chapter 2, page 55) was drawn using the methods described in Exercise 4.1, Chapter 4, and biotic data was taken from 8 stations as shown in figure 391.1 below. The students counted the animals and plants at each station and then made a decision on how to graph their results based on the criteria in the legend box in Figure 391.1. They then collected and graphed the abiotic data as shown on the next page. Study this data and answer the questions on page 393.

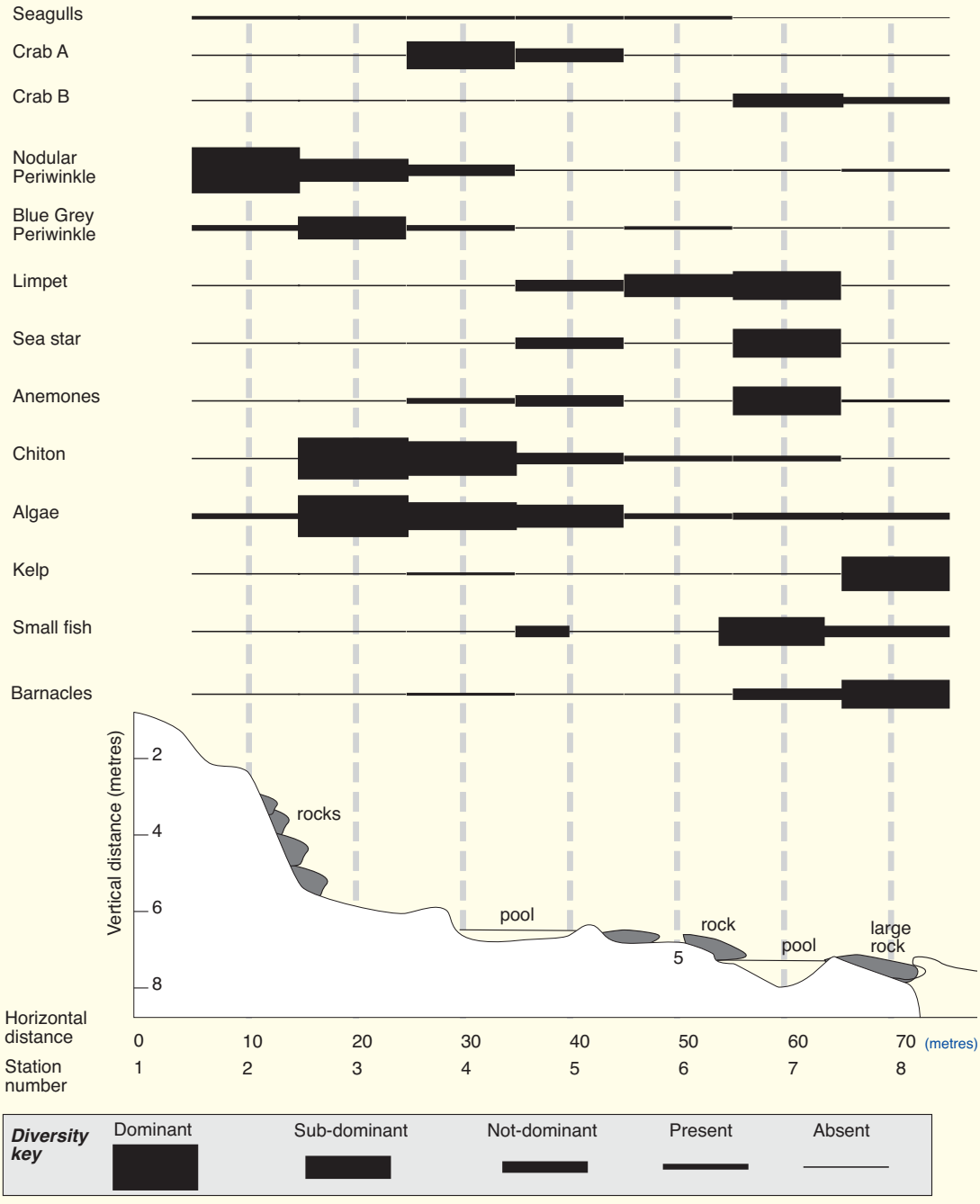


Figure 391.1 Biotic data for rocky shore
(illustration Bob Moffatt)

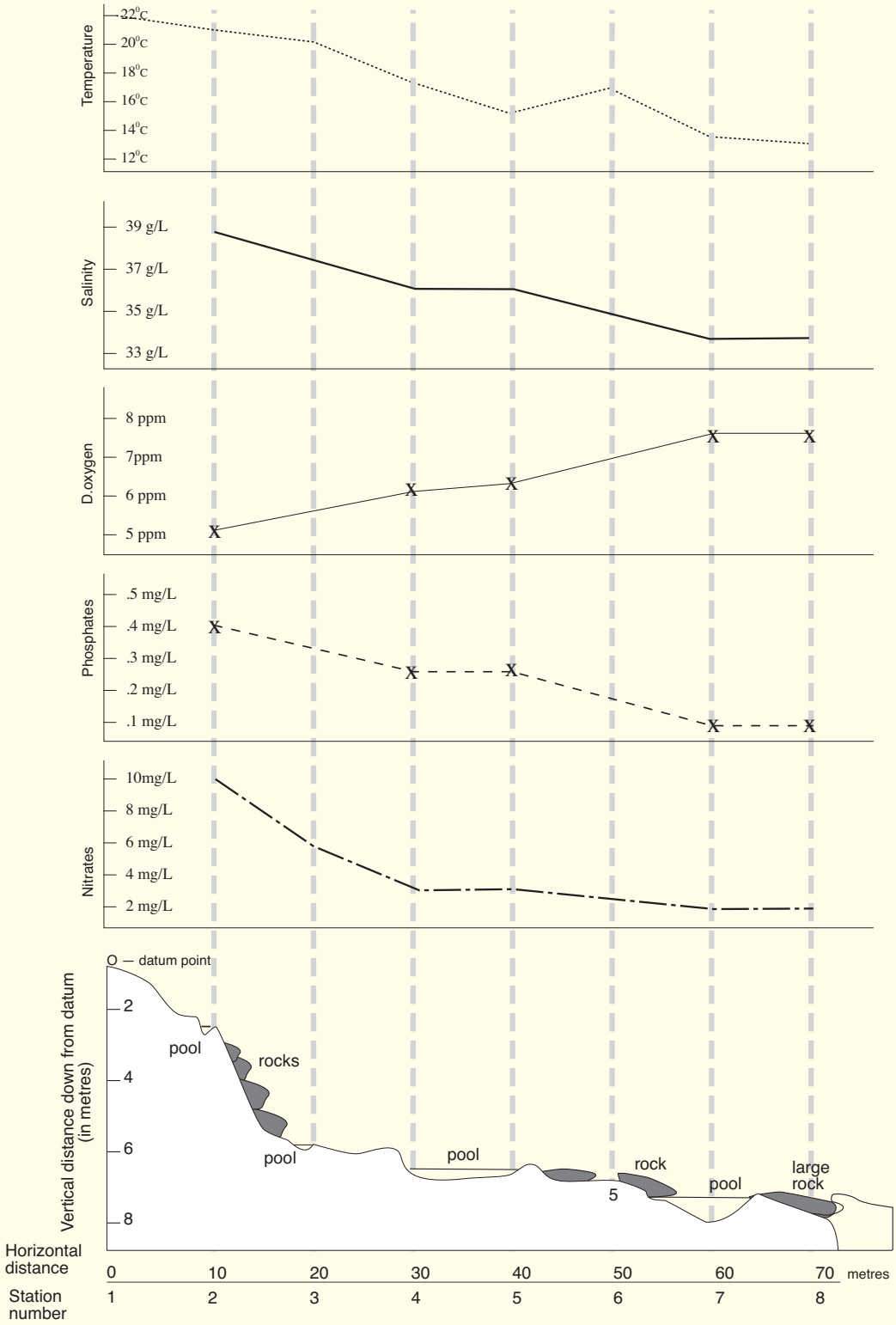


Figure 392.1 Abiotic data
(Illustration Bob Moffatt)

Questions: Exercise 15.1

Knowledge

1. Describe the number of stations measured, the distance covered and the animals and plants in the data presented.
2. Define the words *habitat, limits of tolerance, buoyancy.*
3. Describe the features of the shore at stations 2, 4, 5 and 7.
4. Define the terms *abiotic* and *biotic* giving examples of each from the data presented.

Understanding

5. Describe possible methods for determining the abiotic data and biotic data.
6. Provide an example of a herbivore.
7. What do you think could have happened to the data when the tide came in?
8. Draw pictures to show you know the difference between a barnacle and a chiton.
9. Give an example of an echinoderm and an cnidarian.
10. Prepare a flow chart of the steps involved in drawing the rocky shore profile.
11. Outline the main reasons for the collection of data of this type.
12. Make a list of all the biotic and abiotic factors that were studied.
13. Which animals and plants would be affected by buoyancy?
14. Which animals and plants would be affected by wave action? When and why?
15. Where would temperature pose the greatest problems for rocky shore organisms and why?
16. Name one predator from the data.
17. What could cause the salinity in a pool to drop?

Applying

18. Calculate average temperature on the rocky shore.
19. Classify the blue grey periwinkle into kingdom, phylum and class.
20. Construct a food web for the pool at station 7.
21. A metre square with 100 mm divisions was used to collect the biotic data. A randomly selected 100 mm x 100 mm square was sampled in station 8 and 435 barnacles counted. Calculate the number of barnacles in the metre square.
22. You are told that the dissolved oxygen is 0 ppm and that the temperature is 17°C. Where are you standing?

Analysing

23. Examine all the data and answer questions a-c below.
    a. Explain what happens to the nitrate levels as you go from the sea to the top of the headland.
    b. Identify the least favourable habitat.
    c. Where are barnacles most dominant? Suggest a reason for this.
24. Analyse the data from stations 3 and 7 and answer questions a-e below.
    a. Which are the dominant species?
    b. What abiotic feature affects them the most?
    c. Which is the hottest, saltiest station?
    d. Compare the phosphate and nitrate readings at each and suggest reasons for the differences.
    e. Describe the changes in dissolved oxygen levels and suggest a possible reason for the difference.

Creating

25. From the data presented, create an animal that could live in every station.

Evaluating

26. Analyse both sets of data for station 3 and answer questions a-c below.
    a. Which are the dominant species
    b. Which species are not present and why?
    c. Identity the most favourable habitat justifying your answer using biotic and abiotic data.
27. Why are chitons only found in some places on the rocky shore?
28. Determine which abiotic factor and biotic factor would have the greatest and least effect on the organisms mentioned in the study.
29. A housing development was planned for the headland. Geologists identified acid sulfate soils in the area, but the developers said they would excavate these soils and replace them with environmentally friendly soil.

    As councillor reviewing the submission, make a list of all the environmental factors that would impact on the animals.

    Determine the levels of tolerance of each and determine which would be most affected.

    Then argue the case ***in favour*** of the development.

    What opposition would you expect from the green lobby? Who would you employ to defend your case and what would you ask them to report to you on?

Adaptations

Marine organisms continually battle for survival in the harsh world under the sea. Plants and animals, whether they live on land or in the water, depend on each other for nutrition and shelter.

They compete with each other for these necessities. Their surrounds or environment also affect the plants and animals. These organisms have had to adapt to all the different conditions that can be found in the sea; it is a case of adapt or die.

An adaptation is a characteristic that helps an organism survive. These types of adaptations include:

- structural (body form),
- functional (physiological), and
- behavioural.

For example the porcupine fish in Figure 394.1 has spines (a structural adaptation), toxins in the skin which make you sick (physiological) and blows itself up to look much bigger than it really is (a behavioural adaptation).

Figure 394.1 Porcupine fish
(Photo Mike Sugden, illustration Sharyn Madder)

Significance of adaptations

Humans can control the destiny of much marine life.

An understanding of the adaptations of animals and plants helps us develop ecologically sustainable economies.

For example, barnacles (see Figure 394.2) are adapted to life on a rocky shore free of silt and sediment. They are filter feeders and use their legs to catch microscopic plankton as the waves wash over them. Barnacles suffocate when storm water pipes from coastal developments wash sediments over their rocky platform. In contrast, the mud crab is well adapted to living in sediment because it has claws to burrow and can breathe in that burrow under the mud.

Allowing storm water pipes to flow into wetland communities that can cope with sediment and nutrients is a better proposition than allowing them to flow into clean rocky shores or reefs.

If we understand the adaptations of marine organisms we can better plan for their survival.

Figure 394.2 Barnacles
(Photo Bob Moffatt)

Structural adaptations

Many marine animals have developed specialised body parts for escaping their predators. These parts include body cover, form, camouflage, skeleton, appendages, and mouth parts.

Body cover

Scales or mucous is secreted from the skin. This mucous can form a cocoon in which some fish sleep. Some fish have spines such as the stone fish (Figure 394.3). If you step on a stone fish the spine penetrates the foot causing the venom to enter the blood stream.

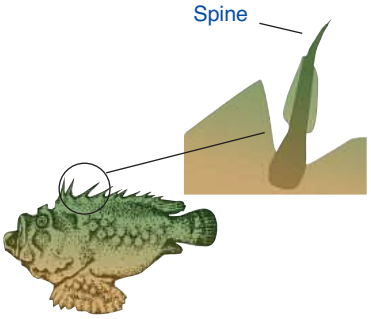


Figure 394.3 Stone fish and spine
(Illustration by Rose Bedford)

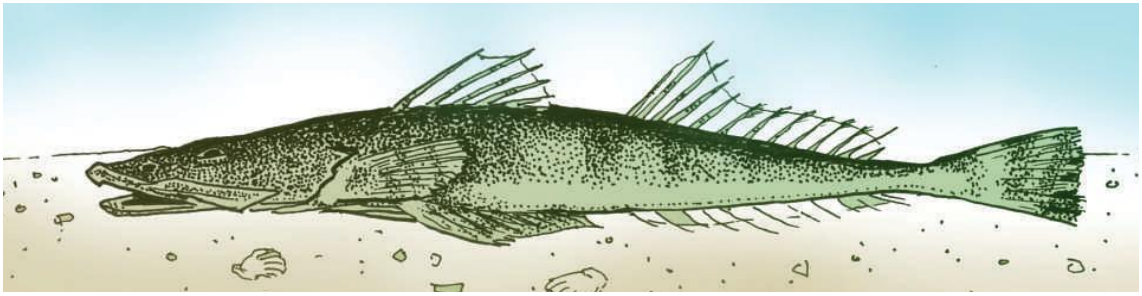


Figure 395.1 Flathead
(Illustration Kerry Kitzelman)

Armour

Barnacles, lobsters, crabs, scallops, clams, oysters and turtles are a few of the animals that have armour to protect their soft bodies from predators. Fish have scales which act as thin armour. Most animals that develop heavy armour are slow moving.

Spines

Some animals have developed spines which make them harder to swallow or harder to pull from caves or holes (Figure 395.2). Some fish may develop spines from scales and may form spines around the gill cover.

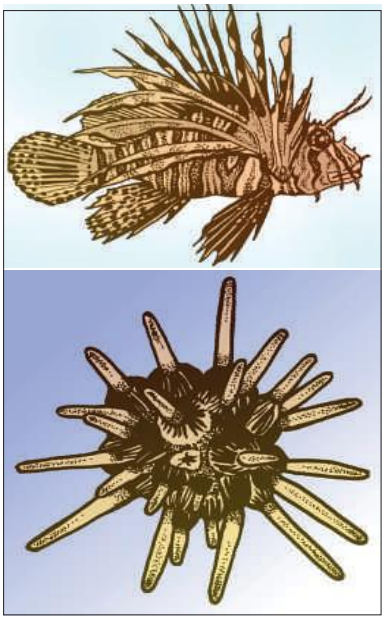


Figure 395.2 Spiny skinned animals
(Illustration Rose Bedford)

Body shape

Many fish are streamlined to allow movement through the ocean.

- Fish that occupy the benthos are flat eg rays, flathead (Figure 395.1) and flounder (Figure 395.3).
- Fish that need to hide in seagrasses have projections from their body eg the sea dragon has projections that look like leaves and the trigger fish has a hook to hold on while it remains motionless.
- Fish in the open ocean have pointed tails and strong muscles (Figure 395.4).
- Deep sea animals have long legs to lift them off the muddy substrate or a foot to slide or burrow through it.

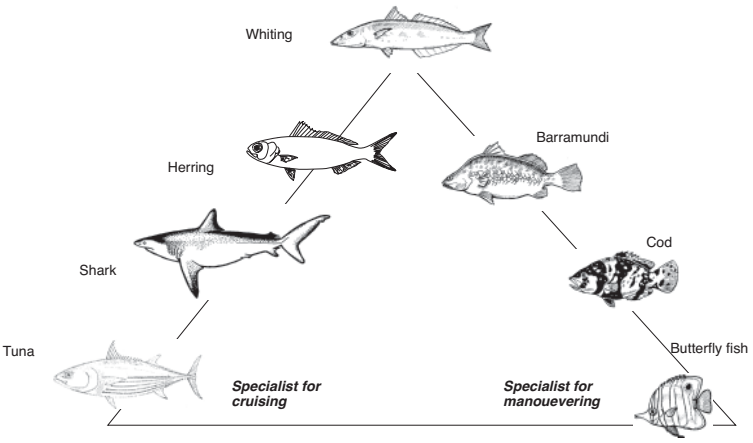


Figure 395.4 Tail shape, streamlining and fish habitat
(Illustrations by Sharyn Madder, Rose Bedford and Steven Byers)

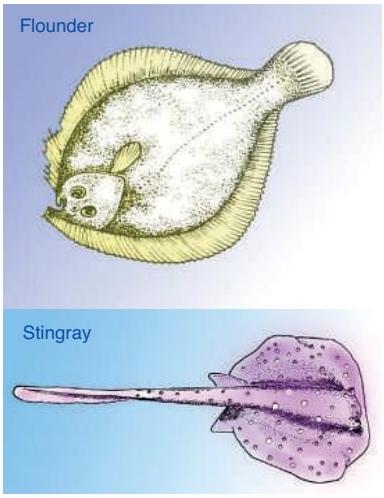


Figure 395.3 Fish that occupy the benthos.
(Illustrations by Steven Byers, Kerry Kitzelman, Sharyn Madder)

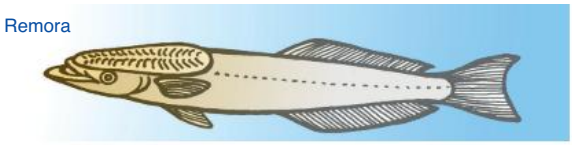
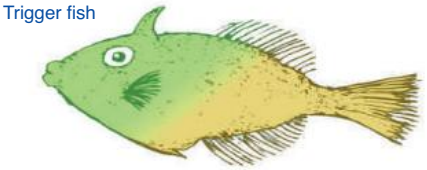


Figure 396.1 Position of body parts
(Illustrations by Rose Bedford and Sharyn Madder)



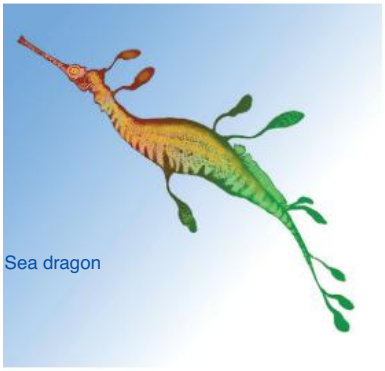


Figure 396.2 Fish that need to hide
(Illustrations by Sharyn Madder)

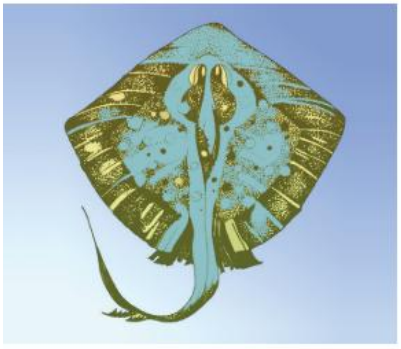


Figure 396.3 Stingray
(Illustration Steven Byers)

Position of body parts

The remora (Figure 396.1), needs a sucker to attach itself to its host. Its head has been modified for this purpose. The trigger fish, has its spine on its head so it can hook onto seagrasses, and the spine on the stingray (Figure 396.3) is on the tail so it can flick up to wound its attacker.

Camouflage

To escape the detection of the predators the prey may try to match its colour or shape with that of its background. The rock cod and the deadly stonefish are masters of the art of protective concealment. The colouration of soles and stingrays also help them avoid detection. Some animals mimic other living things or innate objects. The sea horse looks like a type of sargassum weed. The pipefish, which live among the eelgrass, look like stalks of the eelgrass. They remain floating vertically, imitating the eelgrass.

Camouflage mimicry

Fish use bright colours to blend in with the background. Some fish decorate themselves with pieces of weed to hide in their habitats such as the sargassum fish. This type of camouflage is a form of mimicry.

Figure 396.4 Sargassum fish
(Illustration Kerry Kitzelman)

Skeleton

Fish have light flexible bones for swimming.

The skeleton extends the entire length of the animal as well as to the fins and tail. This allows for an intricate muscular system for precise movement and speed.

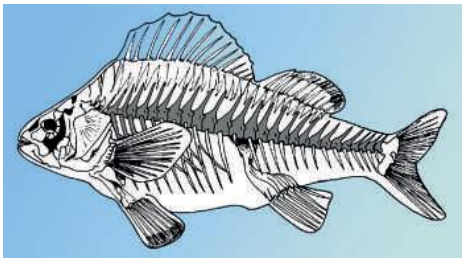


Figure 397.1 Fish skeleton
(Illustration by Brady Moffatt)

Appendages

Fins can be used for balance, steering or moving forward or back (Figure 397.2).

The great white shark is an excellent example of grace and speed. The enormous muscles in the abdomen drive the shark forward and with minute deviations of the fins, the shark can hone in on its prey with great accuracy.

Prawn appendages are excellent examples of adaptations to a benthic life style. The claws grab the food and take it to the mouth parts. The walking legs enable the prawn to move around the bottom and the swimming legs propel the animal forward.

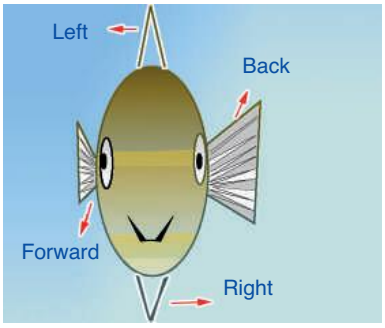


Figure 397.2 Fins
(Illustration Bob Moffatt)

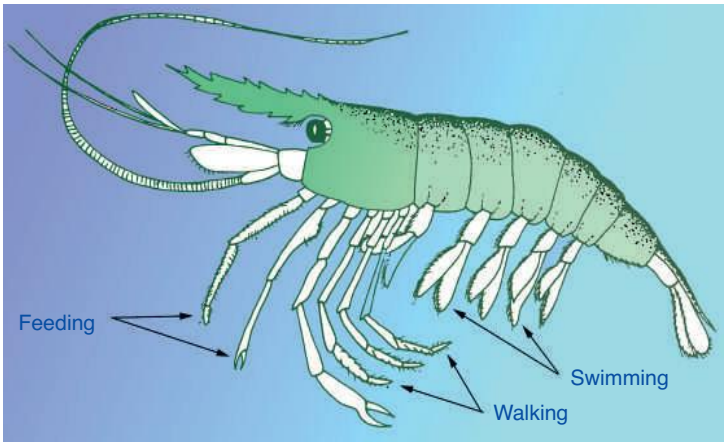


Figure 397.3 Prawn appendages
(Illustration Bob Moffatt)

Mouth parts

The location of mouth parts is also important - dorsal mouths are surface feeders while ventral mouths are benthic feeders.

Mouth parts

Jaws and teeth indicate what a fish feeds on, and how.

- The parrot fish feeds by biting at its prey so has tusk like teeth.
- The butterfly fish has a long elongated mouth so it can eat from hard to get places.
- Deep sea animals have a ventral mouth to feed from.
- Chitons have a specialized feeding mouth, like a radula, or modified mouth parts to scrape food off tough surfaces or bite through other shells.

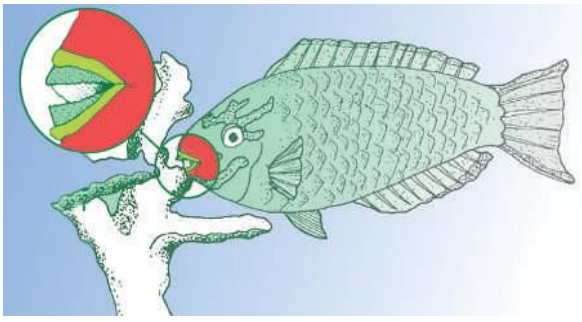


Figure 397.4 Parrot fish feeding
(Illustration by Steven Byers)

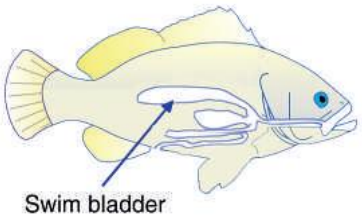


Figure 398.1 Swim bladder
(Illustration Jack Marsh)

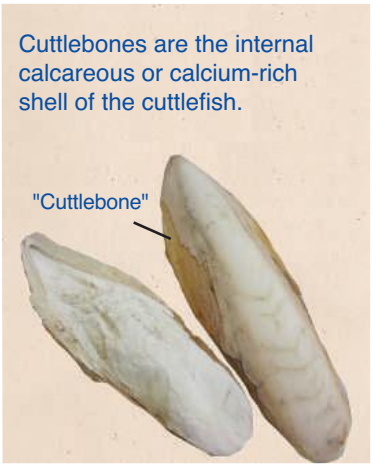


Figure 398.2 Cuttlebones are light and float.
(Photo Bob Moffatt)

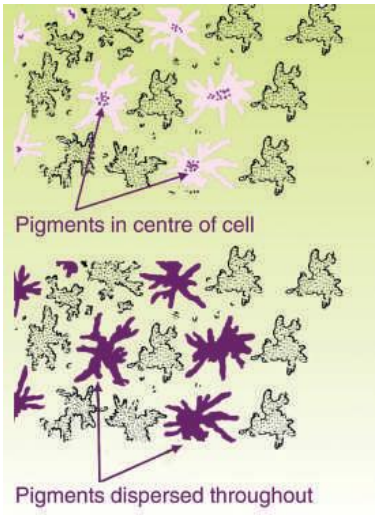


Figure 398.3 Pigmentation
(Illustration Bob Moffatt)

Functional or physiological adaptations

Buoyancy

Some fish have an air bladder or swim bladder (Figure 398.1), in which they can vary the amount of air and therefore, vary their density. This allows these fish to float at different depths in the ocean. This air-bladder can be filled by gases dissolved in the blood or by rising to the surface to swallow air.

Other organs that assist in the buoyancy of animals are:

- Large oily liver of some sharks;
- Light cuttlebone that is found in cuttlefish (Figure 398.2) and the pen of the squid;
- Oil globules in fish eggs;
- Large spines and protrusions of animal larvae;
- Many algae which have air-filled bladders to keep them afloat;
- Small plants which have large protrusions or structures jutting out increasing the surface area and making them more buoyant.
- Phytoplankton which have air-filled vacuoles or oil droplets contained within their body to increase their buoyancy.
- Some plankton have long spines to slow the rate of sinking and increase their surface area/volume ratio.

Poisons

Many marine creatures produce a toxin which makes them poisonous to eat. Many of these toxins are concentrated in certain organs of the body such as the liver. The main poisonous animals are the puffer fish or toad fish, moray eels, and the mackerel and tuna-like fish which often carry ciguatoxin.

Venom glands

Some animals such as the stonefish, sea wasps, blue ringed octopus, cone shells, sea anemones and sea snakes are capable of injecting poisonous substances into the attacking animal.

Colouration

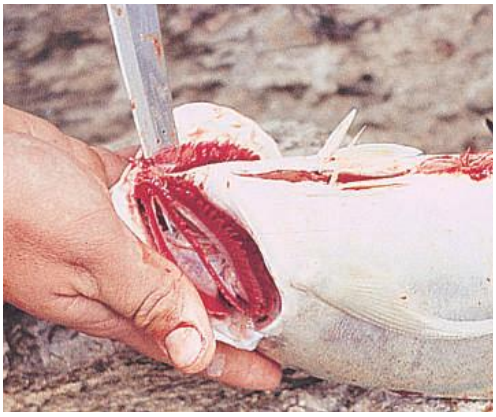
Some fish have markings that hide the position of their eyes. Fish may have an eye marking on the back of their body. This distinctive marking attracts the predator's attention for attacks. This marked part of the body has few vital organs and the fish has a good chance of surviving such an attack.

Colour change

Cells in the skin of some fish have the ability to change colour where pigments can be concentrated or dispersed throughout skin cells.

The pigments react to changing light intensity making the fish fade into the background.

Flounder is one such fish changing skin colour and pattern to blend in with the background.



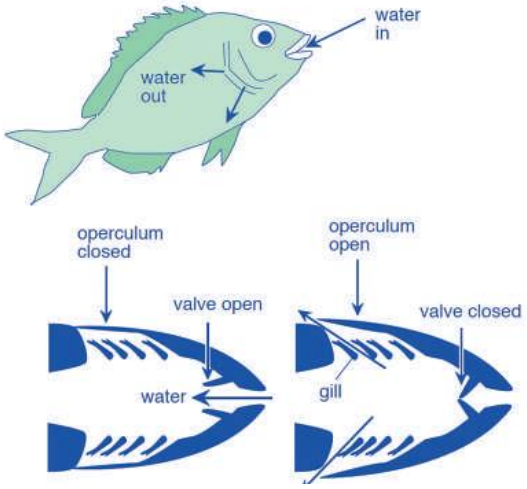


Figure 399.1 Fish gills and respiration
(Photos and illustrations Bob Moffatt)

When the fish is on the sandy bottom its colour is light, but when on a rocky bottom its pattern changes, becoming blotchy and much more black and white.

Respiration

Fish extract oxygen from seawater at the gill surface (Figure 399.1). Water is taken into the mouth and pumped out over the gills. The operculum opens and closes to allow water to escape and the oesophagus must close to prevent water from entering the stomach. These structures are called physiological adaptations.

Salt water balance

The kidneys of a fish allow it to drink seawater and excrete salts and produce very little urine.

The ability of the kidney to process large amounts of salt water and maintain an internal salt balance is a physiological adaptation.

Salt and water balance

Salt and water balance concentrations are important and animals have to rid their bodies of harmful concentrations of urea in the form of urine. To do this, water is used in conjunction with an excretory system. In many birds, salt concentrates in glands and is washed off. In salt-water fish, large quantities of water are used to "flush the system" and so the fish actively drink salt water. This continuous drinking of seawater increases the water concentration in the blood. This water is lost by osmosis as shown in Figure 399.2.

Fresh water fish do not drink water because the water in their blood has high concentrations of salts. Water is taken up automatically in the gills by osmosis as shown, and water has to be removed by the urinary system as part of the urine.

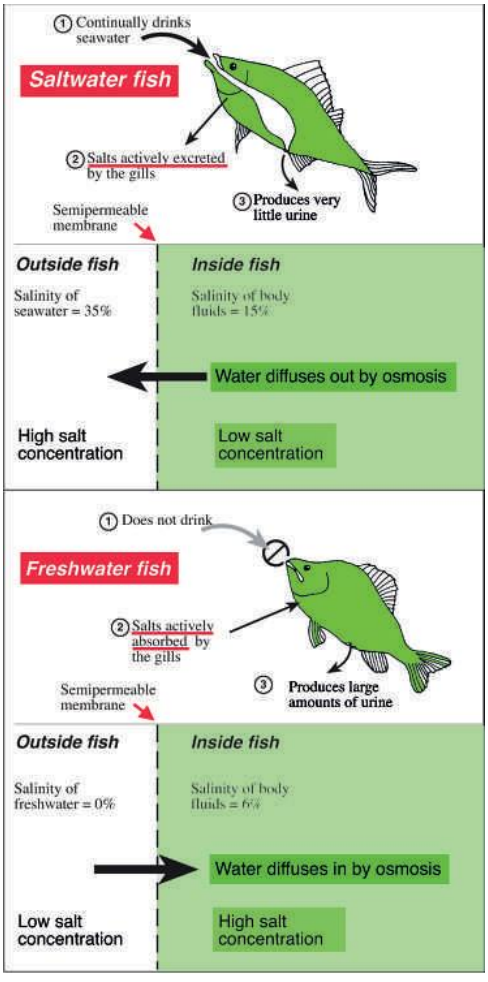


Figure 399.2 Osmoregulation in fish
(Illustration Bob Moffatt)

Reproduction

Marine organisms can breed externally or internally producing live young or eggs that hatch on sea weeds that look like the kelp.

The adaptation will match the physiology and anatomy of the fish. For example fish that have external fertilization will need to produce large numbers of sperm and eggs. However some sharks hold their eggs and only few are required to ensure a continuation of the population.

Many invertebrates such as crabs and prawns, molluscs have life cycles that enable the immature stages to develop in oxygen rich waters of the photic zone near the coast and then migrate back to estuaries to complete their life cycle.

Figure 400.1 Barramundi
Wet Paper

Sex change

Some fish are capable of changing their sex during their lifetime. In this sex reversal the fish may start out in life as males and later develop into a fully functional female. In most cases they do not change into females until they are fully mature. In fish such as the barramundi this may take six to eight years. Other fish that exhibit this phenomenon are the jewfish and sea perches.

Other animals are hermaphrodites. One individual has both male and female gonads. These bi-sexual individuals can act as either the male in one breeding or the female at the next mating.

The barramundi, Figure 400.1, is also an example of a protandrous hermaphrodite (ie male first and female second). Coral trout and anemone fish are also sequential hermaphrodites (ie one sex then another).

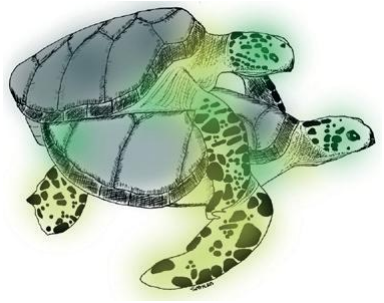


Figure 400.2 Internal fertilization and care of fertilized eggs
(Illustration Steven Byers)

Behavioural adaptations

Escaping

Most animals try to escape their predators. The slower moving animals escape their predators by burrowing under the ground or hiding in holes. Some animals even build their own hiding burrows. Many others are capable of short, sharp bursts of speed to escape the on-coming predator.

Mucous shield

A parrotfish protects itself at night by producing a mucous cocoon in which it sleeps. This cocoon protects the fish from being detected by odour. The fish that hunt at night, such as the moray eel, detect their prey by body odours.

Schooling

Schooling is the best known of these associations. A school is a large mass of fish that swim around together. A large school of fish acts as a unit and increases the chance of survival of the fish. The school appears as a huge object or animal and, in some cases, may scare off intending predators. The erratic movement of the fish within the school may also make it hard for the predator to fix onto one fish as its prey and this confusion may allow the fish to escape.

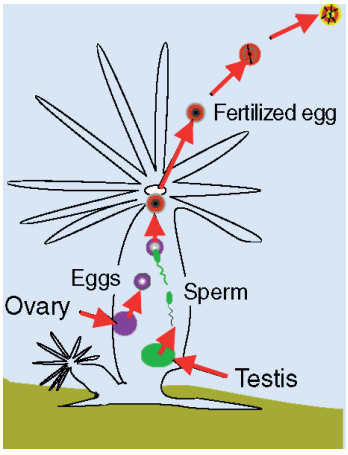


Figure 400.3 Internal fertilization but no care of fertilized eggs
(Illustration Bob Moffatt)

The fish swimming in a school also reduce the drag effect of the water, making swimming easier. The fish slipstream each other to reduce the drag. The fish school has an advantage over the individual as it has many eyes detecting dangers and many noses to seek out food.

The fish, by swimming in the school, reduce the probability or chance of detection by predators. If the predators are spread over a large area, the individuals in the school have less frequent predator / prey one-on-one encounters. The fish in a school do not need to waste energy and time hunting for a mate. The sexes are all together - another advantage for the fish.

Care of their young

Many animals of the sea have elaborate behaviours that increase the chance of survival of their young. One of the interesting examples of this behaviour is the seahorse where the male protects the young in a pouch on its body while the young are developing (Figure 401.1). The female octopus once pregnant does not eat for the period of gestation. The young live off her body tissues and after birth, having spent all her energy, dies.

Some species carry their eggs in their mouths so they can protect them. This occurs in many of the Spotted barramundi. It produces few eggs which are protected by the female. The female carries the eggs in her mouth for a period of one month. These fish are called **buccal incubators**.

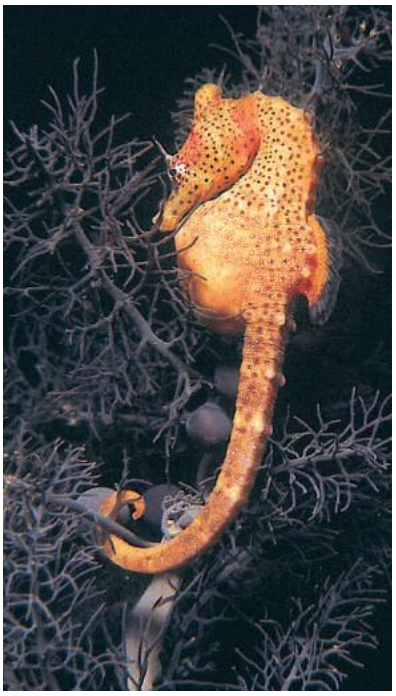


Figure 401.1 Male seahorse with young
(Photo Neville Coleman)

Courtship behaviours

Many animals have courtship behaviour before mating. A good example is the stickleback (a freshwater fish of the Northern Hemisphere) where the male constructs an elaborate nest to protect the eggs. The male does a zig-zag dance when a female of breeding age enters his territory. The male then fertilizers the eggs and continues to watch over the eggs until they hatch. Birds, such as seagulls, are easy to observe in courtship rituals (Figure 401.2).

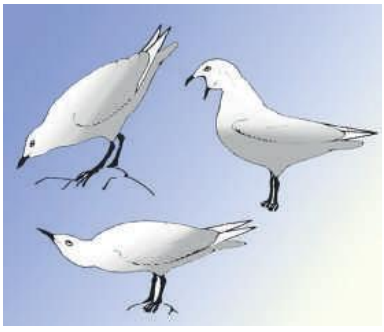


Figure 401.2 Seagull behaviours
(Illustration Bob Moffatt)

Cyclic behaviour

Many animals exhibit rhythms of activity which take a daily cycle and are called circadian rhythms. A good example of this is the nocturnal activities of certain fish. Most of these fish are plankton hunters as plankton become more abundant in the water at night (Figure 401.3). An intriguing example is that of the fiddler crab where, even out of its own environment, the crab has been observed to carry out its same daily routine without the usual stimulus of the tides.

Other animals have a seasonal rhythm that is well demonstrated by the reproductive behaviour of corals. A number of different species of corals will simultaneously release their spawn on mass each springtime following a full moon.

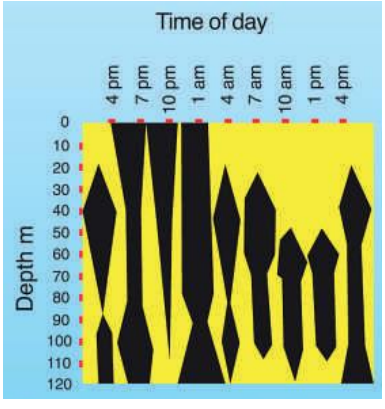


Figure 401.3 Copepod migration
(Illustration Bob Moffatt)

Social organization

Many of the organisms of the sea live in groups, as this will give them a better chance of survival. Many of the sea creatures gather together in a temporary association called aggregation.

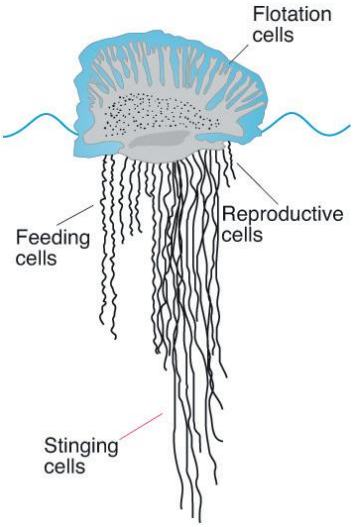


Figure 402.1 Blue bottle colony
(Illustration Bob Moffatt)

A good example of this is the Crown-of-thorns starfish and the gastropod *Drupella* as discussed in the case study in this chapter.

In some cases the organisms are physically joined, as are the coral polyps that join together to form coral structures. Such a grouping of organisms together is called a **colony**.

Another fascinating example of a colony is the jellyfish commonly known as the blue bottle (Figure 402.1). The blue bottle floats on the surface of the sea with its tentacles hanging below a gas filled sac. This animal is in fact a group of physically joined smaller creatures each specialized to carry out a specific job. Some of the individuals have special stinger cells called nematocysts that produce poisons that can kill other animals. Other creatures of the sea are not physically joined but have a social group that helps their survival. They can have elaborate organization and communication within the group.

Locomotion

The octopus, master of locomotion and grace can not only move and squeeze through rocks and crevices, but also change colour and squirt ink as a distraction to predators. The tubed feet of echinoderms or the muscular foot of molluscs are also examples.

Figure 402.2 Whale migration
(Illustration Steven Byers)

Migration

Birds, whales, fish and squid are but a few examples of how animals seek to increase their chance of survival. The herring migrates from Western Australia to South Australia and Victoria. Migration is believed to increase genetic diversity.

Communication through sounds

Fish make sounds by rubbing together body parts such as teeth, spines, or rough surfaces or by using the gases found in their swim bladder. Dolphins make clicks and whales squeals. Shrimp snap and seagulls squark. There is a never ending range of examples to show how animals communicate through sounds for defence, attack, reproduction or establishing themselves in a dominance hierarchy.

Figure 402.3 Concealment
(Illustration Sharyn Madder)

Concealment

Pipe fish or sea horses can float motionless in seagrass or algal beds to escape detection and lie in wait for prey.

These animals also use colouration to blend in with the background.

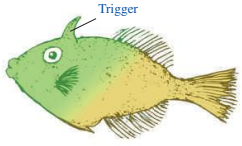
Mimicry

Mimicry in fish is a well established behaviour pattern especially colour.

Colours are used by many poisonous fish to indicate they have poison. Other less poisonous fish have copied the colouration as a behavioural adaptation to fool predators they are poisonous.

Warning signals

Pufferfish blow themselves up with air or water to appear much bigger than they really are. Trigger fish can erect their spine as a signal to predators not to attack.



Territoriality

An area which an individual or group of individuals defends is called its territory. In most cases it is a breeding place that is defended, but it may be a particular food supply or shelter. Once an animal or group of animals establishes a territory other animals tend to stay away from this area. Thus territorial behaviour tends to reduce fighting and competition for the resources.

Territorial behaviour also helps to improve the species. The strong individuals gain the best nesting or feeding sites and the weaker individuals may not even attract a mate.

Thus, the weak individuals, or individuals with less desirable characteristics will not pass on their characteristics to the next generation. This behaviour also helps make sure the population does not outstrip its resources and a balance of numbers exists. Sometimes the territorial fights that one might observe taking place are only mock fights designed to establish physical supremacy.

Other animals such as the fish mangrove jack will viciously attack intruders. The mangrove jack will strike lures pulled through their territory in defence of their territory, rather than for food.

Figure 403.1 Damselfish defend their territories.
(Illustration Sharyn Madder and Bob Moffatt)

Defence of territory

Fish are excellent at defending their territories. Damselfish are well known for their behaviour with dominance hierarchies established to protect territories (Figure 403.1).

Usually the biggest fish is the most dominant and has the greatest range. The hierarchy saves energy in population by reducing competition for food and mates.

Relationships

To survive in the marine environment, marine organisms often engage in a variety of relationships with other organisms. The principal type of relationship is one that involves food and Lerman (1986) identified the following three categories among organisms in the food chain.

- Predator - prey
- Scavenger
- Symbiosis
  - Mutualism
  - Commensalism
  - Parasitism

Other relationships such as competition between species for space or dominance hierarchies may also impact on the food chain.

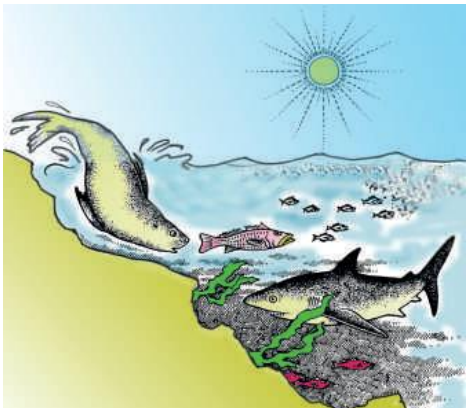


Figure 403.2 Can you see how many relationships are in this illustration?
(Illustration by Sharyn Madder from MESA ABSea by Nancy Tsernjavski)

Food energy flow

The next chapter will discuss this in more detail, but nearly all animals and plants survive by extracting food energy either as a producer, consumer or as a decomposer.

Exercise 15.2 Fish adaptation

Based on an original exercise by Tim Ryan, Maryborough SHS.

Questions

Read the passage in the box to the right, study the illustrations in Figures 404.1 and 404.2 and answer the questions below.

1. Make a list of the words in the *Read this* box that tells you that there are differences between the flounder and the bream.
2. The table below represents the differences between the two types of fish. Make a copy of this table in your note book and use the information in the passage to complete the table.
3. Write a paragraph composed of five sentences. These sentences must show the differences between the flounder and the bream.

Feature	Flounder	Bream
Habitat		
		Strong swimmer
	Both eyes on one side of head	
Body muscles		
		Large eyes
	Dull brown body	
Body pattern		

4. Copy and complete this table in your notebook

Adaptation	Type: behavioural, structural or functional	Benefits	Fish having this adaptation
Sex change			
False eye spot			
Coverage of slime			
Venemous spines			
Poisonous fish			
Peripheral vision			
Schooling			
Muscous shield			
Amour			
Camouflage			
Remove salt from body			
Barbets			

Read this

Flounder

Each particular organism has its own living place - this is called a habitat. In a salt water river, the habitat of a flounder is on the river bottom. The flounder is not a strong swimmer so it does not have well developed muscles. To protect itself from enemies, it lies flat on the sand or mud of the river bottom. Both eyes are on the one side of its head whereas other fish have one eye on each side of their heads. These characteristics, which make the flounder survive well in its habitat, are called adaptations.

The flounder also has another adaptation that increases its chances of survival. It can change its skin colour and pattern to blend in with its background. When the fish is on the sandy bottom (Figure 404.1A), its colour is light, but when on a rocky bottom its pattern changes. It becomes blotchy and much more black and white (Figures 404.1B, C and D).

The bream is found in the same river but has different adaptations (Figure 404.2). It also has a different habitat. The habitat of the bream is the open water of the river. Unlike the flounder, the bream is a strong swimmer. It has a very smooth, streamlined body and the body muscles are strong and well developed. The eyes of the bream are much larger than those of the flounder. This is because the bream catches food on the move.

The bream is a silver–white colour. This colour tends to hide it in the flickering light of the river waters. This compares with the flounder's dull brown and often speckled or spotted colour, which provides camouflage on the river bottom.

If the bream and the flounder swapped habitats, they would become easy prey for predators.

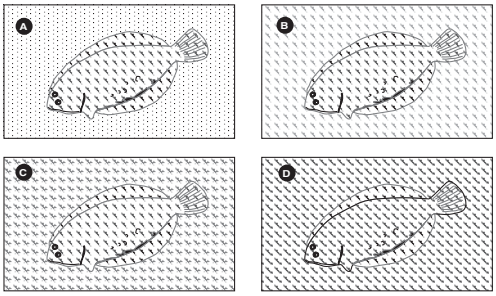


Figure 404.1 Flounder colour changes
(Illustrations Bob Moffatt)

Figure 404.2 Bream

Figure 405.1 Predator - prey relationships
(Illustration Sharyn Madder)

Producers

These are plants such as seagrasses, plankton (Figure 405.2) or algae which extract food from the sun by photosynthesis (see chapters 9 and 10).

Consumers

These include animals that eat plants or other animals. Three types of consumers are:

- Herbivores - Animals that eat plants
- Carnivores - Animals that eat other animals (Figure 405.3)
- Omnivores - Animals that eat plants or animals (Figure 405.4)

Decomposers

Includes the bacteria, fungi and other small invertebrate animals that break down dead and decaying materials. They are the recyclers of the sea returning nutrients and energy back into the system for the producers and lower order consumers.

Predator - prey

In this relationship one animal, the predator hunts and consumes another animal, the prey. An example of this harsh relationship is demonstrated when a shark eats a fish. The shark is the ultimate predator of the ocean. The predator is mostly larger and more powerful than the prey.

Scavenger

Scavengers feed on dead plants and animals that they have not killed. Crabs are a typical scavenger because they rip flesh from animals that have died with their sharp pincer-like claws (Figure 405.5)

Many scavengers however consume detritus (partially decayed or freshly dead plant and animal materials and organic wastes). Detritus-feeders include fiddler crabs (Figure 405.6) and a large number of worms that live in seagrass beds or at the bottom of the sea.

Benthic animals

Many benthic animals are both scavengers and predators because they eat more than one type of food. For example brittle stars can feed on detritus when flesh is not available. Many scavengers live in the deep sea sediment and feed on the rain of dead flesh from above. In complete darkness they must locate the bodies of the dead. Many have strange adaptations to claim this food. The hagfish for example, secretes a mucous slime which repels other fish from the carcass.

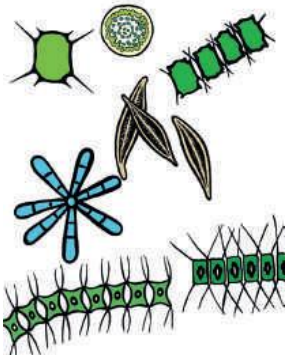


Figure 405.2 Producers - phytoplankton
(Illustration Rose Bedford)

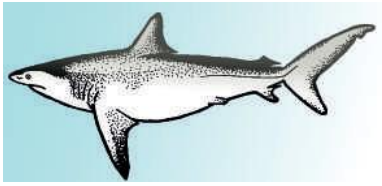


Figure 405.3 Carnivore - shark
(Illustration Rose Bedford)

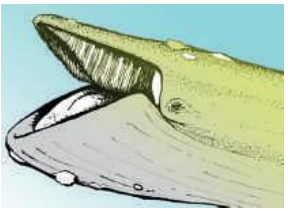


Figure 405.4 Omnivore - baleen whale
(Illustration Kerry Kitzelman)

Figure 405.5 Crabs are an excellent example of a scavenger.
(Illustration Sharyn Madder, courtesy the Gould League)

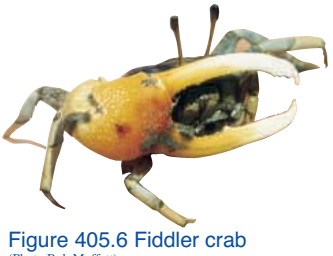


Figure 405.6 Fiddler crab
(Photo Bob Moffatt)

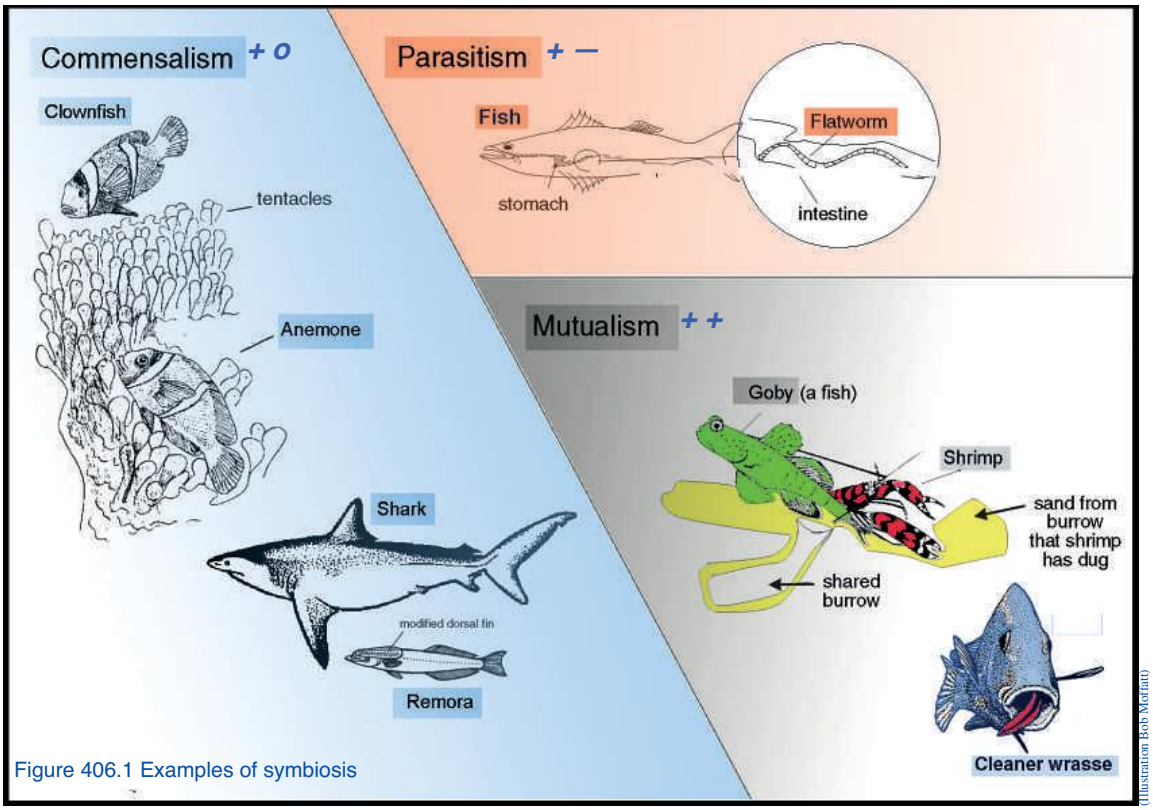


Figure 406.1 Examples of symbiosis

Flashlight fish and luminescent bacteria - mutualism

The bacteria live in the fish's eye where they are supplied with food and oxygen. The bacteria provide the light to feed at night.

Symbiosis

Mutualism + +

Mutualism is a close relationship between two organisms in which both organisms benefit greatly from the association. The association is necessary for the survival of the organisms.

Example

An example of mutualism is the association or relationship between algae and clams (Figure 406.2). The green algae (zooxanthellae) live inside the shell of the clam and provide it with the oxygen and food the clam needs to survive. The clam provides the algae with protection, carbon dioxide and nutrients (waste products). The clam would die without the algae.

Another example of mutualism is the gobie (a fish) that lives in the burrow of the Pistol shrimp. The Pistol shrimp builds the burrow but it has poor eyesight. The gobie acts as a sentry warning of imminent danger. The gobie also captures food that it shares with the shrimp. Some may debate this relationship on the grounds that it is not necessary for survival.

One of the most intriguing examples of mutualism is the cleaning role of an elongated, striped fish called the wrasse. They use their distinctive markings to attract other species of fish to an area then eat the parasites from the fish's bodies. Larger fish even open their mouths and gill covers so that the cleaner fish can swim into their mouths and clean the gills (Figures 407.1 and 406.3).

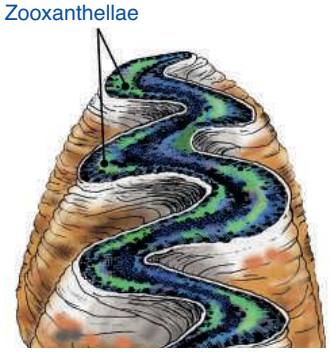


Figure 406.2 Giant clam and zooxanthellae
(Illustration Steven Byers)

Figure 406.3 Cleaner wrasse and fish

Commensalism + o

Commensalism is a loose relationship that exists between two different organisms and which is beneficial to one or both, but is not necessary for their actual survival. The animals having this relationship will have a better chance of survival in their environment.

There are varying degrees of commensalism. In most cases one species benefits from the relationship and the other is not affected.

Some associations make use of the same food source, but not in a competitive way. A good example of this is the anemone and the clownfish (Figure 406.1). The fish benefits from the food the anemone kills with its tentacles, and the anemone benefits from the flesh that results from the fish tearing at the prey **but both** are capable of existing **without** each other.

A good example of commensalism is the remora (shark sucker fish) and the shark. The remora attaches itself to the shark's body and is transported around by the shark. The remora feeds on the scraps of food from the shark's meals. When the shark stops feeding the remora detaches itself from the shark and searches for its own food. It may then attach itself to another shark later on. The shark merely tolerates the presence of the remora.

Some animals of different species live together and share the same shelter. Mostly both animals benefit from the association. Certain fish, crabs and worms find shelter in the burrows of other animals.

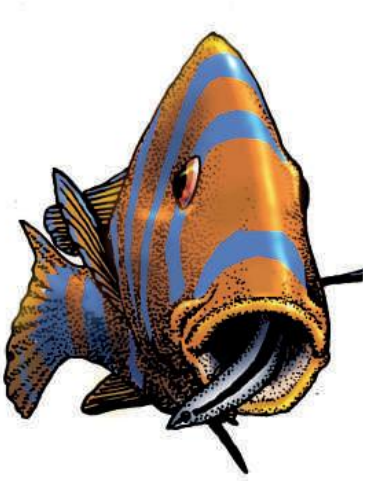


Figure 407.1 Fish and cleaner wrasse
(Illustration courtesy GBRMPA, reproduced with permission)

Parasitism + —

Parasitism is a close relationship where one organism, the parasite, benefits from the association to the detriment of the other organism. The organism from which the parasite gains its nutrients is called the host. The host loses from or is harmed by the association.

Most large living things are at some time in their life affected by parasites. These parasites may be external or internal. A common external fish parasite is the fish louse or copepod. This crustacean attaches itself to the skin or gills of the fish and lives on the blood sucked from the fish.

The internal parasites of fish and aquatic mammals include flatworms, tapeworms, roundworms and threadworms. Some species, which are heavily invested with these parasites, have the digestive cavity filled by a wriggling mass of worms. Bacteria and protozoan also survive in the body of many aquatic organisms.

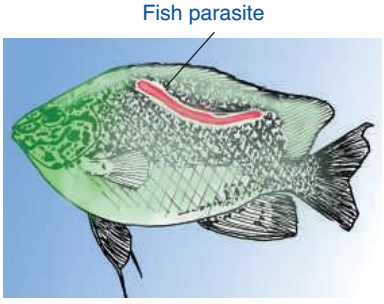


Figure 407.2 Fish and parasite
(Illustration Steven Byers)

Competition

Animals that live in the same area and use the same resources are likely to be competing for these resources. Competition between different species and between individuals of the same species is a form of relationship. An example of competition, can be seen in an mangrove community (page 214, chapter 8). The seagrass is the food source for herbivorous fish, shrimp and crabs, so each of these will be competing against each other. Egrets, larger fish, pelicans and turtles eat small fish. Each of these predators is competing against the others. Plants such as seagrass also compete with mangroves for sunlight, water, minerals and growing space.

Predators

Predators are very important in a community as they control the numbers of prey within that community. Without these natural enemies there would be a population explosion among the prey. The prey may then eat out its own food supply and eventually starve. It is therefore important for a community to have a natural balance of numbers within each species.

Exercise 15.3 Writing definitions

Based on an original exercise by Gwen Connolly, Malanda State High School.

Read the information box in Figure 408.1 and study the example on how to write a definition.

1. Now use your index to locate the chapters and pages that discuss the survival of organisms to write definitions of the following key terms:
   - population
   - community
   - adaptation
   - predator
   - prey
   - omnivore
   - bioaccumulation
   - producer
   - consumer
   - decomposer
   - scavenger
   - benthic
   - territory
   - migration
   - mimicry
   - genetic diversity
   - schooling
   - respiration
   - habitat
2. Use your index to construct a table to distinguish between the following terms:
   - megaplankton
   - ultraplankton
   - microplankton
   - mesoplankton
   - nannoplankton
   - macroplankton

Writing definitions

In writing definitions, the following format could be used.:

Item … class … distinguishing feature … example.

Example

- The definition of the word 'plankton' could be written as follows:

  Plankton are very small organisms that drift in the sea, most of which have to be seen with a microscope

  Item … Plankton

  Class … very small organisms

  Distinguishing feature … that drift in the sea

  Example ... most of which have to be seen with a microscope
- Note that not all definitions require an example.

Practise exercise

Identify the parts of the following definition:

Phytoplankton are plant plankton that contain chloroplasts such as green algae.

Item:

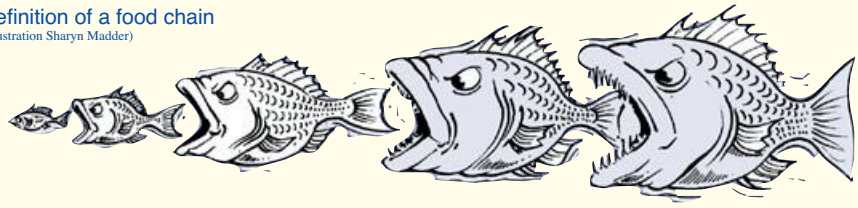
Class:

Distinguishing feature:

Example:

Figure 408.1 How to write definitions

Definition of a food chain
(Illustration Sharyn Madder)



Case study 15.1 The Australian herring

This article is adapted from The Australian Herring, Fishing WA No 3. For copies of the full article, you can write to Fisheries Department of WA, 108 Adelaide Tce, East Perth 6004.

Fish migration

Read the article and study the illustrations in Figure 409.1 and answer the questions below.

The herring found in Australian waters is also known as a tommy rough, ruff or sea herring and is a great fish to eat.

Herrings are silvery in colour with rows of vertical spots as shown in Figure 409.1. Their maximum length is about 40 centimetres and can be caught at 25 centimetres.

They are found south from Shark Bay in Western Australia, in estuaries and bays right across the Great Australian Bight and in South Australia. In Victoria they are found in bays and estuaries all the way to Port Philip Bay.

Adults usually mate in Western Australia where they spawn in the warm coral reefs. The Leeuwin current mixes the sperm and eggs which quickly fertilize and grow into larvae. The current takes the larvae on a trip almost one third of the way around Australia past Perth and Albany to Adelaide and Melbourne. Along the way the larvae are distributed by offshoots of the current in bays and estuaries.

In these sheltered areas the larvae grow into juveniles in the protected waters and feed off the sea grass beds and small crustaceans that inhabit the cooler waters off Australia.

Some enter the coastal estuaries and feast on the rich inshore life and grow larger and fatter than their coastal relatives.

When they are about three years old, they hear the call of the west and undertake a perilous journey back across the bight in a spawning run which finishes in the reefs off Western Australia. Tagging experiments have shown that some fish can travel up to 2190 kilometres.

Fish are caught from boats with lines and recreational net fishing is mostly prohibited. The only other restriction is on size with the minimum legal size set at 18 centimetres (total length).

The commercial fishery is operated by a licence system which has a season. The idea is that the fish are given enough time to migrate and spawn – then it's every fish for itself as the season opens. Fishers usually fish from the beach with a boat that goes a short distance out to sea. The boat carries a seine net and the skill of the skipper is used to circle the herring. A large loop is made around the school and the skipper then drives ashore. The net is drawn closer and closer by helping hands or four wheel drive and gradually the fish are entrapped and hauled up the beach where they are quickly taken to market.

Australian herring are usually eaten fresh and freezing is not recommended as the fish tends to loose their texture when thawed. Herring make excellent fish for smoking but are usually pan fried, grilled or rolled into circles and soaked in pepper corns and onions and eaten raw.

Questions

1. Where do adult Australian herring live?
2. When are the commercial and recreational fishing seasons in Western Australia and South Australia? When do you think the best time would be to go fishing in Victoria?
3. Why don't the fish get to Tasmania?
4. Where do the juveniles develop? What do they feed on?
5. Why do we have to keep pollution out of our coastal waters?
6. How long does it take for a herring to grow to be an adult?
7. What is a spawning run and where does it go to?
8. What is the idea behind a fishing season?
9. Why have a fishing season at all?
10. Draw a diagram to show how a fisher would catch a school of herring from the beach with a seine net.
11. What is the legal catch size of Australian Herring?

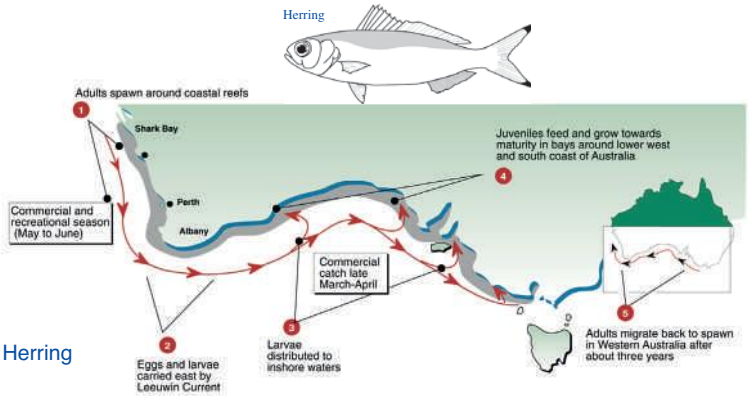


Figure 409.1 Herring migration

Exercises

From the Wet Paper Publication - *Marine Biology Exercises See www.wetpaper.com.au*

D1. Why do we study the biotic and abiotic environments?

D2. How do sea birds survive?

D3. How do animals use structural adaptations to survive?

D4. How do animals use physiological adaptations to survive?

D5. How do animals in the intertidal zone survive and reproduce?

D6. How do animals use behavioural adaptations?

D8. How do abiotic and biotic factors affect life on a rocky shore?

D9. What is the difference between producers, scavengers and predators?

D11. What are three types of symbiotic relationships?

Questions

Knowledge

1. What is the environment of a marine organism?
2. Define the terms *abiotic* and *biotic* giving examples of each.
3. Give two definitions of a *niche*.
4. Define what a *scavenger organism* is and does.

Understanding

5. List 8 abiotic features and give an example of each.
6. Describe some animals and plant tolerances to pH.
7. Distinguish between the following terms:
   - Predator - prey;
   - Symbiosis and competition;
   - Structural, behavioural and functional adaptation.
8. Distinguish between the following terms, giving an example of each.
   - Mutualism;
   - Commensalism;
   - Parasitism.
9. Describe how water temperature can exert a major control over the distribution of marine organisms.

Applying

10. Use your knowledge to defend the argument that territoriality is an important adaptation for damselfish.
11. Examine the illustration in Figure 410.1 and describe the type of habitat each fish would occupy. Give reasons for your answers.

Creating

12. Compose a rhyme to help class members remember the difference between mutualism, commensalism and parasitism.

Analysing

13. Analyse the two paragraphs below to describe examples of symbiosis and predator-prey relationships:

    The giant clam (Tridacna gigas) is only found in shallow, warm tropical waters of the Indo-Pacific region. Like reef-building corals, clams depend on microscopic zooxanthellae for their main source of nourishment.

    These plant cells are 'farmed' within the clam's body. Clams supplement this farmed food by filter feeding, gaining nourishment by straining microorganisms and algae particles from the water. Recent research indicates the giant clams may not actually filter food at all, but rely wholly on zooxanthellae.

14. The male stickleback (a freshwater fish of the Northern Hemisphere) constructs an elaborate nest to protect the eggs. The male does a zig-zag dance when a female of breeding age enters his territory. The male then fertilizes the eggs and continues to watch over the eggs until they hatch.

    Give possible reasons for these behaviours.

Evaluating

15. Write an essay on the adaptations of animals and plants on the rocky shore.

    Identify the biotic and abiotic factors that affect the animals and plants and rate each in order of effect on a marine organisms.

    Give at least one example from each of the following phyla - cnidaria, arthropoda, mollusca, osteichthyes, aves, angiosperm, algae and decide which would have the greatest chance of survival from human influences.

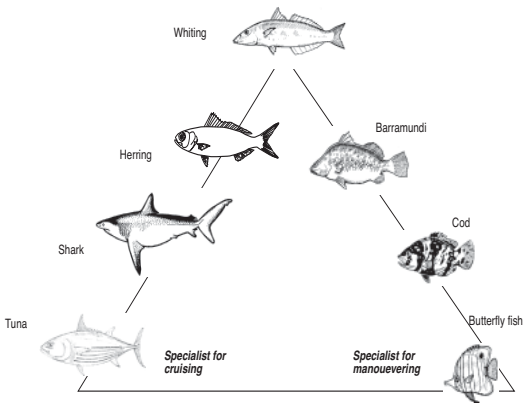


Figure 410.1 Fish shape and movement

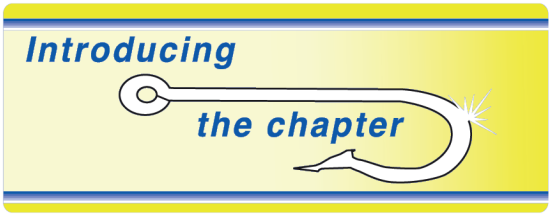
Chapter 16 Ecosystems

Energy and cycles

by

Bob Moffatt and Tim Ryan

Photo Qld Fisheries



Chapter hooks

- Examine excursion data and discuss the boundaries of the ecosystem.
- Revisit the Exercise 15.1, page 391 and use Moffatt Headland from Hypothetical Bay to discuss ecosystem boundaries. Make an overhead transparency and pose the following questions:
  - Where would barnacle larvae go?
  - How do the animals in the rock pools get their energy?
  - Where would the producers be found?
  - Draw a picture of what it would be like underwater just off the rocks at low tide.
  - Find an illustration in this book that best supports your picture.

Why study this chapter

The concept of ecosystems takes a long time to understand and is the subject of much scientific debate. Some argue that a coral clump is an ecosystems in itself, while others prefer a more broader definition. The survival of the marine world depends on our understanding of ecosystems.

Chapter overview

Introduction 413
Food and energy 414
Energy transfer 416
Bioaccumulation 417
Case study 16.1 DDT in the Food chain 418
Nutrient cycles 419
Populations 422
Make a transect square 424
Exercise 16.1 Mangrove transect 425
Exercise 16.2 Ecosystem diversity 426
Case study 16.2 Cool evidence 427
Exercises and questions 428

Key concepts

1. An ecosystem requires a source of energy. The sun is the ultimate source of all energy for most ecosystems.
2. An ecosystem contains organisms capable of capturing this energy to manufacture organic molecules. Seaweeds and other plants perform the job of absorbing light energy. They then convert it into organic molecules for the ecosystem.
3. Organic material must be available to all organisms in the ecosystem. Organic materials pass from organism to organism in a natural ecosystem when animals and plants feed.
4. Nutrients such as oxygen, water, carbon and nitrogen must cycle in natural ecosystems between the biotic and abiotic environment. When animals excrete they return nutrients and decomposers such as fungi and bacteria return them to the ecosystem. The role of microorganisms is to break down dead and decaying materials as well their wastes, into smaller chemical compounds which are reconstituted in plants.
5. Sustainability of a marine ecosystem is said to occur if the above four criteria are met. However there is often exchange of materials between ecosystems and therefore sustainability may be determined by how well other ecosystems are sustained.

Acknowledgement

Parts of the text in this chapter are an adaptation of works written by Matthew Lerman from his book Marine Biology. Many of the illustrations (as acknowledged) were the original ideas of Nancy Tsernjavski and have been reproduced with permission.

Introduction

An **ecosystem** can be defined as all the interacting parts of the abiotic and biotic environment. *A large marine ecosystem (LME) is a relatively large region, of the order of 200,000 km² or more, characterised by distinct bathymetry, hydrography, productivity, species composition and trophically inter-dependent populations (Sherman and Alexander, 1986).*

Natural ecosystems are very complex and exist as a balanced system. The organisms that form part of the ecosystems have certain roles and functions in the system, and there is a close relationship between these organisms and their habitat. Therefore, the animals and plants living in an area are usually studied in conjunction with their habitat. An ecosystem is defined as all the living and non-living things that interact together and how they recycle and exchange materials.

Most natural ecosystems have:

- many different producers;
- complex food webs;
- recycling of nutrients;
- physical, chemical and biological components.

The study of these ecosystems is termed *ecology*; it is important because we obtain all our needs from the environment and in turn need to understand the complexities of it in order to live with it harmoniously. Through the study of ecology we can better understand the relationships between living organisms and their non-living surroundings and gain an understanding that we cannot obtain all our needs without disturbing the balance of nature.

No individual lives alone. Organisms live and interact with members of their own species and compete with, feed on, depend on, are eaten by and fight against themselves and other species.

A community is defined as a group of independent organisms living in a common habitat or area. All communities are dynamic and constantly changing. The different communities found in nature are all inter-related and overlap with each other.

For this reason, most of the natural communities have no defined boundaries (Figure 413.2).

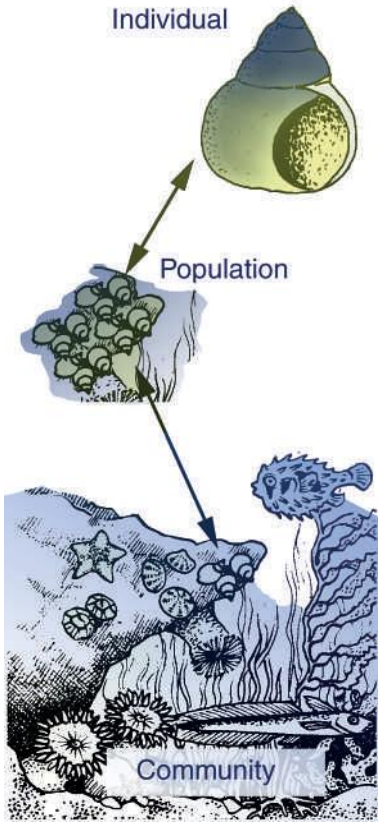


Figure 413.1 The biotic community
(Illustration Bob Moffatt. after Lerman)

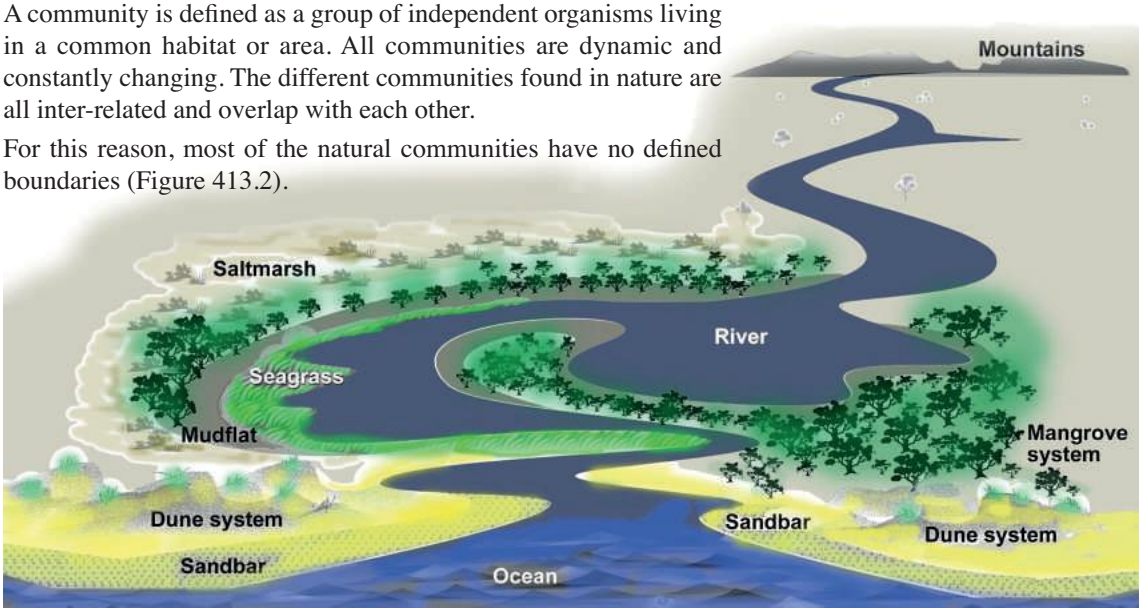


Figure 413.2 Some of the communities found in an estuarine ecosystem. Can you see any clear boundaries?
(Illustration by Bob Moffatt and Kerry Kitzelman)

Photosynthesis (plants) occurs in upper layers of the ocean

$CO_2 + H_2O$ + nutrients + energy from the sun → sugars + O_2

Figure 414.1 Photosynthesis
(Illustration Bob Moffatt)

Respiration (plants and animals) occurs throughout the ocean

sugars + O_2 → CO_2 + H_2O

Figure 414.2 Respiration
(Illustration Bob Moffatt)

Food and energy

Food links all organisms together in an ecosystem (Figure 414.3) and all living organisms need energy to survive. Food provides this energy for all animals.

Producers

The producers of the ecosystem are the plants. These organisms take in simple chemical substances found in the environment and convert them into complex compounds. The process by which this is completed is called **photosynthesis** (Figure 414.1). Most plants have a special pigment called chlorophyll that absorbs solar energy from the sun. It is this energy that is used to convert the simple chemicals into complex organic substances. The energy is then stored in the chemical bonds of these complex organic substances. The sun is therefore the original source of energy for all living organisms. The producers are the original source of food material. The organisms that carry out this process are called autotrophs. The autotrophs, therefore, obtain the energy they require to survive from the sun. The phytoplankton, seagrass, sea lettuce and mangroves are examples of autotrophs (in Figure 414.3).

Consumers

The organisms that eat these producers are called consumers. These organisms take in the complex organic substances and convert them into simple chemical substances.

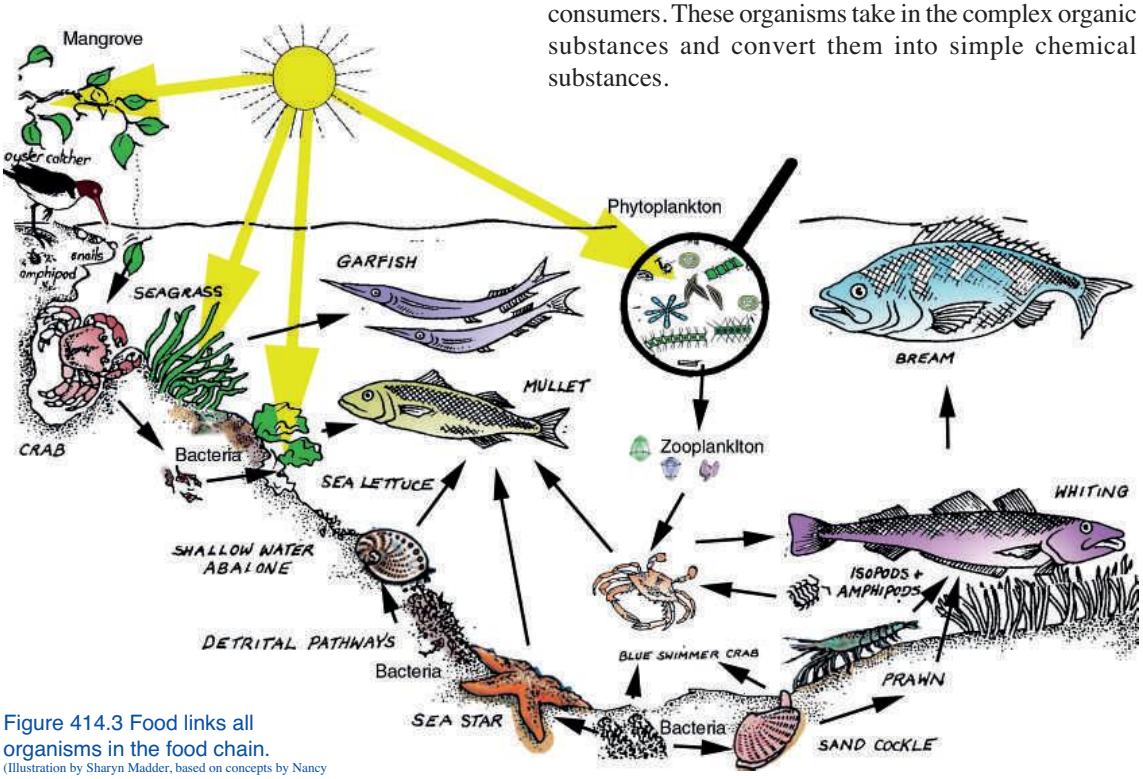


Figure 414.3 Food links all organisms in the food chain.
(Illustration by Sharyn Madder, based on concepts by Nancy Tsernjavski from ABSea, copyright MESA, reproduced with permission)

This process is termed respiration and it supplies the energy needs of the consumer. Can you name six consumers from Figure 414.3?

Respiration is the reverse of the photosynthesis process (Figure 414.2). Plants also carry out respiration, as they cannot use the energy from the sun in its radiant form to provide the energy for normal life processes.

Levels

a. First order consumers - The animals that feed directly on the plants are called herbivores. Examples of herbivores are zooplankton and weed-eating fish.
b. Second order consumers - These animals feed on the first order consumers and are called carnivores. Examples are small fish and filter feeding animals.
c. 3rd, 4th and 5th order consumers - These feed directly on the order below them. They get their energy indirectly from the producers. Examples of higher order consumers are larger fish and sharks.

Consumers, therefore, use the organic substances as a source of energy and are called heterotrophs. These heterotrophs directly or indirectly, rely on autotrophs for the energy and matter they need to survive.

Scavangers and decomposers

Scavengers are a special group of animal consumers that eat dead animals and plants. Ocean scavengers include crabs and prawns which continually eat the scraps of uneaten food. Scavengers are also efficient at cleaning up the dead remains of others. Many species of sharks and fish also scavenge for food.

Decomposers - these organisms break down the dead bodies of other organisms into simple compounds. Decomposers are important in the cycling of nutrients. Examples of decomposers include bacteria and fungi.

Food chains and food webs

The sequence of organisms through which food passes in a community is called a **food chain** (Figure 415.1). Simple food chains or feeding relationships are very rare in nature as most animals have more than one type of plant or animal food in their diet. The feeding relationships become quite complex and involve a number of food chains all woven together. A **food web** (Figures 414.3 and 415.2), shows the network of feeding relationships and gives an idea of the complex inter-relationships that exist in a community.

Odd fact

If people start to manipulate the numbers of certain species eg killing off certain pests such as mosquitoes, major changes of animal numbers in the community may occur. Fish numbers may decrease, while plant numbers may increase.

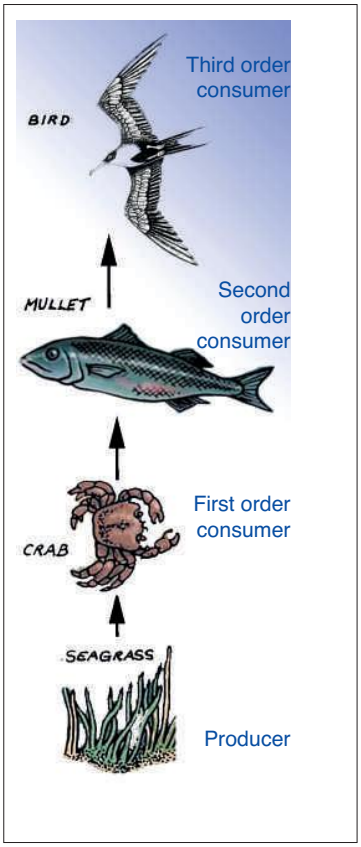


Figure 415.1 Food chain
(Illustrations Sharyn Madder and Kerry Kitzelman)

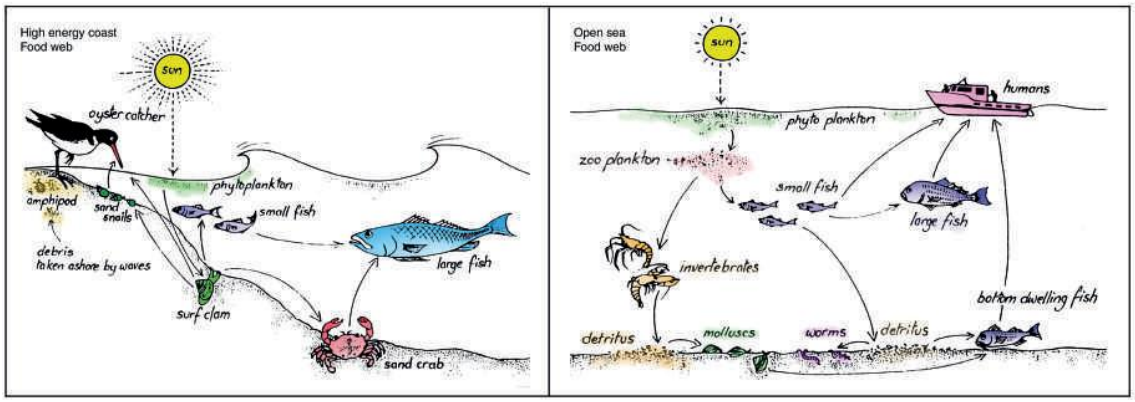


Figure 415.2 Food webs
(Illustration by Sharyn Madder, based on concepts by Nancy Tsernjavski from ABSea, copyright MESA, reproduced with permission)

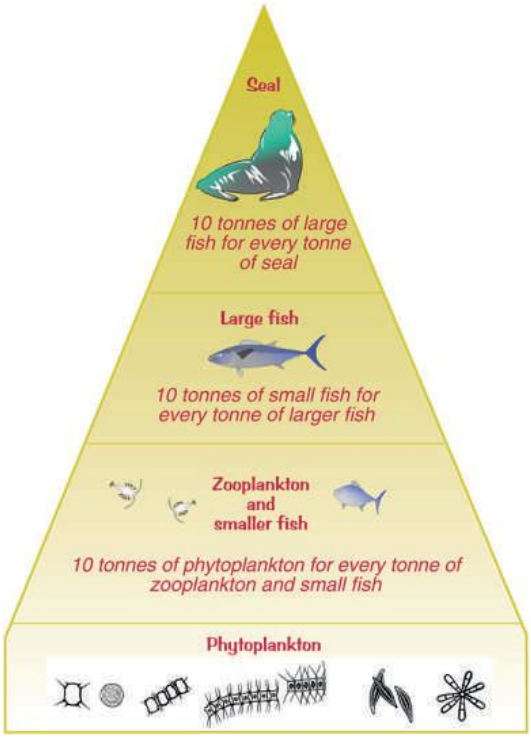


Figure 416.1 Pyramid of numbers
(Illustrations by Bob Moffatt, Rose Bedford)

Odd facts

1. It has been estimated that a colony of seals consumes between 3-5 million tonnes of fish each year.
2. Energy is measured in units called joules. 1000 joules = 1kj
   - When a match burns 2 kj of energy is released.
   - 100 grams of raw whiting flesh contains approximately 340 kj.

Energy transfer

Energy is needed for the life processes such as movement, growth, reproduction and the repair of body parts. The ultimate source of energy is the sun. A tremendous amount of energy from the sun reaches the earth, but only about 1%-2% of this is converted by the producers into chemical energy. This energy is stored in the chemical bonds of glucose and other organic compounds.

The chemical energy taken in by the consumer is mostly wasted or converted into unusable forms of energy. Of an animal's total energy intake only approximately 10% is used to build its body. Much of the food is not completely digested and is simply expelled as waste. The rest of the energy is used to keep the animal alive, and functioning. The heat energy produced by the animal when the food is broken down is lost to the environment.

Pyramids of numbers

The number of large animals or higher order consumers is much less than the numbers of first order consumers or producers. It has been estimated that a seal may eat over 1,000 herrings in a day. Herrings, in turn, consume up to 5,000 copepods each day. A copepod itself will consume up to 100,000 plankton each day. This means 500,000,000,000 plankton each day are ending up inside one seal (Figure 416.1).

Scientists use an energy pyramid to demonstrate this energy flow through a system (Figure 416.2). Energy cannot be recycled and flows in only one direction. Food pyramids differ from food chains in that they show the relative numbers of the organisms in the food chain.

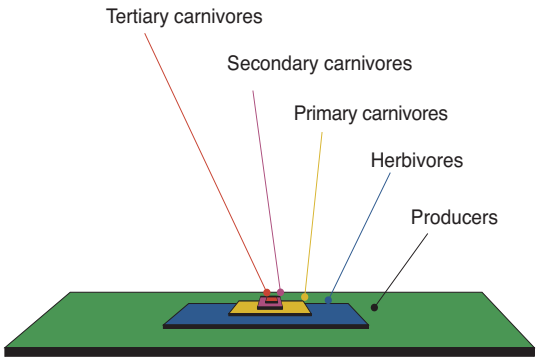
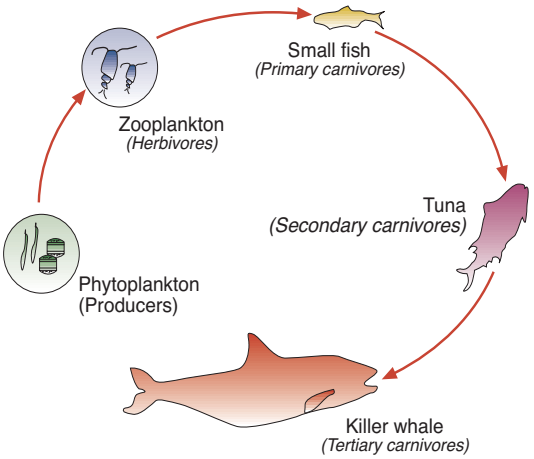


Figure 416.2 Trophic levels and ecosystem productivity (After Thurman and Webber)



Biomass

Biomass is the total amount of living matter per unit of surface or volume, expressed as a weight (g/m^2).

The higher levels of a food chain will contain smaller amounts of biomass than the previous level. For example, a certain marine environment may support a producer with a biomass of 1, 000 g/m^2. The same area may only contain a biomass of herbivores of 50 g/m^2, and 15 g/m^2 of second order consumers. Studies of energy and biomass are important in marine aquaculture as underwater farmers seek to improve their harvest for a world that is discovering the nutritional value of food from the sea.

Figure 417.1 Albatross are subject to bioaccumulation of DDT. (Photo Bob Moffatt)

Bioaccumulation

Many chemicals in the environment are said to be cumulative. Cumulative chemicals build up within the body and in most cases the body cannot rid itself of these chemicals. When a consumer organism eats an organism that contains one of these cumulative chemicals, the amount of chemical found in the prey can be absorbed. If it then eats another organism containing the same chemical, the chemical is again absorbed and the amount found in the predator doubles. The process can repeat itself a number of times resulting in high levels of sometimes dangerous chemicals in higher order consumers. This process is known as bioaccumulation.

Bioaccumulation

Source	DDT Concentration Parts per million
Bottom sediment	0.00006
Phytoplankton	0.06
Zooplankton	0.4
Predatory fish	8 .0
Predatory birds	240.0

Figure 417.2 Data for Q 12, page 428

QUESTIONS

1. What is the ultimate source of energy for the oceans?
2. Write word equations for the processes of photosynthesis and respiration.
3. Distinguish between the terms *herbivore* and *carnivore*. Give 3 examples of each.
4. Explain why it is unusual to find a community without any producers. Can you think of a community without producers – think deeply.
5. Only 10% of energy is passed on in the food chain from one consumer to another. Why is this so? What happens to the other 90% of this energy?
6. Define the terms
   a. ecology
   b. ecosystem
   c. heterotrophs
   d. bioaccumulation
7. Explain the difference between a food chain and a food web. Give an example of a food chain.
8. Do you believe a food web for a community will change ...
   a. during a 24 hour period?
   b. from season to season?
   Give examples to explain your answer.
9. Predict the effect on the food web shown in Figure 414.2 if crabs were removed from the area.
10. Which group of organisms in the sea would you expect to have the highest concentration of pollutants within their body?
11. Accumulation of pollutants occurs in each level of the food chain. How could organochloride used to control termites have appeared in mother's milk?

Case study 16.1 DDT in the food chain

After the Second World War the scientists began to develop synthetic chemical pesticides. They developed the chlorinated hydrocarbon insecticides, of which DDT is the best known. DDT was developed by the Swiss scientist, Paul Muller, and it earned him a Nobel Prize in 1948.

DDT was extensively used in agriculture in the 1950's and 1960's, to control all kinds of insect pests and allowed huge increases in food production. It was believed that DDT had no effect on other animals.

DDT saved millions of lives in malaria-affected countries. Unfortunately, the full effects DDT on the environment and animals were not noted until the late 1960's. DDT is non-biodegradable and is strongly resistant to chemical action and does not dissolve in water. When an animal eats another animal containing DDT most of this DDT is absorbed and dissolves in the fatty tissue where it remains until it dies.

Therefore once DDT is sprayed on crops it will be eventually washed into the rivers and creeks. Here it will then find its way into aquatic plants and phytoplankton. The concentration in these plants is mostly very small and does not affect them. High concentrations do affect their ability to photosynthesise and may stunt their growth. The animals that eat these plants accumulate the DDT in their bodies.

The DDT has a serious effect on these animals, in which it causes (a) some birds to become sterile; (b) the eggshells to become thin and easily broken; (c) the embryo's growth to slow down; (d) the production of sex hormones to stop. The DDT has also built up in the human population. Mother's milk has been shown to contain more than 4 times the accepted level for fresh milk in some communities. DDT can also cause liver damage, stunted growth and nervous problems.

How could we control insect pests if we are not to use chlorinated hydrocarbons?

We could try biological control where we find a natural predator.

Attitudes also play a role - by reducing the sex or food supply or breeding grounds, you can reduce population sizes. Eg. Sterilize males, get rid of places where water accumulates – eg old car types, buckets or pot plants. Pour oil on water (in some places).

Web reference

You can read the complete article on the problem of chlorinated compounds in Australia's marine environment by Bruce J. Richardson, School of Biological and Chemical Sciences, Faculty of Science and Technology, Deakin University, Geelong, Victoria 3217 at

http://www.ea.gov.au/coasts/publications/somer/chapter4.html

Questions

1. Why do you think scientists describing the problems of DDT talk about the 'poison pyramid'?
2. Insects eventually became resistant to DDT even when the original recorded kills were 99%. Explain how this could have happened.
3. How was it possible for DDT to save over millions of lives in malaria affected countries? How could DDT affect the transfer of infectious diseases? Why are some of the effects of DDT on human population not yet known? Why has it taken so long to find out?
4. By how much does the concentration of DDT increase as you move up the food chain?
5. Propose a definition for the term - bioaccumulation.
6. Propose how could we control insect pests if we are not to use chlorinated hydrocarbons?
7. Another chlorinated hydrocarbon in the news lately is Dieldrin. Where has this chemical been a problem?
8. What steps must be taken if history is not to repeat itself with the introduction of new and different insecticides?
9. Who should pay for the cost of cleaning up the DDT mess?
10. The amount of chemicals that is poured into the oceans is enormous. It has been estimated that for the last 25 years, 400,000 tonnes of DDT eventually found its way into the sea.

    How much DDT would now be in the sea? What problems may we encounter in the future?

Nutrient cycles

All feeding relationships discussed so far show a one-way flow of energy through the system called nature. This energy is not recycled. The plants may start the system using radiant energy from the sun, but would not survive without the nutrients that are made available from the nutrient cycles. Unlike energy, the elements such as carbon, nitrogen, oxygen and sulphur are used and reused by plants and animals. Most of the elements have their origin in the rocks that are broken down by nature to release their elements. Violent volcanic eruptions also release elements. Large amounts of these elements such as nitrogen and oxygen are found in the atmosphere.

Nitrogen cycle

Living organisms require nitrogen to build proteins. Life cannot exist without nitrogen or its products. There is ample nitrogen for all organisms in the atmosphere (79% of the air is nitrogen gas), but most organisms cannot absorb nitrogen in this form. Nitrogen is taken up by plants in the form of nitrates (nitrogen compounds). The nitrogen is then passed along the food chain.

Nitrogen is converted into nitrates in one of three ways.

a. Biological fixation. Some bacteria are able to convert atmospheric nitrogen gas into nitrates. These are called **nitrogen-fixing bacteria**. These bacteria can be found living in soil, or floating in water. Others live in the nodules on the roots of plants such as beans and clover. Blue green algae found in the oceans carry out this process.

b. Atmospheric fixation. The high temperatures generated in lightning flashes combine atmospheric nitrogen gas with oxygen gas. The compounds produced are dissolved in the rain and washed into the soil and waterways.

c. Industrial fixation. Factories manufacture artificial nitrogen fertilizers. These factories combine nitrogen and hydrogen gases at high temperatures and pressures. These nitrates are absorbed by the plants and phytoplankton of the oceans and converted into protein compounds.

Fish and other marine animals then consume these proteins. The decomposing bacteria eventually recycle the nitrates. The bacteria that convert the dead bodies and the wastes of the animals into nitrates are called nitrifying bacteria. Denitrifying bacteria convert these nitrates into nitrogen and oxygen gases, thus completing the cycle.

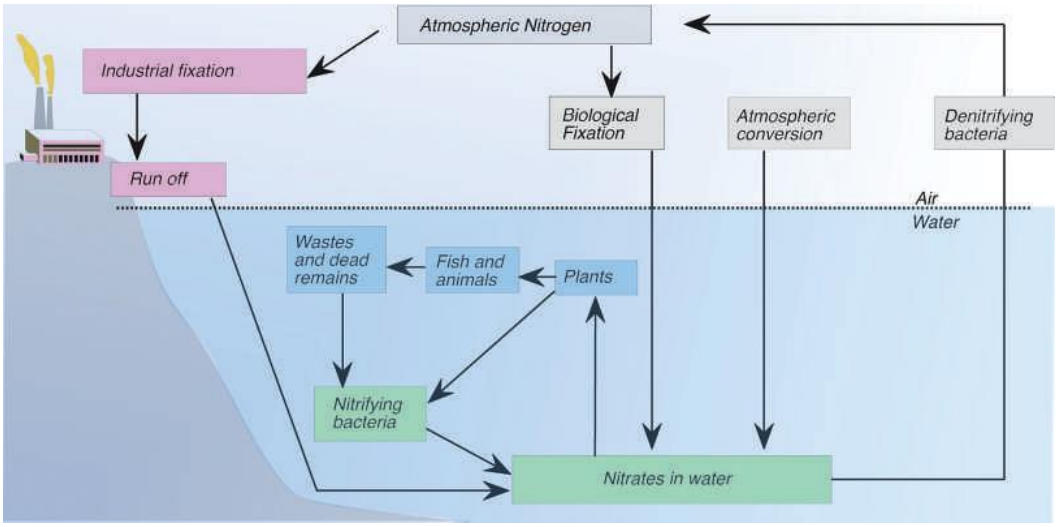


Figure 419.1 Nitrogen cycle
(Illustration Bob Moffatt, from *Pollution - Issues in Marine Conservation* by Tim Ryan)

Carbon cycle

Carbon is another element that is recycled. Carbon is one of the major components of all living bodies and is essential for life. The original source of carbon is the carbon dioxide gas found in the atmosphere (Figure 420.1). This carbon is removed from the air by green plants and phytoplankton while carrying out photosynthesis. Once the carbon is in the form of carbohydrates in the plants it can then be passed along the food chain.

Oceanographers estimate that phytoplankton produce 20 - 30 million tonnes of carbon each year forming 85% of the carbon found in the ocean. Marine organisms complete over one and a half times the photosynthesis of land plants.

The carbon dioxide may dissolve in rain, entering the water by this method. This dissolved carbon dioxide forms bicarbonate ions that can combine with calcium to form calcium carbonate. Many marine animals especially the ones with shells absorb carbon in this form. Large amounts of carbon containing compounds are also brought into the oceans as organic wastes that are washed down by the rivers.

Carbon is returned to the air by the process of respiration. All living organisms - plants, animals and decomp

osers - carry out respiration. Much of the dead and decaying organic matter of the sea is not decomposed and is buried in the sediments. Eventually these remains may form fossil fuels which man can recover and burn. This again releases carbon dioxide into the atmosphere.

The burning of fossil fuels by industry and in vehicles converts the carbon in the fossil fuel into carbon dioxide. Over 500 million tonnes of carbon dioxide are being added to the atmosphere each year. The trees that convert this carbon dioxide back into oxygen are also being removed at a disturbing rate. The end result is a build up of carbon dioxide in the atmosphere.

Greenhouse effect

This build up has a blanketing effect on the earth. The carbon dioxide and other exhaust gases allow the heat from the sun in, but reduce the release of this heat. The heat is absorbed and /or reflected back to the earth, allowing less of the heat to escape. The gas envelope acts like a glass greenhouse (Figure 420.2) and is expected to increase the earth's temperature and cause many changes.

This is known as the greenhouse effect. Weather patterns may change forever, with changing rainfall patterns and more cyclones in the tropical areas.

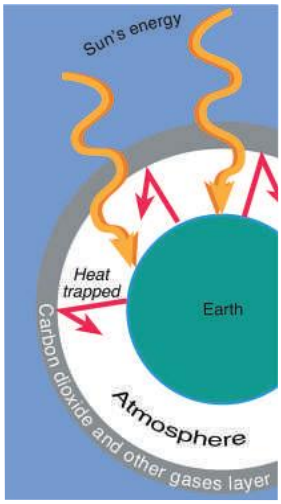


Figure 420.2
Greenhouse effect
(Trent Moffatt)

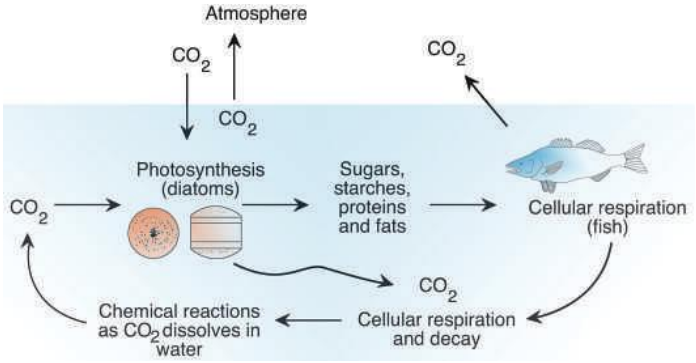


Figure 420.1 Carbon cycle
(Illustration Bob Moffatt)

Odd facts

1. The sea level is also expected to rise by at least 1.4 metres in the next 30 to 50 years. This will cause the inundation of many natural ecosystems with some Pacific islands being almost entirely destroyed.
2. A shoal of krill with an estimated weight of over 6 million tonnes was tracked by satellite off Antarctica in 1998.

Sulphur cycle

Oceans are a rich source of sulphur with large amounts being found in the sediments at the bottom. Sulphur is needed by most organisms to build proteins.

- Plants and phytoplankton take in the sulphur in the form of sulphate ions. This sulphur is then passed along the food chain.
- Dead organisms and wastes are finally converted back into the sulphate ions by bacteria. Some anaerobic bacteria convert hydrogen sulphide, a poisonous smelly pollutant into proteins.

Sulphur is building up in the atmosphere because of the burning of fossil fuels containing sulphur. This turns into sulphur dioxide (SO_2) which is a particular problem. This gas combines with rain to form sulphuric acid with the new mixture now called "acid rain". This acid rain can severely damage buildings, unprotected metals and cause the acidity of lakes and waterways to increase. This acidic water can dissolve many metal elements and these will be consumed in the drinking of this water. The sulphur cycle is not a balanced cycle.

Water cycle

The water cycle is also known as the hydrologic cycle. In this cycle water passes from the atmosphere to the earth and back again to the atmosphere. The oceans lose water by the process of evaporation. The sun provides the energy to convert the water molecules from a liquid state to a vapour.

These water molecules then form clouds where they are carried around the earth by air currents. Eventually the air is cooled and the vapour turns back into water droplets and falls as rain. This process is known as precipitation. Only a minimal proportion of the earth's water is contained in living matter although it is essential for life.

All the water that falls on the land eventually returns to the ocean via a system of streams, rivers and underground waterways. The water cycle is a giant distillation process.

Phosphorus cycle

Phosphorus is another important element for spinifex which has an active root system to seek out this element.

When quartz and feldspar are formed, they contain a fine coating of phosphorus which sticks to the sand grain as it moves along the coast. When the sand grains are washed up on the beach, they dry and are blown towards the spinifex (Figure 421.1).

The broad leaf of the plant catches the grain by reducing the wind velocity and the grains falls to the base of the plant.

Fine root hairs that grow from the main plant then absorb the phosphorus coating from the sand grain providing vital nutrients for the plant to grow (Figure 421.2).

Figure 421.2 Sand contains phosphorus
(Photo Bob Moffatt)

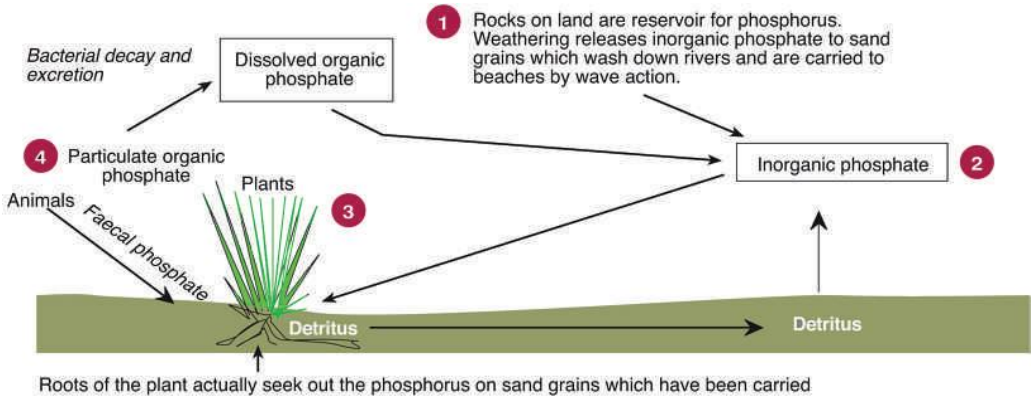


Figure 421.1 Phosphorous cycle in dune plants
(Photos and illustration Bob Moffatt)

Figure 422.1 Marine scientists estimate population size of benthic invertebrates with a grab.
(Photo Tim Ryan)

Populations

Size

There is a natural balance of numbers of consumers and producers in a natural ecosystem. These numbers may fluctuate during a year, but these fluctuations are mostly due to seasonal variations such as the availability of water, light and heat. The term used to describe this natural balance is dynamic equilibrium. The word dynamic means that changes are taking place while the word equilibrium suggests that there is a balance. This suggests that within a natural community the numbers of different species are similar from year to year.

When talking about the numbers of organisms it is convenient to use the term population. A population refers to the number of a particular species living in a particular place at a particular time. Scientists studying populations of different species in an ecosystem often make graphs of their results. The graphs in Figure 422.2 show the fluctuations in the population sizes.

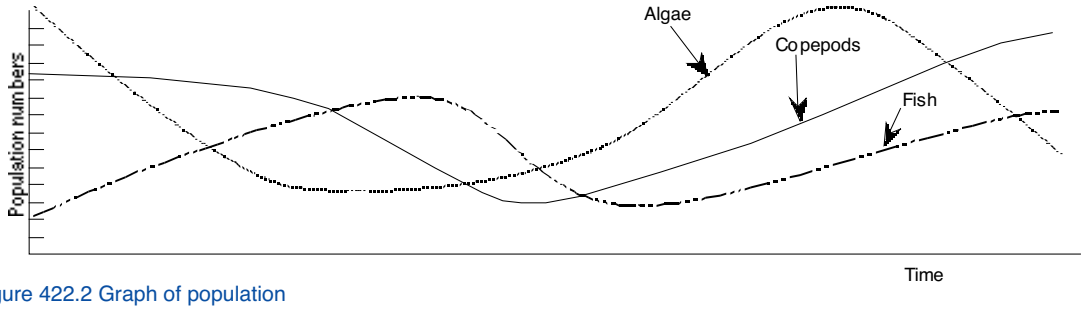


Figure 422.2 Graph of population number of different species versus time.
(Illustration Bob Moffatt)

Estimating population size

Obtain a jar of rice or macaroni.

- Take a sample of approximately 1% of the total amount of rice/ macaroni.
- Count and mark the sample in some way (it may be possible to dye the samples).
- Replace the sample and mix the rice/macaroni in a large container.
- Take another sample and count the number of rice/ macaroni recaptured.
- Estimate the number of rice/macaroni from the original sample.

Densities

In any study of a natural marine environment it is important to have some idea of the number of organisms in that area. To count the total number of organisms is impossible in most cases. Therefore scientists normally compare population densities in an area.

The population abundance is expressed as a density or the number of individuals in a set area or volume. These population densities can then be compared with other areas that have similar characteristics. Scientists expressing a density of plankton in an area may give the population density as the number of plankton per litre or 100 cm^2. The amount of seagrass found in an area may be expressed as the number of plants per square metre.

Estimating population size

In estimating the population size the most common method used is a sampling technique. Representative samples are counted and from an average value the total population is calculated. Obtaining a true representative sample is a problem. An area may have a large concentration of seagrass in some places but none nearby.

To estimate the populations a number of one metre square areas are chosen at random and the number of individuals in these squares is counted.

The size of the area to be counted will of course depend on the type of animal being studied. Such sample areas are called quadrates (Figure 423.1).

Another method that is used in marine studies is to draw a line transect. A straight line or string line is drawn through the study area and the number of individuals along this line or within a metre of the line is counted. This method is very useful in observing community boundaries or changes in types of individuals as one progresses through the area.

Scientists also use a capture/recapture method to observe changes within a population and population numbers. In this technique a number of individuals are captured, tagged and released. The total population will equal the number of tagged individuals, multiplied by the total number of individuals caught in the second capture, divided by the number of recaptured tagged individuals.

This method is also used to record changes in population numbers over time. Turtles for example have been studied in certain nesting areas. They are tagged and released and the number returning to the nesting area in subsequent years gives an indication of population trends.

Tagging programs have also been used to gather information such as growth rate and movements of a species. Fish tagging programs have been set up for a number of years and these have given researchers a great deal of information about the individuals living in the wild.

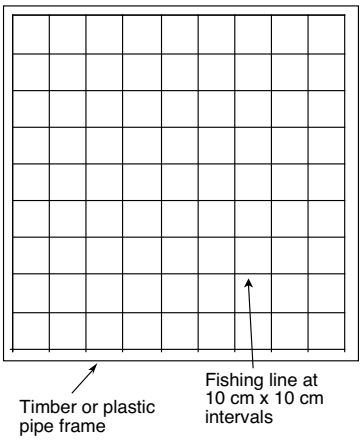


Figure 423.1 A quadrat square
(Illustration Bob Moffatt)

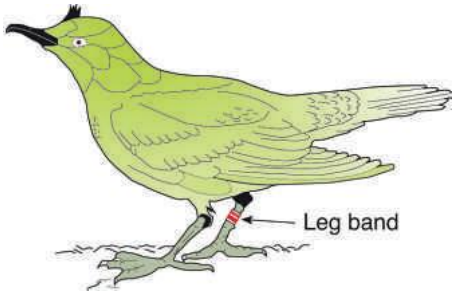


Figure 423.2 A bird band
(Illustration Bob Moffatt)

Transient populations

Transient populations are populations that often develop in an area and then disappear. How long they stay depends on the type of organism and the environmental conditions. Many migratory species form transient populations. Whales for example can be found for a period of time in Hervey Bay in Queensland where they rest and recuperate before continuing their journey to the Antarctic.

Figure 423.3 Turtle tag
(Photograph Bob Moffatt)

Changes over time

New competitors - introduced species

Nature in its pristine state is almost in a perfect state of balance. This fragile environment can be upset forever by the introduction of a foreign species. The inter-relationships that exist in the environment between the species would be altered.

Over the past 200 years many new species of plants and animals have been introduced into Australia. The first fleet brought with it more than soldiers, sailors and convicts. Many of the creatures that have been introduced are nearly naturalized Australians. Most people are well aware that animals such as rabbits, hares and cane toads that have reached plague proportions in some areas were introduced. Other animals such as flies, fleas, animal lice, mosquitoes, silverfish, some species of cockroaches, many species of ants, snails and slugs, rats and mice, foxes, buffalo, camels and several species of freshwater fish have all been introduced.

Look back

See also the Dean the Green Case study in Chapter 14 Page 359.

Estimating population size

R = Rate of change
B = Births
I = Immigration
D = Deaths
E = Emigration

Carrying capacity

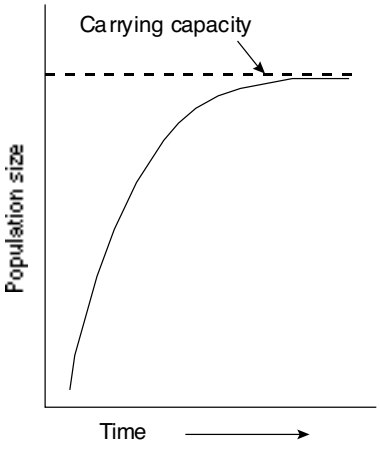


Figure 424.1 Population definitions
(Illustration Bob Moffatt)

Some of these have been introduced accidentally, some deliberately and some for no reason at all causing many of the endemic species to be reduced in numbers. The introduction of plants and animals to our waterways can cause many problems. This is because the introduced species, are better competitors, are predatory, and/or, may change the conditions.

The size of a population

The size of a population is affected by 4 processes. These are birth rates, death rate, immigration and emigration. The rate of change of a population is calculated by

R=(B+I)-(D+E)

When population reaches its carrying capacity due to the limitations of resources there will be zero population growth, R = 0 (Figure 424.1).

Ecological succession

If you study the edge of an ecosystem, you can often see changes from simple organizations of individuals to more complex ones. This is called succession and is defined as, "the replacement of populations in a habitat through the regular progression to a climax or mature community, brought about by organisms that change the environment... " Lerman (1986).

A mangrove swamp has different species at the water's edge compared to 200 metres inland. Succession has said to occur from the water's edge to the well mature mangrove ecosystem. Succession can be seen on the beach as you move through the sand dunes to the headland behind. Succession can be seen on a rocky shore or in a pool. The change from one population to another is another characteristic of ecosystems.

Ecological succession was also discussed in Chapter 8.

Make a transect square

Method

1. Construct or collect a transect square like the one shown in Figure 423.1.
2. Collect three buckets of coloured discs and sprinkle them over a 30 metre line.
3. Now place your transect square at the zero point called the datum point and select three colours to sample.
4. Randomly select a square by tossing a coin over your shoulder so that it lands in the square.
5. Now count each of the colours selected and multiply by the number of squares in the transect square.
6. Record the values for each colour.
7. Use the tape or metre rule to measure out five metres and repeat.
8. When you have finished, assemble your data and plot your graph.

Charlotte Harbour Aq Reserve

Questions

1. How did the numbers of the three discs change?
2. What problems did you experience using this sampling method?
3. Did the temperature change from one sample site to another?
4. What other types of data would be useful to collect in a transect?

Further activity

Calculate the density and population size of students in your classroom since the start of the school year.

Exercise 16.1 Mangrove transect

Method

Study an area of mangroves to become familiar with:

- The different types of mangroves.
- Their different adaptations to the hostile intertidal environment.
- Their importance ...
  - as a habitat for other organisms;
  - in providing a nursery for many aquatic animals;
  - in stopping erosion and extending the land;
  - as a buffer zone.
- The different requirements of various species.

A mangrove study should be conducted from the low tide mark to the extreme high tide level. Quadrat studies will be done at various points.

One successful method is to employ quadrat studies along a transect line.

If zonation of mangroves is important to the study then the site of the transect line must be chosen with care. Zonation tends to loosely follow height above mean sea level since various species prefer varying degrees of inundation.

Study site

1. At each quadrat make observations and take measurements of abiotic factors (Figures 425.1 and 425.2). Identify the mangrove species using a mangrove key*.
2. The distance between the 5 m quadrates is arbitrary and will vary with site conditions, slope, etc. Space the quadrats so that you fit at least five into the intertidal zone.
3. Map out 5 metre square quadrats at various points (every 10 metre) along the transect line.
4. Draw a plan view of each quadrat on your notepad. Draw a simplified profile of the transect line showing any zonation of mangroves that is evident. Use a key to represent the various species.
5. Collect information on organisms present and draw a food web of the transect site.

Questions

1. It should be evident from your field study that mangroves have very large, well developed root systems. What are the two main reasons for this?
2. Mangroves live in salt water. Salt is a toxic substance to most plants and if it was allowed to build up to a large amount inside the mangrove tree it would prove fatal. Outline the various ways mangroves reduce the amount of salt present inside the tree.
3. Mangroves also face problems when reproducing. The intertidal environment, with the tide washing in and out twice a day, makes it difficult for seeds to gain a hold in the mud without getting washed away. Outline the various ways mangroves cope with this problem

Variable	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5
Height above low tide mark (m)					
Wind direction N,N/E etc					
Wind speed km/hr					
Air temperature ^{o}C					
Mud temperature ^{o}C					
Relative humidity %					
Mud composition					
Mud salinity					
Mud pH					
Light intensity (canopy)					
Light intensity (ground level)					
Ground cover %					
Animals present					
Mangrove species present					
Other plant species					

Figure 425.1 Sample data table
(Illustration Bob Moffatt)

* See our web site www.wetpaper.com.au/teacher

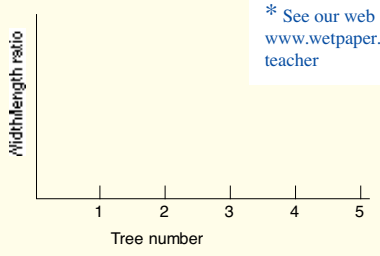


Figure 425.2 Comparison of tree diversity
(Illustration Bob Moffatt)

Exercise 16.2 Ecosystem diversity

Read the following article on hard and soft shores and answer the questions opposite.
Source: Chapter 10 SOMER 1996 Pages 46-51

Hard and soft shores

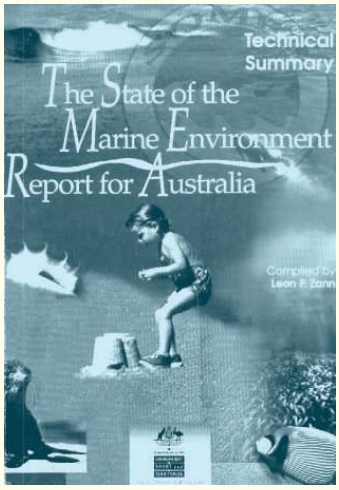
Our island continent is ringed by hard and soft shores that form the interface between the land and sea. Rocky headlands and cliffs, and sandy beaches are features of the open coast, while mud and sandy tidal flats, often merging with seagrasses, mangroves and saltmarshes, are found in more sheltered areas.

Bathed by sea and enriched by land, a great diversity of organisms live between the tidemarks.

Shores are also the most popular areas for recreation in Australia for sunbathing, surfing, diving, boating, collecting bait and fishing. As a result, the shores are particularly subject to physical disturbances and loss of habitat, over harvesting and pollution.

Shores are often the most obviously degraded parts of Australia's marine environment. In most industrial, urban and resort areas, particularly in the more populous south, the soft shores in estuaries and inlets have been extensively reclaimed for seawalls and building sites, or excavated for ports and marinas. Those near industrial areas and ports are often visibly contaminated with industrial discharges and oil.

On the open coast, rocky shores are intensively combed for bait and food. Even the remote beaches are strewn with plastics and other buoyant litter. As coastal strip development spreads along much of south-eastern Australia; management of the coastline is a major environmental issue.



See also - Chapter 10 SOMER 1996 Pages 46-51

Proportions (%) of shore types around Australia
(Source SOMER 1996, reproduced with permission)

State	Rock	Sand	Mud	Mangrove	Total*
Qld	4	36	1	19	59
NSW	33	65	1	2	100
Vic	26	64	7	9	99
Tas	29	68	2	2	99
SA	33	59	1	8	100
WA	19	49	2	19	87
NT	9	40	6	48	97

*The remainder of the totals includes coral reef and estuary mouths. Mud and mangroves are combined as many wetlands are fringed by mud.

Questions

1. What percentage of Northern Territory's coast is mud/mangrove shoreline? What region of the Queensland's coastline is most likely to have mud/mangrove shoreline? Explain your reasoning.
2. Which state or territory of Australia has the highest percentage of mud/mangrove shorelines?
3. What percentage of Victoria's coast is mud? Suggest why this value for Victoria is a lot higher than other states.
4. The table shows the total value of 59 for Queensland shore types. Why is this value not 100 as is the case for New South Wales and South Australia?
5. Draw a pie graph showing the proportion of shore types for NSW?
6. Shores are often the most obviously degraded parts of Australia's marine environment. Using the information supplied in the table and your knowledge of coastlines around Australia, predict which type of coast and which areas would be most prone to degradation. Explain.
7. Although a small number of hard and soft shores around Australia have been specifically designated as marine protected areas, shores are generally not adequately protected. Debate this statement.

FOR RESEARCH

Study the article in the hard copy of SOMER and answer the following questions.

8. Describe the effects of toxicants on our shores (see Page 48 of the report).
9. Draw a graph of the relationships between intertidal zones, tidal levels and degrees of water movement (see page 48 of the report).
10. Comment on jurisdictional difficulties in managing Australian marine ecosystems (see page 49-50 of the report).

Case study 16.2 Cool evidence confirms unnatural rise in methane

From Ecos 99 April-June, reproduced with permission, copyright CSIRO.

Latest analysis of air bubbles trapped in Antarctic ice cores has confirmed a dramatic surge in atmospheric methane concentrations since pre-industrial times and a puzzling trend towards their stabilization since 1980.

The ice cores, some more than one kilometre deep, were drilled by the Australian National Antarctic Research Expeditions at Law Dome, an icy plateau inland of Australia's Casey Base.

David Etheridge, leader of the team that analyzed the cores, says Law Dome was chosen for the drilling because ice formation there is extremely rapid. Faster ice formation reduces both the age spread of air bubbles trapped in each ice core sample, and the extent of changes to their original chemistry. Etheridge's team set out to produce a high-resolution record of methane fluctuations dating back to 1,000 AD.

Etheridge says the fact that natural increases were relatively small strongly implicates human activity as the cause of the dramatic and sustained rise in methane emissions after about 1800.

The measurements also show that since about 1980, the rate of increase in atmospheric methane has slowed markedly. If this situation continues, methane concentrations would stabilize in about 2006. The level of stabilization, however, would be more than 2.5 times higher than the pre-industrial Revolution level of about 700 parts per billion.

Etheridge says the stabilization is a positive sign, because it offers hope that there is a greenhouse gas with the potential to decrease. He says methane, molecule for molecule, is more active at absorbing radiation than carbon dioxide and accounts for about 20% of greenhouse forcing attributable to human activity. But it is also shorter lived.

'We don't have to reduce emissions of methane very much to decrease concentrations because its lifetime in the atmosphere is only 10 years, whereas the carbon dioxide lifetime is about a century,' Etheridge says. 'By pulling down methane levels we could offset some of the warming effects of the rise in carbon dioxide.'

Scientists did not anticipate the stabilization and the reasons behind it could only be speculated upon. Etheridge says it may relate to the attitude shift in recent decades when methane became increasingly tapped as a fuel source, rather than being released as a waste product of oil extraction and urban landfill.

The CSIRO team is now trying to obtain more detailed information about the changes in global sources of methane by analyzing carbon isotope ratios in the ice samples.

Different sources of methane have distinct isotopic signatures. For example, methane derived from bacterial emissions such as from animals, rice paddies and wetlands contains lower levels of carbon-13 than methane derived from the burning of biomass or fossil fuels. But methane originating from fossil fuels does not contain carbon-14. Also, the reaction of atmospheric methane with hydroxyl favours the lighter isotope (carbon-12). The resulting levels of carbon-12, carbon-13, and carbon-14 in atmospheric methane reflect these source and sink contributions. Measurements back in time would help to allow the changes in methane sources to be unravelled.

The Law Dome records can also help climatologists to study feedback effects that may amplify the enhanced greenhouse effect. For example, Arctic warming could release large volumes of methane stored in the frozen tundra, driving further global warming and methane release.

They also provide the necessary records of greenhouse gases for global climate models to simulate observed climate change this century, and to predict future climate.

Questions

1. Why do the scientists believe that the dramatic increase in methane levels after 1800 was due to human activities?
2. How much does the gas methane contribute to the greenhouse effect?
3. Evaluate the growth rate of total methane in 1980. What was the total methane emission in 1980?
4. Estimate the increase in total methane emissions from 1940 to 1980. Where do you believe the methane could have come from?
5. Suggest how the study of methane, by analyzing carbon isotope ratios, may help in the explanation of methane stabilization.
6. How does David Etheridge explain the puzzling trend in atmospheric methane concentrations stabilization since 1980?
7. Discuss the statement "understanding the past will help us predict the future."
8. Explain how the methane growth rate has decreased sharply since 1980 yet the total emissions are still increasing.
9. If the continued trend in stabilization of methane gas continues, suggest methane concentrations for the year 2010. How much higher will these be than the values in the year 1900?

Exercises

From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

D10. What is the difference between a food chain and a food web?

D12. What is the difference between an ecosystem and a community?

D13. What is marine biodiversity?

Questions

Knowledge

1. Describe a natural ecosystem and name their four requirements/criteria.
2. Name any five communities that may exist in an estuarine ecosystem.
3. Write a definition for *biomass* and give an example.
4. Define the terms – community, autrotroph, acid rain, denitrifying bacteria, hydrological cycle.

Understanding

5. Draw a diagram to show you can distinguish between the terms community, population and individual, in a biotic environment.
6. Draw the phosphorus cycle using sand dune plants as an example.
7. Draw diagrams of the carbon and nitrogen cycles to show you can identify the major components for each.
8. What is the greenhouse effect and how might this affect sea conditions around the world?
9. Distinguish between the terms *producer, consumer, scavenger and decomposer.*
10. Redraw Figure 414.2 as a food chain.
11. Restate the pyramid of numbers as shown in Figure 416.1 in 3-4 sentences.

Applying

12. Calculate the percentage of bioaccumulation of DDT for each of the trophic levels in Figure 417.2.
13. Redraw Figure 428.1 below and construct a food web for the marine organisms shown.
14. Complete an energy pyramid of the food web as constructed in the previous question.

Analysing

15. Explain the role plants of the sea play in the carbon cycle and the nitrogen cycle.
16. Identify the form in which carbon is taken up by phytoplankton from their surroundings. How do fish obtain their carbon?
17. 79% of air is nitrogen gas yet some plants growing on the sand dunes grow poorly because of shortage of nitrogen. Explain this phenomena.
18. Explain why the sulphur cycle is not balanced.
19. Explain the statement — *An ecosystem contains organisms capable of capturing (this) energy to manufacture organic molecules*.

Creating

20. Use the map of Hypothetical Bay on Page 55, Chapter 2, to estimate some of the number and types of communities that may exist within the bay ecosystem.

Evaluating

21. Argue a case in 2 paragraphs for the ban of DDT giving an example.
22. Evaluate the statement — *the higher levels of a food chain will contain smaller amounts of biomass*.
23. Why is there a need for a definition of large marine ecosystems?

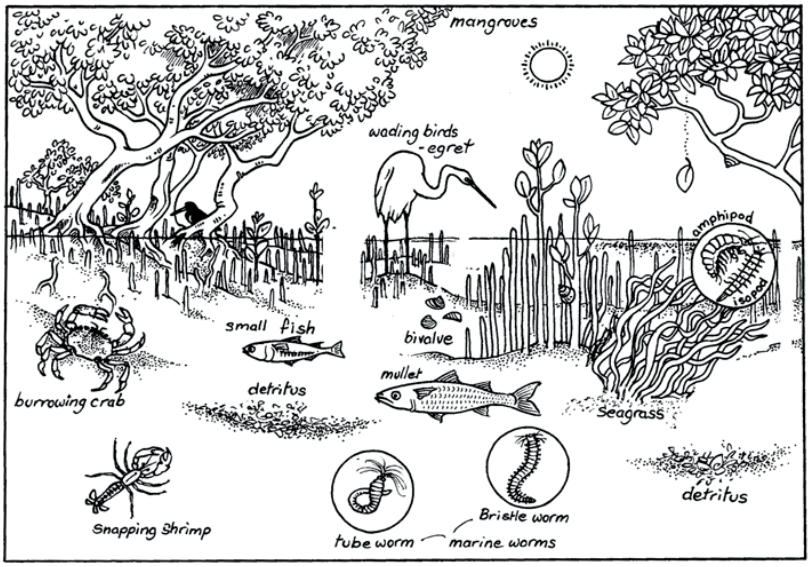


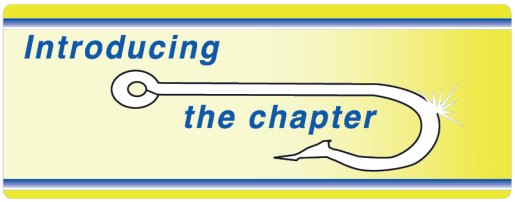
Figure 428.1 Mangrove food web
(Illustration by Sharyn Madder, based on concepts by Nancy Tsernjavski from ABSea, copyright MESA, reproduced with permission)

Chapter 17 Problems in our seas:
The state of Australia's marine environment

by
Leon Zann

Warning:
This chapter contains the images of Aboriginal and Torres Strait islander people now deceased

Photo Qld Transport



Chapter hooks

- Form a group and discuss the following questions. Then make a report to class.
  - Why is it important to know the health of the marine environment?
  - Why is it difficult to generalise on the health of Australia's seas?
  - In your state, where does most of the population reside? Where are the main ports and industrial sites? Consider possible effects on the marine environment in these areas.
  - What is the most remote and sparsely populated coast in your state? What human activities occur there? Consider possible effects on the marine environment.
- Show either of the videos: *European Tourism -Impact and Management, or Fragile Ecosystems* - Palau's coral reefs at risk available from www.classroomvideo.com

Why study this chapter

At the end of this chapter you should have a greater understanding of the health of Australia's marine ecosystems, identify marine ecosystems under particular threat, summarise the trends using 'report cards' and identify the major issues affecting the environment.

Chapter overview

Marine environmental management 431

World ocean facing crisis 432

Overview of Australia's marine environment 434
Health of Australia's marine environment 436
Health of people's environments 441
Major issues affecting Australia's marine environment 442
Who is to blame? 447
Exercise 17.1 Possible projects using the web *449*
Exercise 17.2 Good catchment/bad catchment *450*
Case study 17.1 — Discovering Seamounts *451*
Case study 17.2 - Water Quality: A threat to the Reef *453*
Questions *454*

Marine environmental management

In the first two sections of this book we studied the ocean and marine life. In this last section we will investigate threats to the marine environment and their management.

Figure 431.1 Aerial surveillance is one method of management.
(Photo courtesy Queensland Transport)

The state of Australia's marine environment: 'generally good but ...'

It is difficult to assess, simply and accurately, the general condition or environmental 'health' of Australia's marine environment owing to —

- its vast size, its great diversity,
- the range of issues affecting it, and
- the large gaps in our scientific knowledge.

On the basis of the existing limited information, and in comparison with neighbouring countries and equivalent developed countries in the northern hemisphere, the state of Australia's marine environment is rated as *'generally good'*, but with many important qualifiers. The condition of specific areas ranges from virtually 'pristine' (natural or unspoilt) off remote, undeveloped areas to locally 'poor' off highly developed urbanised, industrialised and intensively farmed areas.

Remote, undeveloped areas less affected

Most of our marine environment is far removed from the highly developed centres and is little affected by human activities. The northern, far north-eastern and western coasts of the continent, the Great Australian Bight and Australia's External Territories in the Indian Ocean, South Pacific, Southern Ocean and Antarctica are amongst the least polluted places on earth. However, fishing occurs in most areas and oil spills from ships are a threat (Figure 431.3).

Urban and developed coastlines more seriously affected

Australia's population is highly urbanised, and is highly concentrated in the coastal cities and towns in the south-east, and parts of the south and south-west. Here, the state of the adjacent marine environment may be locally poor.

While the state of Australia's marine environment is, on average, generally good, the state of the marine environment near where the urban Australian lives often *is not good*.

(from: State of the Marine Environment Report for Australia Zann, 1995 and 1996).

"Australia's population is highly urbanised, and is highly concentrated in the coastal cities and towns in the south-east, and parts of the south and south-west. Here, the state of the adjacent marine environment may be locally poor".

Figure 431.2 Oil spills can occur in pristine areas.
(Photos courtesy AMSA)

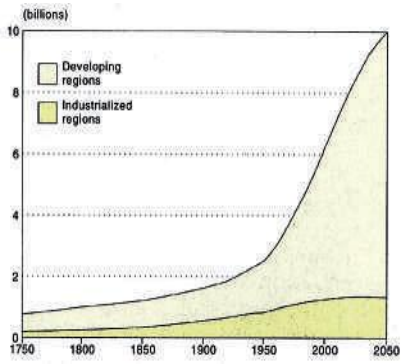


Figure 432.1 Trends in world population growth. Source UN population division, 1992.

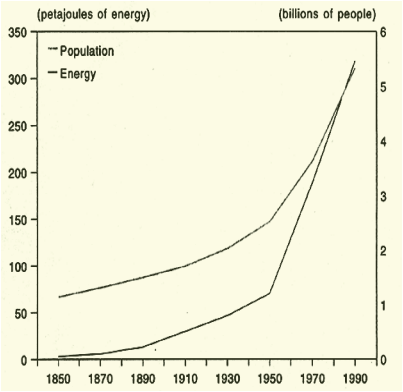


Figure 432.2 Energy usage trends. Source Population and the energy problem by (John Holden, 1991).

Figure 432.3 Captain James Cook
(Photo courtesy Geenwich Museum)

World ocean facing crisis

Barely 50 years ago ocean resources appeared infinite. Today it is facing crisis. Fish stocks have been depleted, coral reefs are dying, much has been poisoned by pollution, and there are grave fears about sea level rise and coastal flooding. How did we get into such a situation?

The reason: population growth and development

The world's human population - and use of natural resources - are increasing exponentially. In 1750 there were fewer than one billion people. By 1950 there were around 2.5 billion and by 1975 there were 4 billion. There are now over 6 billion people. By 2050 there will be around 10 billion people (Figure 432.1). As countries develop industrially they consume far more natural resources. Our current use of natural resources, forests, fish, fossil fuels, minerals and even fresh water has become unsustainable (Figure 432.2).

History of marine resources use

The sea sustained coastal and island people since time immemorial. The ancestors of the Aboriginal people must have been capable seafarers for they had to sail out of sight of land to reach these shores. For 50,000 years Aboriginal people harvested shellfish and fish in their 'saltwater country'. Remains of their countless meals make up the vast shell middens which are scattered around our coasts.

European exploration and settlement

Although native peoples such as the Polynesians have explored the Pacific for thousands of years, the age of European exploration from the 1400's was to change the world. The early explorers mapped parts of the Australian coast and described the fish and other marine life they saw. The pirate William Dampier, who visited the west coast in 1699, drew specimens of fish he caught there. James Cook mapped the east coast and Joseph banks made detailed scientific collections of sealife. The Endeavour's crew caught fish in Botany Bay in 1770 (and Cook himself was poisoned by a pufferfish). The First Fleeters who reached New South Wales in 1788 augmented their meager rations with fish. But catches were lean and it is interesting now to note the complaint from one of the Lieutenants that: *"The universal voice of all professed fishermen is that they never fished in a country where success is so precarious and uncertain."*

Commercial fisheries existed in Australia even before Europeans arrived. The Macassans (from present day Indonesia) had sailed to Northern Australia annually since the 1600s to harvest beche-de-mer (sea cucumbers) for export to China. Whalers and sealing began in Southern Australia in the 1790s. However, within only 20-30 years populations of the slow swimming Southern right whale and the seals were seriously depleted.

Beche de mer

Figure 433.1 Worana women fish from a mangrove raft 1917.
(Photos W J Jackson and (Chantal Conand), courtesy Western Australian Maritime Museum)

Until the 1900s human populations in Australia, and the world in general, remained low, and the exploitation of marine resources was sustained. The sea was vast and virtually unexplored, and its natural resources seemed infinite. Fish were abundant and fed many of the poorer nations. The ocean and its fish were seen as a *common property*, owned by all.

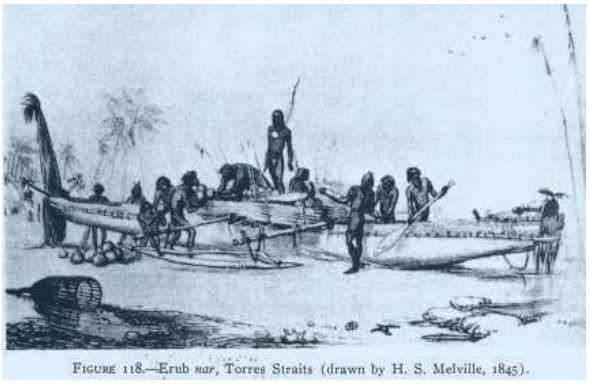


Figure 433.2 Torres Strait islanders
(Illustration supplied by Leon Zann)

Industrial development

However things began to change in the 1950s. Large scale fishing and whaling began, using modern ships and technology developed in the Second World War. In Australia we were busy developing the nation, building fishing boats and seaports, and harnessing rivers and clearing vast tracts of land for agriculture.

During the '60s fishing and whaling ships got bigger and more efficient, and travelled further afield to exploit new stocks. Vast offshore new oil fields were discovered. The sea's resources were enormous. It was even believed that plankton would feed the world's starving masses. But there were the first warning signs. The great whales suddenly disappeared. There were catastrophic oil spills from oil wells in the US, and tankers off Britain. In Japan people became sick and died from eating seafood. Mankind also first set foot on the moon in the 1960's, and their view of a small blue planet made us recognise for the first time that the resources of our planet, land and sea, were limited (Figure 433.3).

During the 1970s and 80's the situation rapidly worsened. Population growth and development increased. The historic Atlantic cod, salmon and tuna fisheries collapsed. *Fishing wars* began amongst nations. Coastal nations extended their territorial waters to protect their fish from the roaming foreign fishing fleets. In the Atlantic, naval gunboats were used to drive off foreign fishing vessels.

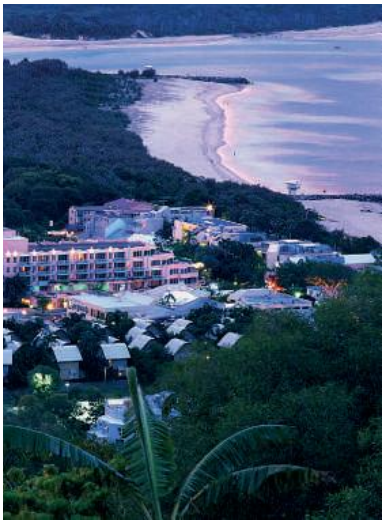


Figure 433.3 As countries develop they consume more resources.
(Photo Murray Waite)

Scientific research on the environment began in the 1970s and 80s to identify the problems, and try to find some solutions.

The United States, followed by other developed countries such as Australia, drafted new laws and created new agencies to protect their environments.

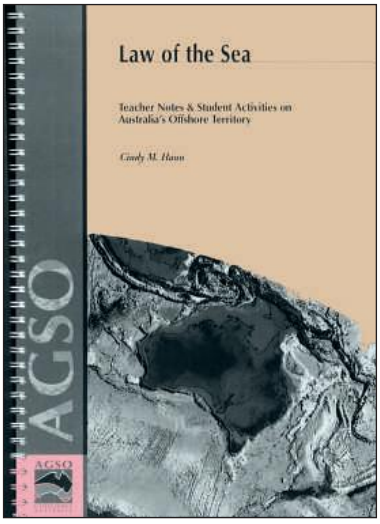


Figure 434.1 An excellent summary International law of the sea - available from Geoscience Australia www.agso.gov.au
(Photo Bob Moffatt)

UNCLOS
The United Nations International Law of the Sea Convention
See - www.un.org/Depts/los/convention_agreements/convention_agreements.htm
or
Type UNCLOS into your search engine

The *energy crisis* occurred in the mid-1980s. Petroleum supplies were reduced and fuel prices soared. There were also first warnings on global warming from burning of fossil fuels. Tropical rain forests, including the vast Amazon, were being cleared at an alarming rate, and the danger of massive extinctions was raised by scientists. It became apparent that the world's resources were already being over-exploited.

One world ocean, global action

The world ocean is interconnected, and the need for international action to protect it was slowly recognised. Coastal nations took their disputes over fish and oil to the United Nations. In 1982 the Convention of the International Law of the Sea was held to draft laws governing the rights and responsibilities of coastal nations, and international shipping (Figure 434.1). Another milestone, in 1987, was the recommendation by the World Commission on Environment and Development that future development should be environmentally sustainable '*without compromising the ability of future generations to meet their own needs*'.

The idea of **Ecological sustainable development** was adopted as a goal in Australia in 1992. In the same year the *UN Conference on Environment and Development* drew nations together to grapple with the issues of sustainable use. The International Law of the Sea came into effect and Australia declared its ocean domain or **200 mile Australian Exclusive Economic Zone (AEEZ - Figure 435.1)**, which is one of the largest in the world. Australia has now developed a detailed plan, **Australia's Oceans Policy** for the sustainable development and protection of its EEZ.

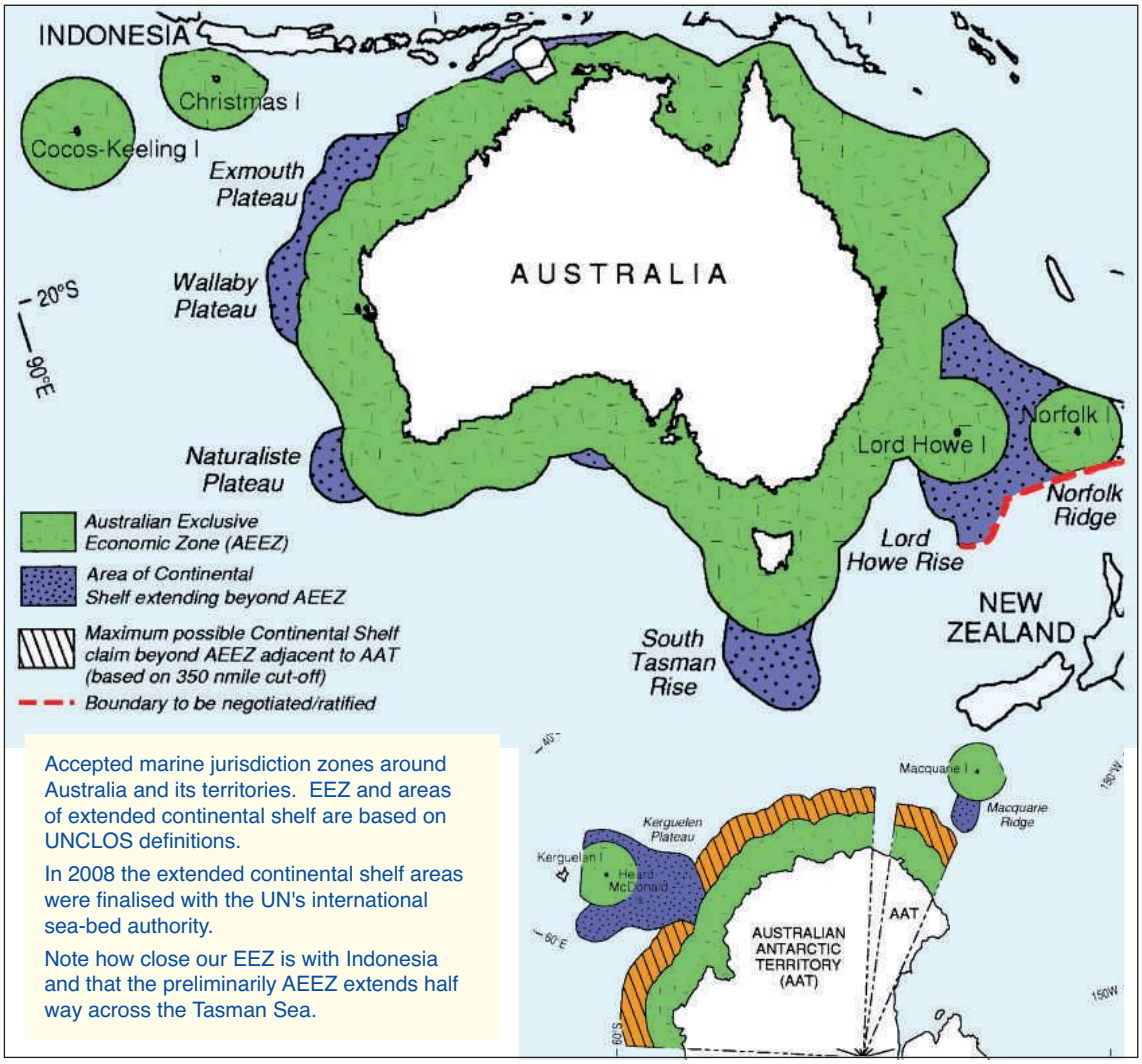
Although we now know the scale of the problems and have plans for its protection, the world environment continues to decline. The challenge of the new millennium, for future generations, is to reverse the problems caused by the unsustainable development of the past century.

Overview of Australia's marine environment

Australia is an island continent with a vast marine environment, twice the area of its landmass. Australia's maritime area, its *Exclusive Economic Zone* (EEZ) which it claims under the International Law of the Sea, UNCLOS, (Chapter 18), is over 16 million square kilometres in area. This is one of the largest EEZs in the world.

Our EEZ spans all geographic zones, from equatorial Christmas island, the tropical north and the temperate south, to the subantartic islands, and the Antarctic Territory (Figure 435.1).

Australia's coastline is around 70,000 km long. Australia is encircled by three great oceans, the Pacific, Southern and Indian. Offshore there are some 12,000 scattered islands of various sizes, and over 4,000 coral reefs.



Accepted marine jurisdiction zones around Australia and its territories. EEZ and areas of extended continental shelf are based on UNCLOS definitions.

In 2008 the extended continental shelf areas were finalised with the UN's international sea-bed authority.

Note how close our EEZ is with Indonesia and that the preliminarily AEEZ extends half way across the Tasman Sea.

Figure 435.1 Australia's claim to world oceans
(Illustration copyright Geoscience Australia, reproduced with permission)

Rich marine biodiversity

Australia's marine environment supports a very rich biodiversity, ranging from coral reefs in the north to pack ice in the south. (The term *biodiversity* describes the life forms of the planet, the ecosystems, the species and their genetic diversity - see also chapter 8.)

World importance

Australia's marine environment has great global importance. It has the largest area of coral reefs in the world, the largest areas of tropical and temperate seagrass, and some of the largest areas of mangroves. We also have the largest populations of endangered species such as giant clams, turtles and dugongs.

UN confirms extended marine jurisdiction

Australia's submission for jurisdiction over an additional 2.5 million square kilometres of seabed was confirmed by the United Nations Commission on the Limits of the Continental Shelf in April 2008.. This decision means Australia now has jurisdiction over an extra 2.5 million square kilometres of continental shelf, which is almost five times the size of France, almost ten times the size of New Zealand, and approximately the same size as Western Australia. In these areas, Australia has exclusive rights to what exists on the seabed, including oil, gas and biological resources.

Under the 1982 United Nations Convention on the Law of the Sea, the continental shelf extends at least 200 nautical miles from Australia's coastline.

Australia is also entitled to the submerged prolongation of its landmass extending beyond 200 nautical miles (the so-called extended continental shelf), to limits defined in the 1982 Convention. To confirm Australia's entitlement, Geoscience Australia analysed an enormous amount of new data gathered on 17 marine surveys conducted over eight years in some of the most remote and inhospitable parts of the world's oceans.

Read more at

http://www.ga.gov.au/news/archive/2008/april

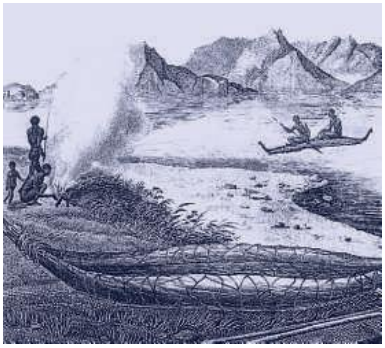


Figure 436.1 Lesuer's painting of Tasmanian aborigines with a thatched canoe
(From "Southland", Western Australian Government, Reproduced with permission - Source G Anderton.)

Figure 436.2 Commercial fishermen
(Photo Qld Fisheries)

Figure 436.3 Recreational fisherman
(Photo Paula Moffatt)

Importance to Australians

Our marine environment is important to us. People are part of the environment. Aboriginal people have lived in Australia for at least 50,000 years, and the sea has always been important for coastal communities (Figure 436.1).

Australians are coastal people. Over 25% of us live within three kilometres of the seashore, and almost 90% live in the coastal catchments. All of our major cities, and capitals (excluding Canberra) lie on the coast. The inland is still sparsely populated.

Australian's lives and leisure activities centre around the sea: *the beach*, swimming, fishing, surfing and other water sports. The sea is also economically very important. Australia's marine industries - tourism, fisheries, aquaculture, petroleum and transport - are valued at over $40 billion per year and provide many jobs.

Australia's marine environment, like the ancient terrestrial environment, is fragile. Two hundred years of European development have had some disastrous effects. The seals and great whales were hunted to near extinction. Turtles and dugongs are declining. The seagrass beds which support valuable fisheries have suffered massive die-back. Parts of the Great Barrier Reef are not so great any more. Over-fishing is widespread, and catches are declining. Some of our estuaries are ranked amongst the most polluted places on earth. The following examines the environmental problems in Australia's marine ecosystems which we have studied in previous chapters.

Health of Australia's marine environment

While we have learnt much about Australia's marine environment, it is still not well understood scientifically. Assessing *health* and identifying the causes of problems in the marine environment are often difficult. Diagnosis of the cause of a problem can be very difficult. As we have learnt, the atmosphere/ocean/land are interconnected, and events in one place can have an influence far away. This is particularly so in coastal environments where clearing of catchments of coastal rivers has a major influence on estuaries and inshore waters.

Estuaries

Estuaries, where freshwaters from rivers meet the sea, are very productive as they are high in terrestrial nutrients. Australia has around 780 estuaries dominated by saltmarsh, mangrove, seagrass, and intertidal flats which support many invertebrates and fish.

Catchment runoff

Many of our estuaries have been affected by catchment land uses. Around 60% of all catchments in Australia have been cleared for agriculture. Australia is an ancient, dry land with fragile thin soils. When vegetation is removed, top soils can be lost in heavy rain and strong winds. Soil erosion resulting from poor clearing and landuse practices is one of the most critical issues in Australia, and is responsible for many billions of dollars of lost agricultural productivity. It also creates serious problems in downstream estuaries

Figure 437.1 Coastal Lake Frazer Island Qld
(Photo Bob Moffatt)

and coastal waters. During floods, silt and nutrients are washed into rivers, to estuaries and coastal waters, promoting growth of smothering algae, and killing seagrass, inshore coral reefs and the countless species which they support.

Changing river flows

Australia's rainfall is low and river flow limited. (The flow of all of our rivers combined is equivalent to that of a single river in New Guinea, the Fly River, and is less than the Mississippi in the US.) Dams and weirs, irrigation, pumping of ground water and draining of freshwater wetlands for agriculture have changed the hydrological (water) characteristics and aquatic environments of many of our rivers and estuaries (Figure 437.1). Many freshwater wetlands, the *lungs of the rivers,* have been drained. For example, in NSW over 60% of freshwater wetlands have been drained.

Rivers of acid

Drains in tropical and subtropical flood plains may expose acidic soils which have formed in mangrove areas. Floods flush out acidic water, and deoxygenated water caused by organic decomposition, into the rivers and estuaries, causing massive fish kills and red-spot disease (open ulcers on scales). Acid soil runoff also dissolves concrete in bridges and other structures, and rapidly corrodes steel girders and reinforcing, causing millions of dollars damage each year. Acid soil runoff is one of the most serious issues affecting NSW and Queensland estuaries.

Coastal lakes (ICOLLS)

There are many coastal lakes in Australia. In the exposed sandy coastlines of the east, waves and currents create sand barriers which block stream mouths and create temporary or semi-permanent lakes. Termed ICOLLs (for *intermittently closing and opening lakes and lagoons*), these lakes have a unique biodiversity which is tolerant to extremes of salinities and low oxygen levels. They are very important nurseries for prawns and many fish species.

Coastal lakes are also very popular holiday destinations for camping, swimming and fishing. However, as they are rarely flushed they can become very polluted. Elevated nutrients from sewage and drains create eutrophic conditions, algal blooms and deplete oxygen. Many ICOLLs are artificially kept open to reduce pollution levels, odours, mosquitos and biting midges. This may affect their natural ecology, and destroy fish nurseries.

Saltmarsh

Saltmarsh are upper intertidal plant communities of salt tolerant herbs and shrubs. They are important habitats for invertebrates, fish and shorebirds, and for some endangered species such as Victoria's Orange-bellied parrot. Large areas have been reclaimed for agriculture, aquaculture ponds, human settlements, ports and industrial estates. The result is loss of shorebird and fish habitat, and invasion by exotic weeds. There are also concerns that possible sea level rises may *squeeze out* saltmarsh in areas where human developments stop them from moving further inland.

Refer back

Acid sulfate soils were discussed in Chapter 7.

Coastal lakes and salt marshes were discussed in Chapter 4.

The Dawsville cut discussed in Chapter 5 is an example of how an ICOLL was repaired using engineering methods.

Figure 438.1 Coastal development seriously affects mangrove and seagrass communities.
(Photo Geoscience Australia, reproduced with permission)

Mangroves

Mangroves are mid-tidal plant communities dominated by salt tolerant trees.

As we have learnt, they are particularly productive, are important nurseries and habitats for fish and other organisms, filter out terrestrial sediments and nutrients, and stabilise shores in storms. Australia's mangroves, the third largest area in the world, are of global significance.

Mangroves are under pressure world-wide, and around 1% are cleared each year. While some mangroves have been cleared in Australia for urban and industrial development, port and marinas, their habitat value is now recognised and they are widely protected in this country.

Mangrove die-back, possibly caused by herbicide products washed from farms, is a recent problem in central Queensland. Studies found that mangrove deaths in the Mackay Region in 2000 were possibly caused by the herbicides diuron and ametryn from sugarcane, washed out of coastal catchments.

Seagrass

Seagrasses are true grasses adapted to intertidal and subtidal conditions. They are also very productive and have great habitat and fisheries value. Australia has the largest area, and highest number of species of tropical and temperate seagrass in the world.

Seagrass die-back — a critical issue

The die-back of seagrass because of runoff of sediments and nutrients from cleared catchments is one of the most serious problems affecting Australia's marine environment. Muddy water decreases light penetration and photosynthesis, and may smother plants. Nutrients increase the growth of algae which coat the seagrass leaves, blocking sunlight.

Figure 438.2 Rock platform
(Photo Bob Moffatt)

In Queensland almost all the seagrass in Hervey Bay near Fraser Island died in 1992-93 after prolonged flooding, and over a thousand dugongs (seacows) died or migrated. In NSW there has been a 60% decline in estuarine seagrasses. In Victoria 85% of seagrass in West Port Bay has been lost. In Western Australia 97% of seagrass in Cock Sound has been lost. They are also very slow to regenerate, and difficult to artificially establish.

The effects on fisheries is certainly great. For example, seagrass and mangroves are critical habitat for 70% of fish species caught by recreational and commercial fishers in NSW.

Rocky shores

Rocky shores, periodically immersed and exposed with the tides, are productive places inhabited by many specialist organisms. They are accessible at low tide (Figure 438.2) and may be vulnerable to over-harvesting for bait and food. Edible snails, bivalves and sea urchins have been depleted around cities for use as bait and food. Some rock platforms are now fully protected, and there are bag limits in other areas.

Sandy beaches and coastal erosion

Sand beaches are great places for recreation. Although they appear lifeless, they actually support many small burrowing worms and crustaceans, some so small that they live amongst the sand grains.

Along exposed coastlines, sandy beaches are very mobile, constantly eroding and re-building. Storms and ENSO weather changes cause massive erosion. In places like the Gold Coast where development has occurred in dunes, buildings are periodically threatened (Figure 439.1). Coastal engineering, sea walls and breakwaters have generally increased, rather than solved, the problem. Greenhouse sea level rises are expected to have a great influence on shore dynamics, and are discussed at the end of the chapter.

Figure 439.1 Houses fall into sea on the Gold Coast in 1968 beach erosion.
(Photo Australian Women's Weekly)

Temperate reefs

The subtidal rocky reefs support important communities of algae such as kelp, as well as sponges, ascidians (sea squirts) and other attached organisms. These in turn provide shelter and food for many fish and invertebrates. Although the rocky reefs are less glamorous than the coral reefs in the north, they have a very high biodiversity value. Over 1,100 different macroalgae alone have been identified on reefs off southern Australia. Of these, 62% are endemic (found only in that area).

Temperate reefs have been heavily fished for lobsters, abalone, snapper, leatherjackets and other fish, and populations have been depleted in many areas. The effects of removal of key predators and grazers on the ecosystem are not known. Overseas there have been increases in sea urchins, and consequent overgrazing, reduction in kelps, and other ecosystem *flow-on* effects.

Figure 439.2 Excavating boulder walls to prevent erosion
(Photo GCCC)

Coral reefs

Coral reefs are amongst the richest and most productive ecosystems. The Great Barrier Reef (GBR) is the largest system of coral reefs in the world. It consists of over 2,900 separate reefs, extending over 2,000 km down the Queensland coast. There are also large areas of coral in Western Australia; Ningaloo is the largest fringing reef of its type. Termed 'rainforests of the sea', coral reefs support many species. Over 350 species of corals, 1,500 species of fish and many thousands of invertebrates and algae have been recorded from the GBR.

Refer back
Reefs and coastlines were discussed in Chapter 4.

Coral reefs threatened worldwide

It has been estimated that 70% of the world's coral reefs have been degraded in some way, mainly from over-fishing, coral bleaching and Crown-of-thorns starfish outbreaks. Overseas, reefs are still mined for lime and building materials, and are being killed by poison and dynamite fishing. Australian coral reefs are better protected, but are subject to the insidious (and less controllable) effects of terrestrial runoff, coral bleaching and Crown-of-thorns outbreaks.

Figure 439.3 Temperate reefs
(Monty Reef WA Photo Bob Moffatt)

Land runoff

Coral reefs, like seagrass, are intolerant of silt and high nutrients, and therefore grow best in clear tropical waters, away from rivers.

Figure 440.1 Stormwater runoff can greatly affect offshore reef systems.
(Photo Bob Moffatt)

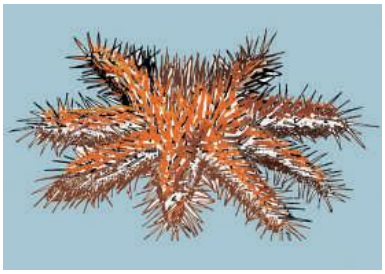


Figure 440.2 Crown of thorns starfish
(Illustration Steven Byers)

Figure 440.3 Coral bleaching
(Photo Craig Reid)

Refer back
Coral bleaching was discussed in Chapter 11.

Clearing of coastal catchments has increased runoff of mud and the nutrients from the soil. Agricultural fertilisers and sewage are also washed into the sea, increasing nutrient levels. Increased nitrogen (N) and phosphorus (P) cause algal blooms which reduce light penetration. They also promote benthic algae which overgrow and kill corals. Coral polyps normally remove silt from themselves on mucus sheets but constant sedimentation drains too much mucus and energy, and they eventually become exhausted and die. It is feared that many of the inner reefs of the Great Barrier Reef have been affected, and coral communities are being replaced by algae.

Starwars continue

The Great Barrier Reef and many other reefs in the Indian and Pacific Oceans have been seriously affected by outbreaks of the coral-eating crown-of-thorns starfish (*Acanthaster planci*). The large, spiny starfish can protrude its stomach and digests coral polyps externally, leaving the dead skeleton behind. Millions of starfish on a reef can kill almost all the corals. There have been three waves or outbreaks over the past 40 years (1960-1977, 1979-92 and 1995-present). Each seemed to start in the Cooktown-Cairns area and spread southwards over the next 12-15 years. Around 20% of reefs, mainly in the central third of the GBR, have been affected. Corals recover in 10-15 years, but the slower growing massive corals may take decades to recover.

Despite years of scientific research and much heated debate, the cause(s) of outbreaks remain unknown. Some scientists think they are entirely natural, but the continuing infestations on the GBR might now suggest otherwise. Theories on human causes include increasing survival of starfish because of elevated larvae nutrients, and/or over-fishing or harvesting of a range of predators, such as Triton shells and snappers. Controls of adults have proved impossible, though eradication through poison injection can keep limited areas free.

Outbreaks of countless millions of small coral-eating *Drupella* snails have caused similar problems at Ningaloo reef (WA). Over-fishing of reef fish such as wrasses was suggested, but firm evidence is lacking.

Global coral bleaching

Of even greater concern has been recent *bleaching* of coral reefs around the world. ***Bleaching*** is the sudden whitening of living corals as they eject their symbiotic zooxanthellae. Corals expel their algal partners when they are stressed. Sometimes they recover, sometimes they die. When whole groups of reefs in the Pacific (from French Polynesia to the Great Barrier Reef), Indian Ocean reefs, and then Caribbean reefs progressively bleached in 1997, it became clear that the world ocean was under stress.

The Great Barrier Reef was very severely affected. Air and dive surveys found that 28% of offshore reefs, and 87% of inshore reefs had bleached. The cause of the global bleaching event was a sudden increase in ocean temperatures, related to the atmospheric/ocean *El Nino/Southern Oscillation* (**ENSO**) in the Pacific, and its equivalents in the other oceans. Some scientists fear that the ocean warming was a result of the *Greenhouse* climate change, and that the world's coral reefs will be devastated.

Shelf and deep water communities

The continental shelf around Australia is covered mainly by soft sediments. Sediments on the inner shelf come from the land. Marine geologists have found that sedimentation has greatly increased since European arrival, because of clearing of coastal catchments.

Most of the deep sea floor is hidden and out of sight, too deep for most submarines to visit. The deep water, the home of bizarre fish, squid and other creatures, is virtually unexplored. Recent mapping by oceanographic ships using sound beams (sonar) has revealed amazing undersea volcanoes, ancient rivers, high seamounts and sheer-sided canyons. In the deeps off Norfolk Island there are undersea vents which sprout superheated water and dissolved minerals.

Effects of trawling

Deep sea trawling for Orange roughy (Figure 441.1) in southern waters is a problem. These ugly (but very tasty) fish are very slow growing (living to 100 years) and stocks have been seriously overfished. Trawl nets damage deep water corals. Fishing has been banned in a deep water marine protected area off Tasmania. In many parts of the world, giant factory trawlers roam the seas taking thousands of tonnes of fish in a single voyage.

Plankton communities

Phytoplankton, the microscopic drifting ocean plants which live in the surface waters, form the basis of most marine food chains. Phytoplankton blooms can occur as a result of elevated nutrients from sewage and land runoff. They reduce light transmission, and may affect other algae and corals on the sea floor. Some phytoplankton are toxic, and blooms kill sea life and may make shellfish poisonous to eat. Some toxic algae may have been introduced into Australia in ships' ballast waters.

Health of people's environments

The sea is important to the way-of-life and economy of Australians, and an assessment of the state of the environment must also consider these human values. Many places of cultural heritage significance are found on the coast and in the sea. These are important to our Australian history and culture.

The ancient Aboriginal shell middens have cultural value to Aboriginal communities, and have great archaeological value to scientists. There are also many ancient places of religious or spiritual significance to Aboriginal people, such as creation and dreaming sites.

There are likewise many historic sites for non-indigenous Australians. These include the landing places of the early navigators, and the places of first settlements. Sites of cultural significance may require protection from coastal development, and from the deteriorating effects of weather and sea.

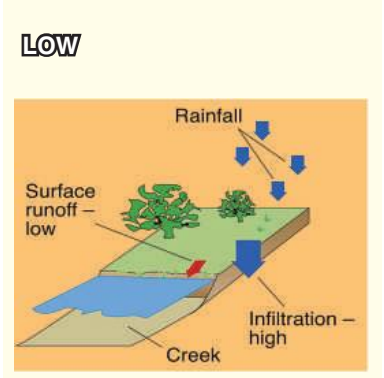
Figure 441.1 Orange roughy from a deep sea fishery
(Photo Bob Moffatt, thanks to AMC Tasmania for photo opportunity)

Figure 441.2 Fishing trawler
(Photo Bob Moffatt)

Figure 441.3 Trawler catch and by-catch
(Photo Qld Fisheries)

Figure 441.4 Seafood is a vital food source for aboriginal and Torres Strait Islander people
(Photo Qld Fisheries)

Figure 442.1 Divers uncover old bottle from Pandora wreck.
(Photo courtesy Qld Museum)



Water quality problems are accelerated because coastal towns create large areas of hard surfaces — pollution just runs off the streets and into the sea.

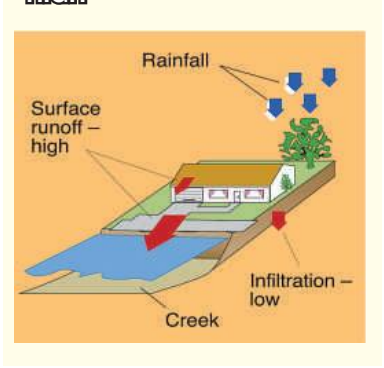


Figure 442.2 Surface runoff is high when vegetation is replaced with roads and concrete.
(Illustration Bob Moffatt)

Objects of cultural significance may be lost, stolen or sold overseas.

Shipwrecks can be vandalised by divers looking for treasure. (Cultural values are described more fully in the following chapter.)

It is important we maintain the recreational values of our coasts and seas. Scenic reserves, beachside parks and gardens, clean golden beaches and unpolluted bathing water can be destroyed through over-development, litter and sewage.

Major issues affecting Australia's marine environment

While the State of the Marine Environment Report for Australia found that the overall condition was *generally good* (see Figure 437.1), this was largely because of our large sea area and small population. Around our population centres there are some serious problems. The greatest of these is declining water quality.

1. Declining water quality

Good water quality is a basic requirement for all aquatic life. Poor water quality can result from specific (or ***point-source***) discharges of chemicals or other pollutants such as discharge pipes or an accidental spill from a ship. It can result from chronic (many small or diffuse) inputs, such as our kitchen drains.

Coral reefs and seagrass developed close to land because of Australia's naturally low runoff.

Relatively small changes in flooding, sediments and nutrients caused by human activity may have disproportionally large effects on seagrass and corals.

Nutrients and sediments from terrestrial runoff widespread problems

Clearing of catchments and runoff of sediments and nutrients have affected Australia's rivers, estuaries, coastal lakes and inshore waters. They have caused massive die-back of seagrass and threaten inshore coral reefs. This has greatly affected fish stocks, and other species such as dugong and turtles. This diffuse runoff (there are literally thousands and millions of different sources of sediment and nutrient) is very difficult to control.

Sewage discharges local problems

Large amounts of nutrients also come from urban sewage and drains. Domestic detergents contribute quantities of phosphorus. Even dogs' droppings flushed from city drains are a significant source of nutrients. Sewage disposal is a particular problem in metropolitan areas.

Sydney discharges secondary treated sewage into the sea, through ever longer and deeper pipes.

During the 1980s and early '90s, many of Sydney's famous beaches were contaminated by sewage and were often closed for bathing.

Deep water pipes have only marginally solved the problem.

It's time for the school report. How does our marine environment rate?

Report Card

Subject: Water quality and the marine environment

(A: excellent, to D: poor)*

Pollution	Sources and Effects	Level
Coastal rivers (developed)	Moderate to serious sedimentation; elevated nutrients from land use, sewage; pollutants from developed and industrial discharges; acid sulphate soil run-off.	C-D
Coastal rivers (undeveloped)	Increased sedimentation; elevated nutrients.(1,6,42)	A-B
Estuaries, coastal lakes (developed)	Many estuaries eutrophic. Coastal lakes moderately to seriously eutrophic.	B-D
Estuaries, coastal lakes (undeveloped)	Possible minor sedimentation; elevated nutrients.(6,42,51-57)	A-
Nearshore coastal waters, bays (developed)	Elevated nutrients (e.g. SA Gulfs; Victorian Bays; NSW Bays; Moreton Bay; possibly Great Barrier Reef lagoon).	B-C
Nearshore coastal waters, bays (undeveloped)	Possible increases in sediments and nutrients.(6,42,51-57)	A
Ocean (developed)	Trace levels of chlorinated compounds etc (much lower than northern hemisphere, but increasing towards coast).(42-45)	A-
Ocean (undeveloped)	As above	A

*Scores
A: No detectable problems, or trace levels of contaminants
B: Some problems or low levels of contaminants
(or widespread low levels, or few sites with moderate levels)
C: Moderate problems or moderate levels of contaminants
(or widespread moderate levels, or some sites with high levels)
D: Serious problems or high levels of contaminants
(or widespread high levels, or many sites with very high levels)

Figure 443.1 SOMER Report Card of marine habitats, in developed and undeveloped parts of Australia. (Note: like your school report card, 'A' is excellent and 'D' is poor.)
(Reproduced with permission Environment Australia)

Figure 444.1 Bird caught in oil spill from tanker.
(Photo courtesy AMSA)

Oil pollution

Oil pollution is a serious problem worldwide (Chapter 7). Oil spills from tankers are catastrophic for seabirds and marine mammals, and can contaminate food chains for decades. Fortunately Australia has had few major spills but the risk is always present. Far more oil comes from urban roads, drains and sewage and creates chronic marine pollution around urban areas.

Chemical pollution

Australia is a leading agricultural nation. Vast amounts of biocides made from synthetic chlorinated hydrocarbon chemicals, are used as herbicides and pesticides in broad-scale farming to control weeds and insect pests. Some of these find their way into waterways and into estuaries and the sea where they may poison aquatic plants and animals. Levels may be low in a water body but they can bioaccumulate or concentrate in the food chain, and become a health hazard for upper-level carnivores such as sharks (as well as for people).

Heavy and trace metals such as mercury, copper, arsenic and cadmium which are used in biocides or are waste products of mining and industry can also be bioaccumulated and become toxic to marine life. Heavy-duty biocides are made by combining metals and chlorinated hydrocarbons. Tributyl-tin (TBT) has been widely used in antifouling paints to repel or kill plants and invertebrates which settle on ships' hulls. TBT has decimated snails and oysters in port areas, and has probably also affected marine food chains.

Figure 444.2 Oil and other chemical pollution on road from vehicle spills
(Photo Bob Winters)

Levels of biocides and heavy metals are generally low around Australia but there are *hotspots* near agricultural, industrial and urbanised regions. Homebush Bay near the Olympics site in Sydney has been seriously contaminated by chlorinated compounds.

The sea floor around Sydney's giant sewage outfalls is very high in pollutants. The Derwent estuary in Tasmania, formerly an industrial and mineral refining centre, is one of the most polluted places on earth (Chapter 7).

Levels of some metals such as cadmium and mercury may be naturally already high off mineral-rich northern Australia, and levels in seafood are naturally high. It is feared that an increase in metals from mines in New Guinea may create an ecological and health risk in Torres Strait for turtles and dugong, and the Torres Strait Islanders who rely on them for food.

2. Loss of habitat

Declining water quality has a widespread effect on estuarine and inshore marine communities and important habitats such as seagrass and inshore coral reefs. Marine habitats have also lost in rural areas by clearing and reclamation for agriculture and aquaculture, and in developed areas for residential and industrial development, dredging for shipping channels, port construction. Seafloor habitats have been damaged by trawl and dredge fishing techniques.

The loss of habitat affects all the other plants and animals associated with these habitats.

These include the fished species (causing declining stocks and increased competition amongst fishers), and endangered wildlife species, and as well as thousands of other species.

3. Overfishing and destructive fishing techniques

Around 70% of world's fisheries have been over-exploited. In Australia many species, from lobsters and abalone, to reef fish, snappers, and even the oceanic School and Gummy sharks and Blue-fin tuna have been overfished, and catches have declined. Even the most remote areas of Australia and Antarctica have been heavily fished.

Some of the fishing techniques, such as bottom trawling for prawns and fish, and dredging for scallops take other (unwanted) species and destroy bottom habitats.

As well as affecting marine habitats, other fished species such as snappers which depend on these habitats are affected. But it is declining water quality which is the major cause of loss of inshore fisheries habitat, as well as causing fish diseases and mass mortalities. As fish populations are smaller, they become more vulnerable to overfishing. (Fisheries and its management are discussed in Chapter 19.)

4. Introduced species: the down-side of globablisation

Island species which have evolved in isolation are vulnerable to introduced competitors from other places. Marine species have been intentionally introduced for aquaculture and aquaria, or accidentally attached to ships' hulls, or as larvae in ballast tanks. Once established, they may displace native species and alter ecosystem function.

Toxic marine algae may have been introduced into southern Australia through ship's ballast waters. The Northern Pacific Sea star was introduced into Tasmanian waters in the 1980s, probably from Japan. Huge numbers now threaten benthic communities, endanger native species such as the Hand fish, and invade aquafarms.

As with the native Crown-of-thorns starfish, they proved uncontrollable by divers. The larvae crossed Bass Strait in the late 1990s, and now threaten Victoria. Their natural distribution in Asia indicates they could spread as far as northern NSW and Western Australia.

A giant tubeworm has recently invaded Victoria's bays in vast numbers, probably introduced from the Mediterranean. A *mutant* marine algae (*Caulerpa taxifolia*) which is invading the Mediterranean seagrass beds has also appeared in Australia, in Botany Bay and South Australia. Strangely, this may have originally been an Australian species, which was genetically altered in European aquaria, and escaped into the wild.

Aquaculture is also a source of exotic species. The Pacific or giant oyster was introduced for aquaculture in southern Australia in the 1970s. It became feral, and has gradually spread northwards, displacing the native Sydney rock oyster.

Figure 445.1 Marina
(Photo Murray Waite)

Figure 445.2 Turtle caught in fishing line
(Photo Qld Transport)

Figure 445.3 Turtle dragging fishing nets and ring pull can holder
(Photos CALM WA and MSQ)

Refer back
Photos of introduced species can be found in Chapters 9 and 11.

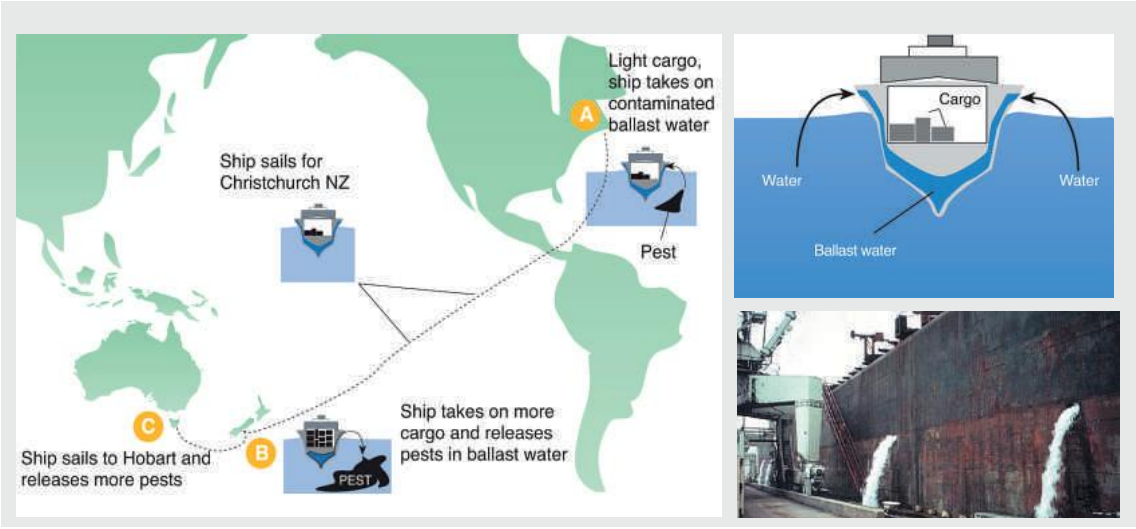


Figure 446.1 How pests are introduced to Australia by ballast water.
(Illustrations Bob Moffatt, Ballast water photograph Simone Baker)

Refer back
Coastal erosion was discussed in Chapters 4 and 5

Various diseases have been carried around the world on aquacultured prawns and salmon. Imported pilchard bait from South America may have introduced a herpes-like virus which has killed Australian pilchards.

Once established, it is extremely difficult to eradicate an introduced species. An exception was in Northern Territory in 2000 when Zebra mussels, a notorious pest, were detected in a marina. In a matter of days, all boats were placed in quarantine, the marina was closed off and massive amounts of chlorine and copper sulphate were added to kill all fouling. It worked.

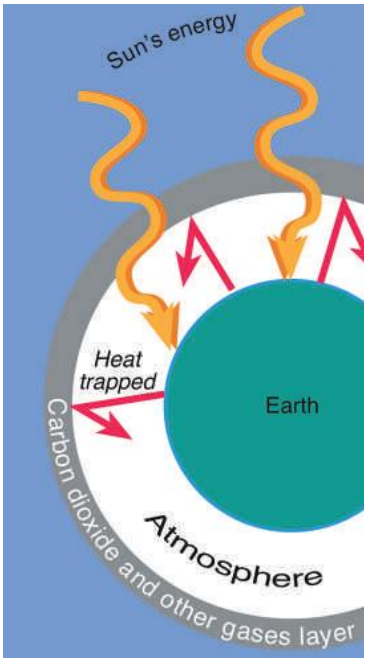


Figure 446.2 Greenhouse effect
(Illustration Trent Moffatt)

5. Coastal erosion

Sandy coastlines are dynamic, ever changing places. Beach erosion is a critical problem in southern Queensland where beachfront development was allowed in the past. Many buildings, roads and other constructions were built too close to the sea and are vulnerable to erosion. Brisbane's Sunshine Coast, Bribie Island, Stradbroke Islands, the Gold Coast, and NSW's Byron Bay, Coffs Harbour, parts of Sydney's coastline, and the south coast are rapidly eroding, threatening coastal developments.

6. Greenhouse effect

Possible global warming may raise sea levels, and increase coastal erosion. The expert ***International Panel on Climate Change***, the world body of scientists investigating Greenhouse effects, predicts sea levels to rise up to 15-20 cm in the next 100 years because of ocean expansion from warming. Increasing storm frequencies and a southwards shift in the cyclone belt (towards Brisbane) is expected to heighten the already serious problems of coastal erosion in eastern Australia. The recent global coral bleaching event shows that warming of oceans will kill many coral reefs.

Figure 447.1 compares Earth temperatures and sea level rise over three different centuries.

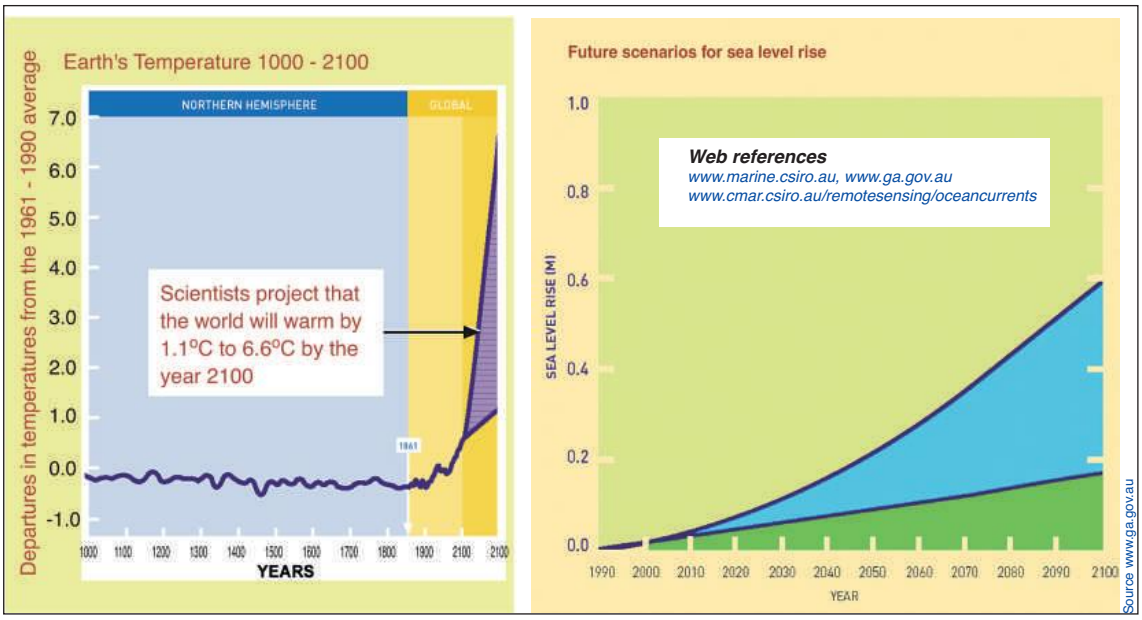


Figure 447.1 Comparison of Earth temperatures and sea levels from three different centuries.

7. Competing human uses

With much of Australia's population crammed into a few cities on the south east coast, and a high demand in scenic areas for tourism developments and retirement homes, there is locally intensive use of some parts of the coastline. Development in the past has largely been unplanned. Housing, often high rises, fringe water edges, blocking the views (and even the sunlight) along coastlines. Competing coastal uses are most obvious in the fastest growing parts of Australia in Queensland and Western Australia

There is competition for mangroves. Canal estates and huge marinas have been dredged out of mangroves, removing fish habitat and exposing acid soils. There is competition for coastal bushlands, from tourism, housing and roads. There is even competition on the water for waves as hundreds of surfers jostle to catch famous breaks.

Figure 447.2 In 1955 sand dunes were close to the coast.
(Photo Thelma Moffatt)

Who is to blame?

Its has been fashionable to blame primary producers like farmers, foresters and miners for all the environmental problems in Australia. Commercial fishers blame the recreational fishers for declining catches (and visa versa). Certainly, some huge mistakes have been made in the past. But we all share Australia's wealth and enjoy high national wages and standards of living, so each one of us must share in the responsibility for environmental management.

What can I do?

We can all do something to help our coasts and seas. You don't necessarily have to become a frontline Greenpeace activist. Don't litter, don't be a *tosser*. At home use environmentally friendly low phosphorus detergents. Wash your family car on the grass, which filters out the nutrients. Compost your food scraps and grass clippings. Limit your home water use (turn off taps, shorter showers).

Figure 447.3 The Glaciers in New Zealand are retreating quickly.
(Photo Bob Moffatt)

Report Card

Subject: Pollution levels in Australia's marine environment

(A: not detectable, to D: very high)*

Pollution	Sources and Effects	Level
Coastal strip development (developed)	Decline in water quality; loss of habitat from reclamations, dredging, marinas; erosion of beaches; over-development; conflicts amongst users; loss of amenity; poor integrated planning. (1,29,40,41,62)	C-D
Nutrients (nitrogen, phosphorus) (developed)	Source: inland waters; sewage and run-off. Effects: widespread locally serious eutrophication; algal blooms; toxic algae; die-back of temperate seagrass; loss of bathing water quality; nutrients.	C-D
Nutrients (nitrogen, phosphorus) (undeveloped)	Source: inland waters (erosion, fertilisers etc). Effects: locally low to moderate eutrophication; occasional algal blooms; die-back of temperate seagrass; threats to nearshore corals.(42)	B-C
Oil (developed)	Source: developed run-off; chronic small spills while fuelling in harbours; occasional large shipping spills. Effects: chronic effects not known; large spills cause concentrated, moderate to long-term environmental damage.	B-C
Oil (undeveloped)	Source: operational discharges from ships, occasional spills Effects: large spills as above.(39,43)	A-B
Heavy metals (mercury, cadmium, copper etc) (developed)	Source: localised industrial discharges; refineries; antifouling paints; sewage; mining; ports. A few areas seriously contaminated (e.g. Derwent Estuary, Tas.; Port Pirie, SA). Results: little known; may be very toxic; bioaccumulate in food chains; contamination of seafood.	B-D
Heavy metals (undeveloped)	Source: natural concentrations and mining (e.g. Torres Strait). Effects: little known; possible bioconcentration in food chain.(44,52-57)	A-B
Chlorinated compounds (pesticides etc) (developed)	Source: industrial discharges; dumps; developed run-off; sewage. Effects: little known; bioaccumulates in food chains; may be very toxic.	B-C?
Chlorinated compounds (undeveloped)	Source: agricultural chemicals; dumps; distant sources. Effects: as above.(45,51-55)	A-B
Litter (developed)	Source: local catchments; dumps; visitors; fishers; shipping. Effects: loss of visual amenity; ingestion by wildlife.	B-C
Litter (undeveloped)	Source: vessels; fishers; visitors. Effects: as above. Locally serious in seal populations.(46)	A-B
Sewage (developed)	Source: primary treatment; ocean sewage outfalls. Effects: pathogenic micro-organisms; bathing water standards frequently exceeded in some developed beaches; important source of nutrients.	C-D
Sewage (undeveloped)	Localised problem.(42,47,51-57)	A-B
Introduced species	Currently localised problems (e.g. Northern Pacific seastar in eastern Tasmania) but potentially very widespread and serious.(48)	B D potentially
Population outbreaks	Currently localised serious problems (e.g. crown-of-thorns starfish on the Great Barrier Reef) but not known whether they are natural or human-induced.(49, 50)	B(?)

*Scores
A: No detectable problems, or trace levels of contaminants
B: Some problems or low levels of contaminants (or widespread low levels, or few sites with moderate levels)
C: Moderate problems or moderate levels of contaminants (or widespread moderate levels, or some sites with high levels)
D: Serious problems or high levels of contaminants (or widespread high levels, or many sites with very high levels)

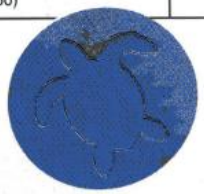


Figure 448.1 Pollution. How does it score? This SOMER Report card rates pollution issues in developed and undeveloped parts of Australia. 'A' is excellent. 'D' is poor

Exercise 17.1 Possible projects using the web

Study the web sites in Figure 449.1 and complete the projects below.

1. Map coastal and environmental information for your local area (web site 1).
2. Examine today's satellite weather images for Australia, and note the forecast for land and sea conditions in your area (web site 2).
3. Compile information on the tides, ocean temperatures and other oceanographic properties of your area (web site 4).
4. What are the recent temperatures of the surrounding ocean? Are any currents visible? If so, what can they tell us about local circulation? (web site 3)
5. How productive is the surrounding ocean? Is it good for offshore (tuna) fishing? (web site 5)
6. Try to locate a satellite image of your area that shows land features and uses, and the coastline and nearby sea. (explore web sites 9-11). Can you relate the different colours on the satellite images to features such as land uses?
7. What's the weather probably going to be in the next few months? (web site 8).
8. How does el Nino affect your local rainfall? Plot Southern Oscillation Indices (SOI) for the past 20 years and compare with your local rainfall and bushfires. Is there a relationship? (web sites 2 and 8)
9. What is the general condition of the coastal and marine environment in your local area? (What does the State of the Marine Environment report for Australia say about your State?)

Other web references

www.marine.csiro.au, www.ga.gov.au
www.cmar.csiro.au/remotesensing/oceancurrents

Web sites

1. For a computer atlas of your local coastline (or any other part of Australia), see *Environment Australia's Coastal Atlas*

   www.ea.gov.au/coasts/atlas/index.html
2. For daily satellite images, weather forecasts and rainfall and other records for your area or anywhere else, check out the *Australian Met Bureau's* great site:

   www.bom.gov.au/weather/satellite/
3. For satellite images of sea temperatures in Eastern Australia:

   www.rsmas.miami.edu/images.html

   www.bom.gov.au/nmoc/archives/SST/
4. For ocean temperatures, salinities, waves, weather etc near you, see the excellent *Royal Australian Navy site Australian Oceanographic Data Centre*:

   www.aodc.gov.au/Products/index.html
5. For ocean colour and ocean productivity from space, see the US *SeaWiFS satellite* site:

   http://seawifs.gsfc.nasa.gov/SEAWIFS.html

   See NASA's school site at:

   http://seawifs.gsfc.nasa.gov/SEAWIFS/TEACHERS/
6. For an excellent database on coral reefs around the world, see NASA's:

   http://seawifs.gsfc.nasa.gov/cgibrs/reefs.pl
7. For information on coral bleaching and hotspots, worldwide, see the NOAA site: http://www.coralreef.noaa.gov/

   For bleaching on the Great Barrier Reef, see: http://www.aims.gov.au/pages/search/search-coral-bleaching.html
8. For El Nino/Southern Oscillation (ENSO) and long range weather prediction, see NOAA's: http://www.pmel.noaa.gov/tao/elnino/nino-home.html
9. For a catalogue of free satellite images:

   http://earth.jsc.nasa.gov/index.html
10. Check NASA's 400,000 satellite images:

    http://eol.jsc.nasa.gov/sseop/
11. For some great satellite images on Australia:

    http://earth.jsc.nasa.gov/query.cgi

Exercise 17.2 Good catchment/ bad catchment

by Leon Zann

Land and sea are linked, and activities on land affect the sea. In Australia clearing of catchments (right), and coastal land and marine uses have created environmental problems in the sea. This is a view of developments along Jensen River which opens into Hypothetical Bay.

What to do

1. Look carefully at the illustration opposite and identify the numbers 1-18.
2. Now list all the activities which may affect water quality of the estuary and waters of Hypothetical Bay.
3. Which 2-3 do you think are the most serious?
4. What are the main 'point-source' sources of pollution?
5. What are the main 'diffuse sources' of pollution?
6. What activities might affect fish populations?
7. How do the issues here compare with those in your local area?
8. Compare and contrast the good catchment with the bad catchment by drawing up a table and summarising your points from question 2.

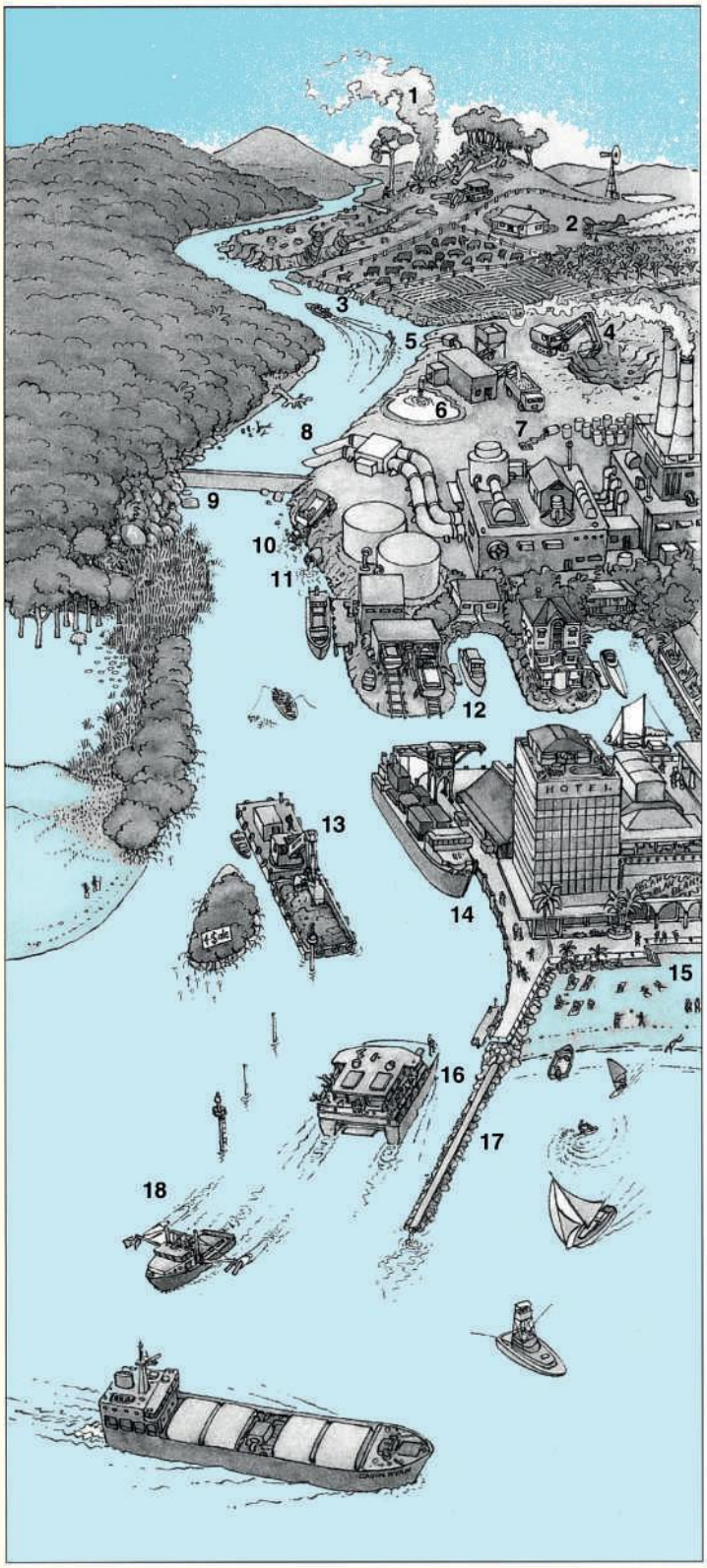
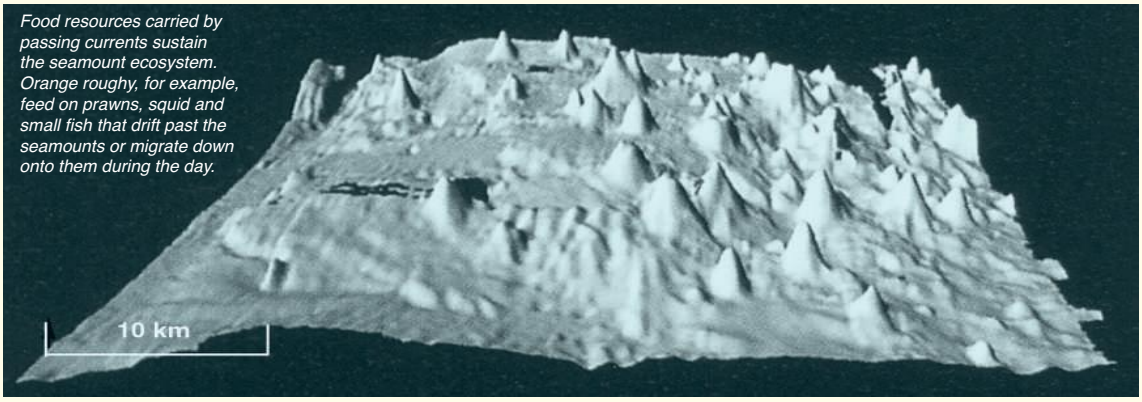


Figure 450.1 Comparison of good and bad catchments

(Illustration Gavin Ryan from SOMER 1996 p91, reproduced with permission, copyright Environment Australia)

Case study 17.1 — Discovering Seamounts



Food resources carried by passing currents sustain the seamount ecosystem. Orange roughy, for example, feed on prawns, squid and small fish that drift past the seamounts or migrate down onto them during the day.

Figure 451.1 Small seamounts off southern Tasmania
(Image courtesy Geoscience Australia)

The following is an extract from Ecos April June 1998 pages 14-19 reproduced with permission courtesy of CSIRO Marine Research.

"There is very strong evidence that these seamounts are virtual islands in a deep ocean where creatures have been effectively marooned for millions of years and have evolved independently," Dr. Tony Koslow, senior ecologist at CSIRO Marine Research.

Seamounts — often extinct submarine volcanoes — are virtual oases on a comparatively barren sea floor. There are an estimated 30,000 undersea mountains in the world, mostly at depths of 1,500 metres or more.

While comparatively few have been studied, recent international research initiatives in the Tasman and Coral Seas near Australia have shed considerable light on the world of seamounts and deep ocean ecosystems.

Seamounts in Australia's oceans

Interest — and concern — about seamounts, their resources and their conservation stems back to the 1980's when substantial orange roughy fisheries developed in the south-west Pacific around New Zealand and Australia.

Off southern Tasmania, the most intensively fished seamounts rise an average height of 400 metres from the seafloor and are between 650 and 1,000 metres below the sea surface. Elsewhere, there are much deeper seamounts at between 1,150 and 1,700 metres below the sea surface.

Deep discoveries

Oceanographers, biologists, taxonomists, and geoscientists have been applying new technologies to evaluate life forms supported by the seamount ecosystems. Deep ocean video camera systems towed by research vessels provide the most graphic evidence of life and environmental conditions at these depths while nets, corers and dredges are deployed to obtain hard evidence.

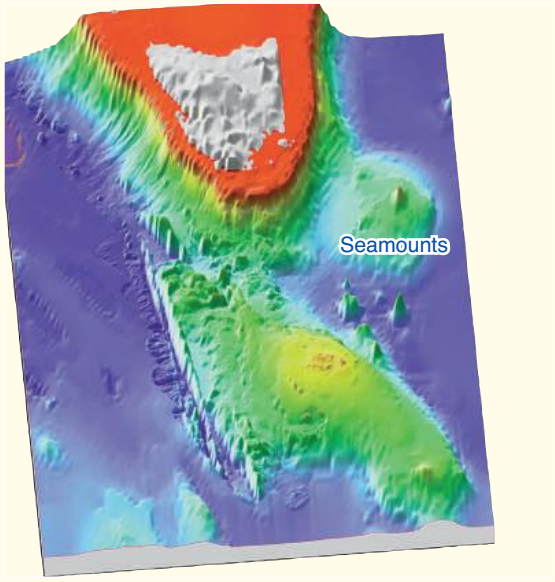


Figure 451.2 Seamounts off Tasmania
(Image courtesy Geoscience Australia)

Australia's seamount research is based on a 1997 voyage to the seamounts south of Tasmania on the CSIRO research vessel, *Southern Surveyor*.

Although the combined French and Australian studies have sampled fewer than 25 seamounts in the Tasman and Coral Sea region, they uncovered more than 850 species, 42% more than previously reported from all studies of seamounts in the past 125 years.

Several of the species are 'living fossils', relict species from groups believed extinct since the Mesozoic, the time of the dinosaurs.

The unique biological communities on seamounts are dominated by corals adapted to life in the deep sea, as well as sponges, sea fans and other organisms that filter their prey from the strong currents.

Figure 452.1 Deep seamount coral
(Photograph courtesy CSIRO Marine Research)

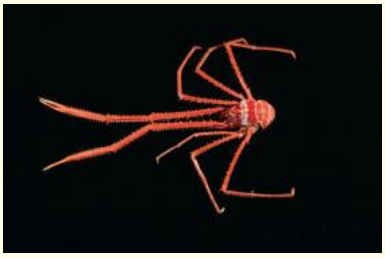


Figure 452.2 Deep seamount squat lobster
(Photograph courtesy CSIRO Marine Research)

Seamounts in Marine Parks

As a result of this research, Environment Australia has initiated, with the support of the fishing industry and conservation groups, a range of conservation measures on seamounts in Australia's EEZ. In 1999 Australia declared its first deep-sea marine reserve on the continental slope 170 km south of Hobart. The Tasmanian Seamounts Marine Reserve has an area of about 370 square kilometres. The seamount region off Tasmania is a distinct geological feature not found elsewhere on the continental margin of Australia. It includes 70 submerged and extinct volcanoes in water between 1,000 and 2,000 metres deep on the continental slope. Some 20 per cent of the seamounts have been placed within the Reserve. Much of the Reserve, particularly the deeper part, has not been trawled and is therefore mostly in pristine condition. The declaration of the reserve by the Australian Government followed extensive consultations with the community including the fishing industry and conservation groups.

A Highly Protected Zone

The Reserve from a water depth of 500 m to 100 m below the sea-bed is managed to protect the integrity of the benthic ecosystem. This means that no method of fishing or petroleum and/or mineral exploration is permitted in this zone.

Managed Resource Zone

The managed resource zone stretches from the surface to the depth of 500m. The aim is to ensure long-term protection and maintenance of biological diversity while allowing the tuna longline industry access to the surface waters.

Questions

1. After reading the research article describe what you believe is a *seamount*. How many seamounts are thought to exist in the world? When were they thought to have evolved?
2. Suggest how the environmental conditions on a seamount will differ from life on a rocky shoreline. Explain why these seamounts have such a different array of life forms. List some of the filter feeders in these unique biological communities.
3. Do seamount food chains contain producer organisms? From where do they get their energy?
4. How many new species have been discovered living near the seamounts?
5. Propose an explanation for the presence of organisms considered to be living fossils surviving in these areas. Do you believe conditions have changed much in these areas over the past few million years?
6. Draw up a facts chart on seamounts of Australia.
7. Write a brief interest paragraph radio or television that will help educate the public about the presence of seamounts and their importance as a natural resource.
8. Commercial fishermen have depleted the fish stocks of some of the seamounts off Tasmania. How long do you think they can remain in pristine condition? Give a reason for your answer.
9. Do you agree with the formation of the two management zones?
10. How are ocean trenches formed and where is Australia's deepest trench (hint watch the *Oceans* video)

Further information

http://www.oceans.gov.au/education/students.jsp - National Oceans Office in Tasmania has a range of materials

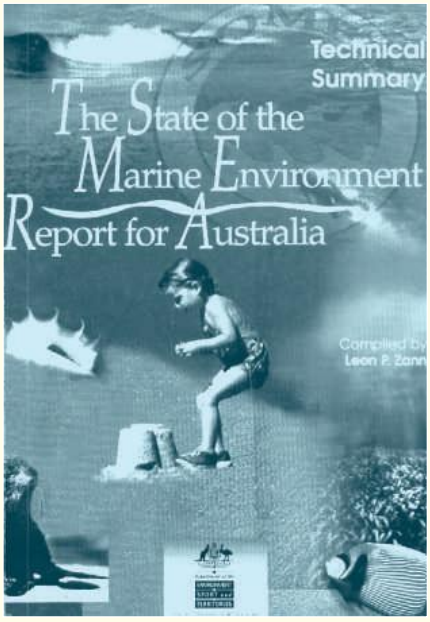
http://www.ga.gov.au (Geoscience Australia)

http://www.csiro.gov.au/ (Check out the Marine Research Division)

Note: AGSO is now known as Geoscience Australia

Case study 17.2 - Water Quality: A threat to the Reef

Copyright Great Barrier Reef Marine Park Authority, reproduced with permission.



What to do

Part A

Read the case study *Water Quality: A threat to the Great Barrier Reef* SOMER page 242. Discuss the information and use the set A questions below to structure a research assignment.

Questions - Set A

1. What is the issue?
2. Where does it occur?
3. How is it caused?
4. Why is this issue a concern for the Great Barrier Reef?
5. What aspects of society have an impact on this issue?
6. What are some of the points of view that relate to this issue?
7. How has this issue developed over time?
8. What are the solutions?

Part B

Investigate the water quality issue further. Read page 242, from the technical summary of the '*State of the Marine Environment Report for Australia*. Research the following set B questions:

Questions - Set B

1. What different types of water quality issues are impacting on the Great Barrier Reef?
   a. Where do they occur?
   b. Why do they occur?
   c. How is the marine pollution caused?
   d. What are the consequences?
   e. What are the alternatives? Are they viable alternatives? What are the social, economic, environmental and health consequences of these alternatives?
2. How can you find out more about these issues?
3. How can you judge the reliability/validity of the information you use on this issue?
4. What are the solutions?

Part C

Make decisions about water quality issues by exploring the following set C questions.

Questions - Set C

1. What is the scope for resolving such issues?
2. What options for actions exist in relation to this issue?
3. Who benefits and who is disadvantaged by these options?
4. What options for action do you consider the most appropriate in relation to this issue?
5. Who or what would be affected by such actions, and in what way?
6. How can individuals get involved and protect marine resources?

You will need a copy of the *SOMER State of the Marine Environment Report* compiled by Leon Zann, available from Wet Paper Publications, PO Box 540, Coolangatta, Qld 4250. Telephone: (07) 5525 6122
Reference: Chapter 42: Nutrients and Eutrophication in coastal waters.

Questions:

Knowledge

1. Define an *estuary*, name three types and recall a reason why they are so productive.
2. Define the term UNCLOS and list its web address.
3. List the web addresses for the National Oceans Office and the SOMER 1996 State of the Marine Environment.
4. Locate the dates when new laws and new agencies were created to protect their environments.
5. Name the commercial fisheries that existed in Australia before Europeans arrived.
6. State the percentage of estuaries in Australia that have been cleared for agricultural or urban use and recall one major problem clearing creates.
7. State why it is difficult to assess, simply and accurately, the general condition or environmental 'health' of Australia's marine environment.
8. For how many years have Aboriginal people harvested shellfish?

Understanding

9. Why does Australia's marine environment have great global importance?
10. Draw a map to show Australia's claim to world oceans.
11. Describe how acid sulfate soils occur and their effect on marine life.
12. Describe the effects of increased nitrogen (N) and phosphorus (P) in coastal streams, on seagrass beds.
13. What is an ICOLL and what effect does it have?
14. Describe the conditions necessary for coral reefs to grow.
15. Why has fishing has been banned in a deep water marine protected area off Tasmania?
16. Outline what happened in the 1960's to fish resources in the sea and compare this to the 1970's and 80's.

Applying

17. Classify the 7 major issues affecting Australia's marine environment into commonwealth, state and local government responsibilities.
18. Create a report card for your local marine environment using Figure 443.1 as a guide.
19. Calculate the number of surfers in the take off zone in Figure 447.2.

Analysing

20. Analyse the statement on Page 433 that "the ocean and its fish were seen as a 'common property', owned by all."
21. Write 4 similarities and 4 differences between temperate and tropical reefs.
22. How are the cultural values of the sea different for Aboriginal, European, Mediterranean, Torres Strait Islander and Asian people?
23. Identify possible benefits to the discovery that in the deeps off Norfolk Island there are undersea vents which sprout superheated water and dissolved minerals.

Creating

24. Research early aboriginal use of the sea in your area.
25. Create a mural for a Seaweek theme.
26. Imagine you are a part of a group of greenies and you have to improve membership numbers.
    a. Plan a membership drive by designing a brochure for general use.
    b. Invent a media event, predict the likely consequences and estimate how many media will turn up.
    c. After all you did no one turned up. Suggest ways to improve you media event.
27. Propose a solution to the *Crown of thorns* and *Drupella* problems on our reefs.

Evaluating

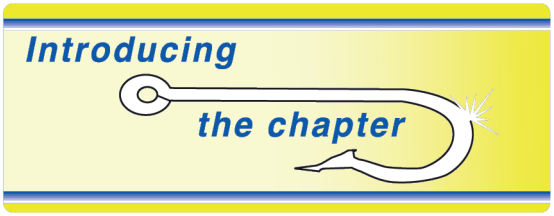
28. Use the economics associated with loss of tourist revenue on our reefs to argue the case for reduced greenhouse emission gases.
29. Use the report card on Page 443 to assess your local area.
30. The challenge of the new millennium, for future generations, is to reverse the problems caused by the unsustainable development of the past century. Determine who should do this and rate the chance of success.
31. Determine if mangroves are under threat from statements made on page 438.
32. Re-read Chapter 10, pages 256-258 on seagrasses and study pages 438-439 and judge which is the more crucial issue - seagrass management or mangrove protection.
33. For many years beach erosion has been a problem. Re-read Chapters 2 and 5, and page 439 and use this information to determine if coastal erosion is still a problem. If erosion is a problem in your area rate the chances of a coastal engineering solution as being successful. Find some old photos of the beach like that in Figure 447.1 and compare the dune systems with those of today.

Chapter 18
Sustainable use of the sea

by

Leon Zann

Photo Murray Waite



Chapter hooks

David Suzuki is Canada's preeminent science broadcaster and carries a global reputation as a geneticist, professor, public lecturer, and environmental and civil rights activist. Read his views on ESD and then discuss if you think it is achievable.

www.davidsuzuki.org

www.davidsuzuki.org/Oceans

Why study this chapter

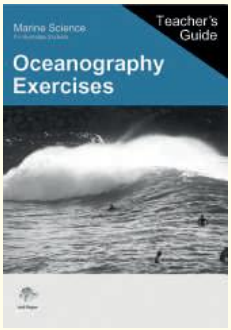
The last chapter was a *bad news story*: increasing populations and development have resulted in the unsustainable use of marine resources, environmental degradation and loss of marine biodiversity.

This chapter contains *some good news*: we can do something about the problems, but it will not be easy! The new goal is *ecological sustainable development* of the planet's natural resources.

New international laws and agreements (especially the International Law of the Sea) are reducing marine pollution. Marine environmental management is a new field, and you can learn about some of the strategies being developed for planning, management, research, education and community involvement.

Activities and worksheets from our Oceanography Exercises Teacher's Guide

In the appendix, try these activities:



- Adopt an NGO
- Attitudes and values
- Conservation principles
- Dilemma exercise
- Ecological sustainable dev
- Ecotourism survey
- Government Management strategies
- Is tourism good for the community?
- Local management issues
- Marpol
- Multiple use
- Sea rights

Chapter overview

Australia's marine resources, uses and impacts **457**

New directions for marine environmental management 463

Marine environmental management 466

Marine conservation organisations in Australia 469

Strategies and techniques for planning and management 471

Conclusions 475

Case study 18.1 Sea rights *476*

Case study 18.2 Small tropical islands *478*

Questions *484*

Australia's marine resources, uses and impacts

As Australia is an island continent and we are mainly coastal people, the sea and marine resources are very important for our economy and way-of-life. Marine industries return around $40 billion per year and provide hundreds of thousands of jobs, directly and indirectly, in fisheries, tourism, shipping and offshore petroleum. But over-use of marine resources has damaged the marine environment.

The sustainable use of marine resources is the main objective of environmental management. Environmental management is largely managing human uses and people's activities. Environmental managers therefore need to know not just about marine life, but also about the human uses, the people involved, the economic and other benefits, and alternatives.

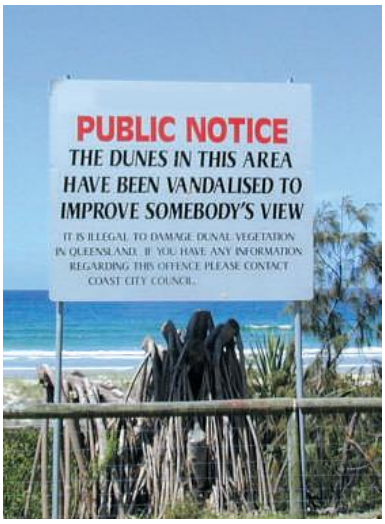


Figure 457.1 Environmental management managing human uses and people's activities.
(Photo Bob Moffatt)

What are *resources*?

What are renewable and non-renewable?

A ***natural resource*** is some part of the environment which has a use or value to us. It may be necessary for our survival (eg food) and/or have an economic value and provide work and an income (eg fisheries and tourism). It may have a less-tangible recreational or cultural value (eg beaches, surf waves, landscapes and seascapes, historic places). Some resources (eg oil and minerals) are extracted and used up. These are termed ***non-renewable***. ***Renewable resources*** are those which are replenished (waves, beaches), or those living resources (eg fish) which are replaced, in theory, through their natural reproduction.

Figure 457.2 Tourism is a renewable resource.
(Photo Bob Moffatt)

Social and cultural values of the marine environment

Before discussing the exploitable resources, it is important to recognise the particular values Australians place on coastal and marine environments.

Indigenous communities

The marine environment has particular spiritual, cultural and social importance for indigenous people living on coasts and islands. This has been moulded over thousands of years of continuous occupation (eg 50,000+ years in the case of Aboriginal people in Australia). Many are fishing communities, and the sea is important in their culture and religion. Because of their long and close association with the sea, Aborigines and Torres Strait Islanders have accumulated a vast amount of knowledge on the sea, the fish and other creatures. Many indigenous people are tribal, with complex societies and cultures, based on blood relationships and sharing, and they hold their land and sea territories communally. (Chapter 20 discusses Aboriginal and Torres Strait Islander fisheries in some detail.)

Figure 457.3 The sea is a fun place
(Photo Neville Coleman)

Figure 458.1 Surfboard manufacturer
(Photo Bob Moffatt)

Figure 458.2 Beach front development at Hervey Bay Queensland
(Photo Bob Moffatt)

Issues

When Australia was colonised many Aboriginal people were driven from their tribal lands (and their sea estates) and placed in missions and settlements. They became landless and marginalised in their own country. Governments did not recognise their ancient customary land rights until the land-mark ***Mabo case*** in the 1990s (see pages 476-477). Countless issues affect Australia's indigenous people. Very important are land- and sea-rights, the opportunity to hunt and fish, and the need to be involved in environmental management.

General community

Australians love the sea. The beach is the centre of our outdoors recreation, especially in summer. We holiday there and older people try to retire there. All humans are part of the environment, and an important objective of environmental management is to maximise the benefits to people - social and cultural, as well as economic.

Australians are in danger of *loving the coast to death* (or at least the best parts of it). The popular beachside developments of the Sunshine and Gold Coast in Queensland and Perth's northern beaches are the fastest growing places in Australia. The NSW north and central coasts, the Victorian Bays and southwestern Western Australia are becoming a continuous residential and tourist belt.

Beachfront developments, highrises, marinas and busy highways are destroying the values which attract people to these areas.

European maritime cultural heritage

Australia's marine environment contains important cultural resources as well as natural ones. The sea has played an important part in all aspects of the social and economic history of Australia. The early European exploration of Australia occurred by sea. The British colonisation was a maritime enterprise conducted by the Royal Navy and largely motivated by the potential of Australia as a supply base for merchant and naval vessels.

The import and export of all goods occurred by sea.

Immigration to Australia is an important maritime influence on our history and provides a continuing story linking the experiences of convicts, 19th century settlers, post-World War 2 migrants and refugees, and most recently, Indo-Chinese boat people.

The sea is also a major focus in our sport and recreation, and has been a rich source of national imagery.

Figure 458.3 Camping Burleigh Heads 1926
Postcard Thelma Moffatt

Maritime cultural heritage is a material record of the history of interaction between people and the marine environment. It includes material remains underwater (eg shipwrecks), movable items in museums and private collections (eg vessels, equipment, paintings), and historical and archaeological sites beside the ocean (eg middens, lighthouses, coastal buildings).

Figure 459.1 Trawling catch
(Photo Qld Fisheries)

Fisheries and aquaculture

The sea is an important source of fish, a high value food. Commercial fishing is the fourth largest primary industry in Australia, and aquaculture is the fastest growing industry. Tens of thousands of people are employed, and over 200,000 tonnes of seafood, worth over $2 billion, are produced each year.

However modern, large scale harvesting practices have proved unsustainable and environmentally destructive, and many fisheries are now declining. Aquaculture can result in loss of marine habitat (Figure 459.3), declines in water quality and introduction of pests and diseases.

Fishing is also one of the most popular recreational activities in Australia and millions of Australians go fishing each year. It has a very high economic value with spending on gear, holidays etc. valued at over $3 billion each year.

Issues

Although fish are (in theory) a sustainable resource, they have been seriously depleted in Australia and throughout the world, and the industry is in crisis. (Because fishing and aquaculture are so important in the marine environment, they are the subject of Chapters 20 and 21.)

Figure 459.2 Over 2 million Australians ride surfboards
(Photo Bob Moffatt, courtesy Surfing Australia)

Tourism and recreation

Tourism is the world's, and Australia's largest industry. Australia's coast and sea are the focus for both domestic and international tourism and recreation. Australians make over 50 million trips each year as domestic tourists. International tourism is a major growth industry with an average growth rate of over 10% per year since the 1980s. Some 2.5 million overseas visitors now come here each year, spending over 65 million visitor nights. The coastal fringe and sea are our greatest attractions, and bring in over $10 billion per year in tourism.

In addition to the three million recreational fishers, two million Australians are surfboard board riders, 700,000 people scuba dive and over 400,000 own motor and sail boats. Specialised nature-based or *eco-tourism* is growing rapidly.

Figure 459.3 Aquaculture ponds
(Photo Qld Fisheries)

Recreation

Recreation includes all the leisure activities engaged in by tourists and local residents. **Tourists** are defined as people who visit a place more than 40 kilometres away, and stay away from home for more than one night.

Figure 460.1 A shark dive brochure
(Courtesy Underwater World)

Swim with the seals

Visit the Underwater World site and find out about seal swims.

www.underwaterworld.com.au

Marine ecotourism

Swim with giant whale sharks off Ningaloo and feed the friendly dolphins at Monkey Mia. Look into the big black eyes of a white pointer shark from the safety of a cage in South Australia. Witness the magic evening march of the fairy penguins, just a short trip from Melbourne. Smell the fishy breath of the leaping humpback whales in Hervey Bay. See turtles nesting on Barrier Reef islands, or kayak the crocodile-infested wilderness of the Hinchinbrook passage. Join a scientific expedition to the Antarctic!

Marine ecotourism is big business

Tourism is largest and fastest growing industry in world, and ecotourism the fastest growing type of tourism (25-30% growth pa). The term ***ecotourism*** was coined to describe nature-based, educative and sustainable tourism. (Note also that many other types of tourism require *natural* environment for example beach, sight-seeing, motoring, sailing and diving.)

Marine ecotourism activities include SCUBA diving, bird watching, wildlife viewing, whale watching, photography adventure and scientific tours to remote places.

The Great Barrier Reef attracts over a million visitors per year. They spend over $1 billion pa, and generate some 70,000 jobs, directly and indirectly. The dolphins at Monkey Mia in Western Australia attract tens of thousands of visitors each year to this remote place.

Benefits of ecotourism

Environmentally sustainable industries provides jobs and infractructure in remote rural areas where employment is often limited and is less disruptive than mass-tourists (most *eco-tourists* come from higher education and social groups). Ecotourists generally stay longer at their destination and spend more money locally.

Issues

Tourism is often considered a *green* or sustainable industry, but may have significant environmental impacts. Construction of new roads, resorts, car parks and marina developments results in loss of coastal vegetation, discharge of wastes, increased levels of sediments, nutrients and oils and other pollutants, disturbances of marine life by increased boat traffic, and increased fishing and damage by divers.

Figure 460.2 Whale shark swim Exmouth Western Australia - the people in the photograph should not be touching the whale. Why?
(Photo Qld Transport)

Over-development may destroy the very features which first attracted visitors. We see the virtual *mining* of tourist sites. Often, an unspoiled site is discovered by tourists, and developed by the industry. As it becomes more popular it is over-developed and spoilt, and then begins to lose its popularity. Tourists then look for a new, unspoiled place, the original tourist destination declines, and the cycle of *mining* continues.

Social impacts on local communities result from increased visitation, crowding, transport and infrastructure pressures, crime etc. Even sensitive ecotourism can affect wild species. The Monkey Mia dolphins now rely too much on hand feeding, and their health is suffering. Whale-watching fleets are disturbing mating and newborn calves. Parts of the Great Barrier Reef are showing signs of being *loved to death*.

Figure 461.1 Cruise ship poses litter pollution.
(Photo Bob Moffatt)

Shipping and ports

Australia exports vast quantities of minerals and grain, and we are one of the largest users of shipping in the world. Each year there are over 12,000 overseas shipping calls in Australian ports, and around 350 million tonnes of freight is handled. Around 6,550 ships (94 over 150 tonnes) are registered in Australia and there are hundreds of thousands of smaller vessels and pleasure craft.

We also have some of the largest bulk cargo ports in the world. There are 68 major ports, and hundreds of minor ports for small fishing craft and marinas for pleasure craft.

Figure 461.2 Ports pose chemical spills.
(Photo Geoscience Australia)

Issues

Marine pollution occurs from accidental spills of fuel and hazardous cargoes (especially oil), and from normal operational discharges of hydrocarbons from motors. Ships dump garbage and litter into the sea. Foreign or exotic species such as toxic plankton, mutant algae, Pacific seastars, and invasive Zebra mussels hitchike on their hulls, or in their ballast waters. Toxic antifouling paints kill not only barnacles but also other marine life in the area.

Sea ports also pose environmental problems. During construction, wetlands habitat may be lost through dredging and reclamation. There are occasional major spills of oil, and frequent small spills of oil and cargo while loading and unloading. Dredging shipping channels and wash from propellers increases turbidity.

Figure 461.3 Most ships are safe these days.
(Photo Queensland Transport)

Offshore petroleum

Oil is essential to keep our industry and transport moving. Petroleum products have a great economic and strategic value to Australia. We produce around 80% of our oil, and over 90% of this comes from offshore fields off Victoria and Western Australia. About 1,100 offshore oil wells have been drilled to date, and around 3,000 million barrels of oil (worth over $150 billion) have been extracted. But oil is a *non-renewable* resource and our reserves are running out.

Figure 461.4 Oil rig
(Photo Queensland Transport)

Issues

There have been some catastrophic blow-outs and oil spills from overseas oil rigs (though Australia does have an excellent record).

Figure 462.1 3-D seismic reflection
(Photo courtesy CSIRO)

Odd fact

3-D seismic reflection

Figure 462.1 shows a survey seismic vessel conducting a 3-D seismic reflection survey, for the petroleum exploration industry. Single or dual airgun seismic sources are used, and up to 16 streamers (containing hydrophones to pick up the echoes bounced off sub-bottom sediments and other geological formations) are towed in parallel arrays behind the vessel. The data are processed to provide a 3-D picture of sedimentary structures, and allow optimal location of exploration wells to test for oil and gas.

Degraded soils

Around 60% of Australia has degraded soils, much of the native forests have been cleared, and large numbers of plant and animal species have become extinct. Despite the relatively short period of European settlement, Australia has the highest number of mammal extinctions of any continent.

During exploration, sonic booms may kill marine organisms in the immediate area (Figure 462.1), and affect echo-location in distant whales and dolphins. Oil drilling releases mud slurries and hydrocarbon lubricants into surrounding waters. The health of local marine organisms and wildlife (birds, turtles, seals, cetaceans) is affected by chronic small spills, and they may be killed by larger spills. Exploration leases have been given in large areas of Australia's continental shelf, preventing the establishment of marine parks. And while oil drilling is prohibited in marine parks, oil spills spread rapidly and may be carried considerable distances into parks and important wildlife habitats.

Other uses of the sea

There are many other uses of coastal and marine environments. They are important for scientific research and education. Australia's rich marine environment - from mangrove wetlands and intertidal rock pools, to coral reefs, Antarctic wildernesses and ocean depths - provides wonderful opportunities for investigation. Scientists explore the sea for new natural resources, or new pharmaceutical products from marine life. They study marine life and ecological processes in order to better understand the living world, the impacts of human activities, and how they can be managed. School students (such as you) visit the seashore and dive nearby reefs to study marine biology. Areas of sea are especially set aside for research and education.

Conservation is also a type of *use*. Marine parks and sanctuaries are set aside to protect marine life. Likewise national defence is an important *use* of the sea. Australia's international borders lie in the sea, and we rely on our navy for protection.

Issues

These uses also create their own specific problems, and increase competition amongst users. Scientists don't want others to interfere with their experiments, and want visitors and other users excluded. Sometimes scientists want to collect rare and threatened species, or kill specimens to study them. Masses of students tramping around rock platforms and overturning rocks can destroy the things they have come to see. Marine parks prevent many other uses, and are often unpopular with locals who had previously used the area. Naval defence areas (often in sheltered, deepwater bays which are in demand for other purposes) are prohibited places. Naval exercises and live weapons testing damages the marine environment and drives sensitive species such as dugongs, turtles and whales away.

Landuses: major issue in the sea

As we saw in the previous chapter, land-uses in coastal catchments have a major impact on the marine environment. Land uses such as agriculture, forestry, mining, industry, transport and urban residential are essential for our economy but have increased runoff of sediments and nutrients, sewage and pollutants which have degraded our waterways, and coastal marine environments. A detailed account of terrestrial environmental issues is beyond this text, but it is important to realise that degradation of Australia's terrestrial environment is far more serious than that of the sea (see box left).

New directions for marine environmental management

Halting environmental damage will require a real commitment (from individuals and governments), changes to our approaches to economic development, and new laws to protect the sea.

Ecological sustainable development — the new goal

Ecological Sustainable Development (ESD) is defined as development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depend.

The goal of ESD has been adopted by the Australian government, and underpins *Australia's Oceans Policy* which is the plan for the management of our seas.

ESD is difficult to define, and there are no set rules or clear steps to achieve it. ESD is more an ideal, a change in our way of doing things. It is a positive step forward, and a great improvement on the short-term thinking which led to the world environmental crisis.

Some basic principles for decision-making for ESD are:

- Decisions on development should be based on economic, environmental, social and equity considerations (not just short-term profits at any cost).
- A precautionary approach is needed where there is scientific uncertainty about the effects of a development (don't take risks with the environment).
- The wider environmental and global effects of developments should also be considered (the oceans and atmosphere are interconnected; the Greenhouse effect is a global issue).
- Involvement of the community is important when issues affect them (do not limit decision-making to government bureaucrats and big developers).

Focus questions

Is ESD feasible?

Critics say it is illogical. We cannot continue to *develop* (consume) natural resources forever. They must run out sometime. Optimists say it could be achievable if we control our population, adopt renewable and non-polluting energy sources, and recycle manufactured material.

1. What do you think?
2. How many people can Australia support?

The International Law of the Sea — *defining national and international rights and responsibilities in the sea*

While societies and nations have always had laws governing their lands, the surrounding seas have been lawless. The need for international laws governing the sea came out of the chaos of fishing wars, and clamour for offshore oil in the 1960s and 1970s. A main reason for the over-exploitation of ocean resources was that they were a *common property*. Ocean resources were there for the taking, before someone else took them. Typically, what people don't own, they don't look after.

In the past, coastal nations claimed the area of sea which they could defend from land: three nautical miles (around 5 km) off their shores, the distance an old cannon could fire.

Figure 463.1 Law of sea web page https://en.wikipedia.org/wiki/International_Tribunal_for_the_Law_of_the_Sea

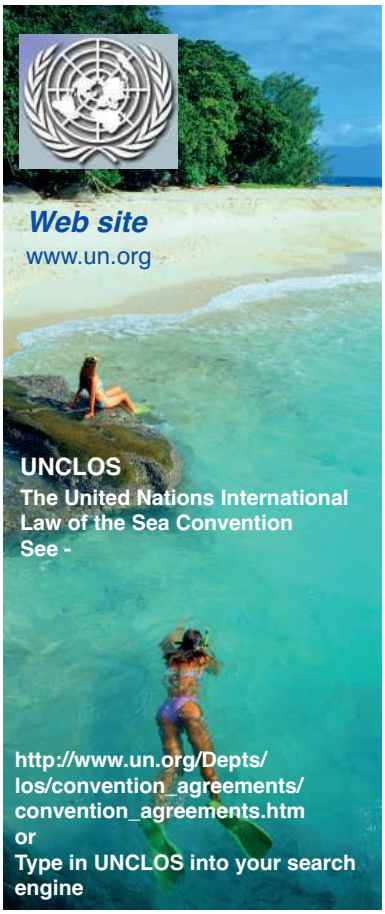


Figure 464.1 Nations with long coastlines or archipelagos of scattered islands gained large EEZs

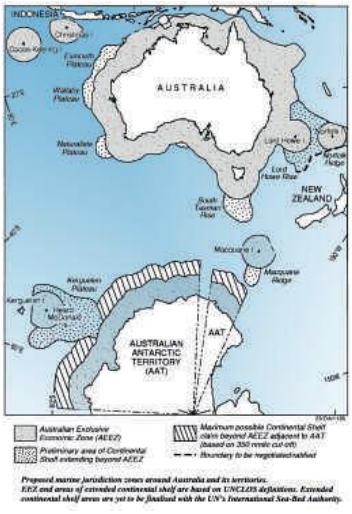


Figure 464.2 See page 435 for a bigger version of our EEZ.
(Illustration courtesy Geoscience Australia)

This was extended to 12 miles in the 1970s and '80s to protect domestic fisheries and offshore oil reserves, and to control foreign shipping movements and marine pollution. As fishing vessels got bigger and travelled further, and oil was discovered much further out to sea, coastal nations wanted to claim their continental shelves beyond 12 miles. The matter of ownership of the sea was taken to the United Nations for resolution.

The UN Convention on the Law of the Sea in 1982 developed a set of laws defining national and international rights and responsibilities in the sea. It gave coastal nations the opportunity to claim, for their own exclusive use, the economic resources within 200 nautical miles of their coastlines. This area is known as the 200 mile Exclusive Economic Zone (EEZ). If nations were unable to use their EEZ resources, they could negotiate usage with other nations who wished to use them. It also gave coastal nations the responsibility to undertake research and to protect the environments of their EEZs.

Nations with long coastlines or archipelagos of scattered islands gained large EEZs. The small Pacific Island nations gained large areas of ocean. Where EEZ claims overlapped with neighbouring nations, borders have to be negotiated (usually by halving the overlap). However, under the Law of the Sea, land-locked nations gained nothing, and the unclaimed areas, the *high seas*, remained nobody's.

Australia's vast EEZ

The International Law of the Sea finally came into force in 1994, and Australia signed on the following year. Because of the large size and long coastline of our mainland, and Australia's scattered offshore territories (Norfolk Island, Cocos-Keeling and Christmas Island, the sub-Antarctic islands of Macquarie and Herd, and the Australian Antarctic Territory), Australia was able to claim a vast area of sea. Australia's EEZ is around 15 million square kilometres, and is amongst the largest EEZs in the world (Figure 464.2 and refer back to page 429).

Australia also found itself with new sea borders with Indonesia, France, Solomon Islands and New Zealand. Australia has a very complicated border arrangement with Papua New Guinea. This had a political border in Torres Strait, and different borders for different fisheries. A complicated border was negotiated with Indonesia to allow offshore oil exploration in the Timor area. This has now been re-negotiated with the new nation of Timor.

Government of Australia's seas

Even within Australia there was bitter fighting about ownership of marine resources. The Australian Constitution does not mention Commonwealth and State government responsibilities in the sea. The States argued that they owned to the three mile limit, and wanted control of the marine resources. The Commonwealth government's claim to the Great Barrier Reef in the 1970s was hotly disputed by Queensland. After years of legal argument the claim was found in favour of the Commonwealth. But many questions remained. Who was responsible for shipping? Oil and minerals? Customs and policing? Fish? The environment?

To avoid the continuing legal disputes on sea jurisdictions and responsibilities, the Commonwealth and State governments reached some agreement in the *Offshore Constitutional Settlement* in 1979. This essentially recognised State control to 3 miles, and the Commonwealth beyond to 200 miles. Certain fisheries and industries would be managed by the States, and others by the Commonwealth.

Within each of the Commonwealth and State governments, different government departments have different responsibilities in the coastal and marine environments (eg shipping and transport, land and water resources, minerals and energy, primary industries, fisheries, environment, environmental protection agencies, national parks etc). But the sea knows no borders, and a coordinated approach to marine environmental management is essential.

International agreements on pollution and migratory species

Countries around the world are cooperating to attack international problems of marine pollution. One of the most important agreements to protect the sea is the International Marine Pollution Convention (MARPOL), which prohibits discharge of oil and dumping of rubbish at sea. Point-source discharges of pollutants have been greatly reduced and oil and litter on beaches is declining.

Many migratory species of fish, shore and seabirds, turtles and cetaceans cross international boundaries and need to be managed cooperatively. The wetlands which are important feeding, resting and nesting sites for shore birds are protected under the international RAMSAR agreement. Some shore birds fly a quarter the way around the world in their migrations and depend on habitats along the way. Australia has entered into international agreements with both China and Japan to protect shorebirds which migrate from distant Siberia.

Figure 465.1 Ningaloo Reef in WA has State control to 3 N miles, and Commonwealth control beyond to 200 N miles.
(Photo courtesy CALM)

Australia's Oceans Policy: future directions

The Law of the Sea requires member countries to sustainably use the resources within their EEZ. The Australian government has developed a detailed policy for Australia's EEZ after detailed negotiations with the States, industry and community groups. The policy was released in 1998 without States or Northern Territory endorsement.

The vision of Australia's Oceans Policy is: '*healthy oceans, cared for, understood and used wisely for the benefit of all, now and in the future*'. The Policy is based on the principles of ecologically sustainable marine development and encourages the development of sustainable marine industries such as marine tourism and fisheries while ensuring the protection of marine biodiversity.

Department of the Environment

The Department of the Environment designs and implements the Australian Government's policies and programmes to protect and conserve the environment, water and heritage and promote climate action. The environmental framework is being delivered under four pillars:

- Clean air
- Clean land
- Clean water
- National heritage

Marine environmental management

What is involved?

The goal of ESD, the rights and responsibilities defined under the Law of the Sea, and the Department of the Environment give us the directions for the future. These can be effected through human actions or *management* to reduce the adverse impacts of our activities, and to restore degraded environments. The main components of marine environmental management are: careful planning, research to provide information for decision-making, and education to inform the users and the wider community.

Department of the Environment website

https://www.environment.gov.au

Australian Government
Department of the Environment

Good planning: the key to environmental management

Effective planning is essential in environmental management (and most other things in life). The past exploitation of the ocean was completely unplanned. When the whale slaughter began, no one knew how many whales there were, and how quickly they bred. When fishermen began trawling up vast numbers of deepwater Orange roughy, they had no idea they lived over 100 years. When Gold Coast beach-front development began, no one thought of future beach erosion and storms, let alone global climate change.

The planning process

Planning is a systematic process, identifying the steps or actions needed to achieve the particular goal or objectives. Environmental planning typically involves the following steps:

- Define the objectives of the plan (Normally this is undertaken by a group of relevant people, and is then more widely circulated for input from others, including the general community.)
- Research to provide the information needed to make proper decisions in the plan. (Focused studies of the environment, threats, endangered species and socio-economic factors.)
- Consider the issues and the various options available to produce a draft plan.(Which is then circulated amongst the interested parties for inputs).
- Incorporate these inputs to produce a final plan. (Sometimes this is again sent out for final review).
- Gain approval for and implement the final plan by the relevant authorities. (This may require new legislation, and allocation of financial resources).
- Develop and implement detailed management plans needed to achieve the objectives of the broad plan.
- Monitor the environment and the management actions to determine if the original objectives are/have been achieved.
- Periodic review of the plan to determine if it has been effective, and to consider any new developments.

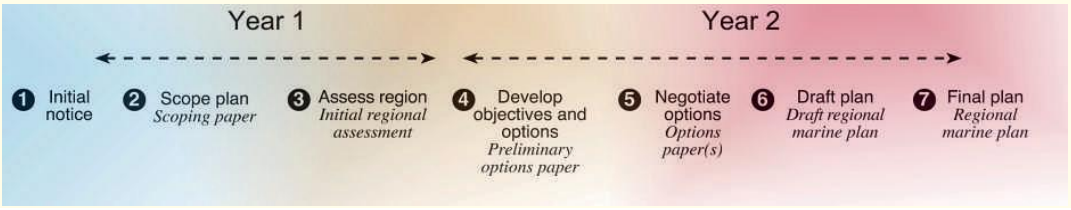


Figure 466.2 Possible stages for the development of the *Regional Plan for South East Australia.*

Management body to implement plan

Special government agencies may be established to implement the marine environmental plans, or to coordinate the various other government departments responsible for the marine environment. The management staff includes technical experts who are able to assess development permits, monitor environmental factors such as water quality, undertake public education programs, and field rangers to patrol the area to identify and deal with day-to-day problems and ensure compliance. Marine management agencies are very costly to operate. The areas of sea are large, boats and aircraft are very expensive and funds are always limited.

Government agencies involved in marine environmental management

Many different government departments are responsible for coastal and marine environmental management. There are both State and Commonwealth agencies responsible for Environmental Protection Agencies (pollution, discharges and water quality), Land and Water Resources (catchment management water usage), Primary Industries (agriculture, mining, offshore oil, fisheries), National Parks and Wildlife Services (biodiversity and cultural heritage conservation), Urban Planning (land uses and development), Shipping and Transport (shipping, navigation and ports), Defence (security, surveillance), and hundreds of Local Councils (local land and water management).

Because a coordinated approach is needed in marine environment management, some special over-arching agencies and arrangements have been created. The National Oceans Office, based in Tasmania, coordinates the Commonwealth Oceans Policy. The Great Barrier Reef Marine Park Authority is responsible for the GBR. NSW Coastal Committee coordinates all the government departments responsible for coastal management.

Scientific research: information for decision-making

Environmental planning must be based on good information. Research for marine environmental planning and management typically involves:

- general mapping of the area (using charts, satellite images and aerial photography);
- site mapping using underwater scuba (quadrates and transects, underwater video) and boats (echosounders, sonar, bottom grabs, drop video);
- specific surveys of certain species (eg *keystone*, *threatened* and *indicator* species);
- surveys of water quality and levels of pollutants (using electronic and chemical tests);
- tests to establish toxic levels, so regulations on discharges can be developed (using live experiments);
- social and economic surveys to identify different human uses, and economic and cultural values (using interviews and questionnaires);

Figure 467.1 Marine park ranger Monkey Mia, Western Australia
(Photo Bob Moffatt)

Class activity

In your particular state or territory, what are the names of the government departments and agencies with responsibilities for coastal and marine environments? (Check out their web sites.)

What do they do, and what employment opportunities do they offer? Start a collection of job advertisements from your main state newspaper or net research.

What types of skills do the jobs require? What kind of training is needed to gain these skills? Discuss employment opportunities with class and your school's careers councillor.

- data storage and analysis of information (using computer databases such as *Geographic Information Systems* GIS).

Australia's EEZ is vast and largely unexplored, marine ecology is a very complex subject, and marine research is time-consuming and very expensive. Quite often we don't know enough to answer the planners' questions. In these cases the ***precautionary principle*** dictates that they should err on the side of caution.

Environmental education: Important for community support

It is important that Australians know about the marine environment, and the threats to it. Care comes from understanding. Once we understand the consequences of our actions, we will accept the reasons for controls, and can even develop ourselves better ways of doing things. ESD requires the support of the wider community and possible sacrifices in life-style. Public environmental education, particularly in subjects such as the one you are currently studying now, is essential so that future generations are better informed.

Figure 468.1 Snorkelling and diving are a great way to learn about the sea.
(Photo Len Zell)

We live in the information revolution where we are bombarded with information by radio, newspaper and TV. The Internet is already a major source of information. The environment is frequently in the news. The sea is a popular subject on TV adventure stories and documentaries. Australians are becoming more environmentally aware. Public perceptions are being changed through education. Only a decade ago the shark was a feared man-eating monster. Now it is a graceful predator which should be preserved.

Stakeholder involvement

Environmental management generally involves regulating the behaviour of particular industry or community groups involved. These are sometimes termed ***stakeholders***. It is now widely recognised that if stakeholders are to support a plan, they need to be well informed and actively involved. (In the past, governments generally passed laws, and then told people they must obey, or else! It was an unpopular approach, and not very successful.)

Figure 468.2 Environmental organisations try to educate the public.
(Photo Bob Moffatt)

Figure 468.3 Student excursion to offshore island
(Photo Len Zell)

Stakeholder and community involvement is always essential. In many cases members of the local community are first to notice an environmental problem, and draw the attention of the government authority to it. In some cases, members of the community may be so concerned about an environmental issue that they take direct action. They may peacefully protest, or even take illegal action such as blocking access to a forest which is to be cut down, or a building which is to be demolished. It is important to note that many forests are now protected because of past illegal protests.

Many government environmental agencies now have *advisory committees* made up of interested members of the public, to provide input on community issues. The planning process now involves public input at several stages.

In 2002 the national oceans office identified five action areas necessary for marine conservation in Australia. These are summarised in Figure 470.2.

Marine conservation organisations in Australia

Some people join an environment organisation to make their voices heard. The main-stream *Australian Conservation Foundation* has more members than any of Australia's political parties. Some people join *Greenpeace*, which is more active or militant in its approach. Greenpeace draws attention to the world environmental problems by blockading Japanese whaling ships in the Antarctic, ship's carrying nuclear materials, and places like refineries which discharge chemicals.

Surfers may join the *Australian Surfriders Foundation* which was formed to protect beach and ocean environments. Every year, hundreds of thousands of Australians come together for the annual *Keep Australia Beautiful* litter cleanup or celebrate the sea during *Seaweek*.

Local self-management

While most environmental management programs in Australia have been established and operated by governments, there is increasing involvement of stakeholders and the wider community. Some communities have formed their own self-help groups.

Coastcare and *Dunecare* groups, modelled after the successful *Landcare* program, have been established along the coast by local residents. Dunes are being revegetated and weeds eradicated.

Some industries and business stakeholders are also banding together to develop their own *codes of practice*, their own rules to safeguard the environment. The private sector is generally more innovative and effective than government bureaucracies, and can better solve their own problems.

Figure 469.1 MESA protest rally
(Photo Bob Moffatt)

Figure 469.2 Surfrider foundation rally
(Photo courtesy Surfrider foundation)

Figure 469.3 Advisory group - AUSMEPA national launch
(Photo courtesy Qld Transport)

Figure 469.4 Greenpeace protest on beach
(Photo courtesy Surfrider foundation)

Figure 470.1 Our defence forces are responsible for our national security.
(Photo Bob Moffatt)

Multiple use definition

All competing and complementary human activities and uses of the living and non-living environment, including use to achieve conservation objectives.

The Australian oil industry has been very effective in developing its own safe environmental practices, and there have never been any major spills.

Indigenous community involvement

The special interests of indigenous people in the coastal and marine environments need to be recognised. As the traditional landholders, they may have important information to contribute to environmental management.

Theirs is oral tradition of communication, so it is important to hear their stories. Aboriginal interests in marine environmental management are increasingly recognised.

For example, the Great Barrier Reef Marine Park Authority now includes an Aboriginal member to look after their interests. Councils of Elders advise on dugong and turtle hunting matters. Around Australia, many National Parks and Fisheries Departments are employing Aboriginal rangers to better involve indigenous communities in environmental management.

Enforcement: the big stick!

Environmental regulations must have a sound legal basis, and be enforced. Education is always necessary to inform users of the reasons for controls, and their legal responsibilities.

But while most people will comply with the law, a few will not, necessitating policing. Penalties for breaches of environmental laws have greatly increased in recent years, increasing their deterrence values.

Figure 470.2 Fisheries patrol officers
Qld Fisheries

Strategies and techniques for planning and management

A variety of strategies and techniques are used for planning and management of the marine environment, and new techniques are being developed.

Legislation and regulations

Environmental agencies, plans and regulations, must be made legal through parliamentary legislation. The Commonwealth and State Government parliaments control different aspects of the marine environment, and Local Councils control local coastal development through town planning and by-laws. The Commonwealth is also responsible for implementing International Laws and agreements, such as the Law of the Sea.

Zoning plans

Zoning plans or maps are a basic tool for large-scale, long-term environmental planning. Each zone stipulates the intended purpose of the area (conservation, commercial or recreational fishing, aquaculture, shipping, tourism) and the types and levels of uses or developments which are permitted and prohibited there. These are like the town plans used by Local Councils. Zoning plans are important tools in marine protected areas and are discussed in detail in Chapter 22.

Regulations and standards

The activities permitted in each zone will also be subject to regulations developed to minimise their environmental impacts. These include design standards for buildings and structures, installation of litter traps in drains, planted wetlands to reduce runoff, types of sewage treatment plants, types of fishing gear, and regulations on the amounts of chemicals and wastes allowed in discharges.

Approvals and permits

The amount of a specific activity or use allowed in each zoned area is regulated through a system of licences and permits. Proposed users or developers must apply for a licence or permit. This may not be granted if the area is reaching the limits for its sustainable use.

Protection of threatened or significant species

Threatened, rare, endangered or other *significant* species may be totally protected from human hunting, fishing or collection, throughout the sea. All whales and dolphins are totally protected in Australia. Dugongs and turtles are protected, but may be taken by indigenous people in some areas (Chapters 14 and 19).

Protection of threatened habitats and ecosystems

Marine protected areas are an important planning and management strategy. Ecosystems or areas which are important, limited or threatened, or are essential habitat for the survival of some threatened species may be totally protected as a marine park or sanctuary. Corals are protected on the Barrier Reef. Mangroves are protected in most States (see chapters 10 and 19).

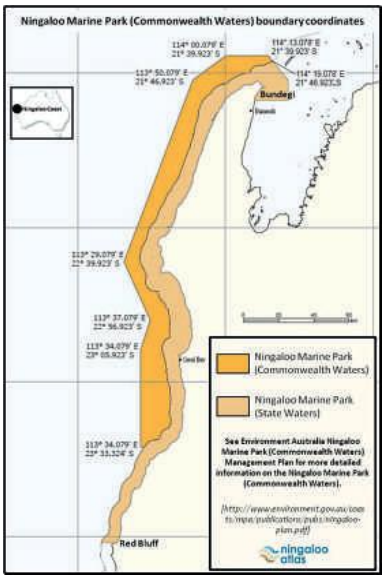


Figure 471.1 Zoning plans
(Illustration courtesy CALM)

Figure 471.2 Activities in zones
(Illustration courtesy GBRMPA)

Figure 472.1 Multiuse marine protected areas
(Illustration courtesy GBRMPA)

Definition

Multiple use management

Multiple use management results in the integration of multiple uses to reach an acceptable balance of outcomes across the full range of uses that is consistent with four fundamental principles.

The four principles are:

1. maintenance of ecosystem integrity,
2. wealth generation,
3. equity among users and generations, and
4. a participatory framework for decision making.

The integration in decision making recognises sector-specific objectives, management plans and strategies, and that less than optimal outcomes could be generated for some users.

Source Oceans Policy 2001

Multiple-use marine protected areas

Large multiple-use marine protected areas are a very important planning and management strategy for biodiversity conservation and ecologically sustainable use. They use zoning plans to protect areas of environmental importance, while allowing certain activities (recreational fishing, certain commercial fishing, research shipping) in certain areas. The Great Barrier Reef (Qld), Solitary Islands (NSW) and Ningaloo (WA) Marine Parks are designed to protect biodiversity while allowing sustainable human uses (Chapter 22).

Controls of harmful activities

Destructive or unsustainable activities may be completely prohibited to protect a threatened resource or ecosystem. Less damaging activities might be permitted, but regulated through controls on intensity of use (through licences), places (closed seasons, closed areas, marine parks), equipment (fishing gear types, diving gear), and organisms taken (fish bag limits and quotas). (Chapter 20)

Controls on discharges

The levels of harmful substances that can be released in industrial or other discharges into rivers and the sea are regulated. Maximum levels are based on scientific studies on effects on certain aquatic species, or on maximum levels allowable in foodstuffs. People exceeding the maximum limits can be fined and forced to use appropriate discharge treatments, or closed down.

Environmental impact assessment

Environmental impact assessment (EIA) is a planning and management tool to assess possible harmful environmental effects of a proposed development such as a port, marina, industry, dam or housing estate. The ecological, social and economic importance of the proposed site are examined, and possible harmful effects of the development or operation are identified. If the developer cannot prevent or minimise these, the development is not approved. EIAs are very time-consuming and very expensive (over $20,000 for a small one, millions for a large one).

Economic tools and user-pays

Licences and fees are used to regulate some activities, and to fund environmental management. Australian governments are introducing the policy of *user pays*, where the service user is charged for the service, rather than the general tax-payer. Commercial fishers, and recreational fishers in some States, must pay licence fees to take fish. Visitors to the Great Barrier Reef are charged a daily surcharge or tax which is used to fund reef research and management.

Environmental restoration

Because some environments have been seriously degraded or lost beyond natural repair, techniques have been developed for their restoration. Seed banks are kept for colonising of pioneer species to naturally re-establish a plant communities. Genetic material of endangered species is being conserved, and in some cases artificially propagated. Mangroves are replanted to replace cleared areas. Coastal developments which necessitate removal of mangroves may have to

plant an equivalent area to compensate the loss of production. Techniques are being developed for re-establishing seagrasses, and corals. In parts of Northern NSW and Victoria, some of the wetlands which had been drained for cattle grazing are now being reflooded to re-create fisheries habitat.

Cleanup techniques for oil spills

Bio-safe chemical dispersants, boom nets to contain spills, and skimmer boats to collect oil have been developed to clean up spills. *Oil-spill contingency Plans* have been prepared so the authorities can act quickly, even in remote areas. Stockpiles of equipment are stored in strategic areas around the coastline.

Prevention of accidents at sea

Prevention is better than cure. Managers try to prevent accidents at sea and oils spills. Satellite *global positioning systems* (GPS) are now used for pin-point navigation and have taken much of the risk from sea transport. (GPS's are now being placed on fishing vessels so the authorities can monitor their position and actions at all times, and at minimal expense.) Oil tankers are being constructed with double walls in case of strandings. Expert ship pilots are employed to take large ships, and those with hazardous cargoes, into ports, and through sensitive areas of the Great Barrier Reef.

Biosecurity measures

The prevention of diseases and other problems from entering the marine environment is also very important. This is termed ***biosecurity*** (originally developed to prevent contagious diseases from entering chicken farms). Australia is a world leader in agriculture quarantine to keep our agricultural industries free from diseases and pests. The problem in the sea was not recognised until fairly recently with the introductions of toxic algae, Pacific oysters, Pacific seastars and Zebra mussels. The transmission of diseases by aquaculture species is proving to be a potentially very serious problem. Research and monitoring has been commenced at CSIRO, and strategies are being developed to control transmission of pests in ships' ballast waters, and the spread of exotic diseases in fresh fish and aquaculture imports.

Technological advances

Just as the environmental crisis is the result of industrial technology, so can technology provide solutions. For example, lead has been removed from car emissions through the invention of special exhausts. Polluting two-stroke outboards are being replaced by clean, small four-strokes. New pesticides and antifouling paints have been developed which do not persist in the marine environment. Filters can remove many emissions from coal stacks. Solar and wind technology is rapidly improving, and becoming cheaper. Solar cells are now widely used to power yachts' lights and marine navigation lights.

Fishing gear is being made more selective to reduce the catch of unwanted species. Prawn trawl nets are now built with slots and shutes to exclude turtles and other bycatch. They also reduce damage to prawns, increasing profits. Tuna long-lines which hook seabirds can

Figure 473.1 Gas tanker loading Western Australia
(Photo AMSA)

The prevention of diseases and other problems from entering the marine environment is called biosecurity.

Class exercise

How is the environment portrayed on TV? Keep a diary of your own TV viewing for the week and make a record for every story about the environment, and particularly the marine environment. Compare your diaries in class. (The teacher will be very interested in your viewing habits!)

Figure 474.1 Government action to stop pollution
(Photo AMSA)

Definition

Ecosystem management

Ecosystem management is management of ecosystem values and uses recognising the interactions with the environment, and responding to signals from the ecosystem to control anthropogenic activities and uses (after Harden Jones, 1994, source Oceans Policy Statement).

Figure 474.2 Individual action to stop pollution
(Photo Bob Winters)

be modified so they sink faster, saving threatened seabirds and bait. Fish and other seafoods can be reared intensively in aquaculture, easing pressure on fish stocks.

Technology has greatly assisted in marine research. SCUBA diving has become safer and more efficient, with computer diving gauges, and computer-controlled mixed gas (helium/oxygen) diving tanks and re-breathers. Relatively cheap remote-controlled underwater robots with videos can be sent anywhere into the sea.

New DNA techniques are now used to identify species, their sex, their parents, their population status, and even their last meal. Genetic engineering is being used to make faster growing and disease-resistent species for aquaculture. Micro-organisms are being developed that will literally gobble up oil pollution.

Satellites are used to map the marine environment and to monitor weather, and pollution. They are used to track the movements of whales, dugongs and fish, and even White pointer sharks. Computers and communications satellites have revolutionised electronic communications and are now indispensable tools in environmental education and management. Pollution is now easily and cheaply monitored and modern electronic instruments can detect even a few molecules of a contaminant. Sensors can then automatically *telemeter* or send their findings to a central computer. Computer databases are used to store and analyse an ocean of complex data. Computers can simulate or *model* complex ecosystems, predict events, and even make decisions for us.

Action on land to reduce diffuse pollution

The millions of small diffuse sources of pollution entering coastal catchments are possibly the greatest, and most difficult problem affecting Australia's marine environment. Nevertheless, there have been some important advances in this area and agricultural practices are improving. Sugar cane drains in NSW and Queensland are being re-designed so that they are wider and shallower, so they do not expose acidic soils. Use of slow-release fertilizers are reducing runoff into the waterways (and saving farmers a lot of money). Litter traps are now added to stormwater drains to remove larger items of litter. Sediment traps of synthetic fabric are used on land and sea to contain erosion and suspended silt.

Landcare-Seacare-Coastcare

Farmers need much technical and financial support to become more environmentally sustainable. *Landcare* programs have been established to assist landholders in revegetating the land to reverse soil loss and salinization. *Rivercare* programs help landholders to restore riparian (stream and river) vegetation, which stabilise banks and act as biofilters to trap sediments and nutrients. *Integrated* or *total* catchment management, which involves all the different uses in a catchment, is a very important approach to the problem. Billions of dollars have been spent in the past decade on the repair of the land, but it will take tens of billions more. And because many of the problems in the sea come from the land, *Seacare* really begins with *Landcare*.

Personal actions

Chapter 8 discussed many of the personal actions we can all take to improve marine conservation in Australia. Some of these involved reducing, reusing and recycling our waste, improving the riparian zone in our catchments, thinking globally and acting locally as well as educating others and promoting companies who are really trying to showcase their environmental achievements.

Conclusions

The problem of unsustainable use of environmental resources is now widely recognised. The adoption by Australia of the ideal of *ecologically sustainable development* (ESD) is an important step forward. ESD requires a new way of thinking, and will be very difficult to achieve. Environmental management requires long-term planning, considerable scientific and other information, widespread community support, some sacrifices in our standards of living, and a great expenditure of funds.

ESD is a new idea, and the tools for ESD are still being developed. They range from legislation controlling harmful activities, to detailed regional planning, to development of technical alternatives and solutions. ESD will be the greatest challenge facing the new generations in Australia, and around the world.

"Ecologically Sustainable Development (ESD) ...

means using, conserving and enhancing the community's resources so that ecological processes on which life depends, are maintained and quality of life for both present and future generations is increased (after the National Strategy for Ecologically Sustainable Development)." Source National Oceans Office.

Figure 475.1 As our use of the sea increases so will the need for its wise management
(Photo Murray Waite)

Case study 18.1 Sea rights

Read the following extract from an article called, *A voice in all places - Aboriginal and Torres Strait Islander Interests in Australia's Coastal Zone*, by Dr Dermot Smyth which was prepared for the Coastal Zone Inquiry, Resource Assessment Commission, reproduced with permission, copyright Commonwealth of Australia 1993.

Then answer the questions on page 477.

The High Court Decision

By a 6-1 majority the High Court made a judgement in favour of Mr. Eddie Koiki Mabo and others in their claim against the Queensland Government for recognition of their native title to Mer – one of three islands of the Murray group in eastern Torres Strait. The finding effectively overturned the long held legal doctrine of *terra nullius,* which had maintained that Australia was unoccupied territory prior to 1788.

The claim arose out of the refusal of Murray Island people in 1982 to accept a lease over the islands from the Queensland Government. The Murray Islanders maintained that the Queensland Government was not in a position to grant a lease over the islands since the Murray Islanders themselves were already the owners under customary law. During the ten years of legal proceedings that ensued, the Queensland Government passed new legislation, the *Queensland Coastal Islands Declaratory Act 1985,* which purported to extinguish any native title to the Torres Strait Islands should such a title continue to exist. In a separate High Court action in 1988 the Murray Islanders established that this legislation contravened provisions of the Racial Discrimination Act 1975. The *Queensland Coastal Islands Declaratory Act* was therefore declared invalid and the original claim for recognition of traditional ownership of the Murray Islands proceeded to the High Court.

The High Court has now established that the Meriam people of Mer hold a 'native title' to their island under customary law which is recognised under Australian common law. The court also found that native title could be extinguished by explicit legislative acts, or by removing customary owners from their land, or by otherwise destroying the customary law under which such native title is held. However, as happened in the Murray Island case, attempts to extinguish native title by administrative or legislative means may contravene provisions of the *Racial Discrimination Act 1975*.

The immediate impact of the decision applies only to the land of the island of Mer in the Murray group. The importance of the case nationally rests with the extent to which it may have firstly set a legal precedent, and secondly altered the way in which Aboriginal and Torres Strait Islander people may hitherto expect to interact with governments on land, sea and resource management matters.

The original claim by Mabo and others included a large area of sea territory surrounding the Murray Island group, including both Commonwealth and Queensland waters and sea-bed. Claims for Commonwealth and Queensland waters were withdrawn as the case proceeded, in part because a Queensland Supreme Court judge determined the customary practices in relation to the ownership and use of fringing reefs were no longer in operation, so that the High Court was only called upon to bring down a decision in respect of the land of the Island of Mer.

As it was made clear during consultations with Meriam people during the inquiry, there was still a determination to proceed with claims on the other two islands and surrounding waters. In October 1993 the Murray Island Council announced its intention to control commercial fishing in waters surrounding the island and indicated that a formal native title sea rights claim would be lodged with the Commonwealth Government in the near future. (See "Sea rights ban hits trawlers," *Courier Mail* 28 October 1993.)

Dimensions of the Mabo Judgement

As has been noted by several legal commentators (e.g. Brennan 1992, Nettheim 1992 and Bartlett 1993) the fundamental implication of the High Court judgement is that British acquisition of sovereignty over Australia and its islands did not in itself bring about a transfer of ownership of the land from the indigenous people to the Crown. Although the Crown acquired 'radical title' (i.e. ultimate control) to land on colonisation, actual ownership and use rights were removed from Aboriginal people parcel by parcel over time as European settlement advanced, as land grants were made and as Aboriginal people were killed, displaced or removed from their traditional estates. Where such events have not happened, and where Aboriginal and Torres Strait Islander people continue to have a relationship to their country based on customary law, then native title may continue to exist and if so is recognised under Australian common law.

Although the Mabo judgement referred only to land, coastal Aboriginal people, as well as the Meriam people and other Torres Strait Islanders who participated in the consultation process, have expressed optimism that their claims to ownership of customary marine estates may also be recognised. This possibility is under active consideration by legal advisers to Aboriginal organisations around the country and was raised during meetings with Commissioners at Broome, Cape Leveque, Maningrida, Cairns, Yarrabah, Gordonvale and Palm Island as well as at formal hearings in Darwin (Transcript, p. 997). Several native title claims which include extensive areas of sea country have already been lodged in courts in Western Australia and Queensland. (The Utemorrah claim in the King Sound area Western Australia and the Fraser Islander claim in Queensland).

The issue of native title over marine estates following the Mabo decision was the subject of a submission to the Inquiry which concludes that:

'Common law recognition of customary marine tenure is highly likely following the Mabo decision . . . there is nothing in the judgement which would seem to preclude the

application of native title principles to the sea-bed. (Ms. Joanna Sutherland 351, p 2).

The likelihood that native title can exist and has persisted in marine environments is supported by many legal commentators, including the Office of General Counsel of the Commonwealth Attorney General's Department. That office has advised the Great Barrier Reef Marine Park Authority that although native title is unlikely to the ownership of the sea, sea-bed or natural resources, claims for native title use rights 'have a good prospect of success.' (Mabo: Implications for The Great Barrier Reef Marine Park . . Advice from Office of General Counsel the Great Barrier Reef Marine Park Authority, p 13, 20 May 1993)

Professor Richard Bartlett, an expert on native title law in the United States and Canada, has pointed out (Bartlett 1993) that native title to the sea, sea-bed and marine resources has been recognised by courts in Canada, United States and New Zealand. He concludes:

'*Mabo* extends to the sea. There may be problems of proof, but they will be no more onerous than on land. Indeed the difficulties of establishing native title in the off-shore may be less than on land because of the lesser extent of inconsistent grants . . .

Native title at common law protects the traditional relationship of Aboriginal people to their environment. To the extent that the environment includes the sea, it is included within the compass of native title. Australia's arrangements to accommodate the rights of non-Aboriginal and Aboriginal people must recognise native title rights to the sea. (Bartlett 1993, p 17).

The implications of the judgement for particular areas of Australia, and the current status of native title over particular parcels of land or water, are not matters for consideration here. It is essential, however, that any recommendations for improved coastal zone management should take note of the probability that some coastal and marine environments and resources are subjected to native title in common law.'

Questions and activities

Complete the three level guide in your note book. Check Appendix 10 Page 599, to see how to do a three level reading guide. For each of the statements in level 1 and 2, write T (true) or F (false) in the space provided.

Level 1 (Literal): Reading for accuracy

Be able to show where these statements appear in the article. Use P for paragraph and L for line.

1. ___ The claim for the Island of Mer arose out of the refusal of Murray Island people in 1982 to accept a lease over the islands from the Queensland Government.
2. ___ The Crown acquired 'radical title' (i.e. ultimate control) to land on colonisation, actual ownership and use rights were removed from Aboriginal people parcel by parcel.
3. ___ Native title to the sea, sea-bed and marine resources has been recognised by courts in England.
4. ___ There is nothing in the Mabo judgement which would seem to preclude the application of native title principles to the sea-bed.
5. ___ In October 1990, the Murray Island Council made claim to Sea Rights.
6. ___ The High Court has now established that the Meriam people of Mer hold a 'native title' to their island under customary law which is recognised under Australian common law.

Level 2 (Interpretive): Drawing conclusions

Be able to show why you arrived at this conclusion with evidence from the article.

7. ___ Sea rights have not yet been settled in court.
8. ___ Many Aboriginal people regard estuaries, bays and waters immediately adjacent to the shore as being part of their land.
9. ___ The limited recognition of Aboriginal interests in the sea provided by sea closures under Northern Territory legislation has been shown to be inadequate in achieving harmonious management of the Top End coastal waters.
10. ___ It now seems unlikely that a 2 km buffer zone alone would have fully protected the legitimate interests of Aboriginal people.
11. ___ Another term used in dealing with sea rights is customary marine tenure (CMT).
12. ___ Native title only applies to Australian indigenous people.

Level 3 (Applied): Defending your opinion

For the following questions, be able to give reasons (argue) why your answer is correct. You may draw on information from other sources to justify your answer.

13. Why does a proposed buffer zone fail to recognise the coastal sea as an integral, inseparable part of Aboriginal Country?
14. The purpose of the Racial Discrimination Act of 1975 was to protect the rights of Aboriginal people. How did the then Queensland Government contravene it?
15. Why should Aboriginal and Torres Strait Islander people have a right to hunt by traditional methods?

See also map of Murray Island on page 514.

Kerry Kitzelman

Case study 18.2 Small tropical islands

Eco-Tourist's dream — Eco-Resort's nightmare

Text and tables copyright Robyn Aiello. Questions and activities copyright Great Barrier Reef Marine Park Authority. Reproduced with permission.

Abstract

Sunny tropical islands are some of the most beautiful places for tourists to visit. However, for ecotourism operations, these same islands can be nightmares to operate in an economically and environmentally sustainable manner. Due to the sensitive nature of small island ecologies, waste and water management systems effectively used on large islands and mainlands will not always work on small islands. The impacts are unacceptable.

Green Island, a small sand cay on the Great Barrier Reef in tropical north Queensland, Australia, serves as an excellent example of how a small island destination can support a luxury ecotourism resort. To be successful, however, the initial investments and ongoing operational costs can be huge.

Green Island

Green Island is located only 27 km offshore from Cairns, a leading tropical tourist destination in northern Australia. The island is a very small sand cay, which takes less than 30 minutes to walk around. The diverse environments, ranging from a tropical rainforest in the centre to dry coastal vegetation on the white sand beaches, makes Green Island very unique. The island lies on top of a large platform (or patch) reef, which supports a highly diverse coral reef and seagrass ecosystem. Due to these natural features, as well as its accessibility from the mainland, Green Island experiences very high tourist visitation levels.

Two commercial tourist operations carry over 250,000 people to Green Island every year. Table 1 outlines the visitation restrictions set by the stakeholders of the island, including the overall managing state government agency, the Queensland Environmental Protection Agency.

Green Island caters to both day-visitors and overnight resort guests. Facilities include two pools (one exclusively for the resort guests), two lunch outlets, a restaurant, a bar, a dive centre, several small shops, changing rooms, toilets, and locker rooms

Table 1 - maximum numbers of visitors allowed on Green Island

Visitors at one time	1400
Visitors per day	2240
Overnight guests	90
Overnight staff	40

Green Island Resort

Bob Moffatt

Green Island Resort is known worldwide for being a luxury destination on a small tropical island. The Resort is managed by Reef Management Pty Ltd, a member of the Daikyo Group (a Japanese based tourism and real estate company).

In 1992, Daikyo spent $43 million dollars to re-develop the run-down accommodation that had been in use on Green Island since the 1940's. The result - a 46-room luxury resort surrounded by 13.2 hectares of National Park. Construction of this resort had to follow strict environmental best practice codes (see Table 2).

Table 2 - Constructional restraints for the development of Green Island Resort

Minimal Impact Features	Environmental Consideration
Resort buildings built up off the ground (1 metre)	• Minimises compaction of island • Prevents inundation during cyclones • Allows free roaming of native animals • Prevents interference with soil systems & tree roots.
Raised connecting boardwalks & pathways	• Minimises local compaction while allowing large numbers of users • Allows free roaming of native animals • Prevents interference with soil systems.
Water, sewerage and fuel lines are suspended under boardwalks	• Reduces visual impacts • Prevents trenching into the thin topsoil • Prevents unnoticed leakage spills underground • Prevents interference with soil systems & tree roots.
Sewage is treated by a tertiary treatment plant	• Prevents impacts of sewage disposal on coral reef
Pavers are used instead of concrete	• Allows rainfall to percolate through to underlying freshwater lens
Gutters and other rainwater collecting devices are prohibited	• Allows rainwater to fall freely and filter through soil to replenish freshwater lens under the cay - this is essential to the survival of plants on the island
All potable(drinking & washing) freshwater is barged in from mainland	• Prevent depletion of the small underlying freshwater lens
Buildings built around existing trees	• Reduces vegetation removal • Maintains natural canopy cover and wildlife • Maintain visual amenity and natural setting
Garden plants propagated from island native plants	• Prevents introduction of non-native plants and weeds
Gardens around resort rooms allowed to grow naturally with minimal maintenance.	• Mimics natural environmental of island
Natural colours of construction materials	• Reduces visual impacts

Today, Green Island Resort represents one of the most environmentally sensitive tourist developments in Australia.

Having a well-constructed "eco-friendly" resort is a good start, but it does not address the ongoing day-to-day issues associated with high visitation, especially sewage treatment, waste minimisation & water management.

Reef Management Pty Ltd must continuously seek innovative ways to address these issues. Sustainability is a fine balance between economic reality, environmental degradation, and tourist/customer satisfaction.

Sewage Treatment on Green Island

The Problems

- Sand cays cannot support a septic sewage treatment system.
- Prior to 1992, it was legal to pump raw sewage from the old resort onto the surrounding reef. At that time, scientists did not anticipate the widespread reef degradation that this action would cause.
- A significant portion of Green Island's shallow coral reef died from excessive nutrient loading.

The Solution - The Tertiary Treatment Plant

The construction of a Tertiary Treatment Plant was a mandatory requirement for the re-development of the Green Island Resort and performance is closely monitored to ensure compliance with strict standards set by state and federal government environmental management agencies..

Effluent is treated in several ways:

1. biological treatment to remove nitrogen and phosphorous,
2. sand filters,
3. UV radiation to disinfect.

There are two waste products from this treatment - sludge and effluent water. The sludge is barged off the island weekly and disposed in the city's system.

Most of the effluent water (which is essentially freshwater) is recycled back into the resort. It is used for:

- garden irrigation,
- toilet flushing,
- fire fighting reserves.

Only a small portion of the wastewater (which due to the treatment process contains minimal nutrients) is discharged off the edge of the reef.

Although the total cost of construction was $5.3 million dollars (AUD), the environmental benefits and contribution to sustainable development are undeniable.

Waste management

Waste management is one of the most important issues on Green Island. The ultimate objective for Daikyo is to become a nil waste generating tourist venture. Since 1994, Green Island Resort has instituted changes which reduced water usage by 27% per annum; reduced treated sewage discharge by 50% and reduced solid waste significantly through enhanced staff training, commitment and cooperation.

They have also set up a Cleaner Production Partnership with the Queensland Environmental Protection Agency.

The Problems

- The topsoil on Green Island is very shallow, preventing the use of landfills. On-land waste disposal would most likely result in contamination of the underlying freshwater lens, which would result in severe vegetation degradation.
- All waste must be removed from the island. Dumping at sea is prohibited in the Great Barrier Reef Marine Park.

The solutions

With landfills and ocean dumping prohibited, removal of waste from the island to the mainland by barge was the only alternative. This came at a huge operational cost.

To reduce costs, waste minimisation practices are essential.

1. Precycling and recycling

Green Island recycles paper, glass, cardboard, engine oil, cooking oil, aluminium and newspaper.

Precycling - all products used by Green Island Resort are carefully chosen to reduce the amount of throwaway packaging that comes with them. Where possible products are bought in bulk, products are packaged in recycled materials and recyclable.

Recycling - Green Island Resort sets aside designated bins for staff to divide the waste. The recent introduction of colour-coded recycling bins in the high-use visitor sections of the resort and day-facilities (e.g. near the beach and eateries) have proven highly effective.

2. Waste Audits

Regular waste audits are performed to determine the effectiveness of existing waste management systems on the island. Results are used to identify weaknesses and strength in the existing waste management systems. The resort is then tasked to implement these findings.

3. Garbage (60% food waste)

With only weekly barges to and from the island, the storage of garbage waiting removal is a major concern. At present, the resort uses a refrigerator garbage compactor, which reduces waste volume through compaction, while keeping the garbage refrigerated.

Waste volume, however remains high, and performance problems with the compacter are ongoing. Alternative ideas for the future are being considered (see Future Innovations below).

4. Littering

Litter is another area of waste minimisation that is important to Green Island. Litter is widely recognised as both a visual impact and an environmental threat. Surveys have shown that ecotourists rate litter as one of the greatest factors contributing to reduced visitor satisfaction.

Several 'no littering' initiatives have been put in place on Green Island. These include:

- Signs stating that Green Island is a National Park, littering is illegal and potential harm litter can cause wildlife.
- Commentaries onboard transfer vessels stating that littering is illegal.

- Brochures and information pamphlets with the 'no littering' messages.
- Well-educated staff that promote proper litter disposal to the tourists.
- Special cigarette butt disposal canisters - plastic camera film canisters (supplied by photographic developing stores) are handed out to smokers. Smokers can carry these small containers with them to deposit their butts.
- Waste bins positioned around the resort, trails and beaches.

Note: All written and verbal messages are presented in several languages to reflect the diversity of tourists (English, Japanese, Chinese, German, Italian, French).

To evaluate the effectiveness of these efforts, observational studies are conducted every 6 months to see how many tourists on the island actually litter. The combination of the above actions have resulted in a huge decline in numbers of 'litterers' - from nearly 50% in 1999 to less than 1% in 2001.

The Resort also won the 2000 Queensland Clean Beach Challenge (Cleanest Beach in FNQ) and award for Resource Conservation and Waste Management.

Future Innovations - the garbage pulper and compost worm farm

A large portion of the budget for Green Island Resort is designated to removal of waste from the island. Therefore, the resort is investigating a way to reduce waste production on the island, not just get rid of it.

A garbage pulper is a great tool for reducing food waste and cardboard. Waste is chopped and pressed until there is only water (which recycles through the system) and pulp (like paper mache, but drier). This process is expected to reduce waste volume by approximately 80%.

The waste pulp can be either composted or used for a worm farm. If a worm farm is used, there is the added benefit of a potential saleable product outcome - fertiliser.

Although the initial set-up and installation costs are high (approximately $50,000 AUD), the savings will be recognised almost immediately, with a near total reduction of barge fees.

Water Management

A lot of water is used on Green Island (an estimated 65 litres per person per day). In order to accommodate this demand, yet prevent exploitation of the island's resources, several different methods are used.

Problems

- Naturally occurring freshwater is practically non-existent on Green Island. There are no natural springs - only a small freshwater lens that lies under the cay. This lens relies exclusively on rainwater replenishment, and provides the only source of water for vegetation on the island.
- Therefore, no groundwater or rainwater can be used by the Resort. All potable (drinking and bathing water) must be barged over from the mainland.

Solutions

Various techniques are used by the Resort to accommodate this demand.

1. Barge water from the mainland - all potable (drinking) water is barged from the mainland. This is an extremely costly exercise, but until recently, it has been the only viable option.
2. Recycle wastewater - wastewater from the Tertiary Treatment Plant is recycled back into all non-potable water needs, such as irrigation, fire fighting reserves, toilets (see Sewage Treatment section above).
3. Restrict water usage - flow-restricting showerheads are used to reduce amount of water used during showers. These save Green Island Resort up to $20,000 per annum in water costs.

Future Innovations - Desalination Plant

Green Island Resort is in the final stages of installing a reverse osmosis desalination plant, manufactured by Pall Rochem Marine. This plant will produce up to 55,000 litres of freshwater every day.

There will be no environmental impacts from this system:

- Unlike conventional desalination plant systems that use anti-scalent chemicals to prevent scaling and fouling of membranes, this system does not require any chemical pre treatment of feed (sea) water.
- Seawater will be pumped from beneath the sand at the water's edge to utilise the natural filtering qualities of the sand to reduce suspended matter in the seawater.
- The only discharge from the system is concentrated brine water. Chemicals and rinse water resulting from occasional membrane cleaning are collected for special disposal on the mainland.
- Although the initial cost of set-up and installation could reach approximately $250,000 dollars, the savings, like the garbage pulper, will be realised almost immediately through cessation of barge activity.

Final Comments

Small islands have unique environmental issues that make waste and water management essential components in any ecotourism operation, especially resort accommodation.

Source

This paper was published as part of the proceedings from *Whose Business is the Environment*? Sustaining Our Pacific Island Resources June 11-15, 2001 20th Annual Pacific Islands Environment Conference, Guam.

Some of the most obvious and easiest remedies for waste removal can also be some of the most costly and environmentally damaging ones.

Repeated evaluation and review of existing management systems is necessary for two reasons:

a. to reduce operational costs, and

b. to reduce environmental impacts.

With the rapid changes in technology, 'state of the art' systems can become obsolete in only a few years.

It is essential to be aware of, and take advantage of, sustainable resource research and changes in technology.

With better understanding of negative impacts caused by improper waste disposal, it is no longer acceptable to rely on dumping in landfills or oceans.

"Out of sight" no longer means "out of mind". There are too many case studies of improper waste disposal resulting in contamination and environmental degradation.

If ecotourism operations fail to keep their environment healthy and impact-free, then their tourist visitation numbers will eventually fade away as word of mouth spreads.

Questions

What is your initial reaction to the content of this case study?

1. What were some of the motives behind the visitation restrictions put in place by the Qld EPA? In table 1 why are the visitors at one time less than the visitors per day?
2. Why are water, sewerage and fuel lines suspended under boardwalks?
3. What minimal impact features have been done to allow free roaming of native animals and reducing compaction of island sand and soil?
4. As a building subcontractor you have been told not to concrete around the pool. What must you use instead of concrete and why?
5. You are the manager and guests complain about getting wet from no gutters. You apply to install gutters and are refused permission. Why?
6. As a room cleaning sub-contractor, you have been told to bring all your water from the mainland. Water is sold to commercial operators at $1.10 per kilolitre. Each room has one bathroom, toilet, shower, vanity basin and 14 squares of living space. On the mainland you charge $4 per square cleaning fee. How much extra will you have to charge to clean a room on the island?
7. Normally fresh water is used for flushing a toilet. Draw a plumbers map to show how you can flush a toilet with waste water from the 46 showers in the resort and what type of energy you would use.
8. On the mainland they use secondary treatment of sewerage. How is Green Islands sewerage system different and why?
9. Explain the difference between precycling and recycling?
10. Draw a diagram to show what you think a refrigerated garbage compactor would look like.
11. A big problem exists with tourists who smoke. You are the guest liaison officer. What pro-active steps would you take to stop cigarette butt litter?
12. You are in charge of eco-tours and have been given the task of making two interpretative signs to show how the garbage pulper and worm farm work. Design two signs 2mx1m for this purpose.
13. You have been told that you are to introduce Robyn Aiello (the author of this case study), a keynote speaker at the Sustainable Use of Marine Resources Conference and by now you have read her paper. Write an introduction to the audience of 200 Year 12 students as well as writing a thank you address summarising her paper and how as concerned year 12 students, we can do something about our marine environment.

Identifying and exploring the issues

Text copyright Great Barrier Reef Marine Park Authority, reproduced with permission.

What to do

- Discuss these in class if you are unfamiliar with the following techniques - futures wheel (Appendix 7), de Bono's's six thinking hats (Appendix 5), Blooms Taxonomy (Appendix 4)
- Define or discuss as a class the following terms - *environmentally appropriate, socially acceptable initiatives*.

Group work

You may like to choose one of the following as a group and then make a report to class, or do the lot as a week's work on sustainable use or do each individually and submit as a separate piece of work.

Your task is to identify information about the sustainable use of the marine environment in and around Green Island by undertaking one or more of the following activities:

Task 1: Futures wheel

- Develop a futures wheel and/or concept map/ consequences chart to unearth a range of topics associated with the sustainable management of Green Island and surrounding waters of the Great Barrier Reef.

  See appendix 7 for details.

Task 2: Risk and threats brochure

- Make two columns on a sheet of paper and brainstorm issues related to the risks and threats to the Great Barrier Reef.
- Take the lists and prepare a brochure or interpretative sign dedicating a paragraph of 3-4 sentences to each to show you understand what each is and can explain it to others. For example litter is a risk to tourists as it may contain broken glass causing cuts, and plastic is a threat to outboard engines as it stops the water intake and cooks the motor.
- Take different positions on these issues, risks and threats and make a list of possible objections the owners of the resort might have to you handing out this brochure to tourists.
- Search the case study for information about risks, threats and issues affecting the Green Island and surrounding waters of the Great Barrier Reef. Find information about how these are also being managed and might be managed better.

Task 3: Can you think in different ways?

Form class groups and use De-Bono's six-hat thinking techniques (see Appendix 2) to examine the initiatives and innovations undertaken at Green Island and any issues, risks and threats that exist from a range of perspectives. Use summary sheets, overhead transparencies or butchers paper to record your groups findings.

For example:

- Red Hat represents feelings and emotions.

  Questions to ask

  - What are your feelings about the innovative, environmentally appropriate and socially acceptable initiatives and innovations undertaken at Green Island?
  - How do you feel about the initiatives and innovations used at Green Island?
- White Hat represents facts and information.

  Questions to ask

  - What are some facts we have learned about the initiatives which seek to achieve sustainable environmental management ?
  - What do we know to be true about the initiatives undertaken at Green Island? What are the facts?
- Yellow Hat represents the positives.

  Questions to ask

  - What are the good points we have learned about the initiatives and innovations in sustainable management of natural resources?
  - What are the positives about the initiatives and innovations used to manage resources sustainably at Green Island?

Kerry Kitzelman

- Black Hat represents the negatives.

  Questions to ask

  - What questions or issues does our learning about the Green Island raise?
  - What are the negatives about the Great Barrier Reef?
- Green Hat represents creativity.

  Questions to ask

  - What is possible for us to do as users of the Great Barrier Reef?
  - What are some of the solutions to Green Island's issues?
- Blue Hat represents thinking about thinking.

  Questions to ask

  - What questions or issues does our learning about Green Island raise?
  - What are some of the main things? What has it made you think about?

Task 4: Framing questions and actions

Discuss the sustainable use of Green Island and the surrounding areas of the Great Barrier Reef by:

- Individual or group formulation of possible inquiries or designs about risks, threats and issues affecting Green Island and the Great Barrier Reef, tested against the reaction of other class members.
- Listing and categorising all types of information related to the task and the risk, threat or issue under two headings-human and non-human.
- Developing a table to outline the information that needs to be gathered, who is responsible, and where they will seek the information and how it will be gathered.

Task 5: Research task - Collecting information

Valuable information can be gathered by a multiplicity of means, for example

- Conduct interviews with staff from Green Island or the Great Barrier Reef Marine Park Authority.
- Identify people who are known to be affected by the risks, threats and issues affecting Green Island and the Great Barrier Reef.
- Make comparisons on issues, risks and threats affecting Green Island the Great Barrier Reef and other national and global contexts.
- Develop contacts within the broader community for relevant information about issues affecting Green Island and the Great Barrier Reef.
- Write or fax letters to groups associated with the issues or management of Green Island or the Great Barrier Reef.

Task 6: Interpreting the information

Interpret the information further and:

- Graph or tabulate findings from investigations.
- Consider the motives of the author(s) of the information.
- Apply De Bono's six-hat thinking to determine the orientation of statements found.
- Check one person's interpretation against another.
- Search for inconsistencies.
- Check information, which presents contrasting opinions, or views to that found.
- Make judgements about how to deal with conflicting information.
- Rearrange the information to detect new patterns.
- Determine the features needed in any technology that might be used on the Green Island.
- Examine the appropriateness of processes used in current activities on the Green Island.
- Identify the key functional, aesthetic, political and environmental features of practices currently undertaken on Green Island.
- Investigate how innovative water and waste management practices and technologies are used on Green Island and explain their impact at a local and global level.

Task 7: Making conclusions from the information

Once investigations have been completed, and additional information has been weighed up:

- Write a series of generalisations based on the information that has been analysed.
- Discuss conclusions with other classes/ groups and be questioned about them.
- Investigate the economic, environmental and social costs and benefits of various risks, threats, issues and solutions proposed.
- Defend conclusions by reference to the information that has been analysed.
- Consider the consequences of acting in different ways on the conclusions.
  - Present the worst and best case scenarios based on factual information.

Task 8: Acting on the information

- Develop an action plan using flowcharts, consequence charts, time lines and visual tools to support others understanding how to work toward the sustainable use of an area like Green Island.
- Generate detailed reports, multi-media presentations, or brochures outlining findings and solutions about sustainable management practices undertaken on Green Island.
- Mount a display in a prominent setting inviting viewpoints and ideas from others.

Kerry Kitzelman

Questions

Knowledge

1. Describe what happened in the 'Mabo case' in the 1990s.
2. Name 3 environmental concerns associated with ports and port development.
3. List six benefits of marine ecotourism.
4. Define ESD and name the four basic principles for decision-making.
5. What is a *stakeholder* and what do they do?
6. State three differences between commercial and recreational fishing.
7. Define the terms *biosecurity, EEZ, ecosystem management* and *multiple use*.

Understanding

8. Make a copy of the EEZ on 435 and use colours to distinguish between the proposed marine jurisdiction zones around Australia and its territories.
9. What is the difference between *recreation* and *tourism*?
10. Describe two reasons for the marine environment having a particular spiritual, cultural and social importance to indigenous people living on coasts and islands.
11. Distinguish between *renewable* and *non-renewable* resources.
12. What did the '*Offshore Constitutional Settlement*' do for State rights in 1979?
13. Write a media release interpreting the national plan for marine environmental management as set out on page 470.
14. What is a *zoning plan* and how is it used?
15. Outline the importance of recording local indigenous stories about marine management or use of the sea.
16. What are the four principles associated with multiple use management and how are they effective in managing the marine environment?
17. Billions of dollars have been spent in the past decade on the repair of the land, but it will take tens of billions more. Why?

Applying

'Nature-based' tourism, or 'ecotourism', is the fastest growth area in the tourism industry. Most tourists visit Australia because of its unspoilt environment and unique wildlife. In 2002 over two million people visited the Great Barrier Reef, and spend in excess of $1 billion. People come from all over the world to dive with the giant Whale sharks at Ningaloo Reef (WA). Dive tourism is a major industry worldwide, and extremely valuable in Australia. Ecotourism is very important economically for it brings money and jobs to remote rural areas.

18. If tourism increased by 2% each year, calculate the value to the economy in 2010.
19. If the fishing industry is worth $125 million, calculate the difference. Now examine this difference and give reasons why this may not be a realistic figure. Why can statistics like this not give an accurate picture?
20. List any six ecotourism ventures and rate them from lowest to highest in economic return.

Analysing

21. Why is a precautionary approach needed where there is scientific uncertainty about the effects of a development?
22. Explain why a new fisheries agreement has to be renegotiated with the new nation of East Timor.
23. Identify at least six government agencies involved in marine environmental management. Draw up a table showing their roles.
24. Investigate how many agencies manage the environment on your local beach. Contact your local councillor to determine the role of the local authority in this marine environmental management.

Creating

25. Create a better sign than 471.3 to get across the message.
26. Formulate a series of research steps that could lead to a biodegradable fishing line.
27. Conduct a survey to see if people value the environment over national security. Record all anecdotal statements.

Evaluating

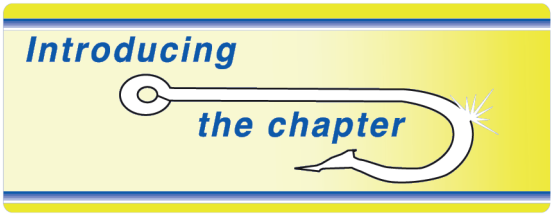
28. The problem of unsustainable use of environmental resources is now widely recognised. What are you personally doing about it?
29. Debate the proposition that the Great Barrier Reef be returned to Queensland State control. (The team arguing the case for the affirmative could consider discussing the benefits for the Queensland Economy and the team for the negative could consider the Queensland political history of the 1970's).
30. Research for marine environmental planning and management typically involves 7 different processes. Decide how many of these are applied on your local beach and determine their effectiveness.
31. Is ESD feasible? Critics say it is illogical. We cannot continue to 'develop' (consume) natural resources forever. They must run out sometime. Optimists say it could be achievable if we control our population, adopt renewable and non-polluting energy sources, and recycle manufactured material. Decide if you agree or disagree with ESD summarising your answers as dot points.

Chapter 19 Biodiversity and protecting marine life

by

Leon Zann

Photo Murray Waite



CHAPTER HOOKS

- Review chapters on ecosystem and discuss the definition of ecosystem integrity on page 491.
- Discuss Nick Gale's research on Page 487.
- Review your data and experiences from exercises on rocky shore ecology or Hypothetical Bay in Chapter 15 (pages 391-393).

WHY STUDY THIS CHAPTER

We learnt much about marine life in the second part of this book, and were introduced to the term 'biodiversity' in Chapter 8.

In Chapter 17 we learnt about the issues affecting marine biodiversity in Australia. In this Chapter we learn how marine biodiversity can be conserved. Marine species which are vulnerable or threatened with extinction are firstly identified, and issues and threats discussed.

The subject of population ecology is introduced, and we learn how the conservation status of species can be determined from their population size.

Case studies of conservation of some fish, turtles, birds and whales are then investigated.

CHAPTER OVERVIEW

New DNA analysis for studying whale diets 487
Australia's marine biodiversity 488
Characteristics of marine biodiversity 488
Protected areas: important strategy in marine biodiversity conservation 491
Conserving endangered marine species 492
New techniques in biodiversity conservation 500
Conclusions 500
Case study 19.1: Threats to Biodiversity —Entanglement *501*
Case study 19.2: Ballast water *502*
Questions *504*

New DNA analysis for studying whale diets

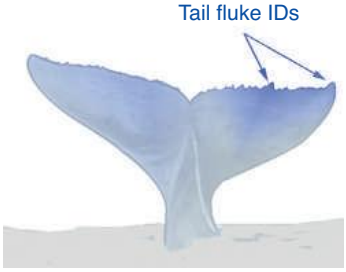
(Extract from Reuters, 15 Feb. 2002.)

Australian scientists have developed a non-lethal way of studying the eating habits of the world's whales - they scoop up their faeces and study the DNA of digested prey. The researchers will present their unique technique at the International Whaling Commission meeting in Japan later this year.

Australian Antarctic Division scientists began their whale waste research in 2001, first by using pygmy blue whales off Australia's southern and western coasts. The pygmy blue whale was selected as it eats a specific species of krill that swims to the surface, enabling scientists to test their new DNA technique. Today, whale researchers are collecting faeces from blue whales off the United States and Canada, humpbacks around the Antarctic and sperm and breeder whales off New Zealand.

Figure 487.1 Humpback whale
(Photo Qld Transport)

Researcher Nick Gales from the Australian Antarctic Division said the collection of whale poo is not difficult. "Animals that live in the water will tend to defaecate near the surface when their bodies are not under a large amount of pressure from the water," Gales explains. "Whale scat breaks up and dissipates in the water quite quickly, so in the water you will see a large brown stain behind a whale as it dives," he said. "We built simple plankton-type nets. You just come along in your small boat when you see whale stains and pull the net through it and collect the sample and preserve it." But until last year scientists could not determine what a whale ate by simply studying its faeces as the digestive process broke down the prey and degraded its DNA. "With animals like whales there is very little left in a scat that you can identify as a hard part, like an air bone from a fish or body of a krill, to identify what it has been eating, so we developed a genetic method of extracting all the DNA out of a predator scat sample and then amplify that DNA to determine what prey was ingested," he said.



Gales said the whale faeces research was still in its early stages as scientists had yet to devise a method to determine the quantity of food a whale consumed. He said the technique would also be used to study the eating habits of penguins, seals and dolphins.

Researchers view this as a possible alternative to Japan's annual kill of minke and sperm whales to study their impact on commercial fish stocks. In the text of the International Whaling Convention, and despite the current ban on commercial whaling, nothing currently prevents Japan to kill hundreds of whales every year for 'scientific research', despite the claims by environmental groups that most of the whale meat ends up in Japan's restaurants.

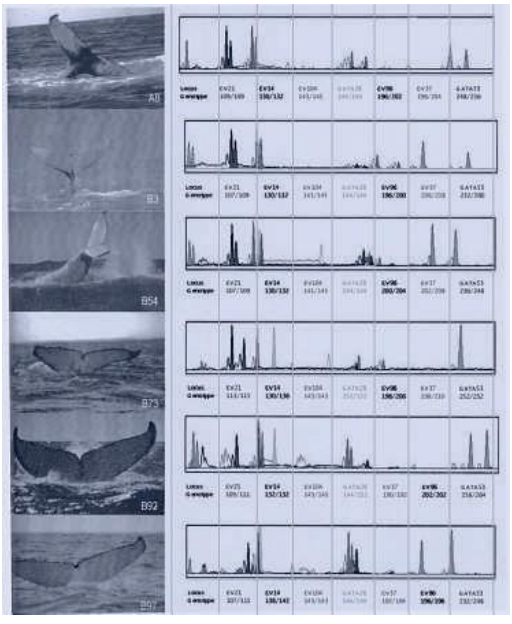


Figure 487.2 DNA from whale skin is being used to finger print humpback whales off Byron Bay. Here the DNA fingerprint is matched with their tail fluke IDs. (Data and photos Megan Anderson, Southern Cross University)

Figure 488.1 Biodiversity is not just numbers of organisms.
(Photo Murray Waite)

What is Biodiversity?

"The word *biodiversity* is a relatively new one that is a shortened version of the term 'biological diversity'. In its simplest form, biodiversity refers to the number and variety of earth's life forms.

This not only includes all of the different species (types) of familiar plants and animals but also includes less well known organisms such as bacteria and other microorganisms.

To date biologists have counted almost 1.8 million different species of living organisms. However, this count is only the tip of the iceberg and estimates of the number of different species on earth vary from 5 million to 100 million with 30 million being a widely accepted figure."

Reference

www.environment.gov.au/biodiversity/

Australia's marine biodiversity

The great whales, amongst the largest animals which have ever existed, have been hunted to near extinction over the past 50 years. They have immense biodiversity value. The term 'biodiversity' (Chapters 8-14) describe the variety of life forms on earth, microorganisms, plants and animals, the DNA they contain, and the ecosystems they form. It emphasises the interrelated nature of the living world. The great whales have become a symbol of marine biodiversity and of marine conservation.

Australia's marine biodiversity is enormous. It includes most marine ecosystems and communities, from all climatic zones, from equatorial to polar. Ecosystems include estuaries: salt marsh, mangrove and seagrass wetlands; soft and hard shores; algal and coral reefs of all types; pelagic (open sea) and benthic (sea floor) communities of continental shelves, slopes and the deep abyss (Chapter 8, pages 210-223). These contain hundreds of thousands of different species, from microorganisms to the great whales. There are over 3,400 fish species, almost 300 different sharks and rays. Each of these species has its own unique genetic diversity encoded in DNA which represents millions of years of evolution.

Highest loss of biodiversity on land since dinosaur extinction

At this moment, the world is currently suffering massive species extinction, the worst since the extinction of dinosaurs around 65 million years ago. Thousands of land species, many undescribed and never seen by scientists, are being lost each year. Australia has suffered many extinctions of land plants and animals since European arrival, and has the highest extinction rate of mammals of any continent. The causes of terrestrial extinctions are mainly loss of habitat, introduced species which out-compete native species, and over-hunting.

Few marine extinctions reported

Despite the biodiversity catastrophe on land, there have been only two known extinctions in the sea. The giant, kelp-eating Stellars seacow was hunted to extinction within a few decades of its discovery, in the Arctic in the late 1700s. The other is a snail whose host saltmarsh plant became extinct in the US. There are probably others, unknown, and many others have been depleted. But generally the risk of extinction is far less in the sea. Why?

Characteristics of marine biodiversity

An understanding of life history characteristics of marine species is important in marine biodiversity conservation. The life histories of most marine species are very different from those of the land.

Most marine invertebrates and many fish are fast growing, short-lived and produce vast numbers of young. (Scientists refer to these as 'R' selected, as opposed to the large, slow growing 'K-selected' species which have few young).

Wide dispersal in the sea

Marine species are generally more widely dispersed than land species. Many can swim, and some migrate great distances for food and reproduction. Ocean currents are used to disperse their young, and algal spores and animal larvae may settle great distances away from their parents. There is huge mortality in the plankton, so most marine species produce enormous numbers of eggs; some females produce many millions of eggs per year. Year-to-year variations in ocean nutrients and currents, and chance events cause great variations in their larval survival, and adult populations fluctuate widely.

Diverse habitats exploited

Marine species also occupy several different habitats during their lives. Their larval stages exploit the different micro-habitats and foods in the plankton, and have several different larval stages. At a critical time in their development, the larvae must find a particular habitat for settlement, or perish. They then change their body forms again, to become miniature adults or juveniles, and commonly live in a 'nursery' habitat (such as seagrass). As they mature they become adults, and move to yet another habitat.

Species with planktonic larvae are therefore very widespread, and they are not vulnerable to total extinction. While some populations may become locally extinct, others will hopefully remain.

Critical nursery habitats

However, some species may be vulnerable to overfishing because of their reproductive behaviour. Species that form spawning schools and seasonally congregate (such as mullet spawning schools, or breeding humpback whales) are vulnerable for they can be captured on mass.

Particularly vulnerable to overharvesting are the turtles which swim vast distances to breed, and nest ashore on certain beaches. Ashore they are helpless and fall easy prey to man. Their eggs are also plundered by natural predators such as goannas, and introduced or feral pests such as foxes and pigs.

Loss of any one of their life history habitats can also be disastrous for a marine species. If water is polluted in any of the different habitats, or if the critical juvenile habitat such as seagrass is lost, then populations of adults (which live in some other area) can also crash. If the turtle nesting beaches are altered by tourism and development, the whole population may be affected. Protection of a marine species therefore requires protection of many different habitats, often great distances apart, and protection of key nursery habitats such as seagrass and wetlands.

Three diversities

A broader definition of biodiversity goes beyond simply counting species to include genetic variety and variability within each species and the ecological complexes in which they occur.

Hence a widely accepted definition of biodiversity states that biodiversity is the variety of all life forms; the different species of plants, animals and microorganisms, the genes they contain and the ecosystems of which they form a part.

As a result of this broadened definition, scientists often talk about three levels of biodiversity:

- Genetic diversity - refers to the genetic variety and variability within each species.
- Species diversity - the number of different species living on earth. At present almost 1.8 million species have been discovered and described by scientists.
- Ecosystem diversity - refers to variety in the combination of species that form ecosystems such as ponds, coral reefs, forests or grasslands.

(Source: Oceans Policy Document)

Figure 489.1. The Leafy sea dragon is greatly affected by loss of habitat.
(Photo Neville Coleman)

Definitions

'***R selected***' — fast growing, short-lived and produce vast numbers of young.

'***K-selected***' — slow growing, long-lived and few young.

Slow growing 'K-selected' species potentially vulnerable.

The larger, slow growing 'K-selected' marine species may also be vulnerable. Turtles, dugongs, seals and whales and fish such as the deepwater Orange roughy are slow growing and long-lived, and produce relatively few young, Some invertebrates and fish which don't have planktonic young, and hatch directly into adults also have restricted distributions, and may be vulnerable to over-fishing and harvesting.

Biogeography important in conservation

An understanding of geographic distributions of species (termed *biogeography*) is important in marine biodiversity conservation. Australian mainland waters can be divided into the tropical north, and temperate south, with large overlaps (***ecotones*** **-** see Figure 490.2) down each coast. Most tropical species (around 80-90%) are widely distributed through the Indian and Pacific Ocean tropics, and there are few tropical endemics (<10%).

Within each bioregion there are many subregions. On the Great Barrier Reef, for example, the reefs close to shore, and in the mid- and outer continental shelf are different. They also vary from north (which are subequatorial and very warm), to south (which lie at the edge of the tropics and the limits of coral growth). The biodiversity of the estuaries, soft shores, and sea floor is also very different.

Australia's unique marine biodiversity

Although less spectacular than those of the colourful coral reefs in the north, the marine plants and animals in temperate southern Australia are more distinctive. Like Australia's unique terrestrial biodiversity, they are ancient inhabitants of Gondwana, long isolated and separated (see Chapter 1). There is a very high proportion of endemic species in Australia's south (around 90%). These species may therefore require greater level of protection than tropical ones.

Figure 490.1 Turtle lays eggs
(Photo Neville Coleman)

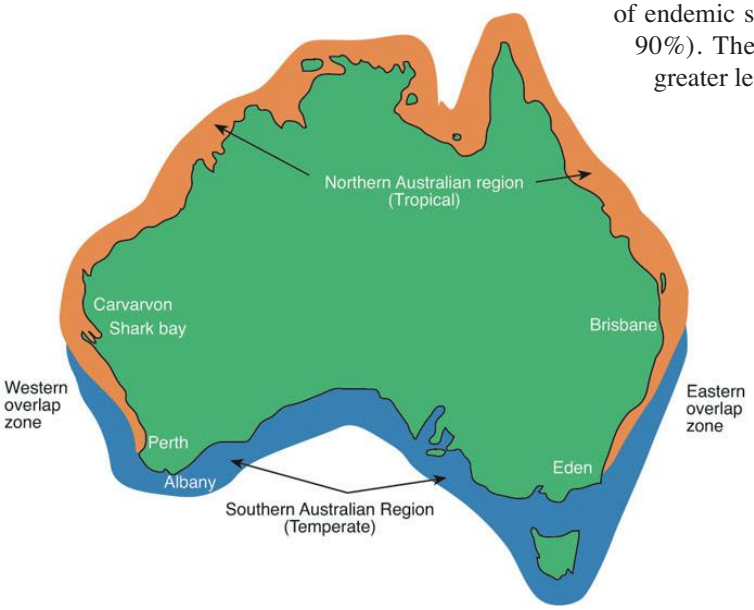


Figure 490.2 Australia's main bioregions (Source CSIRO)

Protected areas: important strategy in marine biodiversity conservation

Conservation of ecosystems or habitat is largely based on protecting a number of different places which typify or *represent* that ecosystem or habitat. Representative areas of different bioregion types are then selected for protection. The areas selected for protection should include a large range of different species, and they should contain all the habitat requirements for these species.

Australia's marine environment has been mapped and divided into different *bioregions*, based on oceanographic characteristics, ecosystems and biogeography (Figure 490.2). Areas in each bioregion are being protected to ensure that its biodiversity will not be lost. The task of protecting areas is more difficult in the sea because of ocean currents and movements of adult and plankton. There are no sharp boundaries in the sea: fences do not work.

Figure 491.1 Research stations in marine protected areas allow scientists to study biodiversity.
(Photo Bob Moffatt)

How much of a bioregion should be protected?

There are no fixed rules in nature conservation but ecologists believe that a minimum of 15-30% of a bioregion or an ecosystem type should be protected. At the moment only about 5-7% of the world's terrestrial ecosystems are currently protected, and <1% of the sea. Australia is a world leader in establishing Marine Protected Areas and currently protects 3-4% of its sea. (See Chapter 24 for details.)

How many protected areas do we need?

Ecologists believe we should protect as many areas as possible. Several different areas should be protected within each type of bioregion in case some natural or man-made disaster wipes one out: there is safety in numbers. On land separate protected areas may be linked by *corridors* of suitable habitat to enable wildlife to travel from one place to the next. In the sea, ocean currents disperse larvae so corridors are not needed. However, it is important to maintain good water quality in the ocean currents, or the larvae may not survive.

How large should each protected area be?

Marine protected areas need to be large in size to protect all the different adult, plankton and juvenile habitats. Marine scientists argue the need for ***large marine ecosystem*** approach to environmental management. This means protecting a large part of the ecosystem, and linked or related ecosystems. As poor water quality often comes from catchment uses, ideally catchments and adjacent marine ecosystems should be managed together.

Unfortunately there is often little choice on *how much*, *where* and *how many*. Sometimes only small fragments of an ecosystem or community are left, or they are too valuable economically to *lock up* larger areas. Large marine protected areas are a fundamental strategy of management and are discussed more fully in Chapter 22.

Protecting 'key-stone' species

Ecosystems can be maintained by protecting the ecologically important or *keystone* species which provide food and shelter for the other species.

Definitions

Ecosystem integrity

Ecosystem integrity is the state of the ecosystem being whole and unimpaired (King, 1993), which should be determined by reference to appropriate ecosystem indicators and criteria.

Ecosystem management

This involves the management of ecosystem values and uses recognising the interactions with the environment while responding to signals from the ecosystem to control human activities and uses.

Figure 492.1 Mangroves are a keystone species
(Photo Bob Moffatt)

These ecologically important or ***keystone*** species include mangroves, seagrasses and corals. These species are widely protected in Australia. Species which threaten keystone species may have to be managed. For example, in Africa elephants which modify their habitats by uprooting trees, have to be regularly culled. In Australia kangaroos which overgraze native grasslands are culled. On the Great Barrier Reef the coral-eating Crown-of-thorns starfish are eradicated in tourist sites. Wider eradication is not undertaken because it is not known whether outbreaks are natural or human-induced.

Conserving endangered marine species

Certain marine species may also be specifically protected because of their ecological importance, because their numbers are low and they are vulnerable to extinction, or because they have some other value.

Managing populations

Hunting reduced populations of Humpback whales species in eastern and Western Australia from over 20,000 individuals to a few hundred by the 1960s. Populations of a species can become so low that the species is threatened with extinction. Population estimates are very important in monitoring species' conservation state, and in biodiversity conservation, but are very difficult to measure in the sea.

What are populations?

A ***population*** is defined as an interbreeding group of a particular species. At any one time, only a proportion of the total population will be reproductively active as there will be some old animals and many young. The number of reproductively active animals is termed the *effective population*. The effective population needs to be sufficiently large to produce enough offspring to offset natural mortality (from disease, predators, old age) and from human impacts such as hunting, fishing or pollution. The population also needs to be large to maintain genetic diversity. This is necessary so that future generations can adapt (through natural selection) to some future environmental change such as ocean temperature rise.

Population ecologists and geneticists have rough estimations of the minimum effective populations for species to avoid extinction.

Minimum population sizes for survival

Population ecologists and geneticists have rough estimations of the minimum effective populations for viability in the long term (ie hundreds to thousands of years). These numbers are based on land mammals and birds, and may provide some idea of minimum viable populations of long-lived *K-selected* turtles, dugongs, seals and whales. They are not very relevant to marine invertebrates and fish with large geographic distributions needing huge numbers of larvae.

Categories of 'threat'

As populations of a particular species decline, it may become *threatened* with extinction. Scientists have devised several categories

to indicate the degree of threat to a species, based on its effective population size:

- *vulnerable* (fewer than 10,000 individuals remaining in world: there is some chance of extinction if there is no reduction of the threat);
- *endangered* (fewer than 2,500: there is a serious risk of extinction);
- *critical* (fewer than 250 individuals: there is a high probability of extinction); and
- *extinct* (no reproductive individuals existing).

Figure 493.1 Dugong
(Illustration Rose Bedford)

Threatened marine species in Australia

While there have been no known marine extinctions in Australia, populations of many species such as whales and turtles have been seriously depleted by hunting and fishing, and some are threatened with extinction.

Plants and invertebrates at risk

We know little about populations of most marine plants and invertebrates. It is assumed that the great majority are immune from extinction because of their planktonic dispersal and great ranges.

Some Tasmania starfish are vulnerable to extinction. Unlike most starfish with larvae, these starfish brood their young in pouches, they hatch as small adults, and have very limited distributions. For example, *Margiaster littoralis* is restricted to an area of less than one hectare near an oil terminal in the polluted Derwent Estuary.

In South and Western Australia, some endemic cowry shells with limited distributions have been depleted by divers because of their beautiful shells. These have been protected, or are subject to strict bag limits. Some other species are so specialised that they may be vulnerable. For example, some symbiotic barnacles live only on the skins of turtles, dugongs or whales and as the populations of the hosts are declining, the symbionts larvae decline also.

Figure 493.2 Some shells have been depleted because of over collection.
(Photo Bob Moffatt)

Sharks at risk

While sharks are fearsome looking and have a bad reputation, they are more vulnerable than they appear. As most sharks are long-lived, slow growing and have few young (ie are *K-selected*), they are vulnerable to over-fishing and hunting. Millions more sharks are eaten by people, than people are eaten by sharks!

In southern Australia School and Gummy sharks have long been the target of net fisheries, and flake is a favourite in the Victorian *fish and chip* market. Numbers are declining from overfishing and possible loss of juvenile habitat in the inshore bays. As snapper and other reef fish decline in southern Australia, fishermen are targeting bottom sharks such as Wobbegongs.

However, one of the most serious threats to the world's shark populations is the increasing demand for sharks' fins. Sharks' fin soup, made by boiling the gelatinious cartilage of the fin, is an ancient Chinese delicacy with reputed medicinal values. In recent decades demand has increased as more mainland Chinese become more affluent, and dried fins now fetch hundreds of dollars per kilogram.

See MESA Seaweek education articles on

www.mesa.edu.au

Most sharks are long-lived, slow growing and have few young —ie they are K-selected.

Figure 494.1 Whale shark
(Photo Below H_20)

Fishermen around the world are now targeting sharks for their fins alone. Only the valuable fins are taken, and the rest of the shark is dumped at sea, a great waste of potentially valuable protein. Sometimes the fins are even cut off while the shark is still alive, and it is left to die an agonising death. The practice of live finning has been banned in Australia, but they are still often caught on tuna longlines.

Whale sharks

The largest of all fish, the giant Whale shark (Figure 494.1), is generally rarely seen and appears to be naturally uncommon. It appears each year off Ningallo Reef (WA) in moderate numbers and it has become the focus of a valuable eco-tourism shark-diving industry. However, numbers are declining and it is listed in Australia as *threatened*. These giants which migrate great distances may have been depleted by fisheries in distant places like India and the Philippines.

Grey nurse sharks

In eastern Australia populations of the fearsome-looking (but relatively harmless) Grey nurse shark have been decimated by spear fishing, shark nets and line fishing. Although they are now fully protected, they are still accidentally taken by shark nets, fishing nets, long-lines and are sometimes illegally targeted for their fins and valuable jaws. Divers in central NSW reported one finless Grey nurse shark survived for a year and 'wriggled' rather than swam through the water.

Figure 494.2 Grey nurse shark
(Photo copyright Great Barrier Reef Marine Park Authority, reproduced with permission)

Grey nurse sharks have been listed as *threatened* and numbers in the east coast may be fewer than 1,000. Underwater surveys in NSW in 2001 located only 292 sharks. The population was listed as *critically endangered* in 2002. They are now fully protected; the maximum fine under NSW threatened species laws is $220,000. Commercial aquaria cannot capture grey nurse sharks for display so some are breeding them for exhibits and export. Young Grey nurse sharks can fetch up to $10,000 in overseas aquaria.

Grey nurses continue to be accidentally caught by recreational and commercial snapper fishermen in NSW, and divers report hooks and wire traces hanging from the mouths of a large proportion of the population. In 2002 many of the reefs where the sharks aggregate were protected from line fishing, but they are still vulnerable to fishing outside these areas.

Great white sharks

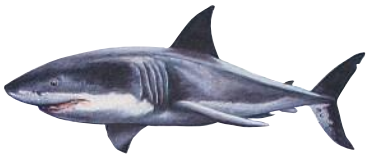


Figure 494.3 Great white shark
(Illustration Rose Bedford)

The most feared of sharks, the giant White pointer ('Jaws') has also been depleted through game fishing, and commercial netting. Numbers have declined such that it is now listed as *vulnerable* in Australia and it has been protected. Australia was the first country in the world to protect it, and it was the first shark ever to be protected.

However, numbers continue to decline as it continues to be accidentally killed in fish and shark nets. The sharks are the focus of an important eco-tourism industry in South Australia where divers can see them from the safety of a steel cage. Divers, who spend very

large amounts of money on the unique experience, are disappointed as there are often no sharks to see.

Tagging of South Australian Great white sharks using satellite transmitters showed they swim great depths and distances, following seals and whale migrations.

Fish at risk

Several species of Australian freshwater fish have become extinct because of poor water quality. Populations of many marine fish have been depleted by overfishing, but none to the point of extinction. Commercial fishing may reduce populations by 60-90%, but most then stop because they become uneconomic (see Chapter 20). However, several species of fish are vulnerable or threatened with extinction because of their limited distributions and specific habits.

Figure 495.1 Spotted handfish
(Photo Neville Coleman)

Spotted handfish

Tasmania's unique handfish species are listed as *vulnerable* and *endangered*. The handfish (so named because they walk across the bottom with hand-like fins) are endemic species, restricted to particular Tasmanian estuaries and harbours. For example, the Spotted handfish (Figure 495.1) is found only in the Derwent estuary. They have a low breeding capacity and the female lays only 80-100 very large eggs and guards them for 2-3 months until they hatch. The eggs are highly susceptible to disturbance or predators such as the introduced Northern Pacific seastar. The Spotted handfish has been listed as *critically endangered*. They have been artificially reared by CSIRO to boost wild populations and artificial surfaces have been deployed to increase habitats for them to lay their eggs on.

Other fish are protected because they are naturally uncommon, or vulnerable to spear fishing or over-collection. For example, the large black cod (a subtropical relative of the gropers), and the quaint leafy sea dragons are protected in southern Australian states.

Figure 495.2 Turtle
(Photo Murray Waite)

Sea turtles at risk

Turtles are ancient reptiles and even pre-date the dinosaurs. Six of the world's seven species of sea turtles are found in Australian waters: the Loggerhead, Green, Hawksbill, Leatherback, Olive Ridley and the Flatback which is endemic to Australia. Sea turtles are all vulnerable as they are a slow growing, long lived species.

The Green turtle takes around 35 years to reach sexual maturity, and may breed only five or so times during its life. World-wide, turtles are threatened with extinction. Although they are protected in Australia (except for hunting by indigenous communities), populations are declining alarmingly.

Figure 495.3 Scientist examines turtle for entanglement
(Photo Bob Moffatt)

Figure 496.1 Turtle on reef
(Photo Qld Transport)

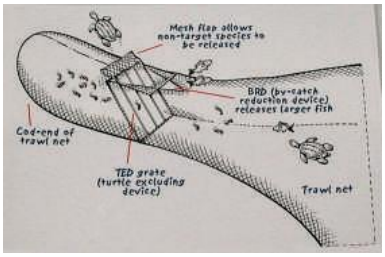


Figure 496.2 Turtle exclusion net
(Photo Qld Fisheries)

Figure 496.3 Seabird caught in line
(Photo Qld Transport)

Australian nesting turtles are very heavily hunted when they migrate to Indonesia and the Pacific Islands to feed. In Australian waters causes of mortalities include: prawn trawls, plastic bags being ingested, speed boat strikes, and predation of eggs by wild pigs and foxes. Turtles have been recently affected by a virus which causes tumours.

Turtle conservation

The critical state of turtles requires urgent measures. Attempts have been made to rear or 'head start' baby turtles to increase their survival in the vulnerable hatchling stage. Eggs are taken from laying wild turtles and incubated in ovens. Interestingly, the sex of the hatchling depends on the temperatures of the sand in the nests, so more females can be produced artificially by incubating eggs at certain temperatures. The hatchlings are kept for several weeks or months on an artificial diet, and are released at an age and size where they are more resistant to bird and fish predators. The success of this *head starting* is difficult to assess as it takes decades before they return to their beaches for nesting.

Mortalities of adults in prawn trawl nets are being reduced through the insertion of *turtle by-catch excluders* (TEDS). These are hatches or shutes built into nets to allow them to escape (Figure 496.2). They are now compulsory in many trawl fisheries. Underwater sonic alarms are also being fitted onto nets to alert turtles and marine mammals of their presence.

An international approach is needed in turtle management as they migrate long distances, and may cross several international sea boundaries. For example, Green turtles nesting on the Great Barrier Reef are strictly protected, but when they return to their feeding grounds in the South Pacific Islands, Papua New Guinea and Indonesia they are still hunted. Traditional hunting has increased and many islanders now use speed boats to chase them down. Large scale commercial turtle fisheries operate in some countries to supply urban areas with fresh turtle meat.

Seabirds at risk

There are over 100 different types of seabirds in Australian waters. Some, like the shearwaters or muttonbirds, are abundant and there are around 17 million breeding pairs of short-tailed shearwaters. Others are rare, and vulnerable to extinction. For example, there are only 500 pairs of Little terns in eastern Australia. The Little tern's nests on sand dunes are robbed by feral cats and foxes, and crushed by 4-wheel drive vehicles.

Species which breed on small oceanic islands are vulnerable to extinction as the entire population could be wiped out by introduced species such as cats and rats, cyclones, ship pollution or illegal poaching. For example, the Norfolk Island Province petrel once nested there in their millions but were hunted to local extinction by starving convicts in the 1790s. They still survived in small numbers on Lord Howe island and a few birds returned to Norfolk to nest for the first time in the 1990s.

Also vulnerable to extinction are Andrew's frigatebird, which breeds only on Cocos-Keeling Island and numbers only 1,300 pairs. Abbotts booby which breeds only on Christmas Island, numbers only 3,000 pairs. In the Southern Ocean the Wandering albatross ((Figure 497.1), has been seriously depleted by Asian long-liners. The birds take the baited hooks as they are shot from the boats and drown. Bird scares and fast-sinking hooks have been introduced on some fishing boats to reduce the problem.

Figure 497.1 Albatros
(Photograph Mike Sugden)

Seals at risk

Australia has three species of seals, the Australian sea lion (endemic) and Australian and New Zealand fur seals. Seals were hunted in Australia in the 1800s for their meat, oil and fur. By 1820, seal populations had been reduced to remnants and some breeding colonies, such as the Australian sea-lion colony in Bass Strait, were completely destroyed. Today, all seals are protected in Australia and most populations are recovering.

Seals may be affected by human activities such as: conflict with commercial fishing and aquaculture; entanglement in discarded fishing gear and other debris; reduction in food supplies; disturbance when resting; oil pollution and diseases. In 1996 and 1999 there were high mortalities (40-55%) of sea lion pups, possibly from disease.

Conservation departments in southern Australia are reducing the incidence of entanglements of seals in fishing gear by reducing discard of fishing gear and other litter. In Tasmania where it was found many seals were being entangled in plastic straps from bait cartons, the carton manufacturers responded by developing an environmentally-friendly strap-free bait box.

Figure 497.2 Australian seal
(Bob Winters)

Dugongs at risk

The dugong or seacow is a tropical, seal-like mammal which eats seagrass. It is long lived, slow to breed and has few young. It has been over-hunted overseas, and northern and western Australia has the world's last secure population, around 80,000. It is protected in Australia, except for indigenous people using traditional methods, under permit. Threats include fishing nets, boat traffic and loss of seagrass habitat. For example, dugong populations collapsed in Hervey Bay in the early 1990s because of the seagrass die-off.

Although they are strictly protected, dugong populations have been rapidly declining in the central and southern Great Barrier Reef over the past 10-15 years. Gill nets were found to be responsible for some deaths and have been banned from many areas, but other factors also appear to be involved. These may include the great increase in boat traffic which prevents dugongs from feeding in coastal pastures, or perhaps even a general decline of seagrass in recent decades. Dugongs stranded in Moreton Bay have been found to have high levels of pesticides.

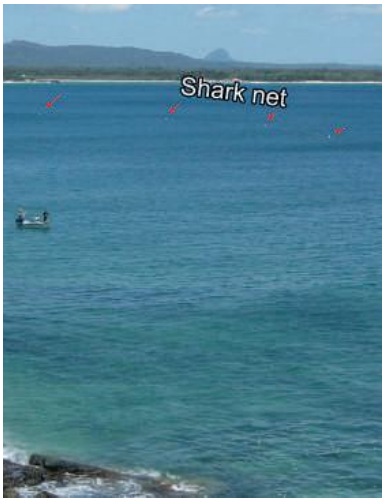


Figure 497.3 Shark nets Noosa Qld
Bob Moffatt

Whales and dolphins: symbols of marine biodiversity

The great whales are amongst the largest creatures which have ever lived and are important symbolic or **icon** species.

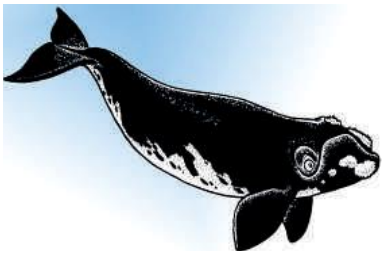


Figure 498.1 Southern right whale
(Illustration Jan Taylor)

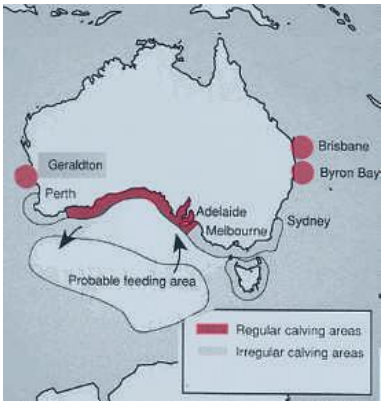


Figure 498.2 Whale breeding areas
(Illustration Environment Australia, reproduced with permission)

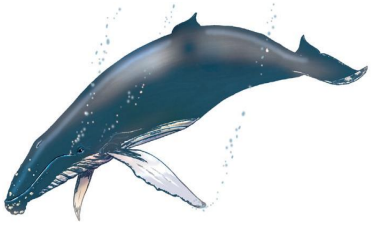


Figure 498.3 Humpback whale
(Illustration Steven Byers)

Figure 498.4 Dolphins
(Illustration Bob Moffatt)

The great whales are now the centre of an important eco-tourism industry, and the friendly, smiling dolphins, have become the symbol of marine conservation and the new age movement.

Around eight species of the giant plankton-feeding *Baleen whales* (Mysticeti) and 35 species of toothed whales, dolphins and porpoises (Odontoceti) are found in Australian waters (Chapter 14). The giant whales were hunted to near extinction during the 1900s. The largest animal that ever existed, the 30 m long, 190 tonne Blue whale, has been reduced to as few as 6,000 individuals world-wide. Whales are prone to over-hunting as they are long-lived, slow to reach sexual maturity, and have low reproductive rates.

Southern right whales

The Southern right whale, which breeds in coastal waters off southern Australia, was hunted to near extinction by the 1840s. Over 26,000 were taken in Australia and New Zealand, and only several hundred now remain. Numbers seem to be slowly increasing. The closely related Northern right whale in the Atlantic continues to decline even though it is strictly protected, and now appears doomed to extinction.

Humpback whales

The Humpback whale, which grows to 17 m, feeds in polar regions and breeds in the tropics, was also nearly exterminated. Whaling commenced from shore bases in eastern and western Australia in the 1950s. By 1963 the populations had been reduced from around 20,000, to only a couple of hundred individuals. The Australian population has increased very rapidly, to around 4,000 individuals in 2001.

Threats to whales and dolphins

Threats to whales in Australia include shark nets and shipping noise, ingestion of plastic bags, and collisions with vessels. There is concern that sonic waves from oil exploration may affect migrating whales in the region. There is growing competition with fishers as over-fishing may be depleting food. Japanese fishermen complain that whales are reducing their catches by eating too many fish.

Although whales are protected by international agreement, Japan continues to hunt them because of the need for scientific research, and Norway hunts them because they ‘always did’.

Many hundreds of thousands of Spinner dolphins have been caught in tuna purse nets in the eastern Pacific. Thousands of dolphins were caught in shark nets off northern and western Australia during the 1980s but the practice has now been banned. In the Atlantic and Mediterranean, there have been epidemics amongst dolphins which have decimated populations. Viruses may be responsible, but autopsies show dangerously high levels of heavy metals and pesticides in their fatty tissues.

Whale and dolphin conservation

Whales and dolphins are now fully protected in most parts of the world, and populations of many species appear to be recovering. In the case of the Humpback whales, populations are recovering even faster than predicted.

The Great Australian Bight Marine Park was established largely to protect the breeding populations of Southern right whales. Efforts by Australia and other countries to establish large whale sanctuaries in the Southern Ocean and the South Pacific have been unsuccessful to date because of Japanese opposition.

The by-catch of Spinner dolphins by tuna nets has been reduced in the eastern Pacific. Pressure from tuna consumers in the US forced the fishing industry to adopt methods to reduce the dolphin catch. Dolphins are now driven away using small underwater detonators, and if they become trapped in the nets, a part can be lowered to allow them to escape.

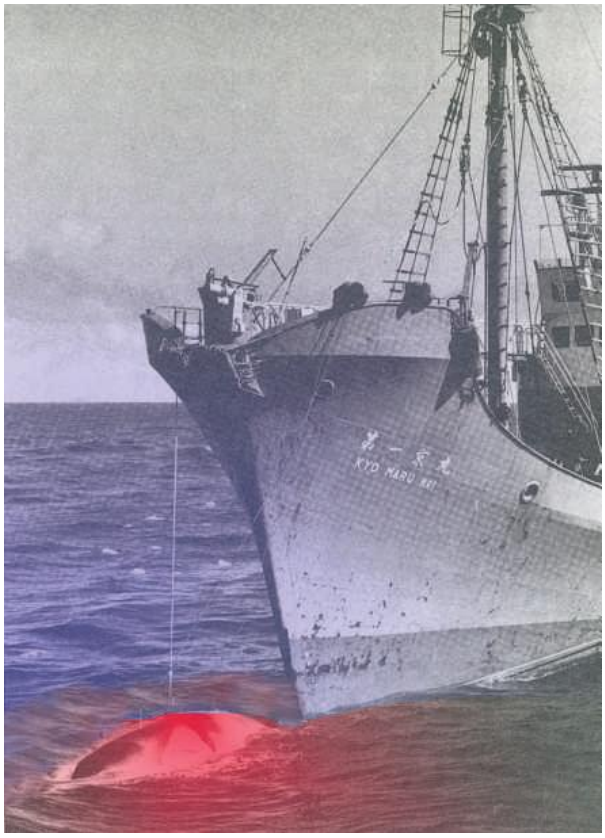


Figure 499.1 Japanese whaling in the Southern Ocean
(Photo Greenpeace)

Whale watching guidelines

Times have changed. Today, whale watching boats take tourists out to view the passing humpbacks from the old whaling ports of Eden, Byron Bay (NSW), Moreton Bay (Qld) and Geraldton (WA). Hervey Bay (Qld) where many whales calve or pause on their northward migrations, has become Australia's whale watching capital. In the south, tourists flock to cliffs along the Otway coast (Vic), the Great Australian Bight (SA), Cape Leeuwin (WA) to view right whales calving. The Great Australian Bight Marine Park (SA) was established as a sanctuary for breeding Southern right whales.

Whales are increasingly hassled by boats and swimmers. Fleets of tourist boats wanting to view whales may come too close and disrupt their courting and breeding activities.

Figure 499.2 Japanese whale harpoon
(Photo Greenpeace)

Have you ever been diving and heard an outboard motor or distant tanker? It seems to be close, and the sound comes from all directions. Sound travels great distances underwater and whales have very sensitive ears that pick up calls from tens of kilometres away. Imagine what they must hear as boats jostle around them for a better view!

Commonwealth laws prohibit vessels and swimmers approaching closer than 100 m to whales, harassing mothers and calves, chasing whales, making loud noises or making wakes which interfere with whales.

Whale rescue plans

Whales, particularly smaller Pilot whales, occasionally strand themselves on a shore. The reasons are not known. Their sonar may be confused in some coastlines, or they may be affected by some inner ear disease. Whales' great sizes makes rescue difficult, but National Parks Services and community groups like Project Jonah have contingency plans for rescues, and have special stretchers and floatation devices.

Figure 499.3 Dead whale
(Photo Qld NP&WLS)

(Photo Bob Moffatt)

New techniques in biodiversity conservation

Estimating populations of even giant air-breathing animals such as whales has proven difficult in the past. Scientists and whale watchers wait on cliffs and count them as they go by on their annual migrations. (But how many pass at night, or out of sight at sea?) Scientists try to identify or 'finger-print' whales by photographing their distinctive tails as they dive. It is a very exciting job, but very time consuming and expensive.

Modern DNA techniques are making it all much easier. DNA can be extracted from tiny skin samples left behind when whales jump, from a biopsy dart fired from a cross-bow, or from whale faeces, as described in the lead story. From this researchers can identify and determine the sex of the whale, and its genetic relationship to other whales. DNA analysis has been widely used in other organisms to identify species and to determine the level of genetic variability in populations, and has great potential for biological *markers* in fish tagging and recapture studies.

Who knows what the future will hold in biodiversity conservation. Techniques have been developed for long-term storage of genetic material, and scientists are archiving genetic material for many species. New individuals can now be cloned from tiny fragments. Jurassic Park is becoming a reality: research is underway to bring back extinct species such as the wooly mammoth and Tasmanian tiger. But far preferable to cold-storage 'biodiversity museums' and zoos with resurrected extinct species, is conserving biodiversity in the wild.

Conclusions

Conserving marine biodiversity is innately difficult. We know little about how marine ecosystems function, the species they support, and their complex interactions. We know almost nothing about their genetic diversity. Many marine species have not even been scientifically named. For most of the others there is little information other than their given scientific name and classification.

The main focus of marine biodiversity conservation is not looking after the animals themselves, but on maintaining water quality, conserving key habitats and reducing human threats or influences. It is important to protect ecologically important species such as mangroves, seagrass and corals.

There is also a need to protect threatened species. Although there have been few marine extinctions to date, the list is sure to grow. There is very grave concern that the ancient turtles, little changed since the Age of the Dinosaurs, will not survive this century. The great whales came very close to extinction. Numbers of the Northern right whale are so low that it appears doomed to extinction. It is still too early to tell if the largest animal which has every existed, the Blue whale, will survive. The world population is pitifully small, the ocean is so vast and noisy with shipping, and it is feared that they may not be able to find mates for breeding.

Human attitudes have changed over the past 20 years. Today we delight to see a leaping whale, or rescue a stranded dolphin or whale. It is still not too late. The conservation of our biodiversity is surely the greatest challenge of the new millennium.

Case study 19.1: Threats to Biodiversity — Entanglement

(Reproduced from State of the Marine Environment Report 1996 a report by D Pemberton, Parks and Wildlife Service, Tasmania. Reproduced with permission, copyright Commonwealth of Australia)

The entanglement of Australian fur seals in synthetic debris in Tasmanian waters has been monitored since 1989 at Australian fur seal breeding colonies, and on an opportunistic basis at haul-out sites in Bass Strait and southern Tasmania.

A total of 136 Australian fur seals (*Arctocephalus pusillus*) and one New Zealand fur seal (*A.forsteri*) with neck collars were observed over the four-year study period. The mean incidence of entanglement of Australian fur seals was 1.6±1.0% which was probably an underestimate as many would die before reaching haul-out sites.

Polyethylene trawl nets accounted for 42% of neck collars, polypropylene straps (packaging straps) 29%, monofilament gill nets 15% and nylon rope 11%. Other incidental items included steel rings (two cases) and a rubber loop.

The high rate of entanglement of seals in packaging straps has continued despite the successful development of a bait box which does not require straps, by SAFCOL and the Department of Parks and Wildlife and Heritage, Tasmania. Whilst the strapless bait box was accepted by some sectors of the industry, they are not being used to a significant extent. Some straps probably originate from other nations fishing either in Australian waters or on the high seas west of Tasmania, indicating that attempts to reduce the amount of debris have to be directed at both national and international levels.

Trawl nets continue to be the major source of entanglement materials affecting seals in Tasmanian waters. This form of entanglement is probably the most lethal as the typically large pieces of entangling netting are both resilient to wear and buoyant. The frequency of occurrence of trawl net entanglements has increased in southern waters and is now similar to that in Bass Strait. The orange roughy fishery shifted from operating over soft bottom to fishing over rocky seamounts off southern Tasmania, resulting in an increase in the number of nets lost due to 'hook-ups'.

The majority of entangled seals were juvenile and subadult animals (75%); of the adults affected, 23% were females and 2% were males. While some seals do survive entanglement, a total of 15% of seals classified as 'entangled' had circular scars around their necks indicating recovery from previous entanglements. The high rates of entanglement of Australian fur seals is considered to be a threat to the status of the population, and is consequently a conservation problem.

Figure 501.1 This young Australian fur seal from Tasmania has a rope 'collar'.

Fishing litter such as net fragments, ropes and bait straps may entangle marine animals, strangling or drowning them. In southern Australia, seals often get discarded or lost fishing gear entangled around their necks.

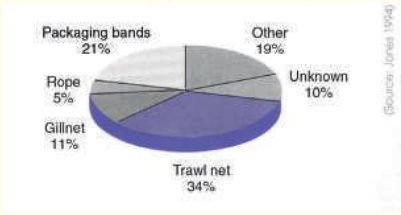


Figure 501.2: Composition of neck 'collars" on entangled seals. (75 seals, 1989-91).

Because entanglement results in gross wounding to the seals and prolonged suffering over years, there is also a moral responsibility by wildlife organisations to alleviate the suffering of individual animals.

QUESTIONS

1. How many fur seals were observed with neck collars in the four year period?
2. What was the rate of entanglement in the population? Suggest why in reality, these figures may have been a lot higher.
3. How do the figures in the pie graph compare with the values given in the text for the four year period? Did the values change over the last two years of the study? Use data supplied to support your answer.
4. What percentage of juveniles and subadults were entangled? Suggest a reason to explain this result.
5. Analyse the information to explain the change in numbers being entangled.
6. Devise an educational campaign for encouraging positive behaviour for students in your school concerning the litter problem.

The first confirmed record of this species in Tasmania is a specimen in the Tasmanian Museum, collected from Rosny Point, Hobart, in October 1986.

More recently it has been recorded in abundance in the Derwent River around Hobart, ranging from just north of Bowen Bridge to Kingston.

It has also been found on the eastern coast at Triabunna, in Mercury Passage and at Promise Bay (Freycinet Peninsula), in each case associated with scallops, and in the Huon River estuaries with one report of it devouring mussels in a mussel farm at Cygnet!

It was not recorded earlier because the first collected specimen had been mis-identified as a relatively common Australian species, *Uniphora granifera* (Lamarck, 1816) (Figures 1 and 2), which it represents superficially. Likewise other zoologists and naturalists assumed it to be this species and took little interest in it, merely noting that it seemed to have increased in numbers recently. This lapse in detecting the introduced species earlier illustrates the importance of having experts on hand to correctly identify species and monitor the marine environment.

Asterias amurensis is relatively easy to distinguish from other native starfish by its general appearance (Figures 3 and 4) with larger specimens having slightly fatter arms

(Figure 5). It can be further distinguished from similar Australian species by the four rows of tube feet on the underside of the arms and by the shape of the spines which are not pointed but semi-circular and chisel-shaped. The colour varies considerably from light brown to yellow or orange, often tinted with violet (Figure 6).

According to Fisher (1930) the species can be very prolific and can be found on a variety of substrates ranging from stones and pebbles to 'sticky soft green mud'. Fisher also gives a temperature range of (0.1 – 7.5 °C) but notes later that the latter might be a few degrees too high! Similarly Hayashi (1973) noted that *A. amurensis* in southern Japan inhabited deeper water than in the north and that: 'in the same region the sea-star seems to be obtained from shallower waters in the winter than in the summer'. He concluded that: 'the vertical and horizontal distribution of the species may be greatly influenced by the temperature of the sea water'. It thus appears that *A. amurensis* is a cold water species.

Just what range in temperature the Tasmanian specimens can tolerate is not known but if they prefer cold waters then the species may be restricted to Tasmania.

Knowledge, monitoring and control

It is most important to first establish the current distribution of *Asterias amurensis* in Tasmanian waters so that the extent of the infestation can be determined. It would also be useful to know the depth range and density of the animals and the temperature of the water they inhabit. The Tasmanian Museum and Art Gallery (TMAG) has produced an informative leaflet to help gather this information. If anyone thinks they have seen this starfish in places other than those mentioned here they should contact the Zoology Department, Tasmanian Museum, 40 Macquarie St, Hobart 7000, preferably with a specimen so that the identity can be confirmed.

The TMAG through this information leaflet and general publicity has alerted the Tasmanian fishing and aquaculture community to this potential threat and is extending its message to the mainland community. The possibility that the starfish may occur in mainland waters cannot be overlooked, particularly in colder waters.

Regardless of what, if any, control methods are adopted, it will be necessary to regularly monitor selected populations of this starfish to ensure that it does not become a threat to the marine environment and hence the fishing industry.

A concern for governments

The introduction of exotic species to Australian waters should be of particular concern to federal and state Governments and the fishing industry. It highlights the following.

- The need for stricter controls on the release of ship's ballast water and other means of passage for exotic species.
- The need for base-line surveys to determine the natural fauna of an area so that the effect of introductions can be determined. This would also identify any introduced species that have not yet been recorded.
- The need to monitor the health of our marine environment by regular follow-up surveys. This sort of data is essential to identify introductions at an early stage and determine the impact of exotic species; it may also alert authorities to other factors effecting the health of the environment such as pollution.
- We have any number of pest control officers employed by various authorities for the terrestrial environment, why not also for the marine environment which is as large or larger and every bit as valuable?
- The need for taxonomists so that species can be quickly and accurately identified. The need for a correct identification becomes immediately obvious when one considers that the scientific name enables the researcher to locate all the literature concerning that species.

A wrong identification of a potential pest will lead to a different data set resulting in control methods which may be inappropriate and could cost millions to rectify. Contrary to popular belief, much of Australia's marine fauna is undescribed and probably new to science, thus compounding the problem of distinguishing native and exotic species.

Unfortunately the number of practising taxonomists in Australia and worldwide is declining. Even worse, it is not something that can be rectified quickly as it takes several years to develop the expertise in just one group of animals to enable quick and accurate identifications.

Wolfgang Zeidler is Senior Curator, Marine Invertebrates, at the South Australian Museum.

References

References for this article can be obtained from AFMA PO, Box 7051, Canberra Mail Centre 2610. Please quote Australian Fisheries, October 1992.

.

Fig 1 *Uniphora granifera — dorsal view*

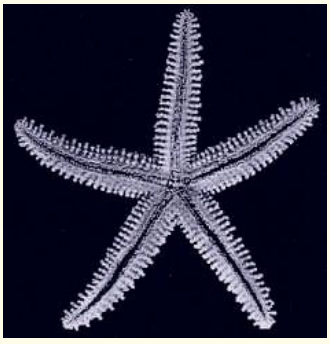


Fig 2 *Uniphora granifera — ventral view*

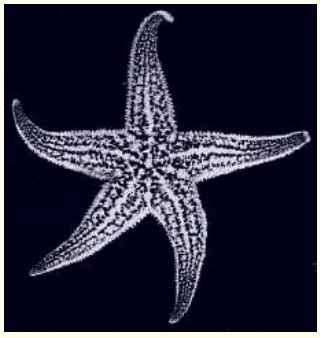


Fig 3 *Asterias amurensis — dorsal view*

Case study 19.2: Ballast water

Acknowledgement is given to the Australian Fisheries Management Authority for permission to reproduce the article from Australian Fisheries, October 1992.

Questions

Read the article on pages 502 and 503 and answer the questions below.

1. What is the scientific name for the northern hemisphere starfish?
2. Suggest how this starfish may have been transported to Tasmania.
3. It is stated that '*Astereas amurensis*' is a voracious species. Explain the meaning of the term 'voracious species'.
4. Predict the effect of this species on the aquaculture, other fisheries and the marine environment.
5. To what group or phylum do the starfish belong?
6. Attempt to define the term 'exotic species' from the way the term is used in the article.
7. Where and when was the first confirmed recording of '*Asterias amuresis*' in Tasmania?
8. How can the species '*Asterias amurensis*' be distinguished from other starfish?
9. The article suggest that governments should spend more money completing base line surveys of material fauna. How would this help in our battle against exotic species?
10. Define the job description of a taxonomist. Why does the article suggest there is a need for more taxonomists?
11. Discuss the biology of the species '*Asterias amurensis*'. Include its habitat, diet etc.
12. Do you believe that the species '*Asterias amurensis*' will eventually threaten the scallop industries in Queensland.
13. Suggest steps needed to be taken to evaluate the magnitude of the problem.
14. Suggest possible methods to control the population of '*Asterias amurensis*'.
15. Outline the measures governments need to take to stop the introduction of other exotic species.

Article

Introduced starfish pose threat to scallops

The recent discovery of a voracious shellfish-eating introduced starfish in Tasmanian waters has aquaculturists and fishermen worried. Wolfgang Zeidler of the South Australian Museum reports on the potential threat of '*Asterias amurensis*' to the fishing industry.

Ballast water suspected

Many foreign species have been introduced to Australian waters since colonisation. In the early days wooden ships were often heavily fouled thus providing the ideal habitat for the transportation of animals and plants. More recently foreign ships have been releasing large amounts of ballast water in Australian ports with recent estimates of around 58 million tonnes being released each year (Jones, 1991). The potential use for the ballast water to carry exotic marine species is well known and the possible harmful effects of these introductions to our marine environment is of particular concern (Hutching et. al., 1987; Jones, 1991).

Obviously not all exotic species transported by ship's ballast survive but some of those that do could have devastating effects on the marine environment and aquaculture. One such potential threat is the recent introduction of a northern hemisphere starfish, *Asterias amurensis* (Lutken, 1871). Just how this species was introduced is not known for certain but, being relatively common in Japanese waters, it was most likely transported to Tasmania in the ballast water of vessels from Japan.

Large species can devour scallops

Asterias amurensis is a voracious species and a well known predator of scallops and other bivalved molluscs in Japan. It's ability to easily prise open and devour scallops is readily demonstrated in an aquarium. Being a relatively large starfish with an arm length of up to 200 mm it is not difficult to imagine the damage a number of these 'monsters' could do to a scallop bed. However, at this stage, the effect of this species on the aquaculture industry, other fisheries and the general marine environment is not known.

A closely related species *Asterias vulgaris* (Verrill, 1866) has been blamed for the demise of the United States oyster industry which was extremely viable early this century.

Distribution and natural history

Asterias amurensis occurs naturally in the northern hemisphere ranging from Kamchatka Peninsula (Bering Sea and Sea of Okhotsk) south to Kyushu (Japan) to about 170 m depth.

In Tasmania I first noticed this starfish in early 1991 as it was common in the dock areas of Hobart and around Sandy Bay.

Believing it to be a Tasmanian species unknown to me, I thought no more of it until a colleague Karen Gowlett-Holmes collected a specimen and concluded it was not an Australian species but an exotic one which was relatively common in Japan.

This identification was later confirmed by Loisette Marsh of the Western Australian Museum who is an expert on starfish and other echinoderms.

Activity

Type CRIMP or marine pests Australia into your search engine and report to class what sites you found.

Fig 4 *Asterias amurensis — ventral view*

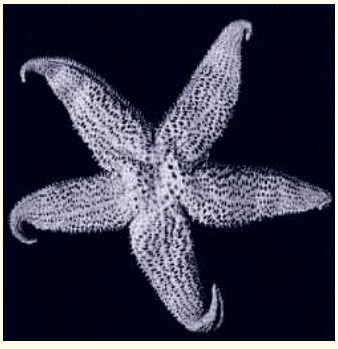


Fig 5 **Asterias amurensis**

Fig 6 **Asterias amurensis**

Exercise

From the Wet Paper Publication - *Marine Biology Exercises*
See www.wetpaper.com.au

D13. What is marine biodiversity?

Questions

Knowledge

1. Define the term *population* and give an example.
2. What is the minimum population size for survival?
3. Define *biodiversity* in its simplest form.
4. Define the term *biogeographic region* and give an example.
5. Locate an endemic species in this chapter and define the term.
6. Name two causes of terrestrial extinction.
7. How much of a bioregion should be protected?
8. State why the leafy sea dragon is greatly affected by loss of habitat.
9. Give examples of two marine invertebrates at risk.
10. Write the correct Commonwealth Government environmental web site address for threatened marine species.

Understanding

11. What is a TED and how does it work?
12. Describe how Wandering albatrosses are killed by longline nets.
13. Give examples of a *K and R selected species*.
14. Give an example of how a diverse habitat is a characteristic of marine biodiversity.
15. Distinguish between the terms *vulnerable*, *endangered*, *critical* and *extinct*.
16. Which species of shark is critically endangered in New South Wales and why?
17. What is the Dugong's greatest enemy? Explain your answer.
18. Outline the method Nick Gales used for determining what whales have been eating using DNA.
19. What is a *keystone* species and give an example of how they are important in protecting an ecosystem.
20. How many marine protected areas do we need and how large should each protected area be?

Applying

21. Study Figure 504.1 opposite and decide what you would attempt to do in a television add to save seals.
22. What species of fish will be affected in the Derwent Estuary if the numbers of the imported starfish increase and why? Decide if this species is vulnerable, endangered, critical or extinct.
23. Examine the statement that "ecosystem management is the management of ecosystem values and uses recognising the interactions with the environment, and responding to signals from the ecosystem to control anthropogenic activities and uses".
    a. What are *ecosystem values and uses*. Give an example.
    b. What are *anthropogenic activities* and give an example.
    c. State why these two issues need to be managed.

Analysing

24. Analyse the Blue whale population statistics in this chapter and decide if it could be classed as endangered.
25. Name two similarities and two differences involved in seagrass and whale conservation.
26. Distinguish between the terms *generic*, *species* and *ecosystem diversity*.
27. Identify four issues involved in habitat conservation and survey your neighbours' knowledge of them.
28. Explain conservation strategies for whales and dolphins.

Creating

29. Devise an alternative to shark fin medicine.
30. Improve on the design of a TED.

Evaluating

31. Assess what would happen to Green turtle populations if all animals under 34 died.
32. Decide why there have been no known marine extinctions in Australia.
33. Loss of a marine organism's habitat can be disastrous. Decide if this applies to any animals you have read about in this chapter. Give an example.
34. Discuss the statement — *protection of a marine species requires protection of many different habitats, often great distances apart, and key nursery habitats such as seagrass and wetlands*.

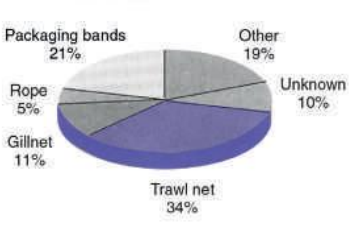


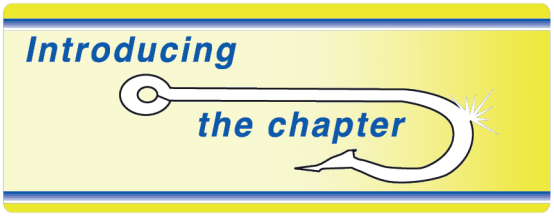
Figure 504.1: Composition of neck 'collars' on entangled seals.

Chapter 20 Australia's fisheries and their management

by

Leon Zann

Photo Qld Fisheries



CHAPTER HOOKS

- Discuss the following questions in class:
  - What basic food types do we need for a well balanced diet?
  - How much fish does your family eat? (On average, how many meals a week or month? Compare class results.)
  - What kinds of fish do you eat? Where are they caught?
  - How many days a week do you eat 'take aways' or 'junk food'?
  - Do you think your diet is a healthy one?
  - Japanese and Mediterranean people live longer than European people. Suggest possible reasons from your answers to the questions above.
- Discuss Figure 511.1 and answer the questions: Are any of these fish in your local market? How does the state of the stock relate to the price of the fish?
- Discuss the following: Is it possible to "count", manage/control the fish in a local area? Why would you? How would You? Who should be responsible?

WHY STUDY THIS CHAPTER

Fishing is a major use of the marine environment and requires detailed study. In Australia commercial fisheries supply fish for domestic consumption and export, and recreational fishing is one of our most popular outdoor activities. But fisheries in Australia, and elsewhere in the world, are in crisis. Catches are declining and some stocks have collapsed. The causes are generally over-harvesting, but environmental degradation and loss of fisheries habitats are often factors. This chapter describes Australia's fisheries and their status, and introduces the study of fisheries science and the theory of fisheries management. Some of the major issues affecting fisheries, and ways in which they can be managed are discussed.

CHAPTER OVERVIEW

World fisheries 507
Australian fisheries 508
Exercise 20.1 Where does our seafood come from? *509*
Types of fisheries 511
Commercial fisheries — fishing for profit 517
Exercise 20.2 Survey of your class fishing practices *517*
Fisheries management 520
Fisheries issues and management 524
Conclusions 526
Case study 20.1 Coasts and Oceans Theme Report *527*
Questions *532*

World fisheries

Fish and shellfish have provided food for coastal people for tens of thousands of years.

The world's fisheries are in crisis and around 75% of fish stocks are declining, or are at the limits of their sustainability. Competition among fishing nations, and between recreational and commercial fishers is intense, and sometimes violent. Fish is already in short supply, and seafoods are becoming very expensive.

The annual global fish catch is around 90 million tonnes, and fishing and related industries provide a livelihood for up to 400 million people. Vital to the poorest countries, fisheries contribute significantly to world food security and account for hundreds of billions of dollars in international trade.

The top fishing countries are China (17 million tonnes), Japan (5.2 million), United States (4.7 million) and Russia (4.5 million).

The top five fish by weight are: Alaska pollock, Japanese anchovy, Atlantic herring, Jack mackerel and Skipjack tuna. The world's major fishing grounds are the North Pacific, west coast of South America and the North Atlantic - areas of high primary productivity and ocean upwelling.

Figure 507.1 Major world upwellings
(After Weinhaupt, illustration Bob Moffatt)

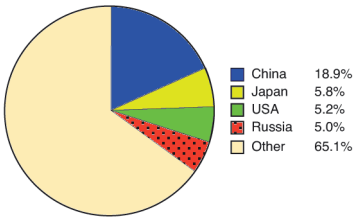


Figure 507.2 Top fishing countries
(Illustration Bob Moffatt)

Although Australia has one of the largest EEZs in the world (Chapter 18), it lies towards the bottom of the list of the world's 55 fishing nations. This is mainly because our oceans are generally low in nutrients and not very productive.

There are no major upwellings and our continental shelves are relatively limited in area. Because our fish stocks are limited, they are more vulnerable to over-fishing.

Leon Zann

Figure 507.3 Tongan fisher folk with the day's catch

Decline of world fisheries

The modern industrial fisheries mainly began in the early 1950s. After World War 2, vessels became larger and gear more efficient. Exciting new fisheries were opened up in the 1950s and '60s. As catches in a fishery began to decline, new fisheries were discovered. The ocean fisheries appeared limitless. However, in the mid-1980s the growth suddenly stopped. We were running out of new fisheries to exploit. Since then the catch has been stable despite more intensive fishing.

This is not because catches are sustainable, but because the rate of new fisheries has about equalled the rate of declines in old fisheries. We are fast approaching the *bottom of the bucket*.

Today only around 25% of the world's fisheries are being sustained; 50% are at the upper limit of their sustainability; 15% are declining; and 10% have collapsed.

Bob Moffatt

Figure 507.4 Will there be enough fish to feed Pacific Island people?

Figure 508.1 Salmon from Canada.
(Photo John West)

Figure 508.2 Snapper from Vietnam
(Wet Paper)

Today only around 25% of the world's fisheries are being sustained.

Figure 508.3 Trawler returns home with day's catch.
(Photo Bob Moffatt)

Globalisation of fish

Today the fish you eat can come from anywhere in the world. Australia exports its highest value seafoods for valuable foreign exchange. We send abalone, king prawns and blue fin tuna to Japan; rock lobster tails to the US; mullet roe to Korea; and eels to Taiwan and Germany. Abalone sell for up to $250/kg, and the others for $30-60/kg. However, we consume far more fish than we produce. Most of our snapper comes from New Zealand. Canned salmon comes from Canada or the US. Canned tuna comes from Thailand but may have been caught anywhere in the Pacific Ocean. We also import large quantities of low cost (and low quality) frozen fish: hake from South Africa, Nile perch from the Central African Lakes, and small *pizza* prawns from Thailand aquafarms. Average wholesale prices are only $3-5/kg.

Australian fisheries

Hundreds of different marine species are fished around Australia, for subsistence, enjoyment and profit. They are harvested from the rivers, lakes and estuaries, offshore reefs and continental shelf, sea floor, deep water off the continental slope and offshore sea mounts, and open ocean.

Seafood consumption in Australia

Each year, Australians eat an average of about 10-12 kg of fish per person. This is about half that eaten by Britons, and only 20% of that eaten by the Japanese.

While we should be eating more fish, the world is starting to run out of fish. Many people are involved in fisheries. There are millions of recreational fishers, and many thousands of commercial fishers, and almost the entire population eats fish. Associated industries employ tens of thousands of people in manufacture and retailing of fishing gear, in boat building and maintenance, and in fish processing and retailing. Fishing is Australia's fourth largest rural industry and an important export earner.

Fishing is therefore one of our most important uses of the marine environment. Fish and shellfish were essential for coastal Aboriginal and Torres Strait Islander people for thousands of years. Today they are important for food and enjoyment.

Fishing is also one of Australia's most important outdoor recreational activities. About four million people (almost a quarter of the population) go fishing for recreation, and a family feed if they are lucky. Commercial fishing supplies fish to the market place. It is economically very important, supplying over $2 billion of fish and shellfish to domestic and overseas markets, and provides thousands of jobs.

Fished species

Fished and harvested marine species include seaweed (for fertilisers, pharmaceuticals and food), molluscs such as gastropods, bivalves and cephalopods (octopus and squid), crustaceans such as prawns, crabs and rock lobsters and echinoderms such as sea urchins and sea cucumbers (for Asian markets).

Exercise 20.1 Where does our seafood come from?

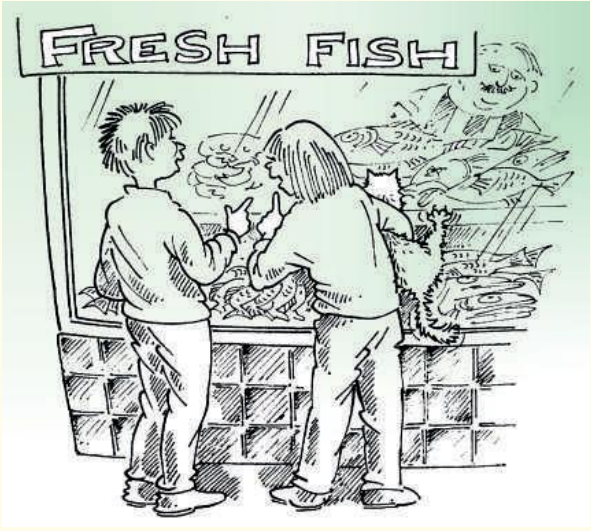


Illustration Sharyn Madder

In this activity you are to make up a report on the current cost of local and imported seafood. Because not all seafood is caught locally, the fish shop will bring in fish from other parts of your state, interstate or even overseas.

Use the following suggestions to complete a report on your local fish shop. This could be a group project with 2 students actually going to the shop and collecting the data with the others analysing the data or following up leads given by the shop owner. If there are a number of shops in town, you may like to split up and compare results. Make sure you tell the owner that you are doing this as a research project for school.

1. Make a list of all the seafood products sold and the price per kg. Is it fresh or frozen? What is its quality? (Bright eyes? Fresh smell?)
2. Make a time that is convenient to the shop owner (try to avoid lunch times or weekends when the owners are flat out trying to make a quid) and match the products that are sold with the places they come from.
3. Find out how the products are transported and stored at the shop.

   Use the map in figure 509.1 to mark where the fish come from.
4. Ask the owners to list the most popular sales and the quantities they order and to tell you any problems they have with supply.
5. Collect any other information your group may feel relevant.

Photo Bob Moffatt

Figure 509.1 Mark in where seafood comes from.
(Illustration Bob Moffatt)

Further research

Use the following words on your search engine to locate commercial deep sea fisheries

Patagoniam toothfish
Orange roughy
Swordfish

Research

Official marketing names of fish.

Check out the Australian Seafood Handbook revised by CSIRO.

www.marine.csiro.au/cmr_pubs/handbook.html

Figure 510.1 The fish *Lethrinus fletus* has the common names - grass sweetlip, red-finned emperor, brown kelp fish, brown morwong, coral bream, piggy, red throat, and squire.
(Illustration Kerry Kitzelman)

In most cases marine species are taken for food, but trochus snails and pearl oysters are harvested for mother-of-pearl shell and gem pearls.

Sharks are very important and large quantities of School and Gummy sharks are harvested, particularly for 'fish and chips'. Around 100 species of bony fish are fished: baitfish such as Herrings and Pilchards; reef fish such as Snappers, Emperors, Leatherjackets; estuary fish such as Bream, Mullet, Whiting and Flathead; pelagic fish such as Mackerels, Tuna and Billfish; and deep sea fish such as Gemfish and Orange roughy (see Chapter 13).

What's in a name?

Common names for fish are confusing. 'Coral trout' and 'Coral cod' are not related to true trout and cod. Common names vary from place to place, making identification and marketing difficult. This is why scientific names, which give relationships and unique names, are so important. (But saying: "I've just hooked a big *Plectropomus leopardus* or *Epinephelus coioides*" is a bit much!) Fisheries departments have compiled *official* common names to help avoid confusion.

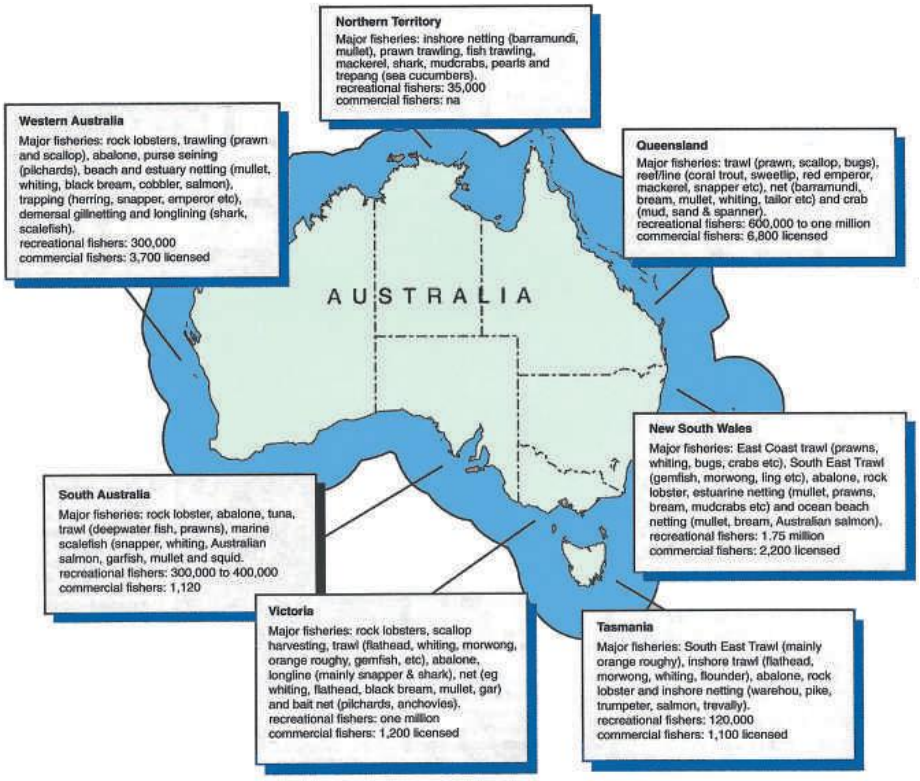


Figure 510.2 Australia's main fisheries, with approximate numbers of recreational and commercial fishers. (Compare the number of recreational and commercial fishers in the State where you live, and with the State's population. What are the main catches? Is there competition between the fishing sectors?)
(From SOMER, p 173, 1996, Copyright Environment Australia, reproduced with permission)

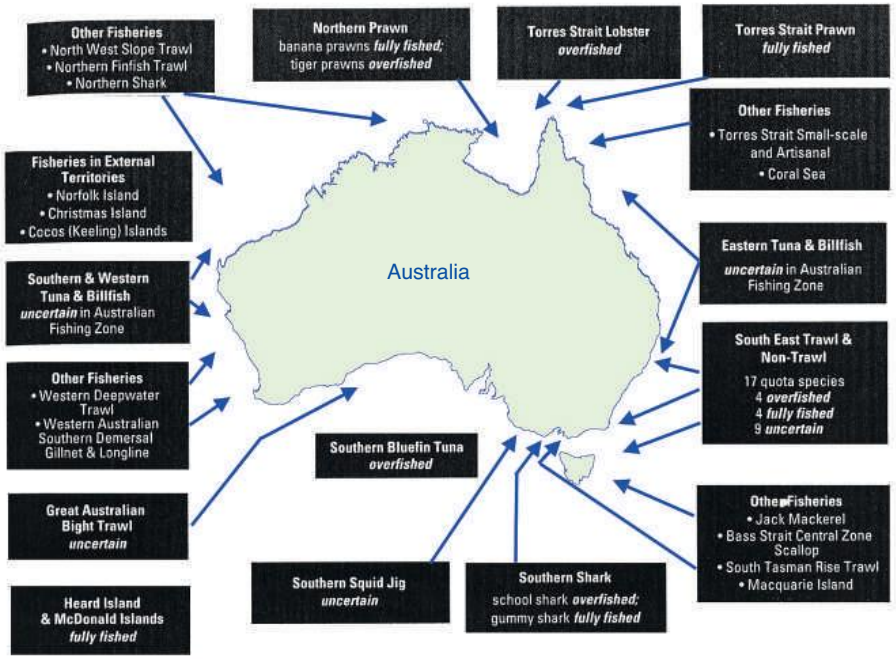


Figure 511.1 The state of Australia's main off-shore fisheries. Were any of these fish in your local market survey? How does the state of the stock relate to the price of the fish? (Source: Bureau of rural sciences, www.brs.gov.au)

Jointly managed fisheries resources in Australia 1996
(From SOMER, p 174, 1996. Copyright Environment Australia, reproduced with permission)

The state of Australia's fisheries

Like fisheries world-wide, many of Australia's fisheries are in decline. Accurate information for all fished species is limited. Of 67 fished stocks in Commonwealth waters, 11 are fully exploited, 11 are over-exploited and have declined, 35 are of uncertain status, and 10 are not known. No species are under-fished. Serious declines have occurred in some Rock lobsters and prawn stocks, and in School sharks, Gemfish and Southern bluefin tuna.

Types of fisheries

People go fishing for different reasons. Some for food, some for enjoyment, and others to sell, and an increasing number are farming their own fish.

Subsistence fisheries: fishing for survival

The sea is important to many of Australia's indigenous people, the Aboriginal and Torres Strait Islanders. Scattered around Australia's shores are huge mounds or middens of oyster, cockle and other shells, some many metres high and hundreds of metres long. These are the accumulated remains of Aboriginal peoples' meals, over many thousands of years. One of the oldest dated middens, on North Stradbroke Island (Qld), is over 25,000 years old. In Shark Bay (WA) shell middens have been dated at 22,000 years old. These were long before the interglacial rise of the sea level began, around 10,000 years ago.

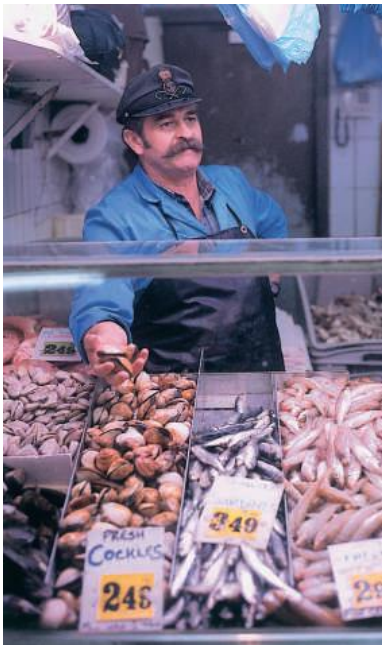


Figure 511.2 Victorian fish markets
(Photo courtesy Gould League)

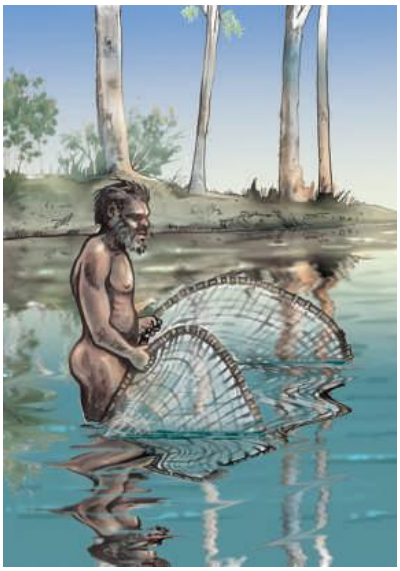


Figure 512.1 Aboriginal fisherman using a net to catch mullet
(Illustration Kerry Kitzelman)

Older middens are certainly buried under the sea on the continental shelf. The middens found along the shore date from since the sea level stabilised, about 5,000 years ago.

The first fishers

The first Aboriginal people to reach Australia must have been fisherfolk living off the sea during their migration down the Malay-Indonesian archipelago over 60,000 years ago. They must have had seaworthy rafts or canoes and been capable sailors, for their migration to Australia involved several long sea passages, out of sight of land.

Early European navigators were met by Aboriginal fisherfolk. The people who met Lt James Cook in 1770 had bark canoes, fishing spears, nets and lines made of plant fibre, and hooks made from oyster shells. Sailing north, Cook saw fishing canoes well out to sea in the Whitsunday Passage, on the Great Barrier Reef. When charting the remote Gulf of Carpentaria in 1804, the navigator Matthew Flinders came across hundreds of boats from Macassar (in present-day Indonesia). They were collecting sea cucumbers or 'trepang', for sale to distant China. This was Australia's first commercial export fishery. The Macassans told Flinders they had been fishing there for several centuries.

Aboriginal fisheries

The sea was (and remains) important for many indigenous people around Australia. Their tribal 'lands' or 'estates' included both land and sea. Depending on seasons, they would go to the sea to harvest their fat oysters, or net mullet or other fish when the schools began to run. When the seas were rough, they would return to their land to hunt possums and kangaroos and other animals, and harvest yams and other 'bush tucker'. There were many ways of fishing. Shellfish were gathered by women and children at low tide, and by diving. Fish were caught using native poisons (which stun fish), baited hook and line, nets of all descriptions, and spears. Lines and nets were woven from fine plant fibre, such as the cottonwood or native hibiscus.

Figure 512.2 Fish hook
(Illustration Wet Paper)

Figure 512.3 Aboriginal mullet fishery Tallebudgerra Creek Queensland. Koombumberri people would call the dolphins to round up the mullet as they swan into the estuary. The fisherman would then spear the fish or catch them in nets like those shown in Figure 512.1
(Illustration Kerry Kitzelman)

Hooks were made from pearl and rock oyster shells which were chipped into a rough circle and then perforated with a rock file and shaped. In the tropics, J-shaped hooks were made from heated strips of turtle shell (Figure 512.2). Gorges, made to jam cross-ways in the fish's mouth, were made from thorns or sharpened twigs. In Torres Strait, lures for pelagic fish were made from shiny pearl shell and feathers.

Early European visitors to Stradbroke Island (Qld) described how the Quandamooka people used dolphins to chase mullet schools into their long nets. Each fisherman would have his 'pets', and call them by splashing spears on the water. Dolphins were sacred 'totems' or spiritual ancestors to some clans. The Quandamooka (meaning 'dolphin people') also hunted dugongs by harpoon, and with long, large-meshed, tangle nets. They collected pipis on ocean beaches, and oysters and other shellfish on sand banks. Today some of the Quandamooka people are commercial fishers and oyster farmers, and still harvest mullet schools as they migrate into Moreton Bay. They use modern beach seine nets, but still hold dolphins in special regard.

Figure 513.1 Aborginal fishers
(Illustration Kerry Kitzelman)

Torres Strait Islander fisheries

The Torres Strait Islanders, who live on the small islands scattered between Australia and New Guinea, are a sea people, and rely on the sea for most of their protein. Torres Strait is strewn with coral reefs and shallow seagrass banks, and its waters are rich in nutrients and flushed by strong tides. At low water women gather clams and other bivalves and crustaceans from the coral reefs, and big mud crabs from the mangroves. Large stone traps or weirs were used to catch foraging reef fish as the tide receded (Figure 513.2). As the tide comes in, women fish in the shallows with light lines for small colourful reef fish such as juvenile snappers, cods and wrasses. The men fish and hunt offshore for bigger game. Once they used big outrigger canoes, which they traded from the forest tribes of Papua. Today these have been largely replaced by alloy dinghies (Figure 513.4) and outboards which they use to troll for big Spanish mackerel, Queenfish and Trevally. They still hunt turtles and dugongs by harpoon from motor boats, slowly drifting down onto the feeding animals.

Figure 513.2 Fish trap
(Source unknown)

Figure 513.3 River trap
(Source unknown)

Traditional fisheries management

Aboriginal and Islander people were careful not to over-exploit their marine resources. They protected their sea estates like their land, for their clan's immediate needs, and their future generations. They fished different species in different seasons, switching from one to another so as to not to over-tax a species. Their fishing gear was not very efficient, and many fish escaped. Small fish were preferred, allowing the bigger and reproductively more important fish to survive. Turtles and dugongs were generally reserved for special occasions such as feasts when clans gathered. Turtles were checked for their body fat before they were slaughtered.

The people on the coral islands, which had few terrestrial resources, had to be particularly careful not to over-fish. Some lagoons and reefs were protected from fishing, and some fish were protected. The Quandamooka people on Stradbroke Island never caught the first and largest mullet as they believed these were the school's 'leaders', the old experienced fish who showed the others where to go.

Figure 513.4 Aboriginal fishers Northern Australia
(Photo Lyle Thompson)

Refer back to Exercise 18.1, page 476.

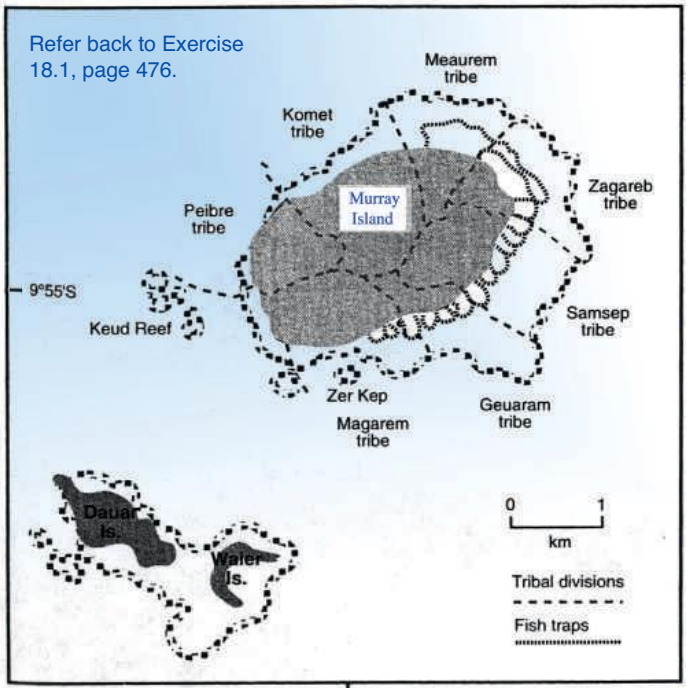


Figure 514.1 Murray Island fisheries
(From SOMER 1996, Copyright Environment Australia, reproduced with permission)

Indigenous fisheries today

With the arrival of Europeans many Aboriginal people were pushed off their land and sea territories, and their cultures were often destroyed. Australian Law did not recognise their ancient Customary Laws and land ownership until the Mabo case and Native Title Act in the 1990s. Aboriginals and Islanders who traditionally held both land and sea territory, are now seeking legal recognition of their ancient sea rights.

In remote areas of Australia, communities still gather shellfish and fish, and hunt for turtle and dugong, for subsistence. In more developed areas fish and shellfish remain an important traditional food, and fishing is an important cultural activity.

Issues in indigenous fisheries

Indigenous communities around Australia complain that they are subject to the same fishing regulations as the recreational fishers. Harvesting of oysters, pipis and other shellfish is strictly regulated, with bag limits intended for recreational fishers. Indigenous people cannot use traditional fishing such as nets and spears in most places. Gradually though, their special situation is being recognised. For example, indigenous people are exempted from laws protecting turtles and dugongs in some places, and are beginning to be consulted by fisheries managers.

Figure 514.2 Beach fishers
(Photo Qld Fisheries)

Figure 514.3 Recreational fisherman's catch
(Photo Jim Kneale)

Torres Strait Islanders complain bitterly about the Spanish mackerel and reef fish boats which fish their traditional reefs, and commercial prawn trawlers which destroy fish habitat. A special border agreement was reached with Papua New Guinea in the 1980s to allow domestic Torres Strait Islander fisheries and protected zones. The Islanders have remained disadvantaged in their own old fishing grounds. The situation reached boiling point in 2001 when young Islanders attacked a fishing boat with spears, and the elders threatened to withdraw Torres Strait Islands from the Australian Commonwealth.

Recreational fisheries: fishing for fun

Fishing is the most popular outdoor activity (outside the garden) for the general Australian community. Its great to go to the coast and sit on a rock or small boat, to relax and enjoy nature, and to (hopefully) catch a feed of fish. It is a ritual on family holidays for dad to take the kids out and show them how to catch a fish. (It might be some primitive urge from our own hunter/gatherer days.)

Around five million Australians go fishing for recreation. Many people fish only once or twice a year. Others are more serious; some 800,000

fishers have more than 20 fishing trips a year. It all adds up. The total number of recreational fishing trips is thought to be almost 50 million a year.

Recreational fishing today is big business. When the cost of the gear, magazines, clothes, bait, boat hire, and travel costs (car, fuel, accommodation) are all considered, the average fisher spends around $700 a year on their hobby. The recreational fishing industry is estimated at over $2 billion per year, and provides employment (directly and indirectly) for over 50,000 people. Many small coastal villages around Australia depend on recreational fishing for their economic survival.

Figure 515.1 Reef fishers
Murray Waite

Recreational fishing techniques

There are hundreds of ways of catching fish. Every species has its particular behaviour, habitat, feeding times and food preferences. Tackle shops carry different hook sizes, and many different shapes. Fishing line comes in a dozen different strengths or breaking strains, and a variety of colours. Racks of fishing rods, made from space age glass and carbon fibre, have different strengths and flexibility, each for different fish and conditions.

Tackle shops carry hundreds of different types of lures, of all sizes, colours, shapes and swimming actions. There are crab dillies and traps, and in some States, cast nets and fine-mesh bait nets. (Nets are banned in some States. Are they legal where you live?)

Fishing secrets

Statistics consistently show that around 20% of the recreational fishers catch around 80% of the total recreational catch. Most recreational fishers go fishing for fun, often as an excuse to relax in the sun and do nothing for hours at a time. They may catch a few fish, if they are lucky. But fish are not stupid, and fishing requires detailed knowledge and skill, particularly now as fish numbers decline.

Serious recreational fishers have a vast knowledge of the habits and biology of their quarry, the best places, the right gear and baits, and the best time of the tide, day, month and year. They spend many hours studying the weather, tides, currents, phases of the moon. They check fish gut contents to see what they are feeding on, and the stage of the gonads in reproduction. Fishers get a *feel* for the fish, how it is biting, when to strike ... and when to go home. Many fishers learn from their own years of experience and have their own well kept fishing secrets. Others learn from fishing books, magazines and newspapers. Fishing shows are popular on TV, and promote responsible catch-and-release sports fishing.

Issues in recreational fisheries

'Fishing is not what it used to be. I can remember when ...' is the universal lament of older fishers, everywhere. There are few long-term scientific data on recreational catches to prove everyone's assertions but some records of fishing clubs show a major decline in catches and weights.

Odd fishing facts

***Catch-and-release* fishing gaining popularity**

Many anglers are satisfied with the excitement of out-witting a cunning fish, and fighting it to submission with light tackle.

They then release the fish, to catch another day. (A study in one US National Park found an average trout had been caught a dozen times.)

Protected species and under-sized fish have to be released by law.

Catch-and-release requires more than a quick kiss good-bye: be gentle, use a soft landing net (not the hard plastic types), or clean damp cloth and wet hands; support large fish carefully, and keep them out of water for as briefly as possible.

During a long fight, fish build up lactic acid and become exhausted. You may have to get it swimming and breathing again by moving it through the water to recover.

Figure 515.2 Estuary fishing
Murray Waite

Figure 516.1 Cast net
(Photo Qld Fisheries)

Figure 516.2 Trawler
(Photo Qld Fisheries)

Who is to blame? — *Everyone else!*

It is a human characteristic to blame someone else for our problems. Recreational fishers blame the professional fishers. The professional line fishers blame the recreational fishers, (there are so many of them), the professional netters and the professional trawlers (who catch juveniles and destroy habitat). Who really is to blame? Probably everyone, because almost all of us eat fish, and contribute to the loss of water quality and habitat which is a common underlying problem.

The hidden reasons: loss of water quality and habitat

Scientific studies show that declining coastal fisheries are at least partially caused by loss of water quality and fisheries habitat. Clearing of catchments, sewage and industrial discharges, draining of freshwater wetlands, clearing of mangroves, die-back of seagrass, fish kills and diseases, as well as over-fishing have a great accumulative impact on coastal fisheries.

Recreational fishers are increasingly aware of the environmental factors. In Northern NSW a group of fishers sued a sugarcane farmer for acid soil runoff from his drains. The matter was settled out of court, but the fishers made their point. Others secretly videoed a professional netter damaging seagrass, and he was successfully prosecuted. Another group took the government's NSW Fisheries department to Court for not doing their duty in managing fisheries, and demanded environmental impact studies for existing fisheries.

I vote and I fish — political power of fishers

There are millions of recreational fishers, and they have begun to use their political power. A National political party, the *Fishing Party*, was formed in 2001 to promote the interests of recreational fishers. They did not win any seats in Parliament, but they did receive a respectable vote.

User pays — introduction of recreational fishing licences

Until recently, recreational fishers could fish almost wherever they wished. Fish were a *common property*, a 'democratic right', there for the taking. Although the individual take of a recreational fisher is small, collectively the millions take a huge amount of fish, and should contribute towards their fishery's management.

Governments now operate on the principle of *users pays* for many services. Several states have recently introduced saltwater fishing licences for recreational fishers, to pay for recreational fisheries management. In NSW licences are $25/year, and there are exemptions for children, Aboriginal people and pensioners. In 2001, the first year of licences, 350,000 people paid over $7 million for licences.

Recreational fishing areas

In competing fisheries, government managers are being forced to decide between the interests of recreational and professional fishers. In the Northern Territory the Mary River was closed to commercial Barramundi fishing in the 1990s because of declining catches. Stocks subsequently recovered, and the sustainable recreational fishery has

brought far more money into the area than commercial landings ever did. In 2002 in NSW, money from recreational fishing licences was used to buy out the professionals from 29 estuaries. Some 400 professional fishers were paid to leave the industry. This has caused loss of jobs and considerable personal hardship. Professional fishers warn that the general public will suffer as fish prices double.

Commercial fisheries — fishing for profit

Australia's commercial fishing industry ranks fourth amongst the nation's rural food-based industries. Total landings are about 220,000 tonnes, worth $2 billion, a year. Some 200 marine species are caught, of which prawns, lobster, abalone, scallops, oysters and tuna are most important. Finfish (sharks and bony fish) make up more than 60% of landings by weight, but the high value invertebrates like abalone, prawns and crayfish provide 75% of the earnings.

Australian fishing industry

About 27,000 people are employed in the commercial fishing industry, and there are more than 9,000 commercial fishing boats. Most are small, under 10 m in length, and owner-operated. Deepwater trawlers and long-liners are much larger, over 15 m in length. The latter are generally owned by larger companies, and are termed *industrial* fisheries. A number of large foreign fishing vessels, from Japan, New Zealand and other countries, are also licensed to fish in Australian waters. Some others fish illegally.

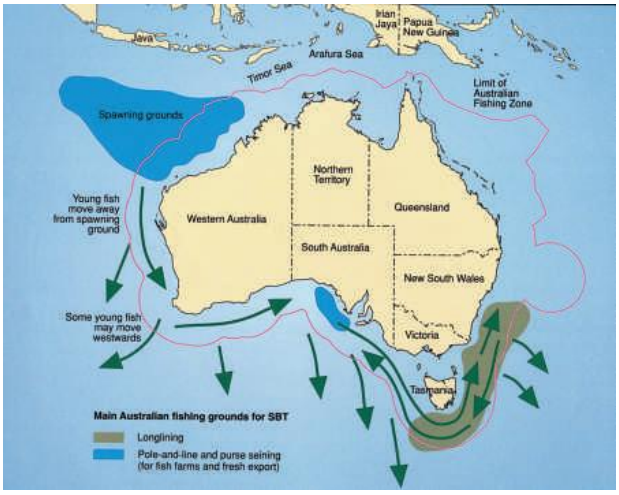


Figure 517.1 Australian tuna fishing grounds
(Illustration from SOMER 1996, reproduced with permission)

Exercise 20.2 Survey of your class fishing practices

Do you ever go fishing? Share some of your tales about the 'ones that got away'. Set up a table to show the following information for your class using fishing frequency as the main identifier. Use at least 4 groupings based on how often class members fish.

Write a two page essay on recreational fishing in your area. Use the following questions as a guide.

a. How many of the class go fishing each year?
b. About how many times?
c. How does this compare with the average local fishing family?
d. What fishing gear do they use?
e. Where do they fish?
f. What do they fish for?
g. On average, how many fish do they catch?
h. What is the most common catch?
i. Would they be willingly to pay $25 a year for a fishing licence if the money went in to managing the fishery?

Figure 517.2 School fishing class
(Photo Geoff Jensen)

Figure 518.1 Gill net and fish
(Photo Mike Sugden)

Figure 518.2 Fyke net
(Photo Qld Fisheries)

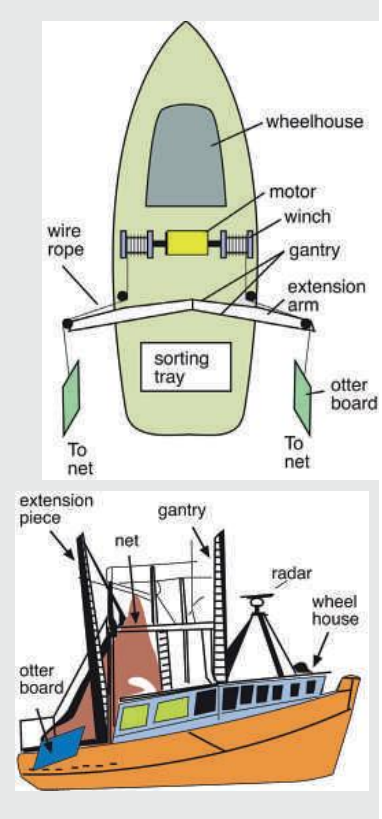


Figure 518.3 Trawler
(Illustrations Bob Moffatt))

Foreign fisheries

Foreign fishing vessels which fish distant waters may be huge in size. Super trawlers are up to 150 m long, and can work in most weather, for months at a time. They have computer-controlled deep water trawl nets. Sonar and video cameras show the catch. Some ships have their own fish processing plants and on-board canneries, and can process 200 tonnes of fish a day. Many tuna boats carry their own helicopters and have satellite receiving stations to find ocean upwellings, ocean eddies and fish schools.

Commercial fishing techniques

Commercial fishing aims for economic efficiencies by using mass-capture techniques such as trawls, traps, nets and multiple-hooks and long-lines.

Gill nets

Nets are used to catch coastal fish such as Mullet, Luderick, Australian salmon, Threadfin salmon and Barramundi. Depending on the mesh size, larger fish trying to pass through become entangled by their gill covers or fins.

They are made of clear nylon filament (almost invisible to fish), with floats and weights to keep them upright. Gill nets are hung in areas where fish pass on the surface, sea floor, or are allowed to drift. Minimum mesh sizes are regulated by law so they don't catch small fish. The 10 km long ocean drift nets have been prohibited in Australia and most other countries because they also capture turtles, dolphins, whales, billfish and sharks. This accidental catch is referred to as ***by-catch***, and is a major issue in fisheries world-wide.

Ring nets or encircling gill nets are set out behind a moving boat to surround a tight school of fish such as mullet or Australian salmon. They are set in shallows to prevent fish from diving under the bottoms.

Beach seines

Beach seines or power hauls are set from a beach by a boat to encircle a mullet or other school. Each end is hauled back onto the beach, manually or with a power winch on a 4-wheel drive.

Purse seines

A modified type of seine is used in the open sea to take schools of Pilchards, Jack mackerel and tuna. The net is shot around the school, sometimes by a large tender launch. The bottom of the net is pulled closed with a rope, like a draw-string purse. Tuna purse seines are kilometres in length, and up to 100 m deep. The tender launch itself may be over 10 m long, with a 1,000 hp motor to drag the heavy nets. Some purse seiners carry helicopters to spot schools and direct the laying of the seine.

Trawl nets

Trawl nets are dragged along the seafloor by a powerful vessel to scoop up bottomfish and prawns. They operate in depths from a few metres to 1,500 m, and are also used in mid-water. The entrance of smaller trawl nets are sometimes held apart by a beam (beam trawls).

The entrance of larger nets are separated by two boards or paravanes. The angles of these are carefully adjusted so they try to fly to either side, thereby keeping the net mouth open. The net bottom is weighted with heavy chain so it sinks and drags along the sea floor. The top is floated up with buoys. Trawl nets taper conically, ending in a heavy bag or ***cod end*** where the catch is concentrated. When the net is lifted out of the water the cod end is pulled open, and the catch released onto deck.

Trawls and other nets are very efficient but they are non-selective, taking many other, unwanted fish or invertebrate, termed 'bycatch'. Trawl bycatch or *trash* may constitute of 90% of a catch. Trawl nets can sweep whole areas clear of sponges, corals and other attached species, which are important biodiversity and fish habitat.

Scallop dredges

Heavy steel boxes or dredges are dragged along the sea floor to catch scallops. They are environmentally destructive as they can plough up many attached species and damage bottom habitats.

Hook and line fishing

Many types of hooks, lures and lines are used for trolling (towing) for fish like Spanish mackerel and Barracouta. Poles with short lines and lures are used to catch feeding tunas. Baited hooks are used to catch reef fish such as coral trout, snappers and emperors, and floating lines are used for pelagic species. Catch rates are increased by using multiple hooks and power reels.

Longlines

Catches are greatly increased by using very long lines. These consist of a main line, to which are clipped many short branchlines (*snoods*), each with baited hooks. They can be laid along the bottom for sharks, sea perch and ling. Surface drifting longlines are used for pelagic tunas, marlin and swordfish. These commonly range from 10-80 km in length, and carry from 200-3,000 hooks.

Traps

Baited traps are used to capture rock lobsters and crabs, and reef fish such as snapper. Lobster pots are often woven like baskets, with a top entrance. They can have gaps built in, so undersized animals escape. Fish traps are larger and rectangular, with several side funnel entrances that are easy to enter and difficult to escape from. Traps also act as habitat, and attract fish seeking shelter.

Crab dillies and snares

Flat hoops of wire and loose netting and bait are used to snare crabs by their spiny legs. They are commonly used for Mud and Swimmer crabs, and for deepwater Spanner crabs.

Figure 519.1 Purse seine
(Photo NSW Fisheries)

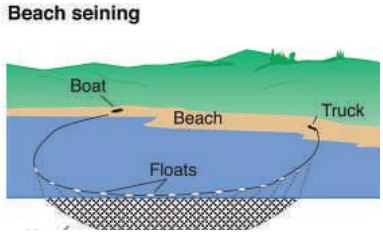


Figure 519.2 Beach seine
(Illustration Bob Moffatt)

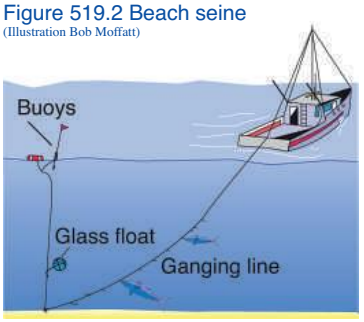


Figure 519.3 Longlining
(Illustration Bob Moffatt)

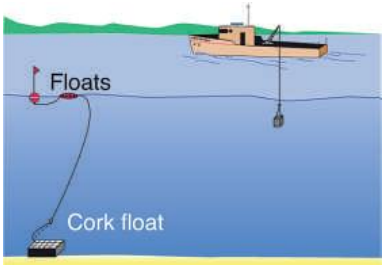


Figure 519.4 Trapping
(Illustration Bob Moffatt)

Figure 519.5 Lobster pots
(Photo Bob Moffatt)

Figure 519.6 Crab dilly
(Photo Qld Fisheries)

Fisheries management

Fish are a renewable natural resource, at least in theory. The aims of fisheries management are to maximise economic returns or recreational enjoyment, while sustaining fish stocks or populations. However, if too many adult fish are caught, the remaining fish may not produce enough young to replace those captured.

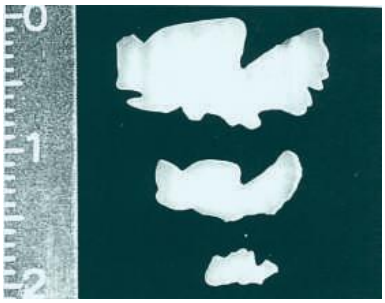


Figure 520.1 Otoliths and bands
(Photo CSIRO, reproduced with permission)

Who manages fisheries?

State departments manage most inshore or coastal fisheries, while the Commonwealth generally manages offshore fisheries. Ocean currents and fish stocks do not recognise government borders. For fish such as tunas which migrate over international borders, there are regional management agencies such as the Forum Fisheries Agency, based in the Solomon islands.

Introduction to fisheries science

Estimates of the numbers of fish that can be sustainably taken are made by fisheries scientists. Estimations of sustainable yields requires detailed biological information such as the species' population distribution and size, its rates of growth, reproduction, the rates at which young join the population, or *recruit*, and rates of mortality in different age classes. ***Fisheries biologists*** estimate ages using daily or yearly bands on fish scales and ear bones which are read like tree growth bands. They estimate population sizes by tagging fish, and estimating what proportion of fish are captured. As tagging is costly, and may kill the fish, it is being replaced by modern DNA tagging techniques.

State departments manage most inshore or coastal fisheries, while the Commonwealth generally manages offshore fisheries.

Fish population dynamics

Fisheries biologists study population dynamics of fish. An interbreeding fish population, known as a' fish stock', is the level at which fisheries management takes place. The number of fish in the stock is naturally increased by reproduction and recruitment. Female fish generally produce thousands or even millions of eggs in its lifetime. These hatch as larvae which drift around in the plankton, then settle as juveniles or ***fingerlings*** (Figure 520.2). These later enter or *recruit* to the adult population.

Figure 520.2 Fingerlings
(Photo Qld Fisheries, reproduced with permission)

Life histories, sex-changes and minimum size limits

To confuse matters, many fish species switch sexes during their life-times. Some start off as males and become females as they grow older, others visa versa. It is important to know sex-change details, as protecting small fish may mean protecting the less important males. Rates of egg production are much greater in older females, so it is far more important to protect these. The size at which fish become sexually mature is used to estimate *minimum* legal sizes for keeping. While young fish are returned to grow up, it may be better to have 'maximum legal sizes' to protect the big females which produce many more eggs. For example, the maximum size limit for Barramundi in some states is 1200 mm.

Mortality

The number of fish in a population or stock is reduced by natural mortality (predators, starvation, diseases), and fishing mortality. Increasingly, pollution and poor water quality may also cause mortality. It is important to know rates of natural recruitment of new fish and rates of mortality in order to estimate sustainable yields from fishing. This is difficult as reproduction rates and recruitment vary from year-to-year in the sea as they depend on rainfall, runoff, ocean productivity and currents. In Australia our annual rainfall and runoff varies greatly with El Ninos, and fisheries recruitment is variable from year-to-year.

Fisheries managers want to keep the level of fishing just below the level which causes decline.

Estimating 'sustainable yields'

From details of their biology and population dynamics, fisheries scientists use mathematical equations and computer models to estimate how many fish can be caught on a sustainable basis, without endangering the whole stock.

Theory of 'maximum sustainable yield'

In a new or developing fishery, there will be many available fish, and the first boats will make large catches. More boats will join, increasing the fishing effort. If the number of boats or effort becomes too high, catches will not be sustained, and they decline as the rate of addition of new fish, or 'recruitment', is exceeded by total mortality. Fisheries managers want to keep the level of fishing just below the level which causes decline. This level is known as the 'maximum sustainable yield' (MSY). The concept of MSY is also used in forest management to estimate the rates in which trees can be sustainably harvested.

Despite MSY predictions, many fisheries been over-fished and collapsed. There are several reasons for the failures of the MSY models. They are very simplistic and do not consider all the different biological and environmental variables. The exact information for the mathematical yield models is often lacking, so fisheries scientists often make various assumptions on recruitment, growth and mortality. The estimates for MSY are therefore very approximate, and because the 'maximum' catch levels are sought, they can be very easily exceeded. Sometimes there may have been an unusually low recruitment in a year because of some seasonal or chance factors. MSY models are often now viewed as unreliable, and they are being discarded as a tool in fisheries management.

Maximum economic yields

Another way of managing a commercial fishery is to manage to seek to maximise the profits. As a fishery develops and more boats join the fishery, catch rates decline, and the total costs of catching each fish increases. If the number of boats is not controlled, the fishery will continue to grow until the costs of catching a fish exceed the value of the fish. The fishery will then cease to be profitable. The number of fish that can be caught with maximum profit is termed the 'maximum economic yield.' It is much lower number than the MSY, so is safer to strive for.

However, sometimes a fishery is subsidised with government grants to keep it going, and an excessive, unsustainable level of fishing will continue to occur until stocks finally collapse.

Figure 521.1 Seafood meal
(Photo Murray Waite)

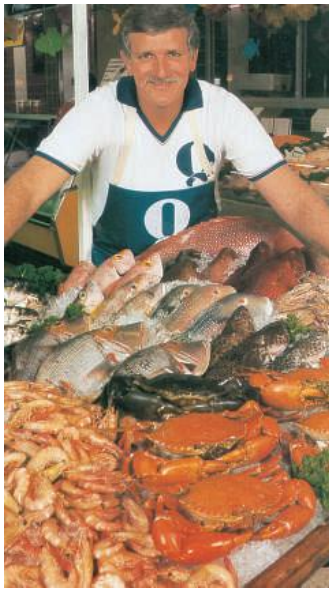


Figure 521.2 Seafood is a valuable export product
(Photo QFMA)

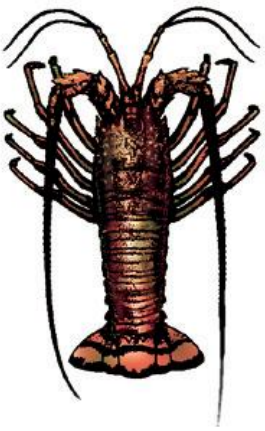


Figure 522.1 Western rock lobster
(Illustration courtesy Environment Australia, reproduced with permission)

Monitoring of catch important

As it is difficult to predict sustainable yields, it is necessary to record or monitor fish catches to determine if catches are being sustained. Often several years of landings data will be needed to determine the real trends. The theoretical estimates of sustainable yields can be adjusted from year-to-year, given these observed trends. Fisheries managers use this information to set ***Total Allowable Catches*** or *fixed quotas* for the following year.

One of the most successfully managed fisheries in the world is the Western Australian rock lobster fishery. Yearly estimates of sustainable yields are very accurate because the number of juveniles recruiting to the fishery can be monitored directly using 'artificial seaweed' collectors. The numbers of adults available in three years time (the period they take to reach legal size) can be accurately estimated, and quotas set. WA rock lobsters are very valuable and fishing licences are restricted, so that fishers can have a good income even in years when their quotas are reduced.

Controlling fishing effort

The commercial catches can be regulated through *input controls* and *output controls*. Input controls limit the amount of effort commercial fishers put into their fishing activities, indirectly controlling the amount of fish caught. These include restrictions on the number of fishing licences, the size and engine capacity of boats, the length and mesh size of nets, and the areas and times which can be worked.

Output controls directly limit the amount of fish which can be taken from the water. The Total Allowable Catch (TAC) for the species can be either fished on a competitive basis (fishing is stopped when that amount is landed), or divided up between the participants in the fishery so that all fishers have an individual quota. For example, the annual TAC for the 2001/2002 lobster season in NSW was set at 150 tonnes, and divided among 174 licence holders.

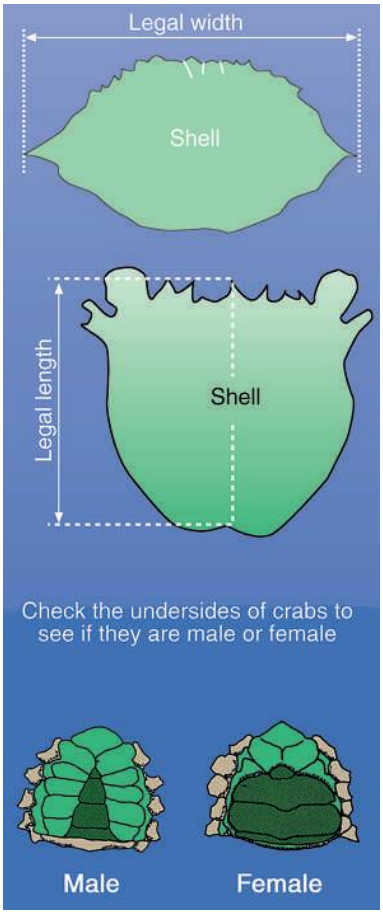


Figure 522.2 Male and female crabs
(Illustration Bob Moffatt)

Managing recreational fisheries

The goals of recreational fisheries management differ from those of commercial fisheries, as they aim to provide for the sustainable use and enjoyment of the fisheries resources. Management aims to control the total harvest in a fish stock or population, and to share the angling experience amongst all fishers.

There are restrictions on the types of recreational fishing gear that are allowed, hook numbers and net sizes, and fishing is prohibited in certain areas and seasons. Bag limits are set to limit the total harvest of certain species to sustainable levels, and to share the catch. Minimum size limits enable fish in the population to grow to breeding size and spawn at least once before they are caught. Maximum size limits also apply to certain species because larger fish often breed more efficiently than smaller fish (eg NSW anglers may only keep two mulloway above 70 cm, per day and Queensland anglers cannot keep Barramundi over 1200mm in length).

Importance of protected areas in fisheries

Areas which are essential fish habitat, and areas which may be important for spawning and juvenile nurseries may be protected from fishing and other disturbances.

A way of protecting a proportion of a stock for breeding is to protect a certain proportion of their total habitat. Studies suggest that around 30% of the population (or of the total area where the fish is found) should be protected to maintain the breeding population. (see Chapter 22).

Environmental impact studies of fisheries

Destructive fishing gear and the removal of fish affect the marine environment. A new way of managing these is through 'fishery environmental assessment'.

Biological, economic and social factors are examined to predict the impacts of fishing on target species, by-catch species, important fish habitat, the broader ecosystem, and economic and social issues.

It also considers the impact on the resource from other fisheries and other non-fishing activities.

Education and enforcement in fisheries

Fisheries education is very important to explain the issues, management actions, and regulations to the fishers. Most people comply with regulations, but enforcement is often required. Fisheries officers with wide powers to search, patrol waters, launching sites and fish markets for undersized and prohibited species. Prosecution and very severe penalties can apply.

Australia's seas are vast in area, and impossibly expensive to patrol. Occasionally naval vessels are sent into the Southern Ocean at enormous expense.

One illegal vessel was chased all the way to South Africa. Satellite trackers are being introduced to follow licensed fishing vessels.

An electronic message, which includes the identity of the vessel and its position, is sent regularly by satellite to the authorities' computers, which may be thousands of kilometres away.

Longline vessels are particularly easy to locate by microwave sensors because they carry radar reflectors on their buoys.

Odd fact

Official marketing names of fish.

Check out the Australian Seafood Handbook revised by CSIRO.

www.marine.csiro.au/cmr_pubs/handbook.html

Figure 523.1 Fisheries officers
(Photo Bob Moffatt)

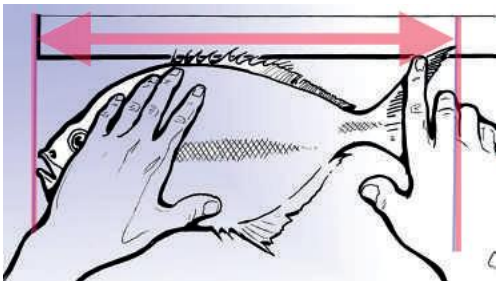


Figure 523.2 . Legal limits are measured from tail to tip.
(Illustration Kerry Kitzelman)

Figure 523.3 Fishing licence
(Photo Bob Moffatt)

Figure 524.1 A fish kill
(Photo Tim Ryan)

Off Tasmania, trawling for deepwater fish is prohibited in sea mounts to protect and conserve their unique cold water coral communities.

Figure 524.2 Trawler by catch
(Photo Qld Fisheries)

Fisheries issues and management

Decades of over-harvesting, combined with declines in water quality and loss of coastal habitat, and poor management practices are the major causes of fisheries declines. Fisheries management agencies are increasingly aware of the problems and are developing solutions.

Loss of water quality and loss of habitat ... fewer fish

Rivers, lakes and wetlands are very important nurseries and fishing grounds. Although they account for less than 1% of the global surface area, they provide over 8% of the world's catch. However, these productive ecosystems are under increasing pressure from the needs of a growing human population.

Increased sediments and nutrients from catchments, draining of coastal wetlands, reclamation of mangroves and die-back of seagrass and coral reefs are critical issues. Environmental and fisheries managers are beginning to take a more 'holistic' approach to fisheries management, by attempting to address water quality and habitat issues (discussed in Chapter 18).

Fish kills and diseases

Massive fish kills and fish diseases are increasingly common in Australia's rivers and estuaries. In the 1990s hundreds of kilometres of the Murray Darling died because of toxic blue-green algae blooms. The causes were elevated nutrients from fertilizers, animal wastes and sewage. Coastal rivers are also dying. Around 30 km of the Tweed River (NSW) became acidic and died in the 1990s. In 2001 the lower Richmond, Evans and Macleay Rivers (NSW) totally died after a minor flood. Mullet, Whiting and Bream in Queensland and NSW estuaries are affected by 'Red spot' disease, which causes large open ulcers.

Many fish kills and red spot disease are caused by acid soil runoff and deoxygenated water from farm drainage channels. Fisheries managers are beginning to work with their land counterparts to reduce the problem. Flood gates which allow the acidic and de-oxygenated water to accumulate, are being kept open or removed. The deep drains which expose the underlying acid soils are being shallowed. There are plans to reflood some of the drained wetlands, to restore the environment and fisheries habitat.

Fisheries bycatch

Fishing gear such as gill nets, trawls, dredges and long-lines take many other fish, juveniles of fished species, and sometimes turtles, birds, dugongs and dolphins. Most are dumped back into the sea, dead. Tuna long-lines also catch many unwanted sharks and billfish, and sea birds such as the threatened Wandering albatross.

The bycatch problem is being addressed in some fisheries. In Queensland, gill netting has been banned from important dugong habitats along the coast. In NSW most estuaries have been closed to gill netters.

In the Southern Ocean, the catch of the threatened Wandering albatross has been reduced by changing the way long-lines are set.

'Turtle excluding devices' (TEDS) or 'bycatch excluders' have been made compulsory in most places. Spring flaps and panels of coarse netting are installed in trawl nets to shoot away larger animals such as turtles before they enter the cod end. Although Australian fishers were initially hostile to the idea, they have found that the quality of prawns has improved because they are not damaged by the larger animals.

Figure 525.1. Trawling by-catch
(Photo Qld Fisheries)

Destructive fishing techniques

Fishing techniques such as trawling and dredging tear up the seafloor. As a result, trawling has been prohibited in many critical seagrass habitats around much of Australia. Off Tasmania, trawling for deepwater fish is prohibited in sea mounts to protect and conserve their unique cold water coral communities. Deepwater sponge communities in Bass Strait are also protected. Technical solutions are less drastic than total closures. Bottom trawls and scallop dredges are being redesigned so they skim over the surface, and don't plough up benthic organisms.

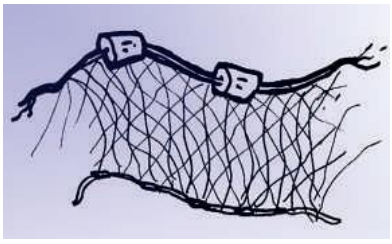


Figure 525.2 Ghost net
(Illustration Kerry Kitzelman)

Lost gear, fishing litter and 'ghost fishing'

Fishing gear, lines, ropes and nets are often lost or discarded at sea. Turtles and whales can mistake discarded plastic bait bags for jellyfish, and choke on them. Australian seals get caught up in discarded nets and ropes. Fishing litter is a significant component of litter on beaches. In the sea, lost fish nets and traps may continue to catch fish, or *ghost fish*.

To counter these problems, International and National laws now prohibit dumping of rubbish at sea, and disposal services are provided at fishing ports. Biodegradable bait bags and cartons have been developed which break down quickly in the sea. To prevent lost traps *ghost fishing*, special wire has been developed to attach trap doors. This corrodes after a few weeks and the doors simply fall off.

Figure 525.3 Dead turtle and plastic ring pull can
(Photo Qld Transport)

Ecosystem effects of fishing

The effects of fishing are not just the removal of fish, or a decline in the species' populations. The removal of *key-stone* fish species may affect the whole ecosystem. Some scientists think that outbreaks of Crown-of-thorns starfish on the Barrier Reef and elsewhere are the result of overharvesting of its natural predators like Triton snails, Maori wrasse and Sweetlip snappers. Likewise, outbreaks of coral-eating *Drupella* snails on Ningaloo Reef (WA) may be the result of over-fishing its predators (Figure 525.4).

Food chains and whole ecosystems can be changed by fishing. US scientists have recently discovered *ecosystem flips*, where fishing has resulted in dominant baitfish species suddenly being replaced by something else.

Figure 525.4 Drupella on coral
(Photo: www.researchgate.net)

Figure 526.1 Fish for local markets Vietnam
(Photo Bob Moffatt)

Figure 526.2 Fish for export
(Photo Tassal)

Figure 526.3 Seeding pearls in northern Australia
(Photo Bob Moffatt)

In 2002 it was suggested by marine researchers that there has been a global increase in squid populations. Squid are fast-growing, short-lived species, and they may be replacing their longer-living fish competitors which have been reduced by over-fishing. Nobody can guess what the complex, long-term 'ecosystem effects' of the massive global overfishing will be.

The human side — social and economic impacts

The fishing crisis has also great social and economic impacts, and caused personal hardship for many people. Overseas, subsistence fishers without any other source of food are hard hit. Faced with starvation, they have to fish longer hours and take smaller fish. They may resort to using poisons to catch what's left, which compounds the problem. National economies have suffered in Canada and Europe with the collapse of Cod and other fisheries. In Australia, many professional fishers have been bought-out, or put out of business. Fish canneries and boat yards have closed down. Unemployment has increased in rural areas, and the economies of many coastal towns have become depressed.

With declining catches and compulsory fishing licences, many recreational fishers are stopping fishing. Outdoors enjoyment and the Australian tradition of *catching a feed of fish* are declining. Some small fishing villages which rely on tourists are already finding visitation rates are falling. Although their other attractions can be promoted, tourist offices find that *ecotourists* only come once, whereas recreational fishers were repeat visitors.

Conclusions

The future of fisheries

Although many fisheries are in crisis, the story is not all gloomy. Fish are a renewable resource and do recover from over-fishing. No species has ever become extinct from over-fishing. Moreover, the crisis in fisheries have forced governments to act on fisheries and marine environmental management.

In Australia, governments are reducing fishing pressure by buying back commercial fishing licences. They are introducing recreational licences to obtain funds to compensate the commercial fishers, and to attack the important issues of declining water quality and fisheries habitat. Recreational fishers are increasingly aware of the problems, and have formed powerful lobby groups to ensure governments take action. The public's attitudes have also changed. They are now better informed and concerned about the problems. Even the once-feared Grey nurse shark is now protected.

And while there has been a crisis in the 'wild' fisheries, a quiet, 'blue revolution' is taking place. Aquaculture has become one of the fastest growing industries in the world, and in Australia, and is fast taking over much of the seafood production. This is the subject of the next chapter.

Case study 20.1 Coasts and oceans theme report

Source: From http://www.ea.gov.au/soe/2001/coasts/coasts05-1.html Australia State of the Environment Report 2001 (Theme Report) Australian State of the Environment Committee , Authors CSIRO Publishing on behalf of the Department of the Environment and Heritage © Commonwealth of Australia 2001, Reproduced with permission. Exercise questions by Bob Moffatt.

Status of commercial wild capture stocks

Fishing occurs over the whole of Australia's marine environment - in estuaries, coastal waterways, nearshore waters, deep oceans and sub-Antarctic waters. Some fisheries extend into international waters. It is one of the few industries operating on the basis of harvesting native species.

The commercial fishing industry is an important primary industry (Figure 527.1). Marine recreational fishing is a significant activity, and fishing is of great importance to many Aboriginal and Torres Strait Islander communities. Because the marine environment is very diverse in terms of the different physical features, species and ecosystems, fisheries management and conservation varies from region to region.

The Australian Fisheries Management Authority (AFMA) is the Commonwealth authority responsible for the management of Commonwealth fishery resources within the 200 nautical mile Australian Fishing Zone (AFZ) and, in some cases, by agreement with the States, to the low water mark.

Australia's Fishing Zone is the world's third largest, comprising some nine million square kilometres. Although Australia ranks only about fiftieth in world fish production in tonnage terms, many Australian fisheries target high-value species such as prawns, lobsters, abalone and tuna. In 1999-2000 the gross value of Australia's fisheries production, including aquaculture, increased by an estimated 13% to A$2.32 billion, despite a 7% decline in production to around 221 400 tonnes.

Of this, the Commonwealth-managed component was

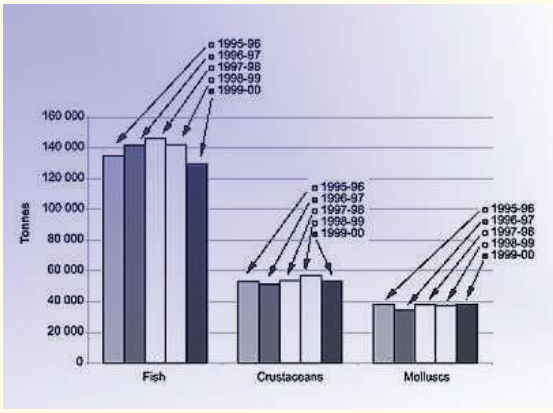


Figure 527.1 Australian fisheries production from 1995-96 to 1999-2000.

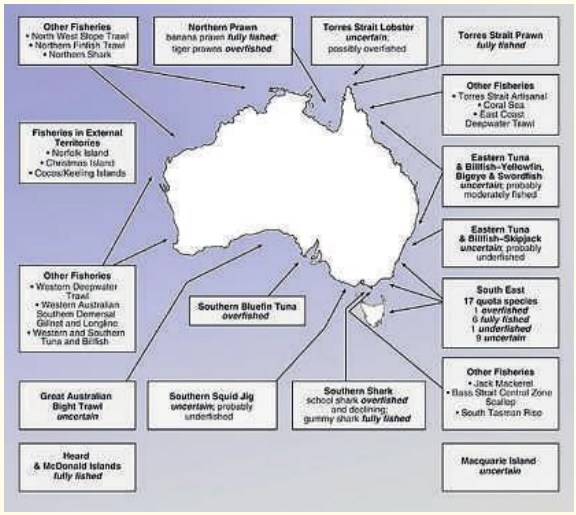


Figure 527.2 The status of Australian fisheries. Source: Bureau of Rural Sciences (2000).

about A$413 million (ABARE 2001), contributing about 20% of Australian fisheries production, the major fisheries being the Northern Prawn, Southern Bluefin Tuna, and the South East Trawl and Non-Trawl Fisheries.

Major State-managed fisheries include the Western Rock Lobster, abalone, and Pearl Oyster fisheries.

Fishing activities affect not only the target species but also the ecosystems from which the fish are captured, and other species that are caught or otherwise affected. Protected species such as turtles, sharks and seabirds may be caught or killed incidentally by fishing activities. A wide range of benthic species may also be caught or affected in trawl nets and dredges. Bycatch species and discarded fish may also be removed from marine and coastal waters during commercial fishing activities.

The state of knowledge of the biology and the stock status of many fish species is incomplete. Around 3600 of Australia's estimated 4500 fish species have been described, but the status of most is unknown.

Fish are captured at the seafloor (demersal fishing with bottom trawls, dredges, traps) and from ocean waters (pelagic fishing with longlines and purse-seines). Aquaculture is conducted in coastal waterways, estuaries or in sheltered nearshore waters. The catch of fish can be related to the productivity of the populations, but is also influenced by technological factors.

Information on the conduct of fishing using lines and nets is given in a study undertaken for SºE reporting purposes (Commonwealth of Australia 2001b). The report found that the intensity of fishing varies greatly from place to place, and there was insufficient information to give a national overview of the spatial extent and intensity of net and line fishing.

The same report investigated trawl areas and intensities of fishing effort.

The study identified that the intensity of trawling in the South East Trawl Fishery is increasing, while in the Northern Prawn Fishery the intensity and area have decreased substantially in the last decade. The area trawled in the East Coast Trawl Fishery off the coast of Queensland has increased steadily over the last two decades but has recently been restricted in the Great Barrier Reef World Heritage Area. Areas of high trawling intensity tend to be very small relative to the total area of the respective trawl fishery. The impact of trawling depends on the combination of trawl frequency and intensity, and the susceptibility of the habitats and species being trawled. Nonetheless, even infrequent trawls may still cause ecological damage in habitats that are slow to recover.

Information about gear or effort is useful for formulating management actions, such as capping fishing effort, targeting species better, or introducing mitigation measures.

The most important issue for fisheries in Australia is to ensure the ecological sustainability of fish stocks in the long term so that ecosystems that are fished remain diverse and healthy. The environmental issues of most importance are:

- the management of fishing effort and activity so as to minimise impacts on habitats and ecosystems and maintain ecological sustainability;
- the sustainable management of target species;
- the reduction of impacts on species, other than target species, removed or injured during fishing activities;
- the impacts of marine pests on the environment (see Introduced marine species and marine pests)
- fishing activities' effects on benthic and pelagic ecosystems; and
- the loss of inshore nursery habitats and pollution from land-based activities.

Status of commercial wild capture stocks

The status of Commonwealth-managed commercial fisheries is assessed and summarised in the annual Bureau of Rural Sciences Fisheries status reports (Caton and McLoughlin 2000). The level of uncertainty in scientific assessments of the status of fisheries remains relatively high, and the 1999 assessments showed a trend within Commonwealth-managed fisheries to fewer fisheries/species classified as 'underfished' and more classified as 'uncertain' (13 in 1998 and 15 in 1999). The increased number of 'uncertain' fisheries/species is a combination of new fisheries and, with increased information, increasing uncertainty in previously assessed fisheries. The status of most bycatch species is uncertain.

Four Commonwealth fisheries/species groups are regarded as overfished.

They are Southern Bluefin Tuna, school shark, tiger prawn in the Northern Prawn Fishery and Eastern Gemfish stocks.

The species are also caught in State-managed fisheries.

About three-quarters of Australia's fisheries are under State and the Northern Territory jurisdiction. Statistics on catches are compiled by the Australian Bureau of Agricultural and Resource Economics each year (e.g. ABARE 2001). Most of the fish stocks managed by Western Australia are still productive, but are nearing the limit of their ability to support further fishing (Fisheries Western Australia 2000a). Queensland fisheries are generally fully fished (Williams 1997) and New South Wales' commercial wild-catch fisheries are fully fished (Fletcher et al. 1999).

A summary of the condition of all of Australia's fish stocks is not yet possible, owing to differing reporting approaches in the various States and the Northern Territory and the Commonwealth.

One of the problems in attempting to assess the overall status of fisheries is that there is no national fisheries statistics database from which to assess trends. As the fishing industry depends on the sustainability of species for its continuing viability, the need for information on the status of commercial fisheries is vital.

There are fisheries developing in Australia's external territorial waters. The Macquarie Island Fishery was established in late 1996 after two seasons of exploratory fishing.

A precautionary total allowable catch (TAC) limit for Patagonian Toothfish has been set. There are strict operating conditions for this fishery to protect fish stocks and non-target species.

It is widely held that the sustainable development of Australia's fishing industry will involve making greater returns by increasing quality or value-adding to the wild caught product rather than by increasing the total tonnage of fish.

Good news-fisheries management

There are very few examples in which fisheries management can claim clear success in achieving regulatory goals. The Western Australian Western Rock Lobster Fishery and the Tasmanian abalone fishery have managed to rebuild stocks over several years.

Western Australian Western Rock Lobster Fishery

Western Australian Western Rock Lobster Fishery

The Western Australian Western Rock Lobster Fishery is an example of a well-managed fishery. Although catches in 1991-92 and 1992-93 were high, scientists highlighted that the breeding stock had been fished down to about 15% of the unfished stock. This was below the internationally safe level of about 25% of breeding stock. Tight management arrangements introduced in 1993-94 were aimed at rebuilding the breeding stock. This aim is being achieved. Catches since 1994-95 have averaged around 10 000 tonnes, with the 1998-99 catch a record 13 009 tonnes (Penn 1999).

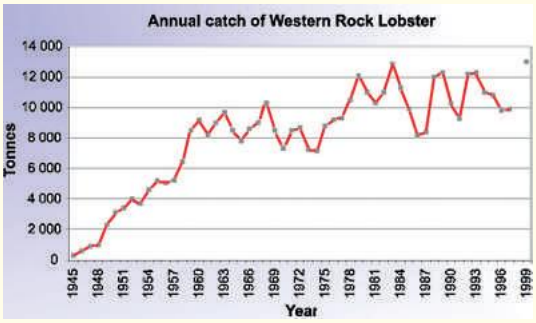


Figure 529.1 Western Rock Lobster annual catch. Source: After SoE (1996) and Fisheries Western Australia Annual Report

The West Australian Western Rock Lobster Fishery is the first fishery in the world to attain certification under the Marine Stewardship Council (London) as well managed and sustainable (see http://www.msc.org [accessed 5 September 2001]).

As part of this certification, to ensure that environmental impacts continue to be minimal, the fishery has been required to improve specific aspects of its environmental performance. These include: the development and implementation of an Environmental Management Strategy based on a comprehensive ecological risk assessment, the increased participation of environmental organisations in decision-making in the fishery, and the implementation of an improved monitoring program for bycatch of species (e.g. sea lions and turtles).

Tasmanian abalone fishery

The Tasmanian abalone fishery is the largest wild harvest abalone fishery in the world. While other wild fisheries are currently grappling with the problems of overfishing, the Tasmanian fishery has been able to lift production following a period of stock rebuilding through the late 1980s and 1990s. Three stepwise increases in the total allowable catch (TAC) have occurred since 1997, the most recent in 2001.

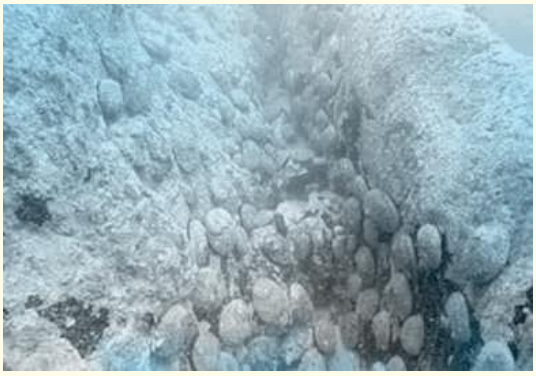


Figure 529.2 An aggregation of abalone in a gutter on the north-west coast of Tasmania. Source: Tasmanian Aquaculture and Fisheries Institute.

Concerns held by members of the fishing industry and the Tasmanian Fisheries Department saw the introduction of a quota system in 1985, associated with a significant reduction in the catch. The quota was further reduced between 1985 and 1989 to 2100 tonnes, a reduction of 45% over four years. The TAC (for Blacklip and Greenlip Abalone combined) remained static from 1989 to 1996 before the first increase in 1997 when the TAC was set at 2520 tonnes. The TAC rose to 2800 tonnes for 2001.

A feature of the fishery over the last few years has been an increasing concentration of effort in the south and south-east and a corresponding reduction of effort in the west and north of the State. It is noteworthy that previous stock assessments have shown high catch rates of above-average size abalone on the west coast, but effort has gradually moved to more accessible areas.

To redress this trend, and spread effort more evenly around the State, a system of regional zones was introduced in 2000, with the catch to be taken from each zone determined by the TAC. Two Blacklip Abalone zones were supplemented by a third zone in 2001 with the TAC allocated as follows: eastern zone 1120 tonnes; western zone 1260 tonnes; northern zone 280 tonnes; greenlip zone 140 tonnes.

The Tasmanian TAC for the entire abalone fishery for 2001 is the sum of these regional TACs, i.e. 2800 tonnes. Figure 529.3 shows the annual landings of abalone in Tasmania.

Another important facet of the fishery is marked geographical differences in growth rates of abalone around the State. For example, Blacklip Abalone generally grow faster in the south of the state than in the north. To address this issue, three different size limits now apply to both Blacklip and Greenlip Abalone.

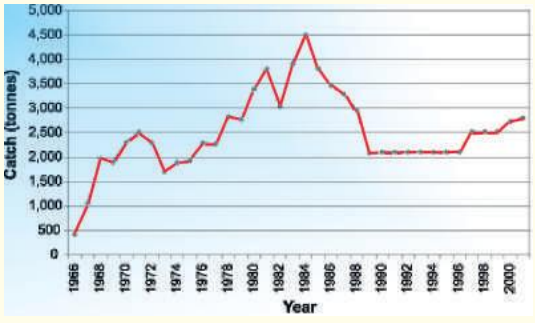


Figure 529.3 : Annual landings of abalone in Tasmania. Source: DPIWE Tasmania (2000).

The value of the fishery has fluctuated over the past eight years and shows little relationship to catch. Prices and catches have varied since the early 1990s with beach prices reaching historic highs over $50 per kilogram during 2000. These strong prices saw the value of the fishery reach $128 million in 2000.

Uncertain news-fisheries management

Orange Roughy

Orange Roughy remains the most valuable single species in the South Eastern Trawl Fishery, with a value of A$12.7 million in 1998 (Caton and McLoughlin 2000). This species is a long-lived, low breeding fish (it produces low numbers of eggs compared to other fish) that is vulnerable to fishing pressure because of its aggregating behaviour. Since 1992 catches of Orange Roughy have continued to decline in the South East Trawl Fishery. The assessment that in 1997 a catch reduction in parts of the Fishery was warranted, was not accepted by the industry. A second wave of Orange Roughy exploitation occurred in the South Tasman Rise (which straddles the AFZ) following discovery of aggregations in September 1997.

Both Australia and New Zealand have fished the South Tasman Rise since 1997 with varying degrees of success in allocating catch levels and capping the fishing of Orange Roughy.

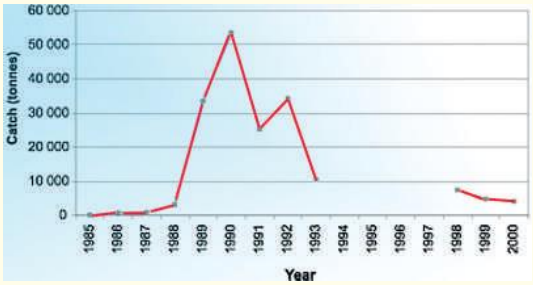


Figure 530.1 Orange Roughy annual catch Source: after SoE (1996) and Caton and McLoughlin (2000

Southern Bluefin Tuna

The Southern Bluefin Tuna is a highly migratory, long-lived species that was heavily overfished by a number of countries in the 1970s and 1980s.

The international management of the fishery involves Australia, New Zealand and Japan, through the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). Other countries also fish for Southern Bluefin Tuna outside the CCSBT management regime, though the Republic of Korea has announced it will accede to the Convention, South Africa is considering becoming a member, and efforts are in train to develop a mechanism that will enable Taiwan to participate in the Commission.

Australia has actively engaged in international forums to bring the global catch of the species under effective management.

The focus of this work has been to bring all major Southern Bluefin Tuna fishing countries into the CCSBT, so that all nations can comply with the Commission's objective of rebuilding the stock by 2020

Australia has maintained catch limits agreed to in 1993 when the Commission established a total catch of 11 750 tonnes, with Australia getting 5265 tonnes, Japan 6065 tonnes, and New Zealand 420 tonnes. Southern Bluefin Tuna is considered overfished, with total global landings of about 19 000 tonnes, mostly landed in Japan or Australia (Caton and McLouglin in press.).

There is uncertainty about the degree to which spawning stock will rebuild under the current global catch regime, given the complexities of management of a species that is not entirely within Australia's control. The nature of the fishery in Australia has changed, with more juveniles being caught and farmed (see Aquaculture).

Bad news-fisheries management

Eastern Gemfish

Eastern Gemfish is taken in the Commonwealth South East Trawl Fishery (SETF) off southern New South Wales. This slow-growing, long-lived species was fished excessively in the 1970s and 1980s and will take many years to recover.

A zero catch limit was set from 1993 to 1996. The total allowable catch (TAC) for 1997 was set at 1000 tonnes but the catch was only 393 tonnes. Scientific advice was that the TAC for 1998 should be zero, but a total of 500 tonnes was allocated to cover bycatch and reduce discarding. The catch, however, was only 214 tonnes. The 1999 allocated catch for bycatch was 250 tonnes (actual catch 158 tonnes) and in 2000 the allocated catch for bycatch was reduced to 200 tonnes.

Eastern Gemfish remains vulnerable to targeted fishing as it aggregates for its spawning run.

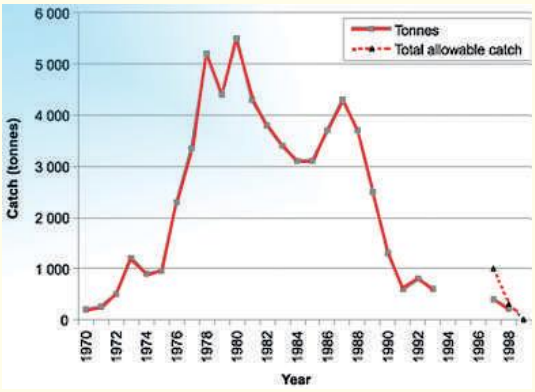


Figure 530.2 Annual Eastern Gemfish catch. Source: after SoE (1996) and Caton and McLoughlin (2000).

Case study 20.1 Questions

Knowledge

1. Complete the sentence — In 1999-2000 the gross value of Australia's fisheries production, including aquaculture, increased by an estimated ..... What dollar value does this represent?
2. True or false? Protected species such as turtles, sharks and seabirds may be caught or killed incidentally by fishing activities.
3. True or false? Around 3600 of Australia's estimated 4500 fish species have been described, but the status of most is unknown.
4. Name 6 environmental issues of most importance to fisheries in Australia.

Application

5. Why is the status of most bycatch species uncertain?
6. The Western Australian Lobster Industry is the first fishery in the world to attain certification under the Marine Stewardship Council (London) as well managed and sustainable. What was the fishery required to do?
7. Concerns held by members of the fishing industry in Tasmania saw the introduction of a quota system in what type of marine species in 1985? What was the reason for this?

Analysis

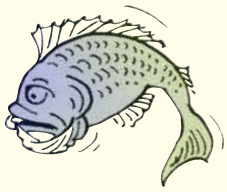
8. What was the weight of fish caught in Australia in 1999-00? Compare this to 1996 as an expression of percentage increase or decrease.
9. Which is the greater catch size - molluscs or crustaceans?
10. Which fisheries are over-fished and in what states?
11. Name the fisheries in Bass Strait.
12. Compare the fisheries in Queensland with those of Western Australia. Are they similar or different? In which bioregion are they found?

Creativity

13. Develop a plan to increase the eastern Gemfish catch in figure 530.2.

Evaluation

14. Distinguish between good news, uncertain news and bad news fisheries management.
    a. Which state do you think is managing their fisheries the worst/best?
    b. Write a letter to your local state parliamentarian and ask for an update on related fishing legislation and implementation.



A guide to fishing the Web

While there are not many books on Australia's fisheries, there are many excellent web sites. Start surfing some of these and make a report to class.

New South Wales fisheries

http://www.fisheries.nsw.gov.au/

Queensland fisheries

http://www.dpi.qld.gov.au/fishweb/

Western Australia fisheries

http://www.wa.gov.au./westfish/

Victorian fisheries:

http://www.nre.vic.gov.au

South Australian fisheries

www.pir.sa.gov.au

Tasmanian fisheries

www.dpiwe.tas.gov.au/inter.nsf

Northern Territory fisheries

http://www.nt.gov.au/dpif/fisheries/index.shtml

Others

AFMA: http://www.afma.gov.au/
www.affa.gov.au/content
www.sydneyfishmarket.com.au/

Some overseas sites

http://www.fishbase.org/home.htm (excellent: 730 collaborators, 2.3 million hits/month, 25,770 species, 30,380 Pictures and 24,500 references)
FAO Fisheries:
http://www.fao.org/fi/default.asp
State of the World's Fisheries and aquaculture (SOFIA)
http://www.fao.org/sof/sofia/index_en.htm

Questions

Knowledge

1. Name any one destructive fishing technique.
2. List 9 commercial fishing methods and draw a sketch of each.
3. Describe the Aboriginal mullet fishery in Tallebudgerra Creek Queensland as related to Kombumberri Elders in stories.

Understanding

4. Draw a plan vie of a trawler to show where prawns are sorted, cooked and iced down.
5. Explain the term *maximum economic yield* and give an example.

Questions 6 - 11 refer to the graphs in Figure 532.1 and the statement below.

Prawns are a major fishing industry in Queensland with its largest landing coming from the Gulf of Carpentaria. Most are caught with otter trawlers.

Applying

6. Determine the catch of banana prawns in 1990 -2001.
7. What percentage of the total number of prawns caught that year were banana prawns?
8. Suggest two hypotheses to account for the fluctuation in catch size over the last ten year period.

Analysing

9. The Gulf fishing area has a limited entry with about 290 vessels. How do you think this can be monitored? What options do authorities have if they determine the fishery at risk?

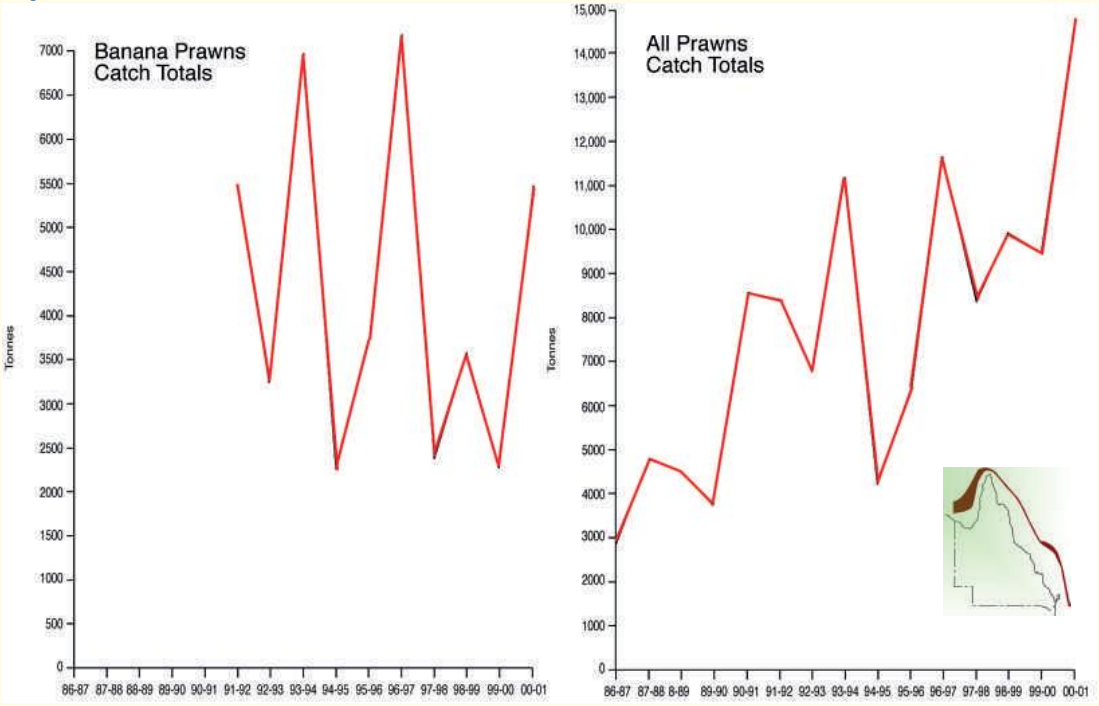
Creating

10. Design a campaign to promote the eating of aquacultured prawns.
11. Design an economic method for spotting and recapturing ghost fishing nets.

Evaluating

12. In many Australian States, governments are using revenue from recreational fishing licences to buy back commercial prawn trawling licences.
    a. Discuss the value of this.
    b Evaluate what problems it is likely to cause.
13. Who is to blame for reduced fish numbers in your area – recreational or commercial fishers or both? Locate some local fish catch statistics and justify your answer.

Figure 532.1

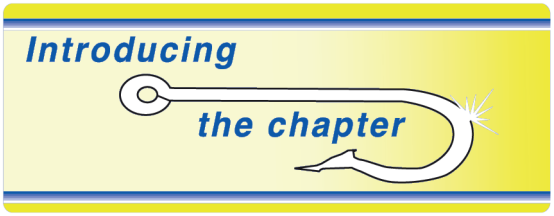


Chapter 21 Aquaculture — The future of fisheries?

by

Leon Zann

Photo Qld Fisheries



CHAPTER HOOKS

1. Read the text below and discuss the marketing issues/options in class.

   A fish called Daisy

   A new campaign to boost public awareness of the aquaculture industry was launched at the Sydney Fish Markets in Ultimo today (Monday, 25 January 1999). The aim of the *Fish called Daisy* campaign is to highlight the potential for aquaculture to be the next big economic success story in Australia.

   Aquaculture will treble in size to $1.5 billion over the next decade, making it comparable in size to the sugar industry. Thousands of jobs will be created in regional and rural Australia, in areas currently hard-hit by changing economic circumstances. Over seven thousand people are now employed on aquaculture farms, and the jobs of an estimated 21,000 other workers are dependent on the industry. These figures will rise dramatically as the industry expands.

   Mr Bill Widerberg, Chair of the Aquaculture Cooperative Research Centre (CRC), says seafood is entering a boom period as a nutritious and healthy food. He dubbed it 'the food of the 21st century'.

   "Aquaculture must grow enormously to meet increasing global demands for seafood. We need to supplement the catch presently taken from natural fisheries in Australia's oceans and rivers," he says. (Source CSIRO Press Release 1999)

2. Read — *A tuna story* text on page 544 and discuss the development of the South Australian tuna fishery in relation to the following questions:
   a. Why did wild stocks decline?
   b. What effect did it have on the local community?
   c. How do tuna prices compare with other fish?
   d. List the various arguments for and against tuna farming.

WHY STUDY THIS CHAPTER

The world's wild fisheries are being depleted (Chapter 20) and we are beginning to farm the sea. Aquaculture is Australia's fastest growing primary industry (over 20% growth per annum), worth over $0.6 billion per annum (2002) and is an important employer. While aquaculture has immense economic potential, it can be ecologically unsustainable unless it is carefully managed. This chapter describes the principles of aquaculture, the major industries in Australia, their environmental impacts and their management.

CHAPTER OVERVIEW

Aquaculture 535

Australia's main aquaculture industries 539

Environmental issues in aquaculture and their management 542

Conclusions: the future of aquaculture 544

Case study 21.1 Environmental effects of aquaculture 545

Exercise 21.1 Local sea farm planned for Hypothetical Bay 548

Exercise 21.2 Set up a classroom aqua farm 549

Questions 550

Aquaculture

Aquaculture*, the farming of freshwater or marine species, is one of the fastest growing industries in Australia.

As *wild* fisheries decline and demand for seafood increases, the gap in supply is being increasingly met by aquaculture (see Figure 535.1). The capture of fish in the sea is similar to hunting of wild animals on land (and is suffering from the similar over-exploitation of wild populations), and the progression to aquaculture is equivalent to that made by our ancestors to agriculture. And like agriculture, aquaculture is proving to be a revolution in our use of natural resources.

Over a hundred different species, from microscopic plants to pearls, and prawns to crocodiles, are currently cultured in Australia. It is worth around $600 million to the Australian economy, approximately 25% of total Australian fisheries production.

World-wide, aquaculture comprises over 20% of all fisheries production, around 25 million tonnes, and is worth over $110 billion. China alone accounts for over half of all world production, mainly of seaweeds and carp (relatives of our goldfish). Japan is also a major aquaculture producer and has pioneered modern aquaculture of pearls, prawns, other molluscs and crustaceans.

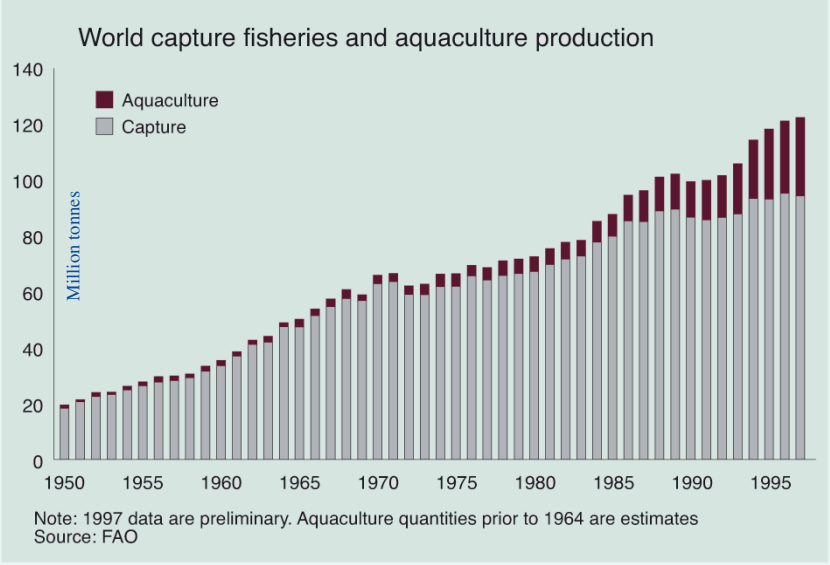
Aquaculture can also have a down-side. The rapid growth of aquaculture has created some serious environmental problems, particularly in SE Asia. Mangrove wetlands and salt marsh have been cleared for aquafarms, resulting in loss of natural fisheries habitat, and loss of natural storm barriers.

Discharges of waste water have contaminated local waters, and serious diseases and pest species have been introduced. Australia can learn from both the positive and negative experiences of aquaculture overseas.

Activities

- Write a commercial for the fish called daisy campaign.
- What will be the turning point in the wild catch fishing in Australia?
- Debate the statement
  - *Aquaculture must grow enormously to meet increasing global demands for seafood.*
- Can you assess and choose a solution to fishing wildcatch as shown in the photo below?

Figure 535.1 Fish market in Vietnam
(Photo Paula Moffatt)



Virtual tour of a prawn farm
http://www.apfa.com.au

Figure 535.2 World fisheries and aquaculture production. The decline in wild fisheries is being increasingly met by aquaculture growth.
(Illustration Trent Moffatt)

*Footnote: The term 'mariculture' refers exclusively to aquaculture of marine species. The more general term 'aquaculture' is used throughout this chapter.

Advantages of aquaculture

Figure 536.1 Aquatic species make very efficient farm animals.
(Photo Bob Moffatt, courtesy Ballina High)

Aquatic species make very efficient farm animals. They are supported by water and use little energy in locomotion and feeding. More of their food intake can then be used for growth. The food conversion ratio (the weight of food per weight gain) can be very high, under 2:1. That is, for every 2 kgs of food eaten, they grow 1 kg in weight.

Aquaculture species are selected for their fast growth, and growth rates can be boosted by increasing the water temperatures, and their metabolisms. Fast growing species such as prawns can produce several crops per year. Fish live in a three dimensional world, and large numbers can be cultured in a relatively small water body. Production rates of some aquaculture species may be incredibly high. For example, intensive production of bivalve mussels and tilapia fish (an African fish which is illegal in Australia) may yield over 200 tonnes per hectare per year. That is huge by conventional farm standards.

Every species requires its particular food types and environmental conditions. Aquaculture, at least initially, requires considerable scientific research on artificial rearing and feeding. Agriculture has had thousands of years of genetic selection to develop crops and farm animals with good traits for farm production. Aquaculture is only beginning to produce genetically selected strains or 'cultivars' for fast growth. CSIRO is producing disease resistant Tiger prawns in Queensland, and NSW Fisheries is producing disease resistant rock oysters. The revolution in genetic engineering will certainly have a huge influence in aquaculture. Already in North America, scientists have spliced genes from Atlantic cod into salmon to create a very fast growing, giant salmon.

Figure 536.2 Extensive farming of oysters - Cowell SA
(Photos Bob Moffatt)

Types of aquaculture

There are many different types of aquaculture, and many different techniques for rearing aquatic species. Aquaculture is a rapidly developing industry, and new technologies are constantly being developed.

'Extensive' and 'intensive' techniques

Aquaculture can involve a range of human inputs, from minor to great. Aquaculture in natural water bodies is termed ***extensive*** (eg farming of oysters and mussels). ***Intensive*** aquaculture is undertaken in artificial ponds or cages, and typically involves nursery production of young, high density mass rearing, use of formulated diets to maximise growth, and increasing water temperatures and oxygenation. Most prawns and fish are farmed intensively.

Extensive techniques have the advantage of being easier and cheaper, but have little control over environmental variables, and production rates are generally low. Intensive techniques have the advantage of being able to provide optimal environmental conditions for maximum growth and profit. However, they are capital- and labour-intensive, and risky, as many things can go wrong. A cut in the electricity supply to the many pumps and aerators on an aquafarm might result in the

Aquaculture is a rapidly developing industry, and new technologies are constantly being developed.

death of the entire crop. This means aquafarms must have back up automatic diesel generators and full-time staff.

Polyculture

More than one species can be cultured in a water body (this is termed ('polyculture'). In China, carp are produced in rice paddies, adding a valuable extra crop. Crayfish are cultured with freshwater fish to clean up wastes on the bottom of ponds. On prawn farms, Mullet and Rabbitfish are used to keep down filamentous algae. Waste water from freshwater fish farms is used to irrigate orchards crops, and hydroponic plants such as tomatoes. This solves the problems of waste water discharge, and adds value through an extra crop.

Hatchery production of 'seed'

Hatcheries are an essential part of modern intensive aquaculture. Most marine species have complex reproductive cycles, and multiple larval stages each requiring a range of habitats and food types. Producing the young (or 'seed') for aquaculture is often difficult, requiring detailed research and specialist laboratories. Parents or *broodstock* may be caught from the wild, and induced to spawn by artificially elevating temperatures, varying light cycles, or artificial hormones. Increasingly, aquaculture-raised individuals showing fast growth and disease resistance in intensive rearing are selected as brood stock.

Most aquatic species produce enormous numbers of young, so once the rearing techniques have been developed by scientists, technicians can then produce large numbers of young or *seed*, at a low unit cost to producers. However use of few *parents* may result in loss of genetic variation. The millions of Atlantic salmon and Silver perch which are now cultured in Australian fish farms are descendants from very few individuals. Some are showing signs of *inbreeding* and genetic disorders such as stunting and misshapen bodies.

Figure 537.1 'Extensive' farming of oysters - NSW
(Photos Bob Moffatt)

Aquaculture foods

Every species has its particular dietary requirements, but it is often not possible (or profitable) to feed them a natural diet in aquaculture so most foods are artificially produced. Manufactured food pellets are made with the required proportions of protein (from fish meal and cheaper soya beans), fats (from fish and vegetable oils), carbohydrates (from bran, flour etc) and micro nutrients such as trace metals and vitamins. Pellets are produced in appropriate shapes and sizes for each species and growth stage. Micro-pellets (milligrams in weight) are made for plankton-feeding oysters. Large pellets are made for carnivorous fish. Depending on the feeding habits of the animal, the pellets are made to float, or slowly or quickly sink. Dry pellets are easier to store, and easy to supply in measured doses. Stock are fed at appropriate times of the day by hand or mechanically. Large fish farms have mechanical pellet broadcasters which blow the food throughout the ponds.

Food is generally the most expensive component of intensive aquaculture. The daily food bill on a tuna feed lot in South Australia, or salmon farm in Tasmania may be over $15,000. The aquaculture of carnivorous fish such as tuna and Barramundi involves large amounts of valuable fish protein or baitfish.

Figure 537.2 'Intensive' aquaculture involves nursery production of young.
(Photo Tertius deKluvier)

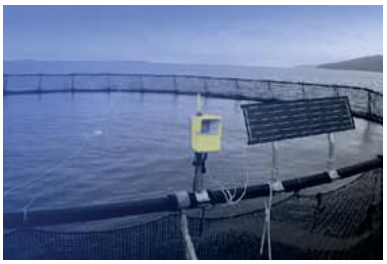


Figure 538.1 Seacage
(Photo courtesy Sunaqua)

Figure 538.2 Measuring salmon from sea cage
(Photo courtesy Tassal Australia)

You can learn more about seacages at www.sunaqua.com

Fish farmers are very careful not to over-feed and constantly check ponds for uneaten food. Uneaten food is not only a waste of money but when it decays it creates serious water quality problems.

Most fish feed contains large amounts of high-protein fish meal. Fish meal is manufactured mainly from small baitfish such as herrings, anchovies and pilchards, and comes mainly from South America and Asia. It is expensive (over $1,500/tonne) and in high demand for agriculture. Environmentalists are concerned about depletion of baitfish and effects on the food chain. There is also a moral argument that it is a waste to feed high value protein to other fish when many people are starving.

Ocean rearing techniques

The young or 'seed' from hatcheries are reared or 'grown out' to market size using a variety of techniques. Oysters are reared attached to the sticks on which they settle in the wild, or in trays or pouches hung from posts or rafts in areas of high plankton and strong currents. Mussels are made to settle on rope which is encased in mesh tubes like nylon stockings, and hung from rafts for 'growout'.

Fish may be reared in floating cages or pens, to keep them in, and their predators out. Ocean cages for salmon and tuna are typically large, 30-50 m in diameter, and 20 m deep. They are supported by a floatation collar made from 'poly pipe'.

They are tethered by a series of anchors in sheltered bays as ocean cages are prone to damage in storms. Growout cages or structures for bottom species such as abalone are placed on the seafloor but these can only be serviced by scuba diving, which is very expensive.

Pond design and construction

Most fish and crustaceans are reared in large ponds on land. These are typically excavated in low-lying coastal areas, near a ready supply of water. The earth excavated to make the pond is used to make the pond walls. Walls are made with wide bases and tapering tops for stability and to resist water pressure.

Figure 538.3
Ocean fish cages
(Photo courtesy Tassal Australia)

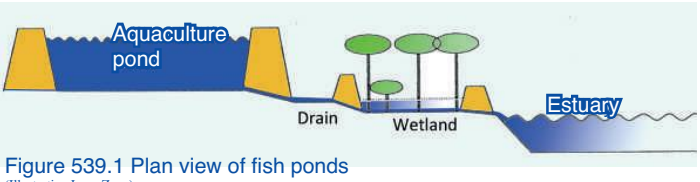


Figure 539.1 Plan view of fish ponds
(Illustration Leon Zann)

Figure 539.2 Aerial view of fish ponds
(Qld Fisheries)

Barramundi and prawn ponds are typically 30-100 m long, by 10-30 m wide, and 1-1.5 m deep. Ideally, the earth should be clay to prevent water seepage, otherwise clay or plastic liners are used to seal the ponds. Earthen ponds are designed to be drained, with a deeper area or depression like a bath tub, so the water can be drained and the crop easily harvested. Water is pumped or channelled from a dam, underground bore, river or the sea. Each pond in a farm should have an independent water supply to prevent spread of any diseases. To avoid costly pumping, freshwater farms often gravity feed water from an elevated reservoir or storage dam, and saltwater farms may use tidal circulation.

Ponds must be well oxygenated, particularly during the night when algae also respire, and the CO_2 builds up. Electrical spray pumps and paddle wheels are often used to circulate and reoxygenate water. Aquafarms are highly reliant on expensive diesel fuel and electricity, and energy is generally their second greatest cost. Discharged waters are generally stored in a settling pond for later discharge or for recirculation. Freshwater is often in short supply in arid Australia, and water re-use is very important.

Australia's main aquaculture industries

Aquaculture is still in a relatively early stage of development in Australia. We are traditionally meat eaters and (until recently) have had abundant, inexpensive, wild-caught seafoods. Intensive aquaculture is labour-intensive and our wage structure is high. It is expensive to grow seafood and our main aquaculture are high-value 'luxury' products such as pearls, rock oysters, salmon, tuna and prawns. However as wild fisheries decline, Australian governments are promoting aquaculture of basic seafoods (such as 'the fish called Daisy').

Molluscs

Pearls

Australia's top aquaculture industry (by value) is cultured pearls, with exports of around $250 million pa. The pearl farms are based in Northern Australia. Artificial pearls are produced in pearl oysters (*Pinctada sp*.) by implanting a small bead of shell into the shell-producing mantle of the oyster. The technique was invented by the Japanese but the industry is now largely dominated by Australians. Single cultured pearls sell from a few dollars to many thousands.

Figure 539.3 Pearls and pearl seeding equipment
(Photos Bob Moffatt)

Figure 540.1 Oysters
(Photo Bob Moffatt)

Figure 540.2 Scallops
(Photo Bob Moffatt)

Rock oysters

Rock oysters are delicious when eaten raw. The Sydney rock oyster (*Saccostrea glomerata*) industry is valued at around $40-50 million pa. Oysters are increasingly cultured in bags or trays of plastic mesh to reduce handling. They reach market size in two to three years, and fetch high prices in restaurants ($10-20 a dozen). Rock oyster farming in NSW has declined by over 30% since its peak in the 1970s. The main problem is caused by poor water quality and oyster diseases such as 'Qx' (from *Queensland unknown* disease). Because oysters are eaten raw, there is also a risk of consumers catching diseases. Contamination of estuaries by sewage has resulted in some serious epidemics of hepatitis and gastro-intestinal diseases in Australia, threatening the viability of the industry. In NSW rock oysters have to be flushed in sterile conditions for several days before they are sold.

The introduced Pacific oyster (*Crassostrea gigas*) is cultivated in the south, but is a pest in NSW. This large, fast-growing species (1-2 years to harvest) was originally introduced as an aquaculture species. But like so many other introductions in Australia, it became feral, and has out-competed and displaced the higher value native rock oysters.

Scallops and abalone

Scallops and abalone, high value seafoods, have been aquacultured in Japan but are still quite difficult to rear. Australia's abalone fetch very high prices in Asia (over $200/kg). Techniques for rearing abalone have recently been developed in Australia and the first farms are appearing in Victoria and South Australia. In New Zealand the paua abalone is now widely aquacultured for its meat, shells and implanted pearls.

Giant clams

Giant clams (*Tridacna sp.*) are ideal species for aquaculture. They are large and fast growing, and do not need to be fed. They are aquaculturists themselves, farming symbiotic algae in their large, colourful mantles. They have been farmed experimentally in Queensland and juvenile clams exported to re-seed reefs in the Pacific Islands where they had been depleted by over-harvesting.

Squid

The farming of squid is in its research stage due to the fact such large populations of wild catch are under exploited.

Figure 540.3 Tiger prawn
(Photo Qld Fisheries)

Crustaceans

Prawns

Prawn (*Penaeus sp.*) farming is a major industry world-wide and is fast growing in Australia. In Queensland Jumbo and Tiger prawns are grown in shallow, 0.5-1 ha earthen ponds in coastal regions. Prawns are detrital feeders but grow fast on a high carbohydrate/protein diet, and reach market size in 6-8 months, depending on temperature. Most are exported live to Japan where they may fetch huge prices (over $300/kg) during festive occasions.

Crabs

Mudcrab (*Scylla*) culture is the next boom industry. Like the prawns, they have proven very difficult to rear. After years of research, hatchery techniques have been recently developed in Queensland and crablets are now becoming available. Mudcrabs are ideal for aquaculture: delicious to eat, a high market demand ($15-20/kg in Australia), easy to feed (they eat anything), fast growing, have few diseases, and can tolerate poor water quality (they naturally live in muddy mangrove areas). However, they are territorial and cannibalistic, and must be grown in separate containers or in large ponds.

Fin fish

Salmon

Atlantic salmon is one of the largest, and fastest growing aquaculture industries in Australia. It is an introduced, cold-water species and its oily red flesh is in high demand. Around 10,000 tonnes, worth some $100 million are now produced each year in Tasmania.

The large ocean cages, 40-120 m in circumference, each produce 8-150 tonnes pa. Salmonids require high protein foods and feed comprises 40-60% of the production costs. Major problems include predation by seabirds, fish and seals.

Figure 541.1 Atlantic salmon
(Photo Bob Moffatt)

Barramundi

Barramundi are farmed in north Queensland, and in heated, indoor ponds in the south. It is a good species for aquaculture. It has a delicate flesh and taste, and a high market demand (wholesaling at over $15/kg). Barramundi can be spawned easily, year-round under controlled conditions, and produce many offspring. They can be farmed in either freshwater or marine conditions. They are a hardy fish and adapt well to crowding, but can be cannibalistic.

Bluefin tuna

Tuna *ranching* is an important industry in South Australia. Tuna, a highly migratory pelagic species, have been overfished in the wild, and stocks have declined. *Ranching* entails the fattening of wild-caught fish in ocean cages to obtain a very high value product for export to Japan for raw fish or sashimi. The technique was developed in Australia and around 2,000 tonnes, worth almost $100 million, are now exported each year.

Problems in tuna ranching include: the need to harvest adult fish (thereby competing with tuna fisheries); the storms which damage the sea cages and kill tunas; the supply and very high cost of food; pollution around cages from uneaten food; and possible introduction of exotic diseases in imported food fish. South American pilchards used for food are suspected of causing massive epidemics in 1995 and 1999 in which countless millions of wild pilchards died in the southern half of Australia. Some of the problems are being resolved. Pellet foods are being developed and research on life cycles and hatchery production of tunas is underway in Japan.

Figure 541.2 Salmon hatchery
(Photo Bob Moffatt)

Activity

Visit your local fish shop or large supermarket. Compare the costs of fresh and canned salmon with wild-caught fish identifying the origin of each.

Figure 542.1 Salmon farm
(Photo Ruth Farley)

Environmental issues in aquaculture and their management

The rapid growth of aquaculture overseas has had great economic benefits but also many problems. Australia has learnt from other countries' mistakes and has an ecologically sustainable approach to aquaculture developments.

Water quality: the number one problem

Maintaining water quality in crowded intensive conditions, such as ponds, is difficult. Cultured organisms take oxygen and release faecal wastes and urea, which becomes toxic ammonia. Bacterial and fungal decomposition of uneaten, rotting food adds to the problem and promotes diseases.

Good water quality is essential for aquaculture. Intake water must be free of contaminants, well oxygenated, neutral pH and of the appropriate salinity for the species. Even tap water is a problem as it contains chlorine and sometimes copper and other metal ions. Tap water in many parts of Australia is slightly acidic, and may slowly dissolve copper and lead from pipes. It is best to use rainwater where possible.

Ways of minimising effluents

- Settlement ponds (Settlement ponds or beds slow water flow so that suspended solids settle out before water is released. The concentrates and sediments can then be treated or disposed of.)
- Wetland filters (Mangrove and wetlands communities are used as biofilters to remove sediment particles and absorb nutrients from effluent water.)
- Biofiltering (Seaweed and bivalves remove nutrients and/or algae from the effluent. They can then be sold as a second crop.)
- Bacterial inoculations (Bacterial cultures can be added to *feed on* nutrients in waste water.)
- Effective farm management (Efficient farm and feed management can minimise nutrients in effluent.)

Odd fact

Managing aquaculture water quality issues

There are strict controls on aquaculture effluent in Australia. In NSW, there is a 'zero release' for fresh-water aquaculture farms, so on-site storage or disposal of effluent is needed. In other States, a 'licence to discharge' is subject to strict conditions. Good planning at the start can reduce many of these problems.

Diseases

Stress from living in crowded conditions and from aggression, poor water quality, uneaten foods and elevated temperatures in ponds, can promote diseases. Diseases reduce growth rates and cause mortalities, necessitate expensive treatments, and can result in an unsaleable product. Overseas, trout and salmon farms are affected by serious diseases and prawn farms in South East Asia now have chronic disease problems. Australia is free of the serious aquaculture diseases. It has strict quarantine regulations on certain species such as salmon, and has a 'disease-free' reputation for its aqua- products.

Prevention is always better than cure. Aquaculturists go to great lengths to avoid the disease problem by ensuring that water quality is maintained.

Food must be of high quality with all the essential vitamins and minerals required so animal health and immune status is maintained. Animals are inspected carefully every day for signs of sickness or abnormal behaviour. Ponds and tanks are kept on separate water intakes to reduce cross-infection, and all new stock must be quarantined before release. Infected ponds are drained, dried and sediments disposed of to avoid re-infection.

Pests and predators

Plump farm-grown oysters, trout or salmon make convenient meals for the local fish, birds and other predators. Cormorants are a particular problem in pond culture. Seals are a major problem for Tasmanian salmon farmers, and South Australian tuna growers. In Australia many of the predators, birds and seals, are protected wildlife species, and it is illegal to kill them. Aquafarmers use a variety of techniques such as nets, screens and 'scares' (loud noises, explosions, scare-crows) to reduce the problem. A Tassie seal with an expensive taste for red salmon has been trapped and removed several times, and even came back a few weeks after being released on the other side of Tasmania!

Community concerns

Local communities are often concerned about the possible effects of aquaculture developments on their activities, and on the environment. Ocean cages and oyster racks in bays compete with recreational users, fisheries and marine conservation. Public access to aquafarms is generally restricted, so they prevent other uses of this area. Important aquaculture proposals to grow pearl oysters in Port Stephens (NSW) and ocean fish cages in Moreton Bay (Qld) in 2002 were rejected by local communities.

The support of local communities and other users of the area can be gained though better consultation and education programs to inform them of the project's benefits (eg local employment, new industries) and the environmental safeguards.

Weighing the positives and negatives of aquaculture

Aquaculture has many positive benefits, but if development is not environmentally managed, it can do more harm than good. Table 543.1 summarises the main points.

Table 543.1 Positives and negatives of aquaculture

Positive effects	Negative effects
• Profit for growers and investors, exports for Australia. • Provision of high quality food product. • Reduced pressures on wild fish populations. • Provides local employment (Australia's rural areas have high unemployment). • Aids in development of local infrastructure, improved roads, facilities. • Broadens the income base for primary producers. • Is potentially ecologically sustainable.	• Competition with other coastal land and sea uses (eg residential, tourism, agriculture, conservation). • Loss of aesthetic values (removal of vegetation, unsightly ponds, machinery sheds, cages etc. Noise from pumps, and smells from ponds and discharges affect neighbours.) • Competition with fishermen for fish and markets. • Loss of water quality. (Effluent is rich in organic material from animal and food wastes.) • Loss of wetlands. (Clearing of mangroves and saltmarsh to build ponds.) • Introduction of exotic species and diseases. (Organisms purposefully or accidentally introduced may escape and become pests.) • Culling of native 'pests' (seabirds, seals etc). • Use of chemicals, antifoulants and antibiotics (may affect natural marine species and seafood consumers). • Increased pressure on bait food fisheries (affecting the natural food chain, and competing with other fishers). • Genetic contamination of wild stocks. (Stock is genetically selected for rapid growth in captivity. Escapees may affect the genetics of natural populations.)

SEAFDEC

Figure 544.1 Aquaculture Philippines
A. Mudcrab B. Seaweed
C.Tilapia D. Mussels

Bob Moffatt

Figure 544.2 Aqua cultured seafood - China

Conclusions: the future of aquaculture

Aquaculture has a great future. As wild fisheries further decline, aquaculture will continue to fill the gap in demand for fresh fish. Australia has been relatively slow to develop aquaculture in the past, but we can now take advantage of the successful technologies developed overseas, by countries such as Japan, and learn from the environmental mistakes in SE Asia.

In future, luxury seafoods such as mudcrabs, lobsters, scallops and abalone will be largely produced by aquaculture. Aquacultured fish such as bream, mullet and silver perch will become fish staples. Even microorganisms will be cultured for biochemicals, drugs and animal food.

Aquaculture will become ecologically sustainable, waste free and non-polluting. The nutrient wastes, which are today's problems, will be re-used to produce algae to feed cultured fish and shellfish. Freshwater aquafarms will produce hydroponic crops and re-use water.

Aquaculture will also shift offshore in large ships and barges to take advantage of the most productive parts of the ocean, nutrient-rich upwellings in cooler waters.

Genetic selection will produce shellfish and fish that are more tolerant to poor water quality and resistant to crowding and disease. The real revolution will come with genetic engineering. If we already have giant, fast growing salmon with cod genes, who knows what we will be eating in 2050!

A TUNA STORY

Sure, these blokes look normal - just a bunch of happy fishermen strolling down a South Australian wharf. But these men are rather abnormal, especially for fishermen. Each of these ordinary-looking blokes is worth at least $10 million.

Their town is also abnormal. Port Lincoln, population 13,000, has the highest number of millionaires per capita in the southern hemisphere. This wealth, shared between 10 families and employing 3000 people, is mostly due to Thunnus maccoyii, or southern bluefin tuna.

This tuna, a fast-swimming, athletic ocean fish, is caught in the Great Australian Bight and then fattened in pens off the lack of foresight. It started innocently enough. Fishermen first poled for the fish, which meant the boat would sidle up to a school, drop a lure and then haul the fish overboard with a pole.

But then the fishing methods improved. On the east and south coasts of Australia, fishermen began netting whole schools for tuna canneries. Planes were sent out to spot ocean ripples of bluefin. The fish, which lives up to 40 years, was netted whether it was a mere juvenile or a huge 200-kilogram adult. For a fish now considered a treasure, the southern bluefin suffered the ignominious fate of being sandwich tuna after it was sold in the 1980s to canneries for as little as 80 cents a kilogram.

Port Lincoln coast. From there it is sold to the Japanese, who crave its fatty flesh for sashimi and sushi.

In the past, the Japanese have preferred the northern bluefin, a tuna that can be caught in the waters around Japan, or in the Mediterranean. But as wild stocks of this tuna decline the value of Port Lincoln tuna is rising. The town's tuna farmers this week celebrated their best-ever prices: $55 a kilogram, or about $1900 a fish. It is now the nation's most lucrative air-freight export of fresh produce, expected to be worth $300 million this year.

Port Lincoln is a modest little port town, but it has a higher-than-average dose of baroque-style mansions and luxury cars. If there is something flashy about the way tuna farmers enjoy their fortunes, they are offering no apologies. Only a decade ago - when the tuna disappeared and the Federal Government brought in a quota system - these same 10 families were almost bankrupt. "Crisis and misery," is how Dinko Lukin, father of Olympic gold-medal weightlifter Dean Lukin, describes the time.

Things were so desperate there were fights in the Bight over patches of fish. In one incident, skippers of two rival boats got out their rifles and fired warning shots over a school of tuna.

The disappearance of the southern bluefin in the 1980s was the result of a textbook combination of greed and

By Melissa Fyfe and Penelope DeBelle
(Reprinted from *The Age*, 9/6/02)

Case study 21.1 Environmental effects of aquaculture

From Coasts and Oceans, Australia State of the Environment Report 2001 (Theme Report) Australian State of the Environment Committee, Authors, CSIRO Publishing on behalf of the Department of the Environment and Heritage © Commonwealth of Australia 2001, reproduced with permission Source: http://www.ea.gov.au/soe/2001/coasts/casestudies.html

Over the past 30 years there has been a significant increase and diversification of aquaculture species farmed in Australia. Of the approximately 60 different species farmed, the major contributors are: pearl and edible oysters, Atlantic salmon, prawns, and Southern Bluefin Tuna (FRDC 2000).

Australia's ability to produce such diverse products is due mainly to its wide-ranging climatic conditions, from the tropical north to the temperate south. Australia is also fortunate to be free of many of the major diseases that affect aquaculture production in other parts of the world.

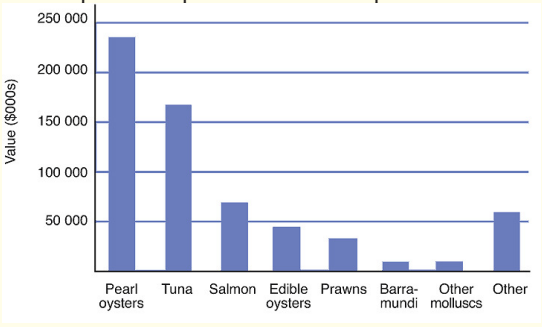


Figure 545.1 Value of aquaculture sectors. Source: O'Sullivan and Dobson, (2000).

Over the last decade, aquaculture production has grown substantially, from 11 900 tonnes and a value of $136 million in 1988-89 to some 32 360 tonnes worth around $614 million in 1998/99 (O'Sullivan and Dobson 2000).

Until the last decade, most commercial aquaculture was for oysters (edible oysters and pearl oysters) and a limited amount of fish and prawn culture. In recent years, the caged culture of fish has grown rapidly. Atlantic Salmon in Tasmania and the fattening of caged Southern Bluefin Tuna in South Australia account for one-third of Australia's production.

Wild-caught Southern Bluefin Tuna have been fattened in sea cages off Port Lincoln since 1994. There are now 110 cages operated by about 12 companies in an area of approximately 200 km2. Predator exclusion nets surround the main nets of many cages. Although the wild catch has been maintained at 5265 tonnes, most is now farmed, leading to significant value-adding of the product. The tuna are fed on pilchards and other bait fish for four to eight months, when they reach a size of about 30 to 40 kg.

However, tuna farming in feedlots can generate a significant amount of pollution (Parliament of SA 2000). Recent research suggests that pollution is causing the

Figure 545.1 Barramundi in aquaculture tank
(Photo Bob Moffatt, courtesy Cairns Department of Fisheries and MTAQ)

sudden appearance of strange micro-organisms capable of poisoning fish. It has been suggested that a toxic algae was the cause of death of the tuna in Boston Bay, Port Lincoln, in 1996.

The Parliamentary Committee (Parliament of SA 2000) noted that the Tuna Farming Code of Practice was still not finalised, and although some of the issues of concern are addressed in the Draft Code of Practice, in reality the Code is not being adhered to.

Dolphins, whales and seals can become entangled in the predator nets. The South Australian Museum has been collecting records of dead and stranded dolphins around the South Australia coast for many years. In an initial study of the problem (Kemper and Gibbs 1997), at least 13% of all dolphin carcasses studied were believed to have died as a result of entanglement, including many in the tuna feedlots near Port Lincoln.

Challenges

There are several challenges for the Southern Bluefin Tuna Fishery in the future, a major one being to breed tuna in captivity and cease the total reliance on capturing wild stock, the availability of which is limited.

There are also many experimental and pilot schemes in place within the aquaculture industry, and some are becoming commercially viable. For example, a pilot-scale culture of the Fat-bellied Seahorse (Hippocampus abdominalis) in Tasmania has recently grown to a commercial scale.

Figure 545.2 Seahorse breeding program Tasmania
(Photo Bob Moffatt)

Web reference

www.seahorseworld.com.au
or try
Seahorse Launceston Tasmania

Successful aquaculture depends on a combination of factors, including appropriate site selection, design and construction of facilities, good water quality, and suitable markets. Site selection and the associated impacts involved in initial developments can be a contentious issue where there are competing uses of the coastal or marine environment, such as urbanisation, recreation or community interests (Preston and Rothlisberg 2000).

Local government and State planning agencies are the responsible land planners, and increasingly aquaculture operations will have to meet strict environmental controls in order to coexist with other land and coastal water uses.

Issues

The major environmental issues for aquaculture are:

- water quality impacts from aquaculture operations,
- introduction of pest species through translocation and possible escape,
- introduction of disease through translocation,
- genetic impacts from possible escapes,
- sourcing of brood stock or juveniles, particularly if it is from wild populations,
- compromising habitat and amenity values, and
- sourcing of feedstock from wild-harvest fisheries.

Environmental effects

Sourcing of brood stock and juveniles

Where aquaculture operations depend on wild-caught juvenile fish, there can be an effect on the wild stock populations. As yet there is little evaluation of this aspect of aquaculture.

Water quality

Aquaculture requires access to high-quality water but has the potential to increase nutrient enrichment of surrounding coastal or estuarine waters.

Land-based practices such as urbanisation and industrial or agricultural practices may also have adverse water quality effects on aquaculture operations, leading, for example, to algal blooms that can affect shellfish quality.

There is the potential for fish feed and wastes to affect water quality through the accumulation of wastes in the vicinity of the farms or the movement of nutrients into the water column. The main source of nutrients in discharge water from prawn farms, for example, is undigested food. The contribution of prawn farming effluent into waters already experiencing impacts can be significant. For example, around 110 hectares of prawn farms are situated in the Logan River catchment in southern Queensland, producing around 45 tonnes of nitrogen effluent.

Possible genetic effects

Unintentional escapes of aquaculture species, either native or exotic, into the wild could affect the genetic diversity of native species. In recognition of the possible risks

Figure 546.1 Aquaculture open day Cairns
(Photo Bob Moffatt, courtesy Cairns Department of Fisheries and MTAQ)

associated with unintentional escapes, the Commonwealth, State and Territory governments have strict policies regarding the transfer and translocation of exotic species, including larvae.

Responses to environmental issues

The responsibility for the development and regulation of aquaculture in Australia rests with local, State and Territory governments. Several States have aquaculture and coastal development plans in place.

Many industry associations have developed codes of practice for their particular aquaculture operations, e.g. the Australian Prawn Farmers Association and the Australian Tuna Boat Owner's Association (Caton and McLoughlin 2000).

There are a number of promising developments for the aquaculture industry.

The use of saline groundwater is being trialed for aquaculture in pilot studies, and may become commercially feasible. The integration of aquaculture with conventional farming systems to allow multiple and sequential usage of water resources and related infrastructure is also attracting significant interest. Another developing trend is the use of genetic engineering in aquaculture.

Disease

The management of diseases that affect aquaculture is a challenge for the future. For example, the marine protozoan pathogen *Neoparamoeba pemaquidensis* that occurs seasonally in Atlantic Salmon in Tasmania is now regarded as a major disease which costs the industry $10 to $15 million annually.

The Australian Prawn Farmers Association recently (2001) decided at a workshop to implement national environmental practices that will ensure prawn farming has no detrimental effect on water quality. The workshop documented potential problems resulting from the discharge of nutrient and sediment-laden pond water and

decided to develop a plan with targets, deadlines and assigned responsibilities to achieve world's best practice within 10 years. This initiative was taken in the knowledge that the total pond area of prawn farms may double during that time to about 800 hectares.

Management of other land-based activities becomes crucial to the maintenance of coastal water quality for aquaculture, as these are generally conducted on a much larger scale. Increasingly, there is a need for planning authorities to engage in integrated catchment management considering all activities that may affect a waterway, rather than attempting to regulate aquaculture in isolation.

Considerable research is under way to develop more efficient and environmentally friendly food for aquaculture species, as the world supply of fishmeal - a major component of aquaculture food - is not increasing and its production is vulnerable to climatic variability. Improvement in feeds and feeding practices also has significant potential to boost the profitability of aquaculture through reduced wastage and costs, as some aquaculture operations are net consumers of fish products rather than net contributors (FRDC 2000). This would reduce the amount of bait fish, currently 50 000 tonnes per annum, used as aquaculture feed.

Figure 547.1 Feeding fish grow out pens
(Photo courtesy Tassal)

Questions

Knowledge

1. Of the approximately 60 different aquaculture species farmed in the last 30 years, name the five most successful species.
2. State why Australia is so fortunate in being able to farm fish species.
3. Name a species of fish that have been fattened in sea cages off Port Lincoln since 1994.
4. Describe a pilot-scale culture in Tasmania that was grown to commercial scale.
5. Name the seven major environmental issues for aquaculture identified in this case study.

Understanding

6. Give one example of a land-based practice that may have adverse effects on aquaculture operations.
7. Where aquaculture operations depend on wild-caught juvenile fish, there can be an effect on the wild stock populations. Explain.
8. Outline the suggested cause of death of tuna in Boston Bay, Port Lincoln, in 1996 and how do you think this occurred?

Applying

9. Calculate the total value of aquaculture sectors in Figure 545.1.
10. Calculate the amount of nitrogen effluent produced by 500 hectares of prawn farms in the Logan River catchment in southern Queensland.

Analysing

11. Compare the increase in aquaculture production tonnage and dollar value in 1988-89 with 1998-99.
12. Explain the need for many industry associations to develop codes of practice for their particular aquaculture operations.

Creating

13. Design an aquaculture seacage for open sea capable of withstanding cyclones.
14. Propose a solution to water quality issues associated with sea cage farming.

Evaluating

15. Estimate the cost of the design for question 13.
16. Justify the need for State and National aquaculture legislation.
17. Recommend guidelines for the introduction of overseas fish for aquaculture in Australia.
18. Prepare first speaker notes for a debate on the future of our seafood - on the side of pro-aquaculture.

Figure 547.2 Lobster aquaculture trial tanks
(Photo Bob Moffatt, courtesy Cairns Department of Fisheries and MTAQ)

Exercise 21.1 Local sea farm planned for Hypothetical Bay

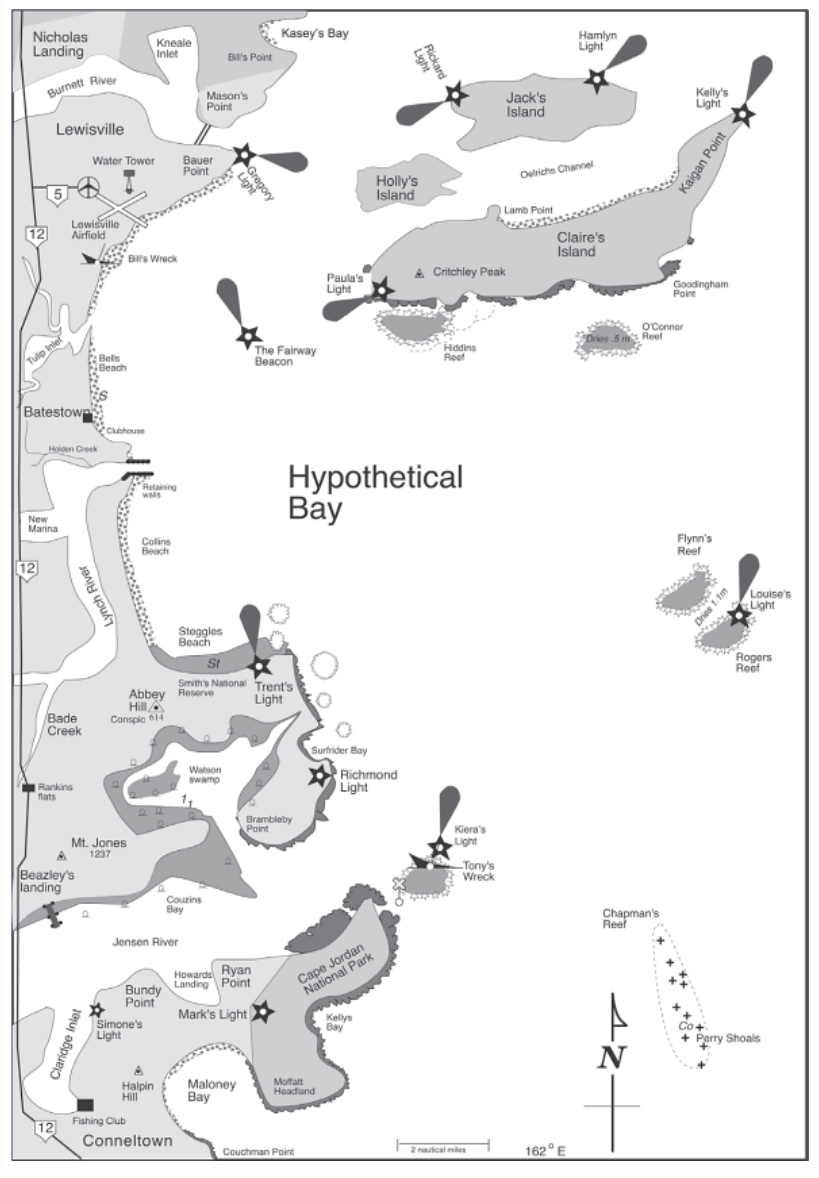
A major prawn farm is planned for Hypothetical Bay (or near your local estuary).

Part A Get your facts right

Prepare a fact sheet on each of the following 9 points by completing the following tasks.

1. Look at the illustration below and decide on possible locations.
2. Define which nutrients will be produced and work out the impact of these. Calculate the size of 1 cage and research the amount of nitrate and phosphate produced by similar cages in the first year of operation.

   Make a statement predicting the effect of these nutrients on the natural cycles (see pages 419-421). List each cycle.
3. Define *eutrophication* and make a statement on its possible effects.
4. Discuss sediment re-suspension, and excess particulate matter effects on turbidity
5. Establish where seagrass beds are and discuss the effects on seagrasses.
6. Make a statement on the potential for an algal bloom.
7. List the effect of aquaculture on endangered species such as dugongs and handfish.
8. Research herbicides and pesticides used on other farms including those to stop antifouling of cages.
9. Discuss the on-site effects of human wastes, gutting of catch etc.
10. Identify the potential economic benefits of such a project.



Part B Defend your role in a role play

In a class role-play, present the arguments of

a. the developer
b. neighbouring property owners
c. the local business community
d. local recreational and commercial fishers
e. the Environment Protection Agency
f. the local conservation society.

Note: You must demonstrate you have a sound grip on your knowledge to score well and where possible, develop solutions to the various problems.

Exercise 21.2 Set up a classroom aqua farm

Students at Ballina High (a Northern NSW school), have their own aquafarm, just outside their class room. Their Science teachers have established an Aquaculture Centre with dozens of large tanks and aquaria, circulating fresh and sea water, filters and air. They are also planning a fully operational fish farm. Students can rear Silver perch, Barcoo grunter, Barramundi and Red claw crayfish, and they are now turning their hands to farming Mud crabs (Figure 549.1).

Your class could also set up a small aquafarm. Set up something simple to start with, like a one metre-long glass aquarium with sub-gravel filter, air pump and heater. (If your school doesn't have the equipment check out your local pet shop or *for sales* section in your local news paper).

A few yabbies or Redclaw crayfish are a good start. They can be territorial and fight, so give them small PVC pipes to shelter in. They will eat vegetable scraps or chicken pellets, but don't over-feed them as it pollutes the water. You could try your own 'polyculture' by adding a few hardy goldfish, and water weed. As you get more experienced, try a few Barramundi, Australian Bass, Silver perch, or even the beautiful Australian native Rainbowfish. (Ask at your local pet shop.)

You could try to induce spawning in your Redclaw by raising the temperature to 28°C, and extending the period of daylight to 16-18 hours, to trick them into thinking it is spring in their native North Queensland waterholes.

Figures 549.1 Measuring crayfish (above) and home-made biofilter (right)
(Photo Bob Moffatt)

Aquaculture is not just keeping animals alive in a fish tank. You should experiment with different foods and temperatures to get the fastest growth rates. Record the water quality, noting water temperatures, pH (low pH can indicate build up of harmful urea and ammonia in fresh water), and if your school has the equipment, monitor oxygen levels and ammonia. Wastes really are a problem, and you might even build a re-circulating system or add a small hydroponic garden of herbs or flowers. Good luck.

Figures 549.2 Part of the Ballina SHS aqua farm
(Photo Bob Moffatt, courtesy Ballina State High School)

Questions

Knowledge

1. Recall Australia's top aquaculture industry (by value).
2. List four Japanese aquaculture industries.
3. Name four Australian cultured molluscs.
4. Name four ways of minimising effluents from aquaculture farms.
5. State what a *wild fishery* is.
6. Define the term *aquaculture*.
7. State the food conversion ratio for aquaculture.

Understanding

8. Draw a plan view of a fish pond.
9. Prepare a table, listing the main environmental factors required by an oyster, mud crab, mullet, snapper and tuna.
   a. Which species would be the easiest and cheapest to aquaculture?
   b. What are the problems in culturing high-order predators such as coral trout and tunas?
10. Describe what polyculture is and give two examples.
11. Describe what happens in a hatchery.
12. Describe either Tuna 'ranching' or Barramundi farming.
13. How can we apply our knowledge of food chains to polyculture? Give possible examples.
14. From your studies on marine food chains, suggest species which might be cultured with oysters, prawns, snapper and tuna.
15. Why is it important to maintain genetic variation in populations?

Applying

16. Calculate the percentage wild catch of fish in 1997 from Figure 535.1.
17. About what weight of food do you eat a week?

    What would you weigh at the end of the year if your 'food conversion ratio' was 2:1?

Analysing

18. Why is Australia free of serious aquaculture diseases?
19. Compare the percentage of wild catch to aquafarmed fish in 1997 with 1950 in Figure 535.1. What is the difference?
20. Name two similarities and two differences between 'extensive' and 'intensive' aquaculture.
21. Compare the methods of growing prawns and oysters. List two similarities and two differences between the two methods.
22. Every aquacultured species has its particular dietary requirements, but it is often not possible (or profitable) to feed them a natural diet in aquaculture so most foods are artificially produced.
    a. Distinguish between the terms profitable and non-profitable foods.
    b. Identify an aquacultured species in this chapter and discuss its food requirements.
23. In North America, scientists have spliced genes from Atlantic cod into salmon to create a very fast growing, giant salmon. Identify one advantage and one disadvantage of this technique.
24. Compare the costs of canned Tuna with wild-caught fish. (Ask your local fish shop).

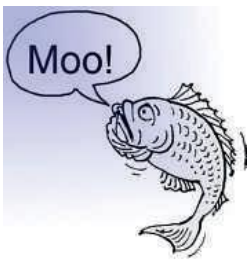
Creating

25. Research the life histories of an oyster, ocean prawn and tuna. How would a hatchery produce them artificially?
26. Design a sea cage that could withstand large ocean swells and still be used to fatten wild caught fish.
27. Devise a polyculture method for sea cages to minimise nutrient effects.
28. Estimate the daily amount of food required for a tuna pen with 5000 tuna.

Evaluating

29. Why is there is a risk of consumers catching diseases from eating oysters off local rocks?
30. Discuss the scientific and ethical arguments for and against genetic engineering in aquaculture in relation to human health.
31. Examine Table 543.1 and rank each of the positives and negatives from highest to lowest.

    Give a reason why for your highest and lowest choice.

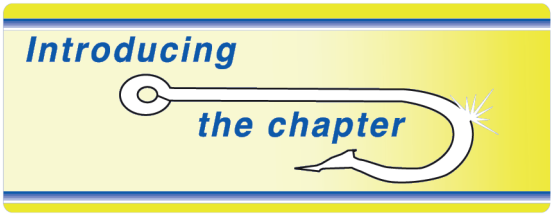


Chapter 22 The future: Marine parks and multiple-use marine protected areas

by

Leon Zann

Photo Neville Coleman



Chapter hooks

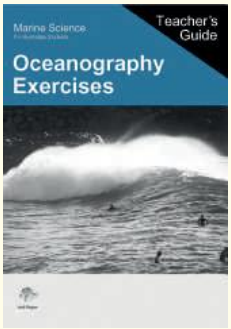
- Discuss the need for management of the areas you have conducted field work at.
- Begin planning for either Exercises 22.1 or 22.2.
- Collect a series of newspaper articles on management issues and display around the room.

Why study this chapter

This concluding Chapter describes an important tool in biodiversity conservation, Marine Protected Areas (MPAs). It focuses in particular on 'Multiple-use' MPAs (such as the Great Barrier Reef Marine Park) which are designed to conserve biodiversity, while allowing for ecologically sustainable uses. This Chapter incorporates many of the subjects studied in this book, for the planning and management of multiple-use MPAs requires the application of information on oceanography, marine biology and environmental management.

Activities and worksheets from our Oceanography Exercises Teacher's Guide

In the appendix, try these activities:

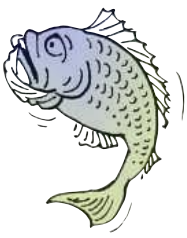


- Best environmental practices
- Controversy at Hypothetical Bay
- Drain stencilling
- Ecotourism
- Hypothetical Bay 2020
- Images essay
- Management proposals
- Managers and user groups
- Master Mariners story
- Problem solving
- Traditional management methods
- Whale Bay game

Chapter overview

Marine Protected Areas 553
Australia's marine protected areas 553
Importance of large, multiple-use MPAs 555

General conclusions 574
Case study 22.1 Estuarine management *575*
Exercise 22.2: Prepare a Zoning plan *577*
Exercise 22.3 Managing a Great Barrier Reef World Heritage Area *578*
Questions *585*



Marine Protected Areas

Marine protected areas (MPAs) are a very important strategy for conserving marine biodiversity. Large marine protected areas are considered a safe, 'catch all' way of protecting marine biodiversity because they provide the range of different habitats a species requires during its life history. MPAs are a particularly important strategy for fisheries management for they can protect juvenile and adult fish habitats, and protect a proportion of the breeding population of adult fish. Larvae from protected areas can 'seed' fished areas outside.

Multiple-use MPAs are especially important for they provide a way of conserving biodiversity whist enabling planned and ecologically sustainable human uses. Their use have been largely pioneered by Australia, and we now have the most, and the largest areas of MPAs in the world.

A marine protected area is an area of estuary, intertidal shore or sea, especially for the protection and maintenance of biodiversity and of natural and associated cultural resources, and managed through legal or other effective means.

Definition of ' Marine Protected Area' (MPA)

A marine protected area is an area of estuary, intertidal shore or sea, especially for the protection and maintenance of biodiversity and of natural and associated cultural resources, and managed through legal or other effective means.

It may be fully protected like national parks or nature reserves on land, or protected from a specific threatening activity such as prawn trawling or netting. There are many different types and functions for MPAs: marine parks, marine reserves, aquatic reserves, fisheries reserves, fish sanctuaries, wetlands reserves and so on. *Multiple use* marine protected areas protect habitats and species of biodiversity importance, but allow for sustainable uses such as fisheries, tourism, shipping and other marine industries.

Australia's marine protected areas

Australia has around 350 different MPAs, with a total area of over half a million square kilometres (3.5% of our EEZ). These MPAs have been established for a range of different reasons, and they are managed by a range of different agencies. The offshore MPAs are controlled by the Commonwealth government, the inshore ones by the State and Territory governments.

World Heritage Areas

Australia's unique marine environment includes many places of world significance. The most valuable natural and cultural sites around the world are identified by the United Nations as having global or 'World Heritage' values, and are listed in the international 'World Heritage Register'.

Figure 553.1 Beach walkway to marine park
(Illustration Rose Bedford)

The places themselves remain the property of the particular country where they are situated, but are also seen to belong to all the peoples of the world, to care for and pass on to future generations. World Heritage sites overseas include outstanding places, such as the Great Wall of China, the Pathenon and Grand Canyon. World Heritage sites in Australia include the Great Barrier Reef, Shark Bay, Fraser Island, Lord Howe Island and Macquarie Island. Australia's World Heritage sites have been listed primarily for their natural values, but the Sydney Opera House has been nominated for its cultural values.

Criteria for World Heritage nomination

For World Heritage listing natural sites must meet one or more of the following requirements:

1. Outstanding examples representing the major stages of the earth's evolutionary history.
2. Outstanding examples representing significant ongoing geological processes, biological evolution and human interaction with the natural environment.
3. Containing unique, rare or superlative natural phenomena, formations or features of exceptional natural beauty.
4. Important and significant habitats where threatened species of animals and plants of outstanding universal value from the point of view of science and conservation, still survive.

For more about MPAs, see Environment Australia: http://www.ea.gov.au/coasts/mpa/index.html

Commonwealth MPAs

Some large MPAs have been established by the Commonwealth government in Australian waters between 3-200 nautical miles, and in Australia's Offshore Territories which it controls. Where these overlap the States' 3 mile zones, the MPAs operate in cooperation with State governments.

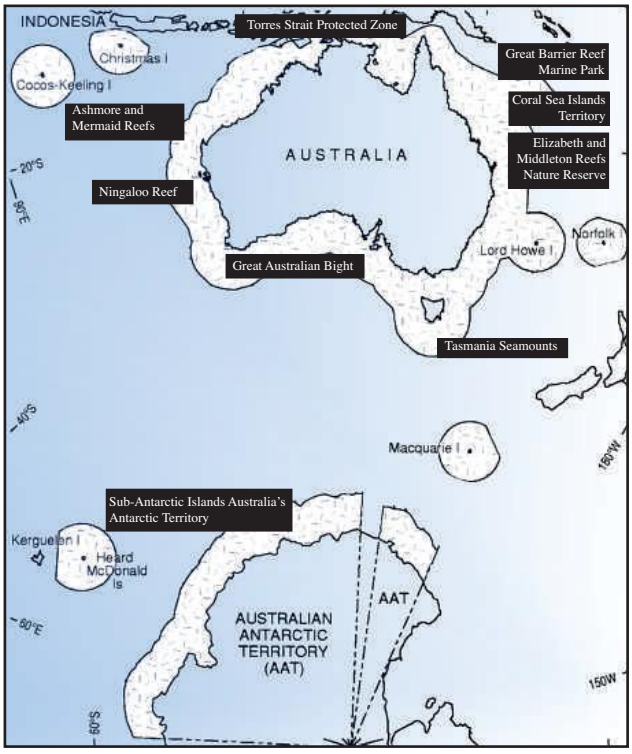


Figure 554.1 Commonwealth marine protected areas (Source EA web page)

Commonwealth MPAs include

- Torres Strait Protected Zone (Established for managing fisheries undertaken by Australia and Papua New Guinea, and to protect the interests of Torres Strait Islander people.)
- Great Barrier Reef Marine Park (Established to protect the GBR, islands and coastal waters.)
- Coral Sea Islands Territory (To protect Lihou, Coringa and Herald Islands and coral reefs in the Coral Sea.)
- Elizabeth and Middleton Reefs Nature Reserve (To protect the most southerly reefs in the world, lying off the NSW coast.)
- Tasmania Seamounts (To protect unique deepwater corals and other life on sea mountains and volcanoes east of Tasmania.)
- Sub-Antarctic Islands (To protect the wildlife on Macquarie and Herd Islands.)
- Australia's Antarctic Territory (To protect Antarctic wildlife and fisheries.)

State and Territory MPAs

State and Territory governments in Australia have also established a large number of MPAs within 3 nautical miles of their coasts. Some of these are extensions of their coastal National Parks or Nature Reserves, down to the water's edge. Others protect specific wetlands, wildlife and fish habitats.

Queensland has a rich tropical marine biodiversity, with large areas of mangroves, seagrass and coral reefs. It has the most MPAs (over 80), and the largest area of MPAs in Australia. Important MPAs include the Great Barrier Reef Islands and Coastal Parks (which form part of the Great Barrier Reef World Heritage Area), Hervey Bay and Fraser Island, and Moreton Bay off Brisbane.

Much of NSW lies in an important tropical/temperate marine overlap zone. NSW has around 20 small MPAs, and a system of protected rock platforms to prevent over-harvesting of shellfish. NSW has recently established large, multiple-use MPAs in the Solitary Islands, Jervis Bay and offshore Lord Howe Island in the Tasman Sea.

Victoria and Tasmania have rich temperate marine biodiversities, with a very high proportion of endemic species. In November 2002 Victoria established a whole set of MPAs, the first time such a systematic approach has ever been undertaken in the world.

South Australia also has a unique, temperate marine biodiversity and supports important fisheries. The large Great Australian Bight Marine Park was established as a multiple-use area and reserve to protect breeding populations of Southern right whales.

Western Australia has the greatest range of marine biodiversity in Australia, for it extends from the temperate waters of the Great Australian Bight, to the rich tropical/temperate overlap in the central west, and the amazing tropical reefs of the north west. It has a large area of MPAs, including the multiple-use Shark Bay and Ningaloo Reef MPAs.

The Northern Territory has a number of small MPAs such as East Point and Casuarina, and the large, multiple-use Cobourg Marine Park. The well known Kakadu Park extends into the sea in some areas. Over 80% of the Northern Territory coast is owned by Aboriginal people, with strong links to the sea.

Importance of large, multiple-use MPAs

Australia has pioneered the development of large, multiple-use marine protected areas.

Unlike terrestrial National Parks, these MPAs protect biodiversity but also allow a range of sustainable uses. They are a good way of planning and managing large regions.

Figure 555.1 Features of marine parks
(Illustration and photo Bob Moffatt)

Colour versions of maps

Full colour versions of each of the sections are available from Public Information
Great Barrier Reef Marine Park Authority
PO Box 1379
Townsville 4810
or visit their web site
www.gbrmpa.gov.au

or check out the reefEd web site
www.reefEd.edu.au

Australian Government
Great Barrier Reef Marine Park Authority

Figure 556.1 Snorkelling on the Great Barrier Reef
(Photo Murray Waite)

Great Barrier Reef Marine Park

The Great Barrier Reef (GBR) is the largest complex of coral reefs in the world. It is made up of 2,900 separate reefs, scattered along 2,000 km of the Queensland continental shelf. The GBR is a multiple-use Marine Park, and is the world's largest marine protected area. It is a World Heritage Area and was listed because of its outstanding geological, biological and cultural heritage significance.

Biodiversity values of GBRMP

The GBR is a vast complex of fringing, platform and barrier types of coral reefs. It includes over 600 rocky or continental islands, and 300 are coral cays, made from the skeletons of corals. There's 360 species of hard coral and 5000 - 8000 species of molluscs (eg. shells). It has some of largest, and safest, populations of threatened species such as giant clams, turtles and dugongs in the world.

Human values and uses

The GBR also has great cultural heritage value. It remains important for the culture and subsistence of coastal Aboriginal communities. It also contains hundreds of shipwrecks, many of which have historic value. 'The Reef' is an Australian 'icon', and has cultural heritage value for all Australians, and others in the world.

Economic values

The GBR also has great economic value. Over two million tourists visit each year, and they spend over a billion dollars. The tourist industry on the GBR and adjacent Queensland coast employs more than 35,000 people, directly and indirectly. It also supports important fishing industries. Around 1,400 commercial fishing vessels operate on the GBR; these employ 1,200 people directly, and earn over $117 million annually. The main targets fished are prawns, mud crabs, reef fish and Spanish mackerel. In addition, there are 35,000 private recreational fishing boats, which largely target reef fish. The recreational catch exceeds the commercial catch of reef fish for many species.

Management goals and arrangements

The GBR Marine Park has the goal to provide for the long-term protection, ecologically sustainable use, understanding and enjoyment of the Great Barrier Reef through the care and development of the Great Barrier Reef Marine Park

Because different parts of the GBR are controlled by the Queensland and Commonwealth governments, the whole area is managed as one, cooperatively. The Commonwealth Great Barrier Reef Marine Park Authority is mainly responsible for planning and policy matters. Queensland's Marine Parks staff are responsible for the actual or 'day-to-day' management. Queensland's Department of Primary Industries manages GBR fisheries.

Oil drilling and removal of coral are prohibited by law. The other uses are regulated by zoning plans, environmental impact assessment, and through a system of permits and licences to control the levels of the activities. Marine Park Zones protect areas of high biodiversity values (like National Parks on land).

Zoning maps - GBRMPA

www.gbrmpa.gov.au/zoning-permits-and-plans/zoning/zoning-maps

+ Legislation, regulations and policies

− Zoning

Zoning maps

Overview maps

About zoning

Commercial fishing and zoning

+ Overview of the Representative Areas Program

+ Plans of management

+ Special Management Areas

+ Site-specific management

+ Permits

+ Environmental management charge

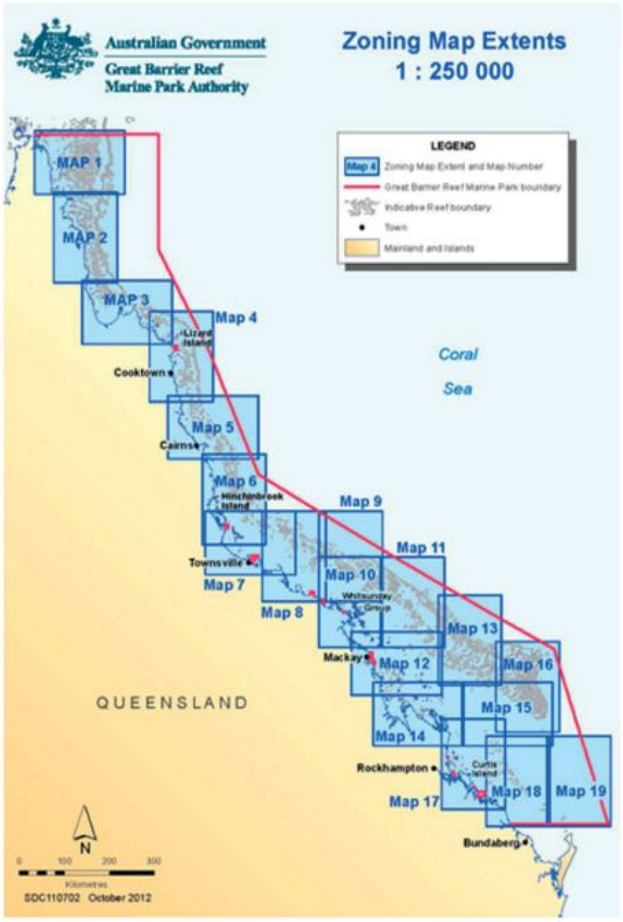
+ Environmental assessment management

Zoning maps

The Great Barrier Reef Marine Park zoning maps are tools to help you get to know the zones in the Great Barrier Reef Marine Park and Great Barrier Reef Coast Marine Park. You can avoid fines if you get to know the zones and what is activities are allowed in each zone.

Zoning exists in the Great Barrier Reef Marine Park to protect plants, animals and habitats. Like a town planning scheme, it defines what activities can occur in each location. If you're heading out on the water make sure you bring a zoning map with you so you can follow the zoning rules and avoid a fine. We've released new look maps to provide you with more information. The zoning itself has not changed, just the look and extent of the maps shown on each map.

You can also access four overview maps (scale 1:1,000,000) and two special edition maps; Whitsunday Group Special Edition map (scale 1:150,000)and the Lizard Island Special Edition map (scale 1:100,000). *note the Lizard Island special edition map is included as an insert in MAP 4 - Cooktown.



For individual maps go to:

http://www.gbrmpa.gov.au/zoning-permits-and-plans/zoning/zoning-maps

Figure 557.1 Great Barrier Reef Marine Park 2016 maps
(Illustration courtesy GBRMPA, copyright, reproduced with permission)

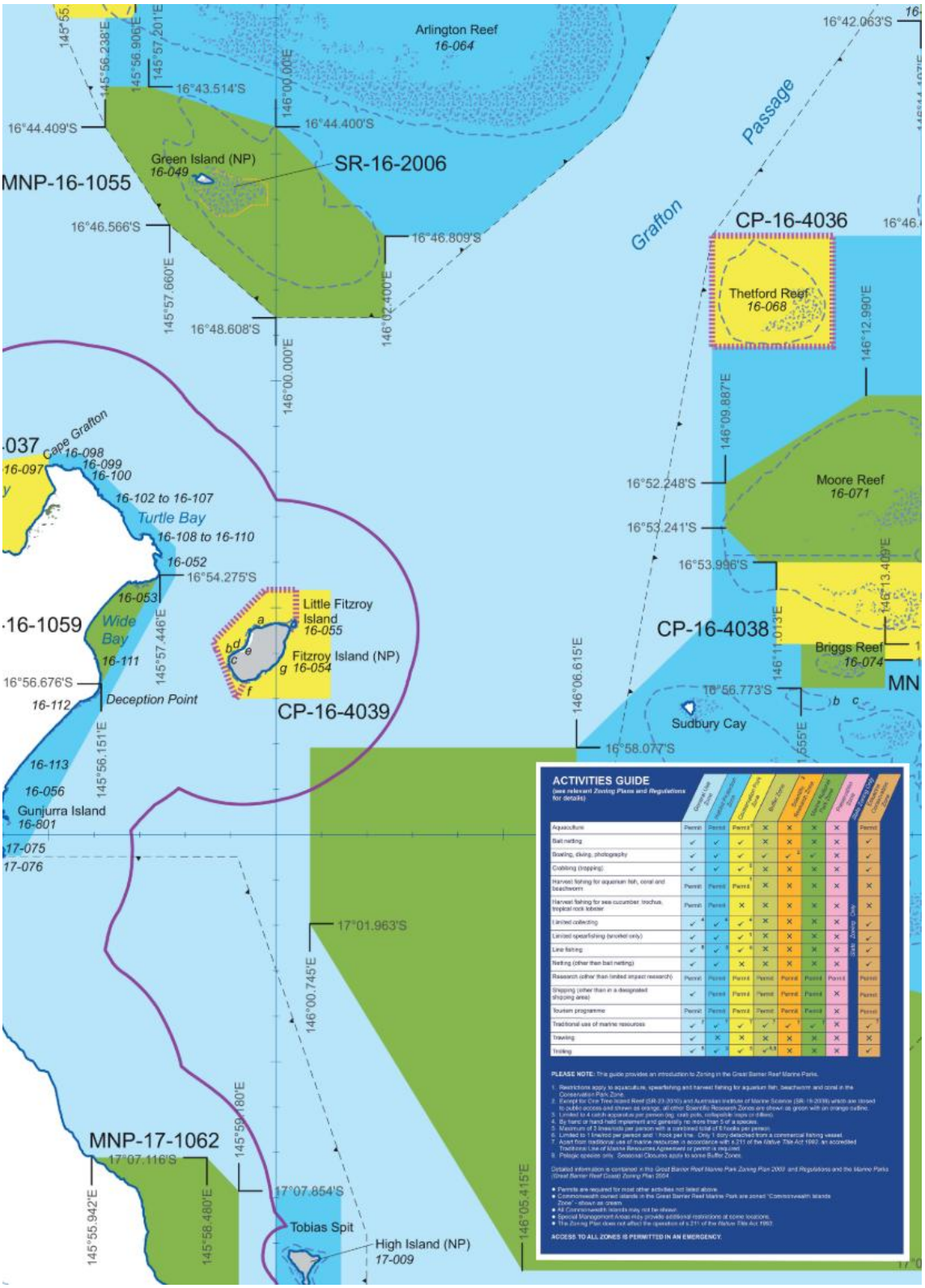


Figure 558.1 An example of marine park zoning.
(Illustration SOMER 1996, copyright Environment Australia reproduced with permission)

Issues and their management

Most of the GBR lies well away from the coast, and well away from human populations. The GBR includes some of the most pristine or natural areas of coral reefs in the world. However, there are many issues and increasing concerns about the 'health' of the GBR.

Runoff from land

There are fears that inner reefs of the GBR, which are closer to rivers, are being degraded by sediments and nutrients washed from the land. Around one third of Queensland's land area drains into the GBR waters, and may bring sediments eroded from land during floods, and fertilizers and other chemicals from sugarcane and other farms.

Effects of fisheries

There are growing concerns about the effects of fishing on the GBR. Prawn trawlers' nets remove many bottom species, such as sponges and juvenile fish, and sometimes drown turtles. Some reefs are heavily fished commercially and recreationally, and populations of Coral trout, snappers, giant cods and Maori wrasses have been locally depleted. Because of its concerns about over-fishing, the Commonwealth government has increased controls on commercial fishing. There are also concerns that too few reefs are fully protected from fishing (less than 15%), and there are plans to increase this number.

Increased tourism

GBR tourism grew very rapidly in the 1980s and 90's. The development of large, high speed catamarans and 'wave piercers' extended the range of tourist vessels, and even the more remote outer reefs were affected by tourism. Large platforms were anchored on reefs for day-trippers, and a floating hotel was even constructed. (The hotel proved unprofitable and was later removed.) Cairns and the Whitsunday Islands became the centres for tourism, and were heavily developed. Large resorts and marinas were constructed on coastal areas and islands. Resorts such as Port Hinchenbrook near Cardwell, and Magnetic Keys on Magnetic Island were very controversial, and divided local communities.

The ecological effects of tourism are controlled. It is prohibited to discharge sewage or other wastes into the Marine Park. Ships must pump out tanks on the mainland, and island resorts must either tertiary treat their sewage, or secondary treat and spray the wastes for irrigation of gardens and golf courses. Visitation to sensitive sites like seabird and turtle nesting sites is regulated.

Shipping

Major shipping channels run along the inside and outside of the GBR, posing the risk of oil and chemical spills. There have been numerous strandings and minor spills, but no major ones so far. 'Oil spill contingency plans' exist for the region and there are stores of equipment and dispersants on hand. However the GBR is vast in size and transport difficult, so the chances of containment of a spill are low. Management has focused more on trying to avoid a disaster, rather than clearing it up.

Bob Moffatt

Figure 559.1 The management of up to 3000 tourists on a reef is a major issue

Over two million tourists visit the reef each year, and spend over a billion dollars.

Murray Waite

Figure 559.2 Water quality becomes an issue when large numbers of tourists swim in the sea

Figure 560.1 Shipping in GBR waters
(Photo Qld Transport)

Figure 560.2 Activities in the catchment greatly affect water quality in the marine park.
(Illustration Kerry Kitzelman)

Figure 560.3 Tourists arrive Moreton Island
(Photo Bob Moffatt)

Ships' pilots, with expert knowledge of GBR navigation, are compulsory on larger ships, and on those carrying potentially hazardous cargoes. Tankers using the GBR shipping routes in the future will have to have double walls. Oil extraction is prohibited within the Marine Park boundaries, but there is a possibility of oil drilling in adjacent areas in the future, and spills could drift into the Marine Park.

COTS and coral bleaching

The GBR has been seriously affected by three periods or episodes of outbreaks of Crown-of-thorns starfish (COTS) since 1960. Each lasted around 10-15 years, and caused massive amounts of coral damage. In the second episode, over 20% of reefs were affected, with most damage in the central third of the GBR, between Cairns and Townsville. The cause of outbreaks, whether natural or human-induced, is still unknown.

The GBR has also been also affected by very severe episodes of coral bleaching. Bleaching is caused when corals discharge their symbiotic zooxanthellae. A massive bleaching event occurred in 1997, and almost 90% of inshore reefs were affected. While many corals subsequently recovered, the longer-term effects are considered to be serious. Another widespread bleaching episode occurred in early 2002, adding to scientists' concerns that this is becoming a recurring phenomenon. The cause of the zooxanthellae stress is thought to be a rise in ocean temperature related to El Nino events. However, some scientists believe this could be related to global warming from the Greenhouse effect.

Conclusions

The GBR Marine Park was the first large multiple use MPA in Australia and the world, and is a model for marine biodiversity conservation, and ecologically sustainable use throughout the world. Although it is effectively managed, there are concerns about effects of fishing, and populations of dugongs and turtles are declining. Runoff from the land is a particularly difficult problem to address, as it lies outside the Marine Park. The problems of crown-of-thorns starfish outbreaks and coral bleaching events are also impossible to prevent.

Moreton Bay Marine Park

Moreton Bay is a large subtropical bay off Brisbane, in South East Queensland. Formed by two of the world's largest barrier sand islands, Moreton and Stradbroke Islands, the bay is shallow and rich in nutrients. It has a high productivity and supports a high biodiversity of tropical and subtropical species.

The Moreton Bay Marine Park stretches 125 km, from Caloundra in the north to the Gold Coast in the south. It is the first multiple-use marine protected area adjacent to a large city. The Bay's catchments are heavily developed and support over 1.5 million people, over half the Queensland population. The catchments are governed by six Local Councils, and many different State Departments, making cooperative management difficult.

Moreton Bay Marine Park

2009 Zoning map

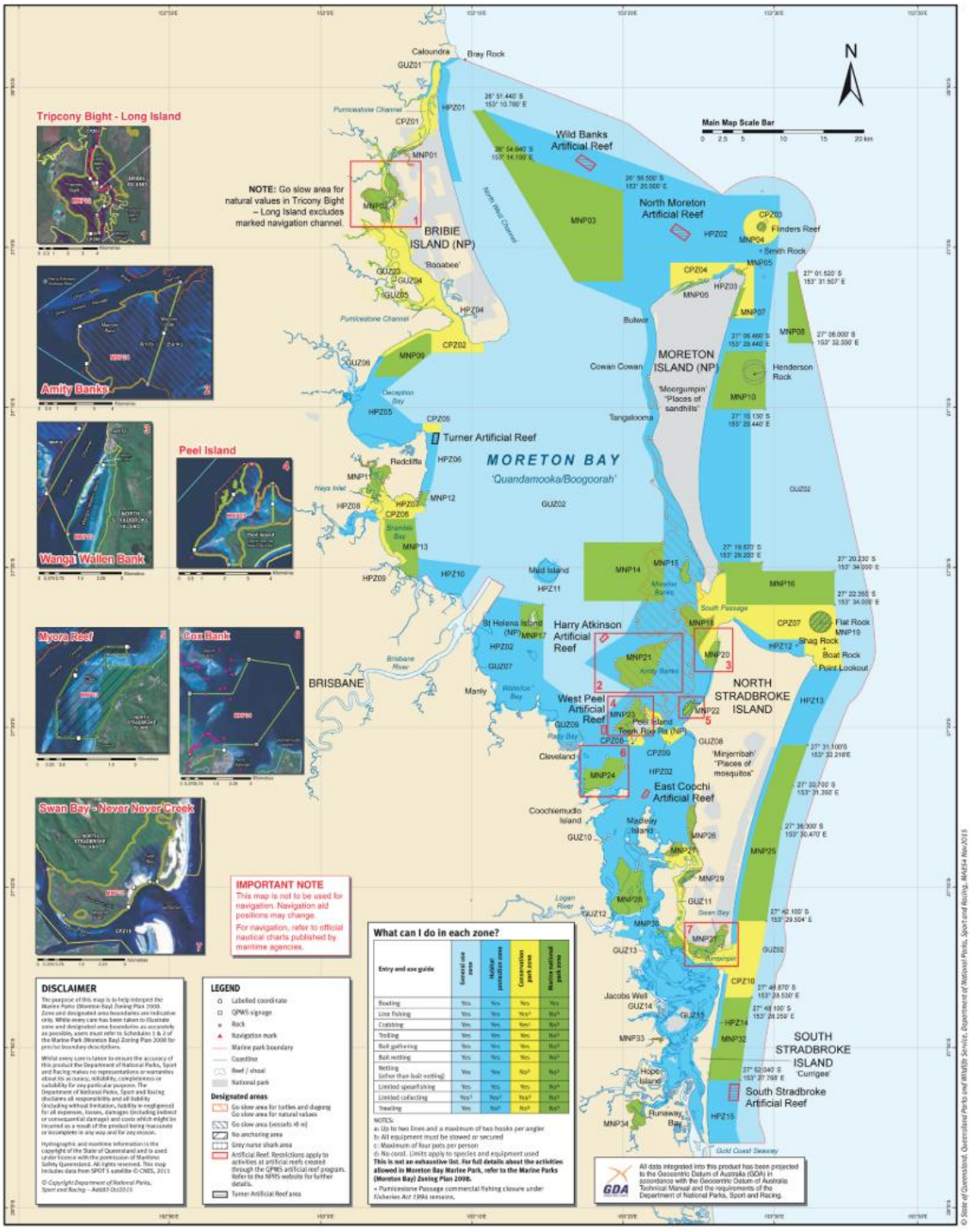


Figure 561.1 Moreton Bay Marine Park
(Courtesy EPA Queensland)

Figure 562.1 Turtle protected areas require boat operators to slow down.
(Photo Bob Moffatt)

Figure 562.2 Turtle slow down sign.
(Photo Bob Moffatt)

Park map reference

The Queensland Government Environmental Protection Agency manages the Moreton Bay Marine Park. Colour maps can be found at:

http://www.env.qld.gov.au/environment/coast/parks/mb.html#Zoning%20plan

Queensland Government
Environmental Protection Agency

Biodiversity values

Moreton Bay lies in the tropical/temperate overlap zone. It has a very high coverage and diversity of seagrass and mangrove wetlands, and corals encrust its rocky outcrops and reefs. These habitats support many fish, turtles, dugongs and dolphins. The Bay is one of the most important fisheries nurseries in eastern Australia, particularly for prawns, mud and sand crabs, and fish such as mullet and tailor. The wetlands and extensive soft shores are important habitat for migratory shore birds.

Human values and uses

Moreton Bay remains important for the Quandamooka ('dolphin people') of North Stradbroke Island. It is also a very important recreational area for the people of the city of Brisbane. Over 300,000 people recreationally fish in the Bay, and around 100,000 pleasure craft use it. The Bay also supports important commercial fisheries, particularly prawns, sand crabs and mullet in season. Industrial developments in the western bay include ports, shipping, shipbuilding, oil terminals and refineries, and many light industries.

Management arrangements

Moreton Bay Marine Park was established in 1993 as a multiple-use marine park, and is managed by Queensland Parks and Wildlife. It has a zoning scheme comprising:

- General use (shipping, trawling permitted),
- Habitat protection (no shipping and mining),
- Conservation (no trawling),
- Protection (designated areas for turtle, dugong and shorebird protection).

Fisheries, a major use and controversial issue, are managed by Queensland Department of Primary Industries, a separate government department. The six Local Governments in the Bay's catchments have collaborated to form the *Healthy Waterways* body which manages the Bay's water quality.

Issues and their management

As is to be expected in a bay near a large city, there are many conflicting uses and environmental issues in the Moreton Bay MP. Over 20% of salt marsh and 10% of mangroves have been reclaimed for development or dredged for marinas. Dredging for limestone for cement, building aggregate and shipping channels has been extensive. North Stradbroke Island has been heavily mined for mineral sands and silica. Fish stocks have declined from overfishing, and there is open competition between commercial and recreational fishers. Anchor and propeller damage to corals and seagrass is a problem. Speed boat strikes on turtles and dugong occur, even in the special 'go-slow' zones which protect feeding areas.

The area of total protection in the Marine Park is also very small, and the Bay's range of biodiversity is not well represented. The zoning plan is to be revised, and hopefully the protected area will be increased.

Water quality issues

Declining water quality is a significant issue. The catchments are heavily used and runoff of sediments and nutrients into the Bay is high. There are problems in the inner bay where the circulation is limited. Seasonal outbreaks of a toxic algae *Lyngbya*, which kills fish and causes skin irritations in bathers, are blamed on elevated nutrients. To improve water quality in the Bay, the Local Councils which control the catchments collaborated in a detailed study of the environment. This found that water quality near Brisbane was not good, but that in the eastern ocean side is excellent. The Councils combined to established *Healthy Waterways*, a body to better manage catchments, and there are already some improvements in water quality.

Conclusions

Moreton Bay is a unique area with high biodiversity value, but is subject to intense human uses. The Moreton Bay Marine Park demonstrates the potential of multiple-use protected areas in areas of high usage. *Healthy Waterways* also demonstrates how a cooperative approach to catchment management is possible.

Figure 563.1 Shipping is a major activity in Moreton Bay Marine Park.

Solitary Islands Marine Park (SIMP)

New South Wales has recently established three large, multiple-use marine protected areas: the Solitary Islands region near Coffs Harbour on the North Coast, Lord Howe island in the offshore Tasman Sea, and Jervis Bay on the South Coast. Another is planned for the Byron Bay area on the far North Coast.

The NSW Solitary Islands Marine Park (SIMP) extends 75 km north from Coffs Harbour to the 3 mile limit, and is over 70,000 ha in area. Commonwealth waters beyond 3 miles increase its size to almost 100,000 ha.

Biodiversity values

The SIMP region includes many different habitats: estuaries, beaches, rocky shores, shallow and deep continental shelf sediments and rocky reefs, supporting salt marsh, seagrasses, mangroves, and intertidal, algal, coral and sea floor communities. The Solitary Islands lie in a tropical/temperate overlap zone, or 'ecotone'. They are bathed by the strong East Australian Current (Figure 563.3) which brings warm tropical water and tropical larvae from the south Pacific and Great Barrier Reef region. This current meets the cold southern water around the Port Stephens area, and is diverted into the Tasman Sea, bringing warm water and larvae to Lord Howe Island, the southern-most coral reef in the world.

The subtropical coral reefs are unique. They are dependent on the warm east Australian Current, and are few in number, small in size and are very widely separated (many by hundreds of kilometres). They occur at the lower temperature limit of coral growth and do not grow fast enough to form reef structures. They are made up of a mix of tropical and cold water species but are dominated by a few specialist subtropical corals.

Figure 563.2 Ball's Pyramid & Lord Howe Island

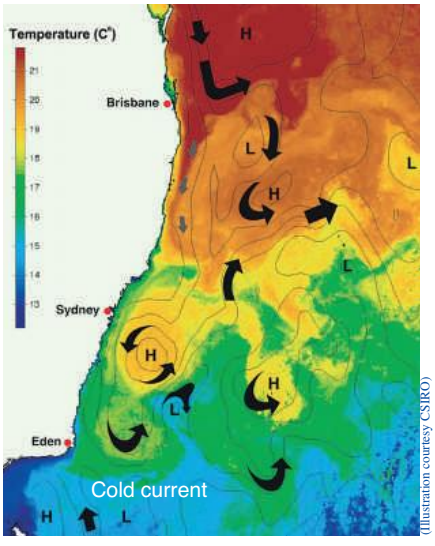


Figure 563.3 Currents off Coffs Harbour

These subtropical species can tolerate colder waters, and have very long-lived larvae which can survive up to 90 days in the plankton. The SIMP reefs support almost 300 species of macro algae, 100 species of coral and 300 species of fish. Many of the reefs are very important breeding grounds for the Grey nurse shark, listed as an endangered species in NSW.

Bob Moffatt

Figure 564.1 Yuraygir National Park

Human values and usage

The region has a low human population (around 60,000), with one small city (Coffs Harbour) and several small towns and villages. The land adjacent the northern part is almost entirely in the Yuraygir National Park. The coastal catchments in the south are intensively cultivated for bananas. The main industries are tourism, and commercial fishing for prawns, snapper and offshore tunas.

Management

The SIMP is managed by the NSW Marine Park Authority, which includes NSW National Parks and NSW Fisheries staff, to provide a more united or integrated approach to marine environmental and fisheries management. It includes many of the rivers and streams in the northern coast, and is the first marine protected area in Australia to do so. The interconnected land, catchments, estuaries and marine ecosystems are all protected in the northern region. The zones, which came into effect in 2002 are: General use (36%: allows trawling, trapping and other fishing); Habitat protection (52%: prohibits trawling, netting, trapping and longliners, and allows other fishing); and Sanctuary (12%: total protection).

NSW GOVERNMENT Marine Parks

Park map reference

Marine Parks Authority
http://www.mpa.nsw.gov.au/)
Executive Officer
GPO Box 5341
SYDNEY NSW 2001
AUSTRALIA

Figure 564.2 Cane fire Ballina
(Photo Murray Waite)

Issues

While the northern catchments are amongst the most pristine in eastern Australia, those in the south have been seriously contaminated by arsenic and other pesticides from banana cultivation. They do not appear to have affected the Marine Park because of the strong coastal currents. With modern landuse practices and environmental regulations, water quality is steadily improving. The offshore rocky reefs are heavily fished, and there is competition between the recreational and commercial line fishers. Lobsters have been overfished, and snapper landings have declined. Because of their small size and isolation, the coral communities are vulnerable to anchor and diver damage, heavy seas, and oil spills.

Initial community hostility

The Marine Park announcement in the mid-1990s was extremely unpopular initially as it was viewed locally as a 'political promise' in a NSW State election to win over 'green votes'. Community education and involvement was inadequate, and people initially feared they would lose all fishing rights. Anti-marine park protests were held, and opinion polls showed that most residents were strongly against the Park. The development of the new zoning plan between 1998-2001 continued to be controversial. Commercial and recreational line fishers and trawler operators were upset about losing important fishing grounds, and conservationists extremely critical of the small area actually protected. However, the final plan has now been well received by the local population. The controversy illustrates the need to involve the community from the early stages of the MPA planning process.

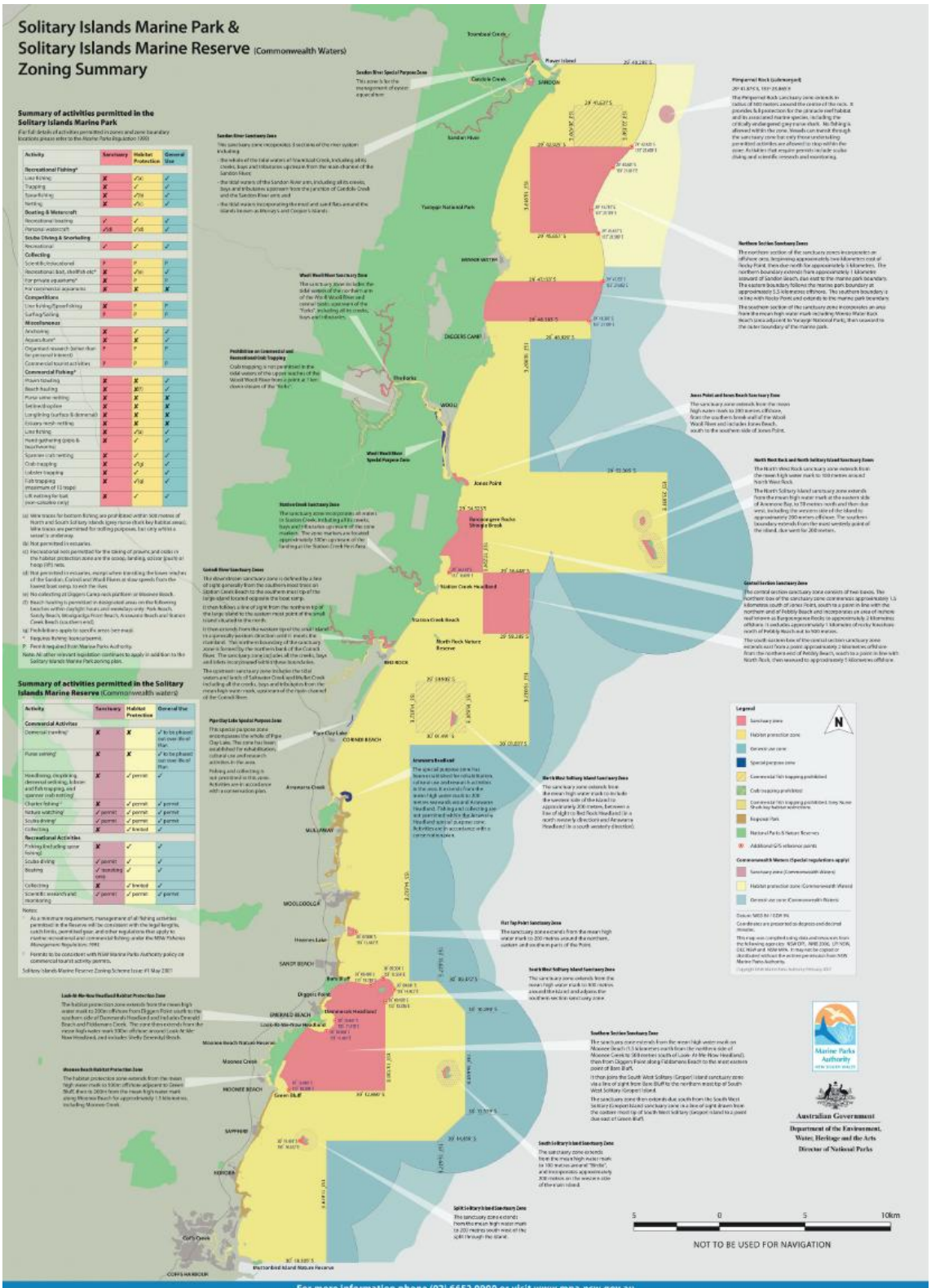


Figure 565.1 Solitary Islands Marine Park
(Illustration courtesy Environment Australia)

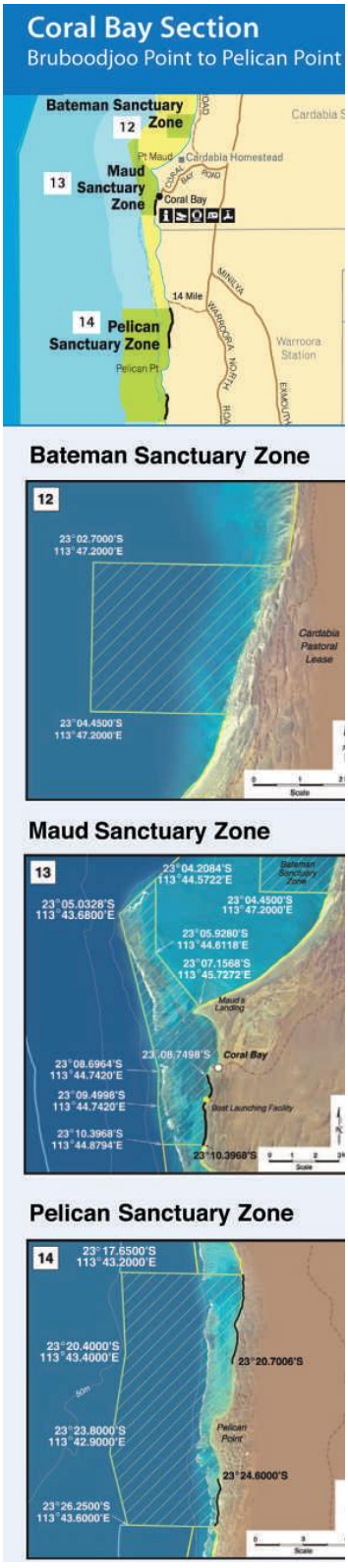


Figure 566.1 Ningaloo marine park
(Illustration courtesy WA Department of Environment and Conservation)

Ningaloo Marine Park

Ningaloo Reef is a unique, 260 km-long fringing coral reef about 1200 kilometres north of Perth. It is the longest fringing reef of its type in the world. The Ningaloo Marine Park, declared in 1987, stretches for some 260 kilometres, from Bundegi Reef in Exmouth Gulf around North-West Cape to Amherst Point, south of Coral Bay, and covers more than 4000 sq km.

Biodiversity values

Ningaloo Reef has around 217 species of corals, 600 species of molluscs and 500 species of fish. There are clumps of stunted mangroves along the coast, and large beds of seagrass in the lagoon. These are important fish habitat and support significant populations of dugongs and turtles. Between March and May each year, it is visited by the world's biggest fish, the Giant Whale shark, which is over 12 metres long and 11 tonnes in weight. Humpback whales visit in winter.

Human values and uses

Ningaloo has high human cultural significance. Aboriginal habitation dates back as far as 33,000 years, and it was one of the first places in Australia to be visited by Europeans, the Dutch in 1618. The townships of Exmouth and Coral Bay lie on the adjacent coast. Ningaloo receives over 60,000 visitors a year; many come to camp and fish in the winter. Recreational fishing pressure is increasing, and a daily bag limit of 17 kg of fish (or 10 kg of fillets) has been imposed. Queensland gropers and Potato cod, are protected, as are all corals and most molluscs and crustaceans. Commercial prawn trawlers fish in the northern zone, and line and trap boats fish in General Use Zones. There are oil leases in offshore areas, but oil drilling is prohibited within the Marine Park.

Management

Ningaloo is managed by the WA Department of Environment and Conservation, and the fisheries are managed by WA Fisheries Department.

General use zones permit commercial fishing and recreational activities. Recreational zones allow only recreational fishing. Seven Sanctuary zones are totally protected.

Issues

In the past human pressures have not been great in the region, and there have been few serious issues. The adjacent coast is arid and sparsely populated, and there is little terrestrial runoff. Fisheries landings are not large, around 200 tonnes per year, but there have been some concerns about over-fishing. There is no pollution, though oil spills are a potential hazard. However, despite the low human impacts, massive outbreaks of a coral-eating snail *Drupella* occurred in the 1980s, killing up to 50% of corals. As with the Crown-of-thorns starfish on the Barrier Reef, the causes were not identified, but it was suggested that it may have been the result of overfishing of snappers and other natural predators.

A major issue facing Ningaloo is development which in the past has been low key, with scattered small caravan parks and motels. Ningaloo has been 'discovered', and a major tourist resort and marina is planned. This will involve major dredging and reclamations in a sensitive fringing reef area, and increased human use.

Ningaloo Marine Park Sanctuary Zones and Muiron Islands Marine Management Area

Marine park zoning

Ningaloo Marine Park is managed under a cooperative arrangement between the Australian Government Department of Sustainability, Environment, Water, Population and Communities and the Western Australian departments of Parks and Wildlife, and Fisheries. Please note that some different regulations apply in the Commonwealth waters (located three nautical miles from the shore) to those of the state waters.

Ningaloo Marine Park (state waters)

Sanctuary zones

Sanctuary zones provide total protection for marine life. They allow visitors to observe marine life in its natural state. No extractive activities are permitted in these zones, which means no recreational or commercial fishing are allowed.

Special purpose (benthic protection) zones

These zones allow visitors to observe marine life in its natural state, however recreational 'troll' fishing is allowed. No other extractive activities are permitted.

Special purpose (shore-based activities) zones

These zones are established alongside some sanctuary zones to allow shore-based recreational fishing for finfish only (no other extractive activities are allowed).

Recreation zones

These zones make up large areas of the marine park. Recreation zones are managed for nature conservation and recreation, including recreational fishing.

General use zones

These zones are managed for nature conservation while allowing for sustainable commercial and recreational activities.

Zone markers

Some sanctuary zones may be marked by yellow in-water buoys or land-based reference posts with directional triangles onshore pointing into the no-take zone. These markers should only be used as a reference guide to line up the zone boundary and the use of global positioning systems (GPS) is recommended at all times (see maps overleaf for sanctuary zone coordinates).

Spear guns and gidgies

These are not to be used in Ningaloo Marine Park between Winderabandi Point and Tantabiddi Boat Ramp and in the Ningaloo Commonwealth Marine Reserve. Species restrictions also apply. Please contact the Department of Parks and Wildlife or the Department of Fisheries in Exmouth for more information.

Marine Management Area zoning

Marine Management Areas provide an integrated management structure over areas that have both high conservation value and intensive multiple use. The Muiron Islands Marine Management Area is one of only two marine management areas in WA.

Conservation areas

Conservation areas within the Muiron Islands Marine Management Area are essentially the same as sanctuary zones. They allow visitors to observe marine life in its natural state. No extractive activities are permitted in these zones, which means no recreational or commercial fishing are allowed.

Fishing rules

Fishing rules apply throughout the marine park. Refer to the *Recreational fishing guide* for details. Available from the Department of Fisheries offices or online at www.fish.wa.gov.au.

Ningaloo Commonwealth Marine Reserve

Recreational fishing must be undertaken in accordance with the current authorisation and conditions for recreational fishing available at:
www.environment.gov.au/marinereserves/north-west/ningaloo/

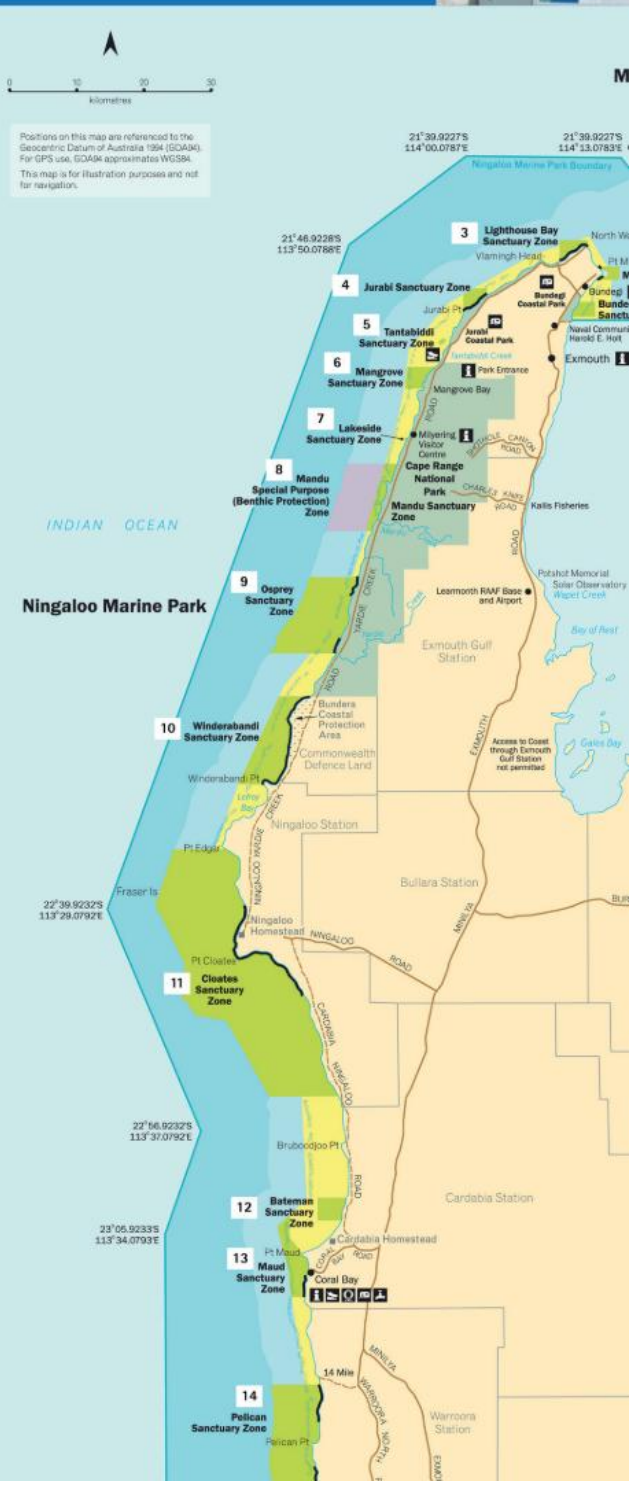


Figure 567.1 Ningaloo marine park map
(Illustration courtesy Department of Environment and Conservation, reproduced with permission)

Marmion Marine Park

Situated just north-west of Perth CBD, Marmion Marine Park was first declared in 1991. The park is used extensively for recreation and contains popular surfing, boating, diving and swimming areas. The major issues that face this park will be the increased use by the residents of Perth and its suburbs and new cities.

Shark Bay Marine Park

Shark Bay, 800 km north of Perth, is on the westernmost part of Australia. Shark Bay was placed on the World Heritage list in 1991, and satisfied all four natural criteria for listing: Major stages of the world's evolutionary history; Geological and biological processes; Natural beauty; and Threatened species.

The Marine Park is part of the Shark Bay World Heritage Area, which includes over 20,000 sq km of terrestrial nature reserves and national parks, and 10,000 sq km of marine protected areas. The Park's coastline is 1,500 km long, and includes the 200 m high Zuytdorp cliffs, which are amongst the highest of the Australian coastline. Shark Bay's salinity gradient ranges from oceanic (salinity 35-40 g/L) in the northern and western parts of the bay, to hypersaline in Hamelin pool (salinity 45-47 g/L). The Gascoyne and Wooramel Rivers run into the eastern part of the Bay but there is very little surface run-off because of the low rainfall.

Biodiversity

Pockets of mangroves are found along the shores, but the most important feature of Shark Bay are the seagrass, the largest beds in the world. Twelve species (35% of the world total) cover an area of 4,000 sq km. These support over 10,000 dugong (12% of the world population) and many turtles. There are over 80 coral species. Large numbers of whalers, Tiger sharks and Hammerhead sharks and rays give the bay its name. Dolphins are abundant, and groups come into Monkey Mia daily to be fed. Humpback and southern right whales use the bay as a migratory staging post.

Figure 568.1 Stromatolites
(Photo CALM)

Hamelin Pools are notable for their stromatolites (Figure 568.1). These are *living fossil* microbial communities, which form coral-like structures. The living microbes that build the stromatolites are similar to those found in 3500 million year old rocks, which are the earliest record of life on earth. Their population densities are 3,000 million individuals per square metre! The organisms use sediment and organic material to build stromatolites up to 1.5 metres high - up to 10 million times their size.

Human values and uses

Aboriginal occupation extends to 22,000 years ago, when most of the area was dry land. Shark Bay was the site of the first recorded European landing in Western Australia, by Dirk Hartog in 1616. It was named by the English buccaneer William Dampier in the late 1600s. Pearling was the biggest industry from 1850-1940s.

Shark Bay has a permanent population of only around 750, at Denham and Useless Loop, but receives over 160,000 visitors a year. The main industries are prawn and scallop fishing (27 trawlers, 2,000 tonnes of prawns, and 3,500 tonnes of scallops, worth around $35 million per year). Tourism is important and more than 160,000 visitors per year; around 100,000 per year come to see the famous Bottle nose dolphins at Monkey Mia.

Figure 568.3 Dolphins at Monkey Mia
(Photo Bob Moffatt)

Shark Bay issues

Prawns and scallops have been overfished in the past, and fishing nets have been responsible for accidental by-catch of dugongs and turtles. Artificial feeding has affected the natural feeding and health of the Monkey Mia dolphins, but this is now rationed.

Management

Shark Bay is managed by the WA Department of Conservation and Land Management (CALM), and its fisheries are managed by WA Fisheries Department.

Marine Parks of South Australia

South Australia's biologically diverse coastal and marine ecosystems are of great ecological, cultural and economic importance.

South Australia was the first State to legislate for MPAs, in 1971. Primary responsibility for the protection of aquatic habitats lies with the Fisheries Act 1981 but MPAs may also be declared under the National Parks and Wildlife Act 1972 and the Historic Shipwrecks Act 1981.

South Australia currently has over 30 MPAs, with a total area of around 20,000 sq km.

Figure 569.1 Whalers Way Marine Reserve South Australia
(Photo Bob Moffatt)

The main MPAs are shown in Figure 569.3:

1. Point Labatt;
2. Cowleds Landing;
3. Blanche Harbour;
4. Yatala Harbour;
5. Goose Island;
6. Troubridge Hill;
7. Chapman Creek;
8. Barker Inlet;
9. Port Noarlunga and Onkaparinga Estuary;
10. Aldinga Reef - see Figures opposite;
11. West Island;
12. American River;
13. Bales Beach, Seal Bay;
14. Clinton Conservation Park;
15. Troubridge Island Conservation Park; and
16. Dangerous Reef Conservation Park.
17. Great Australian Bight Marine Park.

Bob Moffatt

Bob Moffatt

Figure 569.2 Aldinga marine park SA

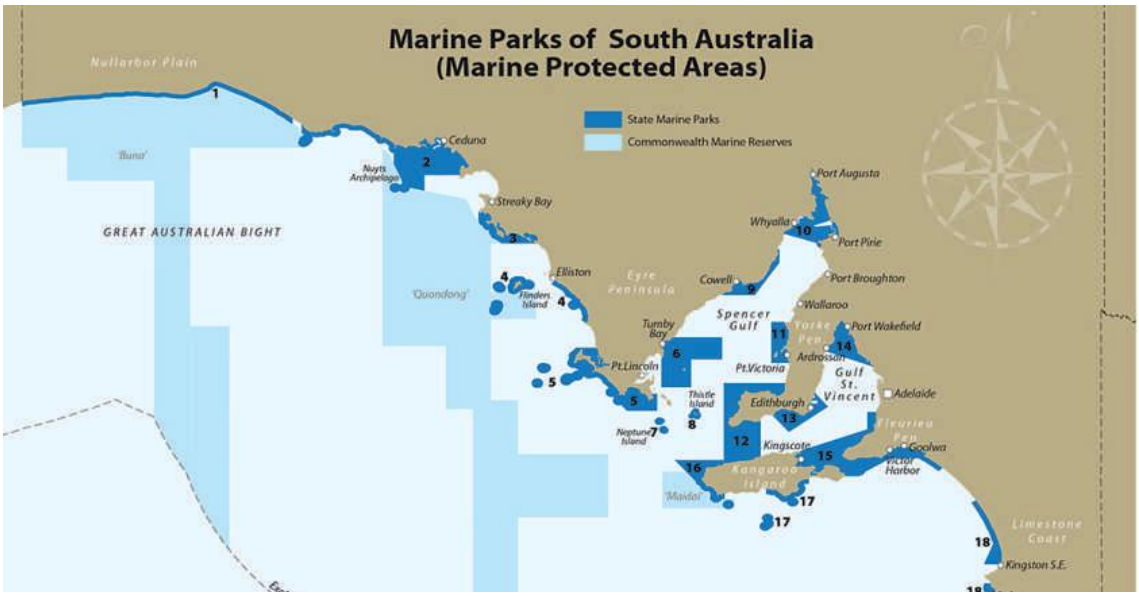


Figure 569.3 Marine Parks of South Australia in 2002.
(Illustration SOMER 1996, copyright Environment Australia reproduced with permission)

Marine Parks of the Northern Territory

The Northern Territory contains some of the most pristine and culturally, scenically and ecologically important coastal and marine areas in Australia's tropics. Aboriginal people control around 84% of the coastline, to the low water marks.

Agencies with responsibilities for marine conservation include the Conservation Commission of the Northern Territory and the Department of Primary Industry and Fisheries. So far MPAs have been established in the Cobourg and Darwin areas and others are planned.

The Northern Territory's major MPAs are:

1. Cobourg Marine Park;
2. Casuarina Coastal Reserve;
3. East Point Aquatic Life Reserve; and
4. Beagle Gulf Marine Park

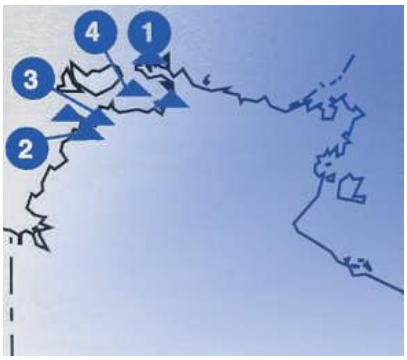


Figure 570.1 Marine parks of NT in 1996
(Illustration SOMER 1996, copyright Environment Australia reproduced with permission)

Figure 570.2 Fishing Northern Territory Marine Park
(Photo Zigler Ent)

Figure 570.3 Cooking barramundi, Northern Territory style
(Photo Zigler Ent)

Victorian's new Marine Parks

Source: www.parkweb.vic.gov.au/

Legislation was passed by Parliament in June 2002 to establish 13 Marine National Parks and 11 Marine Sanctuaries. The National Parks (Marine National Parks and Marine Sanctuaries) Act, 2002, came into effect on 16th November, 2002.

Marine parks and sanctuaries

Marine National Parks feature representative examples of Victoria's marine habitats and their associated flora and fauna, and Marine Sanctuaries are set aside to protect smaller areas with significant natural values. Sites for the new Marine National Parks and Marine Sanctuaries have been chosen to ensure that a system representative of Victoria's diverse marine habitats is protected for future generations. To achieve this the parks have been spread across Victoria's five marine bioregions.

Why marine parks are needed

Marine communities in Australia's southern waters are unique, with around 90% - 95% of the plants and animals found nowhere else on earth.

Just as National Parks are set aside for the preservation of natural environments on land, we also need protected areas in the sea to keep safe our special marine environments. Victoria's new Marine National Parks System will contribute to the long term ecological viability of marine and estuarine systems, maintain ecological processes and protect marine biodiversity.

Victoria's marine environment is interconnected, with eggs, larvae, fish and other marine life moving along the coastal waters.

By having a network of protected areas, marine populations can be protected on a regional and local scale throughout their life cycles. The ecological and other benefits of establishing Marine Protected Areas have been proven both interstate and overseas, and include:

- *Maintaining and enhancing species diversity, genetic diversity and habitat complexity;*
- *Protecting rare species or populations, unique and fragile habitats, representative and highly productive areas and the general functioning of marine ecosystems;*
- *Protecting habitats from damage caused by extractive uses;*
- *Stimulating education, research and tourism in marine systems;*
- *Providing scientific reference sites and benchmarks; and*
- *Helping to achieve sustainable fisheries and insure against fish stock collapses, overfishing and other environmental impacts.*

Habitats that are protected

Marine National Parks and Marine Sanctuaries include examples of Victoria's diverse marine habitats, including intertidal rocky shores, subtidal rocky reefs, seagrass beds, sheltered intertidal flats, mangroves and saltmarsh habitats, kelp forests, sponge gardens, intertidal sandy beaches, subtidal soft substrates and pelagic (open water) environments.

Follow the planning process

You can follow the planning process at:

www.parkweb.vic.gov.au/

http://www.parks.vic.gov.au

Commercial and recreational fishing will not be permitted in the Marine National Parks or Marine Sanctuaries, nor will other extractive or damaging uses such as aquaculture, exploration drilling, oil and gas extraction, dredging, or waste disposal. Access for recreation, tourism, education and research within these areas is generally unrestricted, although subject to permit in some instances.

Yes	*No*
- Swimming, snorkelling and SCUBA diving - Research, filming and photography subject to permit - Boating (including motor boating and yachting) - Anchoring a boat (though care should be taken) - Surfing and wind-surfing - Bird, dolphin and whale watching	- Any form of fishing (both of fin fish and invertebrates) - Collection or removal of shells, coral or any other cultural, geological or biological item. - Removal or disturbance of marine plants and animals - Exploration / extraction of minerals & stone - Waste and ballast discharge - Aquaculture

Figure 571.1 Source www.parkweb.vic.gov.au

Copyright State of Victoria, reproduced with permission

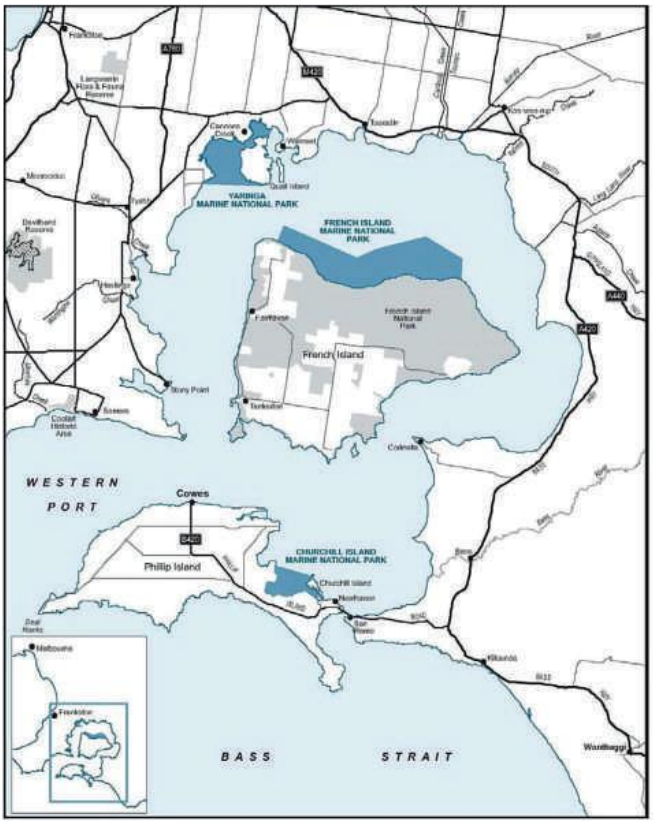


Figure 572.1 Marine Parks Port Phillip Bay
(Illustration Parks Victoria, copyright Victorian Government, reproduced with permission)

How do I know that I'm in a Marine National Park or Sanctuary?

Clear marking of boundaries is important in ensuring visitors to Marine National Parks and Marine Sanctuaries are able to comply with the legislation and regulations which apply in these areas. Boundary identification will be communicated via:

- on-site signage and maps at key access points;
- park notes with maps;
- maps and information available on the Parks Victoria and NRE websites;
- use of in-water navigational aids where practical; and
- shore markers which provide a line-of-sight for vessels.

Marine National Parks and Marine Sanctuary boundaries will also be progressively incorporated into navigational charts and other publications.

What signs are there to help me recognise that I have entered one of these areas?

In addition to shore markers and in-water piles and bouys, signage delineating the boundaries of the park or sanctuary will be provided at key access points such as carparks, boat ramps and information shelters. The diversity and physical nature of the marine environment (particularly along the open coast) poses significant practical constraints to implementing an "in water" marking system for all areas. Global Positioning System (GPS) is therefore considered a more appropriate identification and navigational tool than bouys or pylons in high wave-action areas.

However, in embayments, physical markers will be used wherever practical.

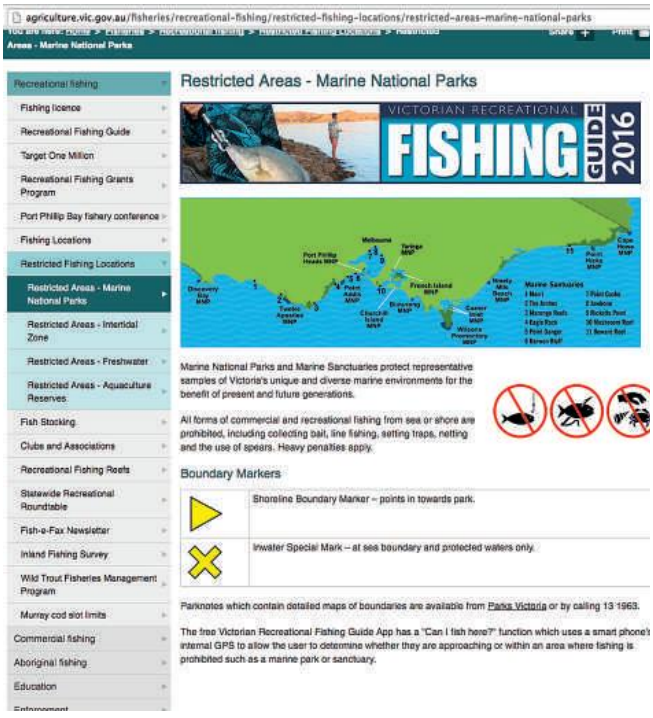


Figure 572.2 http://agriculture.vic.gov.au/fisheries
(Illustration Parks Victoria, copyright Victorian Government, reproduced with permission)

Tasmanian Marine Parks

Tasmania has diverse cool temperate and subantarctic marine habitats. It includes the core of one of the world's smallest marine bioregions, and a bioregion with one of the world's highest diversities of marine plants.

MPAs are declared under the National Parks and Wildlife Act 1970 and are jointly managed by the Tasmanian Parks and Wildlife Service and Fisheries agencies under the Fisheries Act 1959.(79)

Figure 573.1 Wineglass Bay Tasmania
(Photo Bob Moffatt)

Figure 573.2 Penguin
(Photo Bob Moffatt)

In 1996, Tasmania had 19 MPAs (about 2% of the coast), the majority of which were set aside for reasons other than marine conservation. The main MPAs are:

- Maria Island National Park (see Figure 573.3);
- Governor Island Marine Nature Reserve (see Figure 573.3);
- Tinderbox Marine Nature Reserve;
- Nine Pin;
- Point Marine Nature Reserve; and
- Port Davy/Bathurst Harbour in the Southwest National Park.
- Tasmanian Seamount reserve (World Heritage 2002)
- Macquarie Island and Antarctica

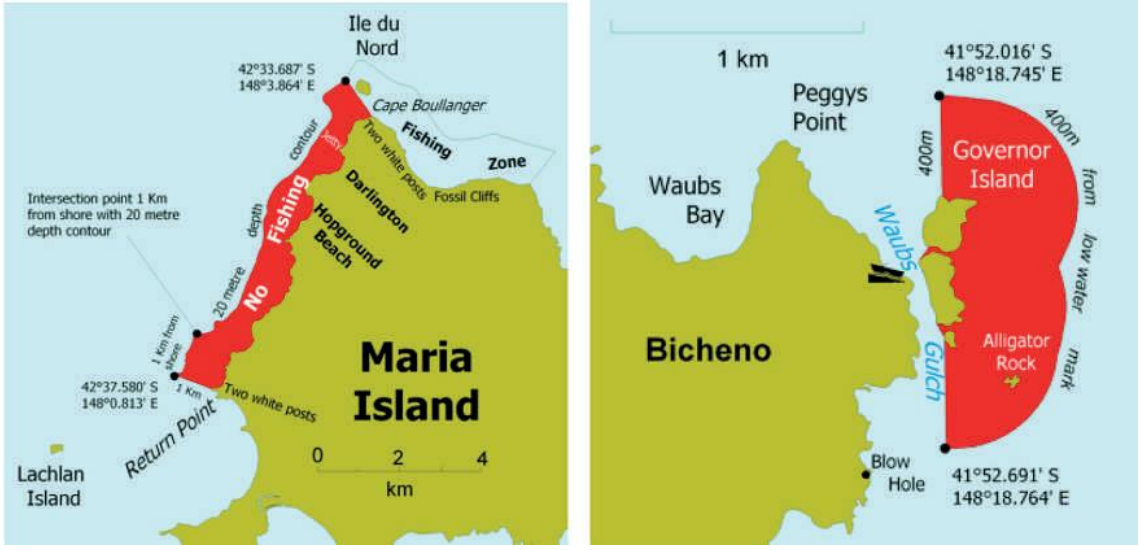


Figure 573.3 Marine parks in Tasmania
(Illustration SOMER 1996, copyright Environment Australia reproduced with permission)

General conclusions

Australia has a unique marine biodiversity, with some of the largest areas and highest diversity of coral reefs, seagrasses, mangroves and algae. We also have some of the largest (and in some cases the last) populations of some threatened marine species such as turtles, dugongs and giant clams.

Australia's marine environment is of great economic, social and cultural value to Australians. However, although we are a young nation and our human populations are small, we have had some serious impacts on our environment. Even estuaries and bays off rural areas with low human populations have been degraded by elevated sediments and nutrients from poor land-use practices. An important lesson we have learnt is that land and sea are interconnected, and marine environmental management really begins on land.

In the past many marine resources have not been sustainably used. The great whales, seals and some other marine species were hunted to virtual extinction. Many fisheries world-wide, and in Australia, have been over-harvested, and are declining. This is compounded by the effects of poor water quality on fish and fisheries habitat.

The ideal of carefully planned ecological sustainable development (ESD) is an important alternative to the ways of the past.

The main problem in the past was the lack of any planning before a new natural resource was developed. Long-term planning is therefore the key. Large, multiple-use marine protected areas, which protect marine biodiversity while allowing for ecologically sustainable uses, have become an important planning and management strategy in the marine environment. The idea has been expanded in Australia's Oceans Policy to Australia's whole 200 mile Exclusive Economic Zone. Large-scale plans for ecologically sustainable use are now being developed for south eastern Australia (mainly Victoria, Tasmania and part of NSW and South Australia), and northern Australia (from Torres Strait to the Gulf of Carpentaria).

However, it is obvious that ESD will be difficult and expensive in the short term, and may involve some changes in our ways of life. But there are really no alternatives. The role of future generations will be to correct the mistakes of the past, to sustainably use and restore our amazing marine environment.

Figure 574.1 Pristine coastline
(Photo Murray Waite)

Case study 22.1 Estuarine management

By Tim Ryan

Variability of Australian Estuaries

Before sound decisions can be made in relation to estuarine management and research, it is necessary to assess the resource.

An assessment was completed for Australia (Bucher & Saenger 1989,1991) with the support of the Australian National Parks and Wildlife Service and the Australian Recreational and Sport Fishing Confederation. Estuaries were defined as semi-enclosed bodies of water and their adjacent wetlands that have input from both marine tidal inundation and terrestrial runoff.

Australian estuaries are being increasingly used for a range of activities even though there is high public awareness of the importance estuarine wetlands hold for conservation. Table 3 in Figure 575.1, shows the total estuarine areas of open water, intertidal, mud/sand flats, mangrove, seagrass and saltmarsh areas in the estuaries of each state.

Part A: Mangrove and Saltmarsh Estuaries

The supply of fresh water to Australian estuaries is highly variable both in amount and regularity. Around Australia the tidal range varies from 1.0 m at Little river, Victoria to 12.2 m at eight estuaries in Western Australia. The nature of fresh and salt water supply will affect the type and extent of wetlands associated with an estuary. Other characteristics such as estuarine configuration and geology and low temperatures (particularly in the south) add further to the overall estuarine variability.

Study Figure 575.2 and answer the questions below.

Questions

1. If an area experiences average rainfalls of 1000 mm per year suggest the percentage of mangroves expected in estuaries in that area.

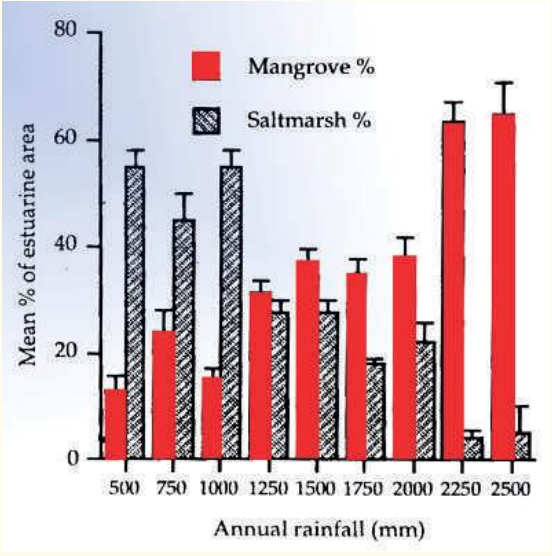


Figure 575.2 Mean percentage of tropical and subtropical estuaries covered by mangrove and saltmarshes with annual rainfall categories.

2. Propose a hypothesis from the information provided on the figure to explain the effect of rainfall on the proportions of mangroves and saltmarshes found in an area. What is the average rainfall in your local area? Do you believe you have the proportions suggested by the figure in your local area? If not, suggest a reason for these discrepancies.
3. Outline other factors, which may affect the proportion of mangroves to saltmarshes in an area.
4. Formulate a plan or method of investigation that could be used to tabulate these factors.

Table 3: Distribution of estuarine habitat types by State (km^2) [n/a: not available]

State	Open water (incl. subtidal seagrass beds)	Intertidal flats (incl. intertidal seagrass beds)	Mangroves	Seagrass (subtidal + intertidal beds)	Saltmarsh area	Total estuarine
Qld	4092.8	1574.4	3423.9	67.7	5321.9	14413.0
NSW	1323.1	n/a	106.8	152.8	57.2	1487.0
Vic	2682.5	443.8	40.5	346.4	124.9	3291.7
Tas	1824.8	274.3	n/a	n/a	37.0	2136.1
SA	759.5	218.5	111.0	n/a	83.7	1172.6
WA	17824.7	2890.7	1560.8	11.3	2965.0	25241.2
NT	5186.7	821.5	2952.4	22.5	5004.8	13965.5
Total	33694.1	6223.2	8195.3	600.6	13594.5	61707.0

Figure 575.1 From SOMER, 1996. Copyright Environment Australia, reproduced with permission.

Part B: Distribution of estuarine habitat

Study Table 3 on the bottom of the previous page and answer the questions below.

1. Which State contains the largest estuarine system? What is the area in square kilometres of estuarine systems in this state? How does this compare with the total area of the state of Victoria? (If this area had a square shape how long would it take driving at 80 km/hr to travel around this area?)
2. The area of mangrove systems varies from state to state. Which state has the largest area of mangrove systems?
3. Which state has the largest seagrass areas? Suggest a reason to explain this occurrence.
4. Identify the differences between intertidal and subtidal seagrass beds.
5. Locate areas in your local estuarine system that contain saltmarshes.
6. Calculate the percentage of the total saltmarsh areas of Australia that are found in Western Australia.
7. Suggest why areas in Western Australia and Northern Territory have such large intertidal areas.

Part C: Human influence on Australian estuaries

Human activity has influenced some estuaries substantially but many remain almost unaffected. Clearance of estuarine catchments is widespread. Study Table 4 below and answer the following questions.

Questions: Case study 22.1 Estuarine management

1. Suggest some reasons to explain the large number of estuarine systems on the Queensland coast. How many estuarine systems can be found in Queensland?
2. Which state has the greatest percentage of catchments cleared of natural vegetations? What percentage of the estuaries in Australia have greater than 75% of its vegetation cleared? Suggest some reasons for the clearing of this vegetation and propose some of the consequences of these actions.
3. Determine the percentage of estuaries in Victoria that have less than 50% catchments cleared of natural vegetation.
4. In Queensland a large number of estuaries have insufficient information on clearing of some estuaries, yet in New South Wales and Victoria all estuaries have data. Suggest reasons to account for these discrepancies.

Table 4: Numbers of estuaries in categories of catchment clearance

Percentage of catchment cleared of natural vegetation

State	<25%	25–50%	50–75%	>75%	Insufficient data	Total
Qld	170	17	4	3	113	307
NSW	20	31	25	5	-	81
Vic	8	6	6	15	-	35
Tas	17	-	-	-	46	63
SA	-	1	1	12	1	15
WA	125	2	3	1	14	145
NT	136	1	-	-	-	137
Total	476	58	39	36	174	783

Figure 576.1 Estuary data
(From SOMER, 1996. Copyright Environment Australia, reproduced with permission.)

Exercise 22.2: Prepare a Zoning plan

For the new Hypothetical Bay Marine Park.

From all the studies you have done on the oceanography and marine biology of Hypothetical Bay, develop a zoning scheme which protects its biodiversity while allowing ecologically sustainable uses.

Produce a series of maps of Hypothetical Bay which overlay:

a. the main estuarine and marine habitats and communities;

b. the different uses of areas;

c. the sustainable and unsustainable uses;

d. hotspots or areas of overlap;

e. a zoning plan which protects key biodiversity while allowing sustainable uses. (Don't forget land uses, and the big issue of runoff and water quality.)

f. Identify all the user groups and others who should be consulted. Members of the class might 'role play' to represent the interests of the various commercial and recreational fishers, divers, water sports (surfing, sailing, canoeing water and jet skiing), conservationists, tourist operators, shipping operators and general community. Try to reach agreeable compromises to come up with an acceptable plan for all users.

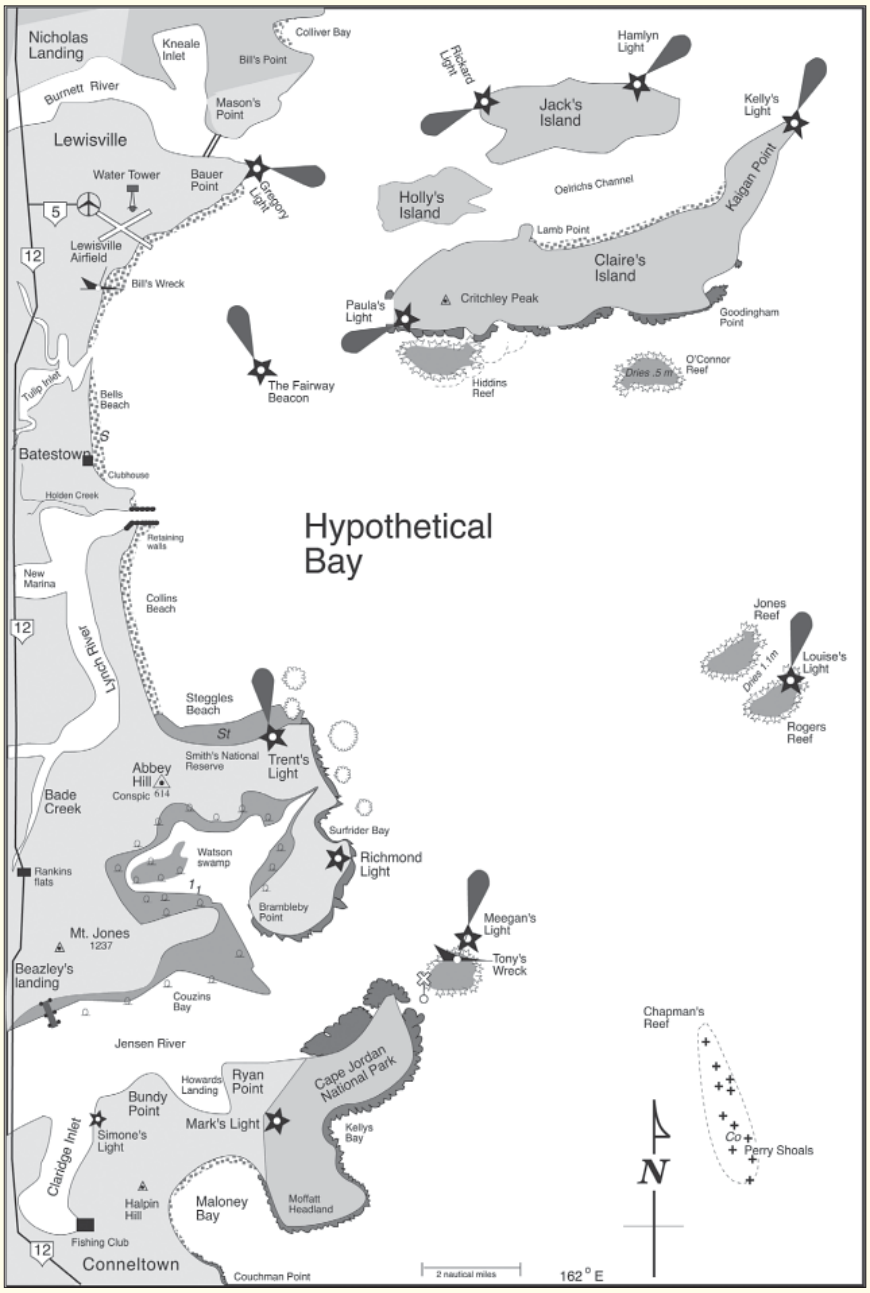


Figure 577.1 Hypothetical Bay 2008
(Illustration Bob Moffatt)

Exercise 22.3 Managing a Great Barrier Reef World Heritage Area

Copyright Great Barrier Reef Marine Authority, reproduced with permission.

Zoning - a management tool for multiple-use resources

The problem with managing the Great Barrier Reef World Heritage Area:

There are many different user-groups (specific groups of people) who want to use the Marine Park for a variety of uses. These user-groups may conflict with each other and damage the reef itself. The Great Barrier Reef Marine Park Authority has to come up with a plan that allows everybody access to different parts of the Marine Park, but ensures that these groups use the reef in a sustainable manner.

What are User Groups?

User-groups include people such as recreational fishermen, tourists, international and local shipping, divers, commercial fishermen, indigenous communities and others. It is hard to put a dollar value to the Great Barrier Reef (GBR) as so many different people use it, but generally speaking tourism activities based in the Great Barrier Reef Marine Park (GBRMP) contribute over $1 billion per year to the Australian economy. Commercial fishing in the region brings in an additional $250 million and other activities such as recreational fishing, sailing and local industries contribute another $750 million. Furthermore, container and oil ships must pass through the Great Barrier Reef to reach ports in Queensland. These ships often load up coal and other natural products for overseas markets and thus, the reef is indirectly involved in Australia's export trade. The activities and use of the Great Barrier Reef often have a huge influence over local economies and thus, can affect the well being of local towns and cities.

Aside from its economic value, the ocean has a great social value to Australian culture. Over three quarters of all Australians live within a half hour drive of the coast and people living further away often holiday on islands or beach resorts. Sailors, divers, surfers, recreational fishermen, local tourists and many others use the Great Barrier Reef Marine Park on a daily basis. Indigenous Australians also place a high value on areas of the Great Barrier Reef Marine Park. Coastal Aboriginal and Torres Strait Islander peoples have been living on the reef for 40,000 to 50,000 years and have strong cultural ties to the sea. These communities rely on the sea for cultural activities, recreation and for the hunting of traditional foods such as turtles and dugong.

Threats to the Living Reef

There are many different threats to the Great Barrier Reef due to human activity. As representatives of different user groups, you should find out as much as you can about how your activities, and those of other groups, can damage the reef. There is a brief description of the concerns of each group in the group descriptions. However, generally speaking the most commonly encountered problems are:

1. Overfishing. Some fish species on the Great Barrier Reef may be threatened by overfishing from both commercial and recreational fishermen.
2. Coastal development. The rapid development of coastal regions may be washing pollutants into the Great Barrier Reef and destroying mangroves and sea grass beds, valuable nurseries for many marine fish.
3. River runoff. It is possible that nutrients washed off farms and into rivers along the coast may be dumping large amounts of nutrients into the relatively nutrient free waters of the Great Barrier Reef. This can potentially cause entire reef systems to collapse.
4. Tourism. It is feared that the rapid growth of tourism, and the use of previously undisturbed areas, will introduce pollution, physical damage and disturb endangered species.
5. Biodiversity. The Great Barrier Reef Marine Park includes habitats used by many endangered species such as dugong, whales and sea turtles.

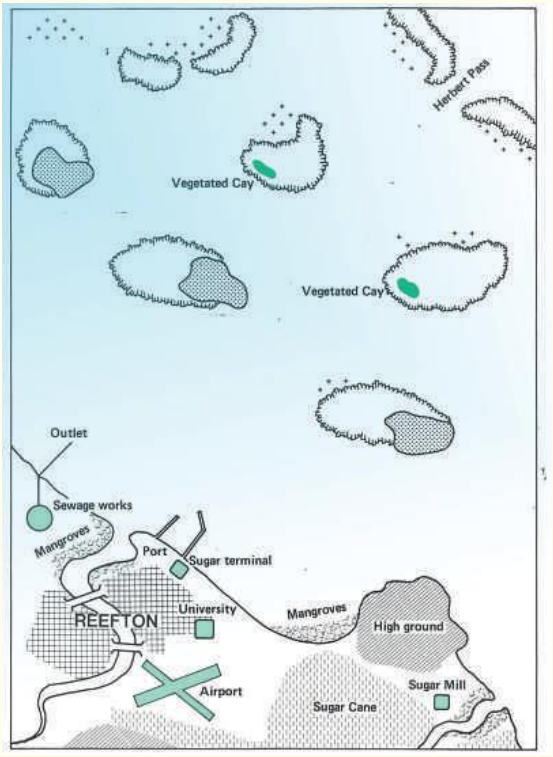


Figure 578.1 Redraw this map on a A4 sheet so you can prepare an overhead transparency for your group

(Illustration copyright GBRMPA, reproduced with permission, may be copied by schools for educational purposes)

Human use of these areas, ranging from commercial fishing to tourism can potentially kill these animals, or disturb their breeding cycles.

6. Shipping. The movements of large ships through the reef present the possibility of oil spills. There have been many incidents of ships running into reefs in the Marine Park. Ships also carry animals and plants from other ports in their ballast water. These organisms are discharged into the water in Australian ports where they can overgrow and wipe out native animals. This has happened in Tasmania and in the Northern Territory.

The need for management

In order to conserve this huge natural treasure, the Great Barrier Reef Marine Park Authority (GBRMPA) was formed in 1979. The Great Barrier Reef Marine Park Authority was charged with the management of the Marine Park with the goal to "Provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park." The Great Barrier Reef Marine Park Authority has to ensure that everyone has the opportunity to use the reef for recreation or work, but in a way that minimises damage. This is the concept of Ecologically Sustainable Development (ESD). The term is a little bit misleading, as it doesn't actually mean building new developments in an eco friendly way, it really means using resources so that the environment is not harmed and can continue to be used.

This may mean closing off areas to use or reducing access to these areas. Ensuring the ecologically sustainable use of the Great Barrier Reef is a complicated and difficult task as people's needs are always changing, and cooperation between all the user groups is not always easily achieved. However, the Great Barrier Reef Marine Park Authority has tackled the problem by dividing the Great Barrier Reef Marine Park into different sections and preparing zoning plans for each section. These zoning plans describe what activities are allowed around the reefs and islands of the section, the aim is to balance human use with the conservation of the Reef and its animal and plant life.

A description of what is and isn't allowed in each zone is outlined below:

General Use 'A' Zone (light blue on zoning maps)

The least restrictive of the zones, this provides for all reasonable uses, including shipping and trawling. Prohibited activities are mining, oil drilling, commercial spear fishing and spear fishing with underwater breathing apparatus.

General Use 'B' Zone (dark blue on zoning maps)

Provides for reasonable use, including most commercial and recreational activities. Trawling and general shipping are prohibited as well as those activities not allowed in General Use 'A' Zones.

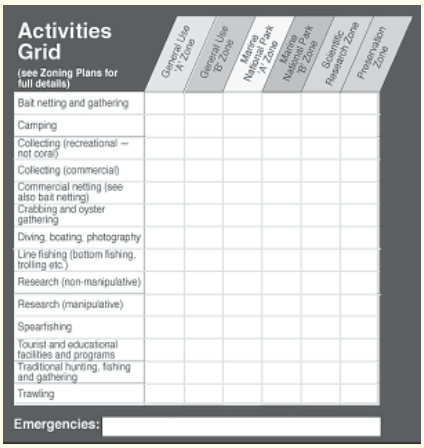


Figure 579.1 Make a copy of this Activities grid
(Illustration copyright GBRMPA, reproduced with permission, may be copied by schools for educational purposes)

Marine National Park 'A' Zone (yellow on zoning maps)

Provides for appreciation and recreational use, including limited line fishing. Fishing is restricted to one line with one hook per person. (When trolling from pelagic species more than one line may be used.) Spear fishing and collecting are prohibited, as well as those activities not allowed in General Use 'B' Zones.

Marine National Park 'B' Zone (green on zoning maps)

Provides for appreciation and enjoyment of areas in their relatively undisturbed state. It is a 'look but don't take' zone. Fishing and all other activities that remove natural resources are prohibited. The development of permanent structures is also restricted except for safety or research: eg, radio towers, navigation buoys, weather stations.

Scientific Research Zone (orange on zoning maps)

Set aside exclusively for scientific research with a permit. Entry and use for other reasons is prohibited.

Preservation Zone (pink on zoning maps)

Provides for the preservation of areas in an undisturbed state. All entry is prohibited, except in an emergency, with the exception of permitted scientific research that cannot be conducted elsewhere.

This Activities Grid clearly specifies what types of activities can occur within the Central Section of the Great Barrier Reef Marine Park and you will need to draw one up like the one shown in Figure 579.1

Your challenges

Reefton (shown on the map provided) is a coastal town located adjacent to the Central Section of the Great Barrier Reef World Heritage Area. You will have to find out all you can about how different organisations and user-groups use the Great Barrier Reef Marine Park. You will be assigned a role as one of the user-groups and using your research, you will present arguments for the types of zoning you want established in the Marine Park.

Figure 580.1 You may want to use your deBono hats in this exercise
(Illustration Kerry Kitzelman)

Step 1 Draw the map of Reeftown

Firstly read all the information provided.

- Redraw Figure 578.1 to develop your user-group's preferred Zoning Plan.
- You will be called upon to argue your case during a user-group meeting attended by all organisations in your user-group and then in a public meeting attended by students representing other user-groups.

Step 2 Compile an Environment Impact Assessment

Each user-group is expected to compile an Environment Impact Assessment (EIA) for the activities that they want to do.

The following key issues and questions need to be answered when compiling Environmental Impact Assessments:

- Title: Your activity needs a title so people will recognise the area you are assessing.
- Description of activity: Briefly outline the activity and when the activity will take place. (Include diagrams of facilities/structures and their location.)
- Need: Why is the activity necessary?

  Impacts:
  - What are the likely impacts on the flora, fauna and ecological processes?
  - What will be the impacts on water, air or surface quality?
  - What are the likely impacts on the heritage, wilderness and/or aesthetic value of the area?
  - What wastes will be generated, how will they be handled and what are the impacts of handling them this way?
  - What cumulative impacts could arise from this activity given other existing or planned activities?
  - What is likely to be the most significant negative impact of this activity?
  - Are there any impacts not addressed above and/or are there any other comments you wish to make?
- Mitigation measures: What action, if any, will be taken to mitigate the impacts of the activity?
- Alternatives: What alternatives to the activity would involve less environmental impact?
- Conformity with management plan: How does the activity accord with any management plan prescriptions applicable to the location?
- Possible public concerns: What public concerns could be expressed about this activity?
- The Environment Impact Assessment must then be signed and dated.
- The Assessment will receive a negative or positive recommendation.
- Finally, the Assessment will receive a Determination stating whether or not the activity will be allowed.

Step 3 Design a set of criteria

- Discuss and negotiate between groups making sure all user-groups are happy with compromises to agree on a zoning plan.
- Now develop a set of criteria, which could be used to evaluate a management plan proposed in Step 5.
  - The management plans should reflect your set of evaluation criteria.

Step 4 Design a management plan

Design a management plan for the proposed activities in the area:

- Formulate a management plan by deciding how and by whom the issues should be managed; and
- Justify your management plan using the criteria you initially developed.

Some questions to be answered when formulating a management plan.

Are you going to ...

- Allow the activity unconditionally?
- Prohibit the activity completely?
- Allow the activity but with some restrictions (certain areas? Certain restrictions or requirements?)

Some decisions to make concerning your plan.

You must decide:

- Who is going to be allowed to engage in the activity.
- How do you propose to monitor the activity and its impact?
- What time span will your plan cover?
- How the issues could or should be managed in the long term.

There may be other factors that you consider important in your management plan. Remember you are the creator of the plan and so it is only limited by your imagination, your analysis of the issue and the set of criteria you have developed.

Background information needed for Step 4

The following are user-groups with vested interests in the Reefton area. Assign students to each of these user-groups. Each user-group has a general overview and range of participants.

Group 1 Tourism operators

The tourism industry is one of the most dynamic and largest of the user groups. The industry generates up to $1 billion dollars every year to the Australian economy and the number of tourists has increased over ten times since the early 1980's. Tourism technology has also rapidly advanced and fast, modern catamarans and seaplanes can carry tourists to remote locations in a matter of hours. In 1985, boats could travel at 10 knots and reach reefs 20 nautical miles away in 2 hours. Today, tourists can get to reefs 50 nautical miles away at 25 knots. Large tourist vessels are capable of speeds of over 50 knots that can reach reefs 100 nautical miles away.

This means that the area tourists are able to reach has increased from 4% to 81% of the Marine Park. The number of coastal and island based tourists resorts has also grown, allowing tourists to spend more time on the reef, and in greater comfort.

In this section of the Marine Park, the tourist user group includes:

Sea Spray Cruises

You operate a fast catamaran from Reefton. The trip takes your guests out to a pontoon off Two Spot Reef where they can snorkel, dive, fish and take glass bottomed boat trips. You want to see the fish and reefs around your pontoon protected so that your clients have the opportunity to see as much-undisturbed reef as possible. This means you want to exclude commercial fishing and shipping from the areas around your pontoon.

Hammerhead Divers

You operate a dive boat that takes divers out on three day/two night trips, diving all the reefs and islands of the central section. You have two moorings installed at Bommie, Crescent and Keeper Reefs. You want as many reefs protected as possible so that your divers can visit undisturbed reefs. You want to exclude shipping and commercial fishing around as many reefs as possible, but you want to be able to visit islands where you conduct shore based activities.

Sunrise Beach Resort Developers

You want to build a new tourist resort on the designated high ground. You need to be allowed to clear the surrounding area and build roads to and from your resort. You want to prevent shipping and commercial fishing in the waters near the resort.

(Illustration Kerry Kitzelman)

Three Tree Island Resort

Your resort is already built and has been operating on Three Tree Island for many years. You also run an education centre to inform guests about the Great Barrier Reef but your energy generation and waste treatment and removal facilities use old, 'dirty' technology. You want to exclude shipping and commercial fishing from the area. However you want your guests to be able to visit other nearby islands and reefs.

Group 2 Conservationists & Indigenous Peoples

Conservation groups are generally non-profit organisations, which aim to protect animals, plants and their habitats from human disturbance. They rely on public support and funding to lobby government organisations, and to increase the environmental awareness of the general public. They realise that people should still be allowed to experience the beauty of the reef, but their priority is still protection and conservation of the animals, plants and their habitats. They will support the use of some areas for recreation but will keep a close eye on the impact to these areas. This user-group includes:

The Nature Council

Your group is concerned with protecting habitats and you work to establish new marine parks and island national parks. You want these areas to be protected from commercial fishing, shipping and uncontrolled use by tourists, recreational fishermen and the general public. These user groups may damage the area and disturb the wildlife. However you will support tourist operators who are committed to minimising their impact on the environment and who actively educate and manage their guests.

(Illustration Kerry Kitzelman)

Reefton Preservation Society

You are interested in preserving the mangroves, beaches and offshore islands in the area. You have no problem with limited access to these areas by members of the public, but you are concerned that commercial shipping, commercial and recreational fishing and tourist development may damage these areas. You also want to see certain areas completely closed to all users, especially sea bird and sea turtle nesting sites, and sea grass beds that are habitats for dugong. Access to these areas should be for scientific research only.

Reefwatch

You are interested in preserving the coral reefs of the surrounding islands as well as off-shore reefs. You want to see shipping and commercial fishing excluded from these areas, but you will support a certain level of tourism that will not damage the fragile corals. However, you are concerned that too many tourists, recreational and commercial fishers and divers may damage the reef. As such, you feel that further tourist developments should be halted. You are also worried about the damage to the reefs caused by boat anchors. As such you want to see certain areas closed to general boat operators, but open to operators who already have pontoons or special underwater moorings.

Wanawanga tribe

Your community has resided in this section since the Dreamtime. For generations you have explored the coastal islands, built communities on these islands and hunted and fished the surrounding waters. You are still permitted under state law to hunt traditional foods such as turtles and dugongs in the marine park. Turtle Island provides very important cultural links to your community including burial grounds, stone-fish traps and middens. You believe that it is very important for people to understand and learn about your culture. You are interested in protecting and conserving endangered species.

Group 3 Fishers

The fishers user group can be divided into two broad categories, commercial and recreational fishers. Commercial fishers use different equipment depending on what they wish to catch. Prawn trawlers drag nets across the sea floor to catch prawns and scallops. However they catch a lot of other animals that are thrown away as by-catch. Near the coast, commercial fishers are allowed to set crab pots and gill nets. Along coral reefs, fishers use hand lines or fishing rods to catch reef fish like coral trout or snapper. A newly developing industry is the live fish trade. When reef fish are caught, they are kept alive in holding tanks on the fishing boats. The live fish are then exported to Asia where they are considered a delicacy. All commercial fishermen have to buy expensive fishing licences to allow them to fish in the Marine Park and in most cases, only a certain number of licensed fishers are allowed to operate at any one time. The commercial fishing industry is very important to the Queensland economy, adding over $250 million annually to local economies. The availability of fresh seafood is also of cultural importance, for example, fresh prawns for the traditional Australian Christmas BBQ. Local food industries may rely on a supply of high quality seafood.

Recreational fishers are another large user group. Over 35% of people living near the coast fish for recreation and the traditional holiday or the weekend fishing trip is an important feature of Australian culture. The recreational fishing and boating industry also generates business for coastal communities. Charter boats take paying clients out to the reef for recreational fishing. It is illegal for these fishers to sell their catch. All fishers have to comply with bag limits, which control the number and sizes of the fish they catch. Certain species such as Barramundi have closed seasons where any fishing for these species is illegal. This allows fish stocks time to recover and may protect them during important breeding seasons.

This user-group includes:

Newhaven Fishing Club

Your club consists of members who own their own boats and fish in the marine park for recreation. You would like to see these areas managed so that the fishing remains good and that not too many fish or crabs are removed. You support the enforcement of bag limits and closed seasons, but you still want to be able to access most areas for line fishing. However you are worried that commercial fishing and crabbing may strip areas clean, leaving none for you to catch. You are also worried that coastal development near mangroves and

(Illustration Kerry Kitzelman)

sea grass beds will destroy these habitats, which are vital nurseries for juvenile fish. You are also concerned that pollution washing down from rivers and streams will kill the fish in estuaries and mangroves.

Commercial Fishers Guild

You represent a group of commercial fishers who are involved in trawling and line fishing for reef fish. The fishing industry provides valuable income and jobs for the local community. Your members are regular people with bills to pay and families to support, and you know that the Marine Park is supposed to be available to all users. You are also worried that recreational fishermen are taking too many fish, and that some are selling their catches illegally. Furthermore, you feel that the clearing of mangroves and sea grass beds will wipe out larval fish nurseries, which can cause fish stocks to collapse. Closing large areas off to commercial fishers will result in lost jobs and will damage the local economy. This is especially damaging if closures occur around peak periods when demand for you product is highest, for example, at Christmas time. You need access to fishing grounds to stay in business.

Black Fin Fishing Charters

You operate a fleet of charter fishing boats, which take tourists and visitors on short fishing trips. You sometimes catch big game fish like marlin and sailfish, but when you do you tag and release them. When fishing for smaller reef fish, you make sure your guests stick to bag and size limits. Your major concerns are that commercial fishing is depleting fish stocks and harming fish habitats. However you support the growth of tourism as this brings more overseas clients to your operation. You want to see the reefs you visit protected from commercial fishing and trawling but open to tourists and recreational fishers.

The Crab Claw Company

Your company conducts commercial crabbing operations in the estuary and mangroves. You already have to follow strict guidelines and bag limits, which manage the crabbing industry. You are concerned that recreational crabbers are taking too many of your crabs, and that residential and tourist developments are causing loss of mangrove and pollution of estuaries which is affecting your catch. You want to see these areas protected from uncontrolled pollution and development, but you want to be allowed access to these areas, even if it means getting special permits.

(Illustration Kerry Kitzelman)

Group 4 Ports and Shipping

Ports and shipping are a very important user group in the Great Barrier Reef Marine Park. They use the park when their ships travel through it, and the ports are often on the edge of the Marine Park. That means that pollution and run off from the port (which can contain oils and other toxic chemicals) quickly enters Marine Park waters . Harbours must also be dredged to remove the sand and silt which builds up on the bottom. This dredging stirs up lots of sediment, which is washed into the Marine Park, killing corals and sea grass beds by smothering them.

Ships also have to navigate through a whole string of treacherous reefs, which have sunk many ships in the past. This poses a potential danger to shipping, although modern navigation aids and equipment have greatly reduced this threat.

However, ships still run aground on the reefs and this can threaten the lives of the crew, and cause serious environmental damage through oil spills and other chemical pollutants. Recently there has been a great deal of concern about the effects of shipboard pollution and the introduction of foreign organisms through bilge water. Shipboard pollution occurs when ships dump rubbish and waste at sea, and during activities such as washing the decks.

This user-group includes:

Reefton Port Authority

Your job is to ensure that shipping through Reefton Harbour and the surrounding waters is safe and efficient. Commercial ships need to unload and load up new cargo as quickly as possible, and they want the safest and quickest shipping routes available. You also have to maintain ships and harbour equipment in top condition, which means using chemicals and detergents, which will pollute the water. You will also have to dredge the harbour to make sure it is deep enough for ships to enter. You want a General Use 'A' zone but you will have to commit yourself to minimising your impacts in and around the port, and in the shipping lane itself.

Orion & North Star Lines

You run a container ship company, which operates three tankers and two cargo/container ships between Reefton and major cities in other states. Your tankers move oil and refined petroleum, while your cargo ships move raw sugar. To get cargo to its destination on time, you need the fastest but safest shipping lane

available through the reefs and islands to Reefton port. You realise that your ships may pose a danger to the reefs but you believe that you can safely navigate the reefs. You are concerned that the declaration of large areas as anything other than a General Use 'A' Zone will force you to go all the way around the Marine Park which takes a lot longer.

Step 5 Come to a consensus

Each group could elect a member to a reef consultative committee whose role is to lead the groups to a consensus and have a management plan with agreed zones and criteria.

The conclusion of the exercise is the publication of the plan with relevant media releases and documentation.

Extension Activities

1. Design a marketing campaign that would be used to communicate the new plan and its zones to the general public. It could include the following communication tools:

   Web site, brochures, maps, signs, television and radio adds, school education program, shopping centre displays, user group meetings, trade and conference displays, power point presentations for keynote speakers.

2. Investigate how Great Barrier Reef Marine Park management decisions are made. Visit www.gbrmpa.gov.au to find out how it is managed. Construct a flow chart showing how decisions are made.
3. Analyse the contribution the Great Barrier Reef Marine Park makes to biological diversity, Australia's economy, society and environment.
4. Undertake a cost-benefit analysis to identify all the costs and benefits the Great Barrier Reef Marine Park makes to our society, environment or economy.

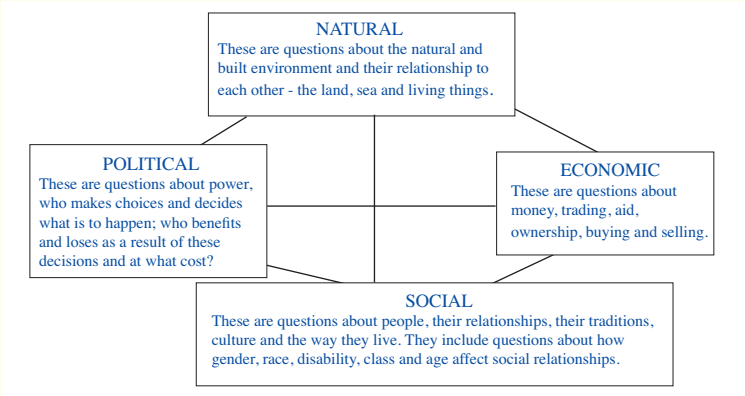
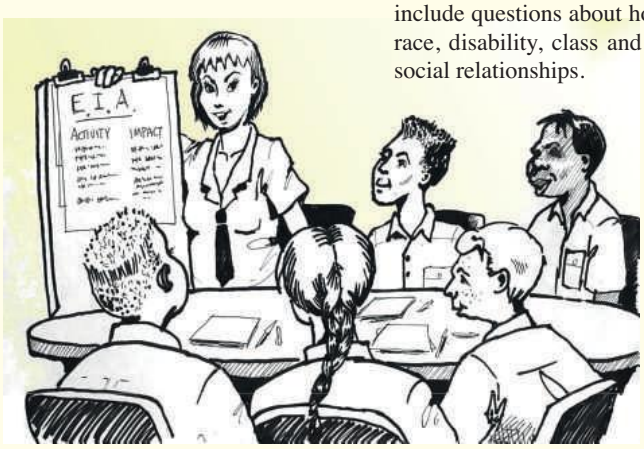


Figure 584.1 Use the following concepts to undertake a cost benefit analysis
(Illustration Fred Nucifora)

If the benefits exceed the costs the cost-benefit analysis is said to indicate an overall gain to society, and vice versa.

- Choose an issue related to the Great Barrier Reef Marine Park and complete a cost-benefit analysis on it. Present your findings to the class for discussion.

5. Debate topics such as:
   - Oceans are for everybody. People should be able to take as much as they want from the ocean.
   - Humans need energy to survive. We should mine the Reef for oil and natural gas.
   - Tourism makes money. More tourists should be allowed to travel within the Great Barrier Reef Marine Park.



(Illustration Kerry Kitzelman)

Tip

Use the following key concepts to help you undertake a cost-benefit analysis (see Figure 584.1).

Natural

These are questions about the natural and built environment and their relationship to each other - the land, sea and living things.

Economic

These are questions about money, trading, aid, ownership, buying and selling.

Political

These are questions about power, who makes choices and decides what is to happen; who benefits and loses as a result of these decisions and at what cost?

Social

These are questions about people, their relationships, their traditions, culture and the way they live. They include questions about how gender, race, disability, class and age affect social relationships.

Questions

Knowledge

1. Describe what a *multiple use* zone is. What types of activities does it include and which are completely excluded?
2. Find Shark Bay on a map. What environmental protection does it have?
3. List three major issues facing the great Barrier Reef.
4. Locate a marine park in this chapter and write two sentences on each of the following:
   a. Biodiversity values;
   b. Human values and uses;
   c. Economic values;
   d. Management goals and arrangements;
   e. Issues and their management.
5. Define the term *marine protected area*.
6. What two issues affect the Solitary Islands Marine Park?
7. Why was Queensland the first state to declare a marine park?

Understanding

8. Describe the location of a marine park in your state.
9. Name a marine protected area in your state.
10. Why has the Commonwealth established its own marine protected areas?
11. How can shipping affect a marine protected area?
12. Use the futures wheel in the appendix to predict effects of increased tourism in a marine park.

Applying

The 4 criteria for world heritage listing are:

a. Outstanding examples representing the major stages of the earth's evolutionary history;

b. Outstanding examples representing significant ongoing geological processes, biological evolution and human interaction with the natural environment;

c. Containing unique, rare or superlative natural phenomena, formations or features of exceptional natural beauty;

d. Important and significant habitats where threatened species of animals and plants of outstanding universal value from the point of view of science and conservation, still survive.

13. Locate a marine park map in your state or local area and identify where each of a-d above could occur.
14. Make a list of the activities that could occur in the park and list the types of regulations that may be necessary to control.

Figure 585.1 Group A
(Illustration Kerry Kitzelman)

Figure 585.2 Group B
(Illustration Kerry Kitzelman)

15. During your time in Marine Studies you should have been snorkelling and boating. Make a list of best environmental practices that should be associated with these activities.
16. Make a list of best environmental practices for recreational fishing.
17. How could you best control shell collectors and four wheel drivers in this world heritage area?
18. Are there any RAMSAR sites in the park?

Analysing

Study Figures 585.1 and 585.2.

19. Write 4 four similarities and four differences between the two groups.
20. The artist has drawn 10 people. Locate the 10 and predict their occupations/interests.

Analysing (Continued)

Study a map of a marine park from your state. (If one is not available use one from this chapter eg Figure 565.1).

21. Now answer the following questions a-k.
    a. Analyse the map for zones or multiple use areas. Make a list of which zones are there and the 4 types of activities permitted in each zone or area.
    b. Arrange the zones in order of least restrictive to most restrictive.
    c. Categorise the activities into destructive, semi destructive, little or no impact.
    d. Compare the zoning plan to that of another state. List three similarities and three differences.
    e. Distinguish between colours/shading used in the maps. How effective are the 4 maps in explaining activities to the general public.
    f. Examine the maps for navigation marks. How do people know if they are in a particular zone? How effective do you think the map is in informing people what they can and cannot do in a particular area?
    g. Explain the use of symbols in the marine park map.
    h. Identify areas that could be affected from the land. Explain these effects and possible consequences for marine life.
    i. Investigate if large scale ecosystem biodiversity has been taken into account. Do you think biodiversity is being protected? Justify.
    j. Make a list of all the features in the map. Separate the good features from the bad features. Make a list of recommendations to the map makers of how the maps could be improved.
    k. Survey your local street to see how may people use the marine park and how many know the zones. Summarise your data and post it back to the management authority with an analysis of their marine park map.

Creating

22. Compose a television jingle informing the public of a seasonal closed fishing zone.
23. Create a media release for the announcement of a proposal for a new marine park in a traditional country coastal town.
24. Design a park sign showing zoning.
25. Propose a solution to cigarette butts in marine parks.
26. Estimate the number of people who would use your local beach in summer.
27. Formulate a plan to zone the school into areas for each year level.
28. Plan a development of a low impact eco-resort in a marine park. Predict what elements of the plan would be necessary to satisfy a variety of user groups

Evaluating

Media Release, Sunday 1 December 2002 — 15,000 rally against giant marina resort.

A huge crowd of around 15,000 people rallied in Fremantle today against the marina resort proposed for Ningaloo Reef. Protesters in Fremantle included well-known identities; author, Tim Winton, basketballer, Luc Longley, stockbroker, John Poynton, West Coast Eagles coach, John Worsfold, Fremantle Dockers captain, Peter Bell and team-mate, Trent Croad. Peter Tagliaferri, Mayor of Fremantle, welcomed the crowd and later said, "It was the biggest rally in living memory in Fremantle." Speakers delivered the message that the community would not accept the marina resort and would take the issue to the next election if necessary. Sustainable, low-impact development was advocated as an achievable and responsible alternative.

Tim Winton said, "The Premier will be in no doubt about the public mood on this issue. It was an awesome display of public feeling. For every person at the rally, we know that dozens more feel the same. By the time the head of the kilometre long march returned to the Esplanade, the tail was still leaving."

Simultaneously, people gathered at the remote Ningaloo towns of Coral Bay and Exmouth. Quiet at this time of year, the whole town of Coral Bay gathered at the proposed site at Mauds Landing and was greeted by the sight of giant manta rays where the seawalls would be built. Over two hundred people also rallied in Exmouth. Both gatherings delivered messages of solidarity from Tim Winton. Campaign spokesperson, Paul Gamblin, said, "Action in these towns today shows the overwhelming support in the region for sensitive development which will not harm the environment. After all, that is what underpins the tourism industry."

29. Assess the effectiveness of well known sports people in the public rally. How effective do you think they are in gaining media attention?
30. Determine what alternatives the group planned.
31. Build 4 life size placards for the rally.
32. Write a media release for the rally.
33. Justify rallies such as this given the high proportion of youth unemployment in Exmouth.

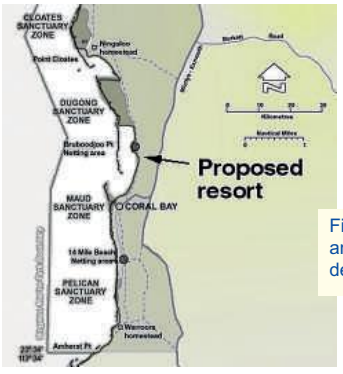


Figure 586.1
Proposed resort development Ningaloo Reef
(Illustration - www.saveningalooreef.org)

Find out where the resort and marina were finally developed

Appendix

Contents

Appendix 1 Workprogram ideas

Appendix 2 Aquaculture project ideas

Appendix 3 Planning a unit of work (assignment contracts)

Appendix 4 Bloom's taxonomy

Appendix 5 De Bono's hats

Appendix 6 Development - consequences chart

Appendix 7 A futures wheel

Appendix 8 Subject associations and peak bodies

Appendix 9 Reference books used in this text

Photo Murray Waite

Appendix 1 Workprogram ideas

One year course

Here are some suggestions based on the following philosophies.

- Not everyone has to learn the same thing at the same time, in the same way or at the same rate.
- Students can learn from each other and/or by learning/ assignment **contracts** (see Appendix 3).

Semester 1

Weeks 1-3

Ch 1 Ocean and coastline formation. *Ex's 1.1, 1.2, 1.3*
Ex 1.4: Time line.

Weeks 4-10

Ch 2 Oceans and waves. *Ex's 2.1, 2.2, 2.3*

Ch 3 Currents and weather. *Ex's 3.1, 3.2*

Ch 4 Coastlines. *Ex's 4.1, 4.2*

Weeks 11-15 Oceanography contract

Prepare a group contract using Appendix 3 on content from Chapters 5-7.

Weeks 16-20

Ch 8 Classification and marine biodiversity.
Ex's 8.1, 8.2. Assignment 2: *Biodiversity*

Semester 2

Weeks 1-5 Marine Biology contract

Prepare a group contract using Appendix 3 on content from Chapters 9-14.

Weeks 6 - 9

Ch 15 How they survive. *Ex's 15.1, 15.2, 15.3*

Ch 16 Ecosystems. *Ex's 16.1, 16.2*

Weeks 10 - 18

Assignment 3: *Management and conservation*

Ch 17 Australian marine environment

Ch 18 Sustainable use of the sea

Ch 19 Biodiversity and marine life

Ch 22 Marine parks

Weeks 19 - 20

Appendix 3 contract on either/or

Ch 20 Australia's fisheries and their management or

Ch 21 Aquaculture

Assignment 4: *Report on local marine environment*

Two year course

This is the preferred option as marine science provides the opportunity to apply traditional science in a practical way. This would suit NSW, 2 unit Stage 6 courses.

Semester 1 Oceanography

Chapter 1 Ocean and coastline formation
Chapter 2 Oceans and waves
Chapter 3 Currents and weather
Chapter 4 Coastlines
Chapter 5 Coastal engineering
Chapter 6 Seawater
Oceanography field trip

Semester 2 Marine Biology

Chapter 8 Classification and marine biodiversity A
Chapter 9 Marine plants (1)
Chapter 10 Marine plants (2)
Chapter 11 Marine Invertebrates (1)
Chapter 12 Marine Invertebrates (2)
Chapter 13 Marine Vertebrates (1)
Chapter 14 Marine Vertebrates (2)
Snorkelling or rock pool field trip

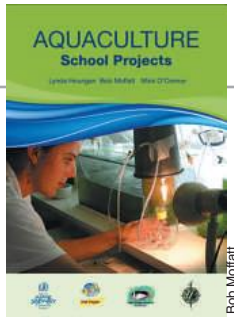
Semester 3 Sustainable use of the sea

Chapter 7 Marine pollution
Chapter 15 How they survive
Chapter 16 Ecosystems
Chapter 8 Classification and marine biodiversity B
Chapter 19 Biodiversity and Marine Life
Chapter 21 Aquaculture
Marine Parks Camping Field Trip

Semester 4 Management and conservation

Chapter 17 Australian marine environment
Chapter 18 Sustainable use of the sea
Chapter 20 Fisheries Biology
Chapter 22 Marine Parks
Marine Parks Zoning Exercise or Role Play

Appendix 2 Aquaculture project ideas

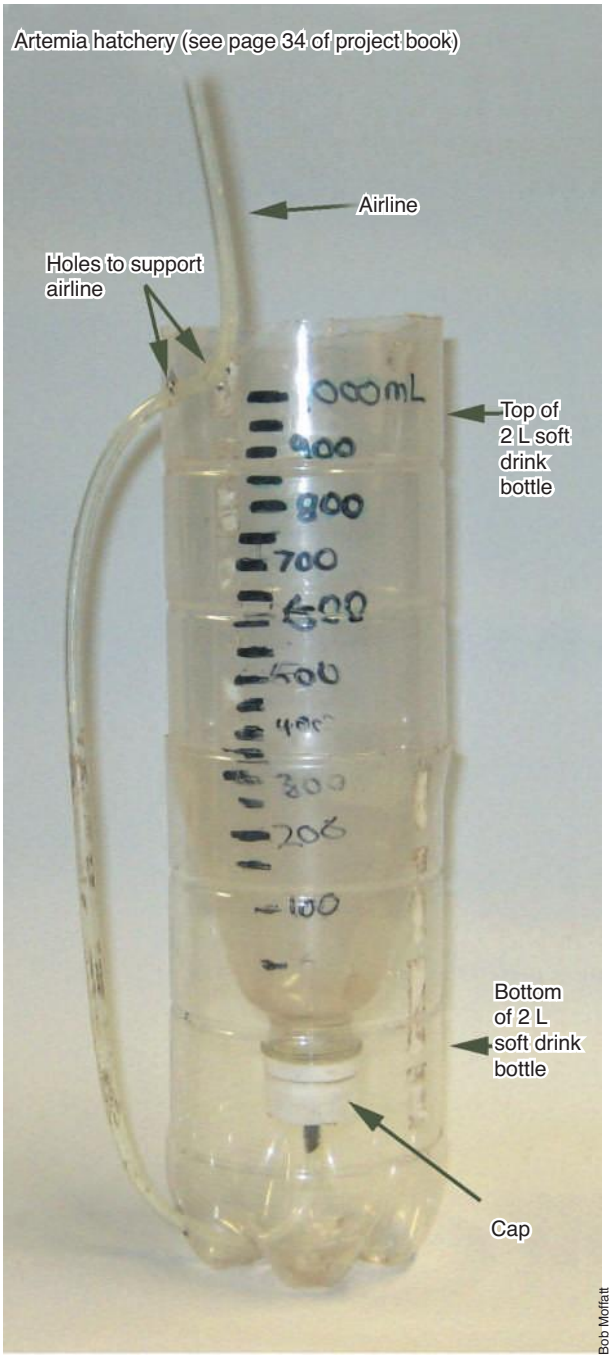


Bob Moffatt

In 2011 the Marine Teachers Associations of New South Wales and Queensland got together with Wet Paper and published the ideas of Ballina SHS in a school project book. Pages 374 - 376 show some of the 55 projects detailed in this 120 page excellent resource for Chs 11 - 15 of this book.

Copies of this *Aquaculture School Project Book* are available from:
www.wetpaper.com.au

Example project:



Bob Moffatt

Mick O'Connor

What to do

1. Select two appropriate 2 litre plastic soft drink containers.
2. Soak the label off the bottles and wash thoroughly with clean water.
3. Rinse the bottle 2 or 3 times in clean detergent free water - all chemicals MUST be removed from the bottle.
4. Using scissors cut off the bottom of one of the bottles. This bottle will become the 'container'.
5. Cut the other bottle in half. It will be the 'stand'.
6. Drill a 5mm hole 10cm from the bottom, up the side, of this 'stand bottle'.
7. Using a poly jetpunch/spanner place a hole in one of the bottle caps.
8. Screw in to this hole the 4mm screwed adapter and attach the airline.
9. Screw the lid back on the container bottle, invert it into the stand bottle and feed the airline out through the hole in the stand.
10. Punch two 4mm holes apart in the 200 mm apart at the top (cut end) of the container bottle with a hole punch (see Figure opposite).
11. Thread the airline through these two holes before connecting to the aerator. This will ensure the airline remains above the surface of the liquid and will prevent siphoning out the aerator.

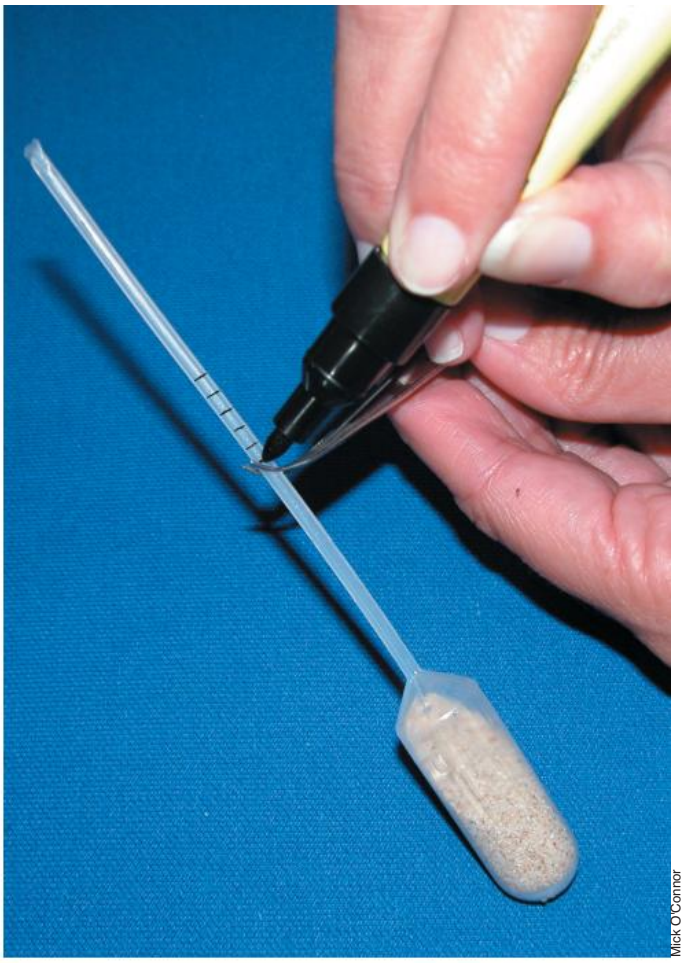
Light cupboard (see page 22 of project book)
Mick O'Connor

Crayfish restrainer and measurer (see page 82 of project book)
Mick O'Connor

Algal growth container (see page 20 of project book)
Mick O'Connor

Salinity hydrometer (see page 44 of project book)

Mick O'Connor



Mick O'Connor

Growing algae (see page 89 of project book)

Mick O'Connor

Fish measure (see page 80 of project book)

Mick O'Connor

Appendix 3 Planning a unit of work (assignment contracts)

In his 1983 book *Frames of Mind*, Howard Gardner introduces us to the concept of multiple intelligences.

To help all our students to learn, the teacher can plan lessons to reach as many of these intelligences as possible. The table below is an adaptation of one given by Ralph Pirozzo. It combines Blooms taxonomy page opposite, with the concepts of seven different ways learners think.

To plan a unit, you could set a learning contract which can have a number of different options.

- Option A — Choose a minimum of 2 activities from each column —> 14 activities
- Option B — Choose a minimum of 2 activities from each row —> 12 activities
- Option C — Complete all activities that have been shaded (see examples) —> 15 minimum activities

Assessment options

Select 12 or more tasks from Columns 1, 2, 3 etc, then assign points and set criteria (Knowledge and understanding) etc. Set a number of points to finish with and shade core activities eg, you must finish with 40 points, 21 have been shaded as compulsory.

Example: Chapters 11 and 12 Choose an invertebrate

Gardner's intelligences Seven ways to complete this unit	Knowing Describe, find, list, locate, name. relate, state, tell, write 1 point	Understanding Convert, draw, describe, distinguish, express, interpret, match, outline, restate, translate, apply 2 points	Applying Calculate, classify, construct, complete, examine, illustrate, record, report, show, solve, use 3 points	Analysing Analyse, arrange, categorise, compare, contrast, distinguish, examine, explain, identify, investigate, separate, survey 4 points	Creating Compose, research, create, design, devise, estimate, formulate, imagine, improve, invent, plan, predict, propose, conduct 5 points	Evaluating Argue, assess, choose, debate, decide, determine, evaluate, discuss, judge, justify, prioritise, rate, recommend, verify 6 points
1. Verbal/linguistic (I enjoy reading, writing and speaking)	Locate the animal you want to study in Chapter 11 or 12 and state why you have chosen it.	Draw your selected animal and describe its external appearance.	From the animals in the hat provided by your teacher, draw one and classify it to species level.	Write 6 similarities and 6 differences between two animals in the same phylum in one A4 page.	Write a poem/ brief skit to describe how this animal feeds or reproduces.	Write 4 of the animals adaptations and rate it's chances of survival from pollution.
2. Maths/logical (I enjoy working with numbers and science)	Count the number of external features on the animal.	Construct a food web showing the trophic relationships of the animal and possible predator-prey relationships.	Explain in clear logical steps how the animal moves .	Decide if the animal is radially or bilaterally symmetrical or another form.	Design another way the animal could defend itself from predators using chemicals. Explain how they may work.	Decide if the animal lives in a population and determine the carrying capacity for a specified habitat size.
3. Visual/spatial (I enjoy painting drawing and visualising)	Paint a colour illustration of the animal showing clearly its external features.	Use a map of hypothetical bay to show where the animal would live. Explain your reasoning.	Prepare a map of Australia to show the distribution of the animal.	Compare the external features of the animal with one from a different phylum.	Make a model of the animal and paint it explaining your choices.	Prepare a map of the continental shelf and decide and label the distribution of the animal.
4. Body/kinaesthetic (I enjoy doing hands on activities)	Mime the movements of how the animal could defend itself from a possible predator.	Describe what could be in an invertebrate board game.	Prepare a museum mount of the animal (microscopic, embedded or preserved).	Analyse the pleopod of a mantis shrimp and work out how it can move at the speed of a .22 calibre bullet.	Make a diorama of the animals habitat to show parts of the food chain.	Evaluate the performance of a group members poem/rhyme/song/ rap.
5. Music/rhythmic (I enjoy making and listening to music)	Recall a song about a marine animal, record it and play it in class.	Make a chant using invertebrates with the same name eg 1,2,3 we love the sea, sea star, sea urchin, sea cucumber.	Convert the words from a song into a story board interpreting the lyrics.	Select some music for a play on the octopuses garden.	Write a song/rap to describe how an invertebrate moves or reproduces.	Review the music of any students work prior to presentation and make a written report.
6. Interpersonal (I enjoy working with others)	In a pair, present a power point or story board/flip card presentation on the life history of a marine invertebrate.	As a group, select any marine invertebrate discussed and make a summary chart.	As a group, select any marine invertebrate discussed and explain using visuals, its role in its habitat.	Make a summary chart comparing an arthropod and a mollusc.	Make a set of back labels for the Who am I game in Chapter 11, page 270.	In a pair evaluate the author's interpretation of any marine invertebrate from Chapters 11 and 12.
7. Intrapersonal (I enjoy working by myself)	Copy and colour in the tree of marine life in Chapter 8.	Make a drawing of a prawn labelling all parts.	Examine any of the case studies and report on their intended purpose.	Analyse all of the appendages of a crab and explain their functions.	Create a model of an echinoderms tubed foot so you can show how the animal uses it.	Find a brochure, museum model or aquarium display and evaluate how the information has been communicated.

Appendix 4 Bloom's taxonomy

Questions in this book have been structured around this taxonomy so students can gain practice before examinations.

Knowledge

Verbs

- Describe
- Find
- List
- Locate
- Name
- Relate
- State
- Tell
- Write

Questions

- Can you name the
- Describe the appearance of
- Find the meaning of the following terms
- How many
- What happened after
- What is the name of
- Who was the person that
- Which is the right answer

Instructions/activities

- List all the stages of
- Make a time line of the events
- Prepare a chart showing
- Recite a poem
- Write the formula for photosynthesis
- Describe the events leading up to
- Locate a place that
- Name the animals in the
- State the formula for
- Tell the story about
- What is the scientific name for, the common name for

Understanding

Verbs

- Convert
- Draw
- Describe
- Distinguish
- Express
- Interpret
- Match
- Outline
- Restate
- Translate

Questions

- Write the formula for photosynthesis in your own words
- Give a definition of species
- Provide an example of a
- Write a brief outline for
- What differences exist between
- What do you think could have happened next?
- What was the main idea of the article?
- Match the ... with the description

Instructions/activities

- Draw pictures to show
- Convert this ..... into a statement
- Describe/express in your own words/restate the
- Give an example of a
- Illustrate the main ideas of
- Prepare a flow chart of the steps involved in
- Outline the main reasons for
- Distinguish between

Applying

Verbs

- Calculate
- Classify
- Construct
- Complete
- Examine
- Illustrate
- Record
- Report
- Show
- Solve
- Use

Questions

- Calculate the number of ... in the square
- Classify the following into the phyla
- Construct a diagram to show
- Plan and conduct an experiment to show that

Instructions/activities

- Calculate the number of ... per minute
- Calculate the number of
- Classify the following
- Construct a food chain from the following
- Complete the sentence
- Examine the illustration and
- Draw a diagram/map/plan and label it correctly
- Use a collection of plants to show that
- Make a model to show that
- Record your results in the table below
- Use your knowledge to show that
- Plan an experiment to show that
- Explain the procedure for
- Illustrate your answer with a

Analysing

Verbs

- Analyse
- Arrange
- Categorise
- Compare
- Contrast
- Distinguish
- Examine
- Explain
- Identify
- Investigate
- Separate
- Survey

Questions

- Which events could not have happened and why?
- How is this similar to or different from
- What was the main theme?
- Distinguish between
- What was the turning point in the development?
- Explain what must have happened when
- Are there any other possible outcomes?
- What were some of the motives behind
- Write a number of questions that could be used in the interview:
- Write ... similarities and ... differences between ...

Instructions/activities

- Design a questionnaire to gather data
- Write a commercial for a coast care add
- Make a flow chart to show the reproductive cycle of a
- Construct a graph to illustrate the relationship between
- Which events could not have happened and why
- Write a number of questions that could be used to
- Explain the difference between the following words
- Identify the following animals from the illustrations below
- Investigate the effects of
- Carry out a survey to
- Prepare a scientific report of

Creating

Verbs

- Compose
- Research
- Create
- Design
- Devise
- Estimate
- Formulate
- Imagine
- Improve
- Invent
- Plan
- Predict
- Propose
- Conduct

Questions

- Create new uses for ...
- If you had access to all the necessary resources, how could you stop ships hitting the reef
- Invent a solution to ...
- Can you develop a proposal which will ..?
- How may ways can you ...
- Propose how we could improve this experiment
- Predict what will happen if ....

Instructions/activities

- Create a new product (fish) and plan a marketing campaign
- Devise a number of ways to improve
- Write and perform a play to illustrate a barnacle feeding
- Invent a machine to
- Design a cover for a brochure
- Compose a rhythm and or add new words to a well known tune
- Devise an experiment that will extract more ..... from tidal energy
- Construct a model of a (copepod)
- Design a wave power house
- Suggest ways to improve the management of
- Choose music to reflect the movement of ...

Evaluating

Verbs

- Argue
- Assess
- Choose
- Debate
- Decide
- Determine
- Evaluate
- Discuss
- Judge
- Justify
- Prioritise
- Rate
- Recommend
- Verify

Questions

- Plan and conduct an experiment to justify your answer/
- How would you defend your position in relation to ...?
- Assess and choose a better solution to .....
- How would you have handled ..... ?
- What changes would you recommend to... ? Why?
- Do you believe that ....
- How would you feel if
- How ineffective are
- What is the most valuable

Instructions/activities

- Prepare a list to be used by .... to judge a
- Organise and conduct a debate about a controversial issue
- Prepare a booklet that could be used by tour operators to
- Write a letter to the editor of the local newspaper advising on changes needed to
- Prepare a report in which you evaluate the research on
- Recommend new strategies to be adopted by the ..... based on your strategic plan and group's analysis

Appendix 5 De Bono's hats

Use Edward de Bono's 'Six Hat Thinking' to explore some issue or place eg the Reef. Place cut out hats on the floor and group responses as a class.

- Red Hat represents feelings and emotions.
  - Ask: What are your feelings about the Reef? or How do you feel about the Reef?
- White Hat represents facts and information.
  - Ask: What are some facts we have learned about the Reef? or What do we know to be true about the Reef? What are the facts?
- Yellow Hat represents the positives.
  - Ask: What are the good points we have learned about the Reef? or What are the positives about the Reef?
- Black Hat represents the negatives.
  - What questions or issues does our learning about the Reef raise? Or What are the negatives about the Reef?
- Green Hat represents creativity.
  - Ask: What is possible for us to do as users of the Reef? or What are some of the solutions to the Reef's issues?
- Blue Hat represents thinking about thinking.
  - Ask: What questions or issues does our learning about the Reef raise? or What is the Reef all about? What are some of the main things? What has it made you think about? Why is it important?

Introducing

Introduce the nature of the six hats, one at a time and practise using them in response to a general event and issues that arise during the day. Once the students are familiar with the nature of each hat, use them in an activity to discuss the Reef. Record the different discussion points and encourage groups to report back on the varying views presented.

http://www.edwdebono.com/

Edward de Bono is regarded by many as a leading authority in the world in the field of creative thinking and the direct teaching of thinking as a skill. He has written 62 books with translations into 37 languages and has been invited to lecture in 54 countries. He is a leading proponent of lateral thinking which treats creativity as the behaviour of information in a self-organising information system - such as the neural networks in the brain. From such a consideration arise the deliberate and formal tools of lateral thinking, parallel thinking etc.

Red Feeling & emotions

White Facts & information

Yellow Positives

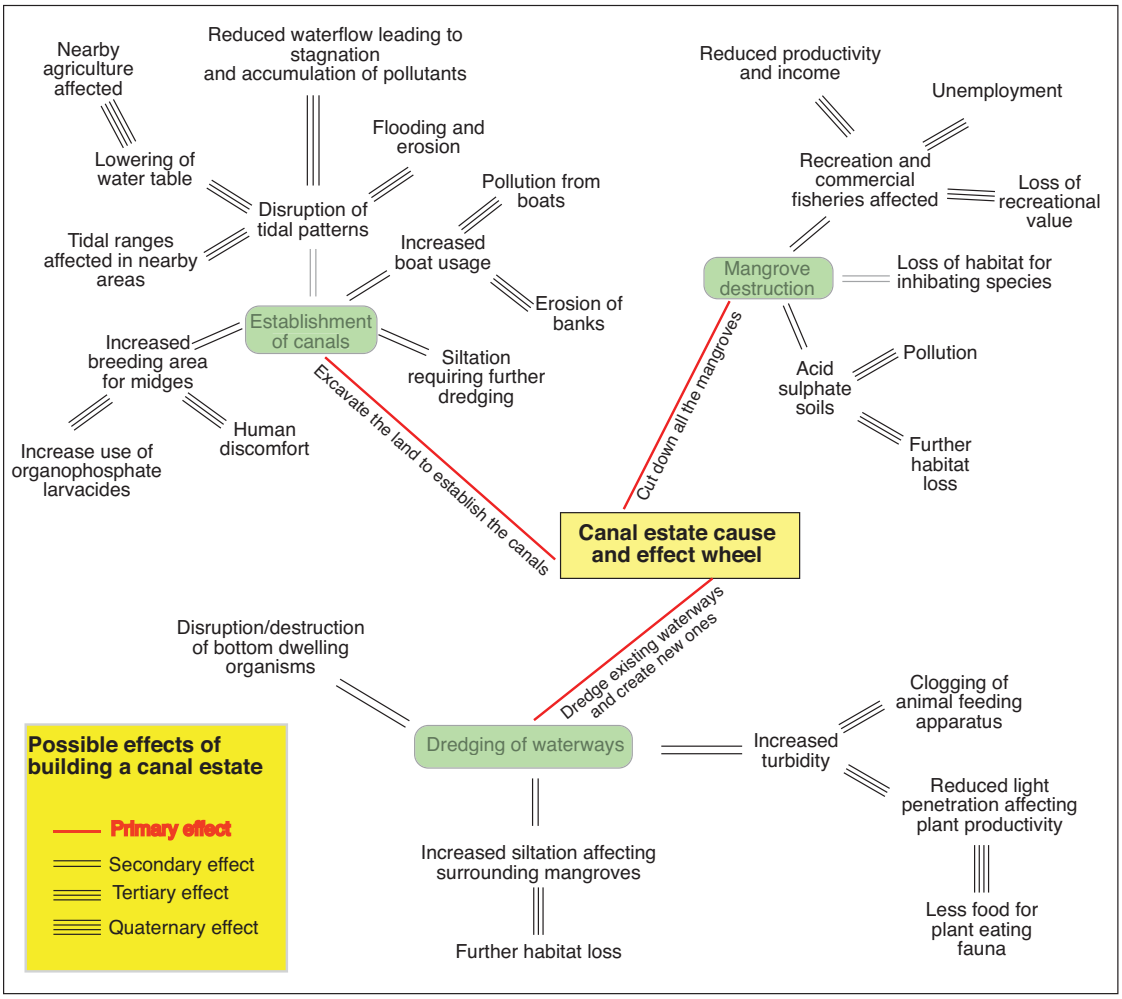
Black Negatives

Green Creative

Blue Thinking

Appendix 6 Development - consequences chart

(For visual/spacial thinkers)



Based on an original idea from, ' Teaching for Ecological Sustainable Development: Guidelines for Years 11 and 12 Geography, Department of Education, Queensland 1992'.

Figure 595.1 Development consequences chart
(From Mangroves in Focus, illustration by Bob Moffatt)

Development /Consequence chart										
Type of development : Canal estate		How likely is this consequence of the development? Answer yes or no.				Your evaluation of the consequence. Answer yes or no.				
Developments that might occur	Possible consequences	Certain	Probable	Possible	Almost impossible	Very favourable	Favour-able	Little or no impact	Unfavour-able	Very unfavour-able
1. Establishment of canals	a. Erosion of banks b. Disruption of tidal patterns									
2. Mangrove destruction										
3. Dredging of waterways										

Source — Modified from P-12 Environmental education curriculum guide (Dept of Education Qld). After an idea from Futures Unlimited, by R.M. Fitch and C.M.Suengalis (National Council for the Social Studies, Washington, D.C. 1979)

Figure 595.2 Development consequences chart table
(From Mangroves in Focus, illustration by Bob Moffatt)

Appendix 7 A futures wheel

(For visual/spacial thinkers)

Futures wheels are used to explore wide ranging consequences that can follow from actions, issues or trends in the present. To use the wheel, decide on the focus for the investigation and place this in the centre of the wheel.

Step 1: Start at the centre with an environmental problem, then a series of consequences can be mapped.

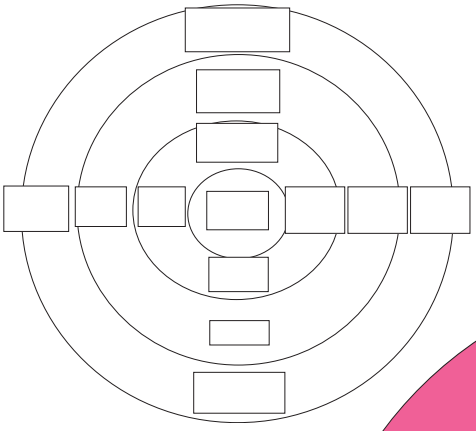
Step 2: Now ask a series of questions starting with the immediate consequences.

Step 3: Write these in the inner ring around the main idea with a single line. This indicates they are first order consequences.

Step 4: Continue to explore second, third and fourth order consequences using the outer circles.

A dropping litter example developed by the project reefEd team from the Great Barrier Reef Marine park Authority is given below:

Kerry Kitzelman



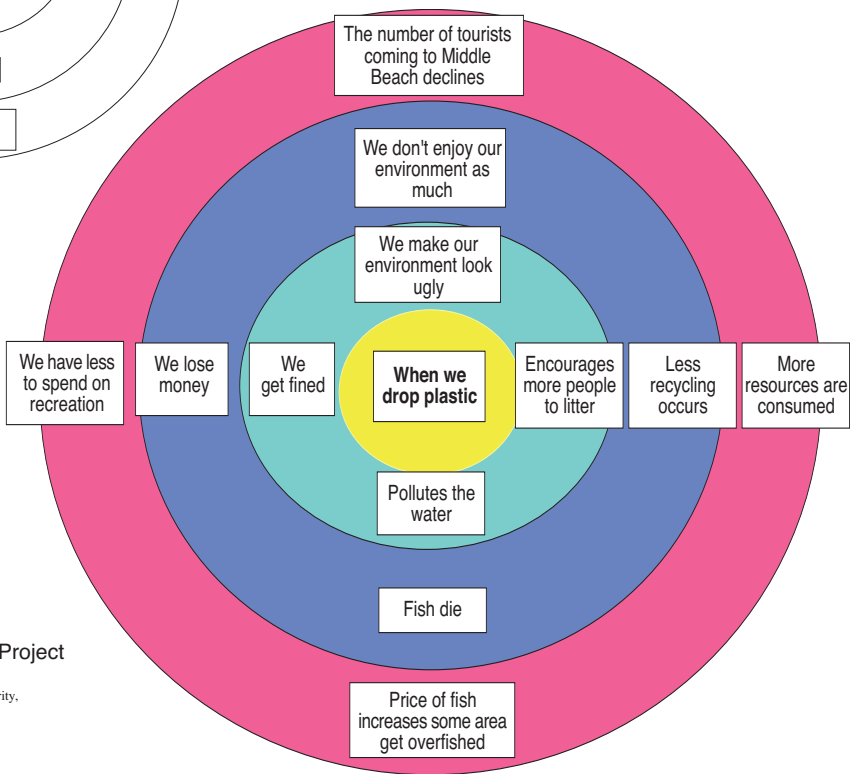


Figure 596.1 Example from Project ReefED

Copyright Great Barrier Reef Marine Park Authority, reproduced with permission.

Appendix 8 Subject associations and peak bodies

The Marine Teachers Association of Queensland Inc.

Who are they?

- The Marine Teachers Association of Queensland is a group of over 250 individuals who are involved with the teaching of marine studies and marine education subjects in Queensland education systems.
- Marine teaching is carried out in Primary and Secondary Schools as well as and in Tertiary Institutions.
- The Association has nine branches covering the coast of Queensland.

Their objectives

- The principal goals of the association are to promote fellowship amongst teachers by:
  - developing in-service and training courses for its members;
  - helping as many classroom marine teachers as possible attend an annual conference;
  - developing policy documents from time to time that will assist in the smooth running of the subject;
  - ongoing communication by producing 4–6 newsletters a year;
  - conducting regional events such as the Marine Olympics, to promote marine safety and skills amongst our students;
  - becoming involved in other activities that promote marine studies in general eg Seaweek, Ocean Care Day, National Water Week, World Water Day and AUSMEPA - A national student marine environment club starting this year.

Conferences

Annually, end of second term holidays.

Electronic newsletter and memberships

Six per year. Individual, corporate or school.

Web site and contact

www.marineteachers.org.au

The Marine Teachers Association of New South Wales Inc.

Their objectives

Similar to Queensland, but in addition focusing on establishing Marine Studies and Marine Science as a recognised school subject in the curriculum from years 7-12.

Management Committee

Ballina High, Locked Bag 1, Ballina 2478
Menai High School, Gerald St, Menai 2234

Branch representatives:

Far North Coast
Evans River Community School, Cyprus & Booyong St, Evans Head 2472
Mid North Coast
Foster High School, Cape Hawke Drive, Foster 2428
Central Coast
Brisbane Waters College, Umina Campus, Vernon Rd, Umina 2251
Sydney Metropolitan
Ambervale High Thomas Rose Dr, Rosemeadow 2560
Illawarra
Illawarra Senior College, Military Road, Port Kembla 2505
South Coast
Eden Marine Technology High, Barclay St, Eden 2551
Murray-Darling
Orange High, Orange 2800

Conferences

Annually, end of first term

Newsletter and memberships

Four per year. Individual, corporate or school

Contact:

The Publicity Officer
Ballina SHS
Locked Bag 1, Ballina NSW 2478

Web site

www.mta.nsw.edu.au

Marine Education Society of Australia

MESA started in April 1985 and is the Marine Education Society of Australasia, a non-profit organisation which brings together people interested in the study and enjoyment of marine and coastal areas.

MESA members work to inspire and educate about our amazing ocean environments. Through education MESA encourages others to take action in caring for our oceans, from the catchments to the deep sea.

A national council administers the overall organisation, seeks support, sponsorship and funds, publishes resources and assists groups and the general public in all facets of marine and coastal education.

Branches and conferences

MESA has branches in each Australian State and runs a national conference each year.

Seaweek

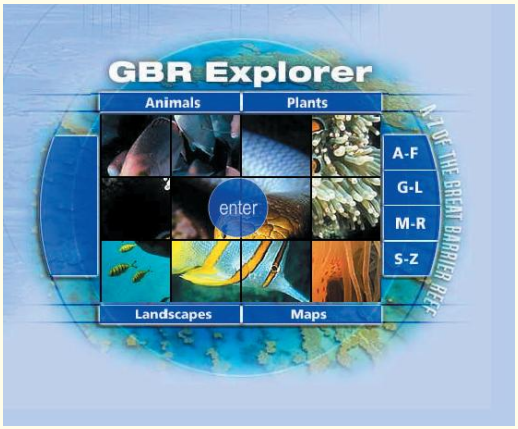
Seaweek is the Marine Education Society of Australasia's (MESA) major national public awareness campaign. It is conducted annually to focus community awareness, provide information and encourage an appreciation of the sea.

Each year a different Seaweek theme is chosen and a national coordinator appointed.

This provides a focus for student and community activities, the publication of educational materials and media promotions about the marine and coastal environments. MESA has a team of dedicated individuals and groups from around Australia who promote marine awareness and provide educational events in their region to make Seaweek a continuing success.

Web site

www.mesa.edu.au



The Great Barrier Reef Marine Park Authority has excellent on-line resources at:

www.reefed.edu.au

www.gbrmpa.gov.au

As well they have an excellent video conferencing classroom where students can interact live with a diver on the Great Barrier Reef.

Contact

Communication & Education

Great Barrier Reef Marine Park Authority

Reef HQ Aquarium

Phone: 07 4750 0800

info@gbrmpa.gov.au

MESA

www.mesa.edu.au

MESA Workshop South Australia
(Photo Bob Moffatt)

Appendix 9 Reference books used in this text

The following reference books and notes were used in the compilation of content for this book.

A.B.Sea TSERNJAVSKI, Nancy (2001), Gould League Victoria

Coastal Studies MOFFATT, Bob (1988) Wet Paper Publications - OUT OF PRINT

Class notes (Senior Zoology) GRIFFITH, Don and SQUIRE, Bob, Ph D (unpublished 1966 and 1967)

Drains to our Waterways Melbourne Water (2002), Gould League Victoria

Exploration of the Oceans WEIHAUPT, John G (1979) Macmillan Publishing Co Inc, New York

Great Barrier Reef World MOFFATT, Bob (1987) Wet Paper Publications - OUT OF PRINT

Introduction to Oceanography (3rd ed) ROSS, David A (1982) Prentice-Hall, Inc New Jersey

Invertebrate Zoology (2nd ed) BARNES, Robert D, Ph D (1968) W B Saunders Co, Philadelphia Pa

Lecture notes (Zoology IIa and IIB) HAILSTONE, Tom, Ph D and GREENWOOD, Jack, Ph D (1969, 1970), University of Queensland, unpublished.

Marine Biology LERMAN, Matthew (1986), Benjo/Cummings Pub Co, California

Marine Biology THURMAN H V & WEBBER H H (1984) Merrill Publishing Co, Ohio

❁ *Marine Studies (1st ed)* MOFFATT, Bob (1992) Wet Paper Publications

❁ *Marine Environment Manual (2nd ed)* MOFFATT, Bob (1997) Wet Paper Publications

Project Reef-Ed Great Barrier Reef Marine Park Authority (1988) *Reef Manual* Great Barrier Reef Marine Park , Authority (2000)

Stradbroke Dreamtime OODGEROO (1993), Angus & Robertson Ltd, Sydney

The Fluid Earth (3rd ed) KLEMM, Barbara E et al (1990) University of Hawaii

Zoology for Senior Forms STEPHENSON, William, Ph D et al (1967) Angus & Robertson Ltd, Sydney - OUT OF PRINT

❁ See www.wetpaper.com.au for old books written by Bob, that have been converted to Ebooks

Web references (2005)

The following web references were extensively used to check information in this edition:

www.reefed.edu.au, www.mesa.edu.au;, www.seafriends.org.nz;, www.fishnet.com.au, www.dpi.qld.gov.au, www.fisheries.nsw.gov.au, www.fish.wa.gov.au, www.austasiaaquaculture.com.au, www.dpi.nsw.gov.au/fisheries, www.csiro.gov.au, www.aims.gov.au, www.dpi.nsw.gov.au/fisheries/aquaculture, ww.dpiw.tas.gov.au, www.bom.gov.au, www.ga.gov.au, www.cmar.csiro.au/remotesensing/oceancurrents, http://epa.gov/climatechange/kids, http://royalsociety.org, www.environment.gov.au/education, www.bom.gov.au, www.gbrmpa.gov.au, www.epa.qld.gov.au, www.coastalwatch.com.au, www.ga.gov.au, www.slsa.com.au, www.surfrider.org.au, www.aims.gov.au, www.marine.csiro.au, www.streamwatch.org.au, www.waterwatch.org.au, www.classroom.antarctica.gov.au, www.aad.gov.au

978-1-86283-167-4