Chapter 8

Estuaries and the Sea

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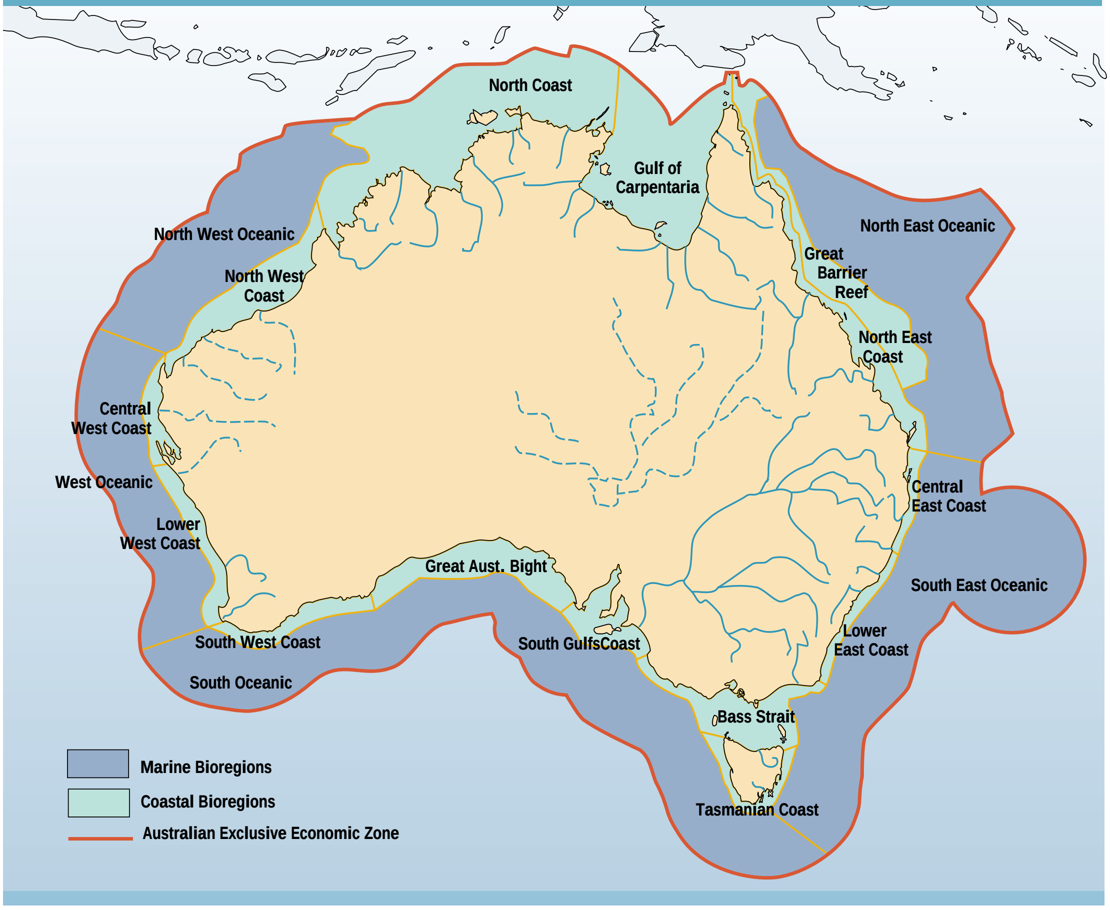
The length of the coastline is 69 630 km at 0.1 km scale; area of the Australian Exclusive Economic Zone is about 11.1 million sq km; area of the continental shelf is 2.5 million sq km and width of the continental shelf is 15 to 400 km.
Note: Norfolk Island, Christmas Island, the Cocos Islands, Macquarie Island and the Antarctic Territories are not included in this map.

Figure 8.1 Australia's major marine bioregions (ACIUCN) and the Australian Exclusive Economic Zone



Introduction

Australia, as an island continent with a long coastline, has many different marine and estuarine environments. Most of these are far removed from the major population centres and are little affected by human activities. The northern, far north-eastern and most of the 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 among the least-polluted places on earth. However, even the most remote regions show traces of persistent global pollutants.

In 1995, the Commonwealth Government published a major report — 'Our Sea, Our Future' (Zann, 1995) — which indicated the growing recognition of the importance of estuaries and the sea. Together with its associated technical papers, the report has provided substantial reference material.

Many different environments

The marine and estuarine environments around Australia's mainland and its many islands cover a considerable area and span a wide range of coastal types, climates, geological and biological regions (see Fig. 8.1). Two major ocean boundary currents — the East Australian Current and the Leeuwin Current — influence the east and west coasts of the continent respectively. (see Fig 2.10). The strength, seasonality and southward extension of both these currents are highly variable and their flow can influence coastal and ocean conditions along the south of the continent.

Australia also has responsibility for southern subpolar territories, such as Heard Island, and polar (Antarctic) regions. However, these areas are subject to separate management and treaties, and are not included in this report.

The best recognised of Australia's marine environments are those populated near-shore areas, such as rocky shores, beaches and intertidal reefs, that are used for recreation and tourism. The near-shore shallow areas also contain a wide diversity of species and are easily accessible. However, Australia's marine environment extends from these coastal shallows to the boundary of its 200-nautical-mile Exclusive Economic Zone (EEZ). This environment includes large areas of the seabed that are important for fishing, oil and gas production, and possibly mining, and areas of water that, in places, are highly productive biologically. The water provides an important pathway both for pollutants and for early life stages of marine plants and animals. As a result, many habitats, although distant from each other, may be interconnected.

Estuaries are semi-enclosed water bodies at the border of marine and fresh-water ecosystems. They are influenced by the tides and also by fresh water from the land. Australia has 783 major estuaries




(415 tropical, 170 subtropical and 198 temperate) (Zann, 1995). Few exist on the long arid coastlines of southern and western Australia. Estuaries are ecologically important habitats, which usually contain naturally high concentrations of nutrients, high productivity and wide biological diversity. Many species of invertebrates, fish, birds and mammals depend on estuaries for feeding, spawning and/or nursery grounds at some stage in their life cycle.

Australia's coastal population creates significant pressures on estuarine ecosystems from urban, agricultural, industrial, tourist and recreational development.

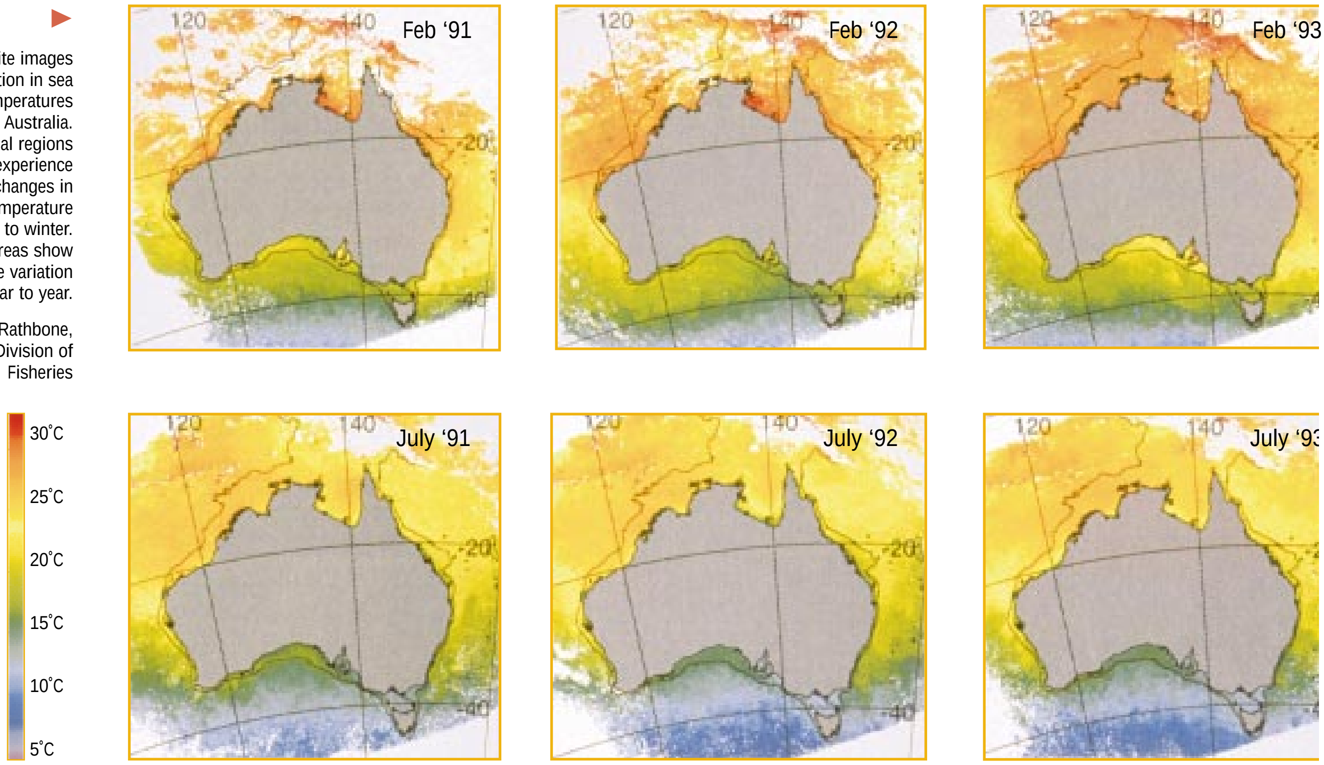
Water bodies that become increasingly saline as their distance from the open sea increases are called inverse or reverse estuaries. Worldwide, inverse estuaries are uncommon and usually occur in arid areas that do not have sufficient fresh-water inflow, or sufficient sea-water flushing, to compensate for evaporation. Australia has several large and important inverse estuaries: Gulf St Vincent and Spencer Gulf in South Australia; Shark Bay and Exmouth Gulf in Western Australia; and some estuaries in northern Australia. The biological communities in these estuaries are consistently subjected to very salty water and, like those in other estuaries, are susceptible to disturbances such as nutrient inputs, suspended sediments and alterations to fresh-water inflows.

Plants and animals

The variation from tropical to temperate latitudes in Australia has created a vast range of biological communities that live in marine and estuarine environments. These environments can be divided into a number of broad regions (see Fig. 8.1) which include well known habitats such as coral reefs, algal reefs, seagrass beds, mangroves and saltmarshes, but also the less understood midwater, outer-shelf and deepwater habitats.

All major groups of marine organisms are represented in Australian waters, and many of the highly diverse species are endemic here. In southern Australian waters, which have been geographically and climatically isolated for around 40 million years, most of the known species are endemic, or restricted to the area. In the waters of northern Australia, which are connected by currents to the Indian and Pacific Ocean tropics, most species are shared with the Asia–Pacific region. Australia has the world's largest areas and highest species diversity of tropical and temperate seagrasses, largest area of coral reefs, highest mangrove species diversity and third-largest area of mangroves (Zann, 1995).

▲ Australia's marine and estuarine environments are important for fishing, maintaining biodiversity, providing genetic resources and for their aesthetic, social and heritage values. *Clockwise from top left:* Kalbarri Cliffs, Western Australia; Coffin Bay, South Australia; northern Great Barrier Reef, Queensland; and Cottesloe Beach, Western Australia.



These satellite images show the variation in sea surface temperatures around Australia. The subtropical regions experience the greatest changes in surface water temperature from summer to winter. All areas show considerable variation from year to year.

Source: C. Rathbone, CSIRO Division of Fisheries

Productivity

Australian near-shore marine waters are generally low in nutrients, which means they have relatively low numbers of phytoplankton and therefore low productivity (see Fig. 8.2). Although upwellings bring nutrients from deep ocean waters to the surface, these are localised and episodic (occurring off parts of New South Wales, South Australia and the North West Shelf). There are no large and continuous upwellings and, historically, run-off from the land has been naturally low in nutrients. Many of the marine species are adapted to low nutrient conditions. Nonetheless, seabed productivity is high in certain habitats (particularly near shore) and in Australia a much greater importance is attributed to the productivity of plants attached to the sea floor (seagrasses, macroalgae, mangroves) and coral zooxanthellae than in some other parts of the world (Zann, 1995).

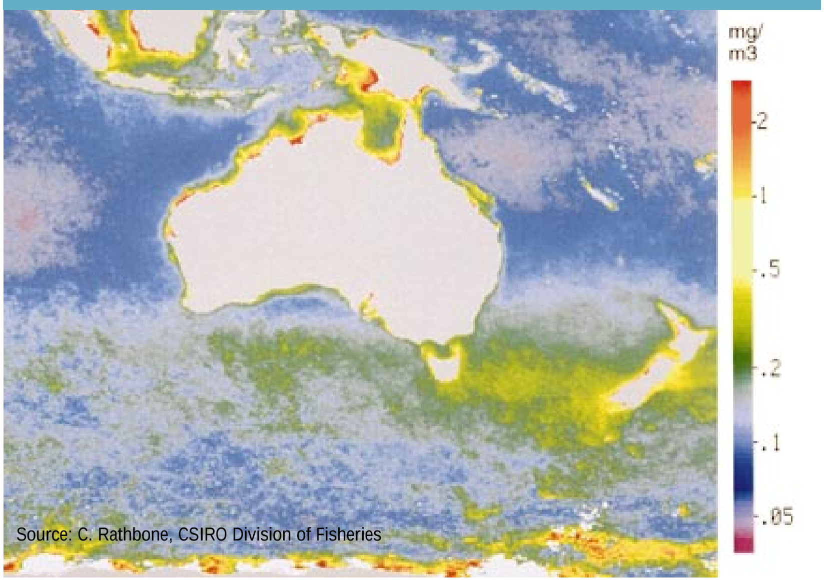
The great variability in the Australian climate — particularly the variability in run-off from the land — creates pulses of increased nutrient supply to coastal waters from time to time. Important ocean upwellings also occur, although these are generally localised and seasonal. Marine and estuarine communities have evolved under this regime of low, but in some places highly variable, nutrient supply.

Biological systems can absorb occasional high fluxes in nutrients, but constant (chronic) inputs, even at low levels, can cause significant imbalances in some communities. For example, temperate seagrasses and coral reefs, both considered highly productive, are found in clear waters with few phytoplankton. Adding nutrients to these systems over a long period of time (even if the increase in nutrient concentrations is only slight) can cause major changes. The elevation of nutrient levels near sewage or industrial effluent outfalls has favoured the growth of algae attached to seagrass leaves (epiphytes). These shade and weigh down the leaves, reducing photosynthesis, and can eventually kill the seagrass.

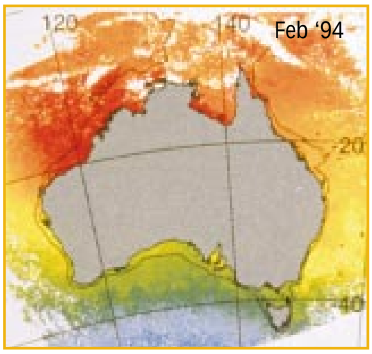
In estuaries, nitrogen and phosphorus are the key nutrients supporting growth of plants and phytoplankton. However, in marine systems phosphorus is readily available in high concentrations, and forms of nitrogen are probably more limiting for plant growth. Both elements can cause imbalances when discharged to estuaries and the sea because of their tendency to stimulate the growth of certain algae to the detriment of other species.

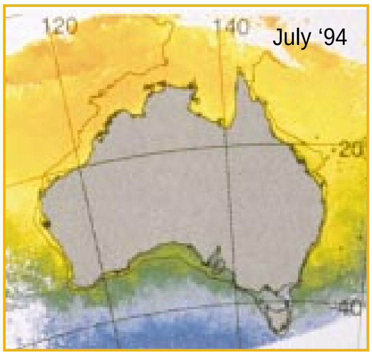
This satellite image shows the average distribution of surface water chlorophyll over the period 1978 to 1986. High concentrations of phytoplankton are consistently recorded in southern ocean waters (known as the Subtropical Convergence), in the Gulf of Carpentaria and in other inshore tropical waters. Other areas, particularly northern oceanic waters, are consistently low in phytoplankton.

Figure 8.2 Average densities of phytoplankton, indicated by chlorophyll concentrations measured by satellite



Source: C. Rathbone, CSIRO Division of Fisheries





Pressure

Marine and estuarine environments are naturally variable. Large-scale natural processes, like rainfall, wind, wave energy and ocean currents, are continuously causing change. The alterations that we make to the environment need to be considered in the context of this natural variability.

Many aspects of human endeavour in Australia contribute to the pressures on estuaries and the sea. These include both direct pressures and downstream impacts from land-based activities. Some of the heaviest pressures on the environment come from: catchment activities; coastal margin development; contaminants (point and diffuse sources); fishing (commercial, recreational and traditional); mining (coastal and off-shore); and transport (ports and shipping).

It is difficult to identify and measure all of these pressures but, for some, practical indicators may provide an indirect measure of their severity. The size of coastal cities or towns, for example, may provide a broad index of the increase or decrease of pressure on the marine environment. Other useful indicators are: the percentage of catchments cleared; the number of visitors per year; the volume and treatment level of effluent discharged per day; and the number of fishing licences or fishing days.

Coastal margin development

Human settlement in Australia has developed at a series of points around the coast, concentrated on what are now the capital cities of the States and Territories (see the box on page 8-8 and Chapter 3). As the populations in these settlements grow and infrastructure for urban development proceeds, changes occur to nearby marine and estuarine environments. People also develop adjacent land areas for activities such as farming and recreation (for example, Queensland's Gold Coast). Pressures from development have been particularly concentrated around the east, south-east and south-west of Australia, where most people live. Although coastal development has directly affected a relatively small proportion of the continent's coastline, many changes have taken place in areas of ecological importance with particular aesthetic appeal. About 70 per cent of Australia's coastline remains sparsely inhabited (Zann, 1995).

Land reclamation, modification of habitats and hydrology, tourism, recreational activities and stormwater discharge and other point sources of pollution all exert major pressures.

Coastal engineering structures such as breakwaters and seawalls associated with ports, harbours, airport runways and canal estates and marinas also have an impact. Estuaries and the coastal lakes and lagoons in the south-east have been particularly affected by seawall construction. Shoreline erosion is an increasing problem in many areas due to alteration of coastal morphology. We can expect this problem to accelerate in the future if the sea level continues to rise.

Habitat destruction and modification

Habitat destruction may occur when the environment is altered to create new land or seabed surfaces suitable for development. It may be caused by land reclamation, canal development, dredging for harbours and similar activities. Most reclamations involve the enclosure and infilling of

Habitat destruction at Wingfield, South Australia. A levee road through mangroves and saltmarsh showing the effect of restricted water exchange.

North Haven, South Australia. This housing development, fishing port and base for recreational activities on the shores of Gulf St Vincent exemplifies coastal habitat modification.

former dunes, saltmarsh, mangrove, mudflat and shallow-water areas for port and industrial developments or disposal of waste materials. Such activities cause a direct loss of natural resources, including the plants and animals that would normally live in these habitats.

Human pressures

Since European settlement, humans have changed coastal processes by clearing and developing land, using resources and changing the flow of rivers. The major pressures on our coast come from the increasing pace of human activity.

Australians enjoy the right to live and work on the coast and to use coastal and shore areas for their recreation — for beach sports, boating, bait-collecting, diving, fishing, sunbathing and surfing. In 1993 the coastal zone supported about 80 per cent of the Australian population and 66 per cent of these lived in coastal cities and large towns.

The population of the non-metropolitan coastal zone is growing at an unprecedented rate. Between 1971 and 1991 it grew by 95 per cent (from 2.1 million to 4.1 million), while the total Australian population grew by 32 per cent.

The most severe pressures on the coastal environment are related to residential development in the most accessible 10 per cent of the coast in and around urban areas, particularly those in the south-east. A further 15–20 per cent is subject to increasing development and eventual urbanisation. Between 1983 and 1990 more than three-quarters of all building approvals concerned the one-third of statistical districts that had coastal populations growing at more than double the national average rate between 1971 and 1991. Over 63 per cent of coastal building approvals were for residential developments and more than half of these (34 per cent) concerned non-metropolitan coastal statistical areas.

Many of the pressures have grown gradually, but they usually interact. Urban growth involves land clearing, damming for water supply, flow modification for flood control, pollution (from sewage, urban and industrial waste disposal) and the impacts of meeting a rising demand for fishing, tourism, coastal recreation and a wide range of transport, health, education and community infrastructure and services.

Source: Kenchington, *in press*

There are no firm data on the extent of land reclamation. Although each of the developments only affects a relatively small area, they can have a substantial accumulated effect as in the case of Moreton Bay (see the box opposite).

The effects of land reclamation can extend well beyond its physical boundaries to affect habitats in adjacent intertidal and subtidal areas. Reflected waves and diverted currents may remove sediment, which may be deposited in areas that become more sheltered (Bird, 1994). Many structures alter the shape of the shoreline, its substrates and seabed level. More direct impacts arise from activities such as selective clearance of vegetation. An increasing source of pressure is the disturbance of acid sulfate soils (see Chapters 4 and 6), which results in increasing acidification of estuaries and death of animals and plants. In some cases habitat modification results in species being replaced by others that are better-adapted to the new conditions.

Hydrological modification

Coastal margin development usually entails structural modification of the shoreline to control or modify the environment. Breakwaters and groynes, for example, can alter water movement along the coast. Most of Australia's rivers that feed estuaries are dammed to provide water for urban supply or power generation (see Chapter 7). This has major impacts on the hydrological patterns and occurrence of above-ground and below-ground flows of water. A dramatic example arose in 1981 when the mouth of the Murray, Australia's largest river system, became completely blocked.

Urban and agricultural developments usually reduce the infiltration of rainwater into the ground and increase the run-off of water and suspended sediments to the sea. On a local scale this can alter patterns and timing of surface and underground water availability, thus causing changes in vegetation and availability of habitat resources to wildlife. Changes to the hydrology can also result in changes to physical, chemical and biological processes such as nutrient cycling, soil development, sediment settlement, erosion and movement of salts.

Recreation

Australia's coastal region has important natural tourist and recreational resources that attract many domestic and overseas visitors. The international tourist industry — most of which is based on the coast — contributes more than six per cent of GDP and is a growth industry. In 1994 Australia had more than 3.3 million international visitors. About half of these participated in some sport or outdoor activity: 900 000 surfed or swam, 580 000 snorkelled or scuba dived, 58 000 went fishing and 102 000 sailing (Bureau of Tourism Research, pers. comm.). During 1991, Australians made 49 million trips as domestic tourists, and spent 215 million visitor nights away from home, mostly in coastal areas (Zann, 1995).

On midsummer weekends, individual Sydney beaches attract crowds of up to 50 000, and Melbourne's Port Phillip Bay beaches attract up to 300 000 bathers. Queensland's Gold Coast, one of Australia's most popular holiday destinations, attracts over nine million visitors each year.

All these visitors require a range of public facilities, from accommodation, transport, shopping, toilets and boating facilities to parks, sports grounds, sewerage, water and electricity supply systems and garbage disposal services. These facilities are typically placed on or near the particular attraction, which may be a picturesque and secluded beach, inlet or island, thus changing its natural and cultural environment and reducing the scenic values (Dutton and Luckie, 1994).

Although tourism and recreation are generally considered to be clean industries, they have had significant negative impacts on many parts of Australia's coastal strip. These negative effects may include beach and dune erosion, loss of habitat to facilities, trampling of reef, collecting of intertidal plants and animals, declines in wildlife and fisheries, reduction in water quality, disturbance of animal feeding and breeding behaviour, seabed damage by boat anchors and moorings and the effects of antifouling materials.

Stormwater discharge

Stormwater discharges to estuaries and the sea are a common feature of coastal urban areas. People have only just started to recognise that stormwater carries significant quantities of debris and contaminants, like litter, oil and heavy metals, that may cause environmental harm.

We do not know the level and content of such discharges on a national basis, but in places, stormwater can carry significant quantities of suspended sediments, nutrients and pesticides, chemicals from domestic and industrial discharge and accidents, vehicle-emission wastes from roadways and litter. For example, researchers in Victoria have estimated that drains, creeks and small rivers (excluding the Werribee Complex and the Yarra River) annually carry about 53 tonnes of surfactants (from detergents) into Port Phillip Bay (NSR Environmental Consultants, 1993). In New South Wales, urban stormwater is regarded as a major pollutant of the coastal environment. Between Palm Beach and Cronulla 200 stormwater outlets of about 450-mm diameter discharge water containing high levels of pollutants such as sediments, bacteria, nutrients, trace metals and organic chemicals (Environment Protection Authority of NSW, 1993). These pollutants are derived from pets (dogs and cats) as well as from vehicles, industry emissions, gardens and roads.

Coastal development in Moreton Bay

Moreton Bay is an estuarine bay enclosed by barrier islands. Biotic communities include mangroves, saltmarshes, seagrasses and coral reefs. The bay is recognised as a significant habitat and nursery area for estuarine and oceanic fish, and an important habitat for turtles, dugongs, dolphins and seabirds. It provides about 10 per cent of the value of east coast fisheries and employs about 1000 full-time fishers. The annual recreational catch (1900–2800 tonnes) is also significant.

Central to Brisbane and surrounding areas, Moreton Bay has been subjected to intense pressure from coastal development — particularly through reduced water quality, fishing, coral-dredging, sand extraction and port operations.

Suspended sediments, heavy metals, nutrients and microbial pathogens from the Brisbane River reduce its water quality. These pollutants arise from both diffuse catchment and point sources. In 1987, researchers estimated that 17 per cent of mangroves and 21 per cent of saltmarsh had been lost to coastal development since European settlement, and that there had also been large impacts on seagrass and algal communities (Queensland Department of Environment and Heritage, 1991). The most recent major development has been Brisbane's International Airport.

The government and community have become increasingly aware of issues affecting Moreton Bay with a resultant intense pressure for protection measures. Piecemeal and uncoordinated decision-making on development issues has had a cumulative detrimental effect and is listed as a significant factor in resource degradation and lack of knowledge about the bay. Significant changes have, however, recently occurred in political, administrative, planning and management attitudes at federal, State and local levels. The Moreton Bay Strategic Plan covers areas designated for preservation and habitat conservation, National Estate registration of areas by the Australian Heritage Commission, coordinated management of the Brisbane River and various local initiatives for foreshore management.

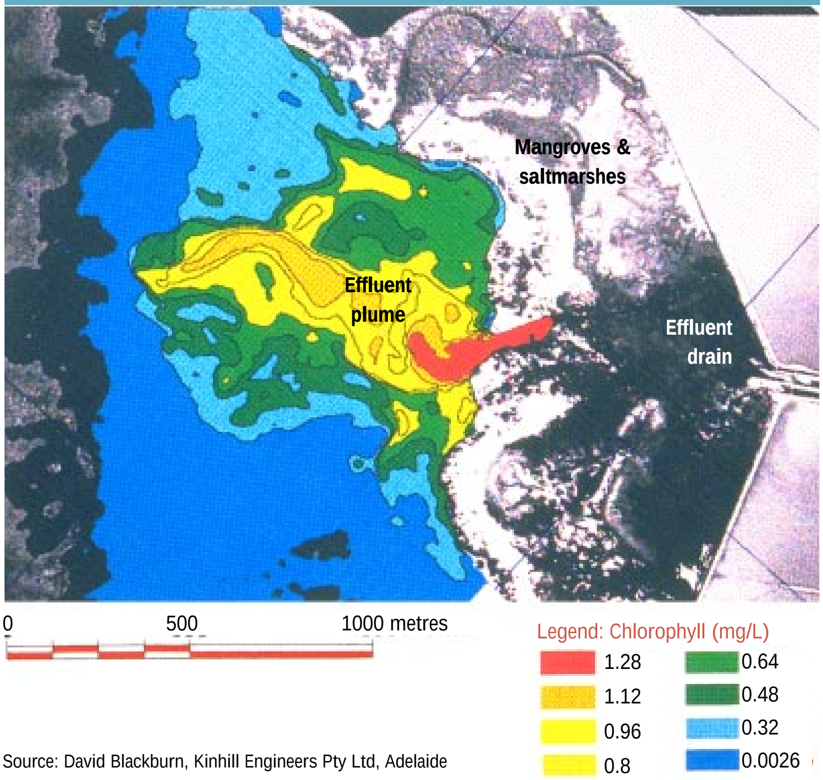
The bay's social, economic and ecological importance is being increasingly recognised and the need for conservation and sustainable management has become a significant factor in decision-making about its uses and development.

Table 8.1 Distribution of commercial tourist accommodation in the coastal zone, 1990–91

	Hotels and motels	Caravan parks	Holiday units, flats & houses	All tourist accom.
Capital cities	960	312	210	1482
Non-metropolitan coastal zone	1824	1248	1050	4122
Total in coastal zone	2784	1560	1260	5604
Total in Australia	**4800**	**2600**	**1400**	**8887**
Percentage in coastal zone	58	60	90	64

Source: RAC 1992 & 1993

Figure 8.3 Chlorophyll concentrations in treated sewage effluent from the Bolivar outfall near Adelaide (from aerial photographs, September 1993)



Source: David Blackburn, Kinhill Engineers Pty Ltd, Adelaide

▲

Sewage effluent from the outfall at Bolivar near Adelaide enhances growth of both phytoplankton and benthic algae. The area has lost extensive seagrass beds

Contaminants

About 80 per cent of contaminants in marine and estuarine environments are thought to enter the sea from the land (Zann, 1995), both from direct point sources such as pipes and drains and from diffuse sources such as river and urban catchments, and from the atmosphere. The main sources include: stormwater run-off that carries contaminants like heavy metals, oils and litter; agricultural run-off containing fertilisers, pesticides and suspended sediments; and sewage effluent discharges, which carry organic matter, nutrients, pathogens and industrial wastes.

Some of the contaminants persist in the environment and can become concentrated in fish and other organisms. Pollutants do most damage in coastal and inshore waters close to the sources. However, the more persistent contaminants may also affect offshore waters, although no data are available to confirm this.

Nutrients

Australia's marine and estuarine systems have evolved with relatively low inputs of nitrogen and phosphorus (the main nutrients controlling the natural growth of marine plants) derived from land run-off and ocean upwelling.

One of the most serious large-scale threats to Australia's near-shore marine environment is the input of excessive nutrients (see page 8-13). Tropical coral systems and temperate seagrass beds are highly sensitive to nutrient impacts. Estuaries and coastal lagoons whose upper river catchments have been cleared for intensive agriculture and whose lower reaches are subject to major urban and industrial developments are also at risk (Zann, 1995). Australia suffers blooms of nuisance microalgae, including toxic species, and macroalgae that can have significant environmental, social and economic impacts. These algal blooms can degrade ecosystems, decrease the recreational value of waterways, affect human health and destroy aquaculture production.

Soil erosion, fertiliser run-off, sewage discharge, intensive animal production and industrial and urban discharges all contribute nutrients to the marine environment. Fertilisers are a significant source of nutrients from agricultural areas, as are sediment leaching and erosion from cleared land (see Chapter 7). Scientists believe that in Queensland the amount of sediments, nitrogen and phosphorus entering the sea each year have increased three to fivefold since European settlement (Moss *et al*., 1993).

Sewage effluent from urban areas contributes significant amounts of nutrients. Most sewage receives only primary or secondary treatment and the effluent remains high in nutrients (see Table 3.38). Each year Australia's sewerage systems discharge around 10 000 tonnes of phosphorus and 100 000 tonnes of nitrogen (Brodie, 1995), much of which finds its way into the sea. However, as mentioned before, stormwater run-off from cities also contains a large quantity of nutrients from animal and other wastes, which may equal that generated from urban sewage (Zann, 1995).

Suspended solids

Suspended solids can include fine sediments and very small particles of organic debris. Clearing of forests, overgrazing and agriculture have greatly increased soil erosion and, consequently, the amount of sediments and suspended solids entering the sea. Urban development is also responsible for increases in suspended solids associated with run-off, erosion, sewage-sludge discharges and localised activities like construction, dredging and dredged-spoil disposal. As well as contributing nutrients, suspended solids can affect marine and estuarine communities by smothering sedentary plants and animals, clogging gills, reducing the light available to plants for photosynthesis and altering seabed level and sediment grain size (Zann, 1995).

The rivers of Queensland's east coast catchments are estimated to deliver about 14 million tonnes of sediment annually to estuaries and coastal marine waters — three to five times more than before European settlement (Moss *et al*., 1993). Most of this sediment comes from the large areas of agricultural land in central and northern Queensland. The finest components of these sediments are widely dispersed into estuaries and the sea.

Pesticides, herbicides and industrial chemicals

Organochlorine pesticides are a particularly persistent and toxic group of synthetic chemicals. The characteristics that make them effective pesticides also make them potential environmental threats. Although organochlorines are only present in very low concentrations in the sea, they can accumulate in animal fats up to 50 000 times the concentration in surrounding waters (Richardson, 1995). They may also accumulate through the food chain into predatory fish, seabirds, marine mammals and humans. Low concentrations of these pesticides and polychlorinated biphenyls (PCBs) contaminate whales and dolphins in all the world's oceans.

A range of organochlorine compounds have been widely used in Australia as herbicides (2,4-D and 2,4,5-T), insecticides (DDT, DDE, lindane and chlordane), fungicides (hexachlorobenzene and chlorinated phenyls) and as electrical insulating fluids (PCBs). Organochlorines are also produced in processes such as chlorine bleaching in the making of paper pulp. Now, they can only be used in Australia for specified purposes like protecting houses from termite attack. Although many former agricultural areas still suffer from contamination, little of this migrates to estuaries or to the marine environment.

Other forms of organic pesticides (such as organophosphates) are still widely used in Australia, often as substitutes for the former applications of organochlorines. An example is endosulfan, a widely used pesticide that has replaced several organochlorines for a variety of uses. There is no coherent national monitoring program for residues of these persistent chemicals in estuaries or marine systems and little is known of their present levels (Zann, 1995). Most studies suggest that their levels are low in water, seafood and sediments, except near known point sources.

Metals

Heavy metals such as copper, lead, cadmium, zinc and mercury, as well as tributyl tin (TBT) from antifouling paints (see page 8-17), have become serious contaminants in the world's estuaries and coastal waters in recent years. Heavy metals can be present on particles or as dissolved compounds — the chemical form strongly determines how toxic or available the metal is to organisms (Batley, 1995). Marine and estuarine species may suffer heavy metal poisoning, but the more likely outcome is chronic exposure at lower levels, with the consequent subtle effects including reduced breeding potential or susceptibility to disease. Of particular concern is the potential impact on humans through consumption of seafood with concentrated heavy metals from water or suspended solids (see page 8-37).

In Australia, most concern for the effects of heavy metals is associated with the discharge of leachates, tailings and waste from point sources like smelters and mining operations. Mining is a major industry in Australia and all States and the Northern Territory have smelters, mines or transport corridors with the potential to release metals to estuaries and the sea. Although some release large amounts of waste metals, their effects are limited to the local surrounding area, usually less than a few hundred square kilometres. However, the large number of these sites is a matter for concern. Australia has no national inventory of the number of point sources for major heavy metal discharges, the amounts discharged or the severity of effects in their local areas. Well-documented examples of affected areas are Spencer Gulf near Port Pirie and the Derwent River near Hobart.

Data on amounts of heavy metals discharged are available only in specific local cases. These figures show a general trend towards reduction in heavy metal discharges from established sources.

Pathogens

Pathogens in the marine and estuarine environments can include a number of natural and introduced soil and faecal bacteria and viruses. Many of these may originate from stormwater (see Table 8.2). Some seafood species, such as oysters and mussels, are filter feeders and can act as concentrators of pathogens. We know little about how pathogens survive in estuaries and the sea or how both endemic and introduced pathogens affect marine and estuarine biota. Viruses in particular are poorly understood, because of difficulties in culturing them, but diseases such as polio and the hepatitis 'A' and 'E' viruses have been associated with swimming (Zann, 1995) and some viruses are reported to be persistent in marine waters.

People come into contact with marine and estuarine pathogens by eating contaminated seafood or enjoying recreational water sports — especially in enclosed water bodies such as bays and estuaries. The microbes can cause illnesses such as gastroenteritis, hepatitis, conjunctivitis and upper-respiratory tract and wound infections (Ashbolt, 1995).

The incidence of pathogens can also have substantial economic implications. In fisheries or aquaculture, for example, contaminated stocks may need to be held in clean or chlorinated water to allow the pathogens to be flushed out before the food is safe for consumption. Contaminated areas may need to be closed to water sports, with consequent losses to recreation and tourism.

Bacteria also cause problems in bathing waters. Beach areas adjacent to stormwater drains can experience increases in the number of indicator bacteria following rain. In Australia, they cause

Table 8.2 Urban stormwater pathogen levels for five Sydney coastal catchments over a two-year period

Percentage of samples with greater than 1000 faecal coliforms per 100 millilitres.

	Dry weather	Wet weather
Whale Beach	98	100
Greendale Creek	98	100
Bondi	98	100
Shelly Beach	44	–
Malabar	11	10

Source: after EPA NSW, 1993.

common wound infections (particularly in people who handle fish) and 'swimmer's ear'. Parasitic protozoans may be transmitted in sea water (Zann, 1995) and ballast water can transport microorganisms.

Some pathogens do kill estuarine and marine organisms. Diseases affecting the oysters in Georges River in Sydney are a well-known recurrent problem.

Litter

Many of Australia's beaches are littered with plastic bottles, plastic bags, tangled fishing lines, nets and other rubbish. This litter is dropped by beach-goers, carried by stormwater run-off, dumped from ships, recreational and commercial fishing boats and also comes as 'drift' from remote sources far across the ocean. Urban beaches are worst affected, but even the most remote coastal and island beaches are not free from litter, often from distant sources (Wace, 1995). However, recent scientific surveys of beaches near Brisbane, Sydney and Melbourne found that most litter came from streets and garbage dumps via streams and drains.

Not only does litter spoil the appearance of the shoreline, it may also endanger marine life. Worldwide, many thousands of marine mammals, turtles and seabirds die each year from swallowing plastic bags and other objects, or get trapped in discarded fishing gear. This gear may also continue to 'catch' fish (ghost fishing). Many seabirds drown each year after becoming entangled in nets of the world's gillnet fisheries. Some seabirds and turtles swallow plastic debris, although the effects of this on their populations are unknown. Overall, researchers have estimated that seven billion tonnes of debris enters the world's oceans each year, 48–99 per cent of which is plastic. While most of this probably occurs in the Northern Hemisphere, the transportation of seeds, spores, eggs, larvae etc, into the Southern Hemisphere on debris may be an issue of concern (ANZECC, 1995).

Litter damages a wide range of marine organisms. Common problems include urban rubbish and lost fishing equipment.

Fishing

Australia makes good use of its diverse fish fauna and Australians enjoy a plentiful supply of fresh seafood. Many also enjoy recreational fishing. Virtually all estuarine, near-shore and off-shore areas support fishing, which may be commercial, recreational or traditional subsistence fishing, or aquaculture. Only commercial fishing exploits the resources of the deeper waters (depths to about 1400 metres), but recreational fishing is also widespread, extending to remote reef areas.

Methods range from the simple hooks and lines of the recreational fisher to the longlines, nets, traps and trawl nets used in commercial operations. Fishing pressure on marine and estuarine environments has a number of impacts. These include: excessive catches of target and non-target species, alteration of food chains, changing species composition, alteration of the genetic composition of fish stocks, introduction of non-indigenous species (aquaculture), habitat modification (particularly seabed disturbance by trawling) and destruction of in-shore reefs by reef-walking and bait-collecting.

The catch and fishing pressure

In the past, people have used indicators such as the number and size of boats in each fishing fleet, number of hours spent fishing and number of lobster-pot lifts to measure fishing pressure. However, the interpretation of these indicators has become increasingly complicated by technological advances such as the use of spotter aircraft, radar, sonar and satellite navigation systems (GPS–global positioning systems) and increased skill of fishing operators.

In the absence of comprehensive data on fishing effort, the increase in total landings of commercial species over time provides a very crude estimate of increased pressure on fish stocks. The total Australian catch, including crustaceans and molluscs, increased from 73 000 tonnes in 1964–65 to 195 000 tonnes in 1994–95 (see Fig. 8.4).

We do not have enough information to assess the impact of recreational fishing on Australian fish stocks. However, one estimate indicates that the total annual recreational catch may be about 50 000 tonnes (Kearney, 1995). A 1984 survey estimated that more than 4.5 million Australians went fishing at least once a year; more than 800 000 went fishing at least 20 times a year.

Recreational activities such as reef-walking, snorkelling, beachcombing and collecting (for food, bait and shells) are also imposing significant pressures, especially near coastal cities, towns and tourist centres. We do not know the overall impact of these activities, but in some local areas it is intense. Collecting overlaps with recreational fishing in terms of its direct pressure and trampling and rock turning can also damage habitats.

Fishers catch many incidental species, which can include a wide diversity of organisms such as

Nutrients: nitrogen and phosphorus in coastal waters

Nutrients — principally nitrogen and phosphorus — are important to the water quality and productivity of marine and estuarine environments for two reasons. First, they have a fundamental role in the functioning of biological systems; and second, their concentrations and availability to aquatic organisms are susceptible to human manipulation.

Nutrient enrichment has adverse impacts on ecosystem diversity, fisheries stocks and the aesthetic and recreational value of coastal waters.

Sources of nutrients

Nutrients continually enter and leave the marine environment and move, or cycle, between the living and non-living components of marine ecosystems. They enter coastal waters through river inflow, upwelled outer-shelf waters, rainfall, regeneration from sediments, localised discharges of sewage and industrial effluent and, in the case of nitrogen, biological fixation of atmospheric gaseous nitrogen. They leave — or become biologically unavailable — largely through deposition and incorporation into the sediments.

While some of these sources are largely beyond the scope of human influence, others, particularly river inflow and waste water discharges, can be changed by human activity.

Nutrient loads

With increasing population growth and urbanisation, the volume of nutrient-rich sewage and industrial effluent entering localised areas of the coast continues to increase. Nationally, sewage effluent contributed some 10 000 tonnes of phosphorus and 100 000 tonnes of nitrogen in 1994. Much of this is discharged to estuarine and coastal waters.

In certain localised areas, waste water discharges are the main source of nutrients entering coastal waters. However, on a national scale, most nutrients (possibly up to 85 per cent) originate from diffuse catchment sources. In the central Great Barrier Reef region, for example, some 39 per cent of all nitrogen and 52 per cent of phosphorus come from river inputs.

While it is difficult to estimate the quantities of nutrients carried by rivers, we do have some indicative values. Mainland catchments annually discharge an estimated average of 77 000 tonnes of nitrogen and 11 000 tonnes of phosphorus to Queensland's coastal waters of which the Burdekin–Haughton catchment alone contributes some 14 000 and 2000 tonnes respectively. Each year between 1977 and 1991 an average of 75 tonnes of phosphorus was carried into the Harvey Estuary in Western Australia, with up to 130 tonnes in wet years. Parent catchments annually deposit an estimated 170 tonnes of nitrogen and 30 tonnes of phosphorus into Tuggerah Lakes, New South Wales.

Many people now recognise the continuing increase in nutrient loads entering estuarine and coastal waters from both river inflow and waste water discharges as one of the most significant pressures on Australia's coastal ecosystems. As nutrient inputs continue to increase, the pressure on coastal waters will escalate further.

Algae

Elevated nutrient concentrations promote excessive algal growth in many estuaries and bays around Australia.

Scientists first noticed increased algal growth in the Peel–Harvey estuary in the 1960s. The problem became progressively worse during the '70s and '80s, with massive blooms of different species of algae occurring at different times. The progressive and severe deterioration in the water quality of the estuary and hence in its amenity, was due to excessive inputs of phosphorus originating from fertiliser applied in the parent catchment (see pages 7-46 and 7-47).

Excessive inputs of both nitrogen and phosphorus from waste water discharges and diffuse catchment sources have contributed to excessive algal growth in the Tuggerah Lakes. The amount of macroalgae (seaweed) in the lake system has markedly increased in recent decades. As a result, the recreational value of the lakes has fallen in recent years.

The discharge of nutrient-rich waste water to shallow waters off the Caloundra coast, Queensland, caused significant changes to the intertidal algal community near the outfall. Some 15 different species of algae that were present at similar, unaffected sites disappeared from the discharge area, while several species grew prolifically, covering the entire intertidal rock platform with a thick algal turf.

In the Great Barrier Reef region, observers have seen signs of reef degradation due to increased nutrient inflows. However, no one knows whether the increased availability of nutrients has increased the frequency or magnitude of algal blooms.

Responses

In some areas monitoring and research are being carried out as the basis for developing remedial action. On the Great Barrier Reef, for example, recognition of the threat of nutrient enrichment has prompted the Great Barrier Reef Marine Park Authority (GBRMPA) to implement a major nutrient monitoring and research program. The program, directed at identifying the major sources of nutrient inputs, their fate once in the marine environment and their effect on reef ecosystems, will provide the basis for the development of appropriate management strategies.

Where very significant adverse effects on coastal systems are already evident, authorities have tried to remedy the problem and rehabilitate the area. In the Peel–Harvey estuary for example, the Western Australian government developed a three-part program following years of research into the cause of the algae problem. The program consists of catchment management to reduce phosphorus inputs by changing agricultural practices, an algae-harvesting component to remove nuisance deposits and a channel-construction program to increase flushing of the estuary. The $57 million Dawesville Channel was opened on 23 April 1994.

In the case of adverse impacts from sewage or industrial effluent outfalls, such as on the Caloundra coast, the response may be to relocate the outfall to a more appropriate position. Responses commonly applied to water quality problems include the relocation of outfalls, improved treatment or the use of different disposal methods. The GBRMPA, for example, now requires nutrients to be removed from sewage effluent before discharge into Marine Park waters.

Source: Cosser, in press.

Fishing: a livelihood and a way of life. Setting rock lobster pots, Western Australia.

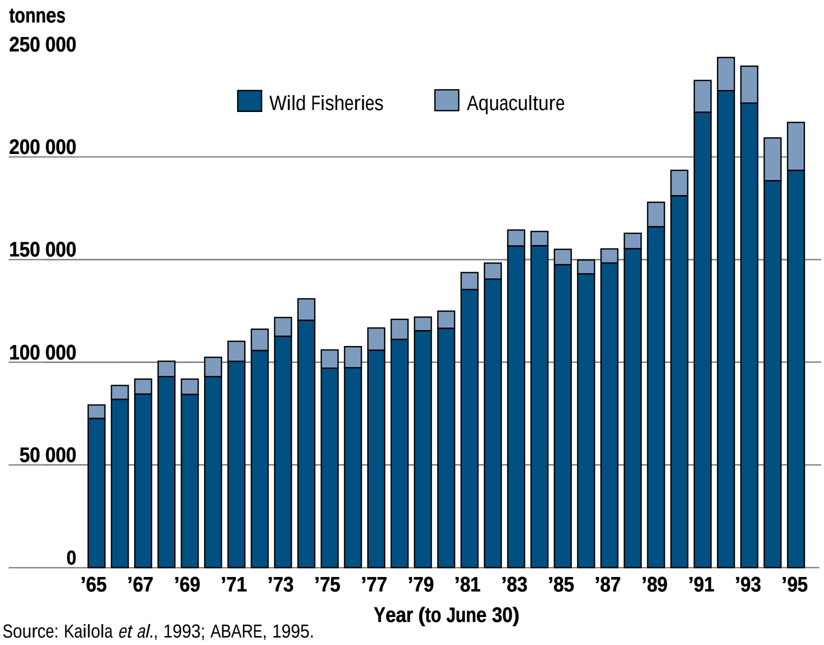
sponges, hard and soft corals, molluscs, crustaceans, fish, marine worms and plants. Some of the non-target species are retained for sale and the rest are returned to the sea as discards. Some fishing methods also unintentionally capture reptiles, birds and mammals.

Commercial fishers use a number of methods, which result in the capture of different types and amounts of non-target species. The discards from prawn trawling, for example, include many species that can make up a high proportion of the catch. Very few of these organisms survive when returned to the water. In the northern and southern prawn trawl fisheries the ratio of non-target discards to prawns can be as high as 8:1 by weight. In 1988, for example, 220 prawn trawlers worked the Australian northern prawn fishery landing 7100 tonnes of prawns and more than 30 000 tonnes of bycatch (Ramm *et al.*, 1990).

Turtles and sea snakes are also taken in prawn trawl nets. The flatback turtle is the main one caught in northern Australia, followed by loggerhead, olive ridley and green turtles. A study of prawn trawlers operating in the tiger prawn segment of the northern prawn fishery found that the trawlers caught around 4100 turtles in 1988, about six per cent of which drowned (Marsh *et al.*, 1995).

Hook fishing, traps and pots generally catch fewer non-target species.

Figure 8.4 Australian fisheries production



Source: Kailola *et al.*, 1993; ABARE, 1995.

Genetic alteration

Fishing can put selective pressure on fish populations to alter their genetic composition. For example, large-scale pressure for a particular size of a target species of fish could result in a shift in the genetic composition of the species. Similarly, trawling or removal of predators may alter habitats, thus favouring particular individuals with a consequent selection for (or against) particular genetically controlled characteristics. This effect is most likely to occur in small populations or populations that are under large-scale pressure (see pages 4-10 and 4-11).

Aquaculture can result in genetic bias when large numbers of juveniles are produced from selected broodstock (for example, oysters or abalone). If these individuals are released to the wild they can influence the genetic composition of natural populations.

Habitat modification

Some kinds of gear used to harvest fish can affect marine and estuarine habitats. Bottom trawling, in particular, has the potential to alter the habitat. It involves towing nets along the seabed, which catch all animals that cannot escape the path of the trawl.

A number of studies have recently been undertaken and others are in progress to obtain more information on how trawling affects both the habitat and the capture of non-target species. Researchers are also trying to develop trawl gear that is more environmentally friendly.

Mining

Coastal and offshore mining activities that can have an impact on the marine and estuarine environments include: sand and gravel mining for minerals, beach replenishment or industrial uses; oil and gas exploration and production; coral (limestone) mining; diamond dredging; and terrestrial mining.

These activities can cause habitat loss and modification, alter the behaviour of animals, spill hydrocarbon from leaks and flaring, release discharges from platforms and increase concentrations of suspended solids and/or heavy metals (see pages 8-10 and 8-11).

Sand mining and dredging

Sand mining for minerals, beach replenishment and land reclamation occurs in many areas along Australia's coastline, including south-east Queensland, northern New South Wales, Western Australia and South Australia.

It can alter and destroy habitats (see the box on page 8-9), alter seabed level and substrates and generate suspended sediments (see pages 8-10 and 8-17). The effects of sand mining and dredging can potentially alter the species diversity of an area and dramatically change the productivity and composition of seabed-dwellers and associated communities, including commercial fish species. For example, in Cockburn Sound, Western Australia, calcareous sand beneath seagrass beds is mined for cement and lime production, and near Adelaide, near-shore sand dredging is used to replenish sand loss on metropolitan beaches. These activities may have serious effects on the plants and animals living in these disturbed habitats.

Seismic surveys

Seismic surveys are a primary, remote-sensing tool used to explore for oil and gas deposits. Some people have feared that high-energy sound waves could cause mortality or injure nearby marine organisms, or affect their feeding, mating or breeding activities (Zann, 1995; Swan *et al.*, 1994). Seismic surveys are sporadic, of relatively short duration and only likely to have a direct effect on marine organisms that are within 200 metres of the trailing cables (Swan *et al.*, 1994). Such surveys may temporarily affect communications and behaviour of marine mammals in the immediate vicinity of the sound source, but this is unlikely over a wider area (Richardson and Malme, 1994). Survey vessels have a policy of keeping a watch for whales and discontinuing surveys while marine mammals are in the vicinity (Swan *et al.*, 1994).

Given the relatively small scale of seismic activity, the often large areas and the low probability of encountering sensitive populations at critical times and provided seismic surveys are avoided at locations and times of particular sensitivity, the risk for disruption appears to be small for most species.

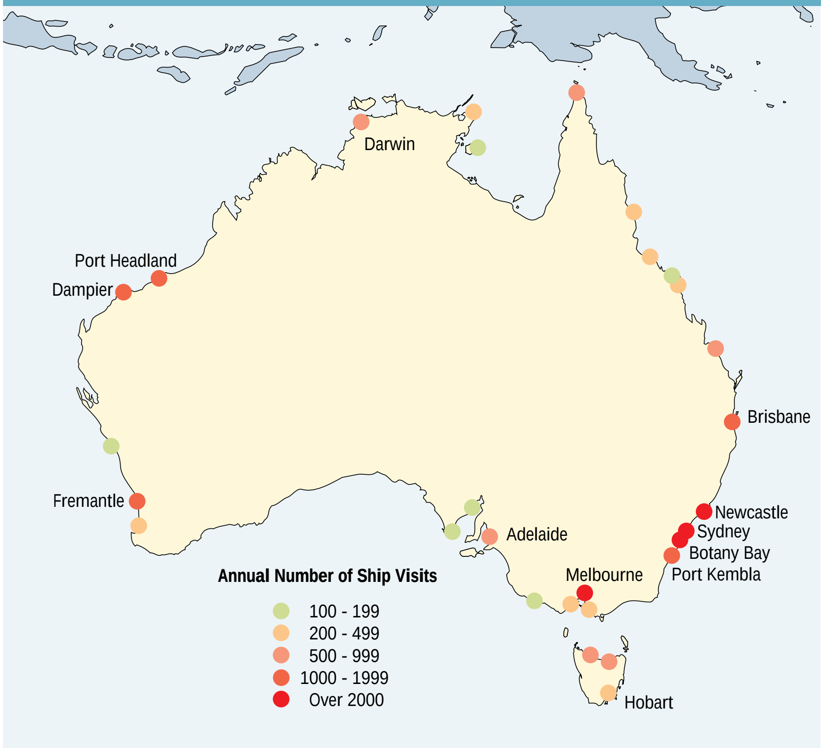
Oil and gas

Offshore petroleum production has significant economic and strategic importance for Australia. About 86 per cent of our liquid fuels and 75 per cent of our natural gas, worth around $5.4 billion a year, comes from offshore wells in Bass Strait, the Timor Sea and the North West Shelf. Over the past 30 years oil companies have drilled more than 1100 wells offshore and extracted 2800 million barrels of oil. The Australian offshore petroleum industry has a very good environmental record to date and has spilt only about 800 barrels during this period (Zann, 1995).

Crude oil and refined petroleum are complex substances made up of many hundreds of different compounds, including alkanes and aromatic hydrocarbons. The latter, which are toxic, include the polycyclic aromatic hydrocarbons — carcinogens that have been implicated in a wide range of human health problems and diseases in aquatic organisms. Polycyclic aromatic hydrocarbons can occur in small quantities in crude oil and can be produced by incomplete combustion. Most components of oil also accumulate strongly in food chains and bind to organic material in sediments (Connell, 1995).

Dredge spoil dumped at sea has the potential to release large amounts of contaminants

Figure 8.5 Annual ship visits to ports in 1992



Source: Australian Maritme Safety Authority

The various environmental impacts of drilling for offshore petroleum include: the effect on the seabed of constructing platforms and laying pipes; the disposal of 'produced water', which is present with the oil and contains traces of hydrocarbons; contamination by drill fluids used to lubricate drill bits; and an increase in shipping activity.

Oil drilling is prohibited in marine protected areas like the Great Barrier Reef Marine Park and the Ningaloo Marine Park.

Ballast water is regarded as a significant vector for the introduction or translocation of exotic or pest species. Clockwise from top left: toxic dinoflagellate *Gymnodinium catenatum;* the giant fan worm *Sabella* cf. *spallanzanii;* the mussel *Musculista senhousia;* and the sea slug *Godiva quadricolor.*

Transport and shipping

For Australia, an isolated island continent with a long coastline, shipping represents a major and essential economic use of our seas, estuaries and coastlines. In terms of tonnage carried and distance travelled, Australia ranks as the fifth largest user of shipping in the world. Each year about 12 000 ships arrive from overseas and almost 380 million tonnes of freight are carried in Australian waters. (see Fig. 8.5) (Raaymakers, 1994; ANZECC, 1995).

Shipping operations and the associated facilities of Australia's 68 major ports can impose significant pressures on marine and estuarine environments. These include pollution from oil, spills of hazardous cargoes, release of toxins from antifouling paints, loss of habitat from reclamation and dredging, litter, waste from inadequate port facilities, sewage and introductions of foreign organisms in ships' ballast waters or attached to ships' hulls.

While ports are among the most disturbed marine environments in Australia, technical, engineering and management solutions do exist to prevent or minimise many of the associated environmental impacts (Raaymakers, 1994).

The international nature of the shipping industry and its economic and strategic importance pose particular problems for environmental management. To deal with these problems, Australia has adopted a number of international conventions covering marine pollution such as the International Convention for the Prevention of Pollution from Ships (MARPOL), which covers the carriage and discharge of oil, noxious liquids, packaged harmful substances, sewage and garbage (Zann, 1995).

Ballast water discharged by shipping is the most urgent issue, because of its potential to introduce pest species and pathogens resulting in significant environmental, economic and human health impacts. Hull-fouling can be another vector.

Ballast water and hull-fouling

In 1991, about 155 million tonnes of ballast water were discharged into Australian ports, of which 121 million tonnes came from overseas (AQIS, 1993), mainly from Asia with about half from Japan (Rigby *et al*., 1993). The other 34 million tonnes was transferred between Australian ports. Ballast water, together with hull fouling, is regarded as a significant carrier of exotic or pest species.

Displaced and introduced species have the potential to replace native species, to cause widespread environmental damage, to endanger human health and to damage fisheries and aquaculture through predation, competition and their impact on seafood quality.

At least 55 species of fish and invertebrates, plus a number of seaweeds, have been introduced into Australia either intentionally, for aquaculture, or accidentally in ships' fouling and ballast waters (Zann, 1995). The principal organisms of concern are the toxic alga *Gymnodinium catenatum* that causes red tides, the invasive giant fan-worm *Sabella* cf. *spallanzanii*, the Japanese seaweed *Undaria pinnatifida*, which displaces and smothers native kelps and the predatory northern Pacific seastar *Asterias amurensis*.

Blooms of introduced toxic marine algae are a serious marine environmental and fisheries problem in Tasmania and Victoria and may threaten the waters of other States. The toxic dinoflagellate *G. catenatum* can contaminate shellfish and produce toxin harmful to humans; it is of particular concern in areas of shellfish aquaculture (Jones, 1991). Introduced diseases pose a serious threat to our growing aquaculture industry. Organisms that cause human diseases such as cholera have been detected in ballast water, but not in boats entering Australian ports. Outbreaks of the northern Pacific seastar are spreading along eastern Tasmania, threatening marine life, aquaculture farms and scallop and abalone fisheries (Zann, 1995).

Antifouling

Ship-owners employ a range of toxic substances to discourage or prevent fouling growth on the hulls of commercial and recreational vessels. The most notable of these agents is tributyl tin. However, antifouling paints can also contain a range of other metals, such as lead and copper and organic and antibiotic compounds. These paints are designed to leach slowly into the water from the vessel's hull during passage and at docks and moorings. They can also be washed into the water in wastes from slipway operations.

The most significant effect of antifouling has been the impact of the highly toxic tributyl-tin-based antifouling on semi-enclosed water bodies such as bays and estuaries, where some species in marine communities (and aquaculture facilities) have shown significant incidences of deformity. As a result, many countries and most States in Australia, have banned the use of tributyl tin antifouling on vessels less than 25 m in length. Larger vessels are exempt because they do not stay in ports or at moorings for very long (Zann, 1995) and less-efficient antifouling would result in greatly increased operating costs.

Antifouling compounds are of most concern around mooring areas and marinas, which are usually enclosed waters with a high density of boats. Heavy metals, which can accumulate in sediments, are particularly prevalent around slipways and dockyards. The discharges from many of these operations are now controlled and toxins that would otherwise have entered the adjacent waterways must be trapped and removed.

Dredging and spoil disposal

Constructing and maintaining harbours, docks and channels is a significant and regular part of port operations. It often involves extensive dredging of the seabed and disposal of the material dredged up (called 'spoil'). Some spoil is used as landfill on shore, but most is dumped on the sea floor near the dredging area.

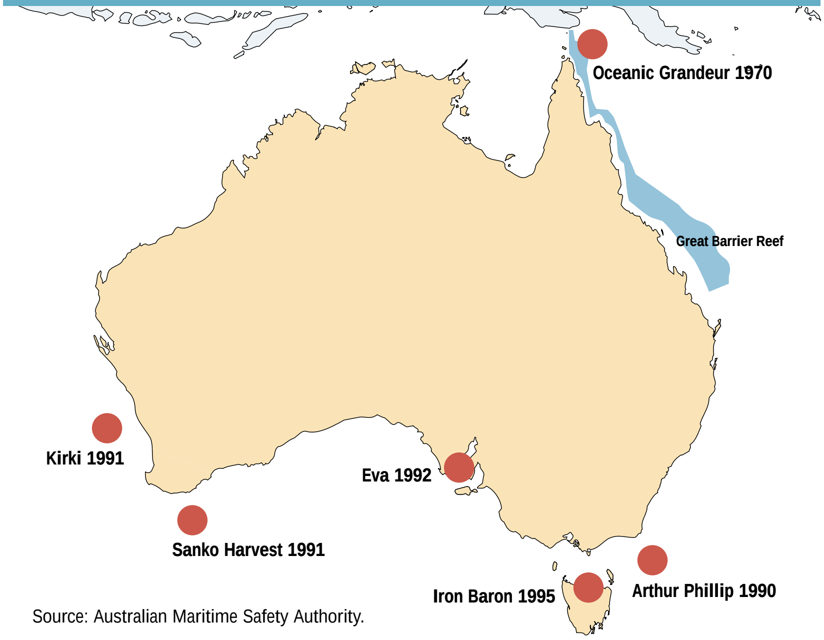
Table 8.3 Locations of species introductions attributed to ballast water or sediment discharged from ships

Swan River-Fremantle	**Fish** *Tridentiger trigonocephalus* (Striped goby) *Sparidentex hasta* (Sobaity sea bream) **Crustaceans** *Pyromaia tuberculata* (crab) **Molluscs** *Musculista senhousia* (Asian mussel) *Theora lubrica* (Asian semelid bivalve) *Polycera hedgepethi* *Godiva quadricolor* **Microalga** *Alexandrium minutum* (toxic dinoflagellate)
Port Pirie	**Crustaceans** *Tanais dulongi* (tanaid)
Adelaide	**Crustaceans** *Eurylana arcuata* (slater) *Carcinus maenas* (Euro shore crab) **Polychaete worms** *Pseudopolydora paucibranchiata* *Sabella* cf *spallanzanii* (fan worm) **Microalga** *Alexandrium minutum* (toxic dinoflagellate)
Port Phillip Bay	**Fish** *Tridentiger trigonocephalus* (Striped goby) **Microalga** *Alexandrium catanella* (toxic dinoflagellate)
Bass Strait	**Polychaete worms** *Mercierella engimatica* *Boccardia proboscidea* *Pseudopolydora paucibranchiata*
Hobart-Triabunna region	**Crustaceans** *Carcinus maenas* (European shore crab) **Macroalga (seaweed)** *Undaria pinnatifida* (Japanese giant kelp) **Microalga** *Gymnodinium catenatum* (toxic dinoflagellate) **Echinoderms** *Asterias amurensis* (North Pacific sea-star)
Port Kembla-Sydney-Newcastle region	**Fish** *Acanthogobius flavimanus* (Yellowfin goby) *Tridentiger trigonocephalus* (Striped goby) *Lateolabrax japonicus* (Japanese sea bass) **Crustaceans** *Eurylana arcuata* (slater) *Neomysis japonica* (mysid shrimp)
Brisbane	**Molluscs** *Aeolidiella indica* (sea slug) **Polychaete worms** *Mercierella engimatica* *Pseudopolydora paucibranchiata*

Source: after Manning, *in press*; with updated information from Wells and Zeidler, *pers.comm*; and Allen, 1994.

Dredging usually causes the concentration of suspended solids to rise around the dredging site and especially at the spoil-disposal areas. This can smother seabed organisms, clog fish and invertebrates' gills and reduce the light available to plants. When sediments are disturbed during dredging and spoil disposal, nutrients may be released, toxic trace metals mobilised and dissolved oxygen in the water column depleted.

Figure 8.6 Location of major oil spills



Source: Australian Maritime Safety Authority.

Oil spills

Shipping is a major source of oil spills, both from normal operations and from accidental discharges by oil tankers. Oil spills from ships are of worldwide concern, and their general effects on the marine environment are well known through a long list of environmental disasters such as that involving the *EXXON Valdez* in Alaska. Internationally, vessel operations and tanker accidents contribute 45 per cent of uncontrolled releases of petroleum to the marine environment (ANZECC, 1995). Most spills result from accidents during fuelling of vessels in ports (Zann, 1995).

Historically, few large oil spills from shipping accidents have happened in Australian waters (see Fig. 8.6). But, there is potential for major damage if a spill occurred in a sensitive area. So far, Australia has had only two large spills (over 1000 tonnes): the *Oceanic Grandeur* (1970, 1067 tonnes) in Torres Strait and the *Kirki* (1991, 17 700 tonnes) off Western Australia (Swan *et al*., 1994). Since 1991, several moderate-sized spills have occurred (South Australia Department of Environment and Land Management, 1993; Swan *et al*., 1994): the *Sanko Harvest* spill (1991, 570 tonnes) off Esperance, Western Australia, oiled more than 100 km of coast and affected 200 fur seals (13 of which died); the *Arthur Phillip* spill (1990, 100-km slick) off Cape Otway, Victoria, oiled 338 little penguins (273 died); the *Era* spill (1992, 296 tonnes) in Spencer Gulf, South Australia, oiled about 300 birds (most died) and damaged 75–100 hectares of mangroves along 10 km of coastline; and the *Iron Baron* (1995, about 300 tonnes) in the mouth of the Tamar River, Tasmania, oiled more than 2000 penguins (300 died) and 60 cormorants (30 died), and oiled over 15 km of coastline before the vessel was towed off the continental shelf and scuttled in 4000 m of water (Australian Maritime Safety Authority, pers. comm.).

The oil spills from the *Kirki* and the *Sanko Harvest* had minor impacts because of their locations and the prevailing weather conditions. However, the *Sanko Harvest* also spilled its cargo of 30 000 tonnes of di-ammonium phosphate and 300 tonnes of superphosphate fertilisers, which dispersed over a wide area. While the measured effects appeared to be restricted to a localised bloom in phytoplankton, if this spill had been near or in an enclosed bay the additional nutrients could have had a large impact on marine communities (Kinhill Engineers Pty Ltd, 1991).

Risks of a major spill of oil (or other substances) from shipping around Australia are considered to be high. The Bureau of Transport and Communications Economics estimated that the risk of a major spill from shipping was 37 per cent in any five-year period and 84 per cent in any 20-year period (Bureau of Transport and Communication Economics, 1991). Ships travelling inside the Great Barrier Reef (the inner route) are required to have pilotage to reduce the risk of accidents that could damage the reef system.

The Sanko Harvest, wrecked off Esperance, Western Australia in February 1991, spilled 570 tonnes of oil and 30 300 tonnes of fertiliser.

State

We need to know about the state of marine and estuarine environments to define their condition, observe changes over time and assess trends in decline or improvement. Key indicators provide a way to monitor the condition (or state) of the environment. We can use many variables to describe any one element of it, but the difficulties of measurement and interpretation mean that only a few make practical indicators.

In this report, we have chosen three types of indicators to assess the state of marine and estuarine environments. The first type are variables that are directly linked to important elements of the environment of major concern — for example, sea-surface colour as an indicator of phytoplankton biomass. The second type are specific measurements of environmental variables that have wider relevance to the general condition of the environment — for example, the area of seagrasses as an indicator of coastal water quality. The third type are values derived from a weighted aggregation of other estimates — for example, total commercial catch and effort linked with species diversity as a general guide to commercial fish stocks.

An indicator needs to be something that is sensitive to the major pressures on the environment, is related to aspects of the state of the environment in a sensible manner, can clearly identify changes relevant to sustainable resource management and can be easily measured and reported. It is also necessary to monitor indicators of the natural variability to avoid confusion with human-induced changes. An example of this is the Southern Oscillation Index (SOI), which is known to be correlated with the settlement of young western rock lobsters (see Fig. 8.7). Specific indicators of the state of marine and estuarine environments could include the existing area of a resource or habitat (for example, area of coral reefs), the quantities of fish stocks or the abundance/incidence of nuisance species (such as algal blooms or crown-of-thorns starfish). For many important aspects of the marine and estuarine environment, however, appropriate indicators are hard to find and for others few data are available.

Plants and animals

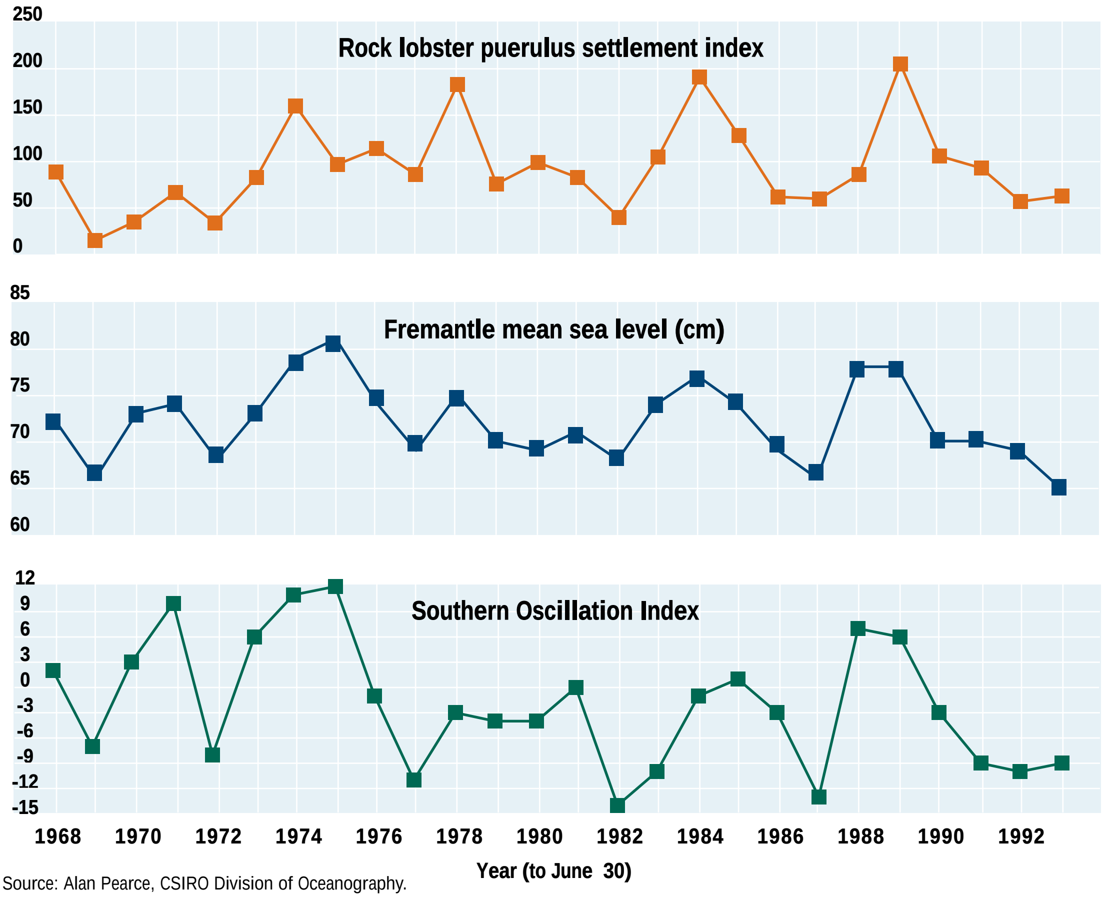
This section outlines, where possible, the state of plants and animals within various important elements of marine and estuarine environments.

Beaches and dunes

Beaches and dunes are the sandy beaches of the open coast and the gulfs and bays (see page 8-21), together with their associated foredune systems including both windward and the leeward slopes (Clarke, 1989).

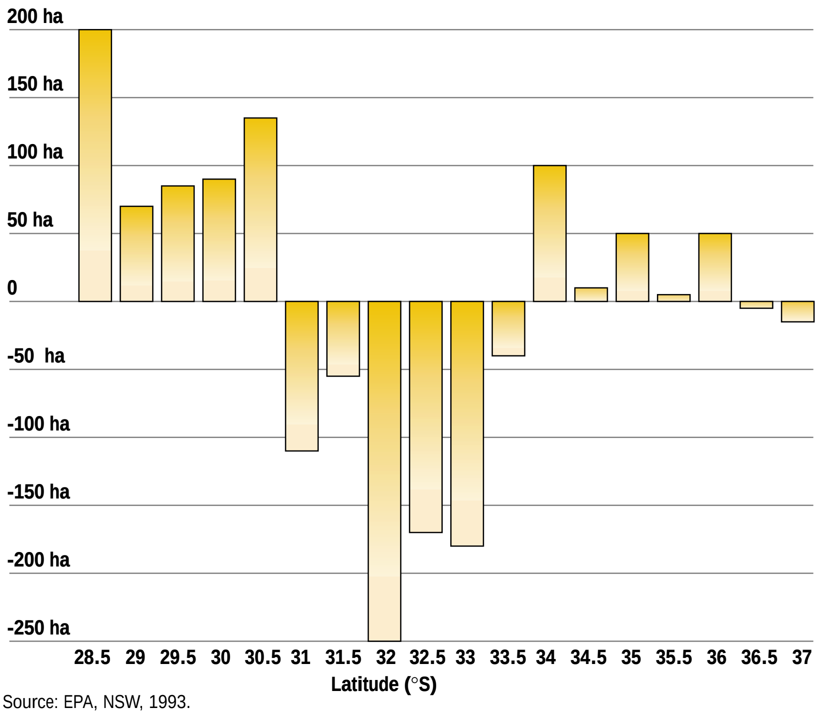
Vegetation plays an important role in forming and stabilising coastal sand dunes. Dunes provide a

Figure 8.7 The relationship between western rock lobster recruitment, sea level and the annual mean Southern Oscillation Index illustrates natural variability



Source: Alan Pearce, CSIRO Division of Oceanography.

Figure 8.8 Gains and losses of sand area along the NSW coast 1967–87



Source: EPA, NSW, 1993.

reservoir for sand during storm erosion. In the absence of dune vegetation, sand moves inland and is lost from the beach. The vegetation, dunes and beach act as a single dynamic system, essential to maintain the beach and protect inland vegetation and coastal buildings.

Dunes have been particularly subject to urban encroachment because of the strong demand for seafront housing. Most of the dune habitats around coastal cities and towns have been engulfed or alienated and the rest are under threat from erosion by pedestrians, off-road vehicles and introduced weeds. Beaches in turn become degraded by accelerated erosion due to the loss of protective dune vegetation and changes in coastal morphology, which alter patterns of sand movement. Erosion is an increasing problem in many areas and it is expected to accelerate in the coming decades in the event of rises in sea level.

We have estimates of the rate of beach erosion for some areas. In New South Wales, for example, many beaches are eroding at the rate of 0.2 to 1.4 metres per year causing damage to land, property and amenity value. By contrast, sand is being deposited on other beaches (see Fig. 8.8).

Degradation of water quality is an issue for tourism and recreation along some beaches, with turbid water and increased risks from pollutants, especially pathogens, reducing their amenity. Australia's beaches are increasingly littered with plastics, glass, fishing lines, nets and other rubbish.

About 16 000 km (23.8 per cent) of Australia's coastline is dune and beach habitat, occupying some 27 900 sq km. In the more populated areas, beaches and dunes are often the focus of recreation, tourism and residential development and as a result they suffer habitat loss and modification. The best

Table 8.4 Area of dunes and beaches along Australia's coastline and proportion of coastline by State

	Area (sq km)	Percent of coastline
Queensland	5 109	18.8
New South Wales	1 236	16.3
Victoria	1 653	28.0
Tasmania	984	13.8
South Australia	5 613	53.4
Western Australia	12 057	33.4
Northern Territory	1 242	5.5
Total for Australia	**27 897**	**23.8**

Source: Zann, 1995.

available indicators for the state of dune vegetation in Australia are the extent of sand dunes (see Table 8.4) and the species composition. In New South Wales, 423 plant species occur on beaches and foredunes up to 500 m inland of the beach strand line. Of these species, 86 have been found on the beach strand zone, 151 on the frontal foredune and 390 on the more protected back-face (lee side) of the foredunes (Clarke, 1989). The number of endemic species increases across the dune zones, from about 20 per cent of species on beach mound areas to the majority of species on the back-face of the frontal dunes.

Estuaries

Estuaries are waterways that are typically marine or brackish, but occasionally are dominated by fresh water (includes rivermouths, deltas and barrier lagoons that may be occasionally or permanently open to the sea).

Australian estuaries occur over a wide range of geological and climatic conditions and consequently display a great variety of form. They are characterised by extremes in conditions and are usually inhabited by species that can withstand variable conditions, particularly salinity. Their sediments and waters can be relatively rich in nutrients from the land so they are potentially very productive. The dominant habitats found in estuaries are saltmarshes, mangroves, seagrass meadows, algal beds, sandflats and mudflats (see Table 8.5).

Estuaries have traditionally been centres of urban and industrial coastal development. Because of their semi-enclosed nature, restricted flushing, shallow water and fine sediments, estuaries readily trap and accumulate pollutants.

Pollution, land reclamation, engineering works, over-fishing, weed infestation and the clearance of catchments all represent major threats to estuaries. Inappropriate developments within catchments may affect water quality by increasing erosion and silt loads and mobilising nutrients and contaminants. In New South Wales, 37 per cent of estuaries have more than half the land area of their catchments cleared. The same applies to 60 per cent of Victorian, 86 per cent of South Australian and three per cent of Western Australian estuaries but in the Northern Territory there are no estuaries with more than half their catchments cleared. There is not enough information to estimate the area of cleared catchment for Queensland and Tasmanian estuaries, but substantial clearing has occurred in central coastal Queensland and in some parts of Tasmania (Zann, 1995).

Generally, Australian estuaries away from the centres of population (in the north and west) have experienced little disturbance.

Gulfs and bays

Gulfs and bays are large (greater than 200 sq km surface area), open (or largely open) and shallow (less than 50 m in depth) coastal waters; typically they are dominated by marine conditions except where rivers flow into them.

The coast of Australia features a number of gulfs and large bays that — because of the protection they afford — are favoured for urban development. Many of them — such as Port Phillip Bay in Victoria, Moreton Bay in Queensland and Cockburn Sound, Western Australia — are important for recreation and transport. Others, like Spencer Gulf in South Australia, Shark Bay in Western Australia, and the Gulf of Carpentaria, Northern Territory/Queensland, are well known for their biological diversity and fisheries. Several of the bays, such as Shark Bay and Jervis Bay in New South Wales, have unique biological and geo-morphological features and are widely recognised for their natural heritage and conservation importance as well as supporting major fisheries. The Gulf of Carpentaria supports Australia's most valuable prawn fishery.

Because gulfs and bays are semi-enclosed or have their water circulation and flushing restricted in some way — by distance from the sea or narrow entrances — cities and towns located on their shores can create many pressures on their natural resources. Fishing, nutrient deposits and land-based run-off like stormwater or farmland drainage may all have detrimental effects on the marine ecosystem.

All the bays and gulfs contain many discrete habitat types, such as reefs, seagrasses and mangroves. Most support a number of potentially competing uses such as tourism and recreation, fishing and mining and, being large, they are typically subject to several levels of government jurisdiction (local and State). They also commonly support many species of high conservation value, such as dugongs and turtles and they may be subjected to various forms of both State and Commonwealth legislation. In this sense, bays and gulfs are diverse and complex systems. However, despite their importance as a class of coastal ecosystem, the only available indicators of their state for most areas are fisheries production data and other indicators of the state of their component habitats, such as mangroves and seagrasses (see pages 8-23 and 8-24).

Continental shelf and slope

The inner continental shelf encompasses the waters and seabed from the shore to the midshelf (about 50 m deep). Beyond this is the outer shelf extending to the 'break' (typically at 150 m to 200 m deep). The continental slope encompasses the area beyond the shelf break into water depths of 2000 m or more.

Most of Australia's marine environment lies in the deeper waters off the coast on the continental shelf and slope, remote from the coastline and human populations. These areas represent the submerged extensions to Australia's continental land mass and the margin with the world's deep ocean basins. Most biological activity is concentrated within the continental shelf and slope zone — in sediments, on the sediment surface and in the overlying water.

Our continental shelf covers about 2.5 million sq km, of which about half lies in less than 50 m of water. At its outer margin lies the continental slope, a further 1.5 million sq km, which starts at depths of 150–200 m and drops down to the abyssal plain at about 4000 m. Very little is known of the deeper-water communities around Australia even though they are subject to trawling and other fishing. The continental shelf surrounding Australia ranges in width from 15 km off the

Table 8.5 Estimated area (sq km) of estuarine habitat types by State, 1988–89

	Open water (incl. subtidal seagrass beds)	Intertidal flats (incl. intertidal seagrass beds)	Mangroves	Seagrass (subtidal and intertidal beds)	Salt marsh	Total
New South Wales	1323	na	107	153	57	**1487**
Victoria	2682	444	41	364	125	**3292**
Queensland	4093	1574	3424	68	5322	**14 413**
Western Australia	17 825	2891	1561	11	2965	**25 241**
South Australia	760	219	111	na	84	**1173**
Tasmania	1825	274	na	na	37	**2136**
Northern Territory	5187	821	2952	23	5005	**13 966**
Total	**33 694**	**6223**	**8195**	**6001**	**13 595**	**61 708**

na = data not available These estimates do not include habitats in bays and gulfs.

Source: Saenger, 1995.

Table 8.6 Distribution and areas of saltmarsh (sq km) by bioregion

	Grass and sedges	Shrublands	Total area
North Coast	4719	3954	8673
North West Coast	1542	1653	3195
West Coast	585	939	1524
South West Coast	21	12	33
Great Australian Bight	21	—	21
South Gulfs Coast	225	951	1176
South Coast	258	1317	1575
Bass Strait	615	45	660
Tasmanian Coast	498	—	498
South East Coast	171	—	171
East Coast	183	—	183
North East Coast	1644	105	1749
Gulf of Carpentaria	3399	465	3864
Total Australia	**13 881**	**9441**	**23 322**

Note: These estimates were derived from aerial photographs taken in the post-war period through to about 1982 and give an approximate estimate of areas in 1982. The estimates for grass and sedges are likely to include a large amount of terrestrial vegetation, but in most places the estimates for shrublands will mainly comprise saltmarsh species.

Source: Galloway *et al.*, 1984.

south-east coasts to 400 km in the Timor Sea. We share a shelf connection with Papua New Guinea across Torres Strait and with Irian Jaya across the Arafura Sea.

Types of communities found on the shelf are closely associated with the type of sediments, terrestrial inputs from rivers and depth of water. The Australian shelf environment differs from those of other continents, especially in the south, for the dominance of coarse sediment particles and the virtual absence of terrestrial material. These factors contribute to complex microhabitats that may be responsible for high densities of seabed organisms and diversity of species.

The south-eastern to south-western shelves are covered with coarse, calcareous, shelly sands, composed of the remains of bryozoans (lace-corals), molluscs (shells) and foraminifera (calcareous plankton). Terrestrial input of silica and finer silt and clay materials is minimal. The eastern shelf of New South Wales comprises sandy sediments that are terrestrial in origin close to the coast and calcareous below 60 m depth. Muds of terrestrial origin dominate the inner shelf sediments of the Great Barrier Reef and carbonates dominate the mid and outer shelf. The sediments of the Gulf of Carpentaria are very fine and rich in faunal remains. Those of the Arafura Sea and most of the west coast are mostly coarse and calcareous, with very little terrestrial sediment.

Scientific knowledge of Australia's shelf and slope communities is very patchy. Many parts are remote and the water is generally too deep for direct inspection by scuba diving. Research requires time-consuming and expensive shipboard sampling using dredges, grabs and, recently, underwater video. Only three areas around Australia (the Barrier Reef and the south-east and north-west shelves) have been studied in some detail. These studies suggest that hundreds of species are found in shelf and slope areas in surprisingly rich assemblages (Ward and Rainer, 1988).

We know little about the human impacts on Australia's shelf communities. Extensive fishing using otter trawls may remove bottom species and modify the bottom habitat (see page 8-14). The non-target discards returned to the sea may alter food chains by providing more food for carnivores, scavengers and decomposers. Discharged muds and effluent from offshore oil platforms and from dumping of industrial wastes at sea may cause localised damage. Fishing pressure has greatly reduced populations of some shelf and slope fish such as the school and gummy sharks at depths to 200 m and the gemfish at depths 100–700 m. We do not know what effect the removal of these high-level predators has on the ecology of the sea floor. The only easily available indicators of the state of the shelf and slope are fish catches (see pages 8-30 and 8-31).

Saltmarshes

These intertidal salt-water wetland habitats comprise low herbaceous shrubs and grasses, on mainly low-energy shorelines, often behind mangroves. In the tropics they may grade into salt-tolerant terrestrial shrubs and grasslands.

Coastal saltmarshes grow in sheltered intertidal zones. They are dominated by herbs and low shrubs, are highly productive and provide key habitats for many organisms, of both terrestrial and marine origin. They provide roosting sites for many migratory wading birds and breeding sites and habitat for certain endangered or rare species, such as the orange-bellied parrot in Victoria. They are often closely associated with mangroves that lie

Table 8.7 Distribution and areas of mangroves in Australia by bioregion

Region	Area (sq km)
North Coast	4 100
North West Coast	710
West Coast	15
South West Coast	0
Great Australian Bight	0
South Gulfs Coast	40
South Coast	160
Bass Strait	15
Tasmanian Coast	0
South East Coast	65
East Coast	180
North East Coast	2 484
Gulf of Carpentaria	2 307
Offshore islands (estimate)	~1 500
Total Australia	**~11 576**

Note: These estimates were derived from aerial photographs taken in the post-war period through to about 1982 and give an approximate estimate of areas in 1982

Source: Galloway *et al.*, 1984.

to seaward. Along arid and semi-arid coasts, the marshes merge with inland saline habitats and on cliffs and headlands saltmarsh species are found in areas exposed to salt spray. They occur in all States, but are most extensive in the tropical north. Species richness, however, increases with latitude, with southern saltmarshes having the greatest diversity.

Land degradation poses a major threat to saltmarshes in developed areas. In many places they have been filled for ports, marinas, canal estates and urban and industrial sites. Other threats include rubbish dumping, off-road vehicles, invasion by weeds (particularly introduced cord grass, pampas grass, para grass and rushes) and drainage for mosquito and sandfly control. As backwater areas, saltmarshes may accumulate pollutants. They are also highly susceptible to invasion by exotic species; five of the 34 plant species in Jervis Bay saltmarshes are introduced (CSIRO, 1994). In rural areas many saltmarshes are heavily grazed by cattle.

Humans have had a major impact on saltmarshes in the process of land 'reclamation'. This has led to the loss of about 21 per cent of the habitat from Moreton Bay, Queensland (see the box on page 8-9). Although the total loss has not been great in Australia, most of it has been concentrated in the south-east, which had the smallest initial area but the highest biodiversity and incidence of endemic species. Losses are therefore considered to be significant both regionally and nationally. A sea level rise could cause significant contractions in saltmarshes (Adam, 1995; Zann, 1995). Compared to the areas of total loss, much larger areas have been degraded, but data on this are not readily available. The best available indicator for this habitat is the size of the remaining area (see Table 8.6).

Mangroves

Comprising a diverse group of largely tropical trees, shrubs, palms and ferns, mangroves live in the intertidal areas of sheltered marine shores, estuaries and tidal creeks.

Australia has the third largest area of mangroves in the world and the northern communities are among the world's most diverse. They line about 6000 km of Australia's coast. Of the 39 species found here, only one, the newly discovered *Avicennia integra*, appears endemic. Mangroves are most diverse in the wet tropics (some estuaries on Cape York may contain up to 35 species), becoming steadily less so on arid tropic, subtropic and temperate shores. Only one species, *A. marina*, occurs along the southern coastline. The composition and form of the communities varies with temperature, rainfall, river run-off, sediment type, size of tides and coastal structure.

Mangroves have both conservation and economic value. They are generally highly productive and provide important habitats for both bait-fish and table fish. Within various mangrove communities, about 197 fish species are recorded for northern Australia, 65 for Brisbane and 46 for Sydney. Some of Australia's most valuable commercial fisheries are directly or indirectly linked to this habitat.

Seagrasses of Australia

These flowering plants grow in marine and estuarine areas — mainly the sediments of subtidal waters — to 10 m in depth. Some species also grow in intertidal sediments and some in very deep waters, down to 40 m in depth.

Australian waters have the world's highest diversity, with 22 species found in temperate waters and 15 in tropical areas. These grasses stabilise sediment and act as filters to overlying water.

Seagrass meadows provide the nursery areas for many important commercial and recreational fisheries and are critical habitats for turtles and dugongs. They support a diversity of flora and fauna and rotting leaves form the basis of a detrital food web.

Australia has about 51 000 sq km of seagrass meadows, with the largest in Western Australia and Queensland and the most diverse in Western Australia. The major areas occur in the Gulf of Carpentaria, Shark Bay, the southern coast of Western Australia, Spencer Gulf and St Vincent Gulf.

Seagrass meadows are affected by human activities, in particular, nutrient addition from farm run-off, sewage and industrial-waste dumping. The extra nutrients cause blooms of epiphytes and/or phytoplankton, which shade seagrass leaves. Changes to hydrology for harbour or marina development and sediment run-off from terrestrial development have also contributed to a decline in seagrass meadows around the major population centres.

Floods and cyclones have damaged about 1000 sq km of seagrass beds over the past 10 years and their recovery has been slower than expected. About 450 sq km of the beds have been damaged directly by human activities such as dredging and habitat reclamation. However, human-induced changes in water quality — particularly poor land management practices that release sediments and nutrients into estuaries, lagoons and other coastal waters — may also affect the ability of seagrass beds to recover from damage caused by natural events.

Temperate beds are particularly susceptible to degradation because all of the species of the genus *Posidonia* (the dominant temperate seagrass) spread very slowly. They may take centuries to recolonise and regrow in damaged areas.

Recent surveys along the southern coastline have shown major errors in previous estimates of distribution due to seagrass beds often being misinterpreted as algal beds from aerial photographs. More detailed mapping is also needed to accurately estimate losses and the reasons for them.

We do not know the capability of temperate seagrass beds to respond to gradual change in climate. If sea levels gradually rise and if land run-off containing suspended material and nutrients increases as a result of changes in rainfall patterns then available sunlight will decrease. No one has studied the ability of seagrasses to respond to such changes. However, their slow growth rates and their critical role in numerous commercial fisheries, make us concerned about their ability to respond successfully to changing climate.

Most States have various forms of legislation to partially protect seagrasses. We do not know how effective these protective measures are and, generally speaking, do not have enough data to determine whether the loss of seagrasses has been reduced by implementation of government legislation to reduce or control human impacts.

There has not been much research on amelioration and restoration of seagrass beds. Some projects have been successful in restoring tropical seagrass species, but it is unlikely that the key temperate species could be restored without major research. This will be especially important to protect and better manage the remaining vulnerable seagrass beds across much of the Australian coastline.

Source: Kirkman, in press.

For example, the early life cycle of the banana prawn is confined to mangrove-lined estuaries, while many fish targeted by Australian recreational fishers, including bream, grunter, mangrove jack and barramundi, live in tropical and subtropical mangroves.

In the arid and semi-arid tropics, mangroves form the only closed-canopy forest available for birds. A recent study found that 22 bird species in the north of Western Australia were confined to this vegetation for at least part of their range.

Mangroves have been cleared extensively for land reclamation near coastal cities such as Sydney, Newcastle, Brisbane, Cairns and Adelaide. For example, about 17 per cent of stands have been removed from Moreton Bay in Queensland. Many estuaries have been extensively modified by breakwaters, channel dredging, flood mitigation and other engineering works, adversely affecting mangrove communities. Significant areas in south-east Queensland, near Gladstone and near Cairns are under direct threat from development.

Mangrove regrowth can occur by natural recruitment processes. In some places, the community is increasing in area, probably because of increased sediment supply from upland clearing (CSIRO, 1994) or increased sedimentation due to coastal modification (Kinhill *et al.*, 1994).

As with other habitat types, it is difficult to make a national assessment of mangroves at various stages of degradation. However, Table 8.7 shows their estimated area in different bioregions.

Seagrasses

Seagrasses are intertidal and subtidal flowering plants found mainly in the shallow waters of protected estuaries and bays; in the southern temperate regions of Australia they often form dense beds, but in the tropics they may also be found at low densities, widely scattered in near-shore areas.

Australia has the largest number of seagrass species and some of the largest and most diverse seagrass beds in the world (see the box on page 8-23).

Seagrass meadows interact with other habitats. For beaches, their stabilising effect is important in reducing erosion. Seagrasses often occur offshore from mangrove and saltmarsh habitats, where they

Table 8.8 Distribution of seagrass by bioregion

	Central West Coast	Lower West Coast	South West Coast	Great Aust Bight	South Gulfs Coast	Bass Strait	Tas. Coast	Lower East Coast	Central East Coast	North East Coast	Gulf of Carp.	North Coast	North West Coast
Amphibolis antarctica	•	•	•	•	•	•	•						
Amphibolis griffithii		•	•	•	•								
Cymodocea angustata	•												•
Cymodocea rotundata										•	•	•	
Cymodocea serrulata										•	•	•	
Enhalus acoroides										•	•	•	•
Halodule pinifolia										•	•		
Halodule uninervis	•	•								•	•	•	•
Halophila australis		•	•	•	•	•	•	•					
Halophila decipiens		•	•	•	•			•	•	•	•	•	
Halophila ovalis	•	•							•	•	•	•	•
Halophila ovata									•	•	•	•	•
Halophila spinulosa	•	•								•	•	•	•
Halophila tricostata										•	•		
Heterozostera tasmanica		•	•	•	•	•	•	•					
Posidonia angustifolia		•	•	•	•								
Posidonia australis	•	•	•	•	•	•	•	•					
Posidonia coriacea		•			•								
Posidonia denhartogii			•	•	•								
Posidonia kirkmanii			•	•	•								
Posidonia ostenfeldii			•	•	•								
Posidonia robertsoniae			•	•									
Posidonia sinuosa		•	•	•	•								
Syringodium isoetifolium	•	•								•	•	•	•
Thalassia hemprichii										•	•	•	•
Thalassodendron ciliatum										•	•	•	•
Thalassodendron pachyrizum		•	•										
Zostera capricorni								•	•	•			
Zostera mucronata		•											
Zostera muelleri						•	•	•					

Source: Kirkman, in press.

may provide refuges and nurseries for juvenile fish and prawns or feeding grounds for birds.

Large areas of seagrass have died in recent decades (see Fig. 8.9). A number of cases are still poorly documented and the reasons for the declines unclear. Many losses, both natural and human induced, are attributed to reduced light intensity caused by sedimentation and/or increased growth of epiphytes from nutrient enrichment. Sediment instability, undercutting and erosion can increase the damage. The dominant temperate seagrass (*Posidonia* sp.) has not been known to recolonise from loss or damage and other subtropical and tropical species take a long time (more than 10 years) to recover and then only if the substrate has not been physically disturbed. None of the attempts to replant seagrasses in temperate Australia have been successful.

There are no simple indicators of the health of seagrass beds, but their area can be estimated by techniques such as remote sensing. Table 8.8 shows the currently available information on the distribution of seagrass species around Australia.

Macroalgae

Macroalgae are the larger multi-celled species of algae generally referred to as seaweed. Their growth-form and appearance ranges from tall leathery leaves several metres in length (kelp), to encrusting mats covering coral reefs, and to dense accumulations of filaments which detach from the seabed and become free floating.

Macroalgal communities, composed of the larger red, brown and green algae, predominantly occur in temperate southern Australian waters, where they form a major component of the shallow-water reef communities. The 5500-km coastline from the south-western part of Western Australia to the New South Wales/Victorian border has a wide diversity of macroalgae, with 558 species recorded on the southern coast of Western Australia, 1151 species in South Australia and Victoria, and 398 species around New South Wales and Lord Howe Island. The area is rich in brown algae (Phaeophyta) and particularly rich in red algae (Rhodophyta)

Kelp reef, Gulf St Vincent, South Australia.

Figure 8.9 Loss of seagrass by area and a brief description of the probable causes of the loss

	Location	Area lost (ha)	(%)	Probable cause
1	Cockburn Sound	3 300	79	Elevated nutrients from factories, sewage and abattoirs
2	Princess Royal Harbour	810	66	Elevated nutrients from factories and sewage
2	Oyster Harbour	720	46	Elevated nutrients from farm run-off
3	Gulf St Vincent	7 000	?	Sewage and stormwater discharge; coastal works
4	Westernport Bay	17 800	85	Siltation
5	Birch Point	397	?	
5	Ralphs Bay	430	?	
5	Pittwater	1201	?	
5	Norfolk Bay	2148	?	
6	Botany Bay	257	58	Erosion, coastal works, elevated nutrients and sea urchin grazing
7	Lake Macquarie	700	44	Increased turbidity
7	Clarence River	445	60	Increased turbidity and general decline in water quality
8	Hervey Bay	100 000	?	High turbidity from flooding of the Mary and Burum Rivers
9	Torres Strait	>10 000	?	Floods in 1991–1992
10	West Island–Limmen Bight	18 300	20*	Damage from cyclone Sandy, 1985; much of the area had recovered by 1994.

*Note: This loss represented 20% of the seagrass of the Gulf of Carpentaria

Source: Kirkman, in press.

(Sanderson, *in press*). An examination of published records shows that, of the nine southern bioregions (see Fig. 8.1), the South West Coast, Tasmanian Coast, Central East Coast and Lord Howe Island regions appear to have fewer species than the others (see Table 8.9). However, this may be simply because some have been much more thoroughly studied than others. Substantial research on the classification of algae is being prepared for publication and the number of known species, especially the red algae, will certainly rise.

Table 8.9 The number of macroalgal species by bioregion for southern Australia and the number of species unique to each region

Bioregion	Green algae		Brown algae		Red algae	
	total	endemic	total	endemic	total	endemic
Lower West Coast	83	(13)	107	(7)	368	(117)
South West Coast	64	(0)	96	(1)	221	(1)
Great Australian Bight	80	(2)	131	(0)	300	(4)
South Gulfs Coast	106	(6)	178	(15)	397	(24)
Bass Strait	87	(3)	174	(8)	381	(18)
Tasmanian Coast	54	(3)	107	(6)	212	(11)
Lower East Coast	67	(7)	107	(9)	272	(49)
Central East Coast	32	(4)	37	(1)	151	(17)
Lord Howe Island	59	(27)	71	(21)	175	(66)

Note: All the numbers need to be treated with caution because some regions have been more thoroughly studied than others.

Source: Sanderson, in press.

We do not understand the effects of human activities on temperate macroalgae and reefs very well. The most serious potential pressures are probably those that affect the habitat-forming species — particularly the large algae. These include discharges and other activities that alter water quality, and direct pressures like fishing and collecting. Victorian and overseas studies claim that sewage outfalls reduce canopy-forming brown algae; and, in California, thermal effluent has reduced kelps. Commercial and recreational fishing may also affect macroalgal communities.

Marine and estuarine algal blooms in Australia

Algal blooms, while a natural phenomenon reported by the first Europeans to explore the Australian coastline, have increased in frequency, intensity and geographic distribution in the past 30 years. Better reporting has increased our knowledge of them. Recurrent and major algal blooms have been reported right around the east coast of Australia from Adelaide to Townsville and around the south-west of Western Australia. Some of those waters affected include: Gulf St Vincent, South Australia; Westernport Bay, Port Phillip Bay and Gippsland Lakes, Victoria; Botany Bay, Tuggerah Lakes, Lake Illawarra, Lake Macquarie, Narrabeen Lagoon, Hawkesbury Estuary and Georges Estuary, New South Wales; Moreton Bay, Queensland; Cockburn Sound, Peel Inlet, Harvey Estuary and Princess Royal Harbour, Western Australia; and Orielton Lagoon and the Derwent and Huon Estuaries, Tasmania.

Blooms of the toxic alga *Alexandrium minutum* were first observed in the Port River estuary near Adelaide in 1986 and seem to occur annually during September–November, making wild mussels from the river highly toxic. Elevated nutrient levels and changing salinity contribute to the formation of these blooms. The alga may have been introduced into Australian waters. In Western Australia's Peel Inlet, observers first noticed enhanced growth of the macroalga *Cladophora* sp. in the late 1960s, which became progressively worse in the 1970s. During the 1980s *Chaetomorpha* and *Ulva* became the dominant genera. In the Harvey estuary, massive blooms of the blue-green alga *Nodularia spumigena* have occurred since 1978. These have affected fish and crab populations and reduced commercial fish catches. Phosphorus inputs originating from fertiliser applied in the parent catchments have enriched the Peel-Harvey system.

In the Tuggerah Lakes, the distribution and density of macroalgae, including *Enteromorpha*, *Chaetomorpha* and *Rhizoclonium* spp., have increased during the past 30 years. Enhanced growth of various species has occurred in Lake Illawarra since the early 1960s, becoming excessive in recent years. The alga *Scrippsiella trochoidea* has been responsible for major blooms causing red-brown sea-water discolouration and fish kills in several estuaries and coastal lagoons, including West Lakes in South Australia and the Hawkesbury River estuary. In Victoria, mussel beds were closed due to blooms of the diatom *Rhizosolenia* sp.

More open, offshore waters also experience significant algal blooms that, while a natural phenomenon, seem to have intensified in recent years as a result of increased nutrient inputs. In Tasmanian waters, blooms of the toxic alga *Gymnodinium catenatum* occurred in 1986, 1987, 1991 and 1993, causing the temporary closure of commercial shellfish beds. A number of algal blooms were recorded around Sydney and the south coast of New South Wales in 1992–93. In Jervis Bay a substantial bloom of *Gephyrocapsa oceanica* occurred in December 1992, while a bloom of *Noctiluca scintillans* extended along the Sydney coast from Avalon to Garie Beach in January 1993.

The species *Trichodesmium erythraeum* is the most common alga responsible for 'red tides' in tropical Australian waters, producing seasonal (February–April) blooms in the Java, Banda, Arafura and Coral Seas, from where the East Australian Current and Leeuwin Current transport them (covering up to 40 000 sq km) as far south as Sydney and Perth. The algae can accumulate on beaches, causing offensive odours and discolouring water and sand. While some scientists believe that the magnitude and frequency of such blooms have increased in some areas over recent years — notably the Great Barrier Reef lagoons — as a result of increased nutrient inputs, the available data are not decisive at this stage.

Source: Cosser, in press.

Trawling may directly remove plants, while the removal of plant-feeding animals (such as fish, rock lobster or abalone) may alter the balance of grazing, resulting in a shift in the relative abundance of algal species.

Reef habitats are being mapped in South Australia, Western Australia and Port Phillip Bay using satellite images and aerial photography. Recent surveys show that stands of *Macrocystis pyrifera*, believed to be an ecologically important species in Tasmanian waters, are a fraction of the size estimated in the early 1950s.

Massive blooms of macroalgae in the Peel–Harvey Estuary and Princess Royal and Oyster Harbours in Western Australia cause significant problems. All States regularly report minor blooms involving a variety of species, especially *Ulva*, *Enteromorpha*, *Cladophora* and *Hinksia* species. No national data are available, and future indicators should be based on a database of macroalgal blooms that monitors location and extent, frequency, magnitude and type of algae.

A number of macroalgal species appear to have been introduced to Australian waters, principally through ballast waters and on ship's hulls. The actual numbers are unknown, because we are still learning about the taxonomy and ecology of Australian species. A significant introduction is *Undaria pinnatifida* in Tasmania. It blankets the rocky reef bottom for large areas, limiting colonisation by native algae and invertebrates. A relatively recently introduced red alga, *Schottera nicaeensis*, first recorded in Port Phillip Bay in 1972, is now reported from every port and harbour in south-eastern Australia.

The first published record of a macroalgal extinction, that of *Vanvoorstia bennettiana*, has been recorded in Botany Bay. Its disappearance may be due to human activities such as heavy shipping traffic, dredging and urban run-off, all contributing to heavy siltation in the Bay.

Microalgae

These single-celled, microscopic plants predominantly live floating in the water, although they may also live on the sea floor.

Microscopic algae support, either directly or indirectly, the entire production of the open sea. They are usually single-celled and usually inhabit the water column, where they are called phytoplankton, although some (benthic species) live on the seabed and as epiphytes.

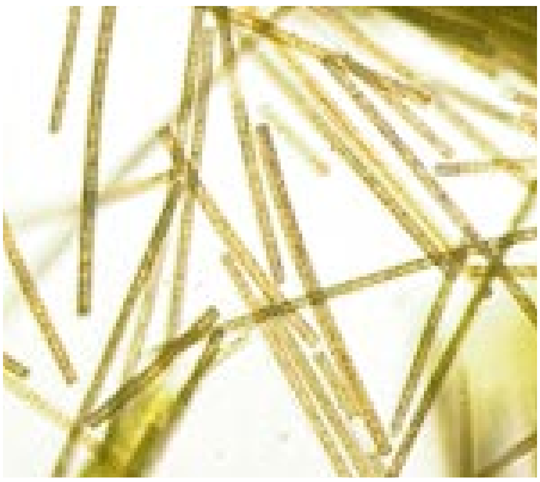
Australia's marine phytoplankton comprise representatives of 13 algal classes, including the well-known diatoms (5000 species), dinoflagellates (2000 species), golden-brown flagellates and green flagellates (several hundred species). Our phytoplankton flora are similar to the warm-water and cold-water phytoplankton floras of the Northern Hemisphere. No species are endemic to Australian waters.

We do not know much about the natural dynamics of phytoplankton. However, scientists recognise three distinct assemblages in Australian waters: a temperate group that inhabit the coastal waters of New South Wales, Victoria and Tasmania; a tropical group confined to the Gulf of Carpentaria and North West Shelf; and a tropical oceanic group in the offshore waters of the Coral Sea and Indian Ocean (Zann, 1995).

Table 8.10 Recorded algal blooms in the waters of New South Wales from 1890 to February 1995

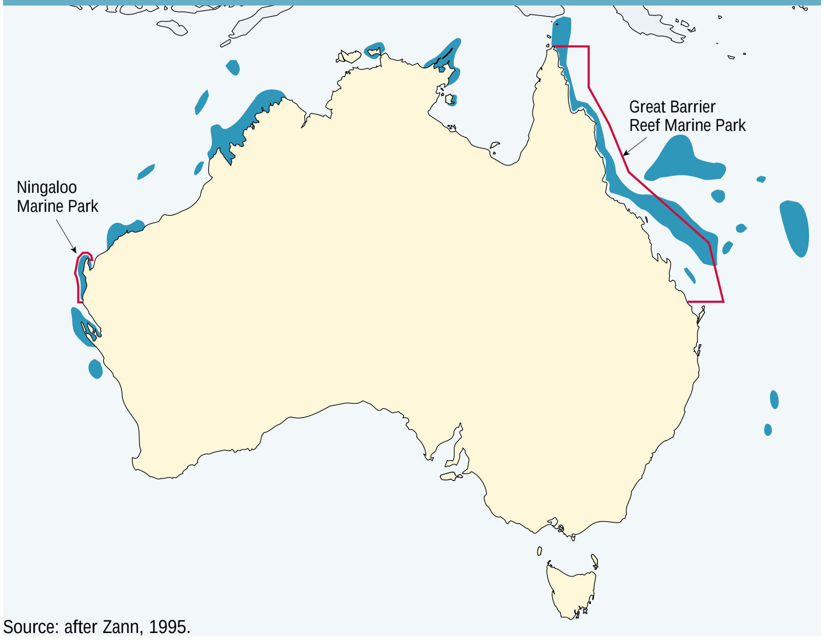
Date	Species	Location
Mar 1890	*Scrippsiella trochoidea*	Sydney Harbour
Jul–Aug 1930–32	*Gymnodinium sanguineum*	Sydney Harbour
Feb 1945	*Alexandrium catenella*	Port Hacking
Dec 1970	*Giffordia mitchelliae*	Port Macquarie
Oct 1972	*Trichodesmium* sp.	Taree and Coffs Harbour
Dec 1972	*Trichodesmium* sp.	Palm Beach and Cronulla
Jan 1980	*Spyridia filamentosa*	Crescent Head
Oct 1980	*Gymnodinium sanguineum*	Lane Cove River
Aug 1982	*Noctiluca scintillans*	Lake Macquarie
Dec 1983	*Trichodesmium* sp.	Newcastle, Narrabeen, Foster, and Bondi Beach
April 1984	*Mesodinium* sp.	Lane Cove River
Nov 1984	*Mesodinium* sp.	Lane Cove River
Dec 1984	*Trichodesmium* sp.	Sydney and Wollongong
Aug–Sep 1985	*Thalassiosira partheneia*	NSW coast
Feb 1986	*Mesodinium* sp.	Lane Cove River
Feb 1986	*Thalassiosira weissflogii*	Alexandra Canal
Jan 1989	*Trichodesmium* sp.	Jervis Bay and Ulladulla
Mar 1991	*Scrippsiella trochoidea*	Hawkesbury River
Jun–Jul 1991	*Gymnodinium galatheanum*	Lake Illawara
Nov 1991	*Heterosigma carterae*	Berowra Creek
Aug 1992	*Noctiluca* sp.	Lake Macquarie
Sep 1992	*Noctiluca* sp.	Berowra Creek
Dec 1992	*Gephyrocapsa oceanica*	Jervis Bay
Jan 1993	*Gonyaulax polygramma*	Darling Harbour
Feb 1993	*Gonyaulax polygramma*	Bate Bay
Jan–Feb 1993	*Noctiluca* sp.	Sydney beaches and Port Kembla
Feb 1993	*Dictyocha octonaria*	Newcastle
Oct 1993	*Alexandrium catenella*	Sydney Harbour
Nov 1993	*Pseudonitzschia multiseries*	Berowra Creek
Apr 1994	*Noctiluca* sp.	Ham and Chicken Bay
Nov 1994	*Alexandrium catenella*	Port Hacking
Feb 1995	*Noctiluca* sp.	Sydney

Source: Hallegraeff, 1993 and Hallegraeff unpublished.



The bloom forming *Trichodesmium sp.*

Figure 8.10 Coral reef distribution; the Great Barrier Reef Marine Park and the Ningaloo Marine Park



Source: after Zann, 1995.

Satellite data have enabled mapping of the general patterns of phytoplankton production in the oceans surrounding Australia (see Fig. 8.2) and confirmed that an area of the Southern Ocean known as the Subtropical Convergence has high phytoplankton biomass.

Concern is growing that the deteriorating environment of most major rivers and estuaries near our large coastal cities is affecting the species composition of natural phytoplankton populations, with potentially far-reaching implications for the structure of entire marine foodwebs, which influence fisheries production.

Microscopic algae can 'bloom', becoming very abundant in the right conditions of nutrients, temperature, salinity and light. Some such blooms, notably by diatoms, are a natural part of the cycle of life in certain parts of the sea, but the intensity and frequency of others have increased because of human-induced changes to the ecosystem — especially the addition of nutrients. Some blooms are spectacular because of their red or green colour and some (not all) of them include toxic species. They may cause fish kills and threaten human health (for example, by paralytic shellfish poisoning), while others are aesthetically 'nuisance' algae, causing spoiling of beaches, offensive odours and slimy water. In the last thirty years, a large number of Australia's estuaries, bays and coastal lakes have had algal blooms reported for the first time (see the box on page 8-26). The frequency of such blooms is increasing, although the rate is uncertain because of better reporting and public awareness (see Table 8-10).

The best-known case of both phytoplankton and macroalgal blooms is the Peel–Harvey system in Western Australia (see page 7-46). The effects of toxic algae are best known from the closure of shellfish beds in Tasmania and Victoria resulting from blooms of an alga suspected to have been introduced in ballast water.

Coral reefs

Formed from the calcareous skeletons of many species of corals and other organisms, coral reefs support a diversity of fish, invertebrates and plant life.

Australia has the largest area of coral reefs in the world. The Great Barrier Reef (see page 8-44) and Western Australian reefs are well developed and diverse. Most of the world's reefs have been affected by human activity, which threatens the continued survival of some major reef complexes. About 70 per cent of those in the central Indo-Pacific are disturbed to some extent. Australia's coral reefs are extensive and extremely diverse and harbour a number of threatened species. Most reefs are still in a relatively good condition. Only a few other countries have such a low population pressure and/or the capacity to regulate human impacts on their reefs.

However, Australia's coral reefs are now exposed to significant pressures from an array of human activities. Only a few systems remain undisturbed and those close to population centres show the greatest signs of damage. While we have no general assessment of coral reefs, recent photographic comparisons of several sites in the Great Barrier Reef show that major changes have occurred to some of the reef flats over the last 40 to 100 years. In four of the 12 locations studied a significant reduction in the cover of living hard coral has occurred (Wachenfeld, 1995).

Outside the Great Barrier Reef Marine Park and the Ningaloo Marine Park, management and monitoring of Australia's coral reefs are limited.

Mushroom coral (left) and Soft coral (right), northern Great Barrier Reef

Fish and fisheries

The terms fish and fisheries are used here to include, as well as the finfish, the sharks and invertebrates, such as crustaceans and molluscs, that are taken by both commercial and recreational fishers.

Australia has an estimated 4000 to 4500 species of finfish, of which around 3600 have been described. About one-quarter of the species are endemic and most of these are found in the south (Zann, 1995).

In 1993–94, production from commercial fishing was approximately 209 000 tonnes, worth about $1.6 billion (ABARE, 1994). Recreational fishing has not been quantified but one estimate indicates that the catch may be of the order of 50 000 tonnes (Kearney, 1995). In 1984 recreational fishers spent about $2 billion on their pastime (Zann, 1995).

Commercial fish markets handle at least 300 species of finfish, sharks and invertebrates. However, about 50 species make up 85 per cent of the catch by weight and only a few of these are widely distributed.

The most important species of commercial fish are either fully exploited and being managed to achieve a sustained yield, or were overexploited and are now being managed in an effort to increase the breeding stock and total catch. Management strategies are based on controls on fishing gear and boats (input controls), limitations on the catch (output controls) or a combination of these.

Population status for a number of the main commercial species is described below and on the following pages to illustrate the state of the population in response to fishing pressure.

Fisheries of Aboriginal and Torres Strait Islander communities

Fish and seafood are significant components of the traditional diet in many communities and are particularly important to Torres Strait Islanders. Torres Strait and northern Aboriginal communities consume a lot of seafood — much more than some other communities in the South-west Pacific. They catch many reef fish species for food and hunt green turtles and dugongs, which form a major part of their diet.

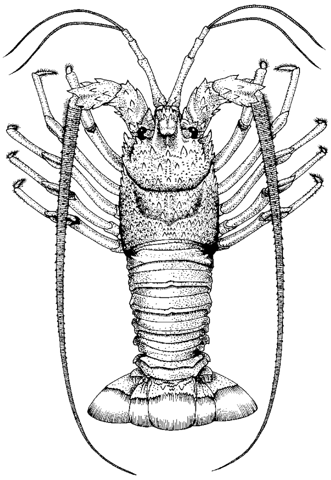
Torres Strait Islanders are increasingly becoming involved in commercial fishing activities, and there is still potential for development in the area. The Islanders sell a growing proportion of their reef fish catch, trolled pelagic fish and tropical rock lobsters.

Table 8.11 Catch, value and status of major commercial fish species (1993–94)

Fishery (tonnes)	Catch ($M)	Value	Catch Trend	Status
Western rock lobster	11 045	287 122	Stable	Fully exploited
Abalone	4 723	176 505	Stable; declining in some areas	Fully exploited; limited by quota
Tiger prawns (two species)	6 062	147 233	Stable overall; some stocks overexploited in 1980s	Fully exploited;
Southern rock lobster	5 060	119 505	Stable	Fully exploited
Southern bluefin tuna	6 080	116 348	Stable;recovery uncertain	Overexploited in 1980s;
Pearl oyster[a]	-	96 500	Stable; depressed in Torres Strait	Fully exploited
King prawns	6 056	68 443	Stable	Fully exploited
Northern scallops(two species)	13 445	51 308	Variable	Some over exploited/variable
Oysters (aquaculture)[b]	2 280	48 846	Increasing	Space limitations
Banana prawns (two species)	3 348	36 536	Variable	Fully exploited/variable
Endeavour prawns (two species)	3 056	31 360	Stable	Fully exploited
Crabs	3 551	17 549	Variable	Fully exploited
Southern scallops	9 006	16 604	Variable	Fully exploited/variable
School and gummy shark	5 152	15 536	Stable; some signs of recovery	School shark overexploited in 1980s;
Coral trout	1 101	13 212	Stable	Some overexploited/uncertain
Barramundi	861	8 439	Stable	Fully exploited
Mullet and sea mullet	4 464	8 235	Stable	Uncertain
Blue grenadier	3 111	7 079	Stable; quota not reached	Possibly under exploited;

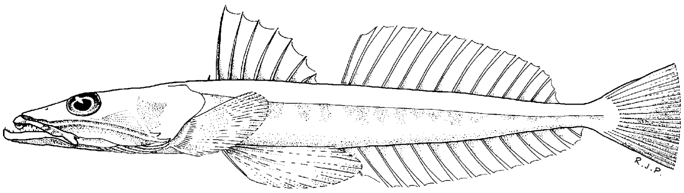
Notes: (a) The value given is the value of the cultivated pearls produced.
(b) The value given is that of the cultured product of oysters. The catch is the weight of cultured product.

Source: derived from ABARE and BRS.



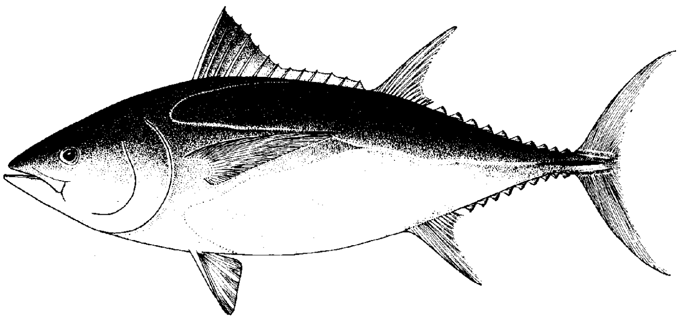
Western rock lobster

The western rock lobster fishery is the most valuable in Australia. The catch has been stable at about 10 000 tonnes over the past 30 years with variations caused by environmental factors. However, heavy fishing pressure reduced the breeding stock to the extent that egg production in 1992–93 had fallen to about 15–20 per cent of its level under light fishing pressure. So far, the reduced level of breeding stock does not appear to have affected recruitment to the fishery. But, as a precaution, fishing pressure is being reduced to allow the breeding stock to increase until egg production reaches about 25 per cent of the original level.



Tiger flathead

Trawl fishing for tiger flathead off south-east Australia has existed since 1915. During the late 1920s the catch rose to nearly 6000 tonnes. It then fell to around 3000 tonnes and subsequent catches have ranged from 1500 to 3000 tonnes. The tiger flathead fishery, which comprises several species, is now an important part of the larger south-east trawl fishery.



Southern bluefin tuna

Australia's southern bluefin tuna fishery is part of an international fishery. In the past, uncontrolled fishing reduced breeding stock so much that the recruitment of young fish was also reduced. The quantity of breeding fish is estimated to be less than 10 per cent of the original and is considered to be dangerously low (CSIRO, unpublished information). Management agencies have implemented controls on the catch over the past 10 years in an attempt to increase the breeding stock to the early 1980s level, but it is hard to tell if this slowly maturing species is recovering.

Figure 8.11 Annual catch of western rock lobster

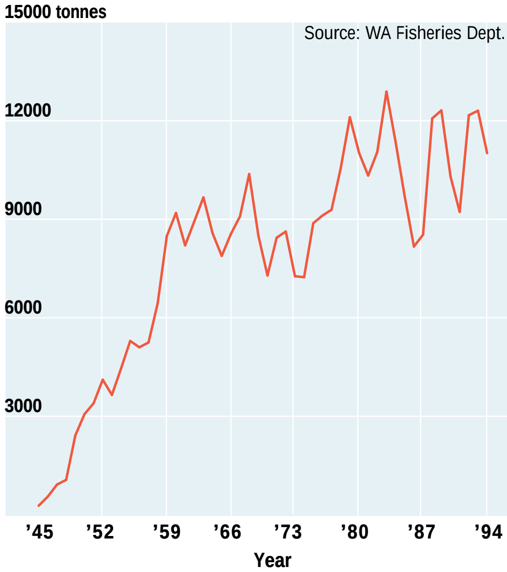


Figure 8.12 Annual catch of tiger flathead

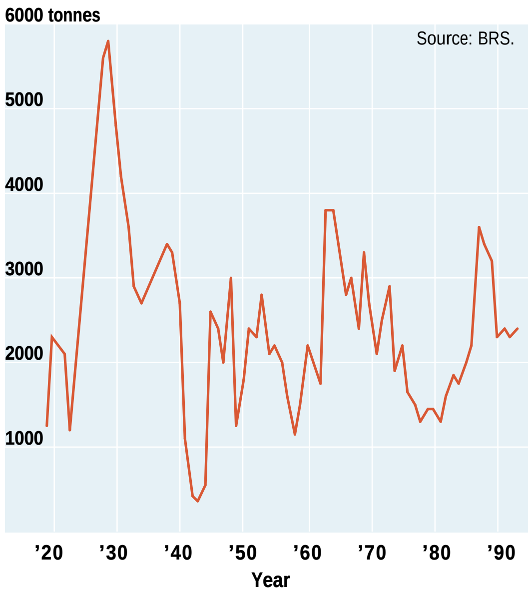


Figure 8.13 Annual catch of southern bluefin tuna

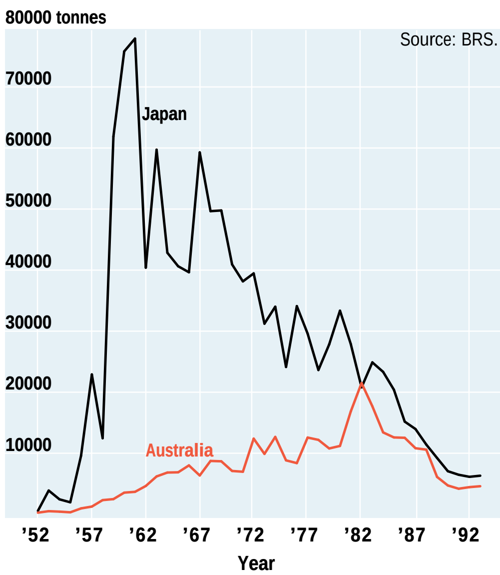
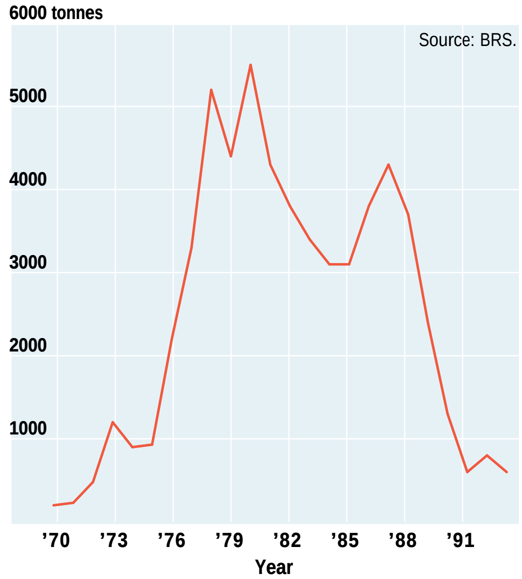
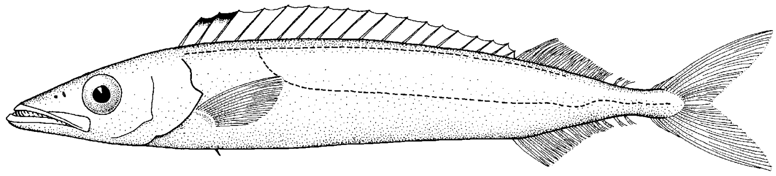


Figure 8.14 Annual catch of gemfish

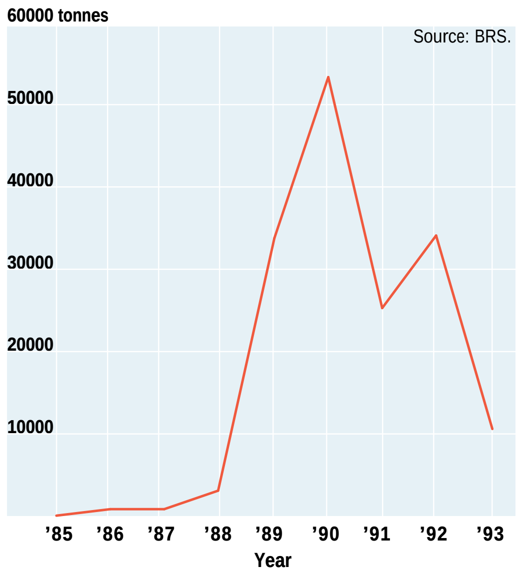


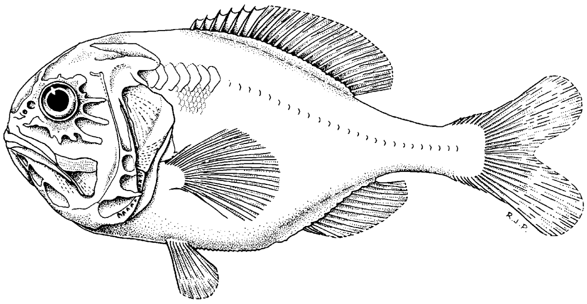


Gemfish

Recruitment of eastern gemfish has been so low for a number of years that the total allowable (targetted) catch was set at zero in 1993 and has remained at zero. However, about 267 tonnes in 1993 and 134 tonnes in 1994 were taken as by-catch during fishing for other species. The biomass of the adult population of eastern gemfish is at a dangerously low level.

Figure 8.15 Annual catch of orange roughy

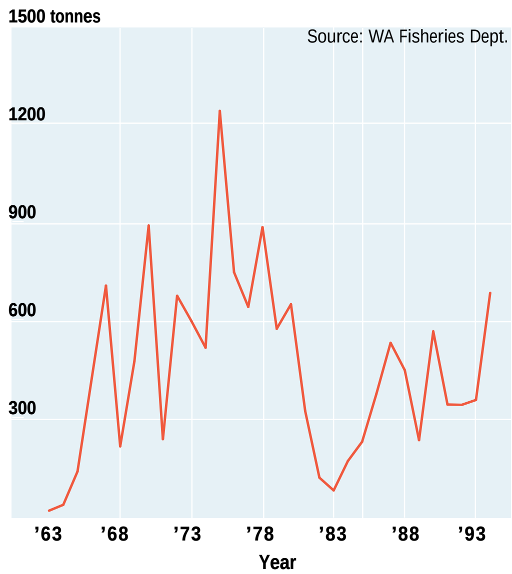




Orange roughy

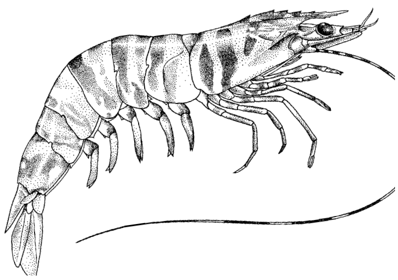
Fishing of this long-lived species began in the mid 1980s. Catches rapidly increased each year until 1990, when about 44 000 tonnes were taken in the south-east trawl fishery. Research indicated that the breeding stock had been reduced to approximately 30 per cent of its original level. In response, management authorities are now acting to reduce the catch to a target of 3500 tonnes for 1998 and beyond, in an effort to maintain the spawning stock at the current level.

Figure 8.16 Annual catch of tiger prawns in Exmouth Gulf



Exmouth Gulf tiger prawn fishery

Heavy fishing during the 1980s resulted in the annual catch of this fishery falling from an average of about 600 tonnes to 100 tonnes. The breeding stock had been reduced to such low levels that, even in those years of a favourable environment, egg production was insufficient to provide high recruitment. Strict controls on the catches planned through cooperative action between the industry and management have allowed the stock to rebuild and catches are again in the order of 600 tonnes per year.



Recreational fishing

Although recreational fishers catch many of the species being fished commercially, they also catch other species. We have few data on the status of the recreational fisheries. However, each of the Australian fisheries agencies is now increasing research on the recreational sector and the species supporting it.

From the limited data that are available it is clear that recreational fishing pressure is increasing. In one case, a study undertaken in New South Wales on boat-based and shore-based recreational fishing on the Clarence and Richmond Rivers found a twofold increase in fishing effort (boat hours) from 1988–89 to 1994–95. Shore-based fishing (angler hours) had also increased, but not to the same extent.

The coral trout fishery in the Great Barrier Reef Marine Park provides another example of increased recreational fishing, as well as increased commercial fishing. A recent study of the private recreational fishing fleet in the region suggests that, since the mid 1980s, the mean fish size has declined by 30 per cent and the catch per unit of effort has fallen by 50 per cent, coupled with a 25 per cent increase in the recreational fishery.

Reptiles

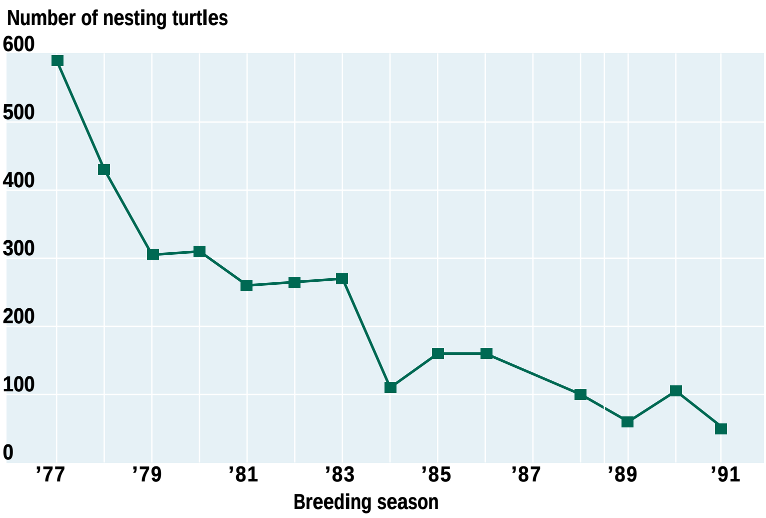
Marine reptiles such as turtles and sea snakes either live in or depend on the sea for their continued survival.

Australia's marine and estuarine reptile fauna includes 30 of the world's approximately 50 sea-snake species, six of the seven known species of turtles and the salt-water crocodile.

Sea-snakes

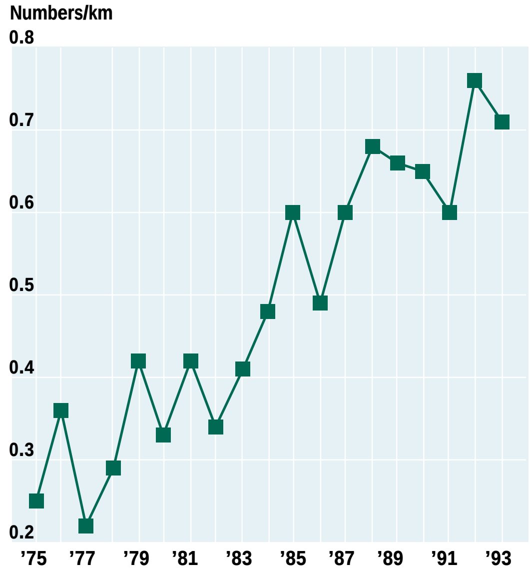
Of the 30 Australian species of sea-snakes from two families (one inhabiting the reefs and the other the inter-reef areas), 15 are endemic. The first group are well protected because they live in reefs and many of them are found in the Great Barrier Reef Marine Park. The inter-reef species, however, are caught by prawn trawling. In the Gulf of Carpentaria in 1991, the mortality from commercial prawn trawling was estimated to be between 29 801 and 67 051 sea-snakes (Wassenberg *et al.*, 1994), but the impact on the populations is not known.

Figure 8.17 Loggerhead turtle population decline at Wreck Island on the Great Barrier Reef



Note: Wreck Island in the Great Barrier Reef is the most significant breeding site for loggergead turtles in the south-west Pacific.
Source: Marsh *et al.*, 1995.

Figure 8.18 Increase in the number of saltwater crocodiles in the Northern Territory since protection began in 1971



Note: These counts are from waterways surveyed by helicopter between 1975 and 1993.
Source: Webb *et al.*, 1994.

Turtles

Turtles are large reptiles that live at least 50 years and reach maturity at between 12 and 25 years of age or older. They seldom breed every year, but may wait two to eight or even ten years between breeding attempts. Six species of turtles occur in Australian waters — the leatherback, loggerhead, green, hawksbill, olive ridley and flatback. All six species breed in Australia, although recorded breeding of the leatherback has been infrequent.

The flatback turtle is endemic to Australia. However, the populations of other species move between Australia and neighbouring countries, where they are extensively hunted. In Australia, commercial exploitation of turtles was permitted on the east coast until the late 1960s and on the west coast until the early 1970s. Hunting by Torres Strait Islanders and some Aboriginal communities for traditional purposes continues. Between 1992 and 1994 the annual Australian catch in Torres Strait was about 2500 turtles, mainly green. (CSIRO, unpublished data).

It is hard to assess the status of most sea turtles because of the lack of information, the dispersed feeding and breeding behaviour and the long wait to maturity. However, nesting populations of loggerhead turtles have declined and regional populations are threatened (see Fig. 8.17). Studies suggest that populations of loggerhead turtles will not withstand mortalities of five to 10 per cent above natural levels (Somers, 1994).

Olive ridley turtles form massive breeding groups of up to 150 000 in some countries. An estimated 11 500 green turtles were recorded nesting on Raine Island off Queensland on a single night in 1984.

Crocodiles

The saltwater crocodile has a wide distribution outside Australia, from India and the Philippines through South East Asia and Papua New Guinea. In most countries, except Australia and Papua New Guinea, the species has all but disappeared.

It was harvested by shooting in Australia throughout its range from 1945 to 1971 and, as a result, populations fell heavily. When hunting was stopped in 1971, the numbers had been greatly depleted but enough remained to provide the basis for a consistent recovery. Since then, the population status of the species has improved (see Fig. 8.18). Most saltwater crocodiles occur in the Northern Territory, where the original size of the population was estimated to be no more than 100 000 animals, including young of the year. By 1984 the upper estimate was 40 000 animals (including hatchlings, non-hatchlings and captives) and the 1993 upper estimate was 60 000.

Populations have always been smaller in Western Australian and Queensland waters than in the Northern Territory. However, the numbers in those areas are either stable or increasing (Western Australia) or there is evidence to suggest a slow recovery (Queensland), though they may still be declining in populated and agricultural areas.

Seabirds

These are birds such as shore birds and highly migratory birds like albatrosses that depend on the sea for their continued survival.

Australia and its external territories have about 110 species of seabirds belonging to 12 families. Of these, 76 species breed and live in the region and the rest are regular or occasional visitors. The conservation status of most species breeding here appears to be satisfactory (see Table 8.12). In cases where seabirds were previously exploited — for oil, food and bait — most populations have now recovered. The only remaining industry is the harvesting of short-tailed shearwaters for the mutton bird industry in Bass Strait.

Scientists consider 14 species or subspecies of Australia's seabirds (13 per cent) are threatened (Zann, 1995), largely because their colonies on oceanic islands are few in number and are vulnerable to illegal harvesting and natural disasters. Colonies can be subject to human disturbance and predation by introduced and feral animals. The wandering albatross on Macquarie Island, Abbot's booby on Christmas Island and the Australian subspecies of the little tern are classified as 'endangered' under International Union for the Conservation of Nature (IUCN) criteria. Lord Howe's Kermadec petrel and white-bellied storm-petrel and Christmas Island's Christmas frigatebird are considered 'vulnerable'.

The wandering albatross (and other species such as petrels) takes bait used on longlines set for tuna. After taking the bait on the longline hooks, the birds often drown as the hooks drag them just below the surface. This practice has caused considerable mortality and is considered the major factor contributing to the worldwide decline in populations of wandering albatross over the last two decades (Gales, 1993).

Australian and Japanese boats use longlines in the Australian Fishing Zone. The Japanese fleet has introduced measures, such as tori poles, bait-throwing devices and the use of night setting of gear, which significantly reduce the albatross bycatch. Researchers are now collecting data on the effect of the Australian longline fishery on the wandering albatross.

Table 8.12 Estimates of numbers of breeding pairs of seabirds along the Australian coast and Coral Sea

Species	Minimum	Maximum
Little penguin	149 130	249 900
Shy albatross	6 900	8 500
Great-winged petrel	33,050	84 100
Herald petrel	3	3
Black-winged petrel	3	3
Gould's petrel	250	500
Fairy prion	1 055 060	1 682 000
Wedge-tailed shearwater	1 301 150	1 344 400
Flesh-footed shearwater	104 540	310 600
Sooty shearwater	300	1 210
Short-tailed shearwater	12 787 070	16 059 700
Little shearwater	27 060	61 600
White-faced storm-petrel	370 180	396 600
Common diving-petrel	127 220	184 000
Australasian pelican	1 030	1 680
Australasian gannet	5 560	6 140
Masked booby	3 750	4 270
Red-footed booby	1 380	4 990
Brown booby	59 940	73 900
Pied cormorant	13 080	19 120
Little pied cormorant	140	200
Black-faced cormorant	7 740	8 110
Great frigatebird	1 610	1 610
Lesser frigatebird	18 680	19 430
Red-tailed tropic bird	290	380
White-tailed tropic bird	2	2
Silver gull	133 890	163 620
Pacific gull	1 900	1 950
Kelp gull	315	315
Caspian tern	1 160	1 410
Roseate tern	7 220	13 370
White-fronted tern	44	44
Black-naped tern	1 710	2 080
Sooty tern	328 760	383 750
Bridled tern	20 040	57 870
Little tern	560	570
Fairy tern	2 420	2 990
Crested tern	74 350	89 940
Lesser crested tern	4 710	8 170
Common noddy	174 480	214 130
Lesser noddy	79 500	79 500
Black noddy	119 340	130 840

Source: Ross *et al*., 1995.

Dugong mother and calf. Many of Australia's marine mammals are threatened by human activities.

Mammals

Marine mammals include whales, dolphins, seals and dugongs.

Australia's marine mammal fauna includes one species of dugong, three species of seals and 43 species of whales and dolphins (Zann, 1995). Despite widespread protection, many of Australia's marine mammals are still threatened by dangers such as loss of habitat, pollution, accidental netting, entanglement in litter and disturbance.

Dugongs (sea-cows)

The tropical dugong is the only fully herbivorous marine mammal and the only sea-cow found in Australia. It is listed by IUCN as 'vulnerable to extinction', but is not listed under the Commonwealth *Endangered Species Protection Act*. It is extinct or near extinct in most of its former range, which extended from East Africa to South East Asia and the Western Pacific. Northern Australia has the last significant populations (more than 80 000 animals) in the world (Zann, 1995).

Torres Strait Islanders and some northern Aboriginal communities catch dugongs for food. The Torres Strait take of dugongs by Australians is estimated to be about 1000 per year. The eastern Cape York catch is estimated to be less than 100 per year.

Aerial surveys being carried out along most of the northern Australian coastline are providing estimates of the dugong population (see Table 8.13). The most important area in Australia and probably the world, is Torres Strait, with an estimated 24 000 animals. Shark Bay, on the west coast, also supports a large population of dugongs and is particularly important as very little human-induced mortality of dugongs occurs in this region.

Dugongs are killed incidentally in commercial gillnets and shark nets set to protect swimmers in northern Australia. A total of 576 dugong deaths were recorded from shark nets in Queensland between 1964 and 1988. These creatures are also potentially threatened by the loss of their habitats to coastal residential, industrial and tourist development, as well as natural causes. For example, many dugongs died in Hervey Bay, Queensland, in 1992 following dieback of seagrasses (Zann, 1995), possibly caused by increased sediments.

Table 8.13 Recent estimates of dugong populations in their 10 principal Australian habitats

Location	Area (sq. km)	Population Estimate	
Shark Bay, WA	14 906	10 529	(±14%)
Exmouth Gulf, Ningaloo WA	28 746	1 974	(±30%)
Northern Territory coast	28 746	13 800	(±19%)
Western Gulf of Carpentaria	27 216	16 846	(±19%)
Wellesley Island	8 848	4 067	(±18%)
Torres Strait	30 560	24 225	(±14%)
Northern Great Barrier Reef	31 288	10 471	(±15%)
Southern Great Barrier Reef	39,396	1 857	(±16%)
Hervey Bay	4 371	600	(±29%)
Moreton Bay	1 400	664	

Source: Marsh *et al.*, 1994.

Seals

Three species of eared seals breed in mainland Australian waters: the endemic Australian sea lion, the Australian fur seal and the New Zealand fur seal. The New Zealand fur seal also occurs in large numbers in New Zealand and Antarctic waters. The southern elephant seal breeds at Macquarie and Heard Islands. This species did occur (and bred) in Bass Strait, but was hunted to extinction there in the nineteenth century. Non-breeding visitors to Australia's southern shores from the Antarctic and sub-Antarctic islands include the leopard, Weddell, crab-eater and Ross seals.

Australia's seals were badly over-hunted in the last century, until about 1825. Sealing at a few remnant colonies in eastern Bass Strait continued on a regulated basis until about 1923 (Warneke and Shaughnessy, 1985). Seals are now fully protected by legislation and some populations appear to be increasing. Major human threats include entanglement in fishing nets and ocean litter, oil pollution and disturbances by visitors. Fur seals are occasionally illegally killed for shark and lobster bait. They are also killed around fish farms, trawls and nets for 'stealing' fish. Many become entangled in discarded nets and plastic box straps.

The breeding range of the Australian sea lion extends from the Houtman Abrolhos, off the Western Australian coast, across the southern coastline to The Pages, just east of Kangaroo Island. It is the most widely distributed Australian seal and also the least abundant. The total population is estimated to be between 7000 and 10 000 animals, producing less than 2000 pups per breeding cycle (Goldsworthy, 1994).

Australian fur seals — population estimated at between 30 000 and 50 000 animals — have an annual pup production of between 8000 and 9000. The population appears to have stabilised, but remains well below the pre-sealing levels when the annual pup production could have been two to five times higher.

The New Zealand fur seal has an estimated population of 28 000 animals in Australian waters and a pup production of about 7000 per breeding cycle.

Whales, porpoises and dolphins

Eight species of baleen whales and 35 species of toothed whales, porpoises and dolphins are found in Australian waters, although none are endemic. They represent almost 60 per cent of the world's cetacean species.

Until recently, hunting exerted the major pressure on them and several species were driven to near extinction. Their populations are slow to increase and are highly vulnerable to overexploitation.

Whalers have caught humpback whales since the early 1800s. However, the greatest effect on the population from hunting began in the late 1940s, from Western Australian land stations and the Antarctic, and during the 1950s off eastern Australia. In 1935, before the major assault began on the humpback whales wintering off Western Australia, the population might have numbered up to 17 000. By 1949 the estimate was down to 10 000 and by 1963 the number of adults had been reduced to only about 500 animals. The east coast population registered a similar decline (Bannister, 1994).

After humpback whaling stopped in 1963, very few were sighted until the early 1970s. Aerial surveys, which began in 1977, have recorded a persistent and encouraging increase in the number of humpback whales sighted off the Western Australian coast. Comparisons with aerial sightings in 1963 indicate that the population now numbers at least 3000 animals and possibly considerably more. A similar 'comeback' has been recorded off the east coast.

By 1845, the population of southern right whales off the Australian coast was sadly depleted. It has grown slowly from small remnants of about 100 animals to number less than 800 today. Encouraging results from aerial surveys undertaken between Cape Leeuwin, Western Australia, and Ceduna, South Australia, show that the number of animals continues to increase, albeit from a very low base.

Whalers caught sperm whales off the south coast of Western Australia from the mid 1950s to 1978. No one has undertaken aerial surveys since then to establish the population status.

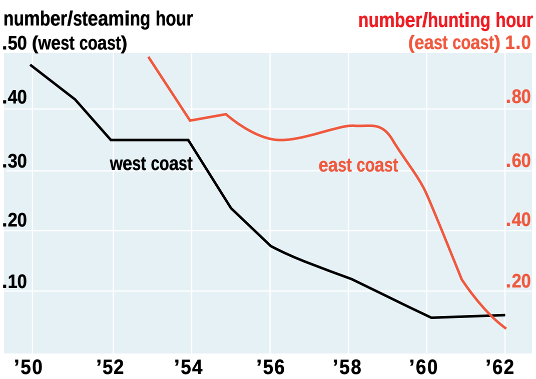
Australians have replaced whaling with a new ecotourist industry, 'whale-watching'. Because of concern that boats, aircraft and divers may affect whale behaviour, regulations have been introduced to govern how closely observers may approach whales. An Australian government paper to the International Whaling Commission (Anon., 1994) recognised that the increase in whale-watching activities required better and more coordinated management.

Australian fur seals at Smith Rocks, Joseph Banks Group, South Australia.

Today whales, porpoises and dolphins within Australia are threatened by gillnets, shark nets, discarded fishing nets, tuna aquaculture nets and the risk of swallowing plastic litter. Protective shark nets off bathing beaches catch considerable numbers. In Queensland, for example, they caught about 520 dolphins between 1967 and 1988. Other pressures, especially on inshore species, may include loss of habitat, reduction in prey numbers, increasing risk of collisions with boats and disturbance of migrating and breeding populations (Zann, 1995). We have little information on a national level on the status of dolphins.

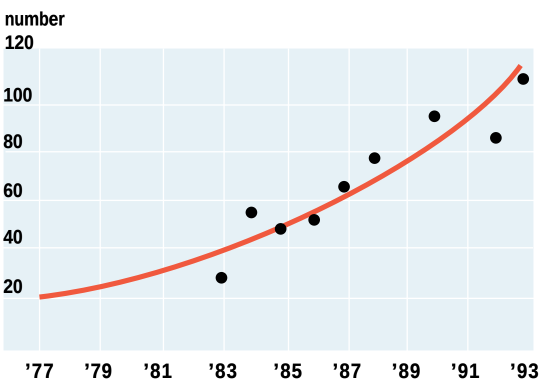
On a worldwide scale, marine mammals face a significant threat of contamination by organochlorine pesticides and polychlorinated biphenyls (PCBs). They are particularly sensitive to reproductive failure due to accumulated PCBs, but we have few data on PCBs in Australian cetaceans (Marsh *et al.*, 1995).

Figure 8.19 Catch rate of humpback whales off the west and east coasts of Australia



Source: After Bannister, 1994

Figure 8.20 Number of southern right whales off southern WA, 1977–93, from aerial survey results



Source: After Bannister, 1994

Species outbreaks

Some species may, for various reasons, undergo population explosions in areas that are part of their normal range.

Problems with pest species are not limited to introductions of species from overseas or movements between localities within Australia. Explosions in the numbers of particular native species may — although we generally lack the evidence — be caused by human-induced changes in their environment. For example, some scientists believe that outbreaks of the coral-eating crown-of-thorns starfish on the Great Barrier Reef might have resulted from overfishing of their natural predators or changes in the nutrient load of the water. Alternatively, the outbreaks may be a natural occurrence, but their frequency may change due to human activity.

Over the past 30 years outbreaks of crown-of-thorns starfish have caused considerable damage to Indo-Pacific reefs, including parts of the Great Barrier Reef and Australia's Tasman Sea reefs. Two such episodes have affected parts of the Great Barrier Reef since 1960 and observers fear that numbers are building up towards a third. The 1979 to 1990 episode affected about 17 per cent of the 2900 coral reefs to some extent, most of them concentrated in the central one-third of the Reef.

Millions of small coral-eating *Drupella* snails have had a significant impact on more than 100 km of the Ningaloo fringing reef off Western Australia. These snails have also caused localised damage in the Cairns section of the Great Barrier Reef (Zann, 1995).

Introduced species

Introduced species are those species which have been spread ouside their natural range.

Complete data on the number of species introduced into Australian waters do not exist. This is especially true of many invertebrate groups, microorganisms and certain algae and higher plants where the Australian flora and fauna are not well studied. Many introductions will not become established or will not reach numbers that cause any concern, but some have done so.

At least 55 species of fish and invertebrates and a number of seaweeds have been introduced into Australia either intentionally, for aquaculture, or accidentally in ships' fouling and ballast waters. The following organisms are of particular concern.

Gymnodinium catenatum, a toxic alga, causes red tides. Blooms of introduced toxic marine algae are a serious marine environmental and fisheries problem in Tasmania and Victoria and may threaten other States (see the box on page 8-26).

The invasive giant fanworm *Sabella* cf. *spallanzanii* has carpeted areas of Port Phillip Bay and has also been found in the waters of Port Adelaide, in Cockburn Sound and in the Bunbury and Albany port areas of Western Australia. It could have a detrimental effect on local shellfish-farming and on biodiversity of native species.

Of Japanese origin, the seaweed *Undaria pinnatifida* displaces and smothers native kelps. Its spread in Tasmania now supports a small commercial harvesting industry.

The predatory northern Pacific seastar (see the box below) is spreading along eastern Tasmania, threatening marine life, aquaculture farms and scallop and abalone fisheries (Zann, 1995).

Many species of introduced plants have invaded Australian saltmarshes. However, four are of particular concern: *Spartina anglica*, groundsel bush (*Baccharis halmifolia*), pampas grass (*Cortaderia selloana*) and *Juncus acuta*. These species are highly invasive and are capable of substantially altering the ecology of Australian saltmarsh habitats where they become established.

The northern Pacific seastar in Australia

This species, which is a voracious predator on molluscs and other animals, is a pest on shellfish farms in Japan, which is within its natural range. Originally detected in Hobart in 1986, the seastar has spread along about 50 km of the south-east coast of Tasmania and its larvae can potentially be carried across Bass Strait to mainland Australian waters. It is already threatening marine life, aquaculture farms and scallop and abalone fisheries. Although scuba divers have removed many thousands of seastars, it is unlikely that this method can achieve total eradication (Zann, 1995).

The seastar was probably introduced into Australia by ships visiting the Hobart area. Predators occurring naturally in Australian waters have little chance of reducing or controlling numbers. There are usually no practical methods to eradicate such introduced species once they become established. This underlines the importance of effective preventive measures such as stringent controls to minimise the risk of introducing exotic pest species through fouling on ship's hulls and in ballast-water discharges. Notwithstanding the best quarantine measures however, pest species will probably occasionally breach the barriers. It is important to have effective plans in place to predict the spread and manage the impacts of any that may become established in Australian waters.

Seafood quality

Seafood quality is determined by both the environment in which the species lives and its treatment after it has been harvested from the sea. This section deals only with the environmental effects on seafood quality. The major issues concern the accumulation of contaminants in the flesh of seafood species.

In general, Australia's seafoods are low in contaminants. However, exceptions occur in those species that accumulate heavy metals, biotoxins, microbes and pollutant chemicals. Heavy metals, for example mercury, cadmium and lead, can be accumulated either naturally from sea water through the food chain or by species inhabiting locally contaminated areas. Levels of mercury naturally become elevated in top-level predators such as sharks and other long-lived fish.

Microalgae produce biotoxins like ciguatera and paralytic shellfish poisons (PSPs). Coral reef fish can accumulate ciguatera poison (ciguatoxin) by grazing on algae, and filter-feeding shellfish similarly accumulate PSPs. These species can accumulate toxins to such an extent that people who eat them suffer food poisoning.

Shellfish can also accumulate microbes, such as bacteria and viruses, when they are grown in contaminated water. Seafood species can accumulate chemicals in a number of ways — through the food chain, direct from the water or from sediments.

The National Food Authority sets standards to prescribe the maximum permitted limits of contaminants for seafood consumption. The level of risk to people depends on how much and what type of seafood they consume. Recommended public health levels are based on criteria derived for the 'average' Australian community. Some communities may differ from this pattern in both the quantity and parts of the organism they eat. Torres Strait Islanders, for example, are among the highest consumers of seafood in the world (Johannes and Macfarlane, 1991). Fish, turtles and dugongs form a major part of their diet and they also consume more offal than the 'average' Australian community. Appropriate safe levels for seafood intake have not been calculated for such communities.

Ciguatoxin occurrence in seafood is well documented (Lewis, 1994). In French Polynesia outbreaks of ciguatoxic poisoning have been associated with human disturbances to coral reefs (Bagnis, 1994). In Australia, however, field studies have not supported such a causal link (Holmes *et al*., 1990).

In New South Wales, sewage wastes from outflows have contaminated cultivated oyster crops. Poor water quality has also caused bacterial and viral contamination of shellfish.

The toxic dinoflagellate *Gymnodinium catenatum*, introduced into waters around Tasmania by ballast-water discharges, has contaminated cultivated shellfish with toxins forcing the periodic closure of commercial shellfish farms in the Derwent and Huon River estuaries since 1986 and in Port Phillip Bay since 1991.

In general, Australian seafoods are low in contaminants.

Contaminant data for four species of fish (sea mullet, bream, flathead and luderick) collected by NSW Fisheries in 1991–92 from 10 estuaries along the New South Wales coast showed that fish collected from the Parramatta and Georges Rivers had relatively high organochlorine concentrations compared with fish from other areas. A few areas in that State have been closed for fishing due mainly to the high pollution of waters or sediments and the concern about possible contamination of fish (Environmental Protection Authority of NSW, 1993).

Table 8.14 Maximum permitted concentrations (MPC freshweight) of heavy metals set for seafood in Australian Food Standard A12 (1992)

Arsenic	Fish, crustaceans and molluscs	1.0 mg/kg (inorganic only)
	Seaweed (edible kelp)	1.0 mg/kg (inorganic only)
	All other foods	1.0 mg/kg (total)
Cadmium	Fish (and fish content of products)	0.2 mg/kg
	Crustaceans (and crustacean content of products)	0.2 mg/kg
	Molluscs (and mollusc content of products)	2.0 mg/kg
	Seaweed (edible kelp)	0.2 mg/kg
	All other foods	0.05 mg/kg
Copper	Molluscs (and mollusc content of products)	70.0 mg/kg
	All other foods	10.0 mg/kg
Lead	Fish in tinplate containers	2.5 mg/kg
	Molluscs	2.5 mg/kg
	All other foods	1.5 mg/kg
Mercury	Fish, crustaceans and molluscs (and fish content etc.)	A mean level of 0.5 mg/kg
	All other foods	0.03 mg/kg
Selenium	All other foods	1.0 mg/kg
Tin	Foods not packed in tin	50.0 mg/kg
	All other foods	150.0 mg/kg
Zinc	Oysters	1000.0 mg/kg
	All other foods	150.0 mg/kg

Source: Australian Food Standard 1992.

Table 8.15 Heavy metals in dugong and green turtle from the Torres Strait

		Mean concentrations (mg/kg fresh weight) cadmium	copper	lead	zinc
Dugong	muscle	0.015	0.2	0.03	12.6
	liver	6.43	184.0	0.08	470.0
	kidney	8.17	2.67	0.06	31.0
Green Turtle	muscle	1.14	4.69	0.07	12.5
	liver	10.7	59.3	0.6	38.6
	kidney	26.0	7.4	0.07	23.8

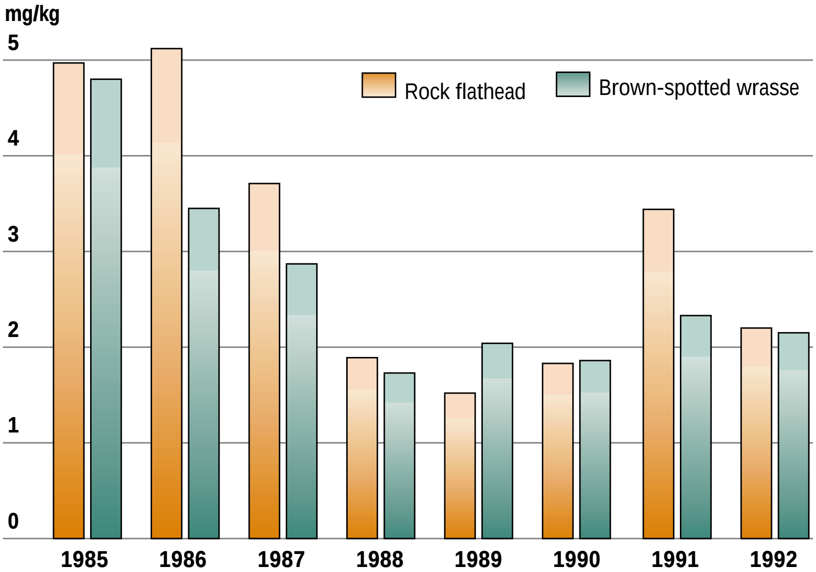
Source: Gladstone, in press.

Heavy metals can also be present in seafood in levels above recommended public health limits. Mercury has been subject to detailed investigation (Hancock, 1980) and most States prohibit the sale of shark and billfish over certain sizes because they contain naturally bioaccumulated mercury above recommended limits.

In Torres Strait, high levels of cadmium occur in a range of food species of importance to the Islanders, but levels of other metals are within public health guidelines — depending on which component of the animal is consumed. In general terms, the offal components (such as the liver and kidneys, or their equivalents in invertebrates) of green turtles and dugongs are high in several metals (see Table 8.15). People who eat a lot of these foods may exceed recommended intake rates for some metals.

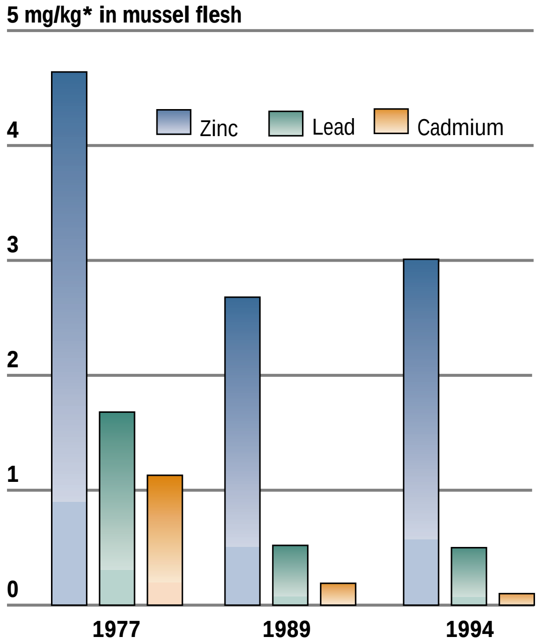
The high cadmium levels are thought to be due to natural bioaccumulation and not mining operations (Dight and Gladstone, 1993). Preliminary information from other sources suggests that cadmium in prawns may also be of

Figure 8.21 Reduction in mercury concentration in rock flathead and brown spotted wrasse in Princess Royal Harbour as a result of stopping an industrial effluent in 1984



Source: WA Marine Research Laboratories.

Figure 8.22 Reductions in zinc, lead and cadmium concentration in mussels in Cockburn Sound and Owen Anchorage as a result of pollution controls



* Note: zinc levels are divided by 10 to fit this scale
Source: WA EPA.

concern, with concentrations across northern Australia ranging up to 10 times greater than the maximum permitted concentration (Fisheries Pollution Committee, 1991).

In Western Australia, researchers found heavy metal contamination of fish above health safety levels in Princess Royal Harbour, Albany, where mercury was an unsuspected component of an industrial effluent. As a result, authorities stopped the flow of effluent into the harbour and closed part of the fishery. Monitoring of fish and cockle species since 1984 shows that contamination has dropped to a level where it is no longer a health risk. The fishery was reopened in 1992. In Cockburn Sound, a similar trend occurred for the heavy metals cadmium, lead and zinc in mussels, in response to pollution control measures.

Monitoring programs have revealed high levels of tributyl tin (TBT) in a number of marine species around Australia (see opposite). We do not know how significant this is for people who eat seafood, but levels are dropping following the reduction in the use of TBTs as antifouling agents, so it is unlikely to cause concern in future.

We lack information — including baseline data — on levels of substances that may affect seafood quality in Australian waters and sediments. Generally, information is only available from areas with a recognised problem or where organisations have had to provide environmental impact studies for developments such as mining. The National Residue Survey of the Bureau of Resource Sciences surveys the levels of contaminants in seafood from a national perspective; however, the results are not released for public scrutiny.

Water quality

The quality of water in Australia's marine and estuarine environments is a matter of considerable concern because degraded water quality can have impacts on seafood quality, tourist potential and biological diversity. Degradation of water quality can have many causes, including excess nutrients, sediments derived from land, chemical contaminants, pathogens such as bacteria and litter.

Declining water quality caused by nutrients and sedimentation is the most serious issue affecting Australia's marine and coastal environments. Elevated sedimentation and nutrients are closely linked and largely the result of inappropriate catchment land use practices.

Nutrients

Australia's open, offshore marine waters have low nutrient concentrations. Nearer the coast, concentrations often rise because of the effects of rivers and other land run-off. In some places, near-shore marine systems are periodically exposed to high-nutrient waters derived from upwelling of deep offshore water. In more enclosed, shallow near-shore waters — coastal bays, lagoons and estuaries — nutrient concentrations can rise because of poor flushing combined with river inflows and waste water discharges.

The increased input of nutrients to estuarine and near-shore waters from both diffuse catchment sources and point discharges has significantly altered the nutrient regime of many of Australia's bays and estuaries. An assessment of 22 estuaries in the south-west of Western Australia indicates that seven have low nutrient levels and are in good condition, six have elevated nutrient levels but remain in satisfactory condition and nine have elevated nutrient levels and are in poor condition. Many of the major estuaries in south-east Queensland, including those of the Brisbane, Logan, Albert, North Pine, Caboolture, Maroochy, Mary and Burnett Rivers, have elevated nutrient concentrations, largely due to sewage discharges. In Victoria and New South Wales, most estuaries located near major population centres are — to varying degrees — also nutrient-enriched.

As discussed in the box on page 8-13, elevated nutrient concentrations enhance the growth of marine algae and, in some cases, contribute to loss of seagrass.

Suspended solids

Levels of suspended solids are highly variable, depending on a range of conditions such as particle size, water turbulence, available wave energy, water depth, seabed characteristics and seasonal fluctuations in sources. In Barker Inlet, near Adelaide, for example, the concentration of suspended solids averaged about 20 mg per L, but it varied from 3.5 mg per L during calm conditions to about 300 mg per L during a storm (Kinhill Engineers Pty Ltd, 1993). We do not have long-term data for changes in the concentration in Australian estuaries or the ocean. In Jervis Bay, suspended solids showed great variations over a three-year period, related both to rainfall in the catchment and to nutrient intrusions from the continental shelf (CSIRO, 1994).

Pesticides and industrial chemicals

Organochlorine pesticides like DDT and DDE are thought to be widely present in marine life around Australia, but in very low concentrations away from urban and intensively farmed lands. Organochlorines resist degradation and persist in the environment for decades. They can be passed through the food chain and between generations of organisms.

In Queensland, organochlorines have been detected in very low concentrations on the Great Barrier Reef and in higher concentrations in the Brisbane River. In New South Wales, before Sydney's three deep-water sewage outfalls were built, researchers measured very high levels of organochlorines in marine organisms near Sydney's three major sewage outfalls (Lincoln Smith and Mann, 1989). In South Australia organochlorines were widely present in fish sampled in the early 1970s (Olsen, 1988).

Few surveys of either polychlorinated biphenyls (PCBs) or dioxins have been undertaken in Australia. While PCBs have been detected in offshore waters, increasing towards the coast, their levels are still lower here than in equivalent Atlantic waters: in Port Phillip Bay levels remain high near Melbourne, but are declining in Corio Bay. Dioxins have been found in fish and sediments in Sydney, at Homebush Bay and in Melbourne near sewage outfalls. We do not know the implications of these levels.

Metals

Tributyl tin — widely used in Australia as a poison in antifouling paints since the 1970s — has been a particular water-quality issue. During the 1980s it was found to affect the growth of oysters and other molluscs, and in 1988 the authorities recommended a ban on its use on non-aluminium-hulled vessels smaller than 25 m, which most States have now implemented. Prior to the recommendation, levels of concentration in the waters of Australian dockyards and marinas were frequently 50 times higher than the guideline, but since 1988 have dropped appreciably — to below the guideline. Likewise, in some surface sediments, concentrations are now less than in older sediments below (Zann, 1995).

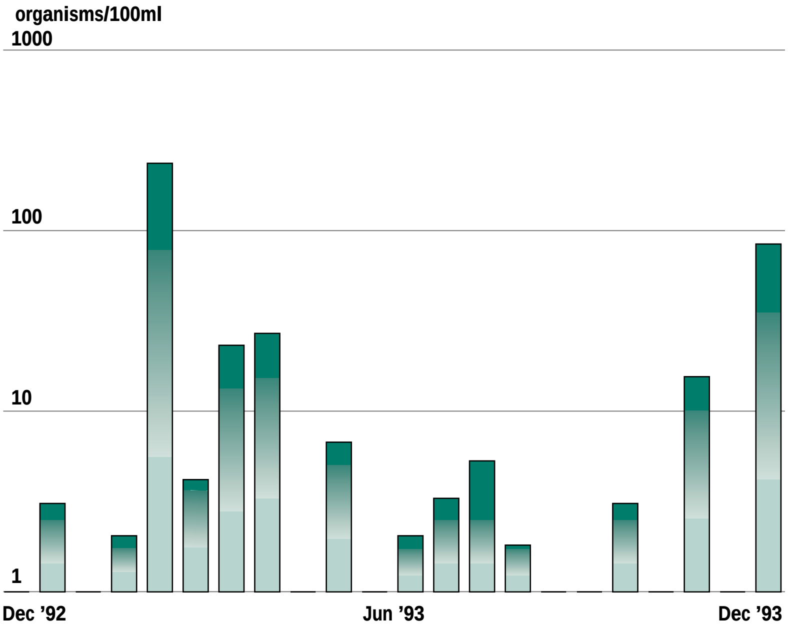
Table 8.16 Levels of tributyltin in selected waters

Place	Level (ng/L)
Kogarah Bay (NSW)	100 (pre-ban)
Port Phillip Bay (Vic)	3-23 (pre-ban)
Southport (Qld)	45 (pre-ban)
Georges River (NSW)	8-40 (pre-ban)
Georges River (NSW)	1-11 (post-ban)

Note:
The Australian Water Quality Guideline for marine waters is 2 nanograms per litre

Source: Batley, 1995.

Figure 8.23 Bacteria (*E. coli*) in water from between bathing flags at Surfers Paradise, December 1992 to December 1993 (The Australian water quality guideline is a median value of 150 organisms/100ml)



Source: Qld DEH.

Pathogens

Concern about pathogens in marine and estuarine environments is largely in the context of human health. The areas of most concern are usually those close to urban development, near the sources of pathogens and where the public is most likely to be exposed. Information about the extent of disease-causing microorganisms (pathogens) in most of our marine environment is scarce (Ashbolt, 1995).

In Australia, we usually assess microbial pollution in sea water by measuring the concentration of certain indicator bacteria, primarily faecal coliforms (see Fig. 8.23 and Table 8.2). However, other pathogens, such as viruses and parasitic protozoa, may survive better than the indicator bacteria. Combined with difficulties of sampling and culture methods, this can result in the number of pathogens being underestimated. Nonetheless, local authorities usually act quickly to close beaches to swimming when they suspect microbial pollution. So, records of numbers and periods of beaches closed to swimming could be used to assess changes in their condition.

Litter

Shipping, beach-goers, recreational boating, commercial and recreational fishing and urban drains all contribute litter to marine and estuarine environments (see Fig. 8.24).

In Australia, a large number of marine organisms become caught in nets, fishing lines and other litter. Researchers estimate that, at any one time, about 500 seals in Tasmanian waters and 45 seals at Victoria's Seal Rocks have 'collars' of plastic litter (see Fig. 8.25). Turtles may die from eating plastic bags, which they mistake for jellyfish (Zann, 1995).

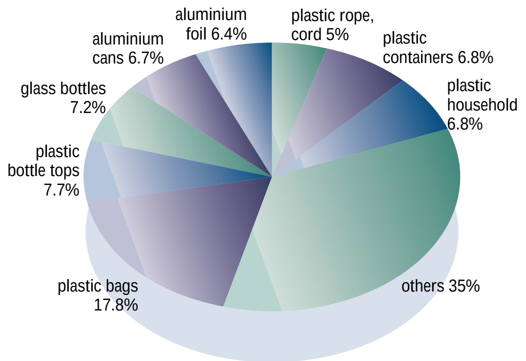
Greenpeace Australia effectively focused public attention on the problem of beach pollution through the 'Adopt-a-Beach' program between 1990 and 1992. Some 123 beaches were 'adopted' by local groups and are now regularly cleaned. The 'Clean up Australia' campaign has continued to focus on the beach litter problem.

Sediments

Sediments form the basis of many marine and estuarine habitats, from sandy beaches, intertidal flats, mangrove muds and seagrass beds to estuarine and deepwater sands and silts. Sediments have several important characteristics that determine what communities inhabit them and how they behave physically. These factors include grain-size composition, organic content, oxygenation and stability. Changes in any of these characteristics usually result in alteration of the associated seabed communities.

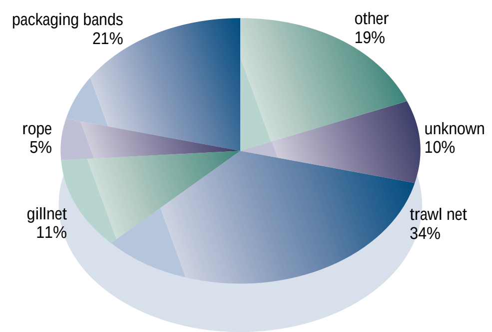
Australia's coastal sedimentary environments have changed significantly since European settlement due to the effects of urban, industrial and agricultural development. The greatest impact has been increased sediment input to coastal areas through land run-off caused by erosion from land clearing and agriculture. Associated with these

Figure 8.24 Composition of beach litter



Source: Zann, 1995.

Figure 8.25 'Neck collars' on seals



Source: Zann, 1995.

deposits, the sedimentary environments usually experience changes in grain-size composition, stability and level of sediments, through siltation or erosion. Although beach stability and profiles are increasingly recognised as important aspects of coastal foreshores, no coordinated national programs exist to document changes.

Run-off may include contaminants, like nutrients or heavy metals, from land-based sources. Many such contaminants entering the marine and estuarine environments become chemically bound to sediments and can be released later in response to disturbance or changes in water chemistry (Brodie, 1995; Batley, 1995). There are few programs to monitor subtidal sediments. Disease-causing pathogens and their spores may also survive longer in the micro-environment between sediment grains than in the water, thus increasing the risk of infection (Queensland Department of Environment and Heritage, 1991).

Contaminants in sediments

A large number of contaminants stick to fine sediments. Those bound to surface sediments can be taken up by sediment-dwelling organisms, such as detritus-feeding worms and transferred further along the food chain by predators. Contaminants can also accumulate and be released later when the sediments are disturbed or the local water chemistry changes.

Contaminants originate from many diffuse sources, but most of the problems with sediments remain localised and near the source, such as a stormwater, industrial or sewage discharge. In Australia, potential problems affect up to a dozen major cities located on the coastal fringe. These include the State capitals, a number of other highly industrialised cities — for example, Wollongong and Newcastle — and places near mining or mineral-processing industries, such as Macquarie Harbour, Tasmania.

Heavy metals are of particular concern. On entering the sea they attach to suspended particles and ultimately accumulate in bottom sediments, where they are not lost but may become diluted or covered by newly settling sediments that are less contaminated. Those contaminants that do degrade often exhibit very different behaviour in sediments from that in the water. For example, tributyl tin has a half-life of only a few days in water, but its half-life in sediment has been estimated at about three and a half years. Although some sources of heavy metals have been reduced, concern remains about the high levels in some sediments and the long-term effects of moderate but sustained levels accumulating in the food chain through fish, molluscs, algae and seagrass (Batley, 1995).

During dredging of ports and estuaries the problem is exacerbated. Large volumes of sediment are disturbed and often dumped at sea with the potential to release large amounts of contaminants, including sulfides and organics that naturally occur in anaerobic (deoxygenated) sediments. Although there are no existing standards for heavy metal levels in dredged sediments in Australia, an ANZECC Task Force is currently developing guidelines for heavy metals in dredged spoil.

Table 8.17 Heavy metals in sediments of selected estuaries in south-eastern Australia

Place	Levels in micrograms per gram (µg/g) dryweight Copper	Lead	Cadmium	Zinc
Corio bay offshore	2-50	2-210	0.1-13	4-400
Corio Bay mid	4-35	14-100	0.2-9	14-166
Port Phillip offshore	8	22	2	40
Port Phillip near shore	1.5	8	0.8	21
Port Phillip Werribee	<5-75	<20-140	<5	9-300
Lake Munmorah*	70	40	-	150
Tuggerah Lake*	20	40	-	110
Lake Macquarie north*	170	1200	160	2400
Lake Macquarie south*	20	68	4	150
Blackwattle Bay, Sydney#	180	520	3	1150
Quilbray Bay, Botany Bay#	3	10	0.5	25
Port Kembla Harbour#	113	113	2	380
Port Adelaide River#[a]	8 - 38	14 - 38	< 0.5	8 - 118
Sydney (100m water depth)	14	15	-	60

Notes: * 5 cm depth; #10 cm depth; [a] Kinhill unpublished data

Source: after Zann, 1995.

Other contaminants that associate with sediments include hydrocarbons and organochlorine compounds. Hydrocarbons have a strong affinity with sediments; but, while most only exist for a matter of days before being broken down, some persist for a long time. Problems with hydrocarbons usually occur around large or persistent discharges. Organochlorine compounds are of particular concern in marine and estuarine environments because of their toxicity, persistence, ability to accumulate in organisms and concentration via the food chain.

Between 1981 and 1992, different authorities extensively studied the concentrations of organochlorine residues in Australian marine waters, sediments and biota. Most investigations examined concentrations in seafood or biota in localised areas around potential sources — mainly near major eastern seaboard cities. Only a few data exist for sediments and background levels in relatively pristine environments. A survey of organochlorine contamination in waters and sediments in Western Australia (1991 and 1992) indicated that river flushing following rainfall contributed relatively high loadings of some organochlorines and that 63 per cent of waters sampled exceeded Environment Protection Authority criteria for the maintenance and preservation of marine aquatic ecosystems (Richardson, 1995).

In Victoria, measurement of DDT and its breakdown products in sediments from Port Phillip Bay and the Yarra River showed relatively low concentrations in comparison with international data, although concentrations in Australian fur seals were at least as high as those reported in Northern Hemisphere species (Richardson, 1995).

▲

Our beaches are a major cultural icon. A quarter of the population lives within three km of the sea.

Response

Managers of the marine environment need to take account of the links both within and between aquatic ecosystems, and between aquatic and terrestrial ecosystems. Many marine organisms are highly mobile at certain stages of their life cycles, with water currents carrying larvae over long distances. This dispersal stage may be a critical process in maintaining many species. Hence, the concepts of resource management and conservation developed for terrestrial systems are not likely to be directly transferable to marine systems (Kenchington, 1993; Jones and Kaly, 1995).

Estuaries, connecting the land to the sea, add another dimension. Actions and events on land can have far-reaching consequences for the marine environment. Nutrients and pollutants move from the land or the atmosphere to the sea, and the life cycles of some species, such as turtles, involve movement between the sea and estuaries or between the land and sea.

Strategies used to manage the marine environment in Australia

- Controlling disposal of wastes and emissions entering catchments, estuaries and the sea
- Prohibiting or regulating destructive and unsustainable activities
- Protecting important marine and estuarine areas
- Zoning for particular activities, to separate and control incompatible uses
- Requiring environmental impact studies to assess and minimise effects of developments
- Monitoring to assess the effectiveness of management policies
- Protecting particularly vulnerable species or groups of species
- Providing positive and negative economic inducements to encourage sustainable resource use
- Regulating fisheries to conserve the resource
- Undertaking education to promote greater awareness of environmental issues and responsibility
- Establishing industry codes of practice
- Maintaining community action programs
- Undertaking research to provide the essential data on which better environmental management can be achieved

Coastal management

Broadly speaking, the States and Territories have jurisdiction over marine areas to three nautical miles from the coast, and the Commonwealth has jurisdiction beyond those waters to 200 nautical miles. The Offshore Constitutional Settlement (OCS), which established jurisdictions between the Commonwealth and States over marine areas, allows for the application of Commonwealth or State legislation to be varied where there is agreement. Most marine fisheries are now managed under an OCS arrangement. Oil and gas, other seabed minerals, the Great Barrier Reef Marine Park, other marine parks, historic shipwrecks, shipping and marine pollution are managed under 'agreed arrangements'.

Marine environmental conservation in Australia involves a large number of different management strategies and international, regional, Commonwealth, State, Territory and local government agreements, arrangements and agencies (Zann, 1995).

Long-term strategic planning includes the National Strategy for Ecologically Sustainable Development (see Chapters 1, 2 and 10). The strategy seeks to bring together government, industry, unions, environment and community groups and experts in various fields to address 'sectoral' issues, which include fisheries, tourism and transport.

No country can manage its marine environment and resources in isolation from other countries in its region, or from activities on the high seas. International shipping operates under international law, with the rights of innocent passage strongly defended by maritime nations. Numerous international treaties, conventions and agreements are relevant to the coastal zone. Many of these deal with general global issues such as climate change, biological diversity and world heritage.

The United Nations Convention on the Law of the Sea allows nations to claim territorial seas (which extend 12 nautical miles from the coastal baseline), a 200-nautical-mile exclusive economic zone (EEZ) and a legal continental shelf. Australia proclaimed its EEZ on 1 August 1994.

Australia's three tiers of government (local, State and Commonwealth) are all involved in managing the coastal and marine environments. Government inquiries have identified the fragmented and often overlapping responsibilities in the coastal zone as impediments to effective planning and management (Kenchington, 1994; Zann, 1995). The draft Commonwealth Coastal Policy (Commonwealth Department of the Environment, 1992) lists 73 Commonwealth programs, 14 strategies, 49 pieces of Commonwealth legislation and 25 treaties pertaining to the management of the coastal zone. The situation within State/Territory administrations is also complex.

At the local level, the complex administrative procedures involved in managing the many aspects of marine and estuarine environments — from catchment management to policing of recreational fishing — make coordination cumbersome and ineffective. A review of government interests in Jervis Bay, New South Wales, showed that at least 22 Acts of Commonwealth parliament and 29 Acts of State parliament applied directly to the management of the Bay's resources (Environmental Management Services, 1991). Although few places are as complex as Jervis Bay, which combines Commonwealth, State and indigenous ownership of lands and waters, nowhere are the three tiers of government completely coordinated to effectively manage marine and estuarine habitats.

Catchments

Catchment management programs to reduce land degradation are in place throughout Australia. Generally these projects do not have specific marine and estuarine goals, but they have the potential to provide considerable benefits. Communities are becoming increasingly aware of the links between land use and the marine and estuarine environments. For example, this chapter has stressed nutrients as a major issue in estuaries and coastal waters. With the exception of point outfalls of sewage, the source of those nutrients is run-off from catchments (See Chapter 7).

Coastal margins

The Resource Assessment Commission (RAC) Inquiry of 1993 into the coastal zone concluded that coordination and integration between institutions responsible for managing the coast was inadequate. Environmental impact assessments and monitoring programs for coastal margin developments usually concentrate on specific areas of concern and do not help comprehensive regional planning, which crosses the boundary between land and sea.

Although almost 60 government reports and inquiries have been undertaken on Australia's coastal zone since 1960, the RAC Inquiry identified the need for an integrated national approach involving local, State and Commonwealth governments to address the problems of Australia's coastal zone. Major findings of the Inquiry were: no single sphere of government can manage the zone alone; issues of national significance and great public concern are involved; the socio-economic development of the coastal zone is of profound importance to the nation; and Australia has international obligations in the zone that necessitate coordination between the spheres of government.

The Inquiry's report contained many recommendations on the management of Australia's coastal zone, the major one being that the Council of Australian Governments should adopt a national Coastal Action Program to manage the resources of the zone. It recommended that the three spheres of government, in consultation with community and industry groups with responsibility for and interests in coastal zone management, implement the plan.

In May 1995, the Commonwealth government announced a coastal policy, 'Living on the Coast', in response to the RAC recommendations.

Aims of the National Coastal Action Program*

- Reduce degradation caused by urban sprawl and activities in urban and remote locations in the coastal zone
- Provide better facilities for recreation in the coastal zone
- Provide better management and preservation of natural processes in coastal areas
- Achieve more effective and rational use of land in the zone for building, development, tourism and other uses
- Improve recognition by the community of the value of the resources of the zone
- Improve recognition of indigenous peoples' interests in management of the zone
- Improve water quality in streams, estuaries and coastal seas
- Improve management of fisheries through more effective management of sea-based resources of the zone

**Proposed by Resource Assessment Commission*

Source: Kenchington, 1994.

The policy included funding for the Coastal Action Program, focusing on increasing support for community and local government participation in coastal management, increasing the capacity and knowledge of coastal managers and developing integrated solutions to problems such as urban sprawl and coastal pollution. Other initiatives in coastal zone management include the Queensland government's Coastal Protection and Management Bill, which aims to integrate all management and planning activities in the coastal zone, and a Western Australian report reviewing coastal management, which was released in May 1995.

The Great Barrier Reef is already managed in an integrated way by the Great Barrier Reef Marine Park Authority (see page 8-44). The cost of this increases as pressure from activities in the area, including tourism and recreation, grows. Annual expenditure by the environmental impact management section of the Authority increased from $829 960 in 1988–89 to $2 524 318 in 1993–94.

Public education and environmental awareness of the condition of and pressures on coastal margins are important parts of any response process. Throughout the country, community groups have initiated a number of programs to protect and clean beaches and the marine and coastal environment. One such national program is the Marine and Coastal Community Network, which forms the community component of the Ocean Rescue 2000 program (see page 8-46). The role of this program is to provide a community information network.

Plants and animals

Conservation

Biological conservation and management are largely directed at particular species, areas or sectors — for example, endangered species, marine park areas and commercial fisheries.

Much of the effort in conserving terrestrial biodiversity is based on protecting rare and

Great Barrier Reef Marine Park

The Great Barrier Reef — the largest system of coral reefs in the world — is about 2500 km in length and comprises 2900 separate reefs and 940 islands. Its high species diversity includes more than 400 species of coral, 4000 species of molluscs, 1500 species of fish, six species of turtles, 35 species of seabirds and 23 species of sea mammals.

Internationally recognised as one of the world's best tourist attractions, the region is Australia's premier marine tourism destination. The combined value of tourism and fishing on the Great Barrier Reef is estimated to be around one billion dollars per year.

Pressure

The main pressures on the Reef include: declining water quality in inshore areas — due mainly to elevated sediments and nutrients from changes of land use in coastal catchments: fishing (particularly trawling of the sea floor and overfishing of reef species); coral mortality caused by outbreaks of the crown-of-thorns starfish (the causes of which still remain unknown); storm events; the threat of oil and chemical spills and ballast water introduced from shipping; and the effects of tourism.

About two million people visit the Reef and its adjacent coast annually and the number of visitors is increasing by 10 per cent each year (30 per cent in the Cairns area).

State

The Great Barrier Reef is one of the least-disturbed coral reef systems in the world and much of it is still in a relatively good condition.

Evidence is growing of coral mortality on the tops of some inshore reefs but the evidence is patchy and not consistent on all reef tops for which we have historical photos. Possible causes include cyclones and increased sediments and nutrients.

Recent evidence also suggests that the Capricorn Bunker sector of the Great Barrier Reef is showing signs of degradation: hard coral and fish appear to be reduced in this sector compared with other parts of the Reef (Oliver *et al.*, 1995). The causes of this are unknown, but do not appear to be related to the crown-of-thorns starfish or to cyclones.

Over the past 30 years the crown-of-thorns starfish has damaged nearly 20 per cent of reefs, largely in the central one-third of the Reef. Damage in affected areas ranges from slight to very severe. The causes of the outbreaks are still unknown.

Response

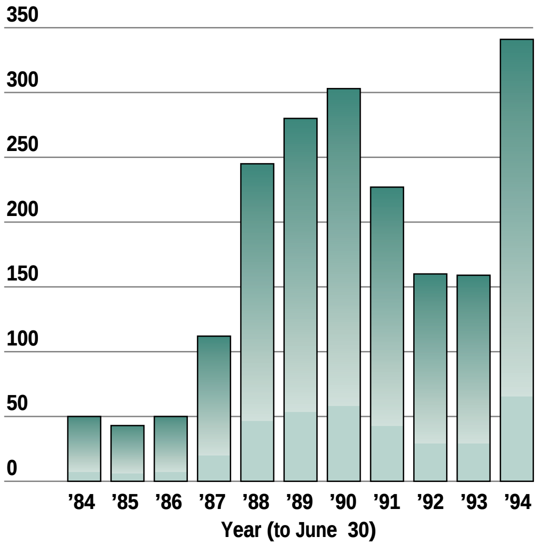
The Great Barrier Reef was inscribed on the World Heritage List in 1981 and is protected under the Great Barrier Reef Marine Park Act. The Marine Park, a multiple-use, protected area of 344 000 sq km, is the world's largest marine protected area. It is managed by the Great Barrier Reef Marine Park Authority, with the Queensland Department of the Environment responsible for day-to-day management. Oil drilling and mining are prohibited in the Marine Park.

The establishment of the Great Barrier Reef Marine Park Authority coincided with a significant period of expansion in tourism, particularly around Cairns. As a result, development and access for visitors has been well planned and regulated within the context of a marine protected area (see Fig. 8.26). Use of the Great Barrier Reef is regulated primarily under a zone-based planning scheme intended to achieve sustainable use of coastal and marine resources. However, better coordination and strategic planning are necessary to maintain environmental protection, particularly in relation to pressures by coastal development, and increasing resident populations and tourist numbers. State and local government bodies and industry need to be involved to achieve this broad management goal.

While the agency approach has worked well on a case-by-case basis and has proved effective even in extremely complex projects — such as the now-defunct floating hotel — it has sometimes proved difficult at a local level. For example, the development of strategic management plans for the Whitsunday and Cairns subregions has highlighted the problems of coordinated management and demonstrated the need for cooperative planning of regional tourism. These cases also reveal the complexity of issues that must be addressed if tourism is to be a sustainable industry in sensitive areas such as the Great Barrier Reef.

The Authority recently coordinated the development of a 25-year strategic plan, involving over 70 user groups, for the Great Barrier Reef World Heritage Area. Variables such as coral cover, crown-of-thorns starfish, dugongs, turtles and nutrients are monitored in parts of the Great Barrier Reef, and the Authority is now developing indicators and a monitoring program for the Area. In 1996 it will publish a report on the state of the Great Barrier Reef World Heritage Area.

Figure 8.26 Number of tourism permits issued for the Great Barrier Reef Marine Park



Source: Great Barrier Reef Marine Park Authority annual reports.

endangered species. However, the endangered species concept is applicable only to a few kinds of marine animals with certain characteristics, such as those with unusually restricted breeding sites, or species that are highly susceptible to environmental stress (Jones and Kaly, 1995).

Many marine species remain undescribed, and relatively little is known about most of the described ones. Among other things, this adds to the problem of determining whether a species is introduced or a natural inhabitant of any area. An enormous taxonomic and monitoring effort would be required to describe all the marine species in Australia and determine their status.

Given this lack of knowledge, precautionary management strategies are important to conserve marine biodiversity. These strategies include: establishing protected areas for endemic species with small geographic ranges or restricted breeding sites; protecting long-lived, large and wide-ranging species; enhancing populations of excessively exploited species; and establishing protected areas containing representative samples of common habitats.

Some conservation measures apply to specific species while others, like marine protected areas, cover a range of species. An example of a species-specific measure is the listing of the leatherback, green, hawksbill and olive ridley turtles as 'vulnerable' and the loggerhead as 'endangered', under the *Endangered Species Protection Act 1992*, and the flatback as 'potentially vulnerable' by the IUCN. Because some species are highly migratory, a regional and international approach to the management of turtles is important (Zann, 1995).

The establishment of marine protected areas (MPAs) is an important mechanism for conserving and managing a range of marine species and their habitats. An MPA can be any area of intertidal or subtidal terrain — together with its overlying water and associated flora, fauna, historical and cultural features — that has been reserved by law, or other effective means, to protect part or all of the enclosed environment. These areas may serve many functions, such as conservation of endemic fauna and flora, protection of commercial fisheries resources, protecton of human heritage and provision of opportunities for tourism, recreation, education and research.

Australia is a world leader in using this mechanism for marine conservation and management and has 24 per cent of the total number of MPAs in the world. In 1992, Australia, including its External Territories, had 303 of them covering 463 200 sq km. However, 74 per cent of this area is within a single multiple-use MPA — the Great Barrier Reef Marine Park — which is zoned for multiple uses ranging from preservation to general use. Although the number of Australia's MPAs has increased by almost 60 per cent in the past decade, some are very small and large sections of our marine environment have few or no protected areas. Nearly all (92.7 per cent) of the MPAs in Australia are for multiple-use. Only a small number are dedicated to sanctuaries and preservation (Bleakley *et al.*, 1994).

Many of the MPAs are on the east coast, especially along the Queensland coast. The area protected in the tropics is more than 10 times greater than that in the south. However, more MPAs lie south of the tropics than in the north (175 as opposed to 98). Most of those in the southern and eastern half of the continent are small, even though this is where human activity is greatest and the demand for conservation action is highest. The largest ones tend to be away from the areas of highest human activity (Zann, 1995).

Some MPAs are in the estuaries. Of these, 62 per cent are subject to some form of administrative classification that restricts their uses and 28 per cent have some form of conservation designation, such as marine park, national park, game reserve, flora/fauna reserve or fisheries sanctuary

Table 8.18 Marine Protected Areas (MPAs) by bioregion, excluding external territories and oceanic regions

Region	No of MPAs	Area of MPAs (sq km)	Area of bioregion protected (%)
North Coast	9	3 056	0.55
North West Coast	0	0	0
Central West Coast	4	11 047	22.96
Lower West Coast	4	163	0.26
South West Coast	6	< 2	< 0.01
Great Aust. Bight	2	< 3	< 0.01
South Gulfs Coast	24	361	0.39
Bass Strait	38	572	0.38
Tasmanian Coast	17	555	1.82
Lower East Coast	18	49	0.23
Central East Coast	32	7 500	26.46
North East Coast	95	110 185	97.22
Great Barrier Reef	6	183 280	100.00
Gulf of Carpentaria	6	4 569	1.11
Overall	**261**	**321 347**	**15.00**

Source: Bleakley *et al.*, in press.

Overfishing of southern bluefin tuna during the 1970s and '80s has severely depleted stocks.

(Zann, 1995). The protection varies in name and intent between States and rarely encompasses an entire estuary. Controls are carried out by a range of different administrative bodies within each State. Generally, the protection reflects local interests and does not constitute a national system of estuarine reserves. The level of surveillance and enforcement is likewise highly variable (Zann, 1995) (see Table 8.18).

The Ocean Rescue 2000 program, which the Commonwealth initiated in 1991, aims to establish a national network of MPAs around Australia. The program is an important national response to promote the conservation and sustainable use of Australia's marine and coastal environment. It builds on existing marine conservation and management programs and is part of the National Strategy for Ecologically Sustainable Development.

Other aims of the program are to: develop and implement a marine conservation plan to guide the use and management of Australia's marine resources; ensure adequate baseline and monitoring information on the marine environment, activities and management and ensure its accessibility to decision-makers and managers; and foster an educated, informed and involved community.

The program comprises six elements: the national representative system of Marine Protected Areas; the Australian marine conservation plan; the State of the Marine Environment Report (SOMER); the national marine education program; the national marine information system; and the marine and coastal community network. The Commonwealth is working with the States and Territories in relation to the national representative network of MPAs.

As well as Ocean Rescue 2000, other responses of a broad nature include the formation in 1995 of the Australian Marine Industries and Sciences Council and the publication by the Australian Committee for IUCN (World Conservation Union) of 'Towards a strategy for the conservation of Australia's marine environment' in 1994. A national fisheries policy is being prepared and an oceans management policy is being discussed within government.

Fisheries management

Australia has responsibility under the United Nations Convention on the Law of the Sea for fisheries management within its Exclusive Economic Zone (EEZ). This responsibility is shared between the Commonwealth and the States, depending on the individual fishery, through a cooperative arrangement developed under an offshore constitutional settlement.

In recent years all of the States and the Commonwealth either have introduced or are introducing new Fisheries Acts to manage resources effectively in the face of increasing fishing pressure. While the precise wording of the Acts may vary, they are all directed towards sound resource management, within the principles of ecologically sustainable development and economic efficiency. An example of the aims can be found in the Commonwealth *Fisheries Management Act 1991*.

Liaison between fisheries management and the fishing industry has been strengthened throughout Australia by the development of management advisory committees, which comprise managers, scientists, industry members and in some cases representatives from the recreational sector.

Functions of the advisory committees include helping to develop management plans for each fishery. Once a plan is proposed, interested parties can comment on it. Community groups, including conservation and indigenous groups, are using this avenue for submissions, which government then takes into account. In the Torres Strait Islands, the community is represented on the Torres Strait Fisheries Management Committee.

The advisory committees try to gain a sound understanding of the status of the stocks being fished, and the effect of fishing on the resource, on non-target species and on the ecosystem generally.

One of their priorities is to produce assessment reports for each fishery. Where data are available, this has included a comparison of the status of the breeding stock now compared with the level when fishing was very light. Where breeding stocks have been reduced to levels likely to affect recruitment, management action is taken to redress the problem. This has led to a more detailed consideration of the management strategies required to ensure that the allowable catch is at a level appropriate to the stock status.

Some of the fisheries, such as the South East Fishery, now have total allowable catches, while for others action has been taken to control the effective fishing effort by a combination of a reduction in boats, fishing gear and the number of days fishing (see page 8-47).

As well as management responses to the state of the various fisheries, community groups often express their concern through petitions to the federal Minister for the Environment. For example:

- In 1993 an unsuccessful bid was made to have southern bluefin tuna and orange roughy listed in the Appendices to the Convention on International Trade on Endangered species of Wild Fauna and Flora (CITES).

Managing the fishing resource

Australia is responsible for managing the living resources in its Exclusive Economic Zone, as required by the United Nations Convention on the Law of the Sea (UNCLOS).

All our major fisheries are managed under either Commonwealth or State legislation. Highly migratory species are managed under multilateral arrangements with other countries. An underlying objective of fisheries management is to conserve the limited resources to ensure their long-term sustainability.

The following management goal is taken from the Commonwealth *Fisheries Management Act 1991*:

'...ensuring that the exploitation of fisheries resources and the carrying out of any related activities are conducted in a manner consistent with the principles of ecologically sustainable development, in particular the need to have regard to the impact of fishing activities on non-target species and the marine environment.'

Four examples illustrate responses to a number of fishing pressures. In each case — except for the tropical rock lobster — the pressure on fish stocks has been caused by a rapid increase in fishing during the 1970s and '80s coupled, in some cases, with unfavourable environmental conditions.

Each year a scientific assessment is made of stocks of the four fisheries: southern bluefin tuna, gemfish, tropical rock lobster and barramundi. In the case of southern bluefin tuna, this involves a multilateral effort with Japan and New Zealand. The status of the other species is based on long-term data including information on the size (and age) of fish. In Torres Strait, divers annually survey the tropical lobster stock.

Southern bluefin tuna were overfished throughout the 1960s, '70s and '80s. While numbers remain dangerously depleted, the latest assessment indicates an end to the long-term decline, but the degree to which the stock will recover is uncertain.

Gemfish were overfished in the 1980s and the recruitment of young fish into the fishery declined alarmingly.

Tropical rock lobsters in the Torres Strait are assessed as underfished. However, local areas may be depleted and the catch rate in some heavily-fished areas has declined.

Barramundi monitoring in 1978 revealed that Northern Territory stocks had been reduced to such a low level that recruitment failure was likely. Recruitment of barramundi is highly variable and appears to be strongly influenced by the amount of rain in the early wet season. These environmental effects are now being incorporated into assessments.

Responses

Controls on fishing activity, through fisheries management, constitute the main response.

Southern bluefin tuna — a range of management strategies were introduced during the 1970s, including voluntary seasonal closures in areas off New South Wales and a freeze on further entry of purse seiners and additional pole-fishing vessels around Australia. However, these measures did not contain the fishing effort. In 1979, following the creation of the 200-mile Australian Fishing Zone, arrangements were made for the Japanese to continue fishing in these waters. In 1983, the Australian catch was limited to 21 000 tonnes with a limit imposed on fish size. However, it was not until 1986–87 that Japan limited its catch to 23 150 tonnes. In subsequent years, the catch limit was reduced and has remained stable at 11 750 tonnes (combined Australia, Japan and New Zealand) since 1989–90. The cooperative approach between the countries has been formalised by the establishment of the Convention for the Conservation of Southern Bluefin Tuna.

Eastern gemfish — a management plan was introduced in 1988 to address the problems of declining catch rates and a shift in the population to smaller fish. It set a total allowable catch (TAC) of 3000 tonnes for the winter fishery. This figure was lowered to 1750 tonnes in 1990, 500 tonnes in 1991, and 200 tonnes in 1992 and set at zero in 1993 and 1994 (trip limits allowed fishers to take gemfish as a bycatch). To return stocks to a sustainable level requires protection of both the spawning stock and new recruits. This is obviously difficult where gemfish are also caught as an incidental catch to other species.

Tropical rock lobster — within the Torres Strait Protected Zone, a joint authority involving Queensland and the Commonwealth manages the fishery, with the goal of protecting the traditional way of life and livelihood of the Islanders by encouraging their participation and restricting that of non-Islanders. The catch is shared each year between Australia and Papua New Guinea.

Barramundi — the resource is managed under State and Territory legislation with the aim of providing a balance between commercial and recreational fishers. In the Northern Territory, it is managed under the *Northern Territory Fisheries Act 1988* and the Barramundi fishery management plan 1991. Aborigines who have traditionally used the resource of an area can continue to do so. Commercial fishing has been drastically reduced with the help of a scheme where fishers are charged a levy to compensate those leaving the fishery. For recreational fishers, the time allowed for fishing is controlled and bag limits have been set.

In Queensland, a management plan covering two sub-fisheries imposes closed seasons, size limits, limited licensing, gear restrictions, closures to fishing in some areas, environment habitat protection and compulsory commercial-catch data collection. Education programs also increase public awareness of the issue.

Adequacy of the response

For the three overfished species, responses have successfully reduced fishing effort. For barramundi, allocation of the resource is now possible between commercial and recreational fishers. For southern bluefin tuna and gemfish, time will tell whether reductions in fishing were sufficient and soon enough to allow stocks to rebuild. Because of the large amounts of capital invested in these fisheries, considerable time elapsed between the degraded state of the stock being recognised by scientists and adequate responses being implemented. This applies particularly to the southern bluefin tuna fishery, where a number of countries are involved. Through its membership of the management advisory committees and the Fisheries Management Authority, industry is becoming increasingly involved in decision making for fisheries management.

Source: D. Staples, Bureau of Resource Sciences, Canberra.

- The incidental catch (bycatch) of seabirds during oceanic longline fishing operations has been listed under the Commonwealth *Endangered Species Protection Act 1992* as a 'key threatening process'. The seabirds include the wandering albatross.
- The Minister is considering a request under the same Act to have prawn and scallop trawling listed as a 'key threatening process' to turtles and two species of fish.
- Community groups have also been responsible for having the wandering albatross listed under the Act as an endangered species.
- Requests to have gemfish listed under the Act as an endangered species and southern bluefin tuna listed as a vulnerable species were unsuccessful. A further request to have eastern gemfish listed as a vulnerable species is still being considered.

Long mesh-nets (drift nets) have been banned in waters controlled by Australia because of their harmful effect on non-target species such as birds and marine mammals.

A fisheries response of a different kind is the action necessary to protect the fisheries resources within the Australian Fishing Zone from illegal fishing by operators from other nations. This response has particular significance for the waters off the northern part of Australia.

Exotic species

Governments and industry have taken a number of steps to prevent the introduction of exotic species. These include increased research, voluntary controls on shipping and promotion of international action through the International Maritime Organisation.

Two of the strategies are: to encourage ships to exchange ballast water in the ocean or flush it en route; and to set up quarantine inspection of ballast water prior to discharge. Ocean exchange is the most practical method but it is limited to smaller vessels because of safety (stability) considerations. The quarantine inspection of ballast water is limited by delays in identifying organisms (Zann, 1995). Some research has been conducted into possible treatment of ballast waters during loading and discharge (AQIS, 1993), but effective methods are costly and not easily implemented.

The Australian Quarantine and Inspection Service (AQIS) has extensively studied the issue of introducing exotic species in ballast water and possible management strategies. The International Maritime Organisation has adopted AQIS's voluntary guidelines, and Australian guidelines are now being formulated. Port and quarantine authorities have the power to prohibit discharge of ballast water when they know or suspect that a ship's ballast tanks contain potentially harmful organisms. Scientists at CSIRO's recently established Centre for Research on Introduced Marine Pests (CRIMP) are investigating various options to reduce and manage marine pests. The recently formed Australian Ballast Water Management Council will coordinate these activities and implement principles to ensure adequate quarantine and to reduce the risk of the accidental displacement of species. Some States already have legislation to control translocation of aquaculture stocks.

Seafood quality

The usual management response to environmental contamination of seafood has been to establish agencies at Commonwealth and State level to directly monitor quality in food, including seafood, and to set safety standards for contaminants.

In 1991, the National Food Authority was established as an independent expert body to make recommendations on the development, variation and review of food standards. Commonwealth, State and Territory governments have agreed that the States and Territories would adopt, without variation, food standards recommended by that Authority and adopted by the National Food Standards Council as prescribed in the Australian Food Standards Code.

Water quality and sediments

Managers of marine and estuarine water quality need to consider all the significant diffuse and point sources of contaminants that affect it. Point sources, such as sewage outfalls, are relatively easy to identify, quantify and manage, whereas diffuse sources such as an urban catchment, are much more difficult to characterise and control. Controlling diffuse inputs of pollutants often means managing sources in areas very distant from the affected marine and estuarine environments but linked to them through the water flow.

Nutrients

Management of nutrient loading to coastal environments and of any subsequent problems of eutrophication, is based on reducing the flow of land-based effluents or better-dispersing existing discharges. Responses aimed at reducing the impacts of nutrients on marine waters include: controlling soil erosion; changing the use or nature of fertilisers; re-using instead of discharging nutrient-rich effluent; diverting discharges into less-sensitive or better-flushed environments; building engineering works to improve flushing; and removing nutrients from effluent. In some places people have tried to rehabilitate existing eutrophic systems by replanting seagrasses or removing nutrient-rich sediments.

The introduction of slow-release fertilisers and improved application regimes is expected to have a major impact on the amount of phosphorus leached from catchments like the Peel–Harvey. Controls over water movement, tree-planting and creation of small wetlands on drainage lines are also being used to slow the movement of drainage water to some estuaries.

In recent years authorities have commonly responded to sewage problems by relocating sewage outfalls into waters with better dilution and dispersion characteristics. While this may be effective in the short term, the full implications for offshore environments are not fully understood and tertiary treatment of sewage to reduce nutrients is preferable in the long term.

Pollution at sea/navigation safety

The Australian Maritime Safety Authority (AMSA) has the national responsibility for marine oil spills. As it is not possible to control a major spill effectively, the primary aim of management is to prevent spills through safe operations and navigation of ships. For example, since the MARPOL Convention took effect, discharges from ships have been reduced by about 60 per cent worldwide. Also, navigation technology has greatly improved, which has helped to reduce the risk of accidents, and oil tankers built after 1993 have double hulls or equivalent construction to reduce the likelihood of oil spillage in the event of accidents such as groundings or collisions (Zann, 1995).

Australia has developed oil-spill-response plans as part of the National Plan to Combat Pollution of the Sea by Oil, which is managed by AMSA and funded by a levy on the shipping industry. The National Plan is a collaborative arrangement between AMSA, the States and Northern Territory governments, the shipping, oil and exploration industries and also includes the Australian Marine Oil Spill Centre, at Corio Quay, Victoria. The Centre was established by the oil industry to assist in responding to major oil spills around the Australian coast and in adjacent areas where Australian-based companies operate (Swan *et al*., 1994).

Pollution-response equipment is stockpiled at strategic ports and oil terminals, with a response capability for an oil spill of up to 10 000 tonnes (Swan *et al*., 1994). While fully laden tankers typically carry 60 000 tonnes of oil, most collisions result in only one or two of their internal tanks being ruptured so they spill much less than their fully laden capacity. Usually the oil is lost progressively rather than instantaneously. For example, the *Kirki* spill happened over two weeks.

If a spill larger than 10 000 tonnes occurs, Australia may need to seek international assistance through arrangements under the international Oil Pollution Response and Cooperation Convention. Australia has concluded a memorandum of understanding with New Zealand under this Convention, which will provide assistance in cases of pollution incidents in either country. Similar agreements are currently being negotiated with Papua New Guinea and Indonesia.

Australia has been a leader in regulating international navigation to protect the marine environment. In 1990 the Great Barrier Reef was the first area in the world designated as a ‘Particularly Sensitive Area’ by the International Maritime Organisation. All ships more than 70 m in length, or carrying oil, chemical or liquefied gas cargoes, must now carry Australian-licensed pilots when using the designated routes within the Great Barrier Reef Marine Park (Zann, 1995). Australia and Papua New Guinea are cooperating to develop and provide specific preventive and response measures to protect the Torres Strait area from oil spills from tankers and other sources. Improved navigational aids and charting and management of ship passages through the Torres Strait and the Great Barrier Reef are being developed.

Overview

Australian marine and estuarine environments and habitats are generally in good condition to the extent that this can be measured. However, only a few can be regarded as pristine, because of wide-ranging pressures such as nutrient loading, pollution with persistent chemicals and fishing, which have some effect on nearly all parts of our marine and estuarine systems. Near many of our cities and in other localised inshore areas, the condition of some habitats is poor. Of particular concern are the coral reefs of the north-east coast and the temperate seagrass beds of southern Australia. Other signs of deterioration include the increasing incidence of algal blooms, recognition of an increased number of introduced species, continuing loss of coastal habitats such as mangroves and saltmarshes and intense pollution of some estuaries and other near-shore areas.

Poor water quality, caused mainly by high nutrient and sediment loads, is a feature of many Australian estuaries. Together with urban and other coastal development and intensive fishing activities, these exert the major pressures on Australia’s marine and estuarine systems. However, for many systems, particularly those offshore or distant from population centres, we do not have enough information to make even a first estimate of their state of health. We believe remote areas are in good health because they face few pressures, but the data to confirm this are scarce.

Governments, industry and the community have recognised the lack of coordination and effective integration of the many levels of government and private-sector interests in management of coastal and marine activities, to the detriment of these ecosystems. In the government sector, many reviews and inquiries have investigated the weaknesses in the coordination of coastal and marine management practices. In the private sector, increased environmental awareness of companies and industry-wide codes of practice are improving approaches to environmental management, both to reduce the inputs of pollutants to waterways and to minimise the unintended consequences of resource utilisation.

At present we lack any integrated framework for management of our marine and coastal systems based on a set of ecosystem-based goals and environmental performance indicators, although steps towards such a system are being taken under the national ESD strategy. Likewise, there is no agreed and common understanding of the ecosystems, their status and the issues affecting them. The development of indicators is essential to this process.

Table 8.19 Summary

Element of the environment/ Pressure	State	Adequate Info.	Response	Effectiveness of response
saltmarshes habitat destruction and degradation	extensive loss near urban centres	✓✓	protected areas, development controls, community awareness	limited – loss and degradation continues in many areas
microalgae algal blooms associated with nutrient enrichment of coastal waters	increasing frequency, magnitude and extent of algal blooms in estuaries, lagoons and bays	✓✓	improved waste disposal treatment and technology: various catchment management initiatives; research on causes	ineffective at present – limited application of technologies
macroalgae blooms due to nutrient enrichment	blooms reported as common; extent and frequency appears to be increasing	✓✓	improved waste disposal treatment and technology: engineering works; changes in land use practice	ineffective at present – limited application of technologies
seagrasses loss of temperate seagrass due to nutrients, sediments, habitat destruction	area diminishing in the south	✓✓✓	protected areas; catchment management; research; protection from trawling and coastal development; improved sewage treatments	inadequate response measure; inadequate at present; inadequate; effective; partially effective;
beaches and dunes habitat destruction from coastal development and mining	generally good, except around human settlements, some areas modified by mining	✓✓✓	zoning; protected areas; impact assessment; rehabilitation	improving but ineffective in addressing cumulative impact
estuaries degradation by pollution, habitat destruction, intensive recreation, introduced pests	most are degraded, particularly south-east	✓✓	pollution controls; catchment management; impact assessment; protected areas; harvesting controls	effective; ineffective at present; limited effectiveness; limited effectiveness; limited effectiveness
gulfs and bays loss of seagrass, algal blooms caused by nutrients, fishing pressures, introduced pests	many degraded especially those near urban centres	✓✓	catchment management; impact assessment; protected areas; pollution controls; fishing controls; management plans	not adequate to cope with existing pressures
continental shelf and slope fishing, oil and gas exploration and production	fisheries fully developed with some over-fishing; habitat conditions unknown	✓	fishing controls, impact assessment; industry codes of practice	partially effective limited effectiveness limited effectiveness
mangroves habitat destruction and degradation	extensively cleared near coastal centres	✓✓✓✓	protection of species; protected areas; development controls; community awareness	mostly effective and improving – rate of decline reduced
coral reefs fishing pressures, recreation and tourism, nutrient enrichment, sedimentation	signs of degradation	✓✓✓	integrated planning and management; protected areas; impact assessment; controls on activities	partially effective – pressures exceeding current response measures
fish and fisheries fishing pressure, both commercial and recreational, impact on habitat and non-target species	most stocks fully exploited; several over-exploited; few under-exploited	✓✓✓✓	fisheries management and planning within the ESD context; research;	partially effective and improving
reptiles previous hunting of crocodiles; threats to turtle population	crocodile populations rebuilding; status of turtle population unknown, susceptible to over-harvesting and disturbance	✓✓✓	national and international protection; croc farming 5 species listed as endangered or vulnerable	effective suspected ineffective because of international nature of issue
seabirds 14 species/subspecies are threatened	populations of most species appear satisfactory	✓✓✓	3 species/subspecies listed as endangered under IUCN; changes in fishing methods;	more information needed
mammals past exploitation of whales and seals; potential habitat destruction and accidental capture; worldwide overexploitation of dugongs	whale and seal populations seem to be recovering although some from a very low base Australian populations of dugongs appear stable	✓✓✓	prevention of hunting; preparation of action plans; increasing community interest; research;	whale and seal population recovery effective; international arrangements are needed for dugong populations

Table 8.19 Summary (continued)

Element of the environment /Pressure	State	Adequate Info.	Response	Effectiveness of response
nutrients high nutrient loads from point and diffuse sources	widespread occurrence of elevated nutrients and associated adverse biological consequences	✓✓✓	improved waste disposal treatment and technology: various catchment management initiatives; research on causes	not effective at present – limited application of technologies
species outbreaks lack of knowledge and understanding of causes, resulting in lack of clear management objectives	crown of thorns major problem in the GBR; Drupella snails a problem at Ningaloo;	✓✓✓	research; localised control of crown of thorns;	inconclusive at present; locally effective
introduced species damage caused by species introduced or translocated by shipping and aquaculture practices	increasing numbers of species documented as introduced; several species recognised as serious pests	✓✓	research; surveys; monitoring of cultured species – closures where necessary; ecological management; codes of practice for aquaculture; control of imports; quarantine and management of shipping practices; pursuit of international agreements	management of established pests ineffective; quarantine and management of shipping practices partially effective; protection of human consumers effective
seafood quality maintenance of high quality seafood; some groups at high risk because of dietary habits	generally good except for heavy metals in large long-lived animals and in seafood from areas where local pollution is high	✓✓	establishment of safe levels in food; closures where levels of contaminants are high; monitoring for export and domestic consumption; community awareness; marketing restrictions	mostly effective, under review; mostly effective; inadequate; inadequate; effective
metals detrimental effects of tributyl tin (TBT); local heavy metal contamination	levels of TBT declining rates of input declining but locally high residual levels	✓✓✓	restrictions on TBT; emission controls; impact assessment	effective but still affecting molluscs locally; control of inputs effective
suspended solids elevated concentrations in many estuaries and near shore waters; impact on reefs; impact on off-shore reefs	trends difficult to determine but thought to be increasing	✓✓	catchment management; dredging controls	ineffective
pesticides accumulation through the food chain with possible impacts on mammals and birds	levels of persistent organochlorines are low, except from some point sources	✓✓	control of use of organochlorine pesticides improved sewage and stormwater management;	usage effectively reduced, changes in residual levels unknown
pathogens threat to public health and recreational amenity	recurrent problem near urban centres	✓✓	closure of beaches when necessary	partially effective
litter impact on amenity and aesthetic appeal; entanglement of and ingestion by marine animals	all parts of the Australian marine and estuarine environment are littered, especially near population centres; impact of litter on marine animal populations unknown	✓✓✓	public awareness programs; waste management for urban areas and shipping (MARPOL)	limited but improving
sediments local pollution and effects on biodiversity and marine resources	local hot spots of contamination but otherwise sediments are thought to be in good condition	✓✓	control of point sources; development of quality criteria; management of marine dumping; catchment management	effective; effective; mostly effective; ineffective at present
marine management fragmentation of management	mess	✓✓	integration of management	ineffective because not widely applied

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