Coasts and Oceans

Prepared by:

Australian State of the Environment Committee

Theme Coodinators:

Dr Gina Newton, (until November 2000)
Jenny Boshier (from November 2000)
State of the Environment Reporting Section, Department of the Environment and Heritage

National Library Cataloguing-in-Publication Data

Coasts and oceans.

Bibliography.
Includes index.
ISBN 0 643 06751 5.

ISBN 0 643 06754 X (8 v.).
ISBN 0 643 06755 8 (7 v.).

1. Coasts – Australia. 2. Oceanography – Australia. 3. Coastal ecology – Australia. 4. Marine ecology – Australia. 5. Coastal zone management – Australia. 6. Marine organisms – Australia. 7. Environmental monitoring – Australia. I. Newton, Gina. II. Boshier, Jennifer A. III. Australia. Environment Australia. (Series : Australia state of the environment 2001).

333.9100994

The book is printed on Regent Recycled paper made in Australia.

Published by **CSIRO** PUBLISHING on behalf of the Department of the Environment and Heritage.
150 Oxford Street (PO Box 1139)
Collingwood VIC 3066
Australia

Telephone: +61 3 9662 7666
Freecall: 1800 645 051 (Australia only)
Fax: +61 3 9662 7555
Email: publishing.sales@csiro.au
Web site: www.publish.csiro.au

Front cover: Pink Lake near Meningie, South Australia © John P Baker

Australian State of the Environment Committee, 2001. *Coasts and Oceans*, Australia State of the Environment Report 2001 (Theme Report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra.

The 2001 *Coasts and Oceans* Theme Report is one of seven produced for the Australian State of the Environment Committee which form the basis of the report *Australia State of the Environment 2001*. Theme reports for the remaining themes: Biodiversity, Atmosphere, Inland Waters, Land, Natural and Cultural Heritage and Humans Settlements are available in print from **CSIRO** PUBLISHING and on the Internet at: http://www.ea.gov.au/soe/

Note: Some of the images included in this report may be more easily read in colour. In those cases, readers are referred to the full-colour PDF or web versions which are available online at: http://www.ea.gov.au/soe/

Cover and text design by James Kelly.
Typeset by Desktop Concepts P/L, Melbourne.
Printed in Australia by Brown Prior Anderson.

Contents

Abbreviations

AAT	Australian Antarctic Territory.
AEEZ	Australian Exclusive Economic Zone.
AFMA	Australian Fisheries Management Authority.
AIMS	Australian Institute of Marine Science.
ANZECC	Australian and New Zealand Environment and Conservation Council.
AOP	Australia's Oceans Policy.
CASS	Coastal acid sulfate soils.
CCAMLR	The Convention on the Conservation of Antarctic Marine Living Resources.
CITES	Convention on International Trade in Endangered Species of Wildlife Flora and Fauna.
COTS	Crown of Thorns Starfish.
CPUE	Catch per unit effort. The quantity of fish caught with one standard unit of fishing effort, e.g. the number of fish taken per 1000 hooks per day or the weight of fish in tonnes taken per hour of trawling.
CRC	Cooperative Research Centre.
CSIRO	Commonwealth Scientific and Industrial Research Organisation.
EEZ	Exclusive Economic Zone.
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999.
ESP Act	*Endangered Species Protection Act 1992* (Commonwealth).
FRDC	Fisheries Research and Development Corporation.
GBRMPA	Great Barrier Reef Marine Park Authority.
IUCN	World Conservation Union (formerly the International Union for the Conservation of Nature and Natural Resources).
IMCRA	Interim Marine and Coastal Regionalisation for Australia. A system of regions around the Australian coast based on biology and physical environment.
IWC	International Whaling Commission.
MPA	Marine Protected Area.
MPC	Maximum permitted concentrations, e.g. for metals in food.
MRL	Maximum residue limits, e.g. for organic compounds in food.
NLWRA	National Land and Water Resources Audit.
NPI	National Pollutant Inventory.
NRS	National Residue Survey, a national scheme of measuring residues of contaminants in food.
OCS	Offshore Constitutional Settlement.
PCBs	Polychlorinated biphenyls, a group chlorinated organic compounds that are long lived in the environment because they are resistant to biological degradation.
SOMER	State of the Marine Environment Report.
TAC	Total allowable catch; the total catch allowed to be taken from a resource in a specified period (usually a year), as defined in the management plan. The TAC may be allocated to the stakeholders in the form of quotas as specific quantities or proportions.
TBT	Tributyl tin (see glossary: *organotin*).
TED	Turtle exclusion device.
UNCLOS	United Nations Convention on the Law of the Sea.

Acknowledgments

Research and preliminary drafting

Dr Colin Gibbs, Colin Gibbs and Associates (lead researcher)
Gus Fabris, Marine and Freshwater Resources Institute
Anne Gason, Marine and Freshwater Resources Institute
Heather Gibbs, Colin Gibbs and Associates
Leanne Gunthorpe, Marine and Freshwater Resources Institute
Andy Longmore, Marine and Freshwater Resources Institute
Greg Parry, Marine and Freshwater Resources Institute
Christine Porter, Colin Gibbs and Associates

Compiling the final text

Jenny Boshier, Environment Australia
Gary Whatman, Environment Australia

Expert review panel

Dr Alan Butler, CSIRO Marine Research
Dr Michael Cappo, Australian Institute of Marine Sciences
Dr Zena Dinesen, James Cook University of North Queensland
Dr David Kay, Environment Australia
Mr Chris Roberts, Cape York Development Corporation
Dr Phil Symonds, Australian Geological Survey Organisation

Peer reviewers

Dr Rob Coles, Northern Fisheries Centre, Queensland Department of Primary Industries
Ms Diane Tarte, Marine Ecosystem Policy Advisors Pty Ltd
Dr Geoff Wescott, Deakin University
Dr Trevor Ward, University of Western Australia

Technical advisers

Australian Antarctic Division, Environment Australia
Marine and Water Division, Environment Australia
Department of Primary Industries, Northern Territory
Department of Primary Industry, Water and Environment, Tasmania

In addition, a large number of other people provided information, usually at very short notice. These include individuals in State and Territory government departments, private industry and voluntary organisations. Commonwealth government departments and members of the ANZECC State of the Environment Reporting Task Force also helped identify errors of fact or omission. Their assistance is also gratefully acknowledged. The efforts of the data coordinators in State and Territory agencies are also appreciated.

Executive summary

Understanding the value of our coasts and oceans

Australia's marine area extends over about 16 million square kilometres, from Antarctica to near-equatorial latitudes. It includes one of the largest Exclusive Economic Zones in the world, and the high degree of endemism (numbers of species found only in a particular region) in the south and the rich tropical diversity of the north create unique opportunities and challenges for Australia.

Australia is highly dependent on its marine resources in a range of ways:

- recreational use of beaches and near shore area,
- preferred living and development in the coastal margins,
- the economic benefits of marine industries, including shipping, tourism, fisheries and offshore oil and gas.

The value of our marine resources has been appreciated by Indigenous cultures for thousands of years and their cultural associations remain strong.

Australians today appreciate the value of these resources in some ways, but not in others. For example, many Australians value the clean, beautiful beaches, the clean ocean waters and the beauty of tourist destinations such as the Great Barrier Reef and the picturesque southern coastlines. Many Australians appreciate the pleasures of recreational fishing.

Some appreciate where it is fragile and where it is resistant to human influence, but relatively few Australians know of the importance to our economy of the shipping and port industries, and of the economic value added to Australia by marine tourism and the seafood industry.

Major issues

Habitats of our coasts and oceans

Mangroves are our marine forests. Australia has 43 species, representing 58% of the global diversity of these species. No mangrove species is considered threatened, and indeed, mangrove area may be increasing. However the reason for the increases in mangrove area include sea level rise, growth in areas of accreting mud banks, and incursion into saltmarsh systems. While some of these may be occurring without human influence, they are all a cause for closer scrutiny of the phenomenon.

Seagrasses are not robust ocean 'weeds': they are flowering plants and represent our productive, shallow marine pastures. They support nursery areas for fish and prawns and other species. They provide food for Dugongs. They are vulnerable to pollution from chemicals and excess sediment runoff—that is, smothering by mud.

The problem with seagrass loss is that their recovery is not assured. In the tropics many species are seasonal and regrow quickly. However in colder temperate waters the dominant *Posidonia* species takes many decades to regrow so their recovery is not practically achievable. Any loss of temperate seagrasses through local pollution pressures, such as the declines in Cockburn Sound in Western Australia, warrant attention. The recent discovery of deepwater beds in the Great Barrier Reef World Heritage Area indicates that our knowledge of seagrass is still expanding.

Dunes and beach habitat occur along 50% of the Australian coastline, yet they are among the most poorly studied coastal habitats. They are under localised pressures from development in the intense urban spread around population centres, but are generally poorly described and monitored. The deliberately introduced Bitou Bush has become a pest on the New South Wales coastal dune systems.

Intertidal mudflats are species-rich, and important in the routes of migratory bird species, but as with dunes and beaches they are not particularly well studied.

Rocky reefs are found in intertidal and subtidal areas. Their high diversity and visibility has attracted more research, which confirms their importance as a base for productive macroalgae, sponges and fish populations. About 50% of Australia's fisheries are supported by rocky reef habitats. The principal human pressures on rocky reefs come from land-based pollution and from fishing pressure.

Estuaries are the waterways where rivers reach the sea. They have been the preferred site for European settlement owing to the transport link they provided to inland waterways before roads and railways, and to the shipping link they provide as ports for ocean-going vessels. In an assessment of 970 estuaries, the National Land and Water Resources Audit has found that about half are degraded in some way, usually owing to human settlement pressure. One of the greatest pressures on estuaries is the decline in water quality caused by agricultural development and changes in water flow regimes.

Gulfs and bays are robust in being more exposed to marine influences than narrow estuaries, but exposed in that they are often a sink for sediment deposition, which is an attractant for adsorbed nutrients and pollutants. In the case of Hervey Bay there was a major loss of seagrass following a large flood event in 1992 carrying greater than normal amounts of eroded sediments into the Bay. In the case of bays near large cities, the concern is for the effects of enhanced nutrient and toxicant inputs, for increased sedimentation and turbidity, and for the input of pathogens to the water through sewage outfalls.

Coral reefs are exceptionally diverse marine systems that thrive in relatively low nutrient tropical waters. The Great Barrier Reef in north-east Australia is well known internationally, but is not our only coral reef. Ningaloo Reef in Western Australia is Australia's largest fringing reef, stretching for 230 km along a very lightly populated coastline.

A dramatic coral bleaching event in 1998 accounted for the damage of 16% of the world's reefs within one year. Australia was fortunate in that only 3% of reefs were destroyed by bleaching in the 1998 event.

Australian coral reefs have been destroyed by sediment and nutrient runoff at certain coastal locations, and brought under pressure from increasing recreational and commercial fishing at others. The Crown of Thorns Starfish (*Acanthaster planci*) is presently causing a major reduction of living coral over very large areas of the Great Barrier Reef, yet the precise triggers for the outbreaks of this boom-and-bust species remain uncertain, although freshwater runoff has been implicated.

Australia's continental shelf and slope cover a huge area, some 2.5 million square kilometres, yet it remains poorly known. It consists mainly of soft sediments, but includes diverse communities of fish and sponge gardens. Some of these may be very long-lived and slow to recover from disturbance. Our seamounts off southern Tasmania harbour similar ecosystems.

Species

The invertebrate species are the huge number of animals without backbones. In Australian waters this includes everything except the fishes, seabirds and mammals (whales, seals and the Dugong).

Expert opinion suggests that although 1000 species of echinoderms (seastars, sea urchins, sea cucumbers and brittle stars) have been described so far, as have 10 000 species of marine molluscs, these numbers represent less than half the total number of species likely to be found in Australian waters.

A variety of invertebrates are exploited by fisheries, and Australia's prawn, lobster and abalone fisheries represent very high value for relatively low volume of harvest. The human impacts on invertebrates come from coastal development and land-based pollution, and from some methods of fishing such as trawling and dredging.

In the past five years there has been an increasing adoption of Marine Protected Areas (MPAs) as a means of conserving marine invertebrates and protecting them from extractive industries. The MPA approach relies less on precise knowledge of species population status and depends more on maintenance of areas of habitat types.

The conservation status of fish species, as listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), shows one fish species is endangered (the Derwent River Spotted Handfish, *Brachionichthys hirsutus*); five species of shark are listed as vulnerable (including the Great White Shark, *Carcharodon carcharias*). Two species of freshwater fish that have a marine life stage (the Freshwater Sawfish and the Australian Grayling) are also listed as vulnerable.

The practice of setting nets for sharks near swimming beaches has affected shark populations, particularly the Grey Nurse Shark (*Carcharias taurus*), which has been reduced to about 1000 individuals. Shark mesh-netting has also killed large numbers of dolphins and Dugongs.

Six of the world's seven species of turtles breed in Australia. The eastern Australian stock of the Loggerhead Turtle breed almost exclusively in the southern Great Barrier Reef and is considered to be endangered, with a 70% to 90% decline in the nesting population in the last 30 years. Other species also show declines. The Hawksbill Turtle is recognised internationally as critically endangered, and relies heavily now on the breeding sites in the northern Great Barrier Reef. About 10 000 turtles are caught accidentally by trawl fishing each year in northern Australia, but an estimated 90% of these are released alive. Approximately 2000 to 4000 green turtles are caught by Indigenous people each year.

The vulnerability of turtles has led to a heightened international profile of the issues and national and State action plans to conserve turtle species. Fishing trawlers in most northern areas now use turtle exclusion devices that prevent turtles being caught in trawl nets. In some areas Indigenous councils have implemented management plans to control their take of Dugongs and turtles.

Disturbance to seabird populations and their habitat come from a wide variety of sources, including urban development, airports, mining and minerals exploration, off-road vehicles, tourism at nesting sites, longline fishing, discarded fishing gear, and introduced rats and feral cats on offshore islands.

There have been several new developments aimed at reducing pressures on seabird populations: for example, the Commonwealth's Threat Abatement Plan of 1998 is aimed at reducing impacts from longline fishing vessels. Nesting areas are being protected in the Great Barrier Reef region, and in southern Australia there are programs to reduce feral animal predator disturbance. Australia also has 32 coastal wetland areas declared as protected under the international Ramsar Convention, and 16 of these sites are significant points in the paths of migratory birds.

Cetaceans (whales and dolphins) are visible and valued by Australians as charismatic species deserving maximum protection. The public concern at the decline of the great whales during the past 100 years has led to international measures through the International Whaling Commission. There are still some countries that regard whales as harvestable species.

Whale-watching is rising in popularity and subject to State controls and a set of national guidelines from ANZECC. The aim is to allow people to view cetaceans and learn about them without interfering with their migration, feeding and breeding.

There are a number of species, such as the inshore dolphins, where so little is known of their population status that they cannot be categorised as vulnerable or not.

There are 10 species of seal occurring in Australian waters, all occurring in southern temperate Australia and sub-Antarctic regions, and their population dynamics are complex. Declines in Elephant Seals at Macquarie Island may be related to rises in Fur Seals and King Penguins (both of which are rapidly becoming more numerous). The cessation of harvesting and climatic changes, for example in the area of pack ice, in the Antarctic is likely to be implicated in these changes.

The Dugong (*Dugong dugon*) is Australia's only strictly marine herbivorous mammal. Dugongs are vulnerable to mesh nets in shallow coastal waters (e.g. those set for sharks and fish), and to loss of their seagrass feeding habitats. Commercial harvesting ceased many years ago, but they are legally hunted in northern Australia by Indigenous people. Dugong habitat is protected by legislation in Queensland.

Coastal settlement

The Australian coastline is lightly populated when measured against more highly populous countries, but about 75% of our population lives within a few kilometres of the coast. The trend to move to the coast is continuing, with all States showing higher population growth rates in the 3 km coastal zone than elsewhere.

Marine tourism is a significant part of Australia's economy. There is a tremendous range of activities including whale watching, visits to the Antarctic, bird watching, recreational scuba diving and snorkelling.

The developed area of Australia's coastal strip is still only a small percentage of our coastline, but its impact is one of the major strategic issues confronting the conservation and management of our coastal zone. Human activity can cause the loss or degradation of specific habitat types, alter tidal water flows in wetlands and streams, cause erosion of beaches and dunes, and degrade water quality through stormwater runoff, sewage and litter.

A New South Wales survey in 1996 found that 73% of beach litter was land-sourced plastics, 14% was other land-sourced materials and 13% was debris from fishing. Even in

remote areas, discarded plastic material can cause the entanglement and death of many species. The disposal of plastic waste at sea is prohibited under the MARPOL Convention (Annex V) and enforced in Australia through the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*. In addition there are national and fishery specific codes of conduct designed to minimise all discards and waste associated with fishing activities. Beach litter is common in Australia, but there are few surveys available to quantify the problem and no consistently collected data to allow assessment of trends.

A coastal species, the Bitou Bush, was deliberately introduced to protect dunes after sand mining, but it has now become a significant environmental weed. It is spreading quickly in New South Wales coastal regions through distribution of seeds by birds, and may affect landscapes further inland if not controlled.

The creation of acid runoff through disturbance of acid sulfate soils has already had a major impact, and there is potential for this damaging phenomenon to expand unless managed properly. These soils underlie large tracts of the populated coastal zone, where alteration to drainage and the excavation of the soil creates very acidic runoff that causes fish kills, corrosion of metal structures and mobilisation of heavy metals. Fortunately the phenomenon can be managed, and in some areas water quality is now improving. Recognition of the phenomenon by local, State and Commonwealth governments has been an essential step in this process.

Water quality

Maintenance or restoration of water quality, particularly in coastal margins of Australia's marine area, is arguably the most critical marine environmental issue confronting Australia in 2001.

Water quality is essential for ecosystem maintenance, for industries such as fishing and tourism, and for recreation and aesthetics. It is difficult to manage because the changes usually occur slowly, perhaps over generations. The incremental decline in quality makes it difficult for regulators to achieve the community support needed to reverse the negative impacts.

While many coastal areas presently have excellent water quality, there are also many that do not. The effects can be local, through land-based pollution, poor drainage and effluent management. The negative effects can also come from land-use practices many hundreds of kilometres away, in catchments far from the coast. For example, deforestation, agricultural chemical use, poor cropping or grazing practices can cause enhanced erosion and increased turbidity and nutrient supply to estuaries and coastal waters. This unwanted fertiliser and excessive sediment flow places stress on other parts of the ecosystem, such as the smothering effects on coastal seagrasses, and alters the habitat of other species—from inshore invertebrates, to fish of commercial and recreational value to the highly valued Dugong.

Individual jurisdictions are working on improving the situation. Point-source pollution is increasingly subject to regulation. For example, in the Great Barrier Reef region new regulations were established in 1999 to control the quality of aquaculture discharges.

There is no national overview of the extent and levels of toxicants found in coastal waters and sediments. Neither is there national scale information on the emission of toxicants from diffuse pollution sources. It is 'nobody's' yet 'everybody's' job to do this.

Precise statistics on the contribution of various human activities to the degradation of coastal water quality are scarce, and it is common for different sectors of our community to lay blame on other sectors. A comprehensive, nationally standardised way of reporting on water quality would build a shared understanding of the issue within the broader community. However, the problem is not owned or managed by any single jurisdiction and there is no standardised, systematic data collection scheme operating at a national level that will tell us how we are going in managing this problem.

In the meantime, the degradation caused by such diffuse or remote sources remain largely unchecked and even identifiable local degradation is often not well managed. The catchment-scale approach to understanding and managing the problem is the most logical approach and implementation should be encouraged wherever possible.

Fisheries and aquaculture

Many Australian fisheries are fully or overexploited. None is pushing species towards extinction, to the best of current knowledge, but clearly sustainable development demands much more than this benchmark. Many types of fishing gear have unwanted impacts on the environment, taking species that are not the target of fishing operations. The introduction of

turtle exclusion devices on trawl nets targeting prawns in the tropics has addressed one problem, but the effect of trawl nets on species such as sponges and other benthos remains a significant issue in some areas.

The longline fishing industry is addressing the problem of accidental capture of seabirds, although the problem is not yet under control.

Government regulators and the industry have recognized the need to accelerate implementing sustainability into all aspects of the seafood industry. Since the 1996 SoE report, a program has been underway with support of the Fisheries Research and Development Corporation, CSIRO, the Australian Fisheries Management Authority and State fisheries management organisations.

There has been progress in some areas such as the Great Barrier Reef Marine Park, where a plan is in place to reduce the amount of trawl effort in the region.

The level of uncertainty in scientific assessments of the status of fisheries remains relatively high, and a report by the Bureau of Resource Sciences on Commonwealth fisheries shows a trend to fewer fisheries classified as 'underfished' and slightly more as "uncertain". It is widely held that sustainable development of Australia's fishing industry will involve making greater returns for industry by increasing quality or value-adding to the wild-caught product, rather than by increasing the total tonnage of the catch.

About three-quarters of Australia's fisheries are under State jurisdiction. Western Australia, Queensland and New South Wales produce regular reports on the status of fish stocks, and all three of these States report that stocks are either at or near their sustainable limit.

There are very few examples for which fisheries management can claim clear success in achieving regulatory goals. A notable success story is the Western Australian Western Rock Lobster Fishery which recently became the first fishery to be accredited under the Marine Stewardship Council. In the early 1990s scientists identified that the parent stock was dwindling at a time when catches remained high. Management restrictions were introduced and parent stock subsequently increased.

It remains to be seen whether the Eastern Gemfish, found in deep water off southern New South Wales, will recover from its depleted state after overfishing in the 1970s and 1980s. Quota levels remain at zero, after stringent management controls since 1993. Orange Roughy, taken off Tasmania and the South Tasman Rise, is also under strong management controls to restrict the catch of this long-lived species.

Recreational fishing is a popular activity in Australia, with the best estimate indicating that a total of 30 000 tonnes of seafood per year is taken by about 5 million people. About 73% of recreational fishing activity is in saltwater. Since the 1996 SoE Report, several States have introduced angling licences to include marine recreational fishing, and a national survey was instigated in 2000 to gather information on the extent of recreational and Indigenous fishing.

The value of aquaculture production has been growing at 14% per year since 1989. Until the last decade, most commercial aquaculture was for oysters (edible oysters and pearl oysters), and a limited amount of fish and prawn culture. In recent years the cage culture of fish has grown rapidly. Atlantic Salmon in Tasmania and the fattening of caged Southern Bluefin Tuna in South Australia account for about one-third of Australia's $600 million production. Aquaculture prawn production is also growing.

The growth of the aquaculture industry has brought new environmental management issues under scrutiny.

Introduced marine pests

Australia is highly dependent economically on the export of bulk commodities such as minerals, agricultural products and oil and gas. The vessels that carry these products usually arrive on our shores empty, except for massive volumes of ballast water, which is needed to maintain the stability and safety of the vessel. The ballast water taken on board in foreign ports and dumped in Australian waters can carry unwelcome hitchhikers.

There have been some 200 species introduced to our waters from foreign regions, most unintentionally in ballast water or by other means. In addition, species are imported in the biological communities growing on the outside of hulls, termed hull fouling.

Many of these species slip quietly and unnoticed into our marine systems, forming small populations that do not interfere with the ecosystem. However some of these species cause

dramatic changes and threaten entire habitat types, and some cause toxic algal blooms that threaten oyster and mussel fisheries and the health of those who eat affected shellfish.

The Northern Pacific Seastar and the Giant Fan Worm are having a major impact on waters on our southern coastline. The exotic Seastar eats oysters, mussels and other sedentary species. The Giant Fan Worm is a filter feeder, but covers existing habitat to the exclusion of other species living on the seafloor.

In 1999 specimens of the Black Striped Mussel were found in three marinas in Darwin Harbour during a resurvey. Having witnessed the ecological and financial disaster caused in the Great Lakes region of North America by its near-relative the Zebra Mussel, the Northern Territory and Commonwealth governments mounted a major effort to eradicate this pest. The effort involved 300 people and cost $2.2 million, but was successful and is thought to be the first eradication of a marine pest species population. However, the eradication of pest species populations may not be as successful in the future.

A program of port survey is now underway through the Australian Association of Ports and Marine Authorities and the CSIRO Centre for Research on Introduced Marine Pests. However these surveys are not yet organised as a routine, repeated procedure across all ports.

The concerns about translocated organisms extend beyond ballast water transport. Exotic organisms may enter Australian waters on the outside of ships' hulls or through the trans-shipment of live or frozen seafood products. Quarantine restrictions apply to the normal importation of products, and some products are excluded on the basis of risk assessments, but there is currently no restriction on movement of the hundreds of species that are attached to ships' hulls.

Marine industry development

Australia is an island nation that depends heavily on shipping, and the infrastructure for this industry includes ports and navigation channels that require dredging. It is the disposal of the dredged material that can be of concern to environmental regulators. In 1998 ANZECC released its guidelines to assist applicants for dumping permits, and the Commonwealth government has updated its legislation to remain consistent with the London Convention. The effect of these controls is that regulators assess the impacts of dredge spoil dumping and draw distinctions between clean waste that has low environmental impact and contaminated waste that is potentially more harmful to the environment.

Antifouling paint is, by definition, toxic to animals and plants. The phasing out of tributyl tin (TBT), the most common antifoulant, is still some years away. Concern over its effects remains high.

The possibility of an oil spill is a constant concern; four incidents with environmental effects have been recorded in the past six years. The most serious occurred in 1999 in Sydney Harbour, where 250–300 tonnes of light crude oil were spilled during a cargo transfer, and harbour foreshores were affected by oiling. Offshore oil drilling effects have been restricted to the local effects of drill cuttings and drilling muds deposited adjacent to wells.

As knowledge of our marine biodiversity increases, the prospects for discovering biologically active compounds have also grown. Some useful substances have already been discovered. Corals contain chemicals that are natural sun-blockers. Sponges and other sedentary plants and animals have chemical defense mechanisms that may find application as human drugs and herbicides. In the past there have been concerns that discovery of a valuable compound may lead to overharvesting of the organism concerned, but current biodiscovery programs emphasise the need to protect natural biodiversity and synthesise, or grow by aquaculture, any valuable substances rather than harvest them from the wild.

Marine resource management

There are some 80 international agreements relating to the use of the oceans, and half of them relate to managing the marine environment, including fisheries. Some prominent ones include the UN Convention on the Law of the Sea 1980, the Convention on the Conservation of Antarctic Marine Living Resources 1980, the International Convention for the Prevention of Pollution from Ships (MARPOL), and the World Heritage Convention.

Indigenous rights to the use of marine resources have been acknowledged in a number of court decisions relating to harvesting of traditional food species, and in legislation in the case of Torres Strait Islanders' use of the marine environment.

Australia has continued to pursue the establishment of Marine Protected Areas. There are now more than 190 protected areas covering 60 million hectares. Australia's Oceans Policy

includes an undertaking to develop a national, representative system of Marine Protected Areas. Progress has been made in planning in most States, and declarations of new protected areas have been made in the Great Australian Bight, Macquarie Island, Solitary Islands, Jervis Bay, Lord Howe Island, Tasmanian seamounts, extensions to the Great Barrier Reef Marine Park, and Cartier Island. However, it is the implementation of management plans that will determine whether ecosystems and threatened species will benefit from the establishment of MPAs.

Australia's Oceans Policy was released by the Commonwealth Government in 1998, the International Year of the Ocean. This policy includes support for some innovative approaches to integrated oceans management, e.g. the concept of regional marine plans. The Oceans Policy acknowledges the need to take an ecosystem approach to natural resource management, striking a balance between environmental, economic and social objectives.

The Coastcare program has funded over 1700 projects involving restoration of habitats, development of local management plans, education and training. Between 1997 and 2000 the number of Coastcare groups rose from 700 to 2000.

As with the term ecologically sustainable development, ecosystem-based management is ill-defined at the operational level of management but nevertheless creates a framework for policy development and decision-making. Its key attribute is the recognition that the effects of any activity in a region should be assessed in light of the linkages and interdependencies within the whole ecosystem rather than focusing only on the local impacts. A good example of this is Integrated Coastal Zone Management, which aims to overcome the fragmentation of management arrangements and the "tyranny of small decisions" leading to incremental degradation through the negative effects of many small decisions that seem, on their own, inconsequential.

Summary

Water quality and loss of habitats have emerged as the major issues. There are many areas where both of these environmental values are in good condition and not of concern, however in some areas stronger action is needed to prevent decline in water quality. Overall the quality of estuarine and coastal waters has not improved, although there are some locations where signs are positive, for example around Sydney.

The effect of poor catchment management is to lower coastal biodiversity through pollution and sediment. People see the effect either directly, such as loss of fish habitat reducing recreational fishing opportunity, or indirectly, through reports of dropping numbers of species such as Dugongs.

Catchment management is a key response, and this has been recognised in most parts of Australia, and in all tiers of government. Implementation requires community involvement, cooperation of industries and governments, and alignment of regulatory regimes between local, State and Commonwealth governments. There is still no nationally applicable Coastal Zone Policy, and delivery of effective catchment management across all jurisdictions is still some way off.

Some conclusions are:

- where population density and land use is light, Australian coastal waters are in excellent condition. However in some areas there are threats to, and actual loss of, shallow marine and coastal habitats through poor catchment management and development, invasive species such as starfish and Giant Fan Worms in the south, and tropical pasture grasses in coastal lagoons in the north. Landowners are often unaware of the downstream consequences when land use is poor. The massively damaging effects of acid soil runoff in some estuaries is a good example of negative downstream consequences, and of how improving our land use practices can remedy the problems.
- mechanisms for resource allocation remain poorly developed in most areas, for example the allocation of fishing rights, among commercial, recreational and Indigenous users of fisheries resources. Our capacity to measure use of these resources is poor.

Implications and looking forward

Managing the activities of people in a way that conserves habitats while sustaining resources and industries is extraordinarily complex and difficult. When environmental, social or cultural

qualities are in decline, a key step in the remedy is for the public to be aware of the changes, and the causes of change.

In 2000 the issue of salinisation of large tracts of Australia's agricultural lands received major national publicity. The problem had been developing for decades, and local and regional governments had been working on it, yet the national will to remedy the problem has emerged only recently. It is public awareness that creates the will and motivation to effect changes in how we use the environment. Therefore publicly available information about the state of our environment is very important.

How much information is readily available to the public and to decision makers on the general state of the coasts and oceans environment? Unfortunately there is not a great a deal, and it is 'nobody's job' to coordinate and deliver such information.

A major positive effect of the 1996 State of the Environment Report has been to promote the development of indicators. Things that can be measured, and when the information is published, provide an indicator of the state of our environment.

The 2001 report has shown that developing indicators is necessary but not sufficient. Many of the important indicators require a national approach to the development of data collection and reporting systems, which is yet to occur.

Introduction

Our diverse environment

Environmental indicators reported in this section:

Environmental Indicator	
CO 8.1	Sea level
CO 8.2	Sea surface temperature variability

As an island continent, Australia has a coastal and marine area that borders three great oceans: the Pacific Ocean in the east, the Indian Ocean in the west, and the Southern Ocean. In the north, Australia is separated from Indonesia, East Timor and Papua New Guinea by the shallow waters of the Timor Sea, Arafura Sea and Torres Strait.

Australia's marine area is one of the largest in the world, extending over about 16 million square kilometres. This is more than double the continent's land area. Australia's ocean domain includes all ocean temperature zones (based on sea surface temperature), from tropical to polar.

Australia's very diverse marine and estuarine habitats range from small estuaries to the extended continental shelf, and from the tropics to the Antarctic and to the island ecosystems of Australia's external territories. The familiar coastal habitats of beaches, dunes, rocky shores, seagrass beds, algae-covered reefs and even mangrove swamps occur in most of the mainland states. These habitats are the home of a wealth of fauna and flora, most of which is found only in Australia. For example, Australia has:

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

Indigenous peoples have been custodians and users of Australia's marine environments for thousands of years, and cultural associations remain strong. From an Indigenous perspective, the sea is not additional to but part of their traditional territory. With some 150 groups whose country abuts the coast and includes the sea, the cultural associations of coasts and oceans are thus of very high significance to Indigenous Australians.

In many respects Australia is established around the coastal rim of the continent, and the coastal and marine environment is important to the culture and lifestyle of Australians and visitors. In 1996 around four out of five Australians lived within 50 kilometres of the coast, in cities and towns on the coastal fringe. The coastal zone is used for activities such as settlement, industry, agriculture and mariculture. The ocean environment supports a number of activities, including petroleum mining and commercial fishing.

Some Australians appreciate where this environment is fragile and where it is resistant to human influence, but relatively few know of the importance to our economy of the shipping and port industries, and of the economic value added to Australia by marine tourism and the seafood industry.

Marine resources have considerable economic value and contribute to Australia's economy. The gross value of fisheries production in 1999–2000 was $2.3 billion (ABARE 2001). The size of economic activity of the major marine industries is estimated to be more than $30 billion annually (Greiner et al. 1997). Marine tourism and recreation is estimated to contribute 50% to the economic activity; oil, gas and engineering 27%; shipping, transport and ship building 13%; and commercial fishing and aquaculture 5%.

Our marine environment also has an important role in the provision of ecosystem services. The concept of ecosystem services is a way of describing the functions (or services) that come from the ecosystems that sustain or fulfil human life and that cannot be replicated in any other way. Some examples of ecosystem services are purification of air and water, biological breakdown of wastes, and recycling of wastes.

Interest in valuing ecosystems services has increased following a global study that estimated the economic value of 17 ecosystem services across 16 biological zones to be

between US$16–54 trillion per year (10^{12}), with an average of US$33 trillion per year (Costanza et al. 1997). This valuation was in turn used to estimate an average value in 1997 for Australian marine ecosystems of US$640 billion per year (Jones and Pittock 1997).

Australia's marine and coastal systems depend on and influence global climatic and other systems. Changes in global systems like sea temperature or the major global ocean currents may have potentially unwelcome effects.

The marine environment differs in some crucial aspects from our terrestrial environment, in that most of the marine environment can be regarded as a common resource, to be used and enjoyed by people who do not possess an exclusive right to own or use the resource. This aspect of a common heritage is reflected in one of the principles for ecologically sustainable ocean use in Australia's Oceans Policy (Commonwealth of Australia 1998a):

> 'the benefits from the use of Australia's common ocean resources, and the responsibilities, for their continuing health and productivity should be shared by all Australians'.

Figure 1: The Australian coastline.

Source: Environment Australia (2000).

The coastline and beyond

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

The coastline encompasses some 61 700 kilometres (including nearby islands) with variable physical characteristics around the country, as shown in Figure 1.

Much of the Australian mainland is surrounded by a relatively narrow continental shelf, with the exception of the Great Australian Bight and the tropics. The continental shelf extends to depths of about 150–200 metres and varies from between 15 and 400 kilometres in width.

At the edge of the continental shelf, the continental slope drops from a depth of about 150–200 metres to 4000 metres. Only a little light can penetrate beyond about 1000 metres. There is complete darkness in this zone, although the deep oceans support a great variety of species and habitats.

Ocean currents around Australia

There are several major ocean currents that affect our marine environment (Figure 2) including:

- The East Australian Current, which brings warm, high-salinity water from the tropics through the Great Barrier Reef along the east coast, reaching south to Tasmania. It carries about 30 million cubic metres of water per second, and as it progresses down the continental margin it generates eddies that spin off and return into the surface waters of the Pacific Ocean.
- The Leeuwin Current, which begins off the North West Shelf and flows down the west coast in winter, extending across the Great Australian Bight to Bass Strait. This current carries about five million cubic metres of water per second.
- The South Equatorial Current, which passes through the Indonesian archipelago from the Pacific Ocean and carries about seven million cubic metres of water per second.
- The predominant current around the Australian Antarctic Territory in the Southern Ocean flows west to east—the Antarctic Circumpolar Current. This current has a major influence on the Earth's climate. Close to the Antarctic shore, the current flows east to west—the East Wind Drift, driven by the polar easterlies.

These water masses and ocean currents have a significant influence upon both the global and Australian climate and the productivity of coastal waters. The strength, seasonality and southward extension of the first three major currents are highly variable, and their flow

influences coastal conditions and larval fish distribution. The Cooperative Research Centre for Antarctica and the Southern Ocean is researching the links between the Southern Ocean currents and the global climate system.

The productivity of Australia's fishery resource is influenced by the absence of upwelling conditions that brings nutrients to the upper layers of the oceans. The productivity of coastal waters is influenced more by land use and the export of nutrients in the catchments draining to the coast.

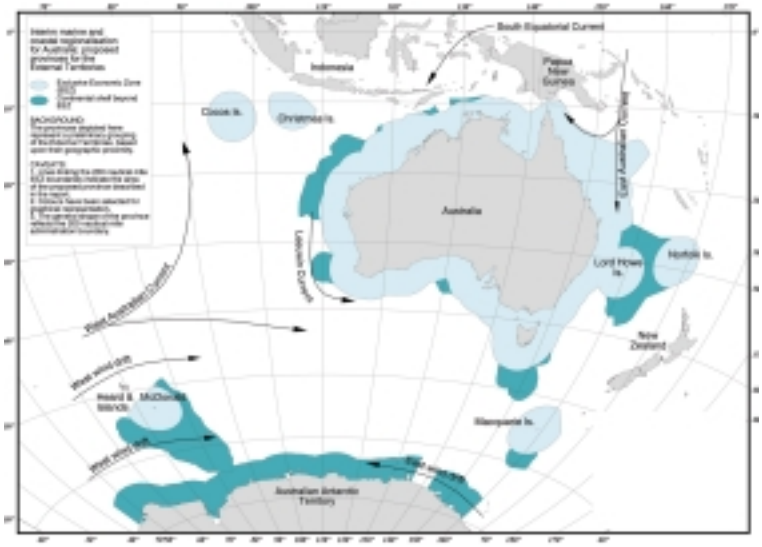


Figure 2: Major global ocean currents that affect Australia.

Source: Environment Australia (2000).

Australia's marine responsibilities

Under the United Nations Convention on the Law of the Sea (UNCLOS) 1982, Australia has sovereign rights to explore and exploit, conserve and manage, the living and non-living natural resources within its Exclusive Economic Zone (EEZ). UNCLOS sanctions the declaration of 200 nautical mile (nm) EEZs, enabling a significant area of ocean to be brought within the jurisdiction of maritime nations. In Australia's case, this amounts to some 11 million square kilometres of ocean beyond the territorial sea. In addition, UNCLOS requires a Coastal State to define the limits of its continental shelf within ten years of the entry into force of the Convention for that State. In Australia's case, this is November 2004. Considerable mapping of the proposed areas is required for this.

There are a range of international agreements to which Australia is party and which influence marine management. Some of these are listed in the marine management section of this chapter. Australia has international obligations in Antarctica. Fisheries in the Southern Ocean are subject to the requirements of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR).

The Australian Antarctic Territory comprises 5 896 500 square kilometres, equal to 77% of the land area of Australia and 42% of Antarctica. It is the coldest, driest, windiest, and most remote continent on Earth. Antarctica is also the continent least affected by human activity, making it an ideal location for studying human impacts and global background levels of anthropogenic agents such as polychlorinated biphenyls (PCBs).

Australia's marine area includes about 12 000 islands. Some of these islands are important in extending Australia's EEZ, and hence our marine responsibilities. For example, Heard Island, the McDonald Islands and Macquarie Island in the Southern Ocean; Christmas Island, the Cocos (Keeling) Islands, Ashmore Island and Cartier Islet in the Indian Ocean; the Coral Sea Islands and Torres Strait Islands; and Lord Howe and Norfolk Islands in the South Pacific Ocean (Figure 2).

Australia has declared a range of maritime zones (Figure 3). The outer limits of all of these zones are measured from the territorial sea baseline, located for the most part at the low-water mark along the coast. However, it also consists of bay and river closing lines, and some straight baselines between the mainland and adjacent islands and across parts of the coast that are deeply indented. The 12 nm boundary may be, in places, much further than 12 nm from the continent. The zones include:

- The territorial sea: the outer limit of the territorial sea is 12 nautical miles seaward of the baseline. Australia has sovereignty over the territorial waters but must respect the right of innocent passage of foreign vessels.
- The Exclusive Economic Zone: the area between the lines 12 nautical miles and 200 nautical miles seaward of the territorial sea baselines.
- The continental shelf: the area between 12 nm and 200 nm seaward of the territorial sea baseline (i.e. it covers much the same area as the EEZ) and any area of physical continental shelf beyond 200 nautical miles.
- The Australian Fishing Zone: declared in 1979, and now managed under the *Fisheries Management Act 1991*. The zone is the area of waters between 3 nm and 200 nm seaward of the baselines.

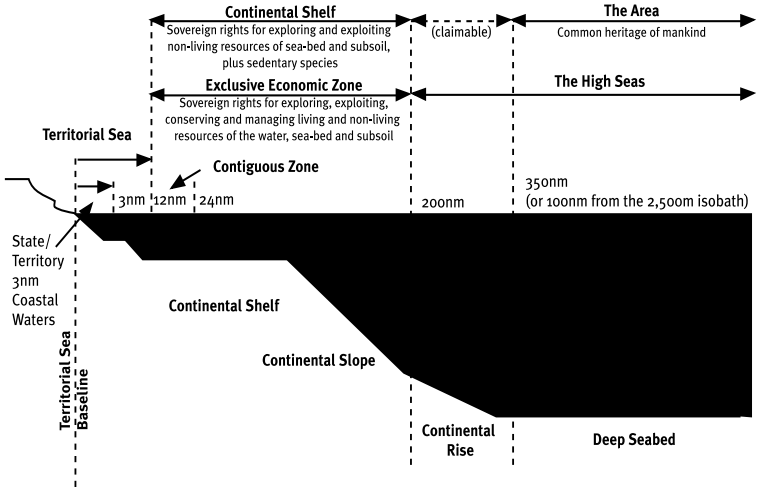


Figure 3: **Australia's marine zones.**

Source: Environment Australia (2000).

Within Australia, the responsibilities of different levels of government with respect to the sea are complex (Symonds et al. 1998), and the multiplicity of legislation relating to the coast and to marine resources has long been a matter of concern because of the potential for overlap and duplication.

In general, the States and Territories have jurisdiction over marine areas to 3 nm from the baseline, and the Commonwealth has jurisdiction beyond those waters to the outer boundaries of the EEZ. The Offshore Constitutional Settlement established jurisdictions between the Commonwealth and the States over marine areas in 1983. The great majority of Australia's marine area is under sole Commonwealth jurisdiction. Issues (such as pollution incidents) which straddle the 3 nm boundary can be complex. These may depend upon the precise wording of the legislation concerned, or require the cooperation of the Commonwealth and States.

Our knowledge of the habitats and species within the EEZ is limited as only 1 to 2% of the EEZ has been surveyed to describe these different marine habitats. Seabed habitat mapping of varying detail has been produced for areas such as the Torres Strait (50 000 km^2), Great Barrier Reef (347 800 km^2) and the south-east Australian continental shelf (30 000 km^2). Scientists from CSIRO Marine Research, the Australian Institute of Marine Science (AIMS) and the CRC for the Great Barrier Reef World Heritage Area have developed and used acoustic tools, together with other equipment, to survey both seabed to a depth of 200 metres and deeper habitats to 2000 metres. A research voyage by CSIRO Marine Research in April–May 2001 was part of an investigation of marine life in waters off Tasmania and Victoria. The voyage made the deepest sampling trawls so far conducted in Australian waters. Innovative use of deepwater video identified environmental conditions and associated marine life, revealing fish and invertebrates new to science as well as reefs and unique canyons.

Climate variability and change—the global context

Antarctica and the Southern Ocean play a critical role in the global environmental system. Processes of interaction between the atmosphere, oceans, ice, and biota affect the entire global system through feedbacks, biogeochemical cycles, circulation patterns, transport of energy and pollutants, and changes in ice mass balance.

Global climate variability may have serious repercussions for Australia's coasts and oceans in the future. The two aspects that could affect Australia's coastal and marine environments are rises in sea surface temperature and sea level change. Climate variability may in the future result in extreme events in different parts of the country and drought in other places. (This is further discussed in the Atmosphere Theme Report.) Floods associated with the increasing trend in extreme rainfall events could result in increased sedimentation and nutrient levels in estuaries and coastal ecosystems and harsher erosion events, threatening coastline stability and coastal infrastructure. Any increase in the frequency of cyclones or storms in tropical areas could also result in increased resuspension of sediments.

Sea surface temperature [CO Indicator 8.2]

Changes in the sea surface temperature are closely linked to climate variability. If sea surface temperatures rise significantly in the future, there is the potential for effects on marine life.

Information from recent studies on Heard Island by scientists from the Australian Antarctic Division, University of Tasmania and Macquarie University has found an increase in many marine species. For example, Fur Seals and King Penguins have multiplied. This may be the result of the rapid decline in the area of Antarctic sea ice that occurred between 1950 and 1973, which appears to be the result of a small rise in sea temperature.

Rising sea surface temperatures in the tropics are considered responsible for widespread bleaching of corals, including on the Great Barrier Reef (Wilkinson 2000). The bleaching was caused by the combination of extremely calm conditions during the 1997–98 El Niño event,

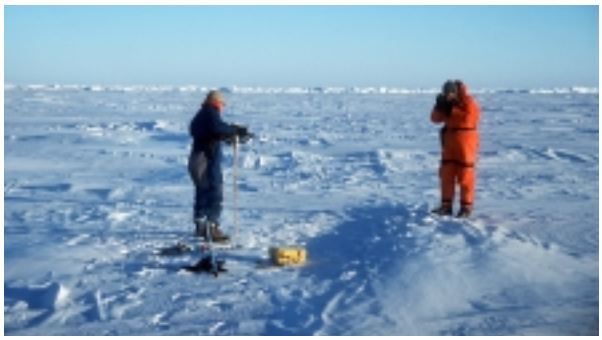
Antarctic sea ice

Antarctica, the 'frozen continent', is blanketed with ice in a layer on average over two kilometres thick. Antarctica is also surrounded by a vast band of ice derived mainly from direct freezing of ocean water. This sea ice forms the Antarctic pack ice zone with innumerable ice floes about 0.5 metres thick, separated by open water.

This sea ice undergoes a dramatic annual change in area, from a minimum of 4 million km^2 in February to a maximum of 19 million km^2 in September. Climatologists consider this cycle to be crucial in the regulation of the Earth's climate. The ice also has a major influence on the Southern Ocean ecosystem, as a wide variety of organisms, from unicellular algae to penguins and seals, depend on its presence.

Most sea ice is formed close to the Antarctic continent and is then transported northwards by winds and currents. The ice provides an efficient insulating layer that reduces heat loss from the relatively warm ocean to the atmosphere. The presence of ice also increases the amount of energy reflected back into space. The balance between these processes—one which retains heat in the ocean, and the other which reduces solar heating—is of prime importance.

The Southern Ocean and the Antarctic pack ice zone play an important role in global climate variability and change. Climate models predict that increased global temperatures will affect the Antarctic sea ice zone, leading to a decrease in its extent. Satellite-based measurements of the extent of sea ice are relatively recent (post-1973), and indicate no major change in its winter extent over the last 25 years. However, this method does not give any information on changes in the thickness of the ice. Also, there is evidence of some regional decrease in ice cover during summer.



Gathering information on the sea ice.

Source: B Wienecke, Australian Antarctic Division.

Historical shipping records of the position of the edge of the pack ice zone suggest that there was a major decrease in the extent of the pack ice between 1950 and 1970. The relationship between this apparent decrease and global warming is uncertain, but it is clear that a major change has occurred. The influence of this change on the physics of the Southern Ocean and its biota are unclear.

(one of the strongest on record) and a steadily rising baseline of sea surface temperatures in the tropics. This is a matter of major concern in the context of climate variability.

Sea level rise [CO Indicator 8.1]

Rises in sea level could be catastrophic for low-lying coasts, islands and cays, and coral reefs. However, on present information, it is not possible to demonstrate consistent increases in sea level arising from global warming, as distinct from other causes.

Sea level changes are calculated from data gathered from tide gauges installed along the coastline of Australia for port operations by the National Tidal Facility at 23 sites for periods ranging from 25 to 100 years (Mitchell et al. 2000).

A number of these gauges are affected by very local processes, such as subsidence, that reflect changes in local land level rather than sea level. All gauge heights are also affected by slower geological processes, whose contribution can be estimated using various techniques. Researchers believe that at least 30 years of good-quality data are required to estimate trends from tide records. Fremantle has some 100 years of data, and Port Denison has data for 85 years. After correction for geological effects, data from these two stations suggest a sea level rise of 12–16 cm during the past century (Lambeck 2001). A slight rise in overall sea level may be accompanied by much larger impacts of extreme events, such as storm surges.

People cause environmental change

The movement of people to live near the coast, identified in the 1996 SoE Report, has continued during the past five years. Although most people live in urban centres, the density of people and their mobility and activities are affecting particular coastal environments and urban localities.

Population pressures are a major driver of environmental change in the estuaries and coastal waters of Australia. This has effects as diverse as loss of important coastal and nearshore

habitat, loss of open space and natural landscape, increased nutrient loads to estuaries, and increased stormwater runoff into coastal waters. The provision of infrastructure to support industrial activities, shipping, tourism ventures and expanding human settlements has both environmental and physical effects. As the predictions of population growth in coastal areas of Australia are for an increasing trend, the quality of our coastal and marine environments will continue to be placed under pressure.

Risks to the marine environment

One of the risks to our coastal environment arises from our dependence on international and coastal shipping to transport goods to and around the country. As the countries with whom we trade change, constant vigilance is needed to reduce the chances of introduced species establishing in either our tropical or temperate waters. Such species could become new pests that could have devastating consequences for our environment and for sectors of the economy. The discovery of the Black Striped Mussel in Darwin Harbour in early 1999 was a salutary reminder of the potential for harm that exists.

Other shipping-related risks are the risks of at-sea collisions or groundings (as happened on the Great Barrier Reef in 2001), loss of containers overboard, and spillage of hazardous cargo at sea or in ports or handling facilities.

Risks to estuarine and coastal waters arise from agriculture and catchment management practices, especially where high sediment loads are transported into coastal and estuarine waters. The effects on habitats and species include those on juvenile stages of commercially important species as well as the potential loss of habitat for endangered species. There are also risks to the coastal and marine environments from fishing of some fish species where the ecosystems of which the fish are part, can be affected by heavy fishing pressure. Aquaculture activities can also pose risks to the coastal and marine environment.

Integrated management

The sheer extent and diversity of coastal environments around Australia, together with the large number of agencies and bodies with an interest in coastal and marine management, has led to a lack of integration and consistent management in the past.

The Resource Assessment Commission (1993) laid down a challenge that still remains: to further enhance consistent, strategic and integrated management of this important environment.

In 1995, the State of the Marine Environment Report (SOMER) (Zann 1995) provided the first comprehensive scientific description of our marine environment, its uses and values, the issues and threats affecting it, and its management. The top five concerns were:

- declining marine and coastal water /sediment quality, particularly as a result of inappropriate land use practices,
- loss of marine and coastal habitats,
- unsustainable use of marine and coastal resources,
- lack of marine science policy and lack of long-term research and monitoring, and
- lack of strategic and integrated planning in the marine and coastal environments.

This Theme Report outlines where progress on some of these issues has been made and where progress is still required, but it is not a repeat of SOMER.

The major element of progress towards integrated management is the development of Australia's Oceans Policy (AOP) in 1998 which sets out a framework for the integrated planning and management of our ocean environment. The AOP is supported by the *Wildlife Protection Act* 1982 and the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) to encourage the sustainable use of marine natural resources.

The need for integrated management is nowhere clearer than in the link between activities on the land and the effects on coastal resources and environments. In the past, management has often been compartmentalised, with various government agencies focusing on separate issues in accordance with their responsibility. The challenge for management is to deal with the whole catchment, from watershed to coast, as a single system, and to integrate action across the many agencies involved in coastal management. Management of ocean resources also requires integration.

State of the Environment reporting

State of the Environment reporting is a tool for providing timely and accessible information to decision makers, the public, industry, non-government organisations and all levels of government about the condition and prospects of the Australian environment. It allows regular reports of trends in environmental conditions and their implications for maintaining ecological processes and systems.The approach to national State of the Environment reporting in Australia is to use a modified version of the OECD's 'pressure–condition–response' model to include an examination of the implications for the environment of the condition, pressures and responses.

A suite of national-scale environmental indicators has been developed (Ward et al. 1998), but so far there has been little progress on compiling the data for these indicators at the national scale. Data for each indicator are generally available for small areas, or for only some jurisdictions, and in many cases have been derived to deal with specific management issues of local concern. The scientific models needed to derive national-scale information from such patchy and non-coherent data are in their infancy, and considerable further development is needed in order to be able to compile and fully utilise (for SoE purposes) the large amounts of existing data held by the various jurisdictions, the private sector, and in the community, NGO and Indigenous groups.

The data used for this report has been synthesised from the best available sources, but nonetheless there are large gaps. This has greatly constrained the nature of the assessment and limited the ability to determine with any certainty the nature and extent of any possible changes in the condition of the environment. Maps and other data presented in this report must be considered to be indicative of the best knowledge that could be compiled.

Key findings of the 1996 report

- **The knowledge base** was inadequate for most areas of the estuarine and marine environments.
- **Habitat loss and degradation** Increasing coastal development, industry and urbanisation had reduced or degraded water quality and habitat elements (e.g. vegetation, beaches) particularly in the south-east and south-west.
- **Nutrient runoff** Excessive nitrates and phosphates flowing into estuaries and bays were causing algal blooms, deteriorating water quality and may have affected inshore corals.
- **Poor water quality** caused by high nutrient and sediment loads was a feature of many Australian estuaries.
- **Coastal pollution** There were localised 'hot spots' off urban and industrial coasts, mostly land-based sources, there was a need for national strategic planning.
- **Coastal vegetation** There was an extensive clearing or serious decline in area, particularly of seagrasses, mangroves and saltmarshes. Seagrass decline was especially serious as there was little regeneration.
- **Fisheries stocks** Most were fully exploited, with little room for further development; management regimes were partially effective and improving; the effects of fishing on habitat and non-target species were largely unknown.
- **Seafood quality** was generally very high around Australia.
- **Introduced pests** threatened most natural ecosystems and mariculture.
- **Integrated management** There was a need for catchment/large marine ecosystem approach. Only the Great Barrier Reef Marine Park had integrated management.
- **Marine reserves** A national representative system was under way.

Habitats and species

Environmental indicators reported in this section:

Environmental Indicator	
CO 1.1	Marine species, rare, endangered and threatened
CO 1.3	Seabird populations
CO 2.3	Coral reef area
CO 2. 4	Dune vegetation
CO 2.7	Mangrove area
CO 2.8	Saltmarsh area
CO 2.9	Seagrass area
CO 3.6	Fish populations

Australia's marine and estuarine habitats are diverse in nature, vary greatly in scale, and are interconnected in a variety of ways.

Coastal and estuarine habitats are closely linked with upstream catchments and the associated land uses, all of which have an effect on the condition of these habitats. The concept of a land water continuum is also well established in the Indigenous world view.

The following sections describe the current condition of significant coastal and marine habitats and the species that frequent them, where data and information permit. Where these habitats or species are under pressure, the pressures are described and any response to these pressures is reported.

Many of the indicators for habitats are for the areal extent of a particular habitat. However, the surface area of a viable habitat type is recognised as a very crude measure of ecological health or ecological value. Similarly, the protected area of a habitat does not give a definitive indication of the area that should be protected or be managed in different ways.

Mangroves [CO Indicator 2.7]

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

Mangroves are our marine forests and are highly productive ecosystems. They are a vital habitat and nursery area for juvenile fish, crabs and prawns. Some Indigenous foods are obtained from mangrove environments, e.g. boring bivalves (*Teredo*), mud clams (*Geloina*) and mud crabs (*Scylla*). Mangroves also provide a natural barrier to storm surges; in more sheltered areas they stabilise large areas of mud and sediments, while in the tropics they also stabilise exposed low-slope coastlines.

Australia has the third largest area of mangroves in the world, totalling 11 500 km^2 (Zann and Kailola 1995). The 43 species found in Australia represent 58% of the world's mangrove diversity, with one species occurring widely in southern Australia. The highest species richness occurs in the wet tropics.

For mapping purposes, mangrove populations are essentially linear features of the coastline. In these small maps it was necessary to enhance their display at the continental scale. Figure 4 represents total richness of mangrove species across a geographic segment of coastline. The actual distribution of mangroves around the coast is displayed in Figure 5. The two maps should be viewed in conjunction. A symbolic linear representation has been employed in Figure 5 to heighten visibility. Data for all patches of mangroves greater than 1 km^2 in area, including those on islands, were mapped. Despite this enhancement the smallest areas mapped are not visible in a map of this size. These maps were compiled from all the data available, but mangrove mapping has not been completed for the whole of Australia.

Figures 4 and 5 indicate that mangrove species richness and area of mangroves are greatest in the northern part of the country and are closely related to both lower latitudes and

greater rainfall. At present, no species are regarded as threatened so the area of mangroves (Figure 5) is a more critical indicator of ecosystem health.

The area of mangroves appears to have increased naturally at a number of locations, usually colonising areas of sediment accretion, as in Trinity Inlet, Cairns (Wolanski and Duke 2001).

The major causes of the reduction in mangrove habitat are clearing for industrial development, agricultural and urban expansion, and changes to drainage. Significant habitat reduction has occurred near several major cities, and localised destruction has occurred near many smaller coastal cities and towns. Mangroves at the southern end of the range, for example in Port Phillip Bay and Barwon Heads, are at risk. Population growth in rapidly expanding areas of the coastal zone continues to be the major pressure upon mangroves.

Some of Australia's mangroves are protected through such means as marine protected areas or fish habitats. In Queensland, for example, there are currently 79 declared Fish Habitat Areas covering 603 000 hectares of tidal wetlands (Beumer et al. 1997).

The consequences of local destruction of mangroves are lower fish productivity and loss of water quality.

Saltmarshes [CO Indicator 2.8]

These intertidal saltwater wetlands habitats comprise low herbaceous shrubs and grasses, on mainly low energy shorelines, often behind mangroves.

Saltmarshes are an important ecosystem and provide nursery areas for a range of fish and invertebrate species, roosting sites for many migratory shorebirds, and habitat for endangered species such as the Orange-Bellied Parrot.

The diversity of saltmarsh species is greatest in the southern temperate areas of Australia; Victorian and Tasmanian saltmarshes may contain up to 50 species (Zann 1995). Tropical saltmarshes contain fewer than 10 species.

It is not possible to document either the extent of saltmarsh habitat or the extent of habitat loss as the data is not available on a continental scale. Although there has been loss of saltmarsh habitat in the past, there is no inventory at State or national levels and little new information since 1996. In 1996 the best estimate of areas of saltmarsh was 13 595 km^2, based mainly on remote sensing data.

Table 1: Area of estuarine saltmarsh habitat in Australia.

State/Territory	Area (km^2)
NSW	57
Vic	125
Tas	37
SA	84
WA	2965
NT	5005
Qld	5322
Total	13 595

Source: Bucher and Saenger (1991), cited in Zann (1995).

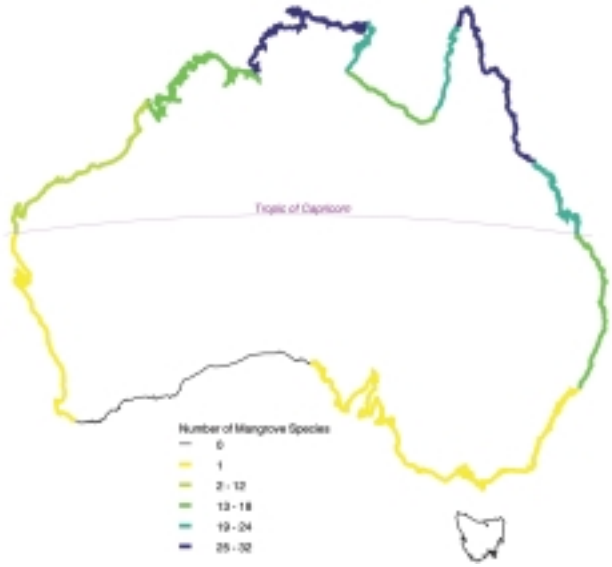


Figure 4: Mangrove species richness for continental Australia.

Source: Environment Australia (2000).

Figure 5: Indicative mangrove distribution in continental Australia.

Source: Environment Australia (2000).

Saltmarshes are sensitive to a range of pressures, including land reclamation in urban areas, alteration of land management practices in catchments, regulation of freshwater and tidal flows, invasion by weeds, and drainage for mosquito and midge control.

Vegetation on saltmarshes is being damaged or removed by activities such as cattle grazing, the use of off-road vehicles, and changing drainage regimes to control pest insect populations (Thomas and Connolly 2001). Pressures on saltflats could, in the future, include the development of aquaculture sites on what may be seen as unproductive land. Saltflats are particularly vulnerable to sea-level rise.

Decline in saltmarsh habitat on a continental scale may appear to be quite small. However, because reductions are concentrated in the south-east of the continent where saltmarsh areas are smallest, but support the greatest diversity of species, their significance is disproportionate to their extent. Several researchers, such as Wilton (2001) and Saintilan & Williams (2000), reported landward expansion of mangroves into saltmarsh habitat. In some cases the rate of mangrove encroachment is high, for example between 10 and 17 metres per year over 30 years on the eastern shore of Gulf St Vincent. The trend is not universal, however, with mangrove–saltmarsh boundaries in many estuaries being stable.

Saltflats

Saltflats are saline, mostly dry habitats in the tropical north that are devoid of large plants. They may be subject to tidal inundation.

Saltflats are common in Australia, with extensive areas in the southern region of the Gulf of Carpenteria where there are some 4000 km^2 (Ridd et al. 1988). Although there are few plants, saltflats do support much algal growth, and algal mats can be found on some saltflats. Occasional tidal inundation of saltflats during summer in this region allows salt and nutrients in outflowing waters to reach the nearshore waters of the Gulf of Carpenteria. The ecological effects of this outflowing are unknown but may be important to the survival of juvenile prawns in the Gulf of Carpenteria.

There has not been much research on the ecological value of saltflat habitat to date.

Seagrasses [CO Indicator 2.9]

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 in low densities, widely scattered in nearshore areas.

Seagrasses represent our productive, shallow marine pastures that provide important nursery habitat for juvenile fish and prawns or feeding grounds for birds. Seagrasses also provide a vital sediment-trapping and stabilising mechanism for some coastal areas. They are a critical habitat for many commercial fish and invertebrates. In tropical areas seagrasses serve as the staple diet of Dugongs and adult green turtles. The Dugong's specialist requirement for seagrass habitat makes it vulnerable to changes in seagrass locations and extent.

Australia has the highest diversity of seagrasses (both temperate and tropical) in the world, with about 30 species relatively evenly distributed around Australia. It has the greatest area of temperate seagrasses and, as large sections of the north-west coast have yet to be surveyed at any scale, possibly also of tropical seagrasses.

Figure 6 is an indicative map of the distribution and sites of disturbance of seagrass. For mapping purposes, seagrasses are essentially linear features of the coastline. A symbolic linear interpretation has been employed, except in Torres Strait where the area is sufficiently large to be represented naturally. All areas of mangroves greater than 1 km^2, including those on islands were included. However, many significantly larger areas are still not visible in a map of this size. This map represents all the data available, but seagrass mapping has not been completed for all of Australia.

The best current estimate of total area is 51 000 square kilometres (Cappo et al. 1998) with Western Australia and Queensland having significant areas of seagrass. The recent discovery of deepwater beds in the Great Barrier Reef World Heritage Area indicates that our knowledge of seagrass is still expanding.

Data on seagrass, algae, benthos and sediment composition in the Great Barrier Reef region has been obtained during a six-year survey (Coles et al. 2000). Seagrasses were surveyed to depths of 60 metres and found at 33% of the sites over the area. From these surveys it is estimated that 40 000 km^2 of lagoon and inter-reef area has at least some seagrass. The

Seagrass-Watch: community-based monitoring of seagrass resources

The Seagrass-Watch program, established in 1998 as an initiative of the Queensland Department of Primary Industries, involves local community groups in mapping and monitoring seagrass habitats vital for fisheries, turtles and Dugongs.

Seagrass-Watch programs have been established in the Hervey Bay and Whitsundays regions of Queensland with the aim of providing an early warning of change in the seagrasses of each region.

Mapping of seagrass communities by trained community volunteers and seagrass researchers resulted in the successful mapping of 22% of the sites in a detailed baseline survey of Hervey Bay and Great Sandy Straits region in December 1998.

Long-term monitoring sites, including areas of high impacts and 'control' sites, have been established at eight locations.

Seagrass-Watch data and associated geographic information systems (GIS) outputs have been used by environment management agencies for:

- responses to dredging proposals,
- an assessment of flooding impacts,
- world heritage value assessments for World Heritage Area listings,
- regional and local Plans of Management, and
- input to the management of Dugong Protection Areas.

Current levels of interest in Seagrass-Watch are high, but maintaining the effectiveness of the program will require continued government support. Further expansion of the program is expected as Aboriginal and Torres Strait Islander communities, and volunteer groups in other areas become involved in the management of their local seagrass resources.

The Seagrass-Watch program is funded by the Natural Heritage Trust—Coasts and Clean Seas Initiative, CRC for the Great Barrier Reef World Heritage Area, Queensland Parks and Wildlife Service and the Queensland Department of Primary Industries.

Source: McKenzie et al. (2000).

Seagrass monitoring in the Whitsundays.

Source: Queensland Department of Primary Industries.

ecological role of inter-reef seagrasses and algae is not well understood. Both shallow and deepwater meadows of *Halophila ovalis* and *Halophila spinulosa* are important Dugong feeding habitat. This seagrass and benthic community data comprises one of the major databases supporting the development of a multi-use zone plan designed to maintain reef biodiversity, and which will eventually determine the location of activities in the Great Barrier Reef Marine Park.

The greatest reduction in seagrass areas has generally been in the tropics, where the causes are mostly natural (cyclones, flooding) but aggravated by anthropogenic effects such as increased sediment discharge. In the tropics many species are seasonal and regrow quickly.

In temperate waters, such as Western Port in Victoria, where disturbances are mostly human induced, the reduction has been proportionately greater and in most cases is irreversible. The dominant temperate seagrass is *Posidonia* which make take many decades to regrow so their recovery is not practically achieveable. Attempts to replant *Posidonia* have failed to date.

Kirkman (1997) estimated the reduction of seagrass during the previous 10 years as a result of human activities to be 450 km^2, and the loss resulting from natural events to be 1000 km^2. Seagrass meadows have declined in Cockburn Sound, Western Australia, because of nutrient discharges that began in the 1950s (see 'Nutrients affecting the Cockburn Sound environment' on page 55). Declines in a

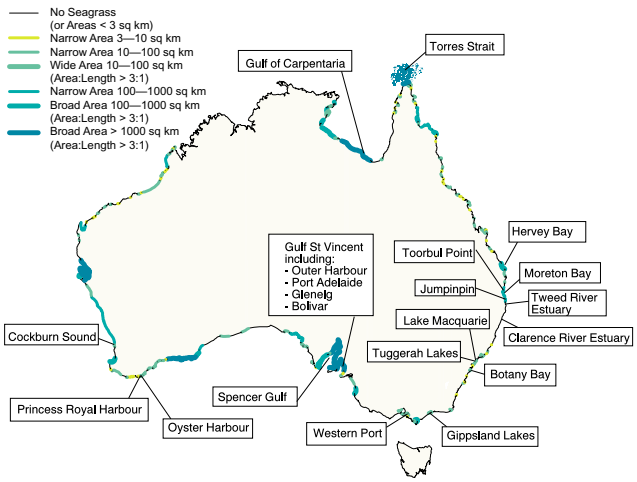


Figure 6: Seagrasses In Australia: indicative distribution and sites of disturbance in continental Australia.

Source: Distribution data compiled from State and Commonwealth sources by Environment Australia (2000) and Kirkman (1997).

range of fisheries have been observed following the reduction in seagrass areas (Butler and Jernakov 1999).

Beds of *Posidonia* have, in the past, been dug up for sand mining. Less than half a hectare of *Posidonia* has been replanted in response to mining of many hectares of seagrass. The ecological success and the persistence of the transplants is quite uncertain.

An emerging threat to seagrass in south-east Queensland is the increased incidence and scale of *Lyngbya* outbreaks in Moreton Bay. *Lyngbya* blooms (see page 63) smother seagrass beds.

Some measures have been undertaken to halt the reduction in seagrass habitats. Seagrasses are protected plants under the *Queensland Fisheries Act 1994*. In the Great Barrier Reef Marine Park, for example, trawling has been prohibited by Marine Park zoning plans in nearly half the mapped seagrass areas, and in additional areas by coastal strip closures. Offshore beds are less protected (Wachenfeld et al. 1998). Some sewage outfalls and stormwater outfalls have been relocated away from seagrass beds.

Beaches and dunes [CO Indicator 2.4]

Beaches and dunes are the sandy beaches of the open coast and the gulfs and bays, together with their associated foredune systems, including both windward and leeward slopes.

Beaches and dunes are among the best-known coastal habitats because of the relative ease of access and the high use they receive. They are also sites of significance to Indigenous people, not only for food collection but also as living places with strong cultural associations.

Dunes and sandy beaches account for over 50% of Australia's coastline and are places of great dynamism. Sand migrates along the coastline under the influence of waves, currents and wind and, according to conditions, sand may accumulate or erode at any given place along the coast. In South Australia, New South Wales and on the Gold Coast, beach erosion is a major problem (see page 47).

Vegetation plays an important role in stabilising sand dunes to buffer the coast against periods of erosion. A recent survey (Sinclair Knight Merz 1998) indicates that dune vegetation has the lowest profile in our knowledge of coastal vegetation, and very few data sets were identified. One of the most detailed was a dune vegetation survey in New South Wales some 10 years ago.

Dunes, beaches and similar foreshores constitute important breeding habitat for a number of animals, including (in southern states) the Little Penguin, pelicans, gulls, terns, and (in the tropics) turtles. The beaches of remote islands and shores are also used extensively by birds and turtles for nest-building, and in many places birds use such beaches for feeding and roosting.

Beach fauna is varied and includes smaller animals such as crabs and other crustaceans, amphipods (sand-hoppers), polychaete worms, bivalve molluscs like the Pipi, and gastropod molluscs (snails). Numerous microscopic organisms live on and between the sand grains that make up a beach. The most abundant animal groups are the marine worms (nematodes), followed by crustaceans and shellfish.

Few studies relating to the monitoring of beach species have been published, and providing an overview of beach condition (even of selected reference sites) is a long way off. Quantifying beach species is complicated by the fact that animals and plants distribute themselves three-dimensionally (depth and surface position) on a beach, and many species actively migrate up and down a beach according to the state of the tide.

The major pressures on sandy beaches and dunes are urbanisation and developments associated with tourism. Other uses that place pressure on beaches and dunes are sand mining, structures such as groynes and breakwaters that impede sand movements, and recreational activities including vehicle access.

There can be severe effects on dune systems as a result of clearing and modification. In places such as the Gold Coast, there is very little unmodified coastal habitat remaining because of the pressures caused by urban settlements along the coastal strip.

Dune vegetation has been extensively cleared for urban development, agriculture and sand mining. For example in Tasmania, the beach/dune areas around urban centres (Hobart, Burnie, Devonport) are heavily modified. Other heavily modified beach dune areas in urban centres are Perth and Bondi Beach in Sydney. Port developments have also caused significant modification.

Estuaries

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

Estuaries are an important part of Australia's coastal environment, and are the preferred sites for many settlements and for industry and ports. Australia has over 1000 estuaries of varying size, diversity of habitat, accessibility and uses, of which 783 are regarded as major estuaries.

Australia's estuaries have important differences from those in other parts of the world (Digby et al. 1999). Drowned river valleys are poorly represented, most being in central New South Wales and Tasmania. In the south-east and the south-west, shallow barrier estuaries predominate. Along the Timor Sea and Gulf of Carpentaria most estuaries are deltas.

Type of Coastal Environment	Sediment Trapping Efficiency	Turbidity	Circulation	Habitat Loss due to Sedimentation
Tide-dominated Delta	Low	Naturally High	Well Mixed	Low Risk
Wave-dominated Delta	Low	Naturally Low	Salt Wedge/ Partially Mixed	Low Risk
Tide-dominated Estuary	Moderate	Naturally High	Well Mixed	Some Risk
Wave-dominated Estuary	High	Naturally Low	Salt Wedge/ Partially Mixed	High Risk
Tidal Flats	Low	Naturally High	Well Mixed	Low Risk
Strand Plains	Low	Naturally Low	Negative/ Salt Wedge/ Partially Mixed	Low Risk

Figure 7: Relative importance of estuary type to its susceptibility to impacts.

Source: Commonwealth of Australia (2001a).

Well-mixed estuaries, which predominate on the east coast, are due to a large tidal range with low river runoff. A regime of high runoff and low tidal range favours stratified estuaries like those in Tasmania. Australia's rainfall patterns—highly seasonal in the wet tropics, and erratic elsewhere—means that many rivers vary dramatically in the freshwater discharge to their estuary. In fact, discharges during flood events, compared to mean runoff, are far greater in Australia than elsewhere in the world. These characteristics contribute to the widely varying physical conditions found in Australian estuaries, as summarised in Figure 7.

Water quality in estuaries is a function of the nutrient loads and processes occurring in the estuary itself (Harris 2001). In the case of Australian estuaries, the nitrogen inputs tend to be low because the freshwater runoff from the land is relatively low. Water residence times in the estuary may be long, and water quality is often a function of tidal flushing. Australian estuaries are predominantly nitrogen-limited because of efficient denitrification of the nitrogen loads. However, there are situations where estuaries can be phosphorus-limiting and where the limitation fluctuates between nitrogen and phosphorus on a seasonal basis.

There have been several studies of estuaries over the past five years, including those of the Derwent Estuary in Tasmania (Coughanowr 1997) and the Tamar Estuary in Tasmania (Pirzl and Coughanowr 1997). The Huon Estuary Study has been a three-year research program to improve knowledge and provide a scientific framework for the management of the estuarine zone of the Huon River in Tasmania (FRDC 2001). It is Tasmania's most valuable estuary; with salmon production and processing valued at $80 million. Key environmental issues in the Huon Estuary are associated with the effects and fate of nutrient and organic matter loads from the catchment, from coastal waters, and from activities in the estuary, especially salmon farming.

The key findings include:

- the water quality of the Huon Estuary is good, and that of its two principal sources—the Huon River and the D'Entrecasteaux Channel—is very high.
- nitrogen distributions and algal production in the estuary are supported primarily by inputs from coastal seawaters, thus algal blooms can be regarded as occurring naturally. However, available nitrogen from either fish farms or agricultural activities in the lower catchments may play a role in stimulating algal blooms.
- fallowing, or resting fish farm sites, allows sediment conditions to recover, but some of the added organic matter still remains one year after the cages have been removed.

A current National Land and Water Resources Audit project (Commonwealth of Australia 2001a) is assessing the condition of all Australia's estuaries and will provide management recommendations for estuaries. The project is being undertaken because there has been very little focus on the environmental aspects of estuaries in the past. For example, there is no nationally acceptable definition of 'estuary'.

The initial (the project concludes in 2002) condition assessment of 972 estuaries is that about half of Australia's estuaries are in a modified condition. The remainder that are in good condition, are relatively small and inaccessible estuaries.

Table 2: **Australian estuaries within each process type and condition class.**

Class	Subclass	Near Pristine	Largely Unmodified	Modified	Extensively Modified	Total
Wave	Wave-Dominated Estuary	28	41	62	25	156
	Strandplain	36	13	10	1	60
	Other	40	30	22	17	109
Tide	Tide-Dominated Estuary	57	25	9	4	95
	Tidal Flat/Creek	210	43	16	15	284
	Other	40	17	23	9	89
River	Wave-Dominated Delta	28	24	30	12	94
	Tide-Dominated Delta	36	16	11	9	72
Other	Other	9	1	3	0	13
	Total	484	210	186	92	972

Source: Commonwealth of Australia (2001a).

Most nutrients, contaminants and sediments flow into estuaries during flood events. In some cases these events are sufficiently large to carry these materials through the estuary into the open sea.

Changes to flow regimes of rivers can affect estuaries. A reduced river flow, for example, may reduce flushing and hence affect water quality. Such changes to flow regimes could occur through the construction of tidal barriers or dams and weirs in the catchments. These barriers not only restrict water flow but also restrict fish movements. Habitat changes could also occur as a result of changes in hydrological cycles.

Current trends in estuary management include a greater emphasis on community involvement and on the incorporation of Indigenous traditional knowledge. A recent study by Smith (2001) found that approaches to Australian estuary management are highly diverse and variable. The reasons include different ministerial and departmental distributions of powers and responsibilities, together with different natural resource legislation of States and Territories.

The condition of an estuary

Macquarie Harbour, an area of 290 km^2 and up to 50 metres deep, is Australia's biggest estuary. It is located on the west coast of Tasmania; the Gordon and the King Rivers flow into the estuary.

The water column is typically three-layered: fresh, marine, and intermediate, trending to a salt wedge structure near the two rivers. Estuarine conditions can extend many kilometres upstream.

The main land uses in the catchment are national parks and tourism, mining, forestry, port operations, aquaculture, and hydroelectic power generation.

Since the 1880s, mine water and tailings have been discharged from the Mount Lyell copper mine via the King River, resulting in an estimated 100 million cubic metres of solids containing toxic metals settling on the banks and bed of the King River and in a delta in Macquarie Harbour. Tailings are no longer discharged, but acidic water still drains into the King River. Measurements in 1998 showed an average of two tonnes of copper per day was contained in drainage from the Mt Lyell site.

Despite this legacy, tourism attracts around 200 000 visitors a year, and fish farming is an important industry.

After the closure of the mine and cessation of alkaline tailings addition to the river, the levels of copper and acidity have increased due to remobilisation of the metals from the sediments in the river and the estuary. Typically, in areas where 100 to 200 parts per billion (ppb) were normal during mine operation, 400–500 ppb became the norm after its closure.

The bottom sediments of Macquarie Harbour contain very high concentrations of copper, lead, iron and manganese. In some surface sediments the metals exceed the binding capacity, so these are a source of metals to the water column. This secondary contamination is gradually spreading further south.

The response to this complex problem has included the Mount Lyell Remediation Research and Demonstration project, embracing the mine site, the King River and Macquarie Harbour. A three-year program was coordinated by Environment Tasmania to assess the situation and provide information for future management. Based on these results, Riverworks Tasmania, a joint Commonwealth–Tasmania program, commissioned pilot trials of treatment procedures for acidic drainage from the Mount Lyell site. Subsequently, under the Strategic Natural Heritage Plan for Tasmania, $7.5 million was allocated for the remediation of the King River and Macquarie Harbour through the construction of a water treatment plant.

Intertidal mudflats

Much of Australia's shore comprises mudflats that are subject to tidal inundation. They are rich in species and frequently are the homes to migratory shorebirds.

Large areas of intertidal mudflats are located in Port Phillip Bay in Victoria, Botany Bay in Sydney, Moreton Bay in Queensland and Roebuck Bay in Western Australia.

Intertidal mudflats are ecologically important, particularly in areas where there are high tidal ranges. Research on intertidal mudflats has been neglected in Australia in favour of studies on coral reefs, rocky seashores and vegetated habitats within estuaries (Fairweather and Quin 1995).

One of the most extensive studies has been conducted in Roebuck Bay in northern Western Australia. This study confirmed the importance of the intertidal mudflats as habitat for migratory shorebirds, and as a diverse habitat in its own right (Pearson et al. 1999). About 200 taxa (species, families or larger groupings) were recognised. This was possibly one of the first detailed studies of benthic biodiversity on tropical intertidal mudflats.

This vast expanse of intertidal sand and mudflat is the first Australian landfall for tens of thousands of migratory shorebirds from August to April. The benthic animals provide food on both inward and outward legs of their migration.

Detailed studies of the benthic fauna were part of this study in Roebuck Bay. They show that the most abundant animals are polychaete worms (about 70%) followed by bivalves (13%) and crustacea (10%) (Pepping 1999). These are distributed quite unevenly both in their proportions and in total density.

The authors concluded there was an urgent need to standardise the methodology of intertidal studies world-wide, as few studies have so far been conducted that are comparable. A better understanding of intertidal ecosystems is needed before these coastal habitats are affected by human impacts.

Gulfs and bays

Gulfs and bays are large (greater than 200 km^2 surface area), open (or already open) and shallow (less than 50 metres in depth) coastal waters; typically they are dominated by marine conditions except where rivers flow into them.

The sheltered nature of bays lends itself to the deposition of sediments, fine muds or sand. These soft bottoms form an important habitat for benthic species sensitive to extreme wave energy, but also act as a 'sink' for those pollutants which readily attach to solids.

Important studies conducted over the past five or more years that assessed the condition of bays include:

- Jervis Bay, New South Wales, baseline studies (CSIRO 1989),
- Storm Bay, Tasmania (Harris et al. 1991),
- the Port Phillip Bay Study, Victoria (Harris et al. 1996),
- the Southern Metropolitan Coastal Waters Study in Western Australia (DEPWA 1996), and
- the Moreton Bay Study, Queensland (Dennison and Abal 1999).

Only in the case of Storm Bay were natural processes the main determinants of condition, other bays being degraded over at least part of their area. Port Phillip Bay was found to be close to its critical nitrogen loading, which was also the case for parts of Moreton Bay. General degradation was greater in the west of Moreton Bay than in the east. The South Metropolitan Coastal Waters Study found that water quality problems had not been solved, Cockburn Sound in particular suffering tributyl tin (TBT) contamination and declining seagrass meadows. Jervis Bay maintained a rich and diverse fauna, despite the increased nutrients and turbidity that follow prolonged rainfall. Introduced organisms were identified as serious problems in both Port Phillip Bay and Cockburn Sound.

In the far north, fewer comprehensive studies of bays have been done, partly because of the lower pressures of population and pollution. However, Hervey Bay to the north of Brisbane is much larger than Moreton Bay, is more rapidly flushed and has less development, but has nonetheless seen dramatic loss of seagrass (Lee Long et al. 2000).

Moreton Bay study

Moreton Bay is a medium-sized shallow lagoon east of Brisbane, separated from the open ocean by Moreton Island and North and South Stradbroke Islands. High sediment loads can be discharged to the estuary after rain, and there are high nutrient loads from agricultural and wastewater discharges. Seagrasses are found on both eastern and western shores, where they provide food for turtles and Dugong.

The objective of the Moreton Bay Study (Dennison and Abal 1999) was to develop an integrated strategy to improve water quality in Moreton Bay and the adjoining rivers. It was undertaken by several organisations (six local councils, State and Commonwealth governments, universities, and consultants). The overall conclusions of the study were that river estuaries and western portions of the bay showed degradation, but that rich and diverse ecosystems of eastern and northern Moreton Bay were 'essentially intact'.

A Moreton Bay 'report card' (Greenfield 2000) ranked the condition of the seven bays, from A to F. Eastern Bay received an A on the basis it was well flushed, and there were extensive seagrass beds supporting Dugongs and turtles. Southern Deception Bay received a C to D rating because of seagrass loss and high turbidity.

Productivity is limited mainly by nitrogen, except where turbidity reduced light levels in the water. In general seagrass declined as turbidity increased.

Much of the degradation is relatively recent. Nitrate concentrations in the Brisbane River increased twenty-twofold from 1950 to 1996, phosphate concentrations increased elevenfold, while suspended solid concentrations quadrupled. Nitrate and phosphate concentrations in Moreton Bay increased two to eightfold over the same period. Management strategies have focused on reducing nitrogen loadings to the Bay.

Stage 3 of the Study is assessing upper catchment issues as they relate to the quality of the rivers and estuaries. Responses to the conditions of some bays that have been affected by land uses have included:

- the establishment of a multi-agency group to coordinate improvements,
- the upgrade of wastewater treatment plants, and
- the protection of vulnerable habitat through a variety of mechanisms.

Coral reefs [CO Indicator 2.3]

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

Coral reefs are exceptionally diverse marine ecosystems that thrive in relatively low nutrient tropical waters. Australia has the largest area of coral reefs in the world, including some of the most diverse and well known internationally.

A global assessment of reefs (Wilkinson 2000) shows continuing decline—about 25% of the world's reefs have been effectively lost. The largest single cause has been the massive climate-related coral bleaching event of 1998, which destroyed about 16% of the world's coral reefs in nine months. Probably half of these reefs will never recover. The bleaching event was indiscriminate: impacts were equally severe on pristine, remote reefs as on reefs already under major human stresses. Coral bleaching occurs when the water temperature exceeds a certain threshold, usually just over 30°C, and the symbiotic algae in the coral tissues are expelled, allowing the white calcium carbonate skeleton to show through the clear animal tissue cover. If the temperature remains high for more than a few weeks the coral dies.

Australia was fortunate in 1998 that only 3% of reefs were destroyed from bleaching. It was also estimated that a further 1% of Australia's coral reefs have been destroyed from other causes, including sediment and nutrient runoff from land, increased recreational and commercial fishing, the Crown of Thorns Starfish, mining of sand and rocks.

Australia's coral reef systems include:

- Great Barrier Reef system in Queensland of some 2300 km in length,
- Ningaloo Reef off the Western Australian coast,
- High-latitude coral reefs, e.g. the Solitary Islands off the New South Wales coast; Elizabeth and Middleton Reefs on the Lord Howe Rise; and Flinders Reef off Brisbane,
- Torres Strait reefs,
- Coral Sea reefs, e.g. the Coringa–Herald Reserve system and the Lihou Reef which is the largest reef system in the Coral Sea,
- North West Shelf reefs, e.g. Ashmore Reef off Western Australia, Scott (a pinnacle) and Seringapatam Reefs and Rowley Shoals (marine park), Australia's only 'shelf-edge atolls',

Ningaloo Marine Park

Ningaloo Reef is Australia's largest fringing reef, stretching 230 km along a very lightly populated coastline.

Ningaloo Reef has an estimated 300 species of coral, 500 fish species and 600 mollusc species. The Marine Park lies on the migration path of the Humpback Whale, is home to turtles and Dugongs, and regularly hosts migratory birds. It is the only place in the world known to be visited regularly and in significant numbers by the Whale Shark (*Rhincodon typus*).

It is a marine park under both Western Australian legislation (for the inshore waters) and Commonwealth legislation (for offshore waters). Ningaloo Marine Park is the site of a burgeoning tourism industry.

Recent monitoring surveys of the Ningaloo Marine Park show that, apart from a few localised areas, the benthic communities in the park, including corals and macroalgae, are in excellent condition. The results suggest that the impact of human activity in the park is minimal, compared to natural events. Most evidence of human activity is litter associated with recreational fishing activities, particularly in the vicinity of popular moorings (e.g. Bundegi and Coral Bay) and fishing areas. Coral damage from boat moorings, boats and divers was observed at several locations in the marine park. The most significant damage to coral communities is in the southern Bills Bay area, adjacent to the coastal town of Coral Bay. Coral bleaching has not been extensive and has been observed on relatively few individual colonies.

- Houtman-Abrolhos Islands reef system, offshore from Perth are the most southerly reefs in the Indian Ocean, and
- Cocos (Keeling) atoll, Australia's only true atoll.

Australian coral reefs are under pressures in some locations. These pressures include:

- sediment and nutrient runoff at certain coastal locations is increasing steadily through human activities—primarily the effects of agriculture and land use practices, combined with increasing industrial and urban development,
- increasing recreational and commercial fishing at some locations, and
- increasing pressure for tourism developments in some locations.

The Great Barrier Reef is managed by a special-purpose Great Barrier Reef Marine Park Authority. The Authority developed a 25-year strategic plan for the Great Barrier Reef World Heritage Area in 1994.

Zoning plans have been implemented over the whole of the Great Barrier Reef Marine Park, with several detailed management plans for specific areas. These plans closely regulate human use over thousands of square kilometres. A Representative Areas Program now under way aims to protect the biodiversity of the World Heritage Area by developing a network of highly protected areas that represent all 72 bioregions recently mapped across the Great Barrier Reef.

The protection of reefs and their habitats through designation as National Nature Reserves has been used for the Coringa–Herald and the Lihou Reefs, located on the Coral Sea plateau east of Cairns.

Rocky reefs

Rocky reefs are found in intertidal areas and subtidal areas.

Rocky reefs support a diverse fauna, including many invertebrate species, some of which are valued by people as food. Rock lobster, abalone, Banded Morwong, wrasse, intertidal shellfish and urchins are all harvested commercially on and adjacent to rocky reefs. They form a significant part of the fauna in many bays and on exposed coastlines.

Both intertidal and underwater reefs have considerable natural, recreational and economic value. The underwater reefs support 51% of the total value of Australia's wild fisheries production (Andrews 1999), with most of this from lobster and abalone fisheries.

The submerged rocky reefs in temperate Australia have a very high species diversity and a high proportion of endemic species. Australia's southern coastline has the world's highest diversity of red and brown algae (around 1155 species), bryozoans (lace corals), crustaceans and ascidians (sea squirts).

The Great Barrier Reef Marine Park

The Great Barrier Reef is the largest single reef system in the world, stretching for over 2300 km. It extends from the tropics to the temperate zone, with diverse habitats and reef types. It is the world's largest World Heritage Area, covering about 35 million hectares. The population density is relatively low on the neighbouring lengthy coastline of north-east Australia and shipping activity is moderate compared to other tropical ports like Singapore (Reichelt 2000). The World Heritage Area covers not only coral reefs but also extensive areas of seagrass, mangrove, soft bottom communities and island communities.

The Great Barrier Reef World Heritage Area supports:

- six of the world's seven species of marine turtles,
- the largest Green Turtle breeding areas in the world,
- over 3000 km^2 of seagrass meadows,
- 2000 km^2 of mangroves, including 54% of the world's mangrove biodiversity,
- 2904 coral reefs, built from 359 species of hard coral,
- more than 1500 species of fish,
- 1500 species of sponges, which is 30% of Australia's diversity of sponges,
- 800 species of echinoderms, which is 13% of the world's diversity,
- over 5000 species of molluscs, and
- over one-third of the world's species of soft coral and sea-pens.

The World Heritage Area is also of cultural importance, containing many middens and other archaeological sites of Aboriginal or Torres Strait Islander origin. Some notable examples occur on Lizard and Hinchinbrook Islands, and on Stanley, Cliff and Clack Islands where there are spectacular galleries of rock paintings.

Research on the Great Barrier Reef habitats and species is published by the Great Barrier Reef Marine Park Authority, the Australian Institute of Marine Science, the CRC for the Great Barrier Reef World Heritage Area and others. For example, populations trends in key groups of organisms in the Great Barrier Reef Marine Park has been monitored since 1985 for management purposes (Sweatman et al. 2000).

The Great Barrier Reef is currently in a near-pristine state over large areas, but there are some provisos:

- runoff of freshwater carrying nutrients, sediments and pollutants is affecting the coastal margins of the Great Barrier Reef region,
- water quality in parts of the coastal margin is likely to be in slow decline from cumulative effects of human activities,
- there are areas of local depletion by fishing (both recreational and commercial) near to human settlements,
- the intensity and frequency of outbreak of the Crown of Thorns Starfish (*Acanthaster planci*) is causing a major reduction of living coral over very large areas of the Great Barrier Reef, yet the precise triggers for the outbreaks of this boom-and-bust species remain uncertain, although freshwater runoff has been implicated, and
- shipping in the region is increasing and so is the possibility of an increased number of pilotage accidents.

Macroalgae (seaweeds) tend to form the dominant cover on reefs in shallow waters (< 20 metres deep), while sessile invertebrates such as sponges, ascidians and bryozoans cover rocks in deeper water. Macroalgal communities, composed of the larger red, brown and green algae, occur predominantly in temperate southern Australia waters. One of the most important effects of kelps (the long seaweed fronds) is thought to be their action in attenuating water movement on exposed coasts.

Pressures on rocky reefs include the effects of sewage discharges. Discharge of sewage effluent close to underwater reefs near Sydney, for example, affected reef fish and encrusting assemblages in the vicinity. Following relocation of the discharge, the composition of the encrusting community at the new site changed from one in which algae and sponges were well represented to one dominated by silt and ascidians (Roberts et al. 1998). In the vicinity of the previous cliff face outfall, the reef communities apparently recovered (Underwood and Chapman 1997).

Management of areas of rocky reef habitat includes:

- protection in existing or future marine parks or reserves, e.g. the Macquarie Island marine reserve,
- relocation of sewage and stormwater outfalls, and
- regulation of fishing activities.

Continental shelf and slope

The inner continental shelf encompasses the waters and seabed from the shore to the midshelf (about 50 metres deep). Beyond this is the outer shelf extending to the 'break' (typically 150 metres). The continental slope encompasses the area beyond the shelf break into water depths of 4000 metres or more.

Australia's continental shelf covers about 2.5 million km^2, half of which is less than 50 metres deep. Its width varies from 15 kilometres off the coast of New South Wales to 400 kilometres in the Timor Sea. The North West Shelf is about 350 kilometres wide, and supports Australia's major offshore petroleum production activities.

The continental shelf consists mainly of soft sediments, but in places, may comprise gravel and pavement rock. These form substrate for a large variety of invertebrate species, including sponges and bryozoans. These long-lived communities are of critical importance as habitat and food for fish.

Most of the slope environment is too deep for plants because of the reduced light conditions, and the main living organisms are the animals that live on and in the sediments. The dominant large animals are marine worms, crustaceans, echinoderms (e.g. sea urchins) and shellfish. The epifauna include hydroids, sea-pens, small bryozoans and sponges.

Some studies of this environment have been undertaken in the last five years. Surveys of benthic habitat in the Twofold Shelf region off Victoria yielded over 60 000 individuals from 803 species (Coleman et al. 1997). About half of these species were previously undescribed.

Seamounts

Seamounts are remnants of extinct volcanoes found in Australia's deep marine environment. They are typically cone-shaped, 200 to 500 metres high and several kilometres across. They are between 650 and 1000 metres below the sea surface.

A number of fields of seamounts exist beneath Australian waters, and these tend to have distinctive flora and fauna. One such field of about 70 seamounts lies between 50 and 170 kilometres south of Tasmania, in water 1000 to 2000 metres deep (Figure 8). There are also seamounts and ridges in the Australian marine environment to the east and north-west of Australia.

Seamounts are frequently places of high biodiversity and the Tasmanian seamounts are important as places of aggregation of spawning Orange Roughy. A CSIRO study of southern seamounts (Koslow and Gowlett-Holmes 1998) collected a number of rare and previously undescribed fish species. Further, between 25% and 50% of the invertebrate species collected are believed to be new to science and between 31% and 48% are known only from this region. The diversity of this invertebrate seamount fauna was emphasised by comparing it with world-wide seamount invertebrate fauna.

The fauna of the Tasmanian seamounts are remarkably different from those of seamounts in the northern Tasman Sea (on the Lord Howe Rise and Norfolk Ridge) within the

CSIRO's oceanographic survey ship *Franklin*.

Source: Environment Australia.

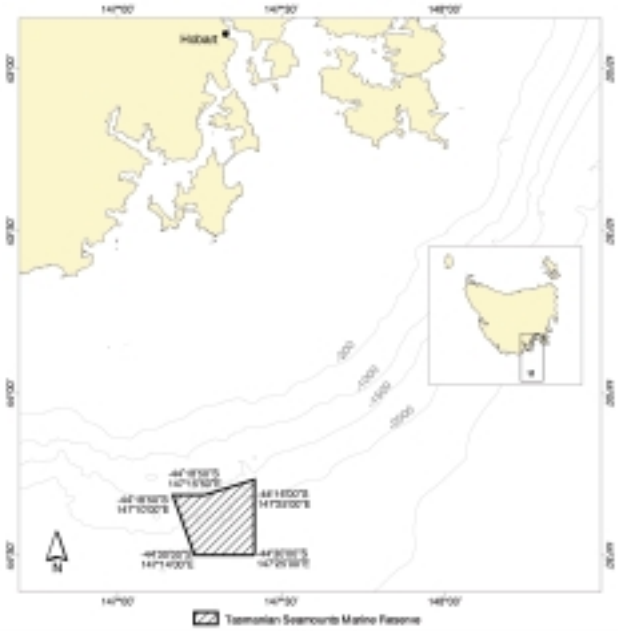


Figure 8: Location of the Tasmanian Seamounts Marine Reserve.

Source: Environment Australia (2000).

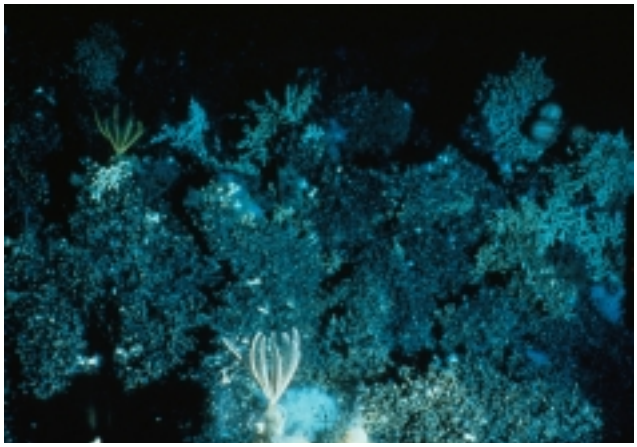
Stalked crinoid or sea lily.

Source: CSIRO Marine Research, Hobart.

EEZ of New Caledonia (de Forges et al. 2000). The biodiversity of other Australian seamounts is still poorly understood and there is little or no information on Antarctic seamounts.

The major pressure on seamounts is commercial fishing. Trawling on the shallow seamounts south of Tasmania has damaged this unique habitat through scraping of the substrate and removing the reef aggregate and associated flora and fauna

The Commonwealth declared the Tasmanian Seamounts Marine Reserve in May 1999, comprising an area of 370 km^2, to protect a sample of the unique bottom-dwelling communities associated with the seamount region. This is the first marine reserve of its type in the world. Under the Tasmanian Seamounts Marine Reserve Management Plan it is proposed to prohibit any commercial activity, below a depth of 500 metres, while in the upper 500 metres there is a multiple use zone, where limited commercial fishing may occur.



Deep ocean coral reef.

Source: CSIRO Marine Research, Hobart.

Basket star.

Source: CSIRO Marine Research, Hobart.

Habitats of Australia's external territories

Australia's seven external territories comprise tropical and temperate islands and a large segment of Antarctica, and include the 200 nm Exclusive Economic Zone surrounding each. The location of several of these islands has resulted in substantial areas of the extended continental shelf being included in Australia's marine area (Figure 2).

Heard Island and McDonald Islands are volcanic in origin and are an undisturbed habitat for sub-Antarctic plants and animals. Heard Island (368 km^2) is dominated by the 2745-metre active volcano Big Ben, whose last major eruption was in 1992. McDonald Island (1 km^2) is the major island in the McDonald Islands group. They might be described as the wildest places on Earth—a smoking volcano under a burden of snow and glacial ice rising above the world's stormiest waters.

All of Australia's uninhabited Island territories are significant breeding sites or migratory staging posts for birds. Ninety-three bird species have been recorded at Ashmore Reef, and 17 breed on the islands. These islands are also important breeding habitat for other species, such as penguins and seals on Heard Island and the McDonald Islands, and turtles and seabirds on and around the tropical islands.

The Antarctic Treaty provides a framework and governing philosophy for the work of nations in the Antarctic, namely the twin ideals of peace and science. Australia was a driving force behind the development and implementation of a Protocol to the Treaty (the Madrid Protocol) in 1998. The Protocol provides the Antarctic with a comprehensive international environmental protection regime.

Antarctic waters have many biological surprises. The biomass of krill rivals that of the human population, while Crabeater Seals may be the most numerous of all the world's larger animals apart from people. At the other size extreme, Antarctic microbes (algae, protozoa and bacteria) can be abundant and diverse in the marine, terrestrial and lake environments. Marine algae in Antarctic waters play a major role in the draw-down of atmospheric carbon dioxide, and some produce chemicals that induce cloud formation that can influence global climate.

Invertebrates

Invertebrate fauna comprises all the very diverse animal taxa other than the phylum Vertebrata—i.e. 'the other 99 per cent' (Lunney and Ponder 1999). Partly owing to the long isolation of southern Australian waters, the diversity of temperate Australian invertebrates is exceptionally high, with many endemic species, particularly in the Great Australian Bight (Edyvane 1998). Australia's tropical waters host a rich diversity of invertebrate species because of their proximity to the Indo-Pacific centre of marine biodiversity and a diversity of available habitats. Most harvested marine fish depend on invertebrates either directly or indirectly, and marine ecosystems and services would largely collapse if invertebrate communities became grossly degraded.

Very little is known about marine invertebrates, apart from the few species that are harvested commercially or recreationally. The following information on some of the invertebrate groups is taken from a draft report commissioned by Environment Australia (Ponder et al. in prep.).

The majority of stony corals are found in tropical and subtropical seas, with around 390 species from the waters surrounding the Australian mainland and another 120 from the external territories. Stony corals are listed under the Convention on International Trade in Endangered Species of Wildlife Flora and Fauna (CITES).

Over 1000 species of echinoderms (sea urchins, starfish, brittle stars, sea cucumbers) have been recorded in the shallow coastal or reef waters of Australia. Sea urchins and sea cucumbers are potentially susceptible to over-harvesting.

About 10 000 marine mollusc species have been described. There are about 25 Australian species of abalone. Shellfish such as abalone, oysters, scallops and pearl oysters, and squid and octopus are commercially harvested. Few mollusc species are threatened at present although CITES lists all members of the family Tridacnidae (giant clams).

Crustaceans are found at all depths in every marine, brackish and freshwater environment. They are ecologically important in a variety of roles, as grazers, scavengers, predators and as prey.

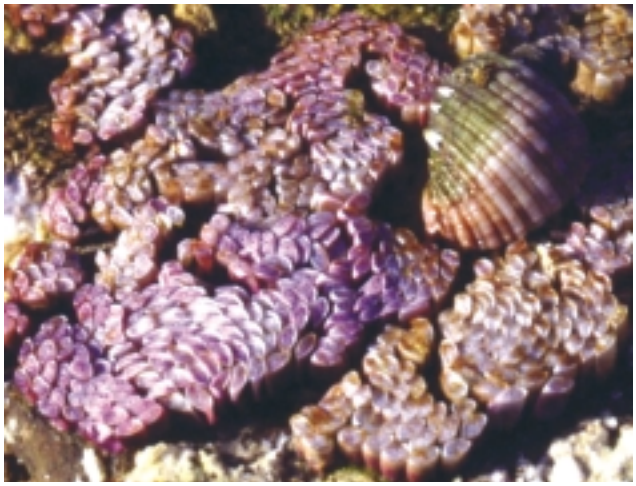
Krill, the 'world's most abundant crustacean', has a key role in southern waters as the staple diet of many seals, whales, fish, squid, penguins and other seabirds, making it uniquely important in the conservation of many other species (Australian Antarctic Division 2000). If krill were to disappear, all of the creatures that feed on them would disappear. It has been fished commercially for over 25 years, the peak catch being 155 000 tonnes in 1981. Currently the annual catch is 100 000 tonnes which is well within 'precautionary' harvest limits set by the Convention on the Conservation of Antarctic Living Marine Resources (CCAMLR). The harvest limit is set in recognition of the importance of krill as food for many other species in the region.

Other crustaceans (such as prawns and lobsters) are fished within the framework of managed fisheries, where harvest levels are set according to catch limits or on the extent of fishing effort that can be used in harvesting. For the majority of crustaceans there is insufficient information to determine whether or not any species are threatened.

Sponges are ecologically important, being host to multitudes of crustaceans, molluscs, worms, echinoderms and microorganisms. They can also be of economic importance as undesirable colonisers of artificial structures, and they have a pharmaceutical potential. Over 1300 species have been recorded in Australian waters. Sponges have been adversely affected by trawling through physical damage and as a significant component of bycatch in some fisheries.

Jellyfish play a significant ecological role as pelagic predators. Fifty species have been recorded in Australian waters.

There are over 900 described and undescribed species of bryozoans in Australian waters, and Australia, together with New Zealand, has the richest bryozoan diversity in the



The marine mollusc *Dicathais orbita*.

Source: K Benkendorff, University of Wollongong.

world. They are economically important as fouling organisms, and the variety of chemical compounds they produce may be useful in the development of medicines. No species are known to be threatened.

A key issue yet to be resolved is the process to be used to unambiguously identify such species and communities.

Protection for invertebrate species can be achieved in some jurisdictions through fisheries or other regulations that prohibit the deliberate destruction or taking of animals in the intertidal or nearshore zones. Habitat and ecological processes protection can be used to conserve invertebrates given their largely unknown and not understood nature.

Listing of threatened communities under EPBC Act and reciprocal State or Territory legislation is another mechanism for protection. So far only one marine community has been listed—the reefs and seagrass flats off San Remo in Victoria—in response to a proposal to develop a large marina on the site. Another special and unique community—the stromatolites of Shark Bay in Western Australia—has been placed in a reserve.

There have been few attempts to restore damaged habitats for the benefit of invertebrates. There has been some transplantation of coral, but its success is very limited. Similarly, seagrass transplantation to restore damaged habitat and degraded invertebrate communities has had only limited success and is very costly.

Fish [CO Indicators 1.1 and 3.6]

All species of fish have ecological as well as commercial or recreational significance and some are threatened or endangered. Fish species that are commercially harvested or fished recreationally are discussed in the fisheries section (see page 66). Only a few hundred species of Australia's fish fauna are harvested in commercial fisheries; the majority of species (several thousand) are not harvested.

Australia has an estimated 4000 to 5000 species of finfish, of which about 80 to 90% have been described. About one-quarter of these species are found only in Australian waters. New species of fish have been discovered in Australia's EEZ, in particular in the upper continental slope (200 to 400 metre depth). However, very little is known about fish species below 1500 metres depth, which comprises the majority of Australia's marine area.

Under the EPBC Act a threatened species may be listed as:

- critically endangered,
- endangered, or
- vulnerable.

The Threatened Species Scientific Committee has outlined criteria that describe each of these categories (http://www.ea.gov.au/biodiversity/threaten/nominations [accessed 5 September 2001]).

It is a requirement of the EPBC Act to prepare recovery plans for all endangered and vulnerable species that occur in Commonwealth areas. The recovery plan must provide for the

Table 3: The conservation status of marine fish listed under the EPBC Act.

Endangered marine fish	
Brachionichthys hirsutus	Spotted Handfish
Vulnerable marine fish	
Carcharodon carcharias	Great White Shark
Carcharias taurus	Grey Nurse Shark
Glyphis sp. A (cf *Glyphis glyphis*)	Speartooth Shark
Sympterichthys sp. [CSIRO #T6.01]	Ziebell's Handfish
Sympterichthys sp. {CSIRO #T1996.01]	Waterfall Bay Handfish
Vulnerable freshwater fish with a marine life stage	
Pristis microdon	Freshwater Sawfish
Prototroctes maraena	Australian Grayling

The Great White Shark

The Great White Shark is relatively uncommon in Australian waters, although its range extends primarily from Moreton Bay in Southern Queensland, around the southern coastline to the North West Cape of Western Australia.

White Sharks are primarily a coastal species and often enter very shallow water in search of prey. They differ from most other sharks in that they are warm-bodied, which has helped them become dominant predators in cool and cold environments.

Great White Sharks are naturally not abundant, are reasonably long-lived, and have low natural mortality and low birth rate. These characteristics mean that Great White Shark populations are poorly adapted to withstand increases in mortality from non-natural sources and, due to their low reproductive potential, would recover slowly if reduced in abundance.

There are no reliable estimates of the number of Great White Sharks in Australian waters. Following international concerns about reported declines in Great White Shark populations, they were listed as vulnerable under the EPBC Act in 1997.

The Great White Shark—a vulnerable species.

Source: B Bruce, CSIRO Marine Research.

Tagged shark.

Source: B Bruce, CSIRO Marine Research.

The Great White Shark is now protected in all Australian State and Commonwealth waters. The Commonwealth Government has developed a draft recovery plan (as at May 2001). It is fully protected in Tasmania, South Australia and Victoria; commercially protected in Western Australia; and protected in New South Wales and Queensland, but with exemptions for beach meshing operations. Additional listings under State threatened species legislation is being considered by Tasmania and Victoria.

With initial funding of $100 000 from the Natural Heritage Trust, CSIRO and a number of agencies and groups have joined forces to collect information about Great White Sharks in Australian waters. The study, begun in 1999, aims to clarify the current population status and to understand the behaviour of the sharks. A juvenile great white, nicknamed Neale, was tagged in March 2001 (http://www.marine.csiro.au/mumeez/sharks/index.html [accessed 5 September 2001]) to enable scientists to track daily and seasonal movement patterns. The information will enable more informed decision-making on white shark conservation management in Australia. However, Neale's tag ceased to transmit in July 2001.

research and management actions necessary to stop the decline of the species so that its chances of long-term survival in nature are maximised.

One of the pressures on sharks and other fish species is shark netting at beaches. Victims of this practice include the Grey Nurse Shark (now thought to be reduced to 1000 individuals), turtles, dolphins, whales and Dugongs. Queensland estimates (EPA 1999a) are that in the last five years fewer than eight turtles died in the nets, 70 being released each year. Information from New South Wales indicates that, over a period of five years, from 1995 until April 2000, shark nets at New South Wales beaches killed 535 sharks and 203 other species. Another 45 sharks and 231 other species were released from shark nets (Davey 2000). The other species included rays, finfish, dolphins, seals, turtles and whales.

A recovery plan has been prepared for the Spotted Handfish and draft (as at May 2001) plans for the Great White Shark and the Grey Nurse Shark. There is an action plan for the Australian Grayling.

The Spotted Handfish

Handfish are small, unusual, slow fish that prefer to 'walk' on their pectoral and pelvic fins rather than swim. The pectoral or side fins are leg-like, with their extremities resembling a human hand (hence their common name).

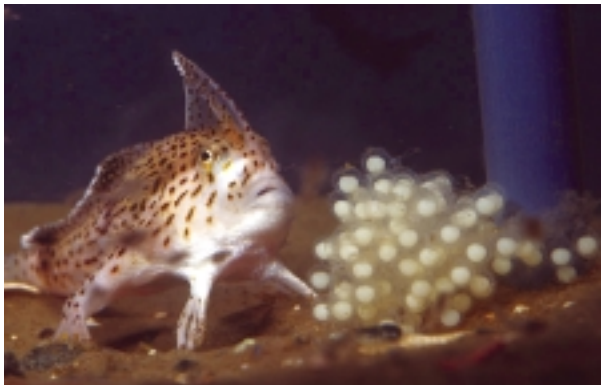
Handfish are found only in Australia, and generally have very limited ranges. The Spotted Handfish is endemic to the Derwent River. It is considered to be at risk due to its very restricted and patchy distribution, low population density, limited dispersal capacity, and a reproductive strategy producing low numbers of eggs that are highly susceptible to disturbance. The eggs are usually laid around the base of a stalked ascidian (sea squirt).

Spotted Handfish were commonly sighted in the Derwent during the 1960s and 1970s. By 1989 researchers failed to locate any in areas previously renowned for sightings. Subsequently, only two were reliably reported between 1990 and 1994. These results were the first indication that Spotted Handfish had suffered a substantial decline in abundance during the 1980s. The cause of the decline is unclear, but may be connected with its unusual spawning habitat.

All Tasmanian Spotted Handfish are now legally protected, and the species is protected under the EPBC Act.

In March 1996 a recovery team involving many organisations was formed to coordinate research and management of the Spotted Handfish. A collaborative research program between CSIRO and the Tasmanian Aquaculture and Fisheries Institute (TAFI) was successful in spawning and rearing Spotted Handfish.

The recovery plan was completed in March 1998 and actions were initiated in 1999 with funds from the Natural Heritage Trust. The plan includes a variety of strategies, including the use of artificial spawning substrates in the wild.



The Spotted Handfish.

Source: M Green, CSIRO Marine Research.

Seahorses

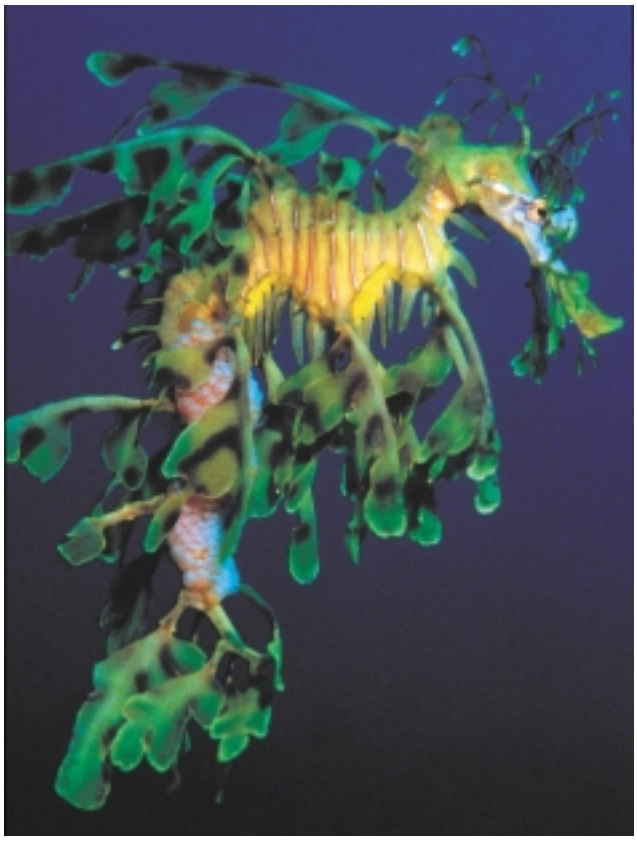
Seahorses are found in most of the world's temperate and tropical coastal waters. Seahorses are considered a curiosity: not only is their appearance unusual, but it is the male which becomes 'pregnant' when a female deposits her eggs into his pouch. Seahorses are caught, particularly in Asia but also in Australia, for traditional Chinese medicines and the aquarium trade.

The families Syngnathidae (seahorses, sea-dragons and pipefish) and Solenostomidae (ghost pipefish), of which there are 117 species in Australian waters, are nationally listed marine species. Sea-dragons are found only in southern Australian waters (Figure 9).

Syngnathids are long, slender fish with bony plates surrounding their bodies. The name 'syngnathid' refers to their jaws, which are united into a 'tube-snouted' mouth. The two species of sea-dragons, the Leafy Sea-dragon (*Phycodurus eques*) and the 'Common' or Weedy Sea-dragon *(Phyllopteryx taeniolatus*), both have many leaf-like appendages on their heads and bodies.

DragonSearch is a Natural Heritage Trust funded program which has gathered distribution information about these little known species through occurrence reports provided by sport and recreational divers (see http://www.dragonsearch.asn.au [accessed 5 September 2001]).

There are controls on taking seahorses in all Australian jurisdictions, for example a prohibition in Commonwealth waters under the EPBC Act. Attempts to culture seahorses in many countries include a successful program in Tasmania.



Leafy Sea-dragon, found only in southern Australian waters.

Source: D Muirhead, Marine Life Society of South Australia Inc.

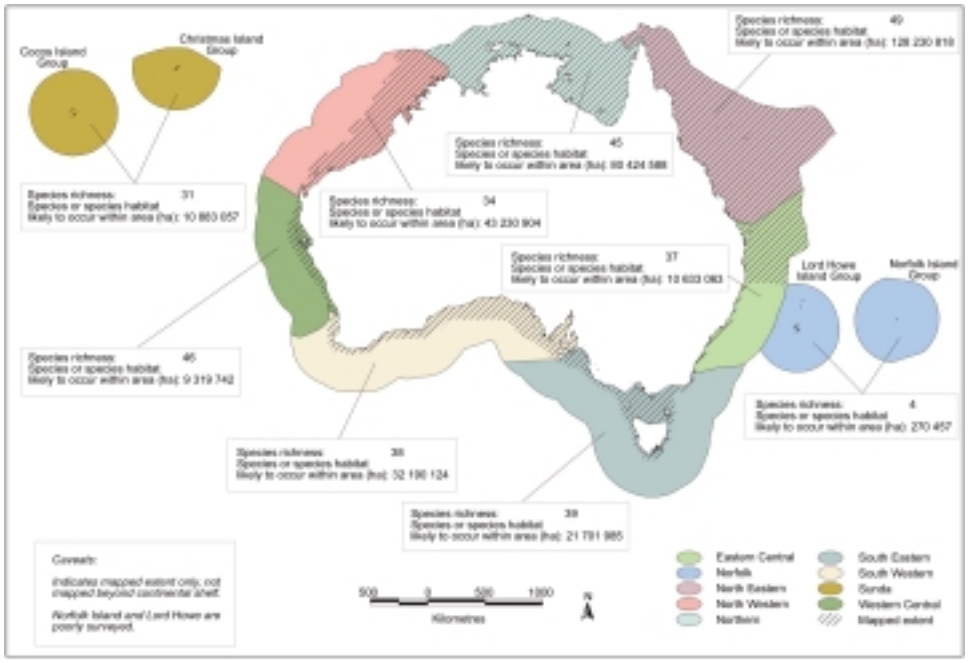


Figure 9: **Seahorses and pipefish distribution.**

Source: Environment Australia (2000).

Reptiles

Australia's marine reptiles include sea snakes, turtles and the Saltwater Crocodile. Of the 30 species of sea snakes, 15 are endemic. While one family inhabits reefs, with many located in the Great Barrier Reef Marine Park, a second group inhabits inter-reef areas and is more likely to be caught by prawn trawling.

Turtles

Turtle populations in Australian waters are not known with any confidence due to their migratory nature (Figure 10). This also makes them susceptible to pressures in international waters and in Australian waters and is reflected in their listings under several international conventions.

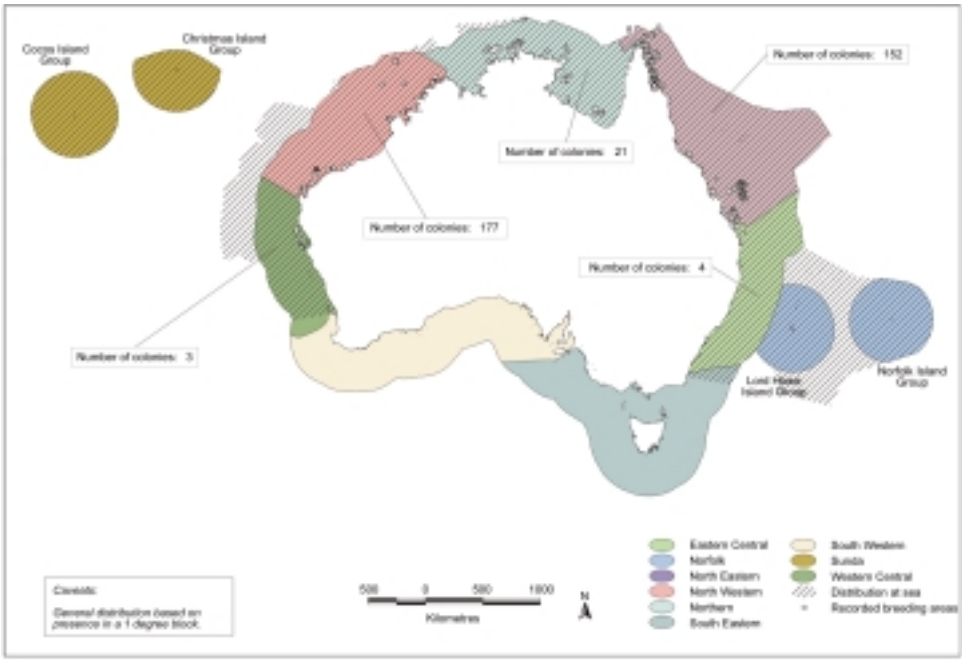


Figure 10: **Distribution of turtles.**

Source: Environment Australia (2000).

Green Turtles eat algae and seagrasses.

Source: G Carter, Great Barrier Reef Marine Park Authority.

Six of the world's seven species of turtles breed in Australia. The eastern Australian stock of Loggerhead Turtles (*Caretta caretta*), breeds almost exclusively in the southern Great Barrier Reef region and is considered to be endangered. Its nesting population has declined by 70 to 90% since the 1970s, from about 1000 to about 300. Fox predation of eggs and hatchlings and mortality due to fisheries interactions are thought to have contributed most to the decline.

Three genetic stocks of Green Turtle (*Chelonia mydas*) breeds in Queensland locations, in the southern and the northern Great Barrier Reef regions and the Wellesley group of islands. The estimated breeding population on the Wellesley group is between 2000 and 7000 females. There are signs that the southern Great Barrier Reef stock may be in the early stages of decline.

Australia is the stronghold for Flatback Turtles (*Natator depressus*), but they are also found in Papua New Guinea and Indonesia. The Hawksbill Turtle (*Eretmochelys imbricata*), internationally 'critically endangered', has its last stronghold in the northern Great Barrier Reef region, where there is an annual nesting population of several thousand females.

Pressures on turtles arise from their being caught as bycatch in prawn fishing and other fishing activities. Queensland studies suggest that about 5000 turtles are caught accidentally by the East Coast Trawl Fishery per year and 5700 by the Northern Prawn Fishery (EPA 1999b). However, over 90% of these are estimated to be released alive and are assumed to be unharmed.

They are also traditionally hunted by Indigenous people and this hunting is regulated by permits. It is estimated that 2000 to 4000 Green Turtles are caught by Indigenous people per year (Caton and McLoughlin 2000).

All species are protected in Australia under Commonwealth and State legislation. All six of the species are protected under the EPBC Act 1999, and a draft (as at May 2001) National Recovery Plan for Marine Turtles has been prepared. A nomination for otter trawling as a threatening process for marine turtles under the EPBC Act 1999 was (as at February 2001) being considered.

Bycatch Action Plans for two Commonwealth-managed fisheries have been prepared. The use of turtle exclusion devices (TEDs) in the Northern Prawn Fishery from 2000 is mandatory. In 2000, turtle exclusion devices were made compulsory for the entire Great Barrier Reef Marine Park and Hervey Bay for all trawling, with the exception of scallop and deep-sea trawling. Large areas of the Park are closed to trawling, and the number of boats in the trawl fishery has been reduced. From mid 2001, turtle exclusion devices have been mandatory for scallop and deep-sea trawling.

Early indications from a Fisheries Research and Development Corporation project by the Bureau of Rural Sciences, CSIRO, the Australian Fisheries Management Authority and the Northern Prawn Fishery fishing industry are that turtle catch and mortality rates in the Northern Prawn Fishery have decreased significantly since the introduction of TEDs (C. Robins pers comm.).

The fishing industry in Queensland has developed a voluntary code of ethics with respect to the capture of turtles, first adopted in 1994 by the East Coast Trawl Fishery. The Australian Seafood Industry Council has released a manual on reducing bycatch. It is expected that the catch of turtles should significantly decrease in the future.

In some areas, Indigenous Councils have been established by communities to regulate turtle and Dugong hunting in their regions with the support from the Great Barrier Reef Marine Park Authority (GBRMPA). The Guugu Yimithirr peoples of Hopevale north of Cooktown, have produced a management plan for turtles and Dugong and embarked on a major research project with James Cook University scientists focussed on a sustainable harvest.

Within the Great Barrier Reef region, important turtle nesting sites have been protected against human interference, but predation by feral animals is more difficult to control.

States are also addressing turtle conservation through:

- a marine turtle management plan, operating since 1985 in Western Australia,

- the commercial development of Hawksbill Turtles though captive husbandry in the Northern Territory, and
- the protection of the most significant breeding sites for turtles in eastern Queensland.

Birds

Seabirds [CO Indicator 1.3]

Seabirds spend most of their time at sea, apart from when they are nesting on land, and they also feed at sea. Examples include penguins, albatross, petrels and terns.

Of about 800 bird species found in Australia, approximately 142 are seabirds. New information since 1996 indicates that bird populations generally are declining. Seabird species are particularly susceptible to being caught as bycatch in longline fishing (see 'Albatrosses and longline fisheries' box on page 39). This threat, together with taxonomic revisions has resulted in the Action Plan for Australian Birds 2000 (Garnett and Crowley 2000) identifying all 20 albatross taxa and several petrels as threatened. Threats to these marine birds are concentrated in the Southern Ocean and on their breeding islands.

The action plan identifies about 65 seabird species as threatened, 35 of which have now been listed under the EPBC Act. The Threatened Species Scientific Committee established under the EPBC Act advises the Minister for the Environment and Heritage on the amendment and updating of this list.

In 1996 only six seabirds were listed under the then *Endangered Species Protection Act 1996*. Of those species, the Little Tern has not been included on the current list because of an increase in its numbers, and the Wandering Albatross has been downgraded to vulnerable.

Table 4 shows the marine bird species currently listed under the EPBC Act, in comparison with the 1996 list. The list reflects the increasing knowledge on the conservation status of birds and the identification of the threatened species. It does not necessarily imply a deterioration in the conservation status of the seabirds between 1996 and 2001.

Islands are significant habitats for seabirds. Lord Howe Island is said to be home to the most diverse and largest number of seabirds in Australia. Macquarie Island supports an estimate of 850 000 pairs of royal penguins and four species of albatross—one of the greatest concentration of seabirds in the world. Figure 11 identifies important breeding sites for seabirds.

Shorebirds [CO Indicator 1.3]

Shorebirds, are also known as waders, and can often be seen feeding on coastal mudflats, estuaries, coastal shorelines, reefs, and along the edges of inland wetlands. They are birds of the seashore, rather than the sea.

Many of the 73 species of Australian shorebirds are dependent upon coastal habitat, either as migrant or permanent residents. Watkins (1993) estimates that Australia has a minimum population of 2 million migrant and 1.1 million resident shorebirds.

The Action Plan for Australian Birds 2000 (Garnett and Crowley 2000) lists seven species of shorebirds, including the Hooded Plover (eastern) as vulnerable and the Hooded Plover (western) as near threatened.

Migratory birds depend heavily on preservation of habitat along their migration routes, both in Australia and overseas. The conservation of migratory birds and their habitats is the subject of several international treaties.

All migratory waterbirds (including shorebirds) listed under the international agreements have now been listed under the EPBC Act; this includes more than 35 species of shorebirds. Prior to the Act no species of international migratory shorebirds were protected by national legislation.

One hundred sites of international significance for migratory shorebirds have been identified in Australia; four sites are of outstanding importance, being recognised for up to 20 species. These are the south-eastern Gulf of Carpentaria, Roebuck Bay, Eighty Mile Beach and the Coorong (Figure 12). About a quarter of the identified internationally or nationally important shorebird habitat is protected within conservation reserves, but this does not include the four most important sites.

There has been a significant decline in shorebird numbers at some sites. An example is at the Coorong in South Australia (Figure 13) (Wilson 2000). However, the survey does not

Table 4: **Listing of seabirds in 1996 and 2000.**

Species	Common Name	ESP Act 1996	EPBC Act 1999
Anous tenuirostris melanops	Australian Lesser Noddy	Vulnerable	Vulnerable
Diomedea exulans	Wandering Albatross	Endangered	Vulnerable
Fregata andrewsi	Christmas Frigatebird, Andrew's Frigatebird	Vulnerable	Vulnerable
Pterodroma leucoptera leucoptera	Gould's Petrel	Endangered	Endangered
Sterna albifrons	Little Tern	Endangered	
Sula abbotti	Abbott's Booby	Endangered	Endangered
Diomedea amsterdamensis	Amsterdam Albatross		Endangered
Diomedea dabbenena	Tristan Albatross		Endangered
Diomedea sanfordi	Northern Royal Albatross		Endangered
Sterna vittata bethunei	Antarctic Tern (New Zealand)		Endangered
Thalassarche eremita	Chatham Albatross		Endangered
Diomedea antipodensis	Antipodean Albatross		Vulnerable
Diomedea epomophora	Southern Royal Albatross		Vulnerable
Diomedea gibsoni	Gibson's Albatross		Vulnerable
Fregetta grallaria grallaria	White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian)		Vulnerable
Halobaena caerulea	Blue Petrel		Vulnerable
Pachyptila turtur subantarctica	Fairy Prion (southern)		Vulnerable
Phalacrocorax nivalis	Heard Shag		Vulnerable
Phalacrocorax purpurascens	Macquarie Shag		Vulnerable
Phoebetria fusca	Sooty Albatross		Vulnerable
Pterodroma mollis	Soft-plumaged Petrel		Vulnerable
Pterodroma neglecta neglecta	Kermadec Petrel (western)		Vulnerable
Sterna vittata vittata	Antarctic Tern (Indian Ocean)		Vulnerable
Thalassarche bulleri	Buller's Albatross		Vulnerable
Thalassarche carteri	Indian Yellow-nosed Albatross		Vulnerable
Thalassarche cauta	Shy Albatross		Vulnerable
Thalassarche chrysostoma	Grey-headed Albatross		Vulnerable
Thalassarche impavida	Campbell Albatross		Vulnerable
Thalassarche nov. sp.	Pacific Albatross		Vulnerable
Thalassarche salvini	Salvin's Albatross		Vulnerable
Thalassarche steadi	White-capped Albatross		Vulnerable

show whether the decline in six most numerous species is caused by local or external factors or by climatic or seasonal effects.

There are a number of pressures or threats to birds and their habitats, such as:

- urban development, mineral exploration, mining,
- infrastructure such as airports,
- off-road vehicles,
- introduced rats, cats and foxes on offshore islands,
- tourism,
- some fishing methods such as longlining, and
- discarded fishing gear.

In the Torres Strait islands, traditional harvesting of eggs and birds has affected bird survival. Gathering of seabird eggs and chicks reduced the breeding seabird population in the Torres Strait, for example Brown Boobies no longer breed successfully on Bramble Cay and on Booby Island (King 1996).

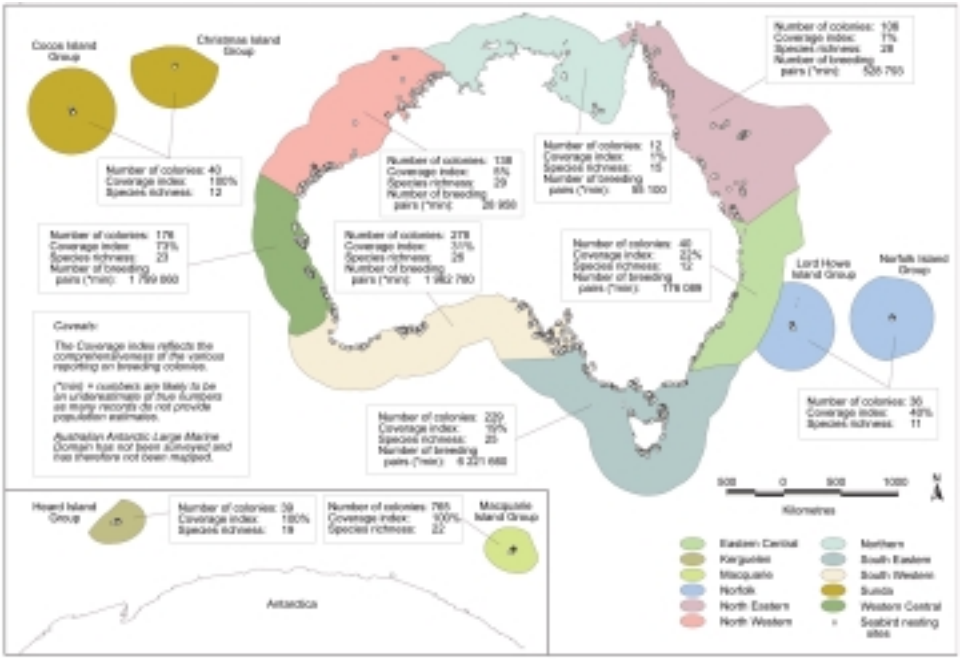


Figure 11: **Important breeding sites for seabirds.**

Source: Environment Australia (2000).

Initiatives

There have been a number of initiatives to address the various pressures on bird populations.

All migratory species of shorebirds are now protected under national legislation; some resident species are also protected by legislation in each State and Territory. The Commonwealth developed a Threat Abatement Plan in August 1998 for the Incidental Catch (or bycatch) of Seabirds during Oceanic Longline Fishing. Under this plan, domestic and foreign fishing vessels must adopt measures to reduce the bycatch of these birds.

The Abbott's Booby Recovery Plan (March 1998) is the only recovery plan for seabirds currently developed under the EPBC Act.

Public buy-back of land has occurred in some instances where critical habitat for a species has been lost to development. In 1985 the Victorian Government committed $1 million per year for 15 years to progressively buy back land and properties in the Summerland estate on

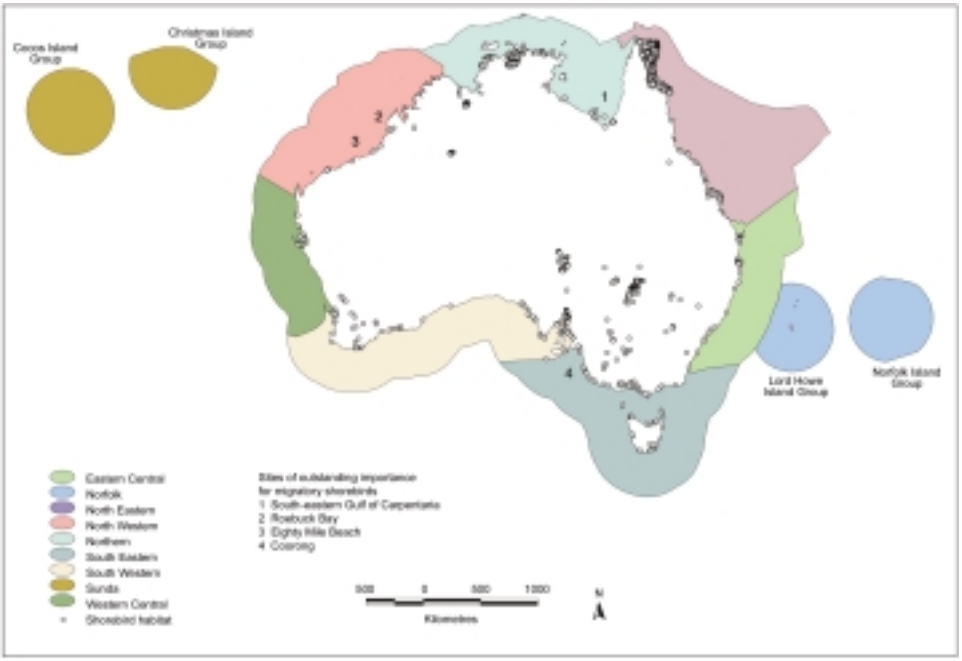


Figure 12: **Important sites for migratory shorebirds.**

Source: Environment Australia (2000).

Phillip Island, where development threatened Little Penguin habitat.

Initiatives are under way to improve the knowledge of some species. Tasmania, with Commonwealth funding, is researching albatrosses, Victoria is studying gannets, and New South Wales has undertaken major studies into Gould's Petrel. On a national scale, there is work on terns under the Australian Bird and Bat Banding Scheme. The Natural Heritage Trust has provided funding for a range of initiatives and activities relating to site protection and rehabilitation, research, raising community awareness of migratory shorebird conservation, and furthering nominations to the East Asian–Australasian Shorebird Site Network.

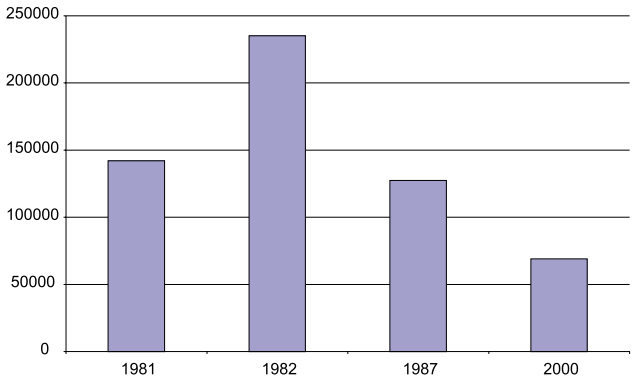


Figure 13: Estimated total counts of shorebirds at the Coorong.

Source: Wilson (2000).

The Commonwealth and States have jointly prepared and adopted guidelines for managing human visits to marine islands with breeding seabirds (Claridge 1997). Disturbance of birds by human visits to Great Barrier Reef islands has been addressed by seasonal closure during the breeding season, restrictions on visitor numbers or purpose (including a permit system), and restrictions on vehicles. For example, the waters surrounding two of the major seabird islands, Eshelby and Wreck Islands, are preservation zones and are closed to all forms of visit except approved research. Seventeen other seabird islands are within Reef Marine Park Seasonal Closure Areas, and if required may be closed during seabird breeding seasons.

Strict guidelines have been developed by the Australian Antarctic Division in cooperation with pilots, researchers, the Civil Aviation Safety Authority and others, for aircraft operations associated with scientific work in the Antarctic. The guidelines are continually evolving and are based on research into the response of fauna to aircraft flying at various heights and speeds.

Many important sites to migratory shorebirds are listed as Ramsar (Convention on Wetlands) sites. Australia currently has 56 sites of which 32 are classified as coastal; 16 of these are internationally significant for a number of species of migratory shorebirds. Ramsar sites are also protected under the EPBC Act and either have management plans in place or plans are being developed.

Another important initiative has been the Asia Pacific Migratory Waterbird Strategy 1996–2000 and 2001–2005 and the associated Shorebird Action Plans and East Asian–Australasian Shorebird Site Network. The Site Network is an informal arrangement which promotes the conservation of migratory shorebirds through the management of internationally significant sites. As of January 2001, Australia has 11 (also Ramsar listed) of the total 29 sites in eight countries in the region. A number of other sites are in the process of nomination, with a target of 25 sites to be nominated by 2005.

Mammals [CO Indicator 1.1]

Australia's marine mammals comprise a rich and varied fauna of some 43 species of cetaceans (whales, dolphins and porpoises), 10 species of seals, and the Dugong.

Cetaceans (whales, dolphins and porpoises)

Many of the cetaceans found in Australian waters are inhabitants of the deep oceans and come to notice infrequently, usually when stranded on shore, e.g. the Pygmy Sperm Whale *(Kogia breviceps*). Several dolphin species habitually or occasionally frequent coastal waters, including the widely distributed Bottlenose and Common Dolphins, and the less common and elusive Indo-Pacific Humpbacked Dolphin (*Sousa chinensis*), and Irrawaddy Dolphin (*Orcaella brevirostris*), both of which are tropical species.

The so-called 'great whales'—Blue Whale (*Balaenoptera musculus*), Fin Whale (*B. physalus*), Sei Whale (*B. borealis*), Bryde's Whale (*B.edeni*), Minke Whale (*B. acutorostrata*), Humpback Whale (*Megaptera novaeangliae*), Southern Right Whale (*Eubalaena australis*), and Sperm Whale (*Physeter macrocephalus*)—were once hunted commercially in Australian waters and in adjacent parts of the Southern Ocean and their numbers were greatly depleted. All these species, with the exception of Bryde's Whale, undergo extensive annual migrations between summer feeding grounds in the Southern Ocean and warmer waters in lower latitudes where calving and mating occur during winter.

Albatrosses and longline fisheries

Since the early 1950s the world's longline fishing fleets targeting tuna (*Thunnus* spp.), broadbill (*Xiphias* sp.) and more recently Patagonian toothfish (*Dissostichus eleginoides*) have expanded into most of the oceans of the world.

It is now likely that pelagic seabirds will interact with longline fishing vessels at some stage in their lives. This interaction can be fatal for the birds, and considerable concern has been raised about the effect of longlining on populations of albatrosses in particular, and on some species of petrels.

During line setting, albatrosses and petrels scavenge the baits attached to hooks on longlines paid out from the stern of the fishing ship before the lines sink beyond their reach. Once hooked, the birds are drawn underwater by the sinking longline and drown. The death rate of albatrosses may average only about 0.4 birds/1000 hooks deployed, but the number of hooks set annually is high: between 50 and 100 million in the world's southern oceans alone. Multiplying the two yields a casualty rate that is unsustainable for most populations.

The populations of albatrosses and petrels at some closely monitored sites have been decreasing in recent decades. The rate of decrease has been insidious, from 1–7%, and it took many years of observation to provide convincing evidence that the decreases were not part of natural cycles. Compounding matters was the lack of an obvious reason to explain the decreases being recorded.

Only in the late 1980s did compelling evidence emerge for the causes of their decline. Data collected on the Japanese tuna longline fleet operating out of Hobart indicated that thousands of albatrosses were being killed annually by this industry alone. This created the impetus for the First International Conference on the Biology and Conservation of Albatrosses, held in Hobart in 1995. The conference brought together seabird and fish scientists, wildlife managers, fisheries managers, representatives of non-governmental organisations, and fishing industry representatives. A series of mitigation measures were suggested, including the provision of bird-scaring lines and streamers, weighted lines to reduce the amount of time baits are near the surface, setting lines at night, and setting lines beneath the waters' surface.

Since this conference, the issue has received global attention. In 1998 the United Nation's Food and Agriculture Organisation (FAO) produced an International Plan of Action to reduce seabird mortality in longline fisheries. This calls for an assessment of the extent of seabird mortality, the species affected and the adoption of mitigation practices.

Another important initiative has been the Agreement on the Conservation of Albatrosses and Petrels, developed under the Convention on the Conservation of Migratory Species of Wild Animals which seeks to protect albatrosses and petrels throughout their entire breeding and migratory ranges. The implementation of this multilateral Agreement through coordinated and cooperative actions will contribute significantly to the conservation of Southern Hemisphere albatross and petrel species and their habitats.

Drowned albatross caught on pelagic longline.

Source: G Robertson, Australian Antarctic Division.

In addition to these initiatives, many nations are currently testing new technologies to determine the most effective methods to reduce seabird deaths. Some of these show great promise, particularly work by New Zealand and Australia, in developing an underwater setting device for domestic tuna vessels. Longline fishing operators are now trialing a bait chute-launcher that will prevent bird losses. The United States and Norway have also trialled techniques for reducing seabird mortality in their coastal longline fisheries. Change is slow, but perhaps there is reason for mild optimism about the future prospects of many of the seabird species that interact with longline fisheries.

Source: Australian Antarctic Division (2001).

A national assessment of cetaceans in Australian waters (Bannister et al. 1996) concluded that the Blue Whale is endangered because numbers remain critically low.

In contrast, the numbers of Southern Right, Humpback and Fin Whales are now increasing, although their populations are still well below pre-exploitation levels. They are still categorised as vulnerable under the EPBC Act. Australia's populations of the Sei Whale have declined by 5% in the past 40 years alone, and there are estimated to be only 25 000 individuals remaining.

As the current status of the Sperm Whale and the Indo-Pacific Humpbacked Dolphin, Irrawaddy Dolphin and Spinner Dolphin (*Stenella longirostris*) is uncertain, they are provisionally categorised as insufficiently known. Even less information is available for the other species, because they normally occur far offshore.

The trend for numbers of Humpback Whales migrating along the east coast is increasing.

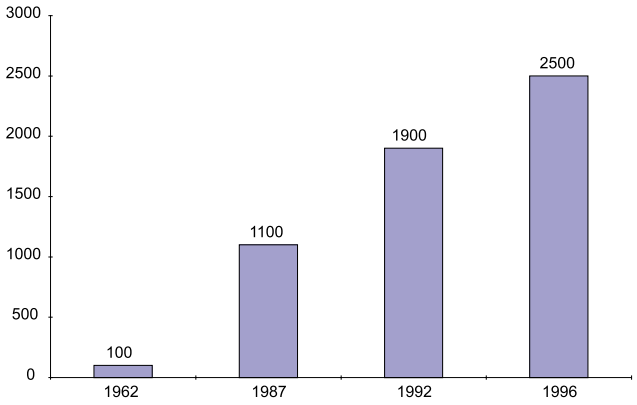


Figure 14: Estimated number of Humpback Whales migrating up the East Coast.

Source: EPA (1999).

Whale-watching is a developing industry based upon the desire by people to see and interact with whales and dolphins, ranging from simply watching whales from the shore to organised boat tours and 'swim with whales' activities. In Victoria, the whale-watching industry is valued at $17 million per year.

However, the activity can be a pressure to the whales. For example, vessels may create noise (and vibration), pollution and may physically injure a whale. Cetaceans have particularly sensitive hearing that plays an important role in communication, navigation and prey location.

Since the 1980s, Australia has pursued a conservation-oriented policy on whales, via membership of international bodies, including the International Whaling Commission (IWC).

In July 2000 Australia and New Zealand presented the South Pacific Whale Sanctuary proposal at the annual meeting of the IWC. Most members of the commission supported the sanctuary, but it failed to obtain the required three-quarters majority. The proposal will be put to the IWC again.

The Government is putting into effect a draft recovery plan for Blue Whales in Australian waters, and a recovery plan for the Southern Right Whale is being drafted. The listing of the Sei and Fin Whales by the Commonwealth in 1998 means that recovery plans will be developed for both species.

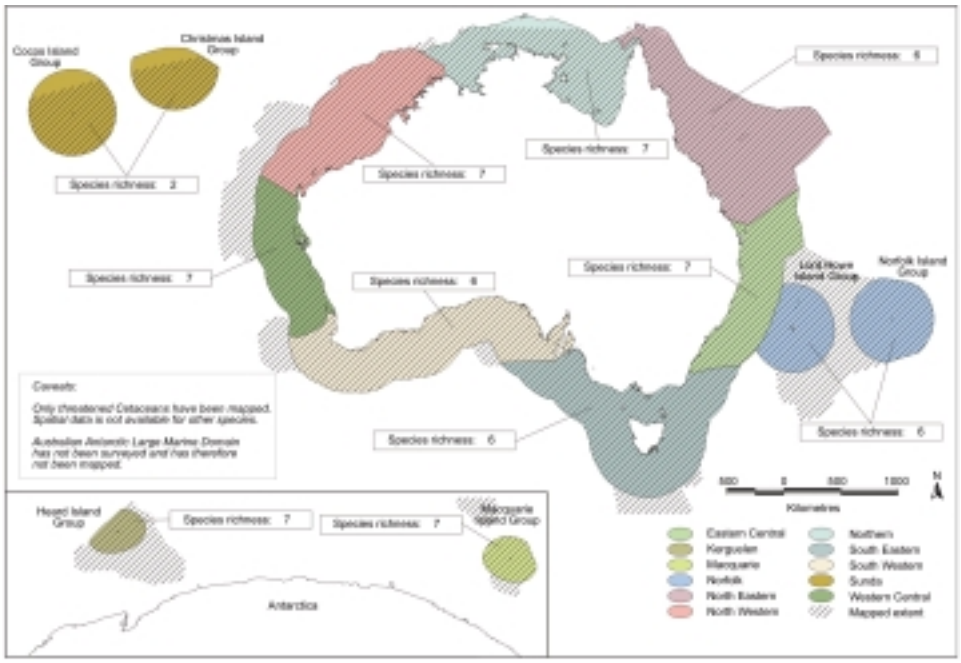


Figure 15: Distribution of threatened cetaceans.

Source: Environment Australia.

Conservation efforts saw Humpback Whale numbers recover to such an extent that the whale was moved from endangered to vulnerable in 1998.

Whale-watching is mostly conducted in inshore waters subject to State controls. National guidelines for whale-watching have been developed (ANZECC 2000) with the aims of minimising harmful impacts on cetaceans and allowing people to enjoy and learn about the animals. These guidelines apply to all whales, dolphins and porpoises.

Humpback Whales are very acrobatic.

Source: M Simmons, Great Barrier Reef Marine Park Authority.

Seals

Australia's sea lions and fur seals were hunted extensively by sealers during the 19th century, mainly for their pelts. Recovery has generally been slow, but in recent years some fur seal breeding colonies have expanded significantly, several new colonies have been established, and numbers have also increased at several traditional resting sites within the wider feeding ranges of the two species. The Australian Sea Lion remains widespread but is nowhere common.

Ten species of seals occur regularly in the Australian region. Five belong to the family Otariidae or eared seals, of which three breed on islands adjacent to the mainland and two on sub-Antarctic islands. Five species belong to the family Phocidae or true seals, of which one breeds on Heard and Macquarie Islands. Others breed around the Antarctic including off the Australian Antarctic Territory. Antarctic Fur Seal breeding colonies at Heard, McDonald and Macquarie Islands are small, but numbers appear to be increasing at all sites. Sub-Antarctic Fur Seals have colonised Macquarie Island in recent times, but numbers are still low.

Pressures on general feeders such as sea lions and fur seals arise from their attraction to fishing activity and they become habituated to taking netted or discarded fish and offal. Adult sea lions and fur seals in mainland and Tasmanian waters are vulnerable to capture in shark nets and trawl nets, and their young risk drowning when raiding rock lobster pots for the bait. The level of incidental bycatch in these fisheries is not well documented.

As a requirement of Marine Stewardship Council certification, the Western Rock Lobster Fishery is developing a detailed monitoring program to document the bycatch and any other interactions with sea lions (and other important species). If the level of bycatch or interaction is unacceptably high, the fishery can take further measures to reduce effects on these species.

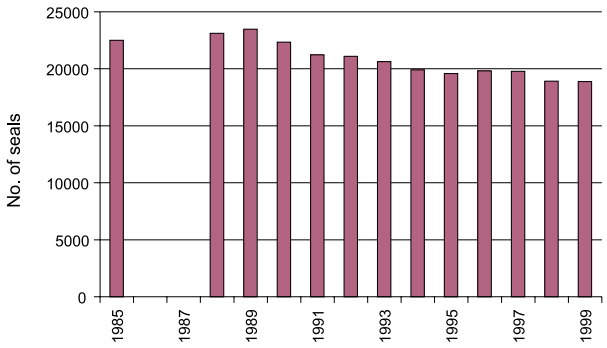
Elephant seals and fur seals on Macquarie Island.

In the sub-Antarctic, the Southern Elephant Seal (*Mirounga leonina*) and the Australian Fur Seal (*Arctocephalus pusillus*) formed the basis of two large sealing industries in the 19th century. Hunting had ceased by early in the 20th century and soon afterwards the elephant seals are thought to have regained their original levels.

Since the 1950s the population trends for the two groups of seals have shown markedly different characteristics. The population of Elephant Seals at Macquarie Island had decreased dramatically by 1999 to approximately 40% of that in 1959. Linear extrapolation of the population trend suggests that Elephant Seals might become extinct on the island by 2050.

In contrast, the numbers of fur seals have increased significantly at both Macquarie and Heard Islands. These populations have been re-established from species breeding elsewhere in the sub-Antarctic.

The reason for the changing populations of the seals is uncertain at present. Competition for food between Australian Fur Seals, Elephant Seals and King Penguins (which are also rapidly becoming more numerous at Heard and Macquarie Islands) may have advantaged Fur Seals and penguins to the detriment of Elephant Seals. Changes in the Southern Ocean environment have also been implicated, including the rapid decline in the area of sea ice that occurred between 1950 and 1973. Elephant seals are known to enter the pack ice zone to feed.



Annual census of Elephant Seals on Macquarie Island.

Source: Antarctic Division (2000).

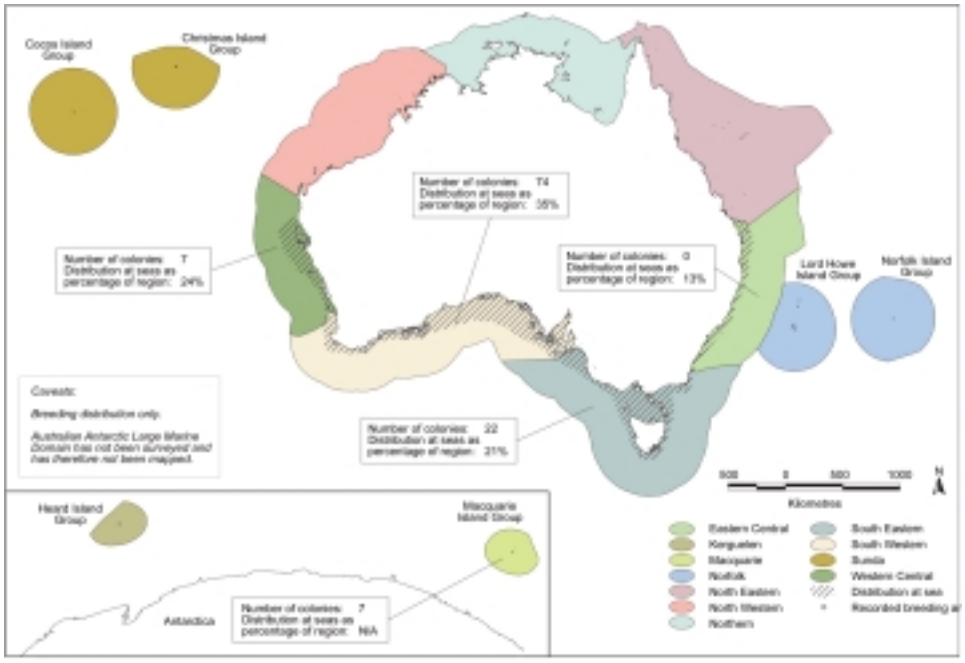


Figure 16: **Distribution of seals and sea lions.**

Source: Environment Australia (2000).

Significant numbers of seals entangled in fishing gear have been seen at colonies in southern Australia and Tasmania, but losses in population terms are unknown because many seals entangled in lost or discarded nets or large pieces of debris probably die at sea. About 2% of seals at haul out or resting sites in Tasmania are entangled in net fragments and other plastic litter at any time (Commonwealth of Australia 2001b). Even in remote regions like Heard and Macquarie Islands Fur Seals have been found entangled in plastic strapping. The fishing industry has initiated measures to reduce the problem of entanglement.

In the sub-Antarctic, critical areas for the breeding of seals (and sub-Antarctic birds) have been recognised by inscription of Heard and Macquarie Islands onto the World Heritage list and through the proclamation of a marine park to the east of Macquarie Island.

Dugongs

The Dugong is the only strictly marine herbivorous mammal, the sole living representative of the Family Dugongidae. Australian Dugongs (*Dugong dugon*) constitute a significant percentage of the world population. They occur in the Australian tropics and subtropics, from Shark Bay in Western Australia to Moreton Bay in Queensland.

Some populations of Australian Dugongs have declined dramatically since European settlement, largely as a result of human activities, but others do not appear to be currently threatened. Their specialist requirement for seagrass habitat makes them vulnerable to human influence. Important populations of Dugongs are given in Marsh et al. (1999).

Dugongs are vulnerable to large sharks, estuarine crocodiles and Killer Whales. They are also at risk from stranding in cyclonic storm surges. Sources of human mortality include: boat strikes, fishing and beach protection nets. Important seagrass habitats may be obliterated by loss of light caused by sedimentation associated with floods and cyclonic storms.

Dugongs are a fishery under the Torres Strait Treaty and *Torres Strait Fisheries Act*. It is estimated that the harvest of Dugongs in the Torres Strait during the 1990s was in the order of 1000 per year (Marsh et al. 1999). It should be noted that if the estimate of Torres Strait Dugong population at about 28 000 is correct, this harvest is greater than the estimated sustainable yield of 2% of the current female population, and may be unsustainable if other pressures such as incidental catch and habitat loss are not dramatically reduced. A recent survey (Marsh & Lawler 2001) indicates that Dugong numbers in the southern Great Barrier Reef region have increased from an estimated 1682 in 1994 to an estimated 3993 in 1999. However, the 1999 numbers are not significantly different from those obtained in 1986-87 surveys. The increase in numbers between 1994 and 1999 is thought to be due to factors other than just natural increase.

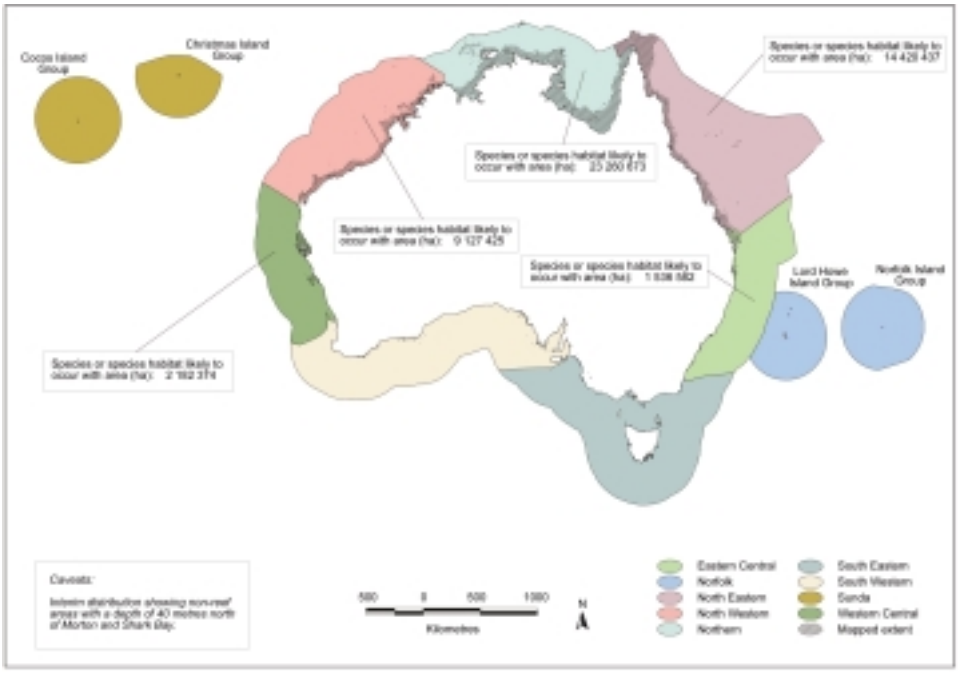


Figure 17: Distribution of Dugong around the Australian coastline.

Source: Environment Australia (2000).

Dugongs are protected under State and Northern Territory Acts. Dugong Protection Areas were declared in the southern and central Great Barrier Reef region in 1997 by the Great Barrier Reef Ministerial Council, particularly to protect Dugongs from certain netting practices. Areas of inshore seagrass habitat in the Gulf of Carpentaria and the Great Barrier Reef region have been permanently closed to trawling. A moratorium on Dugong hunting has been agreed with several Indigenous communities and Indigenous hunting is not permitted in the Great Barrier Reef region, south of Cooktown.

Coastal settlement and development

Environmental indicators reported in this section:

Environmental Indicator	
CO 7.6	Coastal population
CO 7.7	Coastal tourism

Coastal settlement [CO Indicator 7.6]

Increasingly, Australians are moving to coastal environments to live, to retire or to make a living. Some 83% of Australians lived within 50 kilometres from the coast in 1996.

The population of coastal areas is distributed unevenly along the coastline. For example, in Victoria, the most densely populated State with 85% of its population living on the coast, human habitation still occupies less than 10% of the coastline.

People are continuing to shift to the coastal margins of the continent, particularly to the coasts of Victoria, New South Wales, Western Australia and Queensland. These States had higher rates of population growth (1991–1996) in the three kilometre coastal zone compared to the rest of their State. In New South Wales and Queensland alone, an extra 179 000 people moved to the coastal margins (see the Human Settlements Theme Report).

The projections of population growth rates vary widely. For example, the projections for the Richmond Tweed area of northern New South Wales is for an increase in population from 210 000 in 1996 to 311 000 in 2026 (Coastal Council of New South Wales 2001). The critical issue is the impact of existing and future populations scattered in towns, villages and on individual properties along the New South Wales coast.

The projections for 2006 compared with 1996 indicate increases particularly in the areas around Sydney, Brisbane, Perth and the southern coast of Victoria including Melbourne and Geelong (Figure 18).

Coastal strip development along the coastal edge places increasing pressure on specific coastal habitats. Urban sprawl was identified as one of most important problems faced in the coastal zone by the Resource Assessment Commission (1993).

The effects of human activity can cause the loss, degradation or irreversible change in specific coastal habitats, alter both river and tidal flows, cause erosion of beaches and dunes, change water quality by adding stormwater and domestic and industrial sewage and add litter to the environment. In addition, coastal development often occurs on inappropriate soils, resulting in further environmental effects when these are disturbed. To some extent, changes in particular habitats have been documented in the preceding sections of this chapter. However, coverage of all significant habitats on a national scale is not possible at this time. There is insufficient information readily available on the nature and extent of coastal strip development, and about trends in current patterns of coastal development, to assess environmental impacts on the coastal zone.

Another set of more subtle impacts arises from increasing competition for the use of resources in the coastal environment. The provision of water supply to metropolitan areas can affect coastal water quality. For example, water from the Gippsland Lakes catchment is being diverted to the Thomson Dam and hence into a different catchment, the Port Philip Bay catchment.

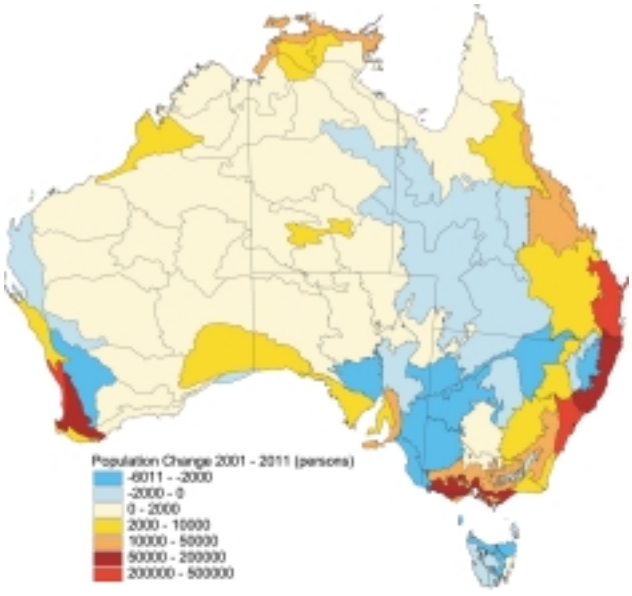


Figure 18: Projected population changes in population density by IBRA region.

Units are persons per square kilometre. Simple difference between 1997 and 2006 ABS projections. This uses IBRA version 5.

Source: Environment Australia 2001, using Australian Bureau of Statistics (1996) data.

Tourism [CO Indicator 7.7]

Marine and coastal-based tourism is important to Australia, not only for domestic tourism where Australians seek to

enjoy the heritage and natural values of the environment, but also for the 20% of tourists arriving from overseas who prize our natural and unspoilt marine environment. According to the Bureau of Tourism Research (DISR 2001a), 50% of international visits and 42% of domestic visits are to coastal and marine areas.

Marine tourism is now a significant part of the economy. It has been estimated that marine tourism and recreation contributed $15 billion to the economy in 1997, or 50% of the economic activity of marine industries **(**Greiner et al. 1997). The Great Barrier Reef World Heritage Area, for example, has experienced a large increase in tourism since the 1980s when visitor numbers were 150 000 visitor-days. Tourism in the Great Barrier Reef World Heritage Area was worth $1 billion, with 1.6 million visitor-days in 1997, and with 1.5 million visitors in 1998–99 and 1999–2000. With this type of use, tourism clearly depends on sustaining environmental and heritage values.

The appeal of the Antarctic wilderness attracts growing numbers of tourists.

Source: R Ledingham, Australian Antarctic Division.

Some places are internationally recognised such as The Great Barrier Reef Marine Park, Sydney Harbour and city, the Gold Coast, and the Great Ocean Road in Victoria. There is, however, a great diversity of tourism experience within Australia and its territories, including:

- Antarctic tourism, with an estimated 10 000 people visiting the sub-Antarctic Islands in 1999 (IAATO 2000), although most vessels depart from South America rather than Australia,
- whale-watching off the coasts of Western Australia, Victoria, Queensland and New South Wales,
- bird-watching, e.g. Little Penguins on Philip Island, shorebirds in Western Australia, and seabirds around the coast,
- diving for fish or to observe marine life around the coast, including on the Great Barrier Reef, on the Ningaloo Reef in Western Australia, and off the coast of Tasmania,
- limited opportunities of swimming with dolphins at Monkey Mia in Western Australia, Port Phillip Bay, Victoria and in Moreton Bay, Queensland, and
- swimming, boating and fishing at the beach.

Six World Heritage Areas in Australia have a predominant marine component:

- The Great Barrier Reef,
- Lord Howe Island Group,
- Shark Bay in Western Australia,
- Fraser Island,
- Macquarie Island, and
- Heard Island and McDonald Islands.

Challenges and issues facing Australia's tourist industry include:

- allocating access to high quality environments (which are also sought for conservation reasons),
- ensuring that the environment is not degraded,
- integrating the interests of marine tourism operators with other users,
- promoting heritage tourism, including nature-based tourism, education and best-practice initiatives,
- ensuring that the overall planning, development, management and monitoring arrangements for marine tourism are well developed and are underpinned by a good information base, and
- ensuring that investment in regional infrastructure does occur.

Impacts

The growth in the number of people visiting an area is dependent on external factors, such as the targeted promotions run by the Australian Tourist Commission and the State and Territory tourism promotion agencies.

There are social, cultural, economic and environmental impacts caused by tourism. It is estimated that one-third of the Australian population is involved in recreational fishing, and in

some areas recreational and commercial fishers compete for species. It is estimated that 700 000 people scuba dive each year, and there are over half a million registered, privately owned motor vessels in Australia and hundreds of thousands of other smaller craft. Activities associated with the use of this equipment have the potential to affect the environment through pollution of water (boat sullage) and disturbance of species and habitats. Recreational fishers tend to target reef ecosystems and remove larger predatory species. The effects of selective removal of such fish are largely unknown. Shore-based recreational fishing can have effects on shore populations of invertebrates that are collected for bait in intensively visited areas.

Tourists leave from Port Douglas to visit the Great Barrier Reef.

Source: J Jones, Great Barrier Reef Marine Park Authority.

A major source of environmental impacts is the provision of infrastructure to support tourism. This can include airports, power generation facilities, accommodation, sewage treatment and disposal facilities, moorings, and marine transport. Often the infrastructure is required in fragile or pristine environments that are susceptible to disturbance and fragmentation.

Infrastructure needs are increasing both on the mainland and on the 19 resort islands within the Great Barrier Reef area for both day visitors and longer stay visitors. An increasing range of sites is now accessible, through the use of bigger and faster boats (since 1982), thus placing more sites potentially at risk of irreversible disturbance.

There are also social and community effects where tourism affects the lifestyle of residents in ways they perceive as intrusive. Negative social impacts may include real or perceived increases in crowding, prices, or crime. Increasing tourism may also result in increasing conflict between various uses and, within the same uses, between commercial, recreational and Indigenous interests.

Response

Because the environmental effects of tourism activities are regulated or controlled by a variety of agencies, it is not easy to summarise the effectiveness of responses to impacts on coastal and marine areas that are subject to tourism pressures.

However, on a national level, the Commonwealth Government developed a National Action Plan for Tourism in 1998. The Plan, which identifies conservation and careful management of the environment as essential to the long-term viability of the tourism industry, makes a commitment to ecologically sustainable tourism development, recognising that environmental considerations should be an integral part of economic decisions.

Management of a wide range of tourism activities within a specified area is a complex exercise. Activities within the Great Barrier Reef Marine Park are managed through broad-scale zoning plans which identify appropriate activities at a subregional level, and through a system of permits and licences, accreditation and self-regulation through Best Environmental Practice Guidelines for some activities. Greater self-regulation has been encouraged, and the marine tourism industry has produced a Code of Conduct which covers issues such as anchoring, removal of rubbish, fish feeding and preservation of World Heritage values. In March 2001 the launching by the Great Barrier Reef Marine Park Authority of a Tourism Operators' Handbook complemented the code. All licensed tourism operators are subject to an environmental management charge.

The Great Barrier Reef Marine Park Authority requires performance bonds to be posted where the construction of semipermanent or temporary structures is involved.

The siting and operation of infrastructure is subject to local government requirements or to the requirements of special-purpose agencies. Local government may also promote and monitor tourism in their areas.

Ecotourism in the Antarctic is generally well regulated, especially in the sub-Antarctic islands. All companies proposing to visit Heard or Macquarie Islands must submit detailed plans and undertake an environmental impact assessment before the trips will be approved.

As of February 2001, the CRC for Sustainable Tourism was working on the Nature Tourism National Review on current practices of Australian protected area management agencies relating to the use of protected areas by visitors. The CRC and CSIRO are also conducting research programs into techniques for monitoring the impact of tourism activities.

A study on how the operation of dolphin-swim ecotours affects the dolphins in southern Port Phillip Bay found that the avoidance reaction of dolphins to humans varied significantly in response to location, approach strategy and tour operation. Direct, deliberate approaches to dolphins from tour vessels or swimmers resulted in higher levels of avoidance responses. The parallel approach provided the animals with the option of ignoring or interacting with swimmers.

Antarctic tourism is an emerging environmental issue. The level of tourism in Antarctica is currently very low, however, while the number of expeditioners associated with national operators is relatively constant, tourist numbers have doubled over the last eight years and tourist activities in the Antarctic continue to diversify. Tourists visiting some Antarctic sites over a short summer season are drawn by very high expectations of Antarctic wilderness.

Summary

Apart from the comprehensive overview of tourism in the Great Barrier Reef Marine Park, there appears to be little information available on a national scale to assess the impacts of tourism on coastal and marine environments. Although local government, tourism agencies, and States and Territories may collect this information, it is not readily available for collation at a national scale. Therefore it is difficult to assess the impacts of activities, and the success or otherwise of measures to maintain environmental quality in marine and coastal areas used for tourism.

Erosion of beaches and dunes

The movement of sand is a natural feature of beaches. Beaches can be described as eroding (losing sand and foredunes) or accreting (gaining sand). The frequency and severity of cyclonic or storm events and seasonal weather patterns can result in fluctuations of beach width and slope.

The causes of erosion can be classified as follows (Tomlinson 2001):

- short-term natural variability—beach fluctuations, storms,
- medium-term natural variability—periodic changes in coastal climate and beach conditions,
- medium-term erosion—disruption to local sediment budget due to people's activities, or
- long-term natural variability—sea level rise, geological realignment, reduction in sediment supply.

Where development has occurred, property and infrastructure integrity can be threatened by landward movement of the erosion. The south-east Queensland – northern New South Wales coastline has been greatly developed since the mid 1970s but has not experienced a significant erosion event similar to the 1967 event that caused five houses to collapse into the sea on the Gold Coast.

Structures designed to reduce the extent of beach erosion can sometimes result in the opposite effects; that is, increased erosion, either on the beach or on an adjacent stretch of coastline. Similarly, the increasing popularity of offshore undersea barriers to create surfing waves or to dissipate wave energy from sensitive beaches will have ecological impacts that have yet to be determined.

It should be an objective of any coastal management plan for an area such as the Gold Coast to proactively mitigate any erosion caused by groynes and retaining walls (Tomlinson 2001). It should also be an objective to enhance the capability of the natural system to respond to natural sand movement by encouraging dune rehabilitation, for example. However, long-term studies to assess the effectiveness of coastal management strategies are hard to find.

Beach and ocean litter

A visible indicator of human influence on beach condition is litter. This is more than an aesthetic matter in that debris forms a hazard to wildlife. Fishing debris such as discarded nets are particularly hazardous, by their very design. Plastic items, for example bags and 'six-pack' plastic binders, are known to kill animals by ingestion or strangulation.

The source of beach litter can be from coastal waters, from the land where it is transported by stormwater onto beaches, or by people discarding materials on a beach.

There is no nationally available information on the extent and significance of litter, although some studies have been carried out over the last five years.

The sources of ocean litter have been studied over the past five years, particularly for Northern Australia. In north-east Arnhem Land, the Dhimurru Land Management Aboriginal Corporation found many turtles entangled in discarded fishing nets (200 turtles in four years) and concluded that 80% of the nets came from foreign fishing boats (Kiessling and Hamilton 2000). A beach survey in this region in 2000 found more than 7561 items, including 500 derelict fishing nets, in 8.25 kilometres of coastline.

Even in remote regions on Heard and Macquarie Islands, litter from the fishing industry is found. The range of wildlife potentially affected by ocean litter includes: whales, sharks, scalefish, penguins and other seabirds, seals, and turtles.

Some studies of beach litter have been undertaken over the past five years; for example:

- an ANZECC survey of marine debris (ANZECC 1996) could not document any consistent information for litter on beaches and noted that there is inadequate information about trends and sources of marine debris,
- a 1996 survey by Ocean Watch Australia Ltd (Herfort 1997) on marine debris on New South Wales beaches reported proportions of debris as: land sourced plastics 73%, land sourced non-plastics 14%, debris attributed to commercial fishing 8%, debris from recreational fishing activities 5%, and
- an intensive marine debris survey of all accessible Groote Eylandt beaches in the western Gulf of Carpentaria Northern Territory was conducted by members of the Angurugu community over a seven-month period in 1997–1998. Debris relating to fishing gear comprised the overwhelming majority of the debris on all beaches (Sloan et al. 1999).

To address the litter problem derived from urban drainage, a number of local councils have installed litter traps, for example Moreland Council's (Melbourne) demonstration litter trap and floating traps on rivers such as the Yarra River. Education campaigns include television commercials and messages painted on stormwater drains in the street have also being used to raise awareness of the impacts of careless disposal of materials.

Garbage from ships is subject to controls under the MARPOL Convention. Under Annex V of that Convention there is a total prohibition on the disposal of garbage containing plastic into the ocean. The MARPOL convention is enforced in Australia through the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*, which is administered by the Australian Maritime Safety Authority.

The Australian Seafood Industry Council has adopted a voluntary 'Code of Conduct for a Responsible Seafood Industry'. This Code commits the industry to strive to minimise all discards and waste associated with fishing activities, record and report the loss and recovery of fishing gear, and retain material such as derelict fishing gear and other garbage recovered during routine operations for disposal on shore.

There are also a number of codes of practice for specific fisheries that include principles to minimise ocean debris. These codes have been adopted by the Western Australian Western Rock Lobster Industry, the South East Trawl Fishery, the South Australian Marine Scale Fishery, the South Australian Inshore Net Fishery and the South Australian River Fishery, for example.

The National Code of Practice for Recreational Fisheries includes principles for behaviour of fishers aimed at minimising marine debris, including the removal and correct disposal of gear and rubbish from fishing sites. Recreational fishers have been targeted by educational campaigns to reduce littering, particularly with respect to discarded fishing gear.

Coastal weeds

Environmental weeds are plants that invade natural ecosystems and have impacts on biodiversity and ecosystem function. The National Weeds Strategy in 1997 listed 20 weeds of national significance. The list covered both environmental and agricultural weeds, but Bitou Bush is the only primarily coastal weed listed.

Bitou Bush was accidentally introduced in the early 1900s. It became established near Newcastle and was confined there for several decades. From the mid-1950s to the late 1960s it was deliberately planted along the New South Wales coastline to revegetate dunes after sandmining.

Bitou Bush is predominantly a problem on New South Wales coastlines. In Victoria, Bitou Bush (also known as Boneseed) is not so widespread. However, it is having a significant effect on important flora in some places. The total area of land infested in New South Wales is estimated to be about 70 000 hectares. The weed, however, continues to spread quickly through natural means. The fruits are eaten by birds and foxes and the seeds are dispersed widely through their scats. Mature plants may produce up to 48 000 seeds per plant per year, and much of what is not eaten or spread persists in the soil seed bank. Bitou Bush appears to spreading more widely inland into the landscapes behind the coastal ecosystems.

Both State (New South Wales) and national strategies to manage the weed have been drafted. The most common management methods are aerial spraying with herbicides, and biocontrol. Fire and revegetation with native plants also are being investigated as a means of reducing the soil seed bank. An integrated pest management approach is being developed by government agencies and the CRC for Weed Management Systems.

Figure 19: Indicative distribution of coastal acid sulfate soils in Australia.
Source: After National Working Party on Acid Sulfate Soils (2000).

Disturbance of coastal acid sulfate soils

Coastal acid sulfate soils (CASS) have, over the last decade, been recognised as contributing to one of the most important water quality issues in coastal lowlands and estuaries. Areas containing disturbed acid sulfate soils have been identified primarily in Queensland and New South Wales, although areas of undisturbed acid sulfate soils are found in all States and the Northern Territory (Figure 19). They underlie coastal estuaries and floodplains where the majority of Australians live. They also underlie significant fish nursery areas and coastal agricultural industries such as sugar cane, dairying and beef.

No comprehensive mapping of acid sulfate soils has been done to date. However, it is known that potential acid sulfate soils cover approximately 2.3 million hectares in Queensland (EPA 1999a) and over 0.6 million hectares in New South Wales.

In their natural, undisturbed state these soils do not pose a threat to estuarine ecosystems. Their exposure to air, as a result of development and land management practices such as drainage and excavation, generates large quantities of sulfuric acid and other substances, which adversely affects estuarine and coastal ecosystems. Studies in the Richmond River in northern New South Wales estimated over 1000 tonnes of sulfuric acid, 450 tonnes of aluminium and 300 tonnes of iron were released from a 4000-hectare catchment following a major flood in 1994. This acidified a 90-kilometre reach of the river for seven weeks, with the pH falling as low as 2.6 (National Working Party on Acid Sulfate Soils 2000).

There have been significant effects on infrastructure; for example, the Tweed Shire Council in northern New South Wales spent nearly $4 million replacing iron water pipes corroded by acid groundwater.

There is increasing recognition of CASS as a national problem needing a coordinated national approach. A National Strategy for dealing with acid sulfate soils has been developed and is being implemented. Through an initiative of Australia's Oceans Policy, the Coastal Acid Sulfate Soils Program, the Federal Government has allocated approximately $3 million for demonstration projects to assist in the better management of coastal acid sulfate soils. Funding for some eight projects to demonstrate a range of options for the management of coastal soils was announced in September 2000.

State strategies and policies have also been developed; for example:

- New South Wales established an Acid Sulfate Soils Management Advisory Committee in 1994.
- Queensland formed an Acid Sulfate Soil Investigation Team in 1995, an Advisory Committee in 1996 and a Strategy in 1999, and
- Victoria developed the Industrial Waste Management Policy (Waste Acid Sulfate Soils) in 1998.

Where mangroves and low coastal land had been drained for sugar farming in the Tweed River region, acid drainage problems had resulted. However, New South Wales sugar farmers are now self-regulatory, CASS management techniques are widely accepted by the industry and individual farmers, and viable crops are being grown on previously drained CASS. Because of the actions taken, the environmental health of drainage systems running from the majority of Tweed sugar cane farms has improved markedly.

Water Quality

Environmental indicators reported in this section:

Environmental Indicator	
CO 6.3	Turbidity
CO 6.4	Water nutrients (nitrogen)
CO 7.5	Coastal discharges

Marine and estuarine waters are valued by the community for a range of purposes or environmental values (ANZECC/ARMCANZ 2000). Those environmental values are:

- aquatic ecosystem maintenance,
- primary industry, and
- recreation and aesthetics.

Australia's coastal waters are generally in good condition and support the above environmental values. In the tropical north most coastal waters are in good condition, but where agricultural, urban or industrial development has occurred, coastal waters have been degraded to some extent.

Pollution of coastal waters is derived from both land and marine sources, with land-based sources generally regarded as either point sources (e.g. waste water treatment plants) or as diffuse sources (e.g. urban and agricultural runoff). Marine sources of pollution are associated with harbour dredging, shipping (including fuel and hazardous cargo spills), the use of hull antifouling paints, and aquaculture. The relative contributions of these sources of pollution are poorly defined, but it is widely considered that land-based sources represent the greatest threat to the environmental values of Australia's coastal waters. Only very limited information is available on marine sources of pollution.

Point-source pollution has been well characterised and is regulated through pollution control legislation. Diffuse source pollution from agricultural and urban runoff, however, remains largely unchecked because of:

- the inability or unwillingness of authorities to enforce regulations (where they exist),
- a failure to plan and control the impact of agricultural and urban development on water quality,
- community perceptions that individual actions do not contribute to cumulative impacts, and
- a lack of an integrated management system that recognises environmental values.

There is no comprehensive national coastal water quality monitoring program, and national trends in water quality cannot be reported. However, all States and some other organisations undertake coastal water quality monitoring programs, particularly adjoining large population centres or where there is extensive catchment development and concerns about degraded coastal water quality.

Key pollutants of marine and estuarine waters

Coastal waters can be degraded by a range of pollutants, including nutrients, sediment, pathogens and toxicants (including heavy metals, hydrocarbons and organochlorines). Some coastal waters are also degraded by acidic leachates from coastal acid sulfate soils.

Nutrients [CO Indicators 6.4 and 7.5]

Nitrogen and phosphorus support the growth of plants and phytoplankton in coastal waters. Nitrogen availability generally limits plant growth, and in estuarine systems where nitrogen fixing algae proliferate, phosphorus is often the limiting nutrient (e.g. in Peel Inlet and Harvey Estuary in Western Australia, and the Gippsland Lakes in Victoria).

The National Pollutant Inventory (NPI) provides information on the relative contributions of nitrogen and phosphorus from both point and diffuse source discharges to

Table 5: Total nutrient emissions for selected coastal regions (1000 kg).

Coastal region	Land use	Phosphorus		Nitrogen	
		Point[A]	Diffuse[B]	Point[A]	Diffuse[B]
Peel–Harvey (WA)	Agriculture	na	260	na	1 800
Esk/Tamar (Tas)	Agriculture	150	360	390	1 600
Dawson River (Qld)	Agriculture	20	1 700	28	6 400
Latrobe–Thomson (Vic)	Agriculture	18	410	44	3 800
Richmond River (NSW)	Agriculture	5.8	250	na	1 700
Darwin Harbour (NT)	Mix	68	47	270	590
South-east Queensland (Qld)	Mix	1 300	1 500	3 300	7 000
Water Catchment Adelaide (SA)	Urban/Industrial	210	64	920	550
Port Phillip Bay (Vic)	Urban/Industrial	2 500	190	8 500	2 300
Botany Bay (NSW)	Urban/Industrial	1 300	48	7 600	280
Lake Illawarra (NSW)	Urban/Industrial	190	25	970	170

A Emissions of Total Phosphorus and Nitrogen from Reporting Facilities 1999–2000.
B Emissions of Total Phosphorus and Nitrogen to Water from Aggregate Sources 1999–2000. Diffuse source pollution represents aggregated data for which there may be significant error of estimation, ranging up to +/- 50% for data for WA and 3 to 13 times for diffuse source estimates in Tasmania. There are significant qualifications to the National Pollutant Inventory estimates and information on the website should be consulted before quoting and/or interpreting these figures.
na none reported.

Source: http://www.environment.gov.au/epg/npi/ (October 2001).

coastal waters. However, it should be noted that the data for diffuse source pollution is likely to be largely an estimate at this early stage of implementation of the NPI.

This early data suggests coastal and marine waters adjacent to:

- heavily urbanised or industrialised areas (e.g. Port Philip Bay, Botany Bay, Adelaide) are likely to receive the majority of their nutrients from point sources, and
- less populated rural and agricultural lands (e.g. Dawson River, Latrobe–Thomson, Richmond River) are likely to receive the majority of their nutrient loads from diffuse sources.

One area that has been well studied is the Great Barrier Reef region, which is particularly susceptible to nutrient enrichment because it is relatively enclosed and shallow (EPA 1999a). A June 1999 workshop discussed the sources, fates and consequences of pollutants within the Great Barrier Reef (Hutchings and Haynes 2000). The reduction of pollution loads from agricultural catchments continues to be the key to the ecological health of the Reef system.

Point sources of nutrient pollution to coastal waters are derived from a number of activities, including wastewater treatment plants, landfills, and industries such as wood product manufacturing and paper production.

Discharges from wastewater treatment plants represent the great majority of phosphorus and nitrogen point source discharges. Table 6 indicates the relative contribution of nutrients from wastewater treatment plants to the total nutrient load from point sources in some coastal regions.

Where urban expansion is planned, there is the potential to increase nutrient loads to already nutrient-rich marine waters. The Western Australian Environment Protection Authority, for example, is concerned that proposed urban expansion along Perth's south-east and north-east corridors could increase nutrient loads to the already highly eutrophic Swan–Canning estuary system. Phosphate inputs from new residential areas in the Southern River catchment could start affecting the Southern River in less than 10 years (Gerritse 1999).

Sediment [CO Indicator 6.3]

Sediment levels in coastal environments are highly variable, depending on climatic and catchment factors. Extreme rainfall events combined with an extensively cleared catchment will result in relatively high sediment losses. Essentially all sediment transported to coastal areas is from diffuse sources, suspended in agricultural and urban runoff. However, building and construction sites can contribute significantly at the local level.

Table 6: Proportion of total point source emissions of nutrients to coastal regions attributable to wastewater treatment plants.

Coastal catchment	Major wastewater treatment plants	%P	%N
Water Catchment Adelaide	Glenelg, Port Adelaide	100	100
Darwin Harbour	Ludmilla, Leanyer Sanderson, Larrakeyah	98	90
Derwent	Macquarie Point, Prince of Wales, Rosny	92	87
Esk/Tamar	Ti-tree Bend, Hoblers Bridge, Newnham, Norwood	87	97
Dawson River	Calliope River	100	100
SE Queensland	Luggage Point, Elanora, Rocklea	92	94
Port Phillip Bay	Werribee, Bangholme	100	99
Botany Bay	Cronulla, Malabar	100	99
Lake Illawarra	Bellambi, Port Kembla, Shellharbour, Wollongong	100	100
Richmond River	Casino	100	na

Source: http://www.environment.gov.au/epg/npi/ (October 2001).

Most sediment exported during infrequent, intense storms, includes adsorbed phosphorus, organic material and pesticides that may be on suspended clay particles. For example, during Cyclone Sadie in 1994 the Herbert River in Queensland discharged over 100 000 tonnes of suspended sediment, sourced principally from grazing land. This would be sufficient to cover the whole of Sydney in 2 centimetres of soil (Mitchell and Bramley 1997). **(**For more information refer to the Land Theme Report).

Queensland's State of the Environment Report (EPA 1999a) notes that the increase in catchment sediment yield is considered to be attributable to higher sediment yield from cleared land. In view of continuing vegetation clearing, the natural sediment supply regime can be expected to be affected further in some regions and be particularly evident in more remote regions. Given the already significant impacts of sediment discharges, this should raise major concerns over permitting additional agricultural clearing and coastal development in Queensland and elsewhere, specifically in terms of the potential for further sediment pollution of estuaries and coastal waters.

Pathogens

Public health may be at risk from high concentrations of faecal coliform and enterococcal bacteria in estuarine and coastal waters, either through contact recreation (especially swimming) or consumption of contaminated seafood. Along some beaches (e.g. in the Sydney Harbour) and under certain conditions (following heavy rains or sewage system overflows), beach users risk a range of illnesses such as carditis, conjunctivitis, hepatitis, and skin and wound infections.

Toxicants

Toxicants are chemical contaminants such as metals, aromatic hydrocarbons, pesticides and herbicides that can potentially have toxic effects at concentrations that might be encountered in the environment. The use of pesticides and herbicides, especially in agricultural production, can result in these compounds being transported by stormwater into estuarine and marine environments where they accumulate in sediments and can affect the communities of invertebrates living in soft sediment habitats.

There is no national overview of the extent and levels of toxicants found in coastal waters and sediments, neither is there nationally available information for the emission of toxicants from diffuse source pollution.

Although concentrations of heavy metals and organochlorine compounds along the Great Barrier Reef coast are generally low, there are hot spots of pollution adjacent to ports and harbours, urban centres and areas adjacent to intensive agricultural activity (Haynes and Johnson 2000).

Although there have been only two reporting periods since the National Pollutant Inventory reporting commenced, there are signs of possible reductions in emissions from some facilities. Most notable in Table 7 are the reductions in emission of:

- various hydrocarbons from the BP refinery at Bulwer Island, Brisbane,

Table 7: Selected emissions from selected reporting facilities for 1998–2000 (kg).
Reporting periods 1 July 1998–30 June 1999 and 1 January 1999–31 December 1999.

Reporting Facility	Substance	1998–1999	1999–2000
Werribee wastewater treatment plant, Melbourne	Arsenic and compounds	—	780
	Chromium VI and compounds	—	1 300
	Lead and compounds	—	520
BHP Steel, Port Kembla	Cadmium and compounds	—	120
	Cyanide	—	3 800
	Lead and compounds	—	520
Caltex refinery, Kurnell	Benzene	—	5 000
	Toluene	—	3 200
	Xylene	—	3 300
BP refinery, Brisbane	Benzene	120	84
	Cadmium and compounds	10	7
	Chromium VI and compounds	10	14
	Lead and compounds	40	40
	Polycyclic aromatic hydrocarbons (PAHs)	220	150
	Toluene (methylbenzene)	130	85
	Xylene and isomers	190	130
Caltex refinery, Brisbane	Arsenic and compounds	15	12
	Cadmium and compounds	7	12
	Chromium VI and compounds	15	9.5
	Cyanide (inorganic) compounds	—	45
Bangholme wastewater treatment plant, Melbourne	Ammonia (total)	3 200 000	3 000 000
	Chromium and compounds	—	900
	Copper and compounds	2 500	2 100
	Lead and compounds	—	900

Source: http://www.environment.gov.au/epg/npi/ (October 2001).

- ammonia and copper from the Bangholme wastewater treatment plant, Melbourne, and
- arsenic and chromium from the Caltex refinery, Brisbane.

Along with reductions to some emissions there are also increased emissions, for example in:

- cadmium emissions from the Caltex refinery, Brisbane, and
- chromium emissions from the BP refinery, Brisbane.

While information in Table 7 represents known discharges of toxicants from point source pollution, unauthorised and unreported spills may be significant, such as the alleged discharge of 1032 kilograms of arsenic to Cockburn Sound by Wesfarmers CSBP between July and September 1999 (DEPWA 2000).

Tributyl tin (TBT) is used as an antifouling treatment for boats and ships, and has been shown to cause imposex in marine snails at extremely low concentrations. Imposex is the development of male reproductive organs in female snails, making the snails sterile. This phenomenon raises concerns about the ecological impacts of continued TBT use (DEPWA 2000).

In general, toxicant contamination is associated with industry and past effluent management practices. Point-source discharges have, since the 1970s, had to meet increasingly stringent emission limits. However diffuse-source discharges of toxicants, from both agricultural and urban sources, continue effectively unchecked.

Acid sulfate soils

Coastal acid sulfate soils (CASS) have been recognised as contributing to one of the most important water quality issues in coastal lowlands and estuaries (see Coastal Settlement section on page 44). Acid runoff causes adverse impacts to the environment, in terms of:

- poor water quality with loss of amenity;
- loss of fisheries, wetland biodiversity and aquacultural production;
- additional maintenance of community infrastructure, particularly from acid erosion; and
- the need for rehabilitation of disturbed areas.

Nutrients affecting the Cockburn Sound environment

Cockburn Sound, located south of Fremantle, is the most intensively used marine embayment in Western Australia. Increasing urban and industrial development of the adjacent coast since 1954, and increased inputs of industrial discharges and sewage during the 1960s, led to substantial loss of seagrass.

Management plans put in place in the 1970s had some success in reducing point source discharges. However, water quality has remained at levels found in the 1970s because high winter river flow from the Peel–Harvey and Swan–Canning estuaries carries land-sourced nutrients into the marine environment. The export of nutrients from these catchments to the ocean is estimated to have increased fourfold over the past 50 years (DEPWA 1996).

Seagrass meadows have continued to decline in area, and the species which grows in Cockburn Sound (*Posidonia*), may only recolonise very slowly (if at all), so the losses may be permanent.

The trend in nutrient-related water quality of Cockburn Sound since the 1970s has been initial improvement and subsequent deterioration (Environment Western Australia 1998).

To deal with the issues of coordination and integration in Cockburn Sound, the Cockburn Sound Management Authority was established in 2000 to manage the various uses of the Sound.

Increased acidity in waterways causes fish kills, outbreaks of fungal diseases in fish and leads to the presence of aluminium and iron flocs in the water. The full extent of ecological impacts of acidic waters in estuaries is not yet known.

Impacts on marine and estuarine water quality

The effects of pollution on aquatic ecosystems are dependent on a range of factors, including the nature of the receiving ecosystem, the mixing and dispersion of pollutants, whether floods have transported materials, and on the bioaccumulation of contaminants in sediments, flora and fauna.

Eutrophication

In general, eutrophication of coastal waters occurs where these waters receive significant industrial discharges or urban and agricultural runoff. For example, a 1991 Parliamentary Select Committee report (1991) noted that, of the 22 estuaries in Western Australia's south-west, only seven had low nutrient levels, and these had forested catchments.

The majority of the eutrophic estuaries are fed by agricultural catchments. The situation for Western Australia's south-west estuaries has not improved, and except for the Peel–Harvey coastal catchment, phosphorus levels have not decreased.

The effects of eutrophication are evident Australia-wide; for example:

- in South Australia, at least 250 hectares of mangroves adjacent to the Bolivar sewage outfall have been lost to dieback and smothered by large drifts of sea cabbage. The proliferation of sea cabbage, promoted by nutrient discharges, is also killing seagrasses off the Adelaide metropolitan coastline, where total seagrass loss since 1935 is estimated at 5000 hectares.
- in Western Australia, toxic algal blooms occur annually in the upper reaches of the Canning and Swan Estuaries, and extensive areas of seagrass have been lost to epiphytic algae in Cockburn Sound, Geographe Bay, and Princess Royal and Oyster Harbours. In February 2000, the Western Australian Health Department warned against eating mussels from the Peel–Harvey Estuary following an outbreak of a toxic algal bloom. At the same time, sections of the Swan River were closed to the public following the first recorded major bloom of the toxic blue-green alga *Microcystis aeruginosa*.
- in Victoria, toxic algal blooms have occurred in the Gippsland Lakes, causing extensive fish deaths and affecting fisheries and the local tourism industry.
- in New South Wales, between 1997 and 1999, two algal blooms potentially harmful to marine organisms and seven blooms potentially toxic to humans were recorded. These bloom frequencies were similar to those recorded between 1994 and 1996.

Contaminated edible bivalves in the Ballina and Newcastle areas lead to 59 and 23 cases of gastroenteritis, respectively.

- an algal bloom in the Wagonga Inlet near Narooma in October 1999 caused a temporary halt to oyster harvesting in affected leases. There were also 50 algal blooms between 1997 and 1999—double the number in the previous three years (EPA 2000a).

Sedimentation

Increased sediment loads are affecting almost all of Australia's coastal waters. Even in the sparsely populated north-west of Western Australia, sedimentation is severe and is directly linked to pastoral activities and over-grazing. Though not a coastal water, Lake Argyle provides an opportunity to evaluate sediment transport from the pastoral areas. Sediment has accumulated in Lake Argyle (since it was created by the Ord River Dam in 1971) at an average rate of 24 million cubic metres per year, which by 1998 represented a little over 10% of the original volume (Environment Western Australia 1998). Rehabilitation of the areas of the Ord River catchment degraded by pastoral activities has been ineffective.

Turbidity from suspended sediment can have serious physical impacts on aquatic ecosystems, including clogging and damaging the gills of fish, and loss of shellfish and other invertebrates from sediment ingestion. Along with the direct physical impacts on marine organisms, sediment contributes nutrient and toxicant loads to coastal waters in both urban and agricultural catchments, and so is a major concern for coastal water quality.

The 1992 Western Australia State of the Environment Report observes that:

- a single summer flood (date unknown) delivered 100 000 tonnes of soil to Beaufort Inlet and reduced its depth by 25 millimetres,
- the depth of Stokes Inlet has been reduced by 20–25 cm in 30 years,
- sediment almost filled the Irwin Inlet in a flood event (date unknown),
- many other south-western estuaries have become shallower since clearing for agriculture began, and
- sediment loads to south-western estuaries are a major source of nutrients, with those estuaries demonstrating eutrophic conditions.

In its studies of Port Phillip Bay, the CSIRO (Harris et al. 1996) has shown that sediments are the primary factor affecting water quality in the Bay. The study uncovered the basic features of nitrogen cycling in the Bay, where biogeochemical processes in the sediments assimilate and release nutrient loads.

Faecal contamination

Faecal contamination is a major concern where it affects recreational or aquacultural environmental values.

Monitoring of Sydney's ocean beaches shows that ocean beach water quality has improved very substantially since the commissioning of the deep ocean sewage outfalls in the early 1990s (see http://www.epa.nsw.gov.au/beach/snapshot.htm [accessed 5 September 2001]), and most of Sydney's beaches are now suitable for swimming most of the time. The New South Wales EPA's Beachwatch and Harbourwatch programs operate throughout the Sydney metropolitan area and in the Hunter and Illawarra regions, and reports to the community on the risks of sewage and stormwater pollution at swimming areas (http://www.epa.nsw.gov.au/beach/index.asp [accessed 5 September 2001]).

Faecal contamination by stormwater and sewage overflows following heavy rains is still causing some beach closures in Sydney's harbour and estuarine beaches, the Derwent Estuary in Tasmania, and Port Phillip Bay in Victoria.

Faecal contamination can also affect aquaculture activities. For example, in February 1997 an outbreak of hepatitis A was linked to oysters grown in Wallis Lake in central New South Wales, where the contamination was caused by poorly treated sewage entering the lake.

Toxicants

Toxicant concentrations are known for some coastal lakes and estuarine areas, but their effects on biota are poorly understood. Reports on toxicant monitoring indicate some 'hotspots' of contamination, for example:

- the presence of hydrocarbon 'biomarkers' in fish sampled in Cockburn Sound, Western Australia. Sampling adjacent to the Fremantle Fishing Boat Harbour had the highest levels of these biomarkers (DEPWA 2000).
- in the Port River estuary, Adelaide, monitoring during 1995–96 showed that sediment heavy metal concentrations (especially of copper and lead) at all sites exceeded guideline concentrations, and found high levels at some sites (copper, lead, zinc, mercury and cadmium).
- heavy metal contamination of Macquarie Harbour in Tasmania continues to be of concern, with the continued drainage of acidic mine water containing heavy metals into the Harbour (see 'The condition of an estuary' box on page 22).
- tests on fish, crustaceans and cephalopods taken from Moreton Bay in Queensland in 1995 found that lead, inorganic arsenic, chromium and nickel concentrations were, in most cases, below the level of detection. No sample contained a concentration of zinc, mercury, selenium or cadmium in excess of the maximum permitted concentration (MPC), but more than half the crustaceans tested for copper exceeded the MPC (EPA 1999a).

Acid sulfate soils

Coastal acid sulfate soils (CASS) disturbance has been linked to major fish kills and outbreaks of red spot disease in fish, and to the increased incidence of acid-tolerant, disease-carrying mosquitoes. The products of acid leachate from these soils have also been implicated in the increasingly severe *Lyngbya* blooms experienced in Deception Bay and Pumicestone Passage, Moreton Bay (although the blooms are also triggered by high phosphorus loads (Watkinson et al. 2000).

In April 2001, acid plumes with a pH as low as 3 have been detected in the Richmond and Macleay Rivers in northern New South Wales (Collins, pers comm.). Although recent acid flows and effects are not as great as in the 1994 floods, frequent low-level acidic discharges will continue to kill benthic organisms and affect estuarine ecosystems. The annual loss of fish catch in New South Wales as a result of disturbed acid sulfate soils is estimated to be $1 million, and a similar figure is estimated for the oyster industry (Department of Natural Resources 1999).

Responses to marine and estuarine water pollution

Society's response to the condition of our coastal waters and its capacity to support the waters' environmental values has taken many forms. The following list is not exhaustive, but intended to give examples of the various approaches adopted, with the focus on actions taken since SoE 1996.

Institutional

- A major revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality was released in 2001. These provide a risk-based framework for setting water quality objectives required to sustain current or likely future environmental values for natural and semi-natural water resources. Each jurisdiction must develop water quality objectives based on the guideline values.
- In 1998, the National Environment Protection Council (NEPC) established a National Environment Protection Measure (NEPM) as the statutory basis for the National Pollutant Inventory. The NPI provides the community and other stakeholders with information on the discharge of pollutants to the environment.
- Australia's Oceans Policy (1998) recognised the continued degradation of Australia's coastal waters. Through this policy the Commonwealth Government is pursuing consistent water quality standards.
- All Australian States except New South Wales and the Northern Territory have finalised or are developing statutory environmental protection and/or planning policies for marine and estuarine water quality.
- In 2001, the Great Barrier Reef Marine Park Authority released a Water Quality Action Plan for the Great Barrier Reef with 10 year targets to reduce discharges from the entire Great Barrier Reef catchment (GBRMPA 2001).
- The Cockburn Sound Management Authority was established in Western Australia in 2000.

Management

- Within the last five years a number of local authorities or corporations have announced or implemented plans to upgrade the level of wastewater treatment. For example:
  - Environment Improvement Plans are in place for four wastewater treatment plants near Adelaide, and include nutrient reduction, additional treatment, greater reuse and improved dispersion from outfalls,
  - Western Australia's Water Corporation is committed to reducing suspended solids, bacteria, nutrient and heavy metals discharged from one of Perth's wastewater treatment plants, and
  - In September 1997, the New South Wales Government announced funding of $60 million to assist councils with preparing stormwater management plans and for a stormwater education program (see http://www.epa.nsw.gov.au/stormwater/usp.htm [accessed 5 September 2001]).
- In April 1998 the New South Wales EPA issued a legal direction requiring councils to prepare stormwater management plans. More than 80 plans were received by July 2000.
- Melbourne Water and local councils have developed a Stormwater Agreement, and 23 metropolitan councils have prepared Stormwater Management Plans.
- The Commonwealth Government has allocated $6.8 million to the Urban Stormwater Initiative, aimed at enhancing water quality in the waterways of major coastal cities through improved stormwater management.
- Sewage, stormwater and industrial discharges are now being viewed as a valuable resource. Wastewater is being treated and redirected away from ocean discharge to productive uses in agriculture and horticulture. Examples of recent programs funded through the Coasts and Clean Seas Initiatives include:
  - The redirection of stormwater and treated sewage from Brighton Council's wastewater treatment plant at Green Point in Tasmania for reuse on land. The redirection started in late December 1999. The outcome was the cessation of treated sewage discharges by the following year.
  - The construction of stormwater detention basins to treat the increased sewage and urban runoff from Hervey Bay's rapidly increasing population in Queensland. Treated water will be pumped into existing sewer and wastewater irrigation infrastructure to provide reuse water for crops such as sugar cane.
- In South Australia, construction of the Virginia Pipeline Scheme, delivering treated effluent from the Bolivar Wastewater Treatment Plant to the Virginia Plains horticultural areas, will reduce by up to 70% Bolivar's nitrogen discharges to the Gulf St Vincent.

Community

- In October 2000 the community-based Fitzroy Basin Association released its Central Queensland Strategy for Sustainability. The Strategy, which covers an area of 200 000 km^2, seeks amongst other matters to 'develop water quality and river health targets . . . and maintain the values of instream, riverine, estuarine and marine ecosystems' and to 'improve the management of landscapes and land uses which contribute excessively per unit area . . . to nutrient and sediment runoff into streams'.
- Introduced in 1998, the Commonwealth Government's Industry Partnership Program provides more than $1.5 million to industry to undertake works that improve the quality, amenity and health of urban coastal waterways by reducing pollution from industrial sources.
- The Natural Heritage Trust's Coasts and Clean Seas Initiative, introduced in 1996, supports sustainable wastewater management in coastal areas. The program also aims to reduce marine pollution from other sources such as shipping, boating activities and aquaculture.

Conclusions and Implications

Many of Australia's coastal waters continue to receive ecologically unsustainable levels of pollutants. Algal blooms, triggered by excess nutrients, are causing massive ecological damage, threatening aquaculture production, and prejudicing the recreational amenity of many highly

valued coastal waters. Meanwhile, sewage overflows and untreated urban stormwater threaten aquaculture production (e.g. oyster farming) and cause authorities to close swimming beaches. Extreme rainfall events cause massive soil erosion and sediment discharges to coastal systems, carrying with it nutrients and other contaminants, and smothering benthic communities.

Over the last 20–30 years, increasingly stringent limits have been placed on point-source emissions, so that in many areas (e.g. Port Phillip Bay in Victoria, Cockburn Sound in Western Australia, Botany Bay in New South Wales, and Lake Illawarra in New South Wales) sediment pollutant concentrations have declined. However, there is still considerable potential for further reducing industrial discharges.

Of the point sources of pollution, wastewater treatment plant effluent remains the most intractable. The discharges from large treatment plants are orders of magnitude greater than other point source discharges and in some areas, the discharges are into relatively protected, poorly flushed coastal water systems where concentrations of pollutants and sediment loads can be high. Sydney Water and Western Australia's Water Corporation, for example, have constructed deep ocean outfalls to discharge large volumes of waste to areas where currents dilute and disperse the pollutants. Monitoring to date suggests there are no unacceptable environmental impacts from this practice, but the long-term sustainability is yet to be demonstrated because the indirect and possibly accumulating effects of various subtle-acting substances (such as hormone mimics) has yet to be assessed.

Wastewater discharges to estuaries and embayments (such as the Derwent River in Tasmania and Moreton Bay in Queensland) continue to contribute substantial loads of nutrients and toxicants to these poorly flushed systems, enhancing the accumulation of these substances in sediment and biota.

To date, the pursuit of estuarine and marine water quality objectives has been through waste management technologies treating point-source pollution, with the current major focus on reducing discharges from wastewater treatment plants. However, it is clear that estuarine and marine water quality will not be protected through point source controls alone. Emissions information in the National Pollutant Inventory indicates that diffuse source pollution is the major contributor to water quality degradation, whether derived from agricultural or urban stormwater.

All of society faces a major challenge to reduce pollution, and all levels of government must show leadership in this regard. There is a pressing need for governments to implement the National Water Quality Management Strategy, identify the environmental values and water quality objectives of our coastal waters, and estimate and pursue the pollutant load reductions needed to protect those environmental values. Once load reductions are established, economically efficient and equitable strategies must be formulated to address point and diffuse sources of the major pollutants of concern.

Also, suitable benchmarks for environmental values, including targets for species and habitats, must be established and incorporated into environmental quality objectives as part of an integrated approach to the management of pollutant loads.

A cooperative reporting and standardisation of methods for water quality assessment will be a key part of building a shared understanding of the problems and potential solutions.

Introduced marine species and marine pests

Environmental indicators reported in this section:

Environmental Indicator	
CO 3.11	Pest numbers
CO 3.15	Species outbreaks

[CO Indicator 3.11]

Because Australia is an island continent, we depend on maritime transport; over 95% of our imports and exports are transported by ship. While Australia has taken steps to reduce pest introductions, for example through border controls, incursions continue to occur. Pest species are a threat to marine biodiversity as well as marine industries such as fishing and aquaculture.

Introduced marine pest species include large seaweeds, such as *Undaria pinnatifida* (Japanese Kelp) in Tasmania and *Caulerpa taxifolia* in New South Wales, and minute planktonic dinoflagellates, and animals such as crabs and starfish. Those of greatest threat have been listed as target species by the Australian Introduced Marine Pests Advisory Council.

There is, however, no continental-scale trend information available on the number of introduced species that are classified as marine pests. Partly this is because the definition of 'pest species' has changed and partly because this information has not been systematically collected in the past. However, it is known that about 200 marine species have been intentionally or accidentally introduced into Australian waters since the start of trade and shipping.

Some existing native species may multiply to the point of being a pest, either through apparently natural cycles or possibly by some human trigger. The best-known example is the Crown of Thorns Starfish on the Great Barrier Reef. The Ningaloo Reef in Western Australia has been affected by outbreaks of *Drupella*, a coral-eating snail. There are other marine pests that have been introduced to Australian waters in some way and which displace native species from their habitat.

One of the most important ways in which marine pests can be introduced is through the discharge of ballast water in our coastal waters. Ballast water is used in ships for stability while travelling to and from Australia. Around 150 million tonnes of ballast water are released in Australian coastal waters annually from international vessels, and a further 34 million tonnes from coastal vessels.

Other ways in which marine pests can be introduced into Australian waters include: as fouling organisms on vessels' hulls and anchor chains, and in internal water systems; attachment to drilling platforms; deliberately and accidentally through the aquarium trade, movement of fish products, mariculture and aquaculture; and in imported seafood.

The relative importance of these different means has changed over recent years, with hull-fouling, recreational vessels and translocation of species between Australian ports becoming recognised as more important means of pest introductions. Information on foreign ship visits to Australian ports is on page 80.

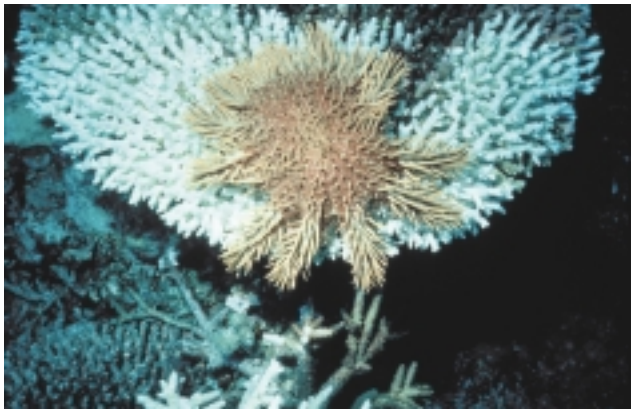
The threat of incursions of new introduced marine pests, or of existing pests to new locations within Australia, is real and immediate (Commonwealth of Australia 2000) and can have significant economic consequences. The outbreak of the Black Striped Mussel in Darwin, for example, had the potential to severely damage the pearling industry ($225 million value of production in 1998).

Introductions of pest species have been detected in all States of Australia. The most intensively studied port region in Australia is Port Phillip Bay in Victoria. This is one of the few areas where it possible to evaluate the historical patterns of invasion by exotic marine species **(**Hewitt et al. 1999). The study identified between 99 and 178 introduced species in the Bay, and estimated that the actual number of exotic marine species is between 300 and 400. The study further estimated that two to three new exotic species are establishing in Port Phillip Bay each year.

A series of baseline surveys of ports and harbours to assess how many marine pests have been introduced into Australian waters was initiated in 1995 by the Australian Association of Ports and Marine Authorities, CSIRO Marine Research, and CSIRO Centre for Research on Introduced Marine Pests. As of 2001, 22 out of 65 ports of first call for international vessels

have been surveyed. When all these port baseline surveys have been completed, a better assessment of the risks posed by introduced species will be possible.

However, this baseline information will not be used to maximum effect unless ports and harbours at greatest risk are re-surveyed on a regular basis. At the same time, measures such as ballast water treatment to reduce the risk of introductions should be developed as a matter of urgency.



Crown of Thorns Starfish feeding on plate coral.

Source: B Legg, Great Barrier Reef Marine Park Authority.

Examples of pest species [CO Indicator 3.15]

Crown of Thorns Starfish

At low densities, this starfish (*Acanthaster planci*) is considered a natural component of the Great Barrier Reef. However, when its density reaches about 30 mature starfish per hectare, the level at which it eats coral faster than coral can grow, a major reduction in living coral occurs. It has been extensively studied (e.g. Wachenfeld et al. 1998), but the cause of outbreaks is still not fully understood, although freshwater runoff has been implicated.

The intensity and frequency of outbreaks have not abated since they were first noticed in 1962. The first outbreak occurred off Cairns, with a slow southwards spread over the next 14 years. A second outbreak followed between 1979 and 1991, affecting about 17% of the World Heritage Area reefs, with 5% severely affected. In 1993 a third outbreak commenced, and has continued. By 2000 the percentage of reefs on the Great Barrier Reef with outbreaks of the starfish was the highest since surveys began (Sweatman et al. 2000).

Tourism operators receive permits to clear Starfish from small areas at selected tourist sites in order to maintain live coral cover, and so consider the Crown of Thorns Starfish to be a pest species in these areas.

The causes of the outbreaks are not fully known, so that it is not possible to assess whether the outbreaks are natural or not. Some factors that could influence Starfish populations include increased nutrients in runoff from the land, freshwater runoff and the effects of the removal of predators from the ecosystems by fishing.

Urchin barrens

An example of a native species becoming a pest in the south of Australia is that of the Purple Sea-urchin (*Centrostephanus rodgersii*), which can cause denuded environments called urchin barrens. It is thought that over-harvesting of competing Blacklip Abalone (*Haliotis rubra*) contributed to the expansion of barrens habitat. Once established, barrens are unsuitable as abalone habitat and populations decline as the biomass of food algae decreases.

The White Urchin (*Heliocidaris erythrogramma*) has also been responsible for the creation of barrens by denuding forests of the Giant String Kelp (*Macrocystis pyrifera*) along the East Coast of Tasmania. In this instance it is believed that over-harvesting of the Southern Rock-lobster (*Jasus edwardsii*), an important predator of urchins, promoted substantial increases in urchin abundance.

Caulerpa

The macroalga *Caulerpa taxifolia* was found on the New South Wales South Coast for the first time in 2001 and is now known at a number of sites along the coast. It can smother seagrass beds that are important nursery habitats for fish. The identity of the *C. taxifolia* strains found in New South Wales is still uncertain, although it appears to be related to native *C. taxifolia* strains found in Queensland. It appears to have been translocated from Queensland on a vessel.

Mussels

The Asian Mussel (*Musculista senhousia*) can dramatically alter habitat by forming major outbreaks that out-compete other shellfish and native species. This mussel was first recorded in the Swan River in Western Australia, arrived in Victoria in 1987, and is now abundant in Port Phillip Bay. An infestation of New Zealand Green-lipped Mussel (*Perna canaliculus*) was found and removed from Port Adelaide River in 1996.

The Black Striped Mussel

The Black Striped Mussel (*Mytlopsis sallei*) can tolerate a wide salinity and temperature range, putting at risk of invasion an area encompassing much of the coast of Australia, from Fremantle in the west to Sydney in the east, and even the warmer regions of the Great Australian Bight.

In early 1999, this exotic marine bivalve was discovered in Darwin Harbour during a resurvey of the Port of Darwin. Its presence in Cullen Bay Marina, and subsequently two other marinas, were the first recorded sighting of the species in Australia. It was not present two years earlier when a baseline survey of the Harbour had been carried out.

Having witnessed the ecological and financial disaster caused in the Great Lakes region of North America by its near-relative the Zebra Mussel, the Northern Territory and Commonwealth governments mounted a major effort to eradicate this pest. This is one of the first instances in the world of a successful eradication of an established marine pest population.

Initial research revealed the Black Striped Mussel is able to grow inside pipes and on any solid surface in contact with seawater. Its establishment in Territory waters had the potential to seriously affect marine biodiversity and threaten the social and economic benefits derived from aquaculture, recreational and commercial fishing, domestic and international tourism, and the shipping industry.

A Special Meeting of the Territory Cabinet enacted regulatory amendments and approved the appointment of a task force and expenditure of funds, within four days of the initial discovery.

Amendments to the Fisheries Regulations empowered the Director of Fisheries to authorise the closure and inspection of potentially infested areas. The Commonwealth *Quarantine Act* and the Northern Territory Fisheries Regulations were subsequently used in tandem to control vessel movements and order the inspection and cleaning of vessels. All vessels known to have been in any of Darwin's three marinas between 1 October 1998 and 31 March 1999 were tracked down by the coordinated efforts of AFMA and the Australian Quarantine and Inspection Service (AQIS) and checked.

The task force was responsible for coordinating research, surveys, vessel movements, inspection and cleaning of vessels, the eradication of the bivalve, and keeping the community informed.

Over 300 people participated in the response. The Northern Territory Department of Primary Industry acted as the lead agency. Further assistance was provided by CSIRO's Centre for Research on Introduced Marine Pests, the Museum and Art Gallery of the Northern Territory, the Northern Territory University (NTU) and the Australian Defence Force. Private business operators supplied supplementary divers, equipment and chemicals.

Research was undertaken at NTU into the efficacy and field logistics of eradication and treatment options such as temperature, salinity, chlorination and copper sulfate. Cullen Bay Marina, which was the worst affected, was dosed with a total of 163 tonnes of hypochlorite and 4.3 tonnes of copper sulfate over a three-week period, resulting in a complete kill of the Black Striped Mussel. Frances Bay Marina was dosed with 51 tonnes of hypochlorite and 1 tonne of copper sulfate, with the smallest private marina, Tipperary Waters, receiving 1.1 tonnes of copper sulfate. The chemical treatments killed all the marine life within the marinas.

The fouling caused by Black Striped Mussels.

Source: Centre for Introduced Marine Pests, CSIRO Marine Research.

Throughout the operation, the public and media were kept well informed via the newspaper, radio, Internet, and fact sheets distributed by volunteers to businesses and households surrounding the marinas.

Following the eradication, an ongoing biological monitoring program for the Black Striped Mussel and other exotic marine species was implemented in Darwin Harbour. In July 1999 the first samples in the greater Darwin Harbour were collected. No Black Striped Mussels were found. In November 1999, the Northern Territory Government established a fully funded Aquatic Pest Management Program to develop and implement protocols to protect Territory waters from the threat of aquatic pest species.

Long-term monitoring of the three Darwin marinas has shown that the 100% kill of all biological material has had no lasting effects, with marine life returning to marina waters within weeks of the lock gates being opened. The annual influx of freshwater during the tropical monsoon season between November and March results in the death of all marine life in the top two metres of marina waters—an effect similar to that of the chemical treatment.

In this incident, eradication of the Black Striped Mussel was successful. There were several reasons for this:

- the initial discovery was made in a small marina,
- the mussel was detected quickly, and
- dosing with chlorine was feasible in the marinas.

There is no guarantee that such a fortuitous set of circumstances would occur again in the future. The successful response to this incident may not be repeatable.

Northern Pacific Seastar — a national pest

The Northern Pacific Seastar (*Asterias amurensis*) is one of the most nationally threatening of the introduced marine pests to invade Australia. It grows rapidly, is highly fecund, forms dense populations, and appears to have few native enemies. It is a major predator of a wide range of marine species, including commercial shellfish.

It was introduced from Japan into the Derwent Estuary in Tasmania in the 1980s, either as larvae in ballast water or as adults on the hulls of international vessels. It was already well established by the time it was correctly identified in 1992. By 1999, the Seastar had become the largest component of the estuary's biomass.

A second population became established in Port Phillip Bay between 1995 and 1997, probably transported from Hobart by shipping. The population in Port Phillip Bay had grown to possibly 90 million by 2001 (Parry and Cohen 2001).

There is now a high risk of the Seastar appearing in other temperate ports in the future, from Western Australia to central New South Wales, and may eventually spread to the mid and outer continental shelf due to its depth tolerance (to 100 metres).

A National Control Plan (National Task Force on the Prevention and Management of Marine Pest Incursions 2000) has been put forward for the next five years to minimise the rate of spread and reduce its impacts. Although eradication of the Seastar is not possible, the Plan aims to reduce the risks of it spreading to new areas.

The Strategic Ballast Water Research Program of AQIS also addresses limiting the translocation of introduced species such as Seastars around the coast.

Dinoflagellates

Toxic dinoflagellates can become part of the shellfish feeding cycle. These protozoa produce toxins which can cause paralysis and sometimes death in humans who eat affected shellfish (see the 'Seafood quality' box on page 72).

In Tasmania, authorities have been forced to close down shellfish harvesting in the Huon River several times in recent years due to the presence of dinoflagellates in south-east Tasmanian waters. Scientists have linked the introduction of toxic dinoflagellates to ballast water and sediment discharged from overseas vessels.

Lyngbya

Lyngbya is a toxic marine cyanobacterium (blue-green alga) that appears to tolerate a wide range of salinity. It has a very rapid expansion rate and can smother seagrass. *Lyngbya* is a contact irritant that can produce skin and eye irritation following direct contact.

Blooms of *Lyngbya* were recorded in Moreton Bay in Queensland in the 1990s. In March 2000, a large bloom of approximately 30 km^2 was reported in Moreton Bay and persisted until about June 2000. This is in excess of previous blooms recorded within Moreton Bay.

Over the 2000–2001 summer, the blooms returned. In January 2001 the bloom at Deception Bay covered about eight to ten square kilometres. The bloom was still affecting Deception Bay in mid-February 2001.

A taskforce has been assembled by the relevant authorities in Queensland to investigate the causes of the bloom formation and to develop a management strategy.

Disease organisms

Ships' ballast water may have the potential to transport cholera organisms (Desmarchelier and Wong 1998), although an outbreak of cholera would depend on the breakdown of effective public health measures. A major outbreak in South America was circumstantially attributed to a ship's discharge.

Disease organisms can affect marine life. There is now some evidence that two mass mortalities of pilchards around southern Australia were caused by an introduced virus, although there are still uncertainties about how it could have been transported to Australia and around the coastline over such distances.

Minimising the risk of introducing pest species

The issue of introduced marine species transported by shipping is complex and involves stakeholders as diverse as the International Maritime Organisation (IMO), Commonwealth and State Governments, the shipping industry, mariculture, environmental organisations, and

The biggest fish kill in Australia

The largest recorded fish kill in Australian history occurred in southern Australia between late 1998 and early 1999. Huge numbers of dead Australian Pilchards (*Sardinops sagax*) were found on the sea surface, on the sea floor, and along beaches in southern Western Australia.

Australian Pilchards are commonly found in bays and coastal waters across southern Australia. Pilchards support purse-seine fisheries in southern Western Australia, South Australia and Victoria. Ten years ago the pilchard population was high and they were fished as an 'on-demand' fishery, relatively independently of the population.

There have been two major pilchard kills in the last five years. The first kill in 1995 originated near the Eyre Peninsula in South Australia then progressed west and east around southern Australia (Gaughan et al. 2000).

The origin of the episode, its fast rate of spread, apparently high mortality rate and the lack of previous comparable kills led Fletcher et al. (1997) to conclude that the disease agent was probably an exotic pathogen to which Australian Pilchards had not previously been exposed.

The second mass kill originated in South Australia in early October 1998 and also spread across southern Australia over a period of seven months. The kill of pilchards on the south coast of Western Australia during early 1999 is estimated to have been at least 28 000 tonnes of mature fish. This equates to three to five years of catch at current purse-seine fishing rates, in a period of only two months (Gaughan et al. 2000).

It is estimated that this mass mortality in both South Australia and Western Australia caused the loss of about 60% of the pilchard stock in both States.

The origin of the infectious agent in Australia is still unknown. Scientists (Whittington et al. 1997) have hypothesised that a herpes virus may have been introduced via ballast water, seabirds or imported baitfish. They noted at that time that more than 10 000 tonnes of pilchards were being imported annually from California, Peru, Chile and Japan without quarantine inspection. They were fed to sea-caged Southern Bluefin Tuna near the southern extremity of the Eyre Peninsula in South Australia.

Dead pilchards on the coast.

Source: South Australian Research and Development Institute (Aquatic Systems).

The imported pilchard hypothesis suggests that importation of untreated frozen pilchards carries a very high risk for Australian stocks of *S. sagax*.

Research aimed at answering some of the questions surrounding the 1995 and 1998–99 mass mortalities is under way. The mass kills have serious implications for our trade, quarantine and for the species dependent on pilchards as a source of food.

recreational interests. Within the shipping sector, no single solution could be applied to recreational, fishing, container and other commercial vessels.

The 1999 Black Striped Mussel incursion prompted the establishment of the National Task Force on the Prevention and Management of Marine Pest Incursions. This task force recommended reforms to current arrangements in December 1999, the major one being the establishment of a single national management regime for vessels. Its recommendations are being implemented through the work of the National Introduced Marine Pests Co-ordination Group to reform border prevention and management of existing pests.

A national coordination mechanism for emergency responses to introduced marine pests was established in 2000 as part of the reforms (the Consultative Committee on Introduced Marine Pest Emergencies). It has available an interim $5 million emergency response fund, pending longer-term arrangements that will be in place after 2002.

Ballast water

Internationally, implementation of improved ballast water management has been slow. The Marine Environment Protection Committee of the IMO has been drafting binding ballast

water management arrangements for international shipping since 1997, but is not expected to have a treaty document available for the signature of member nations until 2001 or 2002.

The Australian Quarantine and Inspection Service (AQIS) is the lead agency for the management of ballast water in international vessels. Voluntary measures and guidelines to manage ballast waters have been in place in Australia since 1990. Australia introduced mandatory ballast water management arrangements in July 2001 for international shipping entering Australian waters. The new arrangements incorporate a risk assessment management tool that provides vessels with an assessment of the likelihood of their introducing exotic species into Australian ports or waters via ballast water. A revised ballast water reporting system and verification inspections is also an integral part of the new arrangements. Vessels are assessed by the Australian Quarantine and Inspection Service (AQIS) as either high risk (in which case full exchange of ballast water at sea is required) or low risk (in which case exchange of ballast waters within coastal waters is allowable).

Another technology, apart from exchanging water at sea, that is showing potential is to heat the ballast water using waste heat from a ship's engine. Development of other technical solutions such as filtration, ozonation and ultraviolet treatment is under way.

Translocation

The Victorian Department of Natural Resources and Environment is managing two projects that are relevant to translocation issues nationally. The projects target two major pests: the Northern Pacific Seastar and *Undaria* seaweed. One project will develop sterilisation techniques and a mandatory code of practice for sterilising mariculture equipment that farmers move from one coastal site to another. The second project will develop voluntary operating practices that encourage small vessel operators and port managers to help prevent marine pests spreading to and between local ports.

Hull fouling

The control and management of hull fouling presents particular challenges that have not yet been analysed on a national basis. Anecdotal information suggests that hull fouling is more likely to be a problem for smaller vessels than for large international vessels. Improved ways of dealing with pest introductions via hull fouling are being sought through the work of the National Introduced Marine Pests Co-ordination Group.

Summary

The susceptibility of Australian waters to the introduction of exotic marine species is significantly higher than previously thought. Our isolation through geological time has allowed a unique and highly endemic fauna and flora to develop and flourish in our waters. This uniqueness means that species introduced from other regions can be particularly damaging to our ecological systems.

Scientists have estimated that there is at least one new introduction per year, but there are large gaps in the data on which to base a national assessment. Both tropical and temperate waters are susceptible to the threat of introduced species.

The surveys of ports and harbours being undertaken by CSIRO's Centre for Research on Introduced Marine Pests are providing a necessary baseline of information on introduced species. However, unless the ports and harbours at greatest risk are resurveyed regularly, we will not become aware of any new introductions either from overseas or from ports around Australia. Currently Darwin is the only port that undertakes an annual survey and monitors for pest species. This lack of survey and monitoring could pose an unacceptable risk to Australia. The use of a standard protocol could enable the issue to be addressed on a consistent national basis.

There are still a number of issues to be addressed by the various stakeholders, mainly those of integrating responses across jurisdictions and across marine industries.

Fisheries

Environmental indicators reported in this section:

Environmental indicator	
CO 4.2	Aquaculture production
CO 4.3	Fish stocks
CO 4.4	Seafood quality
CO 7.8	Fishing effects on non-target species

Fishing occurs over the whole of Australia's marine environment—in estuaries, coastal waterways, nearshore waters, deep oceans and sub-Antarctic waters. Some fisheries extend into international waters. It is one of the few industries operating on the basis of harvesting native species.

The commercial fishing industry is an important primary industry. Marine recreational fishing is a significant activity, and fishing is of great importance to many Aboriginal and Torres Strait Islander communities. Because the marine environment is very diverse in terms of the different physical features, species and ecosystems, fisheries management and conservation varies from region to region.

The Australian Fisheries Management Authority (AFMA) is the Commonwealth authority responsible for the management of Commonwealth fishery resources within the 200 nautical mile Australian Fishing Zone (AFZ) and, in some cases, by agreement with the States, to the low water mark.

Australia's Fishing Zone is the world's third largest, comprising some nine million square kilometres. Although Australia ranks only about fiftieth in world fish production in tonnage terms, many Australian fisheries target high-value species such as prawns, lobsters, abalone and tuna. In 1999–2000 the gross value of Australia's fisheries production, including aquaculture, increased by an estimated 13% to A$2.32 billion, despite a 7% decline in production to around 221 400 tonnes. Of this, the Commonwealth-managed component was about A$413

Figure 20: Status of Australian fisheries, 1999.

Source: Bureau of Rural Sciences (2000).

million (ABARE 2001), contributing about 20% of Australian fisheries production, the major fisheries being the Northern Prawn, Southern Bluefin Tuna, and the South East Trawl and Non-Trawl Fisheries.

Major State-managed fisheries include the Western Rock Lobster, abalone, and Pearl Oyster fisheries.

Fishing activities affect not only the target species but also the ecosystems from which the fish are captured, and other species that are caught or otherwise affected. Protected species such as turtles, sharks and seabirds may be caught or killed incidentally by fishing activities. A wide range of benthic species may also be caught or affected in trawl nets and dredges. Bycatch species and discarded fish may also be removed from marine and coastal waters during commercial fishing activities.

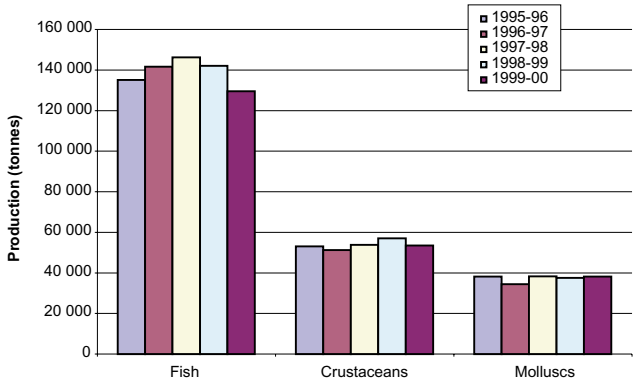


Figure 21: Australian fisheries production from 1995–96 to 1999–2000.

Source: after ABARE (2001).

The state of knowledge of the biology and the stock status of many fish species is incomplete. Around 3600 of Australia's estimated 4500 fish species have been described, but the status of most is unknown.

Fish are captured at the seafloor (demersal fishing with bottom trawls, dredges, traps) and from ocean waters (pelagic fishing with longlines and purse-seines). Aquaculture is conducted in coastal waterways, estuaries or in sheltered nearshore waters. The catch of fish can be related to the productivity of the populations, but is also influenced by technological factors.

Information on the conduct of fishing using lines and nets is given in a study undertaken for SoE reporting purposes (Commonwealth of Australia 2001b). The report found that the intensity of fishing varies greatly from place to place, and there was insufficient information to give a national overview of the spatial extent and intensity of net and line fishing.

The same report investigated trawl areas and intensities of fishing effort. The study identified that the intensity of trawling in the South East Trawl Fishery is increasing, while in the Northern Prawn Fishery the intensity and area have decreased substantially in the last decade. The area trawled in the East Coast Trawl Fishery off the coast of Queensland has increased steadily over the last two decades but has recently been restricted in the Great Barrier Reef World Heritage Area. Areas of high trawling intensity tend to be very small relative to the total area of the respective trawl fishery. The impact of trawling depends on the combination of trawl frequency and intensity, and the susceptibility of the habitats and species being trawled. Nonetheless, even infrequent trawls may still cause ecological damage in habitats that are slow to recover.

Information about gear or effort is useful for formulating management actions, such as capping fishing effort, targeting species better, or introducing mitigation measures.

The most important issue for fisheries in Australia is to ensure the ecological sustainability of fish stocks in the long term so that ecosystems that are fished remain diverse and healthy.

The environmental issues of most importance are:

- the management of fishing effort and activity so as to minimise impacts on habitats and ecosystems and maintain ecological sustainability;
- the sustainable management of target species;
- the reduction of impacts on species, other than target species, removed or injured during fishing activities;
- the impacts of marine pests on the environment (see page 60)
- fishing activities' effects on benthic and pelagic ecosystems; and
- the loss of inshore nursery habitats and pollution from land-based activities.

Status of commercial wild capture stocks [CO Indicator 4.3]

The status of Commonwealth-managed commercial fisheries is assessed and summarised in the annual Bureau of Rural Sciences Fisheries status reports (Caton and McLoughlin 2000).

The level of uncertainty in scientific assessments of the status of fisheries remains relatively high, and the 1999 assessments showed a trend within Commonwealth-managed fisheries to fewer fisheries/species classified as 'underfished' and more classified as 'uncertain' (13 in 1998 and 15 in 1999). The increased number of 'uncertain' fisheries/species is a

combination of new fisheries and, with increased information, increasing uncertainty in previously assessed fisheries. The status of most bycatch species is uncertain.

Four Commonwealth fisheries/species groups are regarded as overfished. They are Southern Bluefin Tuna, school shark, tiger prawn in the Northern Prawn Fishery and Eastern Gemfish stocks. The species are also caught in State-managed fisheries.

About three-quarters of Australia's fisheries are under State and the Northern Territory jurisdiction. Statistics on catches are compiled by the Australian Bureau of Agricultural and Resource Economics each year (e.g. ABARE 2001). Most of the fish stocks managed by Western Australia are still productive, but are nearing the limit of their ability to support further fishing (Fisheries Western Australia 2000a). Queensland fisheries are generally fully fished (Williams 1997) and New South Wales' commercial wild-catch fisheries are fully fished (Fletcher et al. 1999).

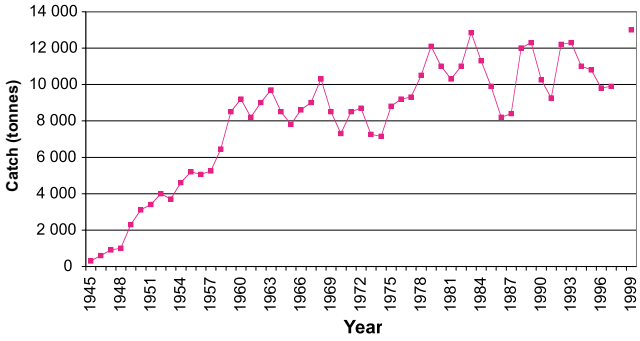


Figure 22: Western Rock Lobster annual catch.

Source: After SoE (1996) and Fisheries Western Australia Annual Reports.

A summary of the condition of all of Australia's fish stocks is not yet possible, owing to differing reporting approaches in the various States and the Northern Territory and the Commonwealth.

One of the problems in attempting to assess the overall status of fisheries is that there is no national fisheries statistics database from which to assess trends. As the fishing industry depends on the sustainability of species for its continuing viability, the need for information on the status of commercial fisheries is vital.

There are fisheries developing in Australia's external territorial waters. The Macquarie Island Fishery was established in late 1996 after two seasons of exploratory fishing. A precautionary total allowable catch (TAC) limit for Patagonian Toothfish (see 'The complexity of fisheries management' box on page 71) has been set. There are strict operating conditions for this fishery to protect fish stocks and non-target species.

It is widely held that the sustainable development of Australia's fishing industry will involve making greater returns by increasing quality or value-adding to the wild caught product rather than by increasing the total tonnage of fish.

Good news—fisheries management

There are very few examples in which fisheries management can claim clear success in achieving regulatory goals. The Western Australian Western Rock Lobster Fishery and the Tasmanian abalone fishery have managed to rebuild stocks over several years.

Western Australian Western Rock Lobster Fishery

The Western Australian Western Rock Lobster Fishery is an example of a well-managed fishery. Although catches in 1991–92 and 1992–93 were high, scientists highlighted that the breeding stock had been fished down to about 15% of the unfished stock. This was below the internationally safe level of about 25% of breeding stock. Tight management arrangements introduced in 1993–94 were aimed at rebuilding the breeding stock. This aim is being achieved. Catches since 1994–95 have averaged around 10 000 tonnes, with the 1998–99 catch a record 13 009 tonnes (Penn 1999). The West Australian Western Rock Lobster Fishery is the first fishery in the world to attain certification under the Marine Stewardship Council (London) as well managed and sustainable (see http://www.msc.org [accessed 5 September 2001]).

As part of this certification, to ensure that environmental impacts continue to be minimal, the fishery has been required to improve specific aspects of its environmental performance. These include: the development and implementation of an Environmental Management Strategy based on a comprehensive ecological risk assessment, the increased participation of environmental organisations in decision-making in the fishery, and the implementation of an improved monitoring program for bycatch of species (e.g. sea lions and turtles).

Tasmanian abalone fishery

The Tasmanian abalone fishery is the largest wild harvest abalone fishery in the world. While other wild fisheries are currently grappling with the problems of overfishing, the Tasmanian fishery has been able to lift production following a period of stock rebuilding through the late

1980s and 1990s. Three stepwise increases in the total allowable catch (TAC) have occurred since 1997, the most recent in 2001.

Concerns held by members of the fishing industry and the Tasmanian Fisheries Department saw the introduction of a quota system in 1985, associated with a significant reduction in the catch. The quota was further reduced between 1985 and 1989 to 2100 tonnes, a reduction of 45% over four years. The TAC (for Blacklip and Greenlip Abalone combined) remained static from 1989 to 1996 before the first increase in 1997 when the TAC was set at 2520 tonnes. The TAC rose to 2800 tonnes for 2001.

A feature of the fishery over the last few years has been an increasing concentration of effort in the south and south-east and a corresponding reduction of effort in the west and north of the State. It is noteworthy that previous stock assessments have shown high catch rates of above-average size abalone on the west coast, but effort has gradually moved to more accessible areas.

To redress this trend, and spread effort more evenly around the State, a system of regional zones was introduced in 2000, with the catch to be taken from each zone determined by the TAC. Two Blacklip Abalone zones were supplemented by a third zone in 2001 with the TAC allocated as follows: eastern zone 1120 tonnes; western zone 1260 tonnes; northern zone 280 tonnes; greenlip zone 140 tonnes.

The Tasmanian TAC for the entire abalone fishery for 2001 is the sum of these regional TACs, i.e. 2800 tonnes. Figure 23 shows the annual landings of abalone in Tasmania.

Another important facet of the fishery is marked geographical differences in growth rates of abalone around the State. For example, Blacklip Abalone generally grow faster in the south of the state than in the north. To address this issue, three different size limits now apply to both Blacklip and Greenlip Abalone.

The value of the fishery has fluctuated over the past eight years and shows little relationship to catch. Prices and catches have varied since the early 1990s with beach prices reaching historic highs over $50 per kilogram during 2000. These strong prices saw the value of the fishery reach $128 million in 2000.

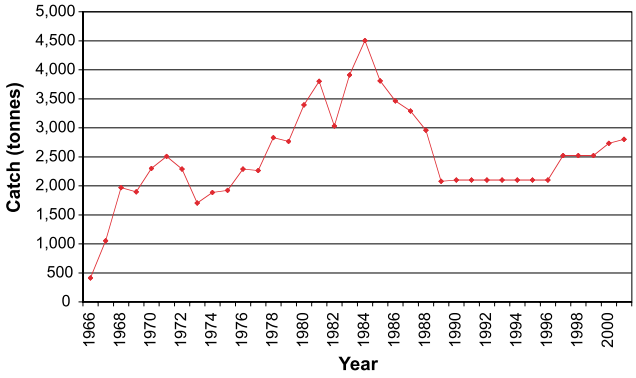


Figure 23: Annual landings of abalone in Tasmania.

Source: DPIWE Tasmania (2000).

An aggregation of abalone in a gutter on the north-west coast of Tasmania.

Source: Tasmanian Aquaculture and Fisheries Institute.

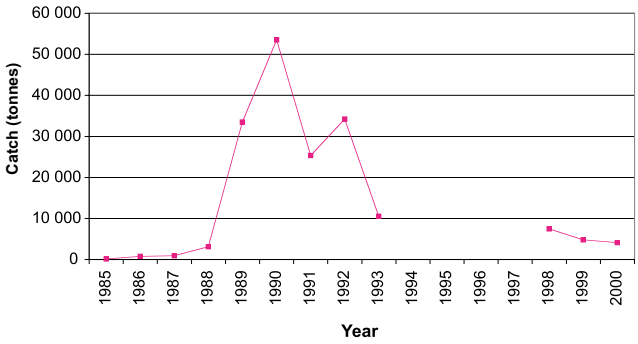


Figure 24: Orange Roughy annual catch.

Source: after SoE (1996) and Caton and McLoughlin (2000).

Uncertain news—fisheries management

Orange Roughy

Orange Roughy remains the most valuable single species in the South Eastern Trawl Fishery, with a value of A$12.7 million in 1998 (Caton and McLoughlin 2000). This species is a long-lived, low breeding fish (it produces low numbers of eggs compared to other fish) that is vulnerable to fishing pressure because of its aggregating behaviour. Since 1992 catches of Orange Roughy have continued to decline in the South East Trawl Fishery. The assessment that in 1997 a catch reduction in parts of the Fishery was warranted, was not accepted by the industry. A second wave of Orange Roughy exploitation occurred in the South Tasman Rise (which straddles the AFZ) following discovery of aggregations in September 1997.

Both Australia and New Zealand have fished the South Tasman Rise since 1997 with varying degrees of success in allocating catch levels and capping the fishing of Orange Roughy.

Southern Bluefin Tuna

The Southern Bluefin Tuna is a highly migratory, long-lived species that was heavily overfished by a number of countries in the 1970s and 1980s. The international management of the fishery

involves Australia, New Zealand and Japan, through the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). Other countries also fish for Southern Bluefin Tuna outside the CCSBT management regime, though the Republic of Korea has announced it will accede to the Convention, South Africa is considering becoming a member, and efforts are in train to develop a mechanism that will enable Taiwan to participate in the Commission. Australia has actively engaged in international forums to bring the global catch of the species under effective management. The focus of this work has been to bring all major Southern Bluefin Tuna fishing countries into the CCSBT, so that all nations can comply with the Commission's objective of rebuilding the stock by 2020.

Australia has maintained catch limits agreed to in 1993 when the Commission established a total catch of 11 750 tonnes, with Australia getting 5265 tonnes, Japan 6065 tonnes, and New Zealand 420 tonnes. Southern Bluefin Tuna is considered overfished, with total global landings of about 19 000 tonnes, mostly landed in Japan or Australia (Caton and McLouglin in press.).

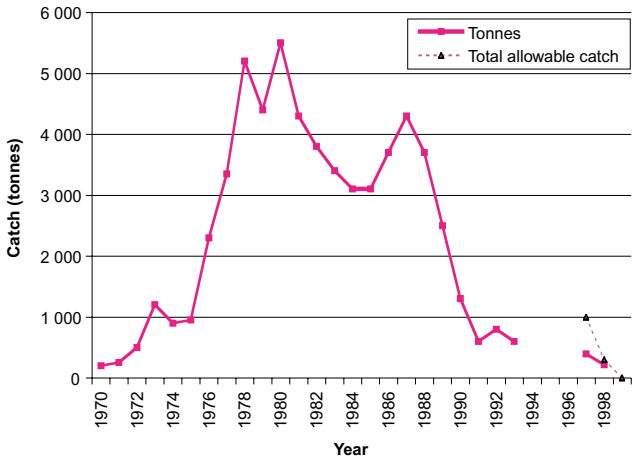


Figure 25: Annual Eastern Gemfish catch.

Source: after SoE (1996) and Caton and McLoughlin (2000).

There is uncertainty about the degree to which spawning stock will rebuild under the current global catch regime, given the complexities of management of a species that is not entirely within Australia's control. The nature of the fishery in Australia has changed, with more juveniles being caught and farmed (see page 77).

Bad news—fisheries management

Eastern Gemfish

Eastern Gemfish is taken in the Commonwealth South East Trawl Fishery (SETF) off southern New South Wales. This slow-growing, long-lived species was fished excessively in the 1970s and 1980s and will take many years to recover.

A zero catch limit was set from 1993 to 1996. The total allowable catch (TAC) for 1997 was set at 1000 tonnes but the catch was only 393 tonnes. Scientific advice was that the TAC for 1998 should be zero, but a total of 500 tonnes was allocated to cover bycatch and reduce discarding. The catch, however, was only 214 tonnes. The 1999 allocated catch for bycatch was 250 tonnes (actual catch 158 tonnes) and in 2000 the allocated catch for bycatch was reduced to 200 tonnes.

Eastern Gemfish remains vulnerable to targeted fishing as it aggregates for its spawning run.

Status of recreational fishing

Recreational fishing in Australia is an activity enjoyed by some five million fishers, who catch an estimated 30 000 tonnes per year (FRDC 2000). Recreational fishing in saltwater accounts for some 73 per cent of recreational fishing. The recreational sector is large and widely dispersed around Australia, and its management is generally the responsibility of State and Territory governments.

Recreational fishing is not controlled to the same extent as commercial fishing. It is limited by a variety of methods, including size limit, bag limit (number of fish per person), boat limit, seasonal closures of areas, and limits on equipment allowed.

Some States have introduced a general angling licence to include marine recreational fishing because of the pressure that recreational fishing is placing on fishery resources (for example, Victoria and New South Wales). Fisheries Western Australia has outlined a new framework for managing recreational fisheries in Western Australia (Fisheries Western Australia 2000b), given that an estimated 600 000 people target and catch a great variety and quantity of finfish and shellfish in that State.

There is little information available on a national scale on the total recreational catch or the catch and effort of recreational fishers. A study conducted for AQIS (McIlgorm and Pepperell 1999) reviewed existing literature in Australia on the structure, activity, expenditure and regional importance of recreational fishing. The study concluded that there is some information available relating to participation rates, fishing effort and catch. Some large-scale studies have provided estimates of the recreational catch for various fisheries. Recreational

The complexity of fisheries management

In the late 1990s a Patagonian Toothfish (*Dissostichus eleginoides*) fishery was established around Heard Island, some 4000 kilometres south-west of Perth. This species is widely distributed in the Southern Ocean. It is large (over two metres long), long-lived (over 40 years) and takes 10–12 years to reach maturity, thus rendering it vulnerable to overfishing.

This and most other toothfish fisheries occur within the area of application of the Convention on the Conservation of Antarctic Living Marine Resources (CCAMLR). The objective of CCAMLR is the conservation of Antarctic marine living resources where conservation is defined to include rational use. The Commission established under the Convention comprises 24 members and takes an ecosystem approach to management of harvesting; i.e. it considers the effects of fishing on the dependent and related species in the ecosystem, not just on the target species. Total allowable catches and other management conditions are set annually by the Commission.

The Heard Island fishery is one of the few examples where research on the abundance and distribution of fish stocks was conducted before commercial fishing commenced. Further research using commercial fishing vessels has been conducted every year. Unlike other toothfish fisheries where longlines are used, fishing in Australian waters is limited to trawling to prevent the bycatch of seabirds, including endangered species such as albatrosses.

Management of the fishery is reviewed each year by the Australian Fisheries Management Authority (AFMA) to take account CCAMLR's decisions on the total allowable catch and other aspects. In addition to CCAMLR's requirements, AFMA has adopted other measures to minimise the environmental impacts of fishing, such as zero discharge of fishing offal and restrictions on waste disposal.

Within Australia's EEZ, the waters surrounding Heard Island are managed principally by the Australian Antarctic Division (territorial waters) and AFMA (waters between 12 nm and 200 nm). All of the Heard Island fishing grounds are within the CCAMLR Area.

A Notice of Intent was gazetted in January 2001 regarding the Government's intention to establish a Marine Reserve, with 'no-take' zones, in the EEZ.

Illegal, unregulated and unreported (IUU) fishing for toothfish throughout the Southern Ocean, including in the EEZ around Heard Island, has been a serious problem in recent years. IUU fishing has caused the commercial extinction of some toothfish stocks and significantly affected toothfish catches in other areas. Tens of thousands of seabirds, including endangered albatrosses, have been killed by IUU longline fishing which does not use mitigation measures.

The question of IUU fishing in the CCAMLR area is complex and involves the nationals and vessels of both parties to CCAMLR and non-parties. Generally, the latter are also not parties to other international fisheries agreements.

Enforcement activities by the AFMA and the Australian Defence Force are difficult in this vast expanse of ocean. Australia has been a leading advocate for strong international action to combat IUU fishing and has initiated many of the measures adopted by CCAMLR. These measures include stronger controls by flag States and port States and, more recently, an international scheme to prevent trade in IUU-caught toothfish.

Source: Australian Antarctic Division (2000).

Patagonian Toothfish.

Source: Australian Antarctic Division.

fishers catch large numbers of many species, but often only a few species constitute the bulk of the total catch. Information on hook-and-line fishing for finfish is reasonable, but information on recreational harvesting of invertebrates is poor. In one of the few studies on fishing for invertebrates that is available, it was found, for example, that the recreational catch of prawns in Lake Illawara was 50% of the total catch during the period 1992–1994.

To fill this gap, a National Recreational and Indigenous Fishing Survey commenced in May 2000 to gather data on fisher participation, catch and fishing effort, economic activity and the attitudes and awareness of fishers to fisheries regulations. Some 19 000 fishers will be interviewed as part of the survey, which will continue for 12 months.

In addition to landing fish, recreational fishers often return fish to the water. This may be in response to prevailing size and bag limits, or because of the popularity of catch-and-release fishing (e.g. for Barramundi in the Northern Territory and big game fishing).

The major issue of recreational fishing is bringing the recreational sector within a fisheries management system. This would of course deal with allocation of total allowable catch to

recreational and commercial fishers; but more importantly, both groups would be then required to abide by the same rules with respect to setting of the total allowable catch, environmental impacts of fishing, closed seasons and areas, and compliance. There is also the issue that some people claim to be amateur fishers, yet take large numbers of fish without paying for a licence, and sell the fish.

Status of Indigenous fishing

Aboriginal and Torres Strait Islander people are involved in traditional, recreational and commercial fishing. The right of access to traditional marine foods (see the discussion of the Yanner High Court case, page 87) does not require traditional techniques to be used for capture. Aboriginal peoples and Torres Strait Islanders may use traditional or other methods when engaging in traditional fishing. Non-Indigenous commercial fishing may, however, affect Indigenous people's access to traditional marine foods, leading to conflicts over who has the primary right to these resources. Aquaculture may also reduce Indigenous access to traditional fisheries in estuaries and other aquatic areas.

The Torres Strait Islands have a strong social and economic association with fishing and seafood is an important part of the diet. The dependence on aquatic resources is illustrated by communities in the remote north of Australia and in the Torres Strait, whose daily consumption of seafood can exceed 500 grams—10 times that for Australia as a whole (FRDC 2000).

The customary diet can include turtle meat and eggs, Dugong, reef fish, shellfish and crustaceans. The Protected Zone Joint Authority (PZJA) for the Torres Strait fishery is responsible for monitoring and managing traditional fishing. A conservative approach to the harvest of turtles and Dugongs is promoted through a school and community education program run by AFMA.

Status of illegal, unregulated and unreported fishing

Illegal, unreported and unregulated (IUU) fishing is a growing problem, contributing significantly to the decline in fish stocks and undermining their sustainable management both world-wide and within the Australian Fishing Zone (AFZ).

Australia, like most other countries, confronts threats from IUU fishing, concentrating on preventing unauthorised foreign fishing inside the AFZ and the detection and apprehension of foreign vessels suspected of fishing illegally.

Each year Australia apprehends and successfully prosecutes around 100 foreign fishing vessels illegally operating inside the AFZ. However, there are significantly more sightings where effective responses cannot be mounted due to the size of the AFZ (the third-largest in the world), and lack of response resources in the immediate vicinity of the sighting.

Illegal foreign vessels apprehended inside the AFZ are predominantly involved in small gill net, longline and sedentary organism gathering operations conducted mainly by people from neighbouring countries. These boats mainly target sea cucumber, shark, trochus shell and finfish.

Periodically, larger industrial vessels such as pair trawlers, single trawl and longliners of various nationalities are apprehended. The biggest impact for Australia has been on Patagonian Toothfish and Orange Roughy fisheries. Australia's apprehension of IUU Patagonian Toothfish vessels (e.g. the apprehension of the *South Tomi* in April 2001) operating in the AFZ surrounding Heard and McDonald Islands has been highlighted recently. New fisheries currently under development by Australian companies could also be at risk if illegal fishing is not addressed.

Illegal fishers generally damage marine ecosystems in a number of ways. They typically remove unsustainable numbers of their target species from the marine environment and often capture large amounts of bycatch (non-target species), due to indiscriminate fishing methods. They also often abandon fishing gear to avoid apprehension, endangering non-target species in the environment.

Seafood quality [CO Indicator 4.4]

Seafood quality in Australia is crucial to maintaining a competitive advantage for the fish export industry in the future. An issue is the concentration of heavy metals that may be

accumulated through the food chain and reach high levels in long-lived fish such as sharks and Orange Roughy. But most important is the lack of pathogens in wild-caught fish and the high quality of our post-harvest handling procedures that maintain the quality of the seafood until it reaches consumers.

Seafood quality may be a significant issue in Indigenous fisheries owing to the high proportion of seafood in their diet, particularly for Torres Strait Islanders.

On a national scale, the residue levels in some wild fish species are monitored through the National Residue Survey (NRS 1998), which is designed to ensure that requirements for export certification are met.

Seafood products, in particular shellfish, have the potential to cause serious outbreaks of food poisoning due to contamination from either biotoxins or pathogens. There have been several incidents where bivalve shellfish have been contaminated with sewage effluent or biotoxins from algal blooms. In 1997, over 400 people in New South Wales were infected with hepatitis A after eating oysters grown in Wallis Lake and one man died as a result (Caton and McLoughlin 2000). The contamination was caused by poorly treated sewage entering the lake.

The Australian Shellfish Sanitation Control Program was developed in 1998 and aims to minimise the risk of harvesting contaminated shellfish through regular monitoring for possible contamination by toxic algae, microbes, antibiotics, hormones and toxins. State and Territory-based shellfish quality assurance programs support this program.

Impacts of wild fish harvesting activity

Fishing activities have impacts well beyond the main target species and include the effects on ecologically related species and on marine ecosystems. In recent years, the effects on other fish species have been the major issue, but the emphasis is now changing to the effects on ecosystems.

Non-target species [CO Indicator 7.8]

The components of fishing bycatch can be described as:

- the non-target species retained,
- the non-target species discarded, and
- the other non-target species affected by fishing gear, but which do not reach the deck.

In most fisheries non-target species may be retained. When there is a commercial market for them, this is described as byproduct and can comprise a significant proportion of a catch in some fisheries**.** Indigenous people who catch only what can be used are especially concerned about bycatch as a waste of resources.

There is very limited information on the non-target catch in many Commonwealth fisheries (Caton and McLoughlin 2000). Recording of bycatch is difficult because there is a need for a high level of taxonomic skills to reliably identify the organisms and because of a lack of skilled observers. The Commonwealth Sub-Antarctic Fisheries have perhaps the most extensive observer coverage.

The Northern Prawn Fishery was one of the first to introduce compulsory logbooks that were completed by fishers and cross-checked by processors. In 1995 it became compulsory for fishers to record the retained catch of non-target species and turtles.

In the far northern Great Barrier Reef Marine Park, for every tonne of prawns harvested, about six to ten tonnes of other species are discarded. A study on the environmental effects of prawn trawling (Poiner et al. 1998) found that about one-third of bycatch species were crustaceans and two-thirds fish.

Some State-managed fisheries record some non-target species, mainly byproduct and vulnerable species (e.g. turtles and marine mammals), but discards of the majority of non-target species are not recorded.

Changes to benthic habitats

Trawling is one of the most widely used commercial fishing methods in Australia, with demersal trawling being the major technique. There are trawl fisheries for fish, scallops, scampi, prawns, and other seafood. The nature of the catch in trawl fisheries can include threatened species and invertebrate and other species.

Because demersal trawling and shellfish dredging makes contact with the seafloor, it can have substantial impacts on seabed habitats and benthic ecosystems (Harris and Ward 1999). The extent of essentially indiscriminate impacts can be significant, including physical removal of organisms and non-living components and increases in water turbidity. Impacts arise from the removal of target and non-target species and the removal and disturbance of invertebrate species and associated benthic habitat. Repeated trawling may prevent the recolonisation of benthic species, both sedentary and mobile.

Commercial prawn trawl fishing on the Great Barrier Reef is important to the Australian economy.

Source: A Elliot, Great Barrier Reef Marine Park Authority.

CSIRO and the Queensland Department of Primary Industries completed a five-year study of the environmental effects of prawn trawling in 1996 (Poiner et al. 1998). The study area covered 10 000 km^2 in the far northern Great Barrier Reef Marine Park. The research showed that each pass of a trawl along the seabed removes about 5 to 25% of the seabed life. However, there is a cumulative effect; seven trawls over the same area of seabed removed about half of the seabed life, and 13 trawls removed 70 to 90%. Different species have different levels of vulnerability. Large sponges, for example, are particularly susceptible to trawling.

A few deep seabed sites have been studied, such as on the North West Shelf and on the continental shelf adjacent to the Great Barrier Reef. However, there is relatively little understanding of benthic communities in Australian waters. Seamounts are trawled for Orange Roughy, and some have been damaged by this activity. Seamounts are sites of highly valued marine biodiversity (see page 27).

Loss of inshore habitat

Coastal habitat especially estuaries are nursery grounds for the juveniles of fish species. These habitats include seagrass beds, saltmarshes and mangroves and other coastal wetlands. Habitat loss or degradation may also result from land-based activities that cause nutrient enrichment (see page 55), pollution from pesticides, or sedimentation (see page 56).

Some States are actively addressing the protection or rehabilitation of inshore habitats. For example, in 1995 New South Wales Fisheries introduced Fish Habitat Protection Plans to facilitate habitat protection on a State, regional or local scale or for particular communities or species (Smith and Pollard 1998). The second protection plan was gazetted in 1997 and applies specifically to seagrass habitats.

Fisheries Western Australia is developing a series of Fisheries Environmental Management Reviews for each of the main regions of Western Australia to, among other things, identify habitats of importance for fisheries. Each Environmental Management Review is to be supported by a Management Plan that will develop and implement responses to the issues identified in the Reviews.

Responses to fisheries issues

Legislative responses

The management of fisheries is a mix of Commonwealth and State or Territory responsibilities. Formal measures to place some fisheries under a single jurisdiction are in place under the Offshore Constitutional Settlement agreement, while other fisheries require collaborative management arrangements.

There are both Commonwealth and State fisheries laws under which fisheries are managed through general regulations or other statutory methods. There are various methods to manage each fishery, such as size and catch limits, and gear restrictions.

Legislative changes in 1999 and 2000 will make a dramatic difference to the sustainable management of commercial wild fish stocks in the future. The most

Mangrove roots at Arnhem Land, Queensland.

Source: G Pure.

significant is the removal of the general exemption of most marine fish from export control regulation under the *Wildlife Protection (Regulation of Exports and Imports) Act 1982*. The removal of the exemption makes the taking of marine native species consistent with the taking of terrestrial native species. This change comes into effect in December 2003. Before a fishery can be exempted from the Act, it must be shown that the fishery is ecologically sustainable in terms of its impact on:

- target species,
- non-target species and bycatch, and
- the ecosystem generally (including habitat).

The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) came into force in July 2000. It requires an assessment and approval process for activities that are likely to have a significant impact on the Commonwealth marine environment, on nationally threatened species and ecological communities, and on internationally protected migratory species. The Act also requires that all Commonwealth-managed fisheries have their environmental impact strategically assessed.

The Commonwealth Government has issued guidelines for the ecologically sustainable management of fisheries as the benchmark against which environmental performance of fisheries should be assessed.

With these changes to legislation and the management of fisheries and ecosystems, there has been a shift in the onus of responsibility, as reflected in Australia's Oceans Policy. Users of ocean resources such as fishers are increasingly expected or required to ensure the ecological sustainability of their activities and to meet their obligations to identify and implement precautionary measures.

Management responses

One of the measures to assess the unintended consequences of fishing activities is the production and use of management regimes that include non-target species monitoring strategies and adaptive management. Some fisheries (such as rock lobster and abalone) are highly selective, and non-target catch is not a major issue with them.

A recent review (Commonwealth of Australia 2001b) reported the number of fishery management plans, as at June 1999, with these objectives and with criteria and performance measures for the effectiveness of those strategies. Of the 60 management plans in existence, only six dealt to some extent with impacts on non-target species. The three Commonwealth plans do not give specific details of the monitoring of non-target species and how the information is fed back into the management system. (Note that Western Australian plans were not made available for the study.)

Another management option that is being used by both State and Commonwealth fisheries is structural adjustment schemes. The purpose of these schemes is to reduce fishing effort in a fishery or, in some cases, to remove the overexploitation of a fishery. An example is the Southern Shark Fishery, where school shark stocks need to be rebuilt. School shark stocks are assessed as being unsustainable at present catch levels. In 1999–2000, government funding of $2.6 million was secured for a fishery structural adjustment and initiation of a buy-back scheme. (AFMA 2001). In 2000–2001, $20 million of Commonwealth and State funding was committed to reduce fishing effort by 10% in the Queensland Eastern Trawl Fishery, while industry contributed a nominal 5% reduction in effort to the scheme.

Western Australia has used a Government–industry buy-back system for some years to reduce the number of Fishing Boat Licences (Fisheries Western Australia 2000c). As a result, a total of 69 licences were sold to the general buy-back scheme between 1987 and July 1999 and were cancelled.

The Great Barrier Reef Marine Park Authority has been undertaking the negotiation of the East Coast Trawl Plan with the Queensland Government and industry. The introduction of the still disputed Plan follows years of challenging negotiations between the Authority, the Queensland Government and the fishing industry. Significant outcomes of the negotiations on the Plan to date include:

- a capped trawl effort at 1996 levels, with an immediate 15% reduction,
- mandatory turtle exclusion devices and bycatch reduction devices,
- the closure of lightly trawled and untrawled areas (approximately an additional 20% of the Marine Park), and

- strict monitoring and recording of bycatch species, which may result in further protective measures.

Increasingly, in the last four years, environmental management systems have been voluntarily adopted by the industry. The most effective of these so far has been the global market-driven ecolabelling program of the Marine Stewardship Council.

Bycatch issue responses

The response to the significant issue of bycatch has improved over recent years. The Commonwealth developed a National Bycatch Policy in 1999 and a Commonwealth Bycatch Policy in 2000. The National Policy restricts its attention to non-target discard species and non-target organisms affected by fishing gear, and does not include byproduct.

A feature of the Commonwealth Policy is the commitment to prepare Bycatch Action Plans for all major Commonwealth fisheries. Plans for the Northern Prawn Fishery and the Torres Strait Prawn Fishery were implemented in 1999.

Turtle exclusion devices (TEDs) and bycatch reduction devices (BRDs) have been trialled in the Northern Prawn Fishery since 1993 and became compulsory in this fishery in 2000. Trials to improve their performance through modifications are continuing. Projects are currently under way to evaluate the effectiveness of these devices, in collaboration with the fishing industry. Seal excluder devices (SEDs) are currently being trialed in the South East Trawl Fishery.

A project by the Bureau of Rural Sciences, CSIRO and AFMA is monitoring the catch of sea turtles in the Northern Prawn Fishery. Results from these projects show that the use of TEDs and BRDs has resulted in a substantial decline in the catches of large animals such as turtles, stingrays and sharks. However, the use of BRDs in this fishery seem to have had little impact on the catch of the smaller, more abundant bycatch.

Bycatch Action Plans for other major Commonwealth fisheries were released in May 2001 by AFMA for the:

- South East Trawl Fishery,
- South East Non-Trawl and Southern Shark Fisheries,
- Sub-Antarctic Fisheries (the Macquarie Island Fishery and Heard Island and McDonald Islands Fishery),
- Great Australian Bight Trawl Fishery,
- Bass Strait Central Zone Scallop Fishery, and
- Southern Squid Jig Fishery.

By the end of 2001, Bycatch Action Plans will have been developed for 14 of the 21 Commonwealth fisheries.

The effects of Commonwealth fisheries on some non-target threatened species, such as albatrosses and turtles had been assessed under previous legislation, and these assessments and their listings have been carried over to the EPBC Act. Some fishing methods are recognised as 'key threatening processes' under the EPBC Act. Regulations were issued in February 2001 placing very specific obligations on longlining operations under the Threat Abatement Plan for the incidental catch of seabirds during oceanic longlining fishing operations. This Plan was developed in cooperation with the fishing industry. A nomination for otter trawling for marine turtles is currently (February 2001) being considered for listing.

The Commonwealth Government has provided $1 075 000 from the Natural Heritage Trust to establish the SeaNet extension service. The project is focused on increasing the rate of adoption by the commercial fishing sector of new fishing gear and practices to aid bycatch reduction and to implement environmental best practice.

The States and the Northern Territory have also been addressing bycatch in different ways. Western Australia and the Northern Territory have adopted the National Policy.

Turtles being monitored before release.

Source: C Robins, Bureau of Rural Sciences.

Action plans or management plans for fisheries are being prepared in three States and the Northern Territory on a priority basis. The use of bycatch reduction devices (BRDs) in two estuarine prawn trawl fisheries in New South Wales has been made mandatory, to save large quantities of juvenile fish. In Queensland, New South Wales and Western Australia, the recording of bycatch is currently being considered for compulsory inclusion in management plans.

However, there has been little or no response to the assessment or management of the non-target retained species (byproduct) in relation to either the effects on the species or the effects on the ecosystems. An exception to this is the Western Rock Lobster Fishery that is developing a number of responses to deal with environmental issues in the fishery.

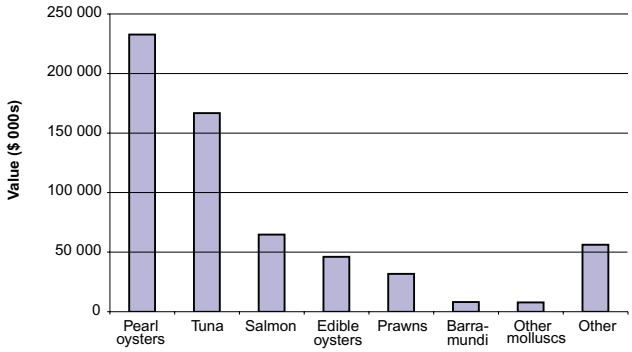


Figure 26: Value of aquaculture sectors.

Source: O'Sullivan and Dobson, (2000).

Aquaculture [CO Indicator 4.2]

Over the past 30 years there has been a significant increase and diversification of aquaculture species farmed in Australia. Of the approximately 60 different species farmed, the major contributors are: pearl and edible oysters, Atlantic salmon, prawns, and Southern Bluefin Tuna (FRDC 2000).

Australia's ability to produce such diverse products is due mainly to its wide-ranging climatic conditions, from the tropical north to the temperate south. Australia is also fortunate to be free of many of the major diseases that affect aquaculture production in other parts of the world.

Over the last decade, aquaculture production has grown substantially, from 11 900 tonnes and a value of $136 million in 1988–89 to some 32 360 tonnes worth around $614 million in 1998/99 (O'Sullivan and Dobson 2000). Until the last decade, most commercial aquaculture was for oysters (edible oysters and pearl oysters) and a limited amount of fish and prawn culture. In recent years, the caged culture of fish has grown rapidly. Atlantic Salmon in Tasmania and the fattening of caged Southern Bluefin Tuna in South Australia account for one-third of Australia's production.

Wild-caught Southern Bluefin Tuna have been fattened in sea cages off Port Lincoln since 1994. There are now 110 cages operated by about 12 companies in an area of approximately 200 km^2. Predator exclusion nets surround the main nets of many cages. Although the wild catch has been maintained at 5265 tonnes, most is now farmed, leading to significant value-adding of the product. The tuna are fed on pilchards and other bait fish for four to eight months, when they reach a size of about 30 to 40 kg.

However, tuna farming in feedlots can generate a significant amount of pollution (Parliament of SA 2000). Recent research suggests that pollution is causing the sudden appearance of strange micro-organisms capable of poisoning fish. It has been suggested that a toxic algae was the cause of death of the tuna in Boston Bay, Port Lincoln, in 1996.

The Parliamentary Committee (Parliament of SA 2000) noted that the Tuna Farming Code of Practice was still not finalised, and although some of the issues of concern are addressed in the Draft Code of Practice, in reality the Code is not being adhered to.

Dolphins, whales and seals can become entangled in the predator nets. The South Australian Museum has been collecting records of dead and stranded dolphins around the South Australia coast for many years. In an initial study of the problem (Kemper and Gibbs 1997), at least 13% of all dolphin carcasses studied were believed to have died as a result of entanglement, including many in the tuna feedlots near Port Lincoln.

There are several challenges for the Southern Bluefin Tuna Fishery in the future, a major one being to breed tuna in captivity and cease the total reliance on capturing wild stock, the availability of which is limited.

There are also many experimental and pilot schemes in place within the aquaculture industry, and some are becoming commercially viable. For example, a pilot-scale culture of the Fat-bellied Seahorse *(Hippocampus abdominalis*) in Tasmania has recently grown to a commercial scale.

Successful aquaculture depends on a combination of factors, including appropriate site selection, design and construction of facilities, good water quality, and suitable markets. Site selection and the associated impacts involved in initial developments can be a contentious

issue where there are competing uses of the coastal or marine environment, such as urbanisation, recreation or community interests (Preston and Rothlisberg 2000).

Local government and State planning agencies are the responsible land planners, and increasingly aquaculture operations will have to meet strict environmental controls in order to coexist with other land and coastal water uses. The major environmental issues for aquaculture are:

- water quality impacts from aquaculture operations,
- introduction of pest species through translocation and possible escape,
- introduction of disease through translocation,
- genetic impacts from possible escapes,
- sourcing of brood stock or juveniles, particularly if it is from wild populations,
- compromising habitat and amenity values, and
- sourcing of feedstock from wild-harvest fisheries.

Environmental effects of aquaculture

Sourcing of brood stock and juveniles

Where aquaculture operations depend on wild-caught juvenile fish, there can be an effect on the wild stock populations. As yet there is little evaluation of this aspect of aquaculture.

Water quality

Aquaculture requires access to high-quality water but has the potential to increase nutrient enrichment of surrounding coastal or estuarine waters. Land-based practices such as urbanisation and industrial or agricultural practices may also have adverse water quality effects on aquaculture operations, leading, for example, to algal blooms that can affect shellfish quality.

There is the potential for fish feed and wastes to affect water quality through the accumulation of wastes in the vicinity of the farms or the movement of nutrients into the water column. The main source of nutrients in discharge water from prawn farms, for example, is undigested food. The contribution of prawn farming effluent into waters already experiencing impacts can be significant. For example, around 110 hectares of prawn farms are situated in the Logan River catchment in southern Queensland, producing around 45 tonnes of nitrogen effluent.

Possible genetic effects

Unintentional escapes of aquaculture species, either native or exotic, into the wild could affect the genetic diversity of native species. In recognition of the possible risks associated with unintentional escapes, the Commonwealth, State and Territory governments have strict policies regarding the transfer and translocation of exotic species, including larvae.

Responses to environmental issues

The responsibility for the development and regulation of aquaculture in Australia rests with local, State and Territory governments. Several States have aquaculture and coastal development plans in place.

Many industry associations have developed codes of practice for their particular aquaculture operations, e.g. the Australian Prawn Farmers Association and the Australian Tuna Boat Owner's Association (Caton and McLoughlin 2000).

There are a number of promising developments for the aquaculture industry. The use of saline groundwater is being trialed for aquaculture in pilot studies, and may become commercially feasible. The integration of aquaculture with conventional farming systems to allow multiple and sequential usage of water resources and related infrastructure is also attracting significant interest. Another developing trend is the use of genetic engineering in aquaculture.

The management of diseases that affect aquaculture is a challenge for the future. For example, the marine protozoan pathogen *Neoparamoeba pemaquidensis* that occurs seasonally in Atlantic Salmon in Tasmania is now regarded as a major disease which costs the industry $10 to $15 million annually.

The Australian Prawn Farmers Association recently (2001) decided at a workshop to implement national environmental practices that will ensure prawn farming has no detrimental effect on water quality. The workshop documented potential problems resulting

from the discharge of nutrient and sediment-laden pond water and decided to develop a plan with targets, deadlines and assigned responsibilities to achieve world's best practice within 10 years. This initiative was taken in the knowledge that the total pond area of prawn farms may double during that time to about 800 hectares.

Management of other land-based activities becomes crucial to the maintenance of coastal water quality for aquaculture, as these are generally conducted on a much larger scale. Increasingly, there is a need for planning authorities to engage in integrated catchment management considering all activities that may affect a waterway, rather than attempting to regulate aquaculture in isolation.

Considerable research is under way to develop more efficient and environmentally friendly food for aquaculture species, as the world supply of fishmeal—a major component of aquaculture food—is not increasing and its production is vulnerable to climatic variability. Improvement in feeds and feeding practices also has significant potential to boost the profitability of aquaculture through reduced wastage and costs, as some aquaculture operations are net consumers of fish products rather than net contributors (FRDC 2000). This would reduce the amount of bait fish, currently 50 000 tonnes per annum, used as aquaculture feed.

Activities and uses of the marine environment

Environmental indicators reported in this section:

Environmental Indicator	
CO 7.14	Ship visits
CO 7.15	Shipping accidents

Shipping and impacts [CO Indicator 7.14]

Commercial shipping and port activity are vital and legitimate uses of our seas and coast, but they present environmental costs and risks. The main shipping lane around the world is from Europe to Asia, with Singapore being the hub port in South East Asia. Shipping to and from Australia is a sublink into the main shipping lane. There are some 11 000 vessels from 600 overseas ports that visit Australia's 65 ports, and a coastal trade distributing goods to the other ports. As the countries with whom Australia trades change, constant vigilance is needed to reduce the chances of introduced species establishing in our tropical and temperate waters.

The main environmental issues associated with shipping and ports include:

- effects of dredging channels and disposal of the dredged material,
- effects of antifouling paints in ports and off-shore,
- risk of introduction of exotic species into ports, harbours and coastal waters (see page 81),
- ship waste in ports,
- risk of oil or hazardous cargo spills in ports and coastal waters,
- reclamation of intertidal habitats, and
- loss of public access.

Dredging channels and ports

Dredging within ports is generally undertaken for two reasons. New berths or deeper shipping channels are needed to accommodate an expansion of the port or access by larger vessels (capital dredging), or there is a loss of pre-existing depths due to a buildup of sediment (maintenance dredging). The latter can be an ongoing issue for some port companies. Channel dredging in gulfs and bays for navigation and safety reasons may also be required.

The nature and quality of the marine and estuarine sediments can vary greatly around Australia, ranging from uncontaminated sands, which are generally suitable for sea disposal, to contaminated (with heavy metals, pesticides etc.) clays and fines that require a careful environmental impact assessment of disposal options. As many Australian ports are located in relatively muddy environments, substantial short-term turbidity can result from dredging activities.

Under the *Environment Protection (Sea Dumping) Act 1981* (the Sea Dumping Act), a permit is required to authorise the loading for the purposes of dumping, and the dumping at sea, of wastes and other matter.

In this context, the effects of dredging and associated dumping have been widely studied in a number of Australian ports. In December 1998 the ANZECC Interim Ocean Disposal Guidelines were released for a two-year trial period. These guidelines were designed to assist applicants to assess environmental impacts from sea dumping of dredged and excavated material, in accordance with the Convention on the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter 1972 (the 'London Convention'), and the 1996

Figure 27: First port of call of international shipping into Australia.
Source: Environment Australia (2000).

Protocol to that Convention. The review of these guidelines, which is currently under way, is likely to be completed in late 2001.

Amendments to the Sea Dumping Act, to reflect the Protocol, commenced to have effect on 16 August 2000. On 4 December 2000, Australia formally ratified the Protocol.

Antifouling paint

Another significant environmental issue is the use of organotins such as tributyl tin (TBT) as biocides in antifouling paints used on vessels to prevent the buildup of organisms on ship's hulls. Its use has been of critical importance to efficient commerce and to impeding the spread of marine pests, parasites and diseases into ports, harbours and coastal waters.

There is international pressure to phase out TBT-based antifouling paints because of its extreme toxicity to marine life and its persistence in the environment (see page 54).

The grounding of a Malaysian container ship on Sudbury Reef in the Great Barrier Reef Marine Park in late 2000 resulted in levels of TBT on the Reef that were 100 times the safe level. In the largest cleanup operation of its kind in the world, divers removed flakes of antifouling paint from a 1500 square metre section of the Reef in January 2001.

The International Maritime Organisation (IMO) is finalising an international convention that would ban the use of organotins in antifouling systems. Under Australia's Oceans Policy, the Commonwealth Government is committed to banning the use of TBT from 1 January 2006 on vessels being repainted in Australian docks unless the IMO sets an earlier date for such a ban.

A long-term project conducting trials of new antifouling paints commenced in Australia in 2000. The project is a cooperative effort between the maritime, paint and coatings industries, the Royal Australia Navy, the Defence Science and Technology Organisation and Environment Australia.

Ship wastes in port

The shipping industry includes shipbuilding and the repair and maintenance of vessels, which are carried out at several ports around Australia. In the course of normal operations there is a risk of spills of oil, wastes from vessel maintenance, bilge water and sewage, and these could affect port water quality. Recreational vessels can also contribute wastes to the marine environment.

There are a number of measures in place, to both systemically and practically minimise this pollution. On a systemic level, discharges from ships are subject to the various Annexes of the international MARPOL Convention, which is implemented through Commonwealth, State and Territory legislation. Up to the present time, Australia has adopted Annexes I (oil), II (noxious liquid substances), III (packaged harmful substances) and V (air pollution). Annex IV (sewage) has not yet been adopted by Australia and consequently the control of sewage discharges from ships is inconsistent between States.

On a practical level, 35 demonstration projects are under way around Australia to build facilities to capture and treat wastes from marinas (as at May 2001). Funds are being provided by industry and port authorities, matched by Commonwealth funds from the Coasts and Clean Seas Initiative.

Oil and hazardous cargo spills [CO Indicator 7.15]

Oil and hazardous cargo spills can occur either in ports and harbours or in offshore waters. Spills can happen as a result of accidents, such as collisions or groundings on off-shore reefs. Their environmental impacts depend on the nature and quantity of oil spilt and the habitat and species that are affected.

In 1998 the Australian Maritime Safety Authority (AMSA) was funded, through the Coasts and Cleans Seas Initiative, to fast-track the production of a computerised Oil Spill Response Atlas for Australia. The major outcome is an Oil Spill Response Atlas for Australia in a computerised geographic information system (GIS). This will enable a more targeted response to oil spills in future by identifying marine and coastal areas of sensitivity that could be affected in the event of an incident.

AMSA also keeps a database of oil spills and since 1995 Australia has not experienced an oil spill with major environmental impacts. Significant spill incidents that have occurred since 1995 are given in Table 8.

AMSA has, since 1973, had in place a national strategy for responding to marine spills. The original oil spill strategy was extended in 1998 to deal with the response to maritime

Table 8: Significant oil spills since 1995.

Date	Situation	Location	Quantity and type	Environmental effects
April 1996	Collision between tanker and tug	Brisbane River	Heavy fuel oil Approx 15 tonnes	Cleanup of foreshore and sensitive areas required
August 1998	Tanker at berth	Brisbane River	Lube oil 8 tonnes	Several foreshore areas required remediation
June 1999	Offshore loading	2 nm offshore Port Stanvic Refinery, SA	Oman crude Approx. 230 tonnes	Light impact at shoreline
August 1999	Cargo transfer	Sydney Harbour	Light crude 250–300 tonnes	Light to medium oiling of some foreshores

Sources: AMSA annual reports.

chemical spills in Australian waters and is now known as the National Plan to Combat Pollution of the Sea by Oil and other Noxious and Hazardous Substances. The responsibility for implementing this plan is shared among the Commonwealth, States and the Northern Territory and the oil and shipping industries.

Offshore petroleum production

Offshore petroleum production has significant economic and strategic importance for Australia, with some 85% of our petroleum demands being met from offshore wells in Bass Strait, the Timor Sea and the North West Shelf.

Exploration drilling for petroleum in Australian waters has been largely focused on the Twofold Shelf (in Bass Strait) and the North West Shelf. In the North West Shelf area, petroleum exploration and production occurs over an area of great conservation value. An application has been made (in late 2000) for an exploration permit for an area west of Carnarvon, Western Australia, which takes in the northern waters of the Shark Bay World Heritage Area.

Environmental approvals for petroleum industry activities in Commonwealth waters are governed by the provisions of the *Petroleum (Submerged Lands) Act 1967* and the *Environment Protection and Biodiversity Conservation Act 1999*. Petroleum operations in coastal waters are the responsibility of individual State and Territory governments.

The petroleum industry in Australia is recognised as having a good environmental record and is strictly regulated regarding environmental protection. As a result, the risks to the offshore environment from petroleum operations are low. However, while the risk of a major incident occurring is low, there could be a potentially very significant effect if such an incident did occur.

Oil companies have drilled over 550 exploration wells in the past 10 years and with a similar trend for development wells (Figure 28).

A review of the environmental impacts of petroleum exploration in offshore Commonwealth waters, together with the implications of the EPBC Act has recently been completed for the Department of Industry, Science and Resources (DISR 2001b). The following discussion reflects some of the compilation of research relevant to SoE reporting.

An independent scientific review of research into the environmental implications of offshore petroleum exploration was conducted by Swan et al. (1994). The review found that the offshore exploration and production industry in Australia not only met statutory requirements, but had 'set an excellent example in taking all possible steps to safeguard the marine environment'. More recent research has been funded by individual petroleum companies and by the Australian Petroleum Production and Exploration Association (APPEA) with a view to further improving the industry's environmental management and continuing to reduce impacts and risks associated with industry activities.

Following the Swan review, APPEA facilitated a scientific assessment of environmental issues and identified several specific areas where knowledge of environmental impacts could be improved. These included:

- the fate and effects of oil and dispersants on mangroves in Australia: protection, clean-up and rehabilitation,

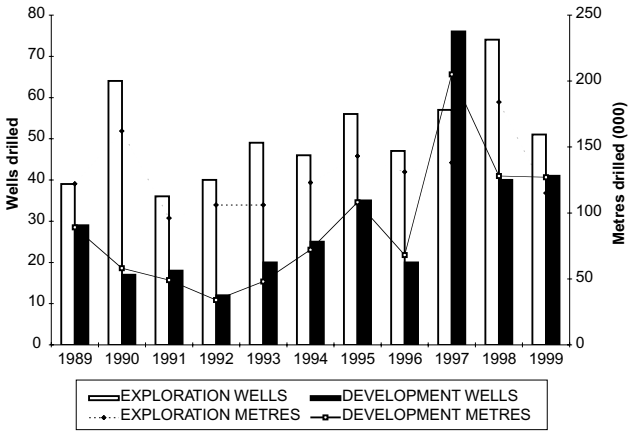


Figure 28: Exploration wells drilled, 1989–1999.

Source: Commonwealth of Australia (2001).

- dispersion and fates of produced formation water constituents, and
- investigation of the environmental effects of offshore seismic survey activities (McCauley et al 2000).

The petroleum industry has a commitment to support scientific research that furthers an understanding of the impacts of industry activities on the environment. In addition to APPEA generated initiatives, company sponsored research projects are regularly supported. Two recent projects include:

- the ecotoxicology of non-water based drilling fluid (Tsvetnenko 1999), and
- the ecotoxicology of some light Australian crudes.

In addition to these studies, a number of companies have investigated the size, chemical composition and longevity of seafloor drill cutting piles resulting from drilling activities.

The Australian Petroleum Production and Exploration Association (APPEA) has prepared its own Code of Environmental Practice **(**APPEA 1996). The Code outlines an environmental management framework, a management system, and a comprehensive set of environmental guidelines for the petroleum industry. Environmental guidelines for offshore petroleum activities address seismic surveys, drilling operations and development and production operations. This Code is currently being revised to reflect advances in technology, new information, and the requirements under the new EPBC Act 1999.

Effects of seismic surveys

The effects of seismic surveys continue to be investigated by independent researchers and industry because of the concern that sound waves produced by air guns could cause mortality or sublethal injury to marine organisms, or might modify the feeding or mating activity of marine mammals, fish and other organisms. The greatest risk from seismic surveys to marine animals appears to be during breeding or spawning periods. Studies have shown that noise associated with air guns can influence the behaviour of some species of mammals, fishes and squid. Further, damage to hearing organs have been reported for some species of fishes, while mortality has been reported for planktonic organisms, usually at very close range to the source of noise.

The general response to seismic surveys of migrating Humpback Whales off the north-west coast of Australia is to take avoidance action. Humpback Whale pods, consisting of cows and calves, have shown avoidance responses at a range of 7 to 12 kilometres from a large seismic source.

The Western Australian Department of Minerals and Energy has developed guidelines to minimise the effects of seismic surveys on Humpback Whales. Environment Australia, with input from the Australian Petroleum Production and Exploration Association, is currently finalising guidelines (linked to the EPBC Act) to minimise the effects of seismic surveys on Humpback, Southern Right and Blue Whales.

Sandmining

Extensive sand extraction occurs in Moreton Bay, Queensland, both for fill for major land reclamation projects associated with the airport and port and as part of a growing demand for marine sands for the construction industry.

Queensland also has substantial silica sand resources that have been mined for many years for export, mostly from Cape Flattery, in Queensland State waters. (EPA 1999a). Production increased from 670 000 tonnes in 1980 to 2.6 million tonnes in 1996–97. Mineral sands are mined for the minerals rutile, ilmenite and zircon, for use as paint pigments, and for foundry applications. Although virtually all Queensland's mineral sands are produced on North Stradbroke Island, these resources will be largely depleted in 20 years.

In Western Australia, the seagrasses of Cockburn Sound are mined for calcium-rich sand for the cement industry, despite the attendant ecological impacts.

The environmental impacts of such mining includes the effects on coastal ecosystems, the need for reinstatement of landforms, and the need for replanting with selected local species. Sandmining can also cause extensive landscape and ecosystem changes to unique and extensive features, such as North Stradbroke Island.

Biodiscovery

There is increasing interest in using the resources of the marine environment for new and novel products. There are, however, some complex issues that may need to be worked through where there is use of Indigenous knowledge as part of biodiscovery.

Some of the research in progress includes:

- the observation that reef-building corals appeared to be protected against sunburn led to research at AIMS to show this was due to specialised amino acids with simple but very efficient light-absorbing ability. These compounds are found in many organisms, including sponges and sea anemones. Synthetic analogues of the compounds are now being tested in the hope that a commercial product can be produced.
- researchers at the University of Melbourne have studied southern Australian and Antarctic marine sponges, and are targeting metabolites that inhibit specific enzyme systems to develop safer, more specific drugs and agrichemicals (Capon et al. 1999).
- work at the University of New South Wales has identified a group of natural products from marine algae which deter the settlement and growth of fouling organisms. The compounds' ability to prevent bacteria forming biofilms is significant because biofilms are responsible for approximately 65% of all human infections, as well as creating a range of industrial problems. In cooperation with multinational organisations, commercial applications are being pursued including development of an antifouling paint and contact lens cleaning solutions.
- a collaborative research project between James Cook University and AIMS to produce a novel class of natural herbicides based on marine compounds has attracted $2 million of research and development funding from Nufarm Ltd. Several compounds have displayed selective herbicide activity that, if commercialised, would be valuable to farmers world-wide.

Once a commercial product is discovered, the molecule is either synthesised or grown in aquaculture systems.

Marine and coastal management

Environmental indicators reported in this section:

Environmental Indicator	
CO 7.4	Coastal care community groups
CO 7.11	Marine network participation
CO 7.12	Marine Protected Areas

Australia's three tiers of government (local, State and Commonwealth) are all involved in managing the coastal and marine environments. Government inquiries have long been advocating more integration in coastal zone planning and management (RAC 1993; Zann 1995). The management of the offshore marine environment includes both international dimensions and Commonwealth–State interactions.

This subsection seeks to summarise the management regimes and to highlight changes since 1996.

International agreements

There are some 80 international agreements relevant to Australia's Oceans Policy, of which about one-half are related directly to marine environmental and fisheries issues.

The most important international agreement is The United Nations Convention on the Law of the Sea 1982 (UNCLOS) that allows coastal states to claim territorial seas (which extend 12 nm from the coastal baseline), a 200 nm Exclusive Economic Zone (EEZ), and a legally defined continental shelf (see page 27). On ratifying the UNCLOS Treaty, Australia took responsibility for one of the largest marine areas in the world: some 11 million km^2, and potentially as much as 16 million km^2, depending on the limits of claimable continental shelf that extends beyond the 200 nm EEZ.

The implications of Australia's proposal to extend its marine area on future marine management will be significant. UNCLOS requires coastal states to observe the following articles:

- Article 61, which imposes an obligation on member states to ensure that the living resources in their EEZs are not endangered by over-exploitation,
- Article 62, which requires states to promote optimum utilisation of the living resources of their EEZs,
- Article 192, which imposes a general obligation on states to protect and preserve the marine environment from pollution, and
- Article 193, which sets out the rights of states to exploit their natural resources pursuant to their environmental policies and in accordance with the duty of protection and preservation.

Australia is part-way through defining the limits of its extended seabed area beyond the EEZ (the extended continental shelf). There are at least eight separate areas requiring delimitation.

Some of the international agreements that influence the way in which Australia manages its marine environment are:

- the Convention on the Conservation of Antarctic Marine Living Resources 1980 (CCAMLR),
- the Convention on Biological Diversity,
- the International Convention for the Prevention of Pollution from Ships 1973/78 (MARPOL),
- the Convention on Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (the London Convention) and its 1996 Protocol, and
- the Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention) 1972.

An extensive list is provided in a background paper for the development of Australia's Oceans Policy (Herriman et al. 1997).

Legislation and policies

At the Commonwealth level, new legislation enacted since 1996 includes the EPBC Act and the *Wildlife Protection (Regulation of Exports and Imports) Act 1982*. The effects of these Acts are discussed in the Fisheries subsection (page 66).

The necessary cooperation for managing fish stocks which extend across Australia's marine zones is achieved through a council of Commonwealth, State and Territory Ministers.

Australia's Oceans Policy

Australia's response to the need for national coordination and consistency of policy following UNCLOS and other international commitments (Ward et al. 1997) was to develop Australia's Oceans Policy, released in 1998. The Policy recognises that ocean ecosystem health and integrity is fundamental to ecologically sustainable development, essentially a triple bottom line approach that recognises the environmental, economic and social dimensions of the oceans. The principles in Australia's Oceans Policy are being integrated into legislative and other Commonwealth management initiatives.

The Policy recognises ocean ecosystems as core national assets which, if managed well, can meet a wide range of economic and other aspirations. Some of the important environmental issues given priority and now under way are:

- development of the National Representative System of marine protected areas,
- development of regional marine plans,
- improved management of fisheries and aquaculture, including bycatch reduction,
- consistent management of ships' ballast water and marine pest incursions,
- phase-out of tributyl tin antifouling paints,
- national standards for marine and estuarine water quality and improved treatment of sewage and stormwater,
- promotion of environmentally sustainable tourism, and
- involvement of Aboriginal and Torres Strait Islander communities in decisions about marine resources.

One of the key responses for sustainable management of Australia's oceans under the Policy is the development of regional marine plans that will address marine conservation and management issues on the basis of ecosystem rather than jurisdictional boundaries. In 1998 the CSIRO identified a series of regional domains called Large Marine Ecosystems covering the entire EEZ. Regional marine planning will develop and implement management regimes appropriate for biogeographical regions that incorporate one or more of these domains. The National Oceans Office is developing these plans.

The first regional marine plan is for the South-East Region, which closely matches the south-east Large Marine Ecosystem and covers 2.5 million km^2 of ocean from southern New South Wales, around Tasmania and Victoria to Kangaroo Island in South Australia. The National Oceans Office released a scoping paper for the South-East Regional Marine Plan in January 2001. Although the Plan concentrates on activities that the Commonwealth manages in the Region, the respective State governments have been invited to take part. Development of the Plan will require finer scale regionalisations of the ecosystems in the South-East Region.

Wescott (2000) has commended Australia for acting rapidly in the development of an ocean policy following the UNCLOS ratification. There are, however, a number of challenges still to be met in the implementation of Australia's Oceans Policy. In particular, there is a need to develop and implement systems that are effective in integrating (as opposed to coordinating) across sectors to meet agreed environmental objectives, and define strategies and targets for sectors to implement.

Coasts and Clean Seas Initiative

Another significant Commonwealth initiative since 1996 addresses major coastal and marine management problems identified in the Resource Assessment Commission's Coastal Zone Inquiry Final Report (RAC 1993) and the State of the Marine Environment Report (Zann 1995).

The Coasts and Clean Seas Initiative, funded from the Natural Heritage Trust, was established to combat pollution problems and threats to water quality and marine life in the coastal zone. Eight complementary programs are being supported under the Initiative; a number of these have been referred to in this report. Programs are funded at a community, regional, State/Territory or national level. The Commonwealth funding is $125 million over five years. A mid-term assessment of the effectiveness the Natural Heritage Trust program found that it was having a

> 'catalytic effect on investment in Australia's natural heritage in coastal and marine areas, with, for example, the $4.8 million approved from the Trust for Coastcare projects in 1997–98 and 1998–99 generating projects with a total value of $28.4 million.' (Natural Heritage Trust 1999).

Indigenous involvement in marine management

Indigenous peoples' connections with the sea occur all around Australia and they have used the sea for millennia. Much of the basis for contemporary Indigenous interest in coastal and ocean management is founded on continuing cultural traditions, rights and responsibilities which pre-date the arrival of Europeans. Aboriginal and Torres Strait Islander peoples' relationship to their sea country is associated with a complexity of rights and responsibilities, including the right to access, use and distribute resources through time from generation to generation (Smyth 1997).

Section 6 of the *Native Title Act 1993* provides a legislative basis for Aboriginal and Torres Strait Islander peoples to lodge claims over areas of sea where Australia asserts sovereign rights.

In May 1995, a claim was lodged in the Federal Court by the Northern Land Council on behalf of saltwater traditional owners in the Croker Island region of the Northern Territory. The claim includes the seas, reefs, seabeds and resources in waters surrounding Croker and adjacent islands. The 1998 Federal Court finding (*The Commonwealth of Australia v. Mary Yarmirr* and *Ors and Mary Yarmirr and Ors v. The Commonwealth of Australia* [1999] FCA 1668) was that 'non-exclusive' and 'non-commercial' native title rights existed. This decision was appealed both by the traditional owners and the Commonwealth Government. Following a majority reaffirmation of the original finding, both parties have appealed to the High Court. The High Court recognised native title rights in relation to the territorial sea. The decision also establishes the primacy of public rights to fish and navigate (The *Commonwealth v Yarmirr, Yarmirr v Northern Terrritory* (2001) HCA56).

A 1999 High Court decision (*Murrandoo Bulanyi Mungabayi Yanner v Graeme John Eaton* (1999) 201 CLR 351; (1999) 166 ALR 258) (the Yanner decision) confirmed that Aboriginal and Torres Strait Islander people may claim a right under native title to hunt living resources according to local customary law. The outcome of the Yanner case has resulted in most jurisdictions recognising Indigenous rights to obtain and consume traditional marine foods.

This decision has implications for the recognition of Indigenous peoples' rights and interest in fisheries management. This area of law is clearly an evolving one.

There is specific legislative recognition of the rights and interests of Torres Strait Islanders in the management of fisheries and the marine environment in Torres Strait, through the Torres Strait Treaty signed by the Australian and Papua New Guinea governments. However, from a local community perspective there are still a number of issues to resolve in regard to Indigenous fishing rights.

Coastal Indigenous groups are involved in projects and programs aimed at regaining self-management of their marine environments. A potentially promising model for Indigenous involvement is being proposed in the region between Cooktown and Bundaberg in Queensland. This is the Sea Forum, which is conducted in accordance with Indigenous peoples' processes and priorities. Sea Forum discusses management issues related to the Great Barrier Reef Marine Park. It is an initiative of traditional owners of sea country in the Southern Great Barrier Reef region involving traditional owners from the area between Cairns and Hervey Bay/Fraser Island.

A second promising model being developed is the Cape York Partnerships for natural resource management, which seeks to integrate government efforts in organised regional service centres on Cape York.

Some of the initiatives taken by Indigenous people towards participation in marine management include:

- involvement of a number of coastal Indigenous communities in local coastal management projects through the Coastcare program (see below),
- the Yolngu people of north-east Arnhem Land, with the assistance of Commonwealth Government funding, developing strategies for co-management of their traditional marine estates off the coast and to the north of Nhulunbuy (Gove), and
- development of the Hope Vale Dugong and Turtle Hunting Management Plan.

Community involvement [CO Indicator 7.11]

One of the outcomes of the development of Australia's Oceans Policy was a recognition that the Policy affects more than the identified key stakeholders, for example the tourism industry and the petroleum industry, and involves a constituency of communities around Australia.

Community involvement in marine and coastal management activities is a relatively recent phenomenon. There has been a high level of public support and awareness of the protection of the Great Barrier Reef and Antarctica, for example. However, public awareness and concern for the overall state of the marine and coastal environment and our ongoing impacts has not been so widespread.

Governments are encouraging more public participation in coastal and marine issues in a variety of ways: for example, through Fishcare, the Marine and Coastal Community Network (MCCN) and the Coastcare program.

Marine and Coastal Community Network

The Marine and Coastal Community Network (MCCN) was established in 1993, with Commonwealth funding, to assist community involvement in caring for oceans and coasts. It is a non-government community-based organisation. The aim of the Network is to develop a more cooperative and coordinated approach to marine and coastal resources protection and management. The Network provides a range of services for organisations and individuals on a regional and a national basis. These include:

- maintaining and expanding a list of individuals and groups who have an interest in marine and coastal issues and to involve them in the Network,
- conducting workshops on marine and coastal issues,
- communicating issues through Newsletters and the Internet, and
- coordinating Ocean Care Day each year in early December

An indicator of public awareness of coastal and marine issues can be gauged by the numbers of people on the MCCN mailing list, which has effectively doubled since 1996. Some 49% of MCCN participants represent organisations and as such indicates a significant multiplier effect of the Network's ability to access key interest groups and individuals.

Table 9: Growth in the number of individuals and groups on the MCCN mailing list.

Date	Aug 1996	June 1997	June 1998	June 1999	June 2000	June 2001
Participants	4 226	5 520	6 175	7 594	7 939	8 456

Source: Marine and Coastal Community Network (2001).

Coastcare [CO Indicator 7.4]

Coastcare is a national program that encourages community involvement in the protection, management and rehabilitation of Australia's coastal and marine environments. The program assists local communities to form partnerships with local managers.

Coastcare is a major component of Coasts and Clean Seas Initiative. It is delivered cooperatively by all three spheres of government: Commonwealth, States, the Northern Territory, and local government. The Commonwealth and State and the Northern Territory governments provide matching funding for Coastcare community grants while local government provides financial and in kind support for Coastcare projects.

Since the inception of Coastcare in 1995 and up to the year 2000, the program has funded over 1700 projects around Australia with approximately $12 million of funding contributed by the Natural Heritage Trust. The focus of Coastcare is to assist on-ground work such as:

- protecting or rehabilitating dunes, estuaries and wetlands,
- monitoring beach conditions, and coastal flora and fauna,
- helping to develop and implement local management plans, and
- providing education and training activities that raise community awareness, knowledge or skills on coastal and marine conservation issues.

The number of Coastcare groups rose from about 700 in 1997 to 1950 in 2000, and the number of people involved in the program rose from about 20 000 to 60 000 in the same period.

About 58% of individuals participating in the year 2000 were members of an established Coastcare or similar type of group. Approximately 150 of the 1950 Coastcare groups operating in the year 2000 are Indigenous groups.

The effectiveness of the Coastcare program was assessed in the Mid-term Evaluation of the Coasts and Clean Seas Initiative (Natural Heritage Trust 1999). The review found that:

> 'over 700 groups are involved in Coastcare projects and that coastal vegetation is being regenerated, coastal access is being improved and controlled, weeds and feral pests eradicated and important marine species such as sea dragons are being monitored'.

Role of volunteers

Volunteers provide invaluable contributions to survey, monitoring and (to a smaller extent) research. For example, the Australasian Wader Studies Group is a non-government organisation formed to coordinate and focus studies on waders, or shorebirds. Their objectives include the development of and assistance with wader research plans, encouragement of scientific programs, promotion of conservation and management policies, and assistance with the publication of results. They are also active in promoting wetland conservation.

Volunteers have also helped in practical ways by, for example, removing more than 21 000 Northern Pacific Seastars from the Derwent River in May 2000. Two hundred volunteers and three scientists worked together on this project.

Fisheries research in Australia has relied on volunteers from the commercial fishing industry on many occasions. A recent example is the use of volunteer fishers in the Northern Prawn Fishery to record sea turtle captures, tag sea turtles, and trial resuscitation techniques.

The marine education community includes many volunteers who provide education to a variety of groups, including schools. The Marine Education Society of Australia (MESA) hosts a website (http://www.mesa.edu.au/ [accessed 5 September 2001]) and has been active, for example, in the marine protected areas debate in promoting the importance of these areas for education.

Integrated coastal zone management

Integrated coastal zone management has been advocated for a long time to improve the systemic hindrances to more effective land management and also more effective management of the coastal zone (Resource Assessment Commission 1993). The description of what is meant by integrated includes both integration of agencies, issues and sectors and tiers of government but also includes integration of an approach to the land-sea interface. Two major problems have been identified which inhibit the sustainable use of Australia's coastal zone:

- fragmented management arrangements based on single issues or sectors, and
- the 'tyranny of small decisions', whereby over time a number of decisions that in themselves are not significant accumulate and interact to result in a significant impact on the coastal zone.

The number of agencies illustrates the challenge in coordination with some coastal responsibilities. In New South Wales, for example, there are 21 Councils and 31 other State agencies with responsibilities under the New South Wales Coastal Policy.

Both Victoria and New South Wales, for example, have established (or re-established) Coastal Councils to give effect to the Coastal Strategy (Victoria) and Coastal Policy (New South Wales). Queensland has recently released a draft State Coastal Management Plan. Tasmania has a State Coastal Policy. These approaches indicate the intended directions and identify the agencies responsible for achieving them, with a central agencies providing coordination.

Wescott (2001) has summarised the effectiveness of State and Territory institutional arrangements for integrated coastal zone management. The conclusion reached is that Victoria, New South Wales, Tasmania and Queensland (with the launch of its draft State Coastal Plan) have established statutory means to implement institutional arrangements including strategic plans and policies. There are still improvements that could be made, but progress is occurring. The other jurisdictions have a 'patchier' performance in their implementation of integrated coastal zone management.

Despite some concerns about the failure to implement all the Resource Assessment Commission recommendations, the Inquiry has certainly stimulated all States and the Northern Territory into action and given them a common objective—integrated coastal zone management—in the reform process over the last five years.

There is clearly still a need for a nationally applicable Coastal Zone Policy to be developed to further assist in reducing the fragmentation of effort to manage the coastal zone and associated coastal waters. This issue was highlighted by a House of Representatives report in 1991 (House of Representatives 1991) which said:

> 'The absence of a national perspective towards the entire Australian coastline could lead to national interests being undervalued or even lost for future generations, as the existing ad hoc, hodge-podge pattern of development slowly nibbles away at a precious and beautiful resource, the natural coastline.'

A key challenge for achieving integrated coastal zone management is the need for an institutional structure (and associated processes and procedures) to establish agreed outcome-based performance objectives for marine ecosystems.

The challenge is also for oceans management to identify the mechanisms and then design, implement and monitor performance by various ocean users to ensure they meet the agreed standards of ecologically sustainable use of ocean ecosystems. One important element of this strategy is the design and implementation of marine protected areas.

The Australian Coastal Atlas [CO Indicator 7.12]

In May 1995 the Commonwealth Coastal Policy defined a need to establish an Australian Coastal Atlas (ACA) to help increase knowledge about Australia's coastal zone, and thus provide an accessible information base to support decision-making for coastal zone management.

The Atlas project commenced in 1997 in consultation with a wide forum of users and has resulted in a network of nodes delivering almost 900 data layers over the Internet. The Australian Coastal Atlas is a partnership arrangement between States, the Northern Territory and the Commonwealth. A diverse range of data is available at a variety of scales (1 : 25 000 to 1 : 1 000 000) to be mapped and queried, including: administrative boundaries, Indigenous sites, species distributions, aquaculture, bathymetry, marine habitats, cyclone tracks, beach safety and coastal regionalisations (see http://www.environment.gov.au/marine/coastal_atlas/ [accessed 5 September 2001]).

Marine Protected Areas [CO Indicator 7.12]

The State, Territory and Commonwealth governments committed themselves to developing a National Representative System of Marine Protected Areas (NRSMPA) through the Australia New Zealand Environment and Conservation Council in the early 1990s. Australia's Oceans Policy includes an undertaking by the Commonwealth Government to accelerate the development of this system.

The primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of Marine Protected Areas (MPAs) in Australian waters. These Marine Protected Areas are to contribute to the long-term ecological viability of marine and estuarine systems and protect Australia's biodiversity (ANZECC 1999).

Marine Protected Areas can be declared under Commonwealth, State or Northern Territory legislation in each jurisdiction's waters. Australian governments are working cooperatively to establish the NRSMPA.

Because of the varying legislation in each jurisdiction, Australian Marine Protected Areas employ a range of naming conventions, subtypes and zones, including marine parks, marine

national parks, marine and intertidal habitat areas, coastal reserves, marine management areas, fish habitat protection areas, aquatic reserves, seaward extensions of national parks, marine nature reserves and marine reserves. However, they share a common intent to protect the marine and estuarine environment, particularly habitats such as reefs, seagrass beds, tidal lagoons, mangroves, rock platforms, coastal, deep ocean and underwater seabed areas and any marine cultural heritage.

Fraser Island, a World Heritage Area.

Source: Department of Foreign Affairs and Trade Photo Library.

Under the Australian IUCN Reserve Management Principles, Commonwealth Marine Protected Areas are zoned and classified according to the IUCN categories of protected area management, ranging from highly protected areas to sustainable multiple-use areas. A range of activities may be allowed in a Marine Protected Area, depending on the reason for declaration and management strategies. In some cases, virtually all human activity is excluded (as in strict nature reserve or 'no take' zones, corresponding to IUCN category 1a). Other areas have seasonal restrictions on activities; for example, closure to all activities during the whale breeding season. The States and the Northern Territory have agreed to apply IUCN categories to their Marine Protected Areas to ensure that the NRSMPA achieves its goals, and most also now require a management plan for the area prior to declaration.

A study of the effects of marine reserves on Tasmanian reef fish, invertebrates and algae (Edgar and Barrett 1999) found that their effectiveness appeared to correspond with reserve size. Many overseas studies indicate that highly protected and well-managed reserves protect species in proportion to reserve size.

The number and extent of Marine Protected Areas as at November 2000 are shown in Table 10. Marine Protected Areas declared for Commonwealth waters since 1996 are shown in Table 11.

A formal notice of intent to establish the waters around Heard Island and McDonald Islands as a marine reserve was announced in January 2001. The proposed reserve would cover 7.6 million hectares, making it the world's largest highly protected marine reserve.

Table 10: Number and extent of Marine Protected Areas, November 2000.

Jurisdiction	Number of MPAs	Area in MPAs (ha)	Management Plans produced
Commonwealth (incl. GBRMP)	13	53 329 431	5
New South Wales	50	127 707	4
Victoria	12	50 312	7
Tasmania	5	77 110	0
South Australia	17	252 371	1
Western Australia	8	1,393 387	4
Northern Territory	7	230 426	0
Queensland	82	5 421 117	6
TOTAL	**194**	**60 881 861**	**27**

Sources: CAPAD (1997) and recent survey for Environment Australia (2000).

Table 11: Marine Protected Areas declared for Commonwealth waters since 1996.

MPA and date of declaration	Area (ha)	Reason
Great Australian Bight Marine Park (Commonwealth waters) (April 1998)	19 769	Protect habitat for marine mammals and the diversity of benthic communities
Macquarie Island Marine Park (1999)	16 200 000	Habitat protection for threatened species
Tasmanian Seamounts Marine Protected Area (1999)	37 000	Protect unique benthic community
Twelve extensions to GBRMP into Queensland waters (2000)	520 000	Multiple use management
Cartier Island Marine Reserve (2000)	16 700	Protect biodiversity and representative area
Lord Howe Island Marine Reserve (Commonwealth waters) (2000)	300 510	Protect biodiversity and seamount habitats

Sources: CAPAD (1997) and recent survey for Environment Australia (2000).

Table 12: Marine Protected Areas declared by States and Territories since 1996.

Jurisdiction	MPA and date of declaration	Area (ha)	Reason
Western Australia	Albrolhos Islands Fish Habitat Protection Area (1999)	246 744	
Northern Territory	Charles Darwin National Park (marine component) (1998)	250	
Tasmania	Macquarie Island Nature Reserve (2000)	74 715	Protect biological diversity
New South Wales (13 in total)	Solitary Islands Marine Park (1997) (previously a Marine Reserve of 85,000 ha) Jervis Bay Marine Park (1998) Lord Howe Island Marine Park (State waters) (1998)	42 000 21 450 48 000	Protect biodiversity, sub-tidal reefs, soft substrates and open ocean ecosystems Conserve biological diversity and protect representative areas Conserve biodiversity and protect representative areas
Queensland	Kinkuna Fish Habitat Area Burdekin Fish Habitat Area	774 91 985	

Sources: CAPAD (1997) and recent survey for Environment Australia (2000).

The Commonwealth Government's Marine Protected Areas Program, a component of the Coasts and Clean Seas Initiative of the Natural Heritage Trust, provides funding to the State and Northern Territory governments to declare MPAs in their jurisdictions. States have established Marine Protected Areas since the 1970s. In 1971, for example South Australia introduced legislation to protect marine habitats. Western Australia commenced in the mid-1980s, and in 2000 issued a notice of intent for the Jurien Bay Marine Park.

In August 1999 the Tasmania released a draft Marine Protected Areas Strategy for the identification, selection and establishment of MPAs. The strategy is expected to be completed in 2001.

The Great Barrier Reef Marine Park Authority and Queensland Government agencies are currently undertaking a major program to increase the protection of biodiversity through a new representative network of highly protected areas. It is envisaged that all major habitat types will be included within the next two years.

Marine protected areas declared by States and Territories since 1996 are shown in Table 12.

Benefits of marine reserves

The Tasmanian Government declared the Maria Island Marine Nature Reserve in 1991. It extends seven kilometres along Maria Island and covers 1500 hectares. It was established to conserve a range of habitats typical of the Tasmanian east coast, including small areas of rocky reef with large underwater caves, sandstone reefs, kelp forests and seagrass beds.

A scientific monitoring program has been undertaken for this and other reserves (Edgar and Barrett 1999), entailing sampling from a number of sites both inside and outside the reserves immediately before declaration and then annually for five years.

After six years of protection in the Maria Island Marine Nature Reserve, the number of fish species has increased by 5%, while it fell by 23% in unprotected areas. The new species included Bastard Trumpeter, Ling and Draughtboard Shark, which are species targeted by fishers. The diversity of mobile invertebrates and algae has also increased within the marine reserve.

The numbers of large fish have increased by over 240% in the Reserve. Rock lobster abundance and size also increased.

A review of the global literature on reserves for use in fisheries management (Ward et al. 2001) concluded that, for many fisheries, and when integrated with the existing management practices, no-take sanctuaries would be highly likely to make an important contribution to modern fisheries management systems where environmental issues were also considered to be important. Sanctuaries were considered to offer a range of benefits to fully and over-exploited fisheries, as well as for biodiversity conservation more broadly.

Summary

Marine management is clearly progressing with Australia's Oceans Policy in place and a number of initiatives flowing from it. The fragmented nature of coastal zone management still leads to the 'tyranny of small decisions'. There is now a need for a corresponding coastal and estuarine policy to further improve coastal zone management.

Australia has made good progress towards achieving conservation of biodiversity through establishing Marine Protected Areas since 1996, and with the introduction of new legislation to improve the sustainability of fisheries.

The establishment of an NRSMPA has been an important issue for Australia since 1992. Increased funding allocated in 1997 from the Natural Heritage Trust has resulted in greater progress in achieving the program's goal. However, there is still a need at all levels of government for collaboration to manage and conserve marine biodiversity to achieve national commitments for ecologically sustainable use of resources and the conservation of species and habitats.

While many elements of policy are in place, the next challenge is to implement and then monitor the outcomes of the policies to ensure the ecologically sustainable use of the marine environment actually occurs and results in maintained or improved conditions.

Conclusions

Key findings

When compared with much of the world, Australia's coasts and oceans are in relatively good condition. However, the condition of inshore waters varies. While there are many areas that are largely in good condition, areas near human settlements have been affected, sometimes severely.

Although there is a consistency between the findings of the 1996 State of the Environment Report and those of this report, many important initiatives have started in this five-year period that will continue to have a positive effect in future years.

Substantial progress has been made in addressing the introduction of marine pests, upgrading sewage treatments plants, reusing treated wastewater, treating and reusing stormwater, and implementing measures to achieve sustainability in commercial fisheries and protecting marine biodiversity.

State of the coastal and marine environment

Our knowledge of the marine environment remains limited, particularly for areas remote from population centres and for the deep-sea environment and continental shelf. Progress is being made, however, with the mapping of the extended continental shelf.

Much existing information is scattered and in many cases is not collected in a consistent manner. It is still not possible, for example, to assess the loss of important habitat areas such as seagrass, mangrove or saltmarsh on a continental scale.

The quality of estuarine coastal and inshore waters has not improved over the past five years on a national basis. Water quality has improved in specific localities and regions, such as coastal waters off Sydney. Diffuse agricultural runoff and stormwater runoff significantly affects inshore waters. The management of disturbed coastal acid sulfate soils has been recognised as an important issue.

Understanding the sources of nutrients and how they behave in coastal waters has improved over the last five years. However, the overall loads of nutrients discharged into the coastal environment appear to be increasing.

More than half of Australia's estuaries are modified and are not in good condition, as a result of the pressures caused by human settlements. Fragmentation of responsibilities for estuary management is delaying improvements to the condition of estuaries.

Coastal and marine species have been subject to pressures, including loss of habitat and the effects of fishing activities. Measures to reduce the mortality rates of threatened species such as albatrosses and turtles have been implemented in the past two years and should result in fewer deaths in the future.

Pressure for coastal development, including the expansion of human settlements and tourism, has resulted in further modification of coastal habitat in the past five years. In some coastal areas of Australia, there is no unmodified coastal environment remaining.

Management of the coastal and marine environments

The development of Australia's Oceans Policy has been a major response to the fragmentation of marine management responsibilities. Progress is being made on the first of 12 intended Regional Marine Plans.

Coordinating bodies such as Coastal Councils are beginning to integrate the efforts of the various agencies and communities involved in coastal management. However, Indigenous peoples are currently finding it very difficult to participate fully in coastal and ocean discussion processes.

Funding from the Natural Heritage Trust since 1997 for coastal and marine environment issues has been substantial and has acted as a catalyst for many practical improvements to coastal environments by a wide range of stakeholders.

The establishment of Marine Protected Areas to conserve marine biodiversity has progressed. Ten Marine Protected Areas have been declared since 1996 by State, Territory and Commonwealth governments.

Although the overall catch from commercial fisheries over the last five years is similar, there have been large variations in individual fisheries. Some species that were heavily fished in the 1970s and 1980s have still not recovered.

It is difficult to assess the state of Australia's commercial fisheries. There are some sustainably managed fisheries, including one now internationally recognised by independent audit, but they are in the minority. Recent legislative amendments to ensure fisheries are managed on a sustainable basis in the future have been enacted by the Commonwealth.

The management of bycatch is now being addressed by the industry and governments.

Aquaculture is one of Australia's fastest-growing primary industries. Its expansion may increase competition in the coastal zone for access to suitable sites. The environmental effects of aquaculture activities are not yet fully understood and there are many ecological challenges to be addressed.

Risks to the marine and coastal environments

The susceptibility of Australian waters to the introduction of exotic marine species is significantly higher than previously thought. Australia has a well developed strategic approach to managing ballast water. However, hull fouling is now recognised as an important source of introduced marine pests and should be given a similar priority. There have been a number of infestations discovered in Australia in the last five years and contrary to earlier opinion, there are threats to tropical habitats as well as temperate ones.

There are risks to the economic viability of the $2.3 billion commercial fishing industry if we cannot manage the sustainable use of the marine ecosystems from which the fish are caught. The tendency in the past has been to discount the ecosystem risks or uncertainties because of economic pressures.

There are both economic and environmental risks from the contamination of seafood by pollution. Seafood quality is generally good. There have been only a few occurrences of sewage pollution affecting seafood quality with significant human health and economic consequences.

Shipping and offshore oil and gas operations have relatively good management systems in place, but need continual assessment and improvements to ensure the minimisation of risks.

Emerging issues

- The future development of aquaculture, with all its ramifications, particularly sea cages, ranching, and associated effects.
- The potential for the occurrence of coral bleaching and associated indirect effects to occur as a result of climate variability and change.
- The continuing development of fishing technology, particularly cheap spatial location and deep-water fishing gear.
- The emerging recognition of the ecological effects of invasive species in both temperate and tropical habitats.
- The continuation, despite public recognition, of weak attempts at integration of management.
- The effects on coastal structures and infrastructure from sea level and other potential climate changes.
- The lack of knowledge about the continental shelf and slopes of the EEZ, which creates a limited set of values.
- Tourism in the Antarctic, as tourist numbers have doubled over the past eight years and tourist activities continue to diversify.
- The involvement of Indigenous people in fisheries management issues across Australia. Indigenous involvement in marine resource management will require knowledge exchange, capacity building and communication. Regional Marine Plan boundaries do not mesh with Indigenous cultural boundaries, for example.

Key implications

In Australia there has been a big emphasis on the management of land and the value of agriculture to our economy and our communities. There has been less emphasis on the value of wetlands, estuaries and other coastal environments. The issue to be addressed is the balance to be achieved between the value of the land and the value of the coastal environment. A whole-of-catchment approach to resource management is worth pursuing. The danger is that the issue will become so hard that all the stakeholders—managers, community, Indigenous people and industries—will retreat from a systemic view.

Marine management should in the future look at the pressures and people's interactions with the environment, rather than strictly the management of the resource.

The quality of coastal and marine water is vitally dependent on land management practices and activities in the catchments. As point-source pollution is being tackled, the management of diffuse sources of pollution will become of greater importance.

The competition to use coastal and marine space will intensify. There may be competing environmental values in progressing alternative energy systems such as tidal power in coastal areas. Without a full account of environmental and economic values for any proposal, irreversible environmental changes may occur.

Glossary

aggregating behaviour The concentration of fish for unknown reasons or direct causes such as the concentration of food organisms, or for spawning.

anthropogenic Caused by human activity.

Australia's Marine Area The area of sea or seabed for which Australia has jurisdiction and/or rights under the Law of the Sea Convention. It includes the Exclusive Economic Zone and continental shelf off the Australian mainland.

barrens An area of (usually) rocky reef without vegetation, caused by excessive grazing.

benthic The organisms or environment of the seabed, for example plants and animals living on or in the sub-sea sediment.

benthos Organisms living on or in association with the seafloor.

bioaccumulation The accumulation of a chemical in plant or animal tissue at concentrations higher than in the surrounding water.

biocide A chemical which kills animals and plants.

biodiversity The variety of all native life-forms: the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form; often considered at three levels: genetic diversity, species diversity and ecosystem diversity.

biogeochemical The movement of chemical elements between organisms and non-living compartments of atmosphere, aquatic systems and soils.

biota All living organisms of a region.

broodstock Specimen or species, either as eggs, juveniles, or adults, from which a first or subsequent generation may be produced in captivity, whether for growing as aquaculture or for release to the wild for stock enhancement.

bryozoans Marine animals commonly known as moss animals, sea mats or (for some forms) lace coral. The majority of living byrozoans are encrusting, forming flat sheets that spread out over the substrate but others grow upwards into the water column.

bycatch (or incidental capture) The catch of species other than those targeted by fishing activity.

cephalopods molluscs characterised by a distinct head with arms or tentacles attached to it, e.g. cuttlefish.

cetaceans Members of the mammalian group Cetacea, including whales, dolphins and porpoises.

crustacea A class of arthropods, which have gills and bodies covered by a hard shell (e.g. crabs, lobsters, shrimps).

demersal Living on or near the bottom of the sea.

denitrification The process by which nitrogen, which would otherwise be available to plants, is converted to a gaseous form and lost from the soil or water column.

dinoflagellates A group of single-celled algae.

echinoderms A member of the class Echinodermata comprising sea urchins and sea cucmbers. The skin of the typical species is covered with spines.

ecosystem A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

ecosystem services The role played by organisms and environmental processes in creating a healthy environment for human beings, from production of oxygen to soil formation and maintenance of water quality.

El Niño An extensive warming of the central and eastern Pacific that leads to a major shift in weather patterns across the Pacific. In Australia (particularly eastern Australia), El Niño events are associated with an increased probability of drier conditions.

endemism species found only in a particular region, e.g. a species endemic to South Australia is not found anywhere else.

enterococci An indicator organism used to assess the presence of human pollution (as distinct from animal pollution) in waterways or the sea.

epifauna invertebrates that attach themselves to rocky reefs or to the seafloor. They include hydroids, sea-pens, small bryozoans and sponges.

erosion The removal of a fairly uniform layer of soil from the land surface by raindrop splash and/or runoff.

eutrophication Excessive nutrients which causes high plant growth. Often resulting in nuisance algal blooms, turbid waters and subsequent decay and decomposition of the plants.

faecal coliform The portion of the coliform bacteria group which is present in the intestinal tracts and faeces of warm-blooded animals. A common pollutant in water.

fishing effort The amount of fishing gear of a specific type used on the fishing grounds over a given unit of time, e.g. the number of hauls of a beach seine net per day.

formation water (or production water) Water produced together with oil from the oil-bearing strata in oil wells. Usually underlies the oil in geological formations and is produced in increasing quantities as the oil is depleted.

heavy metals Metallic elements with relatively high atomic weights such as lead, cadmium, arsenic and mercury. Generally toxic in relatively low concentrations to plant and animal life.

hydrocarbons Organic molecules containing hydrogen and carbon, the major components of petroleum.

hydroids Small invertebrates whose colonies can take many growth forms including flower-like, tree-like or feathery. Hydroids are best represented in cool temperate southern Australian seas.

imposex The imposition of male characteristics on female organisms, as caused by some pollutants.

infrastructure The built systems of, for example, water supply, wastewater treatment, drainage, airports, roads and ports.

invertebrates Animals without internal skeletal structure.

leachate A soluble substance that is washed out of the soil.

Lyngbya A toxic marine cyanobacterium (blue-green algae) that appears to tolerate a wide range of salinity.

macroalgae Large algae, e.g. kelp.

mariculture Fish farming or aquaculture of marine animals or plants.

middens Very old rubbish pits of former inhabitants of an area, usually Indigenous.

nutrients Substances required for the growth of plants, e.g. nitrogen and phosphorus.

organochlorines Complex organic molecules with chlorine atoms attached (e.g. pesticides).

organotin Highly toxic chemicals comprising tin combined with organic molecules, used in antifouling paints such as tributyl tin.

pathogens An organism that can produce disease.

pelagic Associated with the open sea, particularly the surface or middle depths of the water column, e.g. fish swimming freely in the open sea.

phytoplankton Small plants that are suspended in water and free-drifting.

pollutants A substance in excess in an ecosystem or not belonging to an ecosystem.

polychaete worms A class of segmented worms with several seta (bristles) per segment. Very widespread in the marine environment.

ppb parts per billion.

Ramsar Convention The Convention on Wetlands, signed in Ramsar, Iran, in 1971, providing the framework for the conservation and wise use of wetlands and their resources.

sessile Organisms fixed in one position to a substrate.

substrate A surface on which organisms live or a substance serving a biochemical reaction.

syngnathids A family of fish including the seahorses and pipefish.

taxa The named classification unit to which individuals or sets of species are assigned, such as species, genus and order.

temperate zone The zone where the temperatures are mild.

threatened species A species of plant or animal threatened with extinction either locally or globally, without defining its formal status as to the degree of threat.

toxicant A substance that could cause adverse effects in a living organism.

upwelling The phenomenon of deep water rising to the surface, usually bringing nutrients which can increase productivity.

vulnerable species A species of plant or animal vulnerable to extinction, but carrying a lower level of concern than ‘endangered’.

References

ABARE 2001, *Australian Fisheries Statistics 2000*, Australian Bureau of Agricultural and Resource Economics, Canberra.

Andrews N (ed.) 1999, *Under Southern Seas*: *The Ecology of Australia's Rocky Reefs*, UNSW Press, Sydney.

ANZECC 1999, *Strategic Plan of Action for the National Representative System of Marine Protected Areas: A Guide for Action by Australian Governments*, ANZECC Task Force on Marine Protected Areas, July 1999.

ANZECC 2000, *Australian National Guidelines for Cetacean Observation & Areas of Special Interest for Cetacean Observation*, Australia and New Zealand Environment and Conservation Council.

ANZECC/ARMCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australian and New Zealand, Canberra.

ANZECC Working Party on Marine Debris 1996, Final Report 1996: The Australian Marine Debris Status Review, February 1996, submitted by Maunsell Proprietary Limited (consultants).

APPEA 1996, *Code of Environmental Practice*, Australian Petroleum and Production Exploration Association, Canberra.

Australian Antarctic Division 2000, *Looking South: the Australian Antarctic Program into the 21st Century*, Australian Antarctic Division, Environment Australia.

Australian Fisheries Management Authority 2001, *Annual Report 2000*, Australian Fisheries Management Authority, Canberra.

Bannister JL, Kemper CM and Warneke RM 1996, *The Action Plan for Australian Cetaceans, Wildlife Australia, Endangered Species Program, Project No. 380*, Australian Nature Conservation Agency, Canberra.

Beumer J, Carseldine L, Zeller B 1997, *Declared Fish Habitat Areas in Queensland*, Fisheries group, Queensland Department of Primary Industries.

Butler AJ and Jernakoff P 1999, *Seagrass in Australia: Strategic Review and Development of an R&D Plan*, CSIRO Publishing, Melbourne.

Capon RJ et al. 1999, Geodin A magnesium salt : A novel nematocide from a southern Australian marine sponge, Geodia sp., *J. Nat. Prod.* 62: 1256–9.

Cappo M et al. 1998, *Major Threats, Issues and Gaps in Knowledge of Coastal and Marine Fisheries Habitats—A Prospectus of Opportunities for the FRDC 'Ecosystem Protection Program'*, Volume 2: Scoping Review, Australian Institute of Marine Science and Fisheries Research and Development Corporation.

Caton A and McLoughlin K (eds) 2000, *Fisheries Status Reports 1999: Resource Assessments of Australian Commonwealth Fisheries*, Bureau of Rural Sciences, Canberra.

Caton A and McLoughlin K(eds) (in prep), *Fisheries Status Reports 2001: Resource Assessments of Australian Commonwealth Fisheries*, Bureau of Rural Sciences, Canberra.

Claridge G 1997, *Guidelines for Managing Visitation to Seabird Islands*, Report prepared by Claridge and WBM Oceanics for the Great Barrier Reef Marine Park Authority and the Australian Nature Conservation Agency, Publ. by Great Barrier Reef Marine Park Authority, website: http://www.gbrmpa.gov.au/corp_site/info_services/publications/seabirds/index.html (accessed September 2001).

Coastal Council of New South Wales 2001, *Annual Report 1999–2000*, Coastal Council of New South Wales, Sydney.

Coleman N, Gason ASH and Poore GCB 1997, High species richness in the shallow marine waters of south east Australia, *Marine Ecology—Progress Series* 154: 17–26.

Coles RG, Lee Long W, McKenzie L, Roelofs A, De'Arth G 2000, Stratification of seagrasses in the Great Barrier Reef, World Heritage Area, Northeastern Australia, and the implications for management, *Societa Italiana di Biologia Marina* 7: 345–348.

Commonwealth of Australia 1998a, *Australia's Oceans Policy*, Canberra, Australia.

Commonwealth of Australia 2000, *Report of the National Taskforce on the Prevention and Management of Marine Pest Incursions*. For the Joint SCC/SCFA National Taskforce on the Prevention and Management of Marine Pest Incursions, Environment Australia/

Agriculture, Fisheries and Forestry – Australia, 23 December 1999 (Revised edition October 2000).

Commonwealth of Australia 2001a, *Estuary Assessment 2000*, Published by the CRC for Coastal Zone, Waterways and Estuaries Management, Townsville for the National Land and Water Resources Audit, Canberra.

Commonwealth of Australia 2001b, *Implementing Selected Indicators of Marine Disturbance in Parts of the AEEZ*, Prepared by the Bureau of Rural Sciences for the Department of Environment and Heritage, Canberra.

Costanza R, d'Arge R, de Groot R, Farber R, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P and van den Belt M 1997, The value of the world's ecosystem services and natural capital, *Nature* 387: 253–260.

Coughanowr C 1997, *State of the Derwent Estuary: A Review of Environmental Quality Data to 1997*, Supervising Scientist Report 129, Supervising Scientist, Canberra.

CSIRO 1989, *Jervis Bay Baseline Studies Third Progress Report, December 1989*, CSIRO Fisheries Division, Jervis Bay Territory.

Davey K 2000, Australia's shark cull—will it stop?, *Australian Marine Conservation Society* p.11.

de Forges BR, Koslow J and Poore GCB 2000, Diversity and endemism of the benthic seamount fauna in the southwest Pacific, *Nature* 405: 944–947.

Dennison WC and Abal EG 1999, *Moreton Bay Study: A Scientific Basis for the Healthy Waterways Campaign*, South East Queensland Water Quality management Strategy, Brisbane.

DEPWA 1996, *Southern Metropolitan Coastal Waters Study (1991–1994)*, Final Report No. 17, Department of Environmental Protection, Perth, WA.

DEPWA 2000, *Department of Environmental Protection, Annual Report 1999–2000*, Department of Environmental Protection Perth, Western Australia.

DISR 2001a, Bureau of Tourism Research data, viewed on the Department of Industry, Science and Research, website: http://www.disr.gov.au/ (accessed 5 September 2001).

DISR 2001b, *Review of Environmental Impacts of Petroleum Exploration and Appraisal Activities in Commonwealth Waters*. Report prepared by URS Australia Pty Ltd for the Petroleum and Electricity Division, DISR, Canberra.

Department of Natural Resources 1999, *Acid Sulfate Soils Management Strategy for Queensland*, Queensland Acid Sulfate Soil Management Advisory Committee, Brisbane.

Desmarchelier P and Wong F 1998, *The Potential for Vibrio Cholerae to Translocate and Establish in Australian waters*, prepared for the Australian Quarantine and Inspection Service, Ballast Water Research Series No 10, Canberra.

Digby MJ, Saenger P, Whelan MB, McConchie D, Eyre B, Holmes N and Bucher D, 1999, *A Physical Classification of Australian Estuaries*, Land and Water Research and Development Corporation Occasional Paper 16/99 (Urban Sub-Program, Report no 9).

DPIWE Tasmania 2000, *The Tasmanian Abalone Fishery Revised Policy Paper July 2000*, Tasmanian Department of Primary Industries, Water and Environment.

Edgar GJ and Barrett NS 1999, Effects of declaration of marine reserves on Tasmanian reef fishes, invertebrates and plants, *Journal of Experimental Marine Biology and Ecology* 242(1): 107–144.

Edyvane K 1998, *Marine Biodiversity and Conservation in Southern Temperate Australia, Victoria's National Parks: The Next Century*, Conference Proceedings, Melbourne, Victorian National Parks Association Inc.

Environment Western Australia 1998, *Environment Western Australia 1998: State of the Environment Report*, Department of Environment Protection, Perth.

EPA 1999, *State of the Environment Queensland 1999*, Environmental Protection Agency, Brisbane.

EPA 2000a, *New South Wales State of the Environment Report*, Environment Protection Authority, NSW.

Fairweather PG and Quin GP 1995, *Marine Ecosystems: Hard and Soft Shores*, Technical Annex I, The Marine Environment, State of the Marine Environment for Australia, Great Barrier Reef Marine Park Authority for the Dept of Environment, Sport and Territories, Ocean Rescue 2000 Program, Canberra.

Fisheries Western Australia 2000a, *Protecting and Sharing Western Australia's Coastal Fish Resources*: *The Path to Integrated Management*, Fisheries Management Paper No 135 p. 8, February 2000, Fisheries Western Australia.

Fisheries Western Australia 2000b, *Management Directions for WA's Recreational Fisheries*, Fisheries Management Paper No 136, Fisheries Western Australia.

Fisheries Western Australia 2000c, *Management Directions for WA's Coastal Commercial Finfish Fisheries*, Fisheries Management Paper No 134, Fisheries Western Australia.

Fletcher R, Keech S, McVea T and Hannan J (eds) 1999, *Status of Fisheries Resources 1997–98*, New South Wales Fisheries Research Institute, Cronulla.

Fletcher WJ, Jones B, Pearce AF and Hosja W 1997, *Environmental and Biological Aspects of the Mass Mortality of Pilchards (Autumn 1995) in Western Australia*, Fisheries Western Australia, Fisheries Research Report No 106.

FRDC 2000, *Investing for Tomorrow's Fish: The FRDC's Research and Development Plan, 2000 to 2005*, Fisheries Research and Development Corporation, Canberra.

FRDC 2001, *Huon Estuary Study*, Environmental Research for Integrated Coastal Management and Aquaculture, website http://www.frdc.com.au/pub/reports/files/96-284.htm

Garnett ST and Crowley GM 2000, *The Action Plan for Australian Birds*, Environment Australia, Canberra.

Gaughan DJ, Mitchell RW and Blight SJ 2000, Impact of mortality, possibly due to herpes virus, on pilchard *Sardinops sagax* stocks along the south coast of Western Australia in 1998–99, *Marine and Freshwater Research* 51: 601–612.

GBRMPA 2001, Water Quality Plan, Great Barrier Reef Marine Park Authority website http://www.gbrmpa.gov.au/

Gerritse RG 1999, *Nutrients, Water Quality and Algal Blooms in the Canning Catchment*, Canning Catchment Coordinating Group Inc.

Greenfield PF 2000, *The Way Ahead in Sustainable Australia?* Proceedings of the 2000 Invitation Symposium, Australian Academy of Technological Sciences and Engineering, 21–22 November 2000.

Greiner R, Young MD, McDonald AD and Brooks M 1997, *Australia's Oceans Policy, Oceans Planning and Management Issues. Paper 2, Management Instruments for Marine Resource Allocation and Use*, Environment Australia. Canberra.

Harris ANM and Ward P 1999, *Non-Target Species in Australia's Commonwealth Fisheries: A Critical Review*, Bureau of Rural Science, Canberra.

Harris G 2001, *A Nutrient Dynamics Model for Australian Waterways*, Australia: State of the Environment, Second Technical Paper Series (Inland Waters), Department of Environment and Heritage, Canberra.

Harris G, Batley G, Fox D, Hall D, Jernakoff P, Molloy R, Murray A, Newell B, Parslow J, Skyring G and Walker S 1996, *Port Phillip Bay Environmental Study Final Report*, CSIRO, Canberra, Australia.

Harris GP, Briffiths FB, Clementson LA, Lyne D and Van der Croc, H 1991, Seasonal and interannual variability in physical processes, nutrient cycling and the structure of the food chain in Tasmanian shelf waters, *J. Plankton Research* 13: 109–131.

Haynes D and Johnson JE 2000, Organochlorine, heavy metal and polyaromatic hydrocarbon pollutant concentrations in the Great Barrier Reef environment: a review. *Marine Pollution Bulletin* 41 (7–12): 267–278.

Herfort A 1997, *Marine Debris on Beaches in New South Wales with a Special Focus on Fishing Debris*, A marine environmental study funded by the NSW Environmental Restoration and Rehabilitation Trust, Ocean Watch Australia Ltd.

Herriman M, Tsamenyi M, Ramli J and Bateman S 1997, *Australia's Oceans Policy: International Agreements*, Background Paper 2, Commonwealth of Australia.

Hewitt CL, Cambell ML, Thresher RE and Martin RB (eds) 1999, *Marine Biological Invasions of Port Phillip Bay*, Victoria, Centre for Research on Introduced Marine Pests, Technical Report no. 20, CSIRO Marine Research, Hobart.

HOSCER 1991, *The Injured Coastline*, House of Representatives Standing Committee on Environment, Recreation and the Arts, AGPS, Canberra.

Hutchings P and Haynes D 2000, Sources, fates and consequences of pollutants in the Great Barrier Reef, *Marine Pollution Bulletin* 41 (7–12): 265–266.

IAATO 2000, *Overview of Antarctic Tourism*, Information Paper 33 submitted by the International Association of Antarctica Tour Operators to the Antarctic Treaty XII Special Consultative Meeting, September 1999. Website: http://www.aad.gov.au/goingsouth/tourism/research/treatysys/zzatcm/Year/2000SATCM12/SATCM12ip33.asp (accessed 5 September 2001).

Jones RN and Pittock B 1997, Assessing the impacts of climate change: the challenge for ecology. In *Frontiers of Ecology*, Klomp N and I Lunt (eds), Elsevier Science, Oxford.

Kemper CM and Gibbs SE 1997, *A Study of Life History Parameters of Dolphins and Seals Entangled in Tuna Farms Near Port Lincoln: Comparisons with Information from Other South Australian Dolphin Carcasses*. Report to the Department of Environment and Heritage (ANCA), Canberra.

Kiessling I and Hamilton C 2000, *Marine Debris at Cape Arnhem, Northern Territory, Australia*. WWF Report Northeast Arnhem Land Marine Debris Survey 2000, published in April 2000 by World Wildlife Fund for Nature Tropical Wetlands of Oceania Program, Darwin.

King BR 1996, The status of seabirds in Queensland. In *The Status of Australia's Seabirds*, Ross GJB, Weaver K and Greig JC (eds), Proceedings of the National Seabird Workshop, Canberra, 1–2 November 1993, Biodiversity Group, Environment Australia, Canberra.

Kirkman 1997, *Seagrasses of Australia*, Technical Paper, State of the Environment, Department of the Environment and Heritage, Canberra.

Koslow and Gowlett-Holmes 1998, *The Seamount Fauna off Southern Tasmania: Benthic Communities, Their Conservation and Impacts of Trawling*, Report to Environment Australia and the Fisheries Research and Development Corporation.

Lambeck K 2001, Sea-level change from mid-Holocene to recent time: An Australian example with global implications. In *Glacial Isostatic Adjustment and the Earth System*, JX Mitrovica and B Vermeersen (eds), American Geophysical Union, Geodynamics Monograph Series, Washington DC.

Lee Long WJ, Coles RG, McKenzie LJ 2000, Issues for seagrass conservation management in Queensland, *Pacific Conservation Biology* 5: 321–28 .

Lunney D and Ponder W 1999, Emergent themes from the Other 99%. In *The Other 99%: The Conservation and Biodiversity of Invertebrates*, Ponder W and Lunney D (eds), Transactions of the Royal Zoological Society of News South Wales, Mosman.

Marsh H, Eros C, Corkeron P and Breen B 1999, A conservation strategy for dugongs: implications of Australian research, *Mar. Freshwater Res.* 50: 979–90.

Marsh H and Lawler I 2001, *Dugong Distribution and Abundance in the Southern Great Barrier Reef Marine Park and Hervey Bay: Results of an Aerial Survey in October–December 1999*. Research Paper #70, Great Barrier Reef Marine Park Authority, Townsville.

McCauley RD, Fewtrell J, Duncan AJ, Jenner C, Jenner M-N, Penrose JD, Prince RI, Adhitya A, Murdoch J and McCabe K 2000, Marine seismic surveys – a study of environmental implications, *APPEA Journal* 2000: 692–706.

McIlgorm A and Pepperell JG 1999, *A National Review of the Recreational Fishing Sector*, Report to Agriculture, Fisheries and Forestry – Australia.

McKenzie LJ, Lee Long WJ, Coles RG, Rodger CA, 2000 Seagrass-Watch: community-based monitoring of seagrass resources. *Biol. Mar. Medit.* 7(2): 393–396.

Mitchell AW & Bramley RGV 1997, Export of nutrients and suspended sediments from the Herbert River catchment during a flood event associated with cylcone Sadie. In *Cyclone Sadie Flood Plumes in the Great Barrier Reef Lagoon: Composition and Consequences November 1994*, Steven A. (ed.), Great Barrier Reef Marine Park Authority Workshop Series 22.

Mitchell W, Chittleborough J, Ronai, B, and Lennon GW 2000, Sea level rise in Australia and the Pacific, *The South Pacific Sea Level and Climate Change Newsletter*, 5(1), January 2000, website: http://www.ntf.flinders.edu.au/TEXT/CONF/cook2000/papers/billdoc.pdf (accessed 5 September 2001).

National Residue Survey 1998, *Report on the Australian National Residue Survey*, National Office of Food Safety, National Office of Animal and Plant Health, Department of Agriculture, Fisheries and Forestry – Australia, Canberra.

National Working Party on Acid Sulfate Soils 2000, *National Strategy for the Management of Coastal Acid Sulfate Soils*. Report prepared by the National Working Party on Acid Sulfate Soils on behalf of SCARM and ARMCANZ, NSW Agriculture, Wollongabar, NSW.

Natural Heritage Trust 1999, *Improving Performance in Partnership. Mid-term evaluation of Coasts and Clean Seas 1997 to 1999, Final Report*, Marine Group, Environment Australia.

O'Sullivan D and Dobson J 2000, Status of Australian aquaculture in 1998/99, In *Australia Aquaculture Trade Directory 2000*, Turtle Press, Hobart, pp. 3–17.

Parliament of SA 2000, *Inquiry into Tuna Feedlots at Louth Bay*, Parliament of SA Environment Resources and Development Committee: Thirty-Eighth Report of the Committee, Third Session, Forty-Ninth Parliament.

Parry G and Cohen B 2001, *Asterias amurensis* biomass, distribution and abundance in Port Phillip Bay following a survey during March–April 2001. Unpublished paper Marine and Freshwater Research Institute, Queenscliff, 31 May 2001.

Pearson G, Grosse A and Willing T 1999, Management implications for Roebuck Bay from ROEBIM '97. In *Intertidal Sediments and Benthic Animals of Roebuck Bay, Western Australia*, Pepping M, Piersma T, Pearson G and Lavaleye M. (eds), Netherlands Institute for Sea Research, Western Australian Conservation and Land management, Curtin University for Technology, Perth, WA.

Penn JW (ed.) 1999, *State of the Fisheries Report 1998/1999*, Fisheries Research Division, Fisheries Western Australia.

Pepping M 1999, Intertidal benthic community structure, In *Intertidal Sediments and Benthic Animals of Roebuck Bay, Western Australia*, Pepping M, Piersma T, Pearson G and Lavaleye M (eds), Netherlands Institute for Sea Research, Western Australian Conservation and Land Management, Curtin University for Technology, Perth, WA.

Pirzl H, Coughanowr C 1997, *State of the Tamar Estuary: A Review of Environmental Quality Data to 1997*, Supervising Scientist Report 128, Supervising Scientist, Canberra.

Poiner I, Glaister J, Pitcher R, Burridge C, Wassenberg T 1998, *Final Report on Effects of Trawling in the Far Northern Section of the Great Barrier Reef Marine Park: 1991–1996*, CSIRO Division of Marine Research, Cleveland, Qld.

Ponder W, Hutching P and Chapman R (in prep.), *Overview of the Conservation of Australian Marine Invertebrates*, A Report for Environment Australia.

Preston N and Rothlisberg P 2000, *Aquaculture: Environmental Impacts, in Outlook 2000: Oceans Policy, Fishing and Aquaculture*, ABARE Conference 29 February–2 March 2000, Vol. 1: 255–261, ABARE, Canberra.

RAC (Resource Assessment Commission) 1993, *Coastal Zone Inquiry: Final Report*, AGPS, Canberra.

Reichelt R 2000, *Sustainability of the Great Barrier Reef*, Proceedings of the 2000 Invitation Symposium, Australian Academy of Technological Sciences and Engineering, 21–22 November 2000.

Ridd P, Sandstrom MW, Wolanski E 1998, Outwelling from tropical tidal salt flats, *Estuarine Coastal and Shelf Science* 26: 243–253.

Roberts DE, Smith A, Ajani P, Davis AR 1998, Rapid changes in encrusting marine assemblages exposed to anthropogenic point-source pollution: A 'Beyond BACI' approach, *Marine Ecology Progress Series* 163: 213–224.

Saintilan N and Williams RJ 2000, Short note, The decline of saltmarsh in south-east Australia: results of recent surveys, *Wetlands (Australia)* 18(2): 49–54.

Sinclair Knight Merz 1998, *Review of Coastal Vegetation and Geomorphological Data*, Report prepared by the State of Environment Reporting Unit, Environment Australia.

Sloan S, Wallner B, Mounsey R 1999, *A Report on the Groote Eyland Fishing Gear Debris Project 1998*, Prepared for the Australian Fisheries Management Authority.

Smith AK and Pollard A (eds) 1998, *Policy and Guidelines: Aquatic Habitat Management and Fish Conservation*. New South Wales Fisheries, Sydney.

Smith T 2001, *Australian Estuaries: A Framework for Management*, CRC for Coastal Zone, Waterways and Estuaries Management, Townsville.

Smyth D 1997, *Socio-Cultural Considerations: Australia's Oceans Policy Issues*, Paper No 6, Commonwealth of Australia, Canberra.

State of the Environment Advisory Council 1996, *Australia: State of the Environment 1996*, CSIRO Publishing, DEST, Canberra.

Swan JM, Neff JM & Young PC 1994, *Environmental Implications of Offshore Oil and Gas Development in Australia. The Findings of an Independent Scientific Review*. APPEA, Sydney.

Sweatman H, Cheal A, Coleman G, Fitzpatrick B, Miller I, Ninio R, Osborne K, Page C, Ryan D, Thompson A, Tomkins P 2000, *Long-Term Monitoring of the Great Barrier Reef*. Status Report No 4 2000, Australian Institute of Marine Science in conjunction with the CRC Reef Research Centre.

Symonds PA, Murphy B, Ramsay D, Lockwood K and Borissova I 1998, *The Outer Limits of Australia's Resource Jurisdiction Off Western Australia*, Sedimentary basins of Western

Australia 2: Proceedings of Petroleum Exploration Society of Australia Symposium, Perth, WA, 1998, pp. 3–20.

Thomas BE, Connolly RM 2001, Fish use of subtropical saltmarshes in Queensland, Australia: relationships with vegetation, water depth and distance onto the marsh. *Marine Ecology Progress Series* 209: 275–288.

Tomlinson R 2001, Vanishing Beaches—Perception or Reality. Professional lecture delivered on 28 June 2001, Griffiths University, Gold Coast.

Tsvetnenko Y 1999, Development of bioassays to determine drilling mud toxicity. In *International Workshop on Drilling Fluid Ecotoxicology and Biodegradation*, 8–9 October 1998, Curtin University, Perth Western Australia, pp. 114–120.

Underwood AJ and Chapman MG 1997, Subtidal assemblages on rocky reefs at a cliff-face sewage outfall (North Head, Sydney, Australia): What happened when the outfall was turned off?, *Marine Pollution Bulletin* 33: 293–303.

Wachenfeld DR, Oliver JK and Morrissey JI, 1998, *State of the Great Barrier Reef World Heritage Area 1998*, Great Barrier Reef Marine Park Authority, Townsville.

Ward T, Alder J, Margules C, Sainsbury K, Tarte D and Zann L 1997, *Australia's Oceans Policy*, Biodiversity Conservation Issues Paper 7, November 1997, Department of the Environment, Canberra, Australia.

Ward T, Butler E and Hill B 1998, *Environmental Indicators for National State of the Environment Reporting, Estuaries and the Sea*, Environment Australia.

Ward TJ, Heinemann D, and Evans N 2001, *The Role of Marine Reserves as Fisheries Management Tools: A Review of Concepts, Evidence and International Experience*. A Report for Bureau of Rural Science, Canberra.

Watkins D 1993, *A National Plan for Shorebird Conservation in Australia*, Report No. 90, Royal Australasian Ornithologists Union.

Watkinson AJ, Dennison WC, O'Neill JM and Hewson I 2000, *Blooms of the Marine Cyanobacterium* Lyngbya majuscula *in Deception Bay: Potential Implications of Hydric Soil Disturbance*. Paper presented at Acid Sulfate Soils: Environmental Issues, Assessment and Management, Technical Papers, Brisbane, 20–22 June 2000.

Wescott G 2000, The development and initial implementation of Australia's 'integrated and comprehensive' Oceans Policy, *Ocean and Coastal Management* 43: 853–878.

Wescott G 2001, Integrated coastal zone management in the Australian states. In *Integrated Oceans Management: Issues in Implementing Australia's Oceans Policy*, Haward M (ed.), Cooperative Research Centre for Antarctica and the Southern Ocean, Research Report 26, Hobart, Australia, pp. 133–147.

Whittington RJ, Jones JB, Hine PM and Hyatt AD 1997, Epizootic mortality in the pilchard *Sardinops sagax* neopilchardus in Australia and New Zealand in 1995, I Pathology and epizootiology, *Diseases of Aquatic Organisms* 28: 1–16.

Wilkinson C (ed.) 2000, *Status of Coral Reefs of the World: 2000*, Australian Institute of Marine Science, Townsville.

Williams LE (ed.) 1997, *Queensland's Fisheries Resources—Current Condition and Trend 1988–1995*, Department of Primary Industries Queensland QDPI Information Series Q197007.

Wilson JR 2000, *South Australia Wader Surveys, January and February 2000*, J Wilson, 13 Giles Street, Kingston ACT 2604.

Wilton KM 2001, Changes in coastal wetland habitats in Careel Bay, Pittwater, NSW from 1940 to 1996, *Wetlands (Australia)* (in press).

Wolanski E and Duke NC 2001, Muddy coastal waters and depleted mangrove coastlines—depleted seagrass and coral reefs. In *Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef*, Wolanski E (ed.), CRC Press LLC.

Zann L (ed.) 1995, *Our Sea, Our Future: Major Findings of the State of the Marine Environment Report for Australia*, Great Barrier Reef Marine Park Authority for the Dept of Environment, Sport and Territories, Ocean Rescue 2000 Program, Canberra.

Zann L and Kailola P (eds) 1995, *State of the Marine Environment Report for Australia: Technical Annex I – The Marine Environment*, Great Barrier Reef Marine Park Authority for the Department of Environment, Sport and Territories, Canberra.

Index