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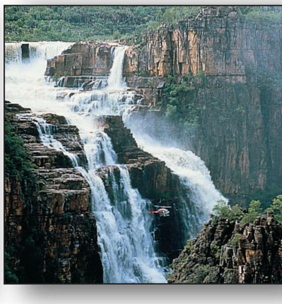
Australian Bureau of Statistics

Australia's Environment: Issues and Trends

2001



Australian Bureau of Statistics

New Issue

Australia's Environment: Issues and Trends

2001

Dennis Trewin
Australian Statistician

AUSTRALIAN BUREAU OF STATISTICS

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INQUIRIES

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CONTENTS

LAND USE AND SELECTED ENVIRONMENTAL IMPACTS *continued*

ENERGY AND ATMOSPHERIC POLLUTION

ADDITIONAL INFORMATION

LIST OF TABLES AND GRAPHICS

POPULATION: ENVIRONMENTAL IMPACTS AND RESPONSES

LAND USE AND SELECTED ENVIRONMENTAL IMPACTS

PRESSURES ON THE MARINE ENVIRONMENT

ENERGY AND ATMOSPHERIC POLLUTION

PREFACE

This is the first edition of *Australia's Environment: Issues and Trends*. The publication is intended for a general audience and explores some of the relationships between Australia's society, economy and environment. Similar publications produced by the ABS in the past have sought to provide a comprehensive view of Australia's environment but this is not the intent of this publication.

Instead *Australia's Environment: Issues and Trends* will be dynamic, examining a selection of topical issues each year. It will integrate ABS data and external data to present current environmental information in an easy to understand format. This publication does not provide technical or methodological information nor does it use the pressure-state-response model as is the case with the State of the Environment report.

The production of this publication would not have been possible without the contributions of numerous organisations and individuals. The ABS is grateful for this help and looks forward to continuing and expanding this important network.

We hope to improve on the first edition of this publication. Suggestions and comments on this publication are welcome, including topics that might be covered in future editions, and should be sent to the following addresses.

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INTRODUCTION

Australia's Environment: Issues and Trends is the fifth general publication about Australia's environment produced by the Australian Bureau of Statistics. It differs from these other environmental publications in that it covers a selection of issues only. Enhanced understanding of environmental issues within the wider community is its ultimate goal. With this in mind, technical information has been kept to a minimum, although referencing will allow such material to be found by readers desiring this level of detail. A glossary of the technical terms is also provided.

Chapter 1 of *Australia's Environment: Issues and Trends* begins by presenting a brief summary of the main demographic trends that shape Australia's population, along with discussion of the links between the environment and population. The second part of the chapter provides examples of our responses as a nation to environmental problems.

Chapter 2 discusses issues concerned with land use, chapter 3, the use of Australia's water resources, and chapter 4, pressures on the marine environment. Each chapter briefly outlines selected environmental issues and examines some of the major issues in detail.

Chapter 5 begins by examining Australia's patterns of energy consumption. Other major issues discussed in this chapter include air pollution, greenhouse gas emissions and global warming.

Future editions of *Australia's Environment: Issues and Trends* will cover new issues and the ABS will continue to develop the issues based approach used here. This is intended to provide the Australian public with an environmental publication that is flexible and responsive to user needs and the emerging discipline of sustainable development.

CHAPTER 1 POPULATION: ENVIRONMENTAL IMPACTS AND RESPONSES

INTRODUCTION

In 1998 the world's population was around 5.9 billion with Australia's population representing around 0.3% of this total (World Resources Institute et al. 2000). The global population is projected to increase to 9.4 billion by 2050, an increase which will exert pressure on ecosystems in many parts of the world (Boyden and Dovers 1997). The effects of human populations on the natural environment, however, are not just a function of increasing numbers, as new technology and consumption patterns influence ecological impacts. For instance, relatively wealthy industrial countries represent about 25% of the world's population, but use over 80% of natural resources consumed and produce 75% of municipal and industrial waste (Simpson et al. 2000).

Population growth in Australia has been accompanied by an increase in production and the use of resources. Moreover, the Australian economy has become progressively more reliant on energy: in 1998 total energy products used in Australia or exported were 2.8 times the level used or exported in 1978, while population size increased 1.3 times in the same period (ABARE unpublished data in ABS 2001).

Technology has been instrumental in the ability to remove natural resources at a greater rate for production and consumption, but it also plays a role in mitigating environmental impacts. However, declines in the quality of Australia's environment (SoE 1996) suggest that technology to date has not countered all of the effects of a resource intensive economy.

Increasing awareness of the need to protect our environment has seen the formulation and implementation of international treaties, and policies at the Commonwealth, State and local government level. Ecologically Sustainable Development (ESD) is central to environmental policy in Australia, and is defined as: 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development 1987). In keeping with this, the aims of Australia's international environmental policies are to 'protect the national interest while promoting environmental and sustainable development, to seek to improve the standard of living and provide aid to developing countries' (OECD 1998).

Responses to environmental problems have been made by the three levels of Australian government and are broad and multifaceted. Key areas of environmental management include: the impacts of land use and in particular, agriculture; the sustainable use of natural resources and materials; minimising waste and pollution; protecting and conserving biodiversity and ecosystem health; and integrating social, economic and ecological goals based on the principles of ESD. To some extent, and with varying levels of effectiveness, all these broad areas are influenced by government policy and related statutory frameworks. In the case of individuals, survey data about household behaviour and attitudes provide some insight into the nature of individual responses to environmental issues.

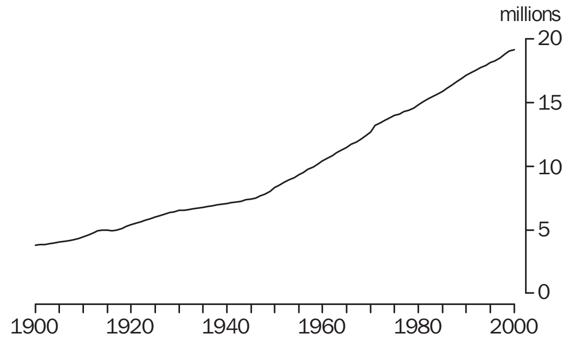
POPULATION AND THE ENVIRONMENT

Population size and growth

The estimated resident population of Australia in June 2000 was just over 19 million. There is no accurate measure of the population in 1788: a recent estimate of the Indigenous population was 750,000 but other estimates have ranged from 300,000 to 1,000,000. The Indigenous population today is estimated to be 400,000.

The factors determining the growth of populations are the rates of birth, death, immigration and emigration. The difference between the number of children who are born and the number of people who die in a year is termed 'natural increase'. The difference between the number of settlers and long-term overseas arrivals and the number of permanent and long-term departures of Australian residents is termed 'net migration'. Governments may influence population growth by affecting the rate of natural increase and net migration through policy and legislation.

1.1 AUSTRALIA'S POPULATION—1900 to 2000



Source: ABS 1997; ABS 1999a.

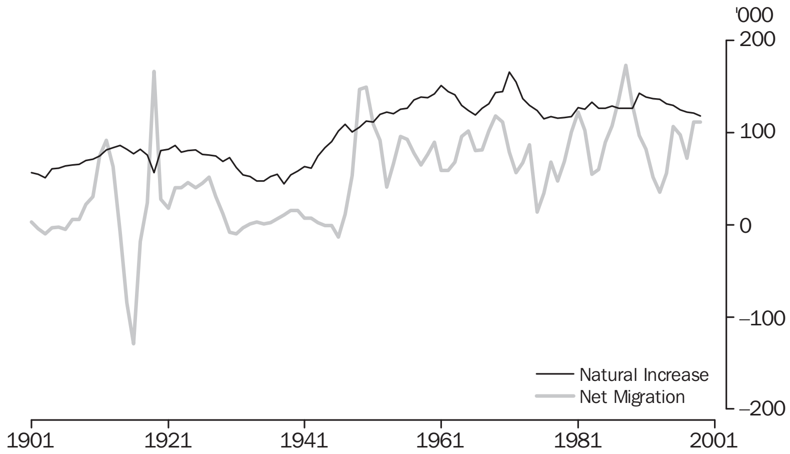
Components of population growth

Graph 1.1 shows Australia's population between 1900 and 2000. Natural increase has been the main source of Australian population growth over the past century (graph 1.2). Only for short periods around 1911–12, after each of the two World Wars and again in 1987–89 did net migration exceed natural increase. Net migration varied considerably from year to year, depending on government decisions or global circumstances.

The rates of growth have been variable, but the rise between the population in 1900, of around 3.8 million, and 2000 represents an annual growth rate of about 1.7%. Australia's population growth rate was high in the years following World War II, reaching a peak of 3.3% in 1950. This growth resulted from the large post-war migrant intake and the 'baby boom' (children born between 1946 and the mid 1960s). The baby boom peaked in 1961 when the average number of births per woman was 3.6 (ABS 1998a). The number of births per woman had fallen to 1.8 by 1998, while the population growth rate in 2000 was around 1.3% (which was, coincidentally, the world average for that year). In 2000 over half of the growth (52%) was due to natural increase. Currently there are about twice as many births as deaths in Australia each year.

Components of population growth *continued*

1.2 NATURAL INCREASE AND NET MIGRATION, Australia—1901 to 1999



Source: Hugo 2001 in ABS 2001.

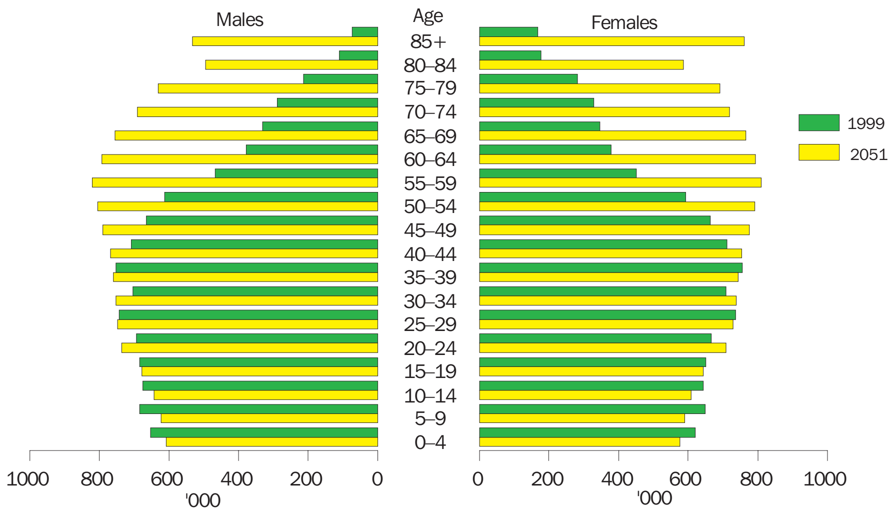
Future population size

The age and sex of a population affect its current and future growth rates. Therefore the composition of Australia's population is of interest to planners and decision makers. The population pyramid in graph 1.3 displays the age and sex composition of the Australian population for 1999 and the projected composition of the population in 2051. The bulge in the middle of the 1999 pyramid reflects the baby boom. The shift to an older population between 1999 and 2051 is pronounced, and is reflected in the dramatic increase in the proportion of the population aged 65 or older. In 1999, 12% of the population were aged 65 years or older, but this is projected to increase to 26% by 2051. The environmental implications of changes in the age and sex characteristics of a population are not well known. Changes related to an ageing population, such as increased consumption in leisure activities, less intensive use of housing in some areas (Kendig and Neutze 1999), increased social expenditure by the public sector (Johnson 1999) and high concentrations of older people living in coastal retirement towns (McDonald and Kippen 1999), may have direct or indirect environmental effects.

The ABS has published three population projections for Australia to the year 2101 (graph 1.4). Australia's population is projected to grow to between 24.1 million and 28.2 million by the year 2051 and to reach between 22.6 and 31.9 million by 2101. Australia's agricultural production in the nineties was enough to provide food and fibre for around 55 million people (see Chapter 2). These projections suggest that some of the agricultural production currently exported may be needed for domestic use in the future, assuming that levels of agricultural production remain largely unchanged.

Future population size *continued*

1.3 AGE STRUCTURE OF AUSTRALIA'S POPULATION—1999 and 2051(a)

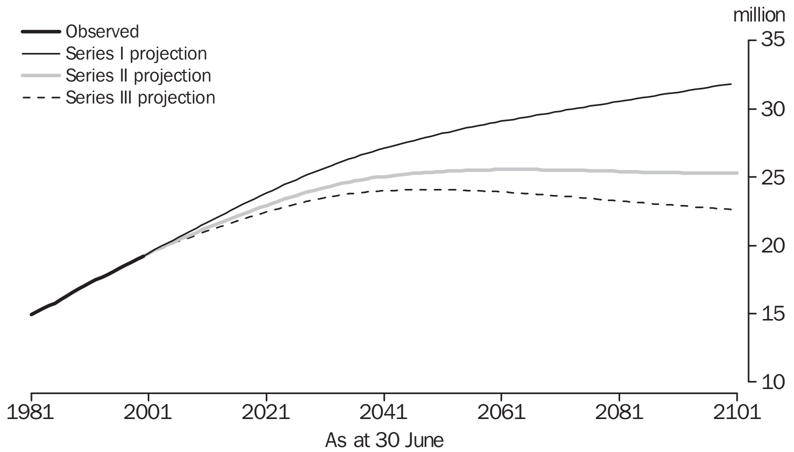


(a) Based on series II projections—low fertility and medium net overseas migration.

Source: *ABS 1999b*.

There is debate about how large a population Australia's environment can support. The four main environmental arguments which have been advanced for stabilising Australia's population are: the limited amount of land suitable for agriculture; our climate patterns and in particular the limited amount of rainfall; the severe nature and extent of Australia's current environmental problems; and that Australia should make a contribution toward the globally agreed goal of stabilising the world's population (Yencken and Wilkinson 2000). There are divergent views on the validity of these arguments and the debate concerning population policy in Australia is ongoing.

1.4 OBSERVED AND PROJECTED POPULATION, Australia



Source: ABS 1999b.

Distribution of Australia's population

Human settlements typically do not conform to natural boundaries in terms of the area that is required to support them, and they acquire resources from other regions and nations through trade. Concentrating people in an area has localised effects on the environment, for example, air pollution in cities. Therefore, the distribution of Australia's population has important environmental implications.

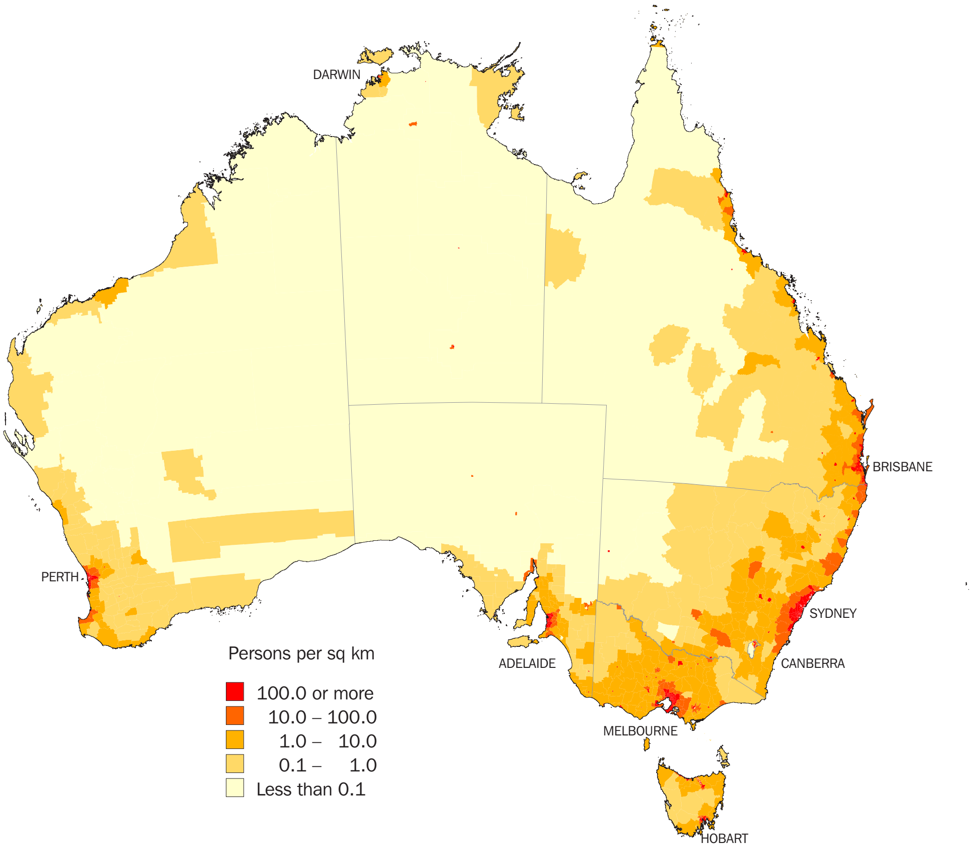
Australia is large in area, but has a relatively small population. For every square kilometre of land there are only 2.5 Australians. This statistic hides the facts that the urban areas where people live comprise 0.1% of the continent (Barson et al. 2000) and that the population is overwhelmingly concentrated around the coastal fringes: about 83% of the population live within 50 kilometres of the coast (ABS 1996a, see also map 1.5). In 1996 around 63% of Australians lived in major urban centres (those with more than 100,000 residents). A further 19% lived in smaller urban centres (those between 3,000 and 100,000 residents).

The distribution of the Australian population changed over the course of the twentieth century. One of the changes has been the decline in the number of people living in rural areas (towns or settlements smaller than 1,000 people). Much of the decline took place before the 1970s. Since the beginning of the 1970s the number of people in rural areas has been around 14%. Recent trends (1991–1996) have shown that more people are living in coastal areas, particularly on the eastern seaboard (map 1.6).

The concentration of the population in a few areas, and particularly the growth in population in coastal areas of south-east Australia, has been marked. Historically, development along Australia's coastline has been poorly managed (Yencken and Wilkinson 2000). Concentrating our population in these areas is likely to exacerbate many of the exisiting problems, unless there are major improvements to the management of environmental impacts in the coastal zone. Direct adverse changes occur when native vegetation is removed for urban development. Ongoing impacts are associated with the need to provide water, sewerage, and landfill sites. Increased levels of ongoing pollution will also result from the existence of housing and industry in these areas.

Distribution of Australia's population *continued*

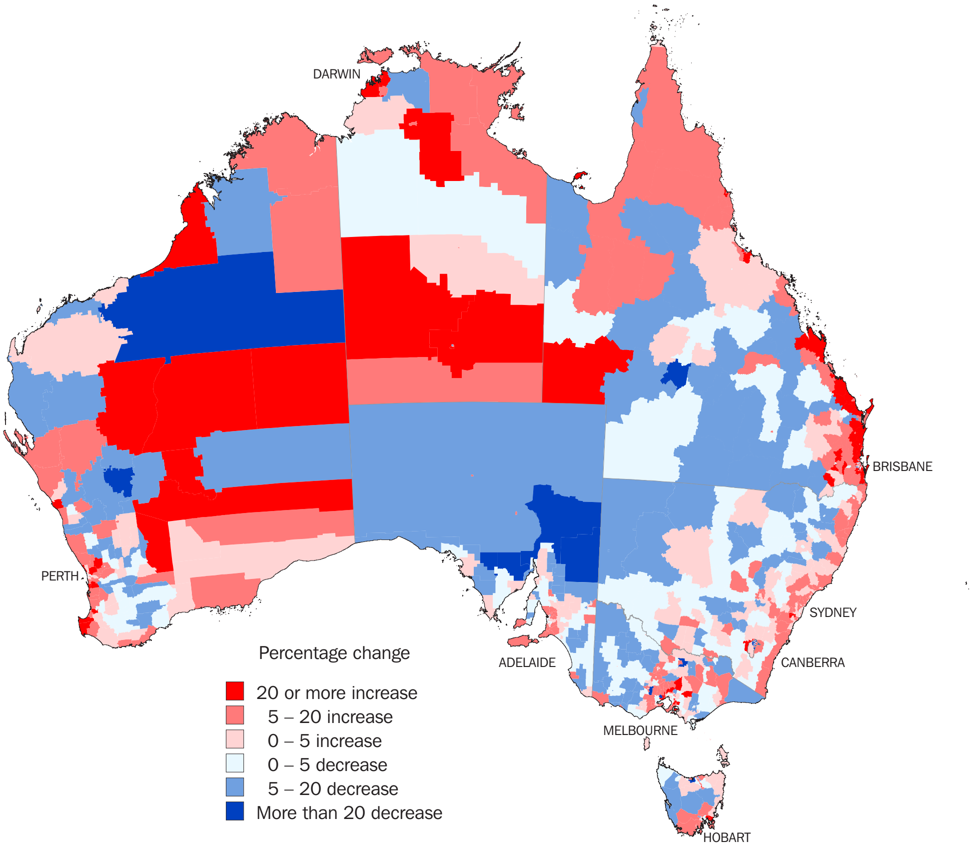
1.5 POPULATION DENSITY—1996



Source: Australian Census of 1996 based on Statistical Local Areas, 1996 edition.

Distribution of Australia's population *continued*

1.6 CHANGE IN POPULATION DISTRIBUTION—1991–96

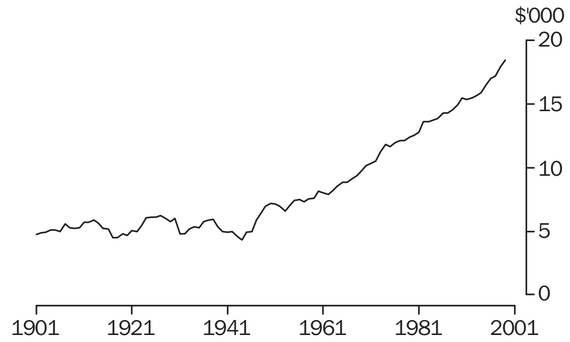


Source: ABS 2001.

CONSUMPTION AND GDP

The growth of the Australian population has been accompanied and outpaced by the growth of the economy and household consumption. It is clear that each person existing today uses more than was the case in the past (graph 1.7). Per capita consumption levels in Australia are among the world's highest (Deni Greene Consulting Services et al. 1995).

1.7 HOUSEHOLD CONSUMPTION(a), Per Capita—1901 to 2001



(a) Measured in 1997–98 prices.

Source: Saunders 2001 in ABS 2001.

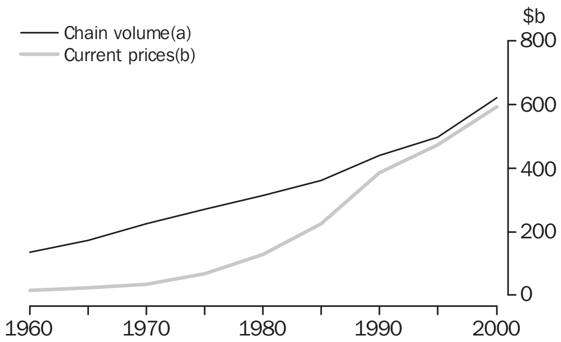
Over the period 1901 and 2001 the growth of GDP (at current prices) averaged 7.4% per annum, more than four times the rate of population growth. Much of this growth is due to inflationary effects. GDP per capita in nominal terms rose from around $110 to $31,226, representing a growth rate of 5.8% per annum. Most of this growth took place in the last four decades, for which two measures of GDP growth are available: current price and chain volume (graph 1.8). In terms of both measures growth has been substantial, but the rate of growth of chain volume estimates is more evenly spread. Chain volume estimates are preferred over current price estimates as they account for the effects of relative price changes, but the series only extends back to 1960.

The growth of the economy has not been evenly distributed through industry sectors. In general primary production (mainly mining, forestry and agriculture, see Chapter 2) has become relatively less important than the manufacturing and services sectors of the economy. It is, however, important to note that even though the relative economic importance of sectors has changed, both the volume and value of primary production have increased.

The impacts of the Australian economy are not limited to the Australian environment. Imported goods consumed by Australians use resources and create wastes in the overseas nations where they are produced. Conversely the Australian environment accumulates impacts from goods that are produced for export.

CONSUMPTION AND GDP *continued*

1.8 GDP GROWTH, Chain Volume and Current Prices—1960 to 2000



(a) Reference year is 1997–98.

(b) Dollar values are the actual values for each year, unadjusted for the effects of inflation.

Source: ABS 2001.

GDP and consumption growth have environmental impacts. More resources are used and greater amounts of waste are generated. For example, in the mid 1990s Australia was the second largest producer of solid waste per capita among OECD countries (SoE 1996), and in 1996–97, 21.2 million tonnes of solid waste were disposed of at landfill (ABS 1998b).

ECOLOGICAL FOOTPRINTS

Australian settlements consume relatively large amounts of energy, water, land and building materials and produce relatively large volumes of waste, when considered on a per capita basis and compared to other nations (SoE 1996).

An evolving method, developed mainly in Canada, of comparing the combined environmental effects of extracting natural resources and disposing of waste is by estimating the relative size of the 'ecological footprint' of different populations.

An ecological footprint is an estimate of the area a population uses to produce the natural resources it consumes and to assimilate the waste it generates. This method assesses per capita material and energy requirements of a region or nation and expresses them as an area of land. The larger the ecological footprint the more demanding that population is per person on natural resources and on the capacity of the environment to cope with waste products. It is also possible to derive estimates of the 'carrying capacity' of the global environment expressed in the same terms as an ecological footprint (i.e. hectares per person).

ECOLOGICAL FOOTPRINTS *continued*

Carrying capacity in this sense is defined as the level of resource consumption and waste discharge that can be maintained indefinitely by a population without seriously impairing the ecological integrity and productivity of natural systems (Simpson et al. 2000). This allows comparison of a nation's ecological footprint with a theoretical ecological limit, based around the concept of sustainable development (i.e. development which maintains biodiversity and essential ecosystem functions indefinitely). An important use of ecological footprint analysis is educational, as this method highlights the concept of ecological limits to consumption and production (Yencken and Wilson 2000).

Criticism of ecological footprints arise from the way the model is constructed and the data that are included in the calculation: the size of the footprint is largely based on converting fossil fuel consumption into an estimate of the land area required to assimilate carbon dioxide emissions (Simpson et al. 2000). This approach conceals a great deal of the complexity involved when considering the effects of economic activity on the environment.

As table 1.9 shows, Australia has a large ecological footprint relative to other nations, indicating high levels of consumption. Key problems caused by high levels of consumption in Australia include: land and water degradation; loss of biodiversity; and rising greenhouse gas emissions. In the context of ESD, the rates of resource use and waste production by relatively affluent nations represent a disproportionally high level of pressure on the environment (Boyden and Dovers 1997). This has led a number of commentators to call for reductions in the scale of resource use by developed nations, in order to 'make room' for poorer nations and the needs of people in the future (Yencken and Wilkinson 2000).

1.9 COMPARISON OF ECOLOGICAL FOOTPRINTS

	Ecological footprint without sea products	*Ecological footprint with sea products*
Nation	*Hectares per capita*	*Hectares per capita*
	Top five consuming nations of the world	
Iceland	4.2	10.1
New Zealand	8.6	9.8
United States	7.4	8.4
Australia	7.4	8.1
Canada	6.0	7.0
	Bottom five consuming nations of the world	
Egypt	0.8	1.2
Ethiopia	1.0	1.0
Pakistan	0.8	0.8
India	0.7	0.8
Bangladesh	0.4	0.7
World average	**1.8**	**2.3**

Source: Wackernagel et al. 1997 in Simpson et al. 2000.

RESPONSES TO ENVIRONMENTAL PROBLEMS

Responses to environmental concerns are evident at many levels. As individuals, Australians have changed their attitudes and behaviours in relation to the environment, while governments have enacted legislation and implemented policies to protect it. This section examines a selection of responses to environmental problems. It begins with governmental responses, then discusses collective and individual responses.

National and international

All levels of government in Australia have responded to the impacts of people on the environment. Many environmental problems are not contained within country borders, making it necessary for the Australian government to work closely with other governments around the world. Environmental issues having global responses include greenhouse gas emissions and associated climate change, impacts on migratory bird species and depletion of the ozone layer. Australia is signatory to 56 multilateral treaties related to the environment, including the following:

- Convention on International Trade in Endangered Species of Wild Fauna and Flora (1 July 1975);
- Convention on Wetlands of International Importance (21 December 1975);
- Convention for the Protection of the World Cultural and Natural Heritage (17 December 1975);
- Convention on Biological Diversity (29 December 1993); and
- Framework Convention on Climate Control (21 March 1994).

These agreements have implications for the policies and laws that are implemented within Australia.

Commonwealth government departments administer legislation and develop policies and strategies which address different aspects of environmental impact. Table 1.10 shows selected legislation that has been passed through parliament since 1974 in response to increased awareness and concern about the impact of people on the environment. Several of these Acts are discussed below. Others are discussed in later chapters. A longer list of legislation is presented and discussed in *Australians and the Environment 1996* (Cat. no. 4601.0).

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the most recent significant change to legislation. This Act replaced five previous Acts (table 1.10). In December 2000, the Commonwealth and Tasmania signed the first bilateral agreement under the EPBC Act. Under this agreement, the Commonwealth has accredited two Tasmanian environmental assessment processes. Projects in Tasmania that require Commonwealth approval under the EPBC Act can now be assessed using these processes.

The Intergovernmental Agreement on the Environment, published in 1992, seeks to coordinate approaches between the three tiers of government by defining the roles of each level of government, reducing intergovernmental disputes and providing both certainty in government and business decision making and better protection of the environment.

National and international *continued*

1.10 SELECTED COMMONWEALTH ENVIRONMENTAL LEGISLATION

Year	*Legislation(a)*
1974	Environment Protection (Impact of Proposals) Act*
1975	Great Barrier Reef Marine Park Act
1975	Captains Flat (Abatement of Pollution) Agreement Act
1975	National Parks and Wildlife Conservation Act*
1975	Australian Heritage Commission Act
1980	Whale Protection Act*
1981	Environment Protection (Sea Dumping) Act
1982	Wildlife Protection (Regulation of Exports and Imports) Act
1983	World Heritage Properties Conservation Act*
1984	Aboriginal and Torres Strait Islander Heritage Protection Act
1989	Ozone Protection Act
1989	Hazardous Waste (Regulation of Exports and Imports) Act
1992	Endangered Species Protection Act*
1994	National Environment Protection Council Act
1994	Wet Tropics of Queensland World Heritage Area Conservation Act
1997	Natural Heritage Trust of Australia Act
1999	Environment Protection and Biodiversity Conservation Act(a)
2000	Product Stewardship (Oil) Act

(a) The *Environment Protection and Biodiversity Conservation Act 1999* replaced the five previous Acts marked with asterisks.

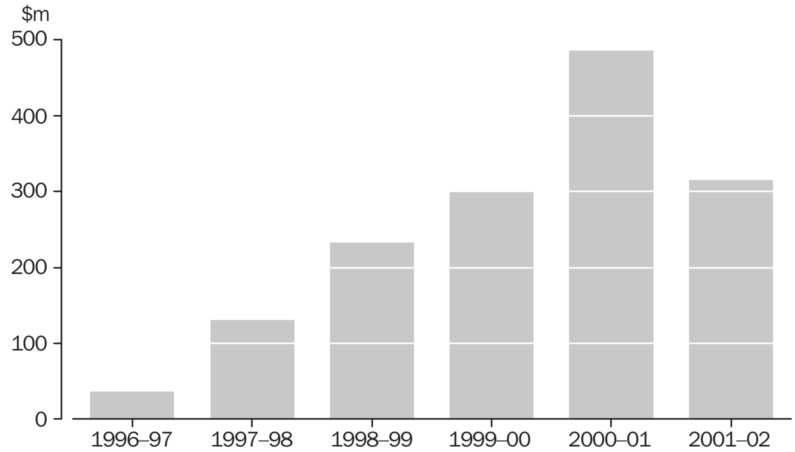
Source: Environment Australia.

Several Commonwealth Government agencies have responsibility for environmental protection and management. These include Environment Australia and the Department of Agriculture, Forestry, Fisheries–Australia (AFFA). Other government bodies, such as the National Greenhouse Office and the Bureau of Rural Sciences, are responsible for responding to more specific environmental issues.

The Natural Heritage Trust (NHT) was set up under the *Natural Heritage Trust of Australia Act 1997* initially using money from the part-sale of Telstra. It allocates funding to community groups for environmental repair and rehabilitation projects under five key environmental themes: land, rivers, coast and marine, vegetation and biodiversity. Graph 1.11 shows the distribution of the total $1.5b over six years. Some of the achievements of the NHT Programs have been 620,000 hectares of native vegetation works, 11,500 km of protective fencing and 485,000 hectares of works that protect/enhance threatened species. Table 1.12 shows the breakdown of funding between the various programs.

National and international *continued*

1.11 NATURAL HERITAGE TRUST FUNDING—1996–97 TO 2001–02(a)



(a) 1996–97 to 1999–00 figures are actual funding; 2000–01 and 2001–02 figures are estimates.

Source: NHT 2001.

1.12 NATURAL HERITAGE TRUST FUNDING

Program	*1999–00 (actual)* $m	*2000–01 (estimate)* $m	*Total 1996–97 to 2001–02* $m
Air Pollution in Major Cities	2.9	6.3	18.5
Bushcare	81.6	104.8	346.5
Coasts and clean seas	28.1	35.4	116.8
Endangered Species Program	5.8	5.6	27.8
Farm Forestry Program	11.9	16.8	47.2
Farm Business Improvement Program: Farmbis	5.6	6.0	15.0
Fisheries Action Program	3.2	3.8	13.0
Murray Darling 2001 Program	43.0	53.8	195.6
National Feral Animal Control Program	2.0	6.1	18.9
National Land and Water Resources Audit	9.8	13.7	44.4
National Landcare Program (including Landcare Tax Measures)	49.2	109.4	326.5
National Reserve System Program	11.4	38.2	84.2
National River Health Program	2.6	7.6	15.8
National Rivercare Program	19.1	28.8	82.9
National Weeds Program	0.9	17.8	28.5
National Wetlands Program	3.8	5.8	17.1
Oceans Policy	1.5	10.0	20.0
Riverworks Tasmania	4.2	—	8.8
Waste Management Awareness Program	1.0	2.4	6.0
Waterwatch	3.1	2.9	13.0
World Heritage Area Management and Upkeep	8.6	9.7	52.5
Total	**299.4**	**485.0**	**1 499.0**

Source: NHT 2001.

State/Territory Governments

The State/Territory Governments in Australia have the power to make decisions regarding land and natural resource management, and play a significant role in environmental protection and management. Environmental legislation and policies are broadly similar in each State and Territory, although a significant proportion is specific or 'one-off'. The amount of legislation in each jurisdiction is substantial. For example, around 80 Acts are administered by the Department of Land and Water Conservation in NSW.

The main State/Territory agencies responsible for environment protection and management are outlined in table 1.13. There are many others that have responsibility for particular environmental issues such as urban affairs, agriculture, energy, national parks and wildlife. Further information can also be found on the website for each State Government.

1.13 SELECTED ENVIRONMENTAL AGENCIES, States and Territories

State/Territory	*Government agency*	*Website*	*Expenditure 1999–00*
			$000
NSW	Department of Land and Water Conservation	www.dlwc.nsw.gov.au	518 540
	Environment Protection Authority	www.epa.nsw.gov.au	83 720
Vic.	Department of Natural Resources and Environment	www.nre.vic.gov.au	850 463
	Environment Protection Authority	www.epa.vic.gov.au	31 360
Qld	Environment Protection Agency	www.env.qld.gov.au	223 981
WA	Department of Conservation and Land Management	www.calm.wa.gov.au	218 254
	Department of Environmental Protection	www.environ.wa.gov.au	35 219
SA	Department for Environment and Heritage	www.environment.sa.gov.au	180 131
Tas.	Department of Primary Industries, Water and Environment	www.dpiwe.gov.au	132 588
NT	Department of Lands, Planning and Environment	www.lpe.nt.gov.au	50 740
	Parks and Wildlife Commision	www.nt.gov.au/paw	38 600
ACT	Department of Environment and Heritage	www.act.gov.au/environ	22 550

Source: Various websites listed in table including annual reports; listed government agencies (pers. comm).

The general government sector financed $2.6b of environmental protection expenditure in 1996–97 (ABS 1999c). State expenditure represented approximately 50% of general government expenditure. This data does not include environmental management and relates only to environmental protection. Environmental protection expenditure data has not been collected since 1996–97.

Local government

There are approximately 630 local councils in Australia. They play an important role in representing the community and implementing national policies at a local level. More specifically, they are responsible for waste management, natural resource management, improvement of the built environment, incorporation of environmental and heritage concerns and adoption of Agenda 21 and sustainable development principles.

An ABS survey of local councils found that in 1998–99 environment-related activities accounted for 18% ($2.8b) of revenue and 20% ($2.7b) of expenditure (ABS 2000a). These figures can be broken down by Environment Protection and Natural Resource Management (table 1.14).

Based on the UN Classification of Environmental Protection Activities, environment protection includes all activities aimed at the prevention, reduction or elimination of pollution or any other degradation of the environment. For example, waste management and protection of biodiversity, landscape, air and climate are included in this category. Environment protection expenditure was primarily for solid waste ($881m) and waste water management ($965m).

Natural resource management consists of activities which manage and make more efficient use of natural resources, such as management and supply of water, land management and development, and other resource management (such as quarrying to provide raw materials for council works). The largest expenditure on natural resource management was on land management activities ($704m).

1.14 ENVIRONMENTAL REVENUE AND EXPENDITURE, By Account—1998–99

	Environment protection	*Natural resources*	*Total*
Transaction	$m	$m	$m
Revenue	1 813	967	2 780
Expenditure	2 126	1 331	3 457

Source: ABS 2000a.

Non-government organisations

Australia has many non-government organisations that are concerned about a wide range of environmental issues. They range from large, well-established organisations which attempt to influence government policy across Australia to small groups aimed at protecting specific areas or species. Over 50 of the larger national non-government environmental organisations are listed in Stirling (2000).

Industry

Industry sectors have worked towards reducing the environmental impacts of production through the use of cleaner and more environmentally friendly technologies. Two factors which contribute to industry improving environmental performance include regulations governing pollution and waste and economic benefits from increased efficiency. Surveys of environmental protection expenditure measure the response of the various sectors to environment protection regulations and policies (table 1.15). It is important to note that environment protection expenditure is limited in scope to spending for which environment protection is the primary purpose of the expenditure. This means that not all expenditure that benefits the environment is included in these figures. Management of solid waste is the area on which industry spends the most to protect the environment.

Industry associations have also responded to environmental issues. For example, the Minerals Council of Australia has developed an Environmental Code of Conduct (see Chapter 2).

1.15 ENVIRONMENT PROTECTION EXPENDITURE, By Industry—1996–97

	Turnover	*Expenditure*	*% of Turnover*
	$m	$m	%
Mining	34 101.0	368.8	1.07
Agriculture	27 122.3	191.7	0.71
Utilities	23 976.0	170.8	0.71
Manufacturing	208 348.0	896.3	0.43
Service Industries	677 053.8	1 019.9	0.15

Source: ABS 2001; ABS 1999c.

Individuals

In 1999 around 9% of adult Australians ranked environmental problems as the most important social issue (table 1.16), but 69% of people reported having environmental concerns. The proportion of people expressing concern for the environment has declined slowly since 1992 (graph 1.17). Concern for the environment varies with the age of the respondent (ABS 1999d). People aged over 55 were more likely to nominate health as the most important social issue. Income and education were also important in explaining levels of concern for the environment (graphs 1.18 and 1.19). Income and levels of education are not independent of each other: people with more education generally earn more income (ABS 1996c).

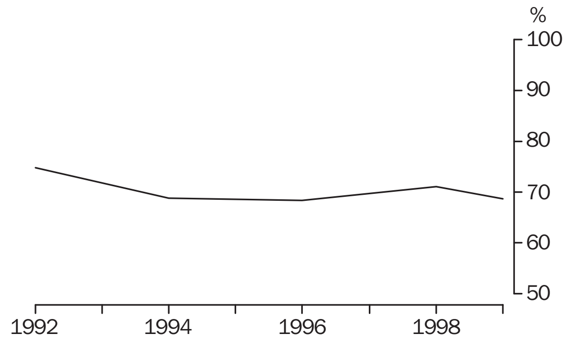
Individuals *continued*

1.16 MOST IMPORTANT SOCIAL ISSUES, Adult Australians

	1998	*1999*
	%	%
Health	28.8	29.7
Crime	23.8	25.5
Education	16.4	16.6
Unemployment	16.4	13.3
Environmental problems	8.6	9.0
Interest rates	3.2	3.1
Can't decide/don't know	2.8	2.8

Source: ABS 1999d.

1.17 CONCERNS FOR ENVIRONMENTAL PROBLEMS, Australia(a)



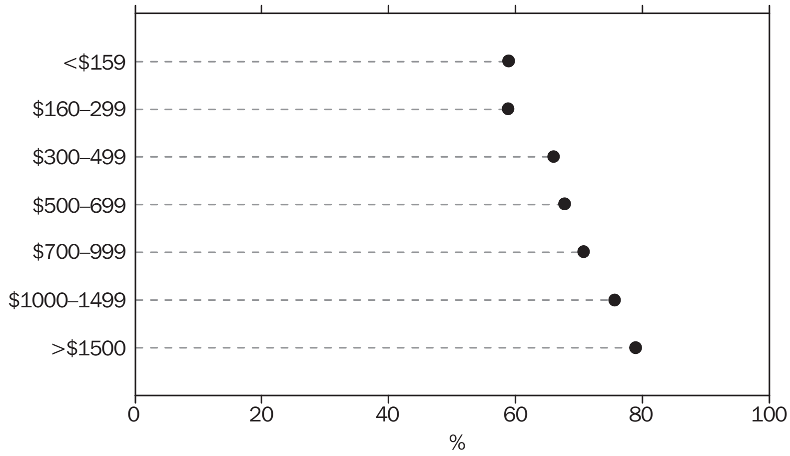
(a) Households were surveyed in 1992, 1994, 1996, 1998 and 1999.

Source: ABS 1999d.

In 1996, while a majority of Australians reported being concerned about environmental problems, concern increased slightly with income (graph 1.20). Supporters of traditional economic growth sometimes argue that rising incomes, resulting from a growing economy, provide the will and resources to protect and improve environmental quality.

Individuals *continued*

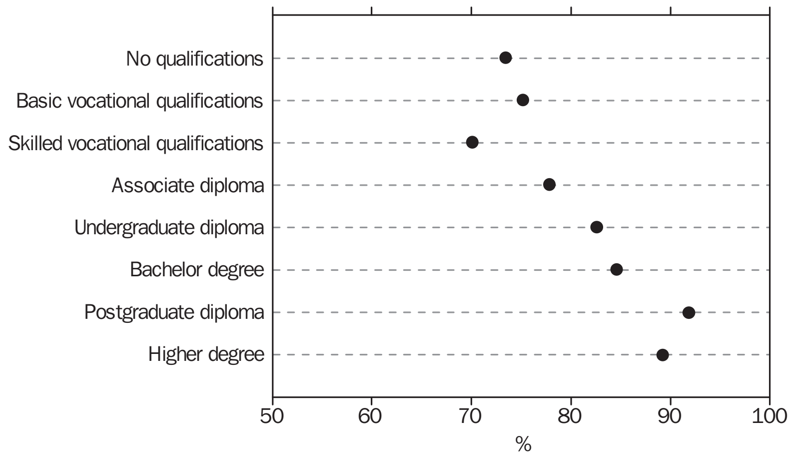
1.18 CONCERNS FOR ENVIRONMENTAL PROBLEMS, By Weekly Income(a)—1996



(a) Gross (before tax) household income.

Source: ABS 1996d.

1.19 CONCERN FOR ENVIRONMENTAL PROBLEMS, By Education Level—1996



Source: ABS 1996d.

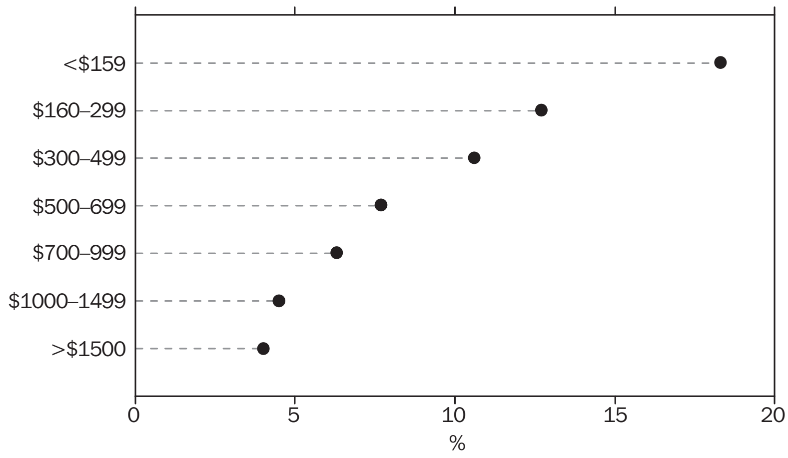
People's behaviours in relation to the environment have changed over time. Recycling and the use of motor vehicles and public transport are two examples of this. In April 1996 about 85% of people travelled to work/study by car. In March 2000 this level had fallen slightly to around 81% (most travel was as a driver but it also included passengers). In 2000 about 12% used public transport as their main form of transport to work or study. The main reason for using public transport was not owning a car, and only 2% of respondents used public transport for environmental reasons.

Individuals *continued*

Household recycling has increased in Australia during the nineties: in 1992 around 85% of people recycled; in 2000 this had risen to about 97% (ABS 2000e). Paper, glass and old clothing were the most recycled items.

Income was a factor in household recycling rates (graph 1.20). Households with lower gross weekly incomes were less likely to recycle. Reasons given for not recycling were: insufficient recyclable materials accumulated (51%); the lack of availability, adequacy or knowledge of recycling services and facilities (35%); a lack of storage area (9%). A large percentage of people (24%) did not specify a reason.

1.20 HOUSEHOLDS NOT RECYCLING, By Income(a)—1996



(a) Gross (before tax) household income.

Source: ABS 1996b.

While recycling rates have improved, more waste still goes to landfill than is recycled. An audit by the Beverage Industry Environment Council in 1997 found that the average Australian household produces 15.7 kg of waste for collection each week (ABS 2001). This consisted of 11.9 kg of garbage, 3.1kg recyclables, 0.2 kg of contaminants and 0.5 kg of green waste. Advances in technology have allowed for more items of waste to be diverted from landfill for recycling.

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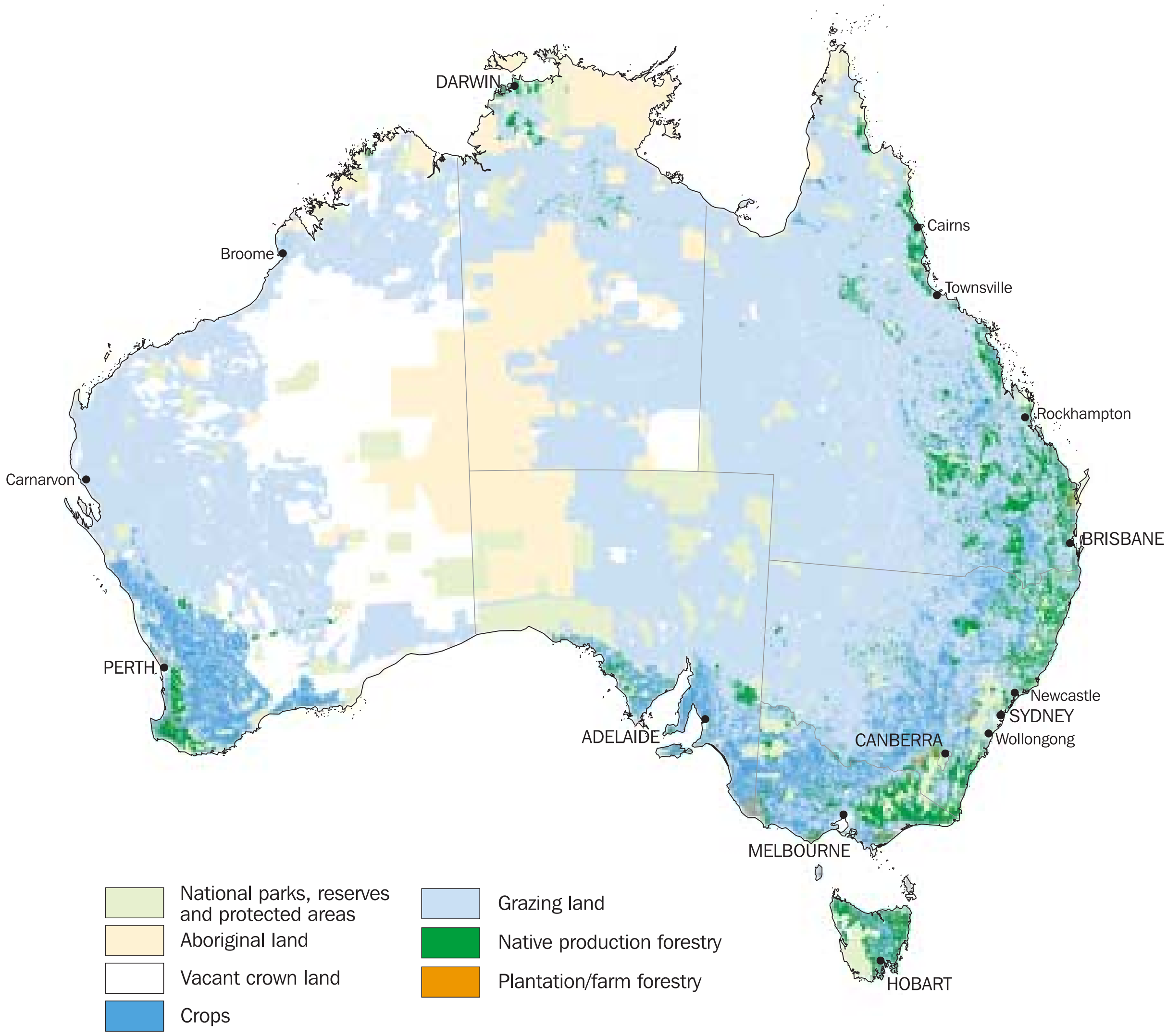
CHAPTER 2 LAND USE AND SELECTED ENVIRONMENTAL IMPACTS

INTRODUCTION

This chapter deals with selected issues concerning Australia's land environment. It describes how the land is used to provide for the physical (agriculture, forestry and mining) and cultural needs of the Australian people, and gives examples of how these uses have changed the environment. Impacts covered include native forest clearing, weeds and dryland salinity. Many other issues have not been covered— acidic soils, vertebrate pests, chemical residues in food, etc.

2.1 LAND USE—2000



Source: NLWRA 2000.

INTRODUCTION *continued*

The chapter deals only with the environment, and changes to it, since European settlement. Many environmental changes occurred before that time. Continental drift, volcanic activity, long-term climatic cycles and asteroid impacts have all caused changes in the composition of the Earth's and Australia's flora and fauna (Archer et al. 1998). The arrival of Aboriginal peoples, at least 40,000 years ago, altered the environment through fires, hunting and gathering (Kirkpatrick 1994). For example, since 1788 around 38% of the area of native forest has been cleared, mostly to make way for agriculture.

Land use

A map of land use in Australia has recently been completed by the National Land and Water Resource Audit (map 2.1). Agriculture is the major land use in Australia, and has changed the environment in many ways. A selection of these environmental changes is discussed in this chapter, including land clearing, weed invasion, salinity and other forms of soil degradation.

Forestry and mining each use less than 1% of Australia's land area. However, the environmental impacts and risks from these activities are significant. For example, flooding of tailings dams from mining can poison whole river systems (e.g. the cyanide poisoning which affected the Danube in Hungary), while logging in native forests has changed the structure and species composition of these ecosystems. There are also concerns about long term resource depletion of forest and mineral reserves. The impacts of forestry and mining and the size of the current resource base for these activities are discussed later in the chapter.

Urban areas use a little more than 0.1% of Australia's land (Barson et al. 2000). However urban development can have regional effects. For example, future housing development in the Australian Capital Territory is only a tiny fraction of planned land use in Australia, but may entail clearing endangered woodland communities (Landsberg 2000).

One response to threats posed by different land uses in Australia has been for governments to reserve a total of around 6.8% of land for conservation. These areas help to generate wealth from tourism. Information on conservation reserves, tourism and protecting natural and cultural heritage is outlined later in this chapter.

Land tenure

The current range of land uses is the result of complex interactions between social, economic and environmental factors. Ownership of land in Australia is a key factor. There are three main categories of land ownership in Australia: private, public and Aboriginal and Torres Strait Islander. The area and percentage of different tenure types vary across the States and Territories (table 2.2). For example, 90% of the land in Queensland is private land; in the Australian Capital Territory the figure is around 37%.

Nearly 63% of Australian land by area is privately owned. This means that individuals or non-government organisations largely determine what occurs on the majority of land in Australia. Governments can, however, make laws regulating the way private land is used. While private land is used for a variety of purposes, agriculture is the primary use.

2.2 LAND TENURE—1993(a)

	NSW	*Vic.*	*Qld.*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Total*
Tenure type	'000 km^2	'000 km^2	'000 km^2	'000 km^2	'000 km^2	'000 km^2	'000 km^2	'000 km^2	'000 km^2
Private land	714.4	155.3	1 567.0	576.8	1 105.0	27.2	673.0	0.9	4 819.6
Aboriginal and Torres Strait Islander land	1.5	—	42.2	189.6	325.5	—	536.0	—	1 094.8
Public land	85.7	72.3	118.0	217.6	1 095.0	40.6	137.2	1.5	1 767.9
Total	**801.6**	**227.6**	**1 727.2**	**984.0**	**2 525.5**	**67.8**	**1 346.2**	**2.4**	**7 682.3**
BREAKDOWN OF PUBLIC LAND TENURE									
Nature reserve	38.1	30.6	54.2	203.7	155.0	13.5	27.8	1.2	524.1
Aboriginal freehold—National Park	—	-—	—	—-	—	—	10.8	—-	10.8
Vacant crown land	1.4	—	0.6	8.3	863.3	4.3	82.8	—	960.7
Other crown land	6.4	2.0	13.9	0.8	42.7	2.5	12.3	—	80.6
Forestry reserve(b)	34.6	36.4	40.1	1.0	20.9	15.1	—	0.1	148.2
Water reserve	2.8	1.5	0.3	0.2	5.3	0.9	—	—	11.0
Defence land	0.4	0.4	3.8	3.6	6.6	0.3	3.5	—	18.6
Mining reserve	—	0.3	4.3	—	0.4	—-	—	—	5.0
Mixed category lands	2.0	1.1	0.8	—	0.8	4.0	—	0.2	8.9

(a) This is the latest national information available from AUSLIG. Some changes have occurred since, particularly in the composition of public land tenures.

(b) The area available for timber production is about half of this as some areas cannot be harvested for practical reasons. See NFI 1998.

Source: AUSLIG 1993.

AGRICULTURE

Agriculture is an important part of Australia's social and economic fabric. Around 60% of the land area of Australia is used for agriculture (table 2.3). This section examines the benefits and impacts of this land use. Benefits include a secure source of food and fibres (wool, cotton, etc.) as well as of income and jobs. In the nineties it was estimated that the food and fibre produced in Australia could provide for 55 million people (ABS 1996).

Extent and value of agriculture

Agricultural production took place on around 453.7 million hectares (table 2.3) and had a total value of around $28.8b for 1998–99 (ABS 2000a). Of the total value of agriculture, crops contributed $16.2b and livestock $12.6b. Agriculture contributed $16.8b (3%) to Gross Domestic Product (GDP) for 1998–99.

Intensive agriculture is concentrated on the coastal fringes of Australia and in the Murray–Darling Basin (map 2.4). In 1996–97 the produce from the Murray–Darling Basin contributed around 43% of the total value of agricultural production. Cropping generates the highest output per hectare in dollar terms, accounting for 56% of the total value of agricultural production in the year to March 1997, while occupying only 4.5% of agricultural land. Inland Australia is used mainly for grazing livestock, such as beef cattle, which produces a lower value of output per hectare than crops.

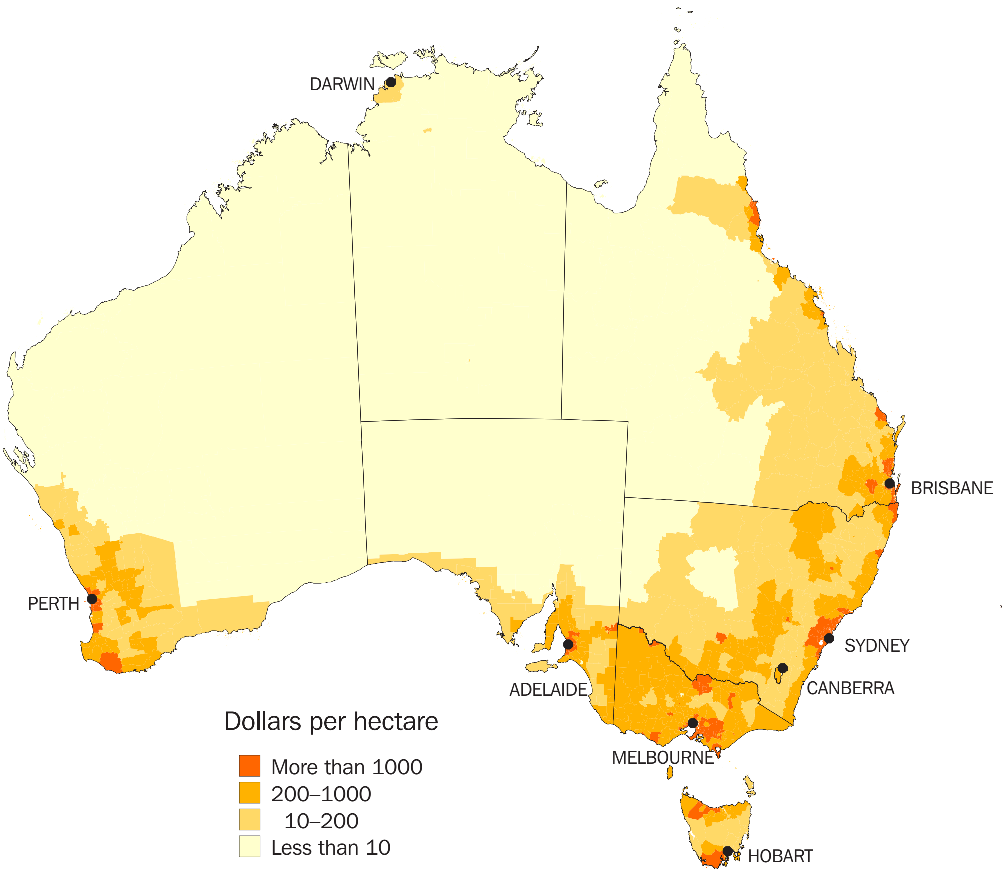
In 1998–99, agriculture employed just over 311,100 people on a little over 145,200 farms (ABS 2000a), with approximately 165,000–190,000 (the actual number changed over the year) people employed in manufacturing food, beverage and tobacco products. Some 66% of farms were less than 500 hectares in size. In the year to March 1999, total turnover was $27.6b of which 49% was from around 11% of farm businesses. Turnover for 50% of farms was less than $141,500, though average turnover was higher at $269,000. The average before tax profit (cash operating surplus) of farms was around $53,900, while the average return on assets was 4%.

2.3 AGRICULTURAL LAND USE—Year ending March 1999

	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Aust.*
Land use	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha
Crops	6 173	2 749	3 014	3 648	7 597	76	7	—	23 264
Pastures and grasses	5 588	4 739	4 004	2 491	4 902	743	41	13	22 523
Agricultural land	59 284	12 790	140 310	59 385	113 099	1 928	66 885	49	453 729
Non-agricultural land	20 780	9 952	32 755	38 963	139 889	4 912	68 028	187	315 474
Total area	**80 064**	**22 742**	**173 065**	**98 348**	**252 988**	**6 840**	**134 913**	**236**	**769 203**

*Source: ABS 2000*a.

2.4 PRODUCTION INTENSITY, Value of Production per Hectare of Agricultural Land—1996–97



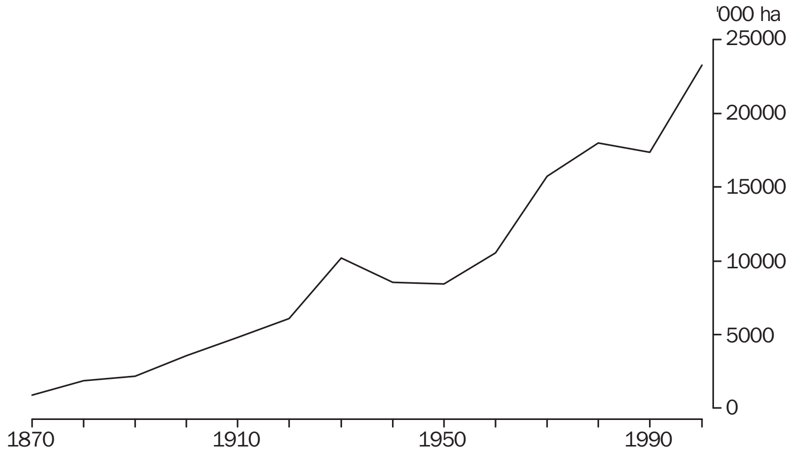
Source: Agricultural Census and Agricultural Finance Survey 1996–97. Map based on ABS Statistical Subdivisions 1996.

Changes in agriculture over time

There has been a steady expansion of agricultural activities for more than a century, with related increases in the use of irrigation, fertiliser and other inputs. For example, the area planted with crops, the agricultural activity of which generates the highest per hectare returns, has more than doubled in the past 50 years (graph 2.5) and the nation's beef cattle herd has grown from just six in 1788 to 8.6 million in 1900, and to 23.8 million in early 1998 (graph 2.6). The beef cattle herd and the total area used for agriculture have declined from the peak levels reached in the 1970s and early 1980s, while the area of crop and sown pasture has continued to grow.

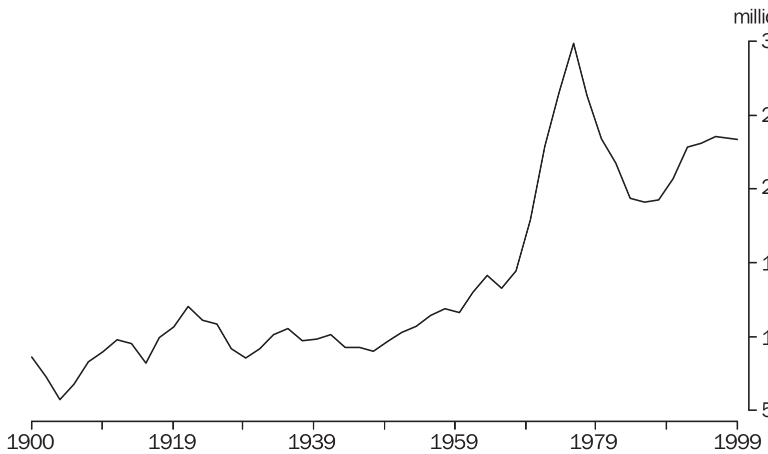
Changes in agriculture over time *continued*

2.5 CROP AREA, Australia—1870 to 1996



Source: ABS 2001.

2.6 BEEF CATTLE HERD, Australia—1900 to 1998



Source: ABS 1999a.

The growth of crop land and sown pastures is indicative of a shift towards more intensive agricultural systems, producing more output with fewer inputs of labour, slightly more capital and a greater amount of knowledge (Gretton and Salma 1996). Use of inputs such as fertiliser has increased (table 2.7), as has the use of irrigation. Excessive application of fertiliser can increase nutrient levels and lead to the eutrophication of waterways (see Chapter 3) and increased levels of soil acidity, while irrigation may cause salinity and sodicity (discussed later in the present chapter).

Changes in agriculture over time *continued*

2.7 FERTILISER CONSUMPTION—1980–81 to 1998–99

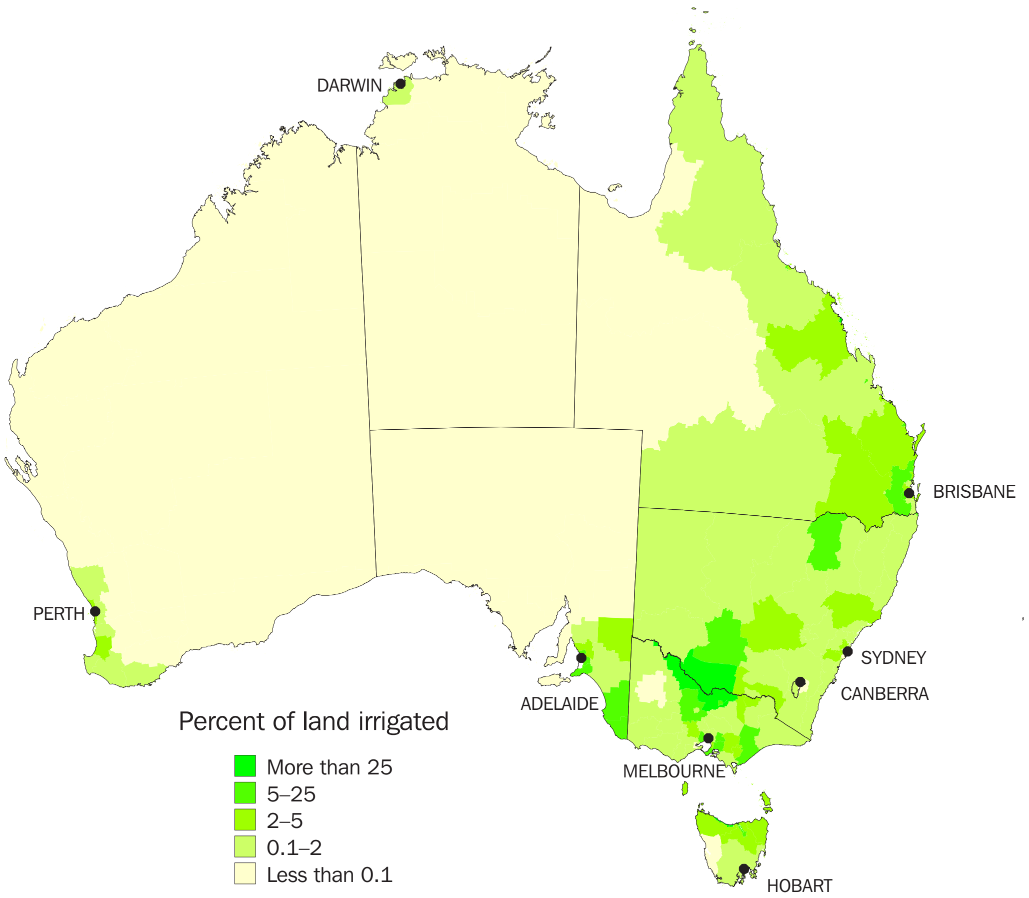
	Phosphate (P_2O_5)	Nitrogen (N)	Potash (K_2O)
Year	kilotonnes	kilotonnes	kilotonnes
1980–81	823.0	248.0	128.0
1981–82	762.0	250.0	137.0
1982–83	742.0	258.0	127.1
1983–84	764.0	305.0	140.7
1984–85	685.0	344.0	141.2
1985–86	726.2	340.0	130.0
1986–87	871.8	332.5	135.7
1987–88	842.5	363.1	147.4
1988–89	790.5	392.6	160.8
1989–90	578.9	440.3	162.6
1990–91	580.0	439.4	145.4
1991–92	680.2	462.4	142.1
1992–93	801.4	488.0	145.2
1993–94	790.5	548.0	172.6
1994–95	950.0	564.5	201.2
1995–96	977.5	644.3	219.0
1996–97	1 016.0	772.7	196.5
1997–98	1 148.1	839.7	249.0
1998–99p	1 058.7	880.1	223.0

p preliminary.

Source: ABARE 1999a.

Water is a vital input to agriculture—some 70% of water used in Australia is for agriculture (see Chapter 3 and ABS 2000b). In 1996–97 just over two million hectares of land were irrigated with 15.5 million megalitres of water. The water consumed by different crops varies, but for most crops water use increased slightly between 1993–94 and 1996–97. Vegetable growing achieved the maximum value of crops produced per megalitre of water used. Map 2.8 shows which regions have the greatest percentage area of irrigated land.

2.8 IRRIGATION, Percent of Agricultural Land Irrigated—1996–97



Source: *Agricultural Census and Agricultural Finance Survey 1996–97. Map based on ABS Statistical Subdivisions 1996.*

The area devoted to different crops or land uses changes from year to year, depending on a range of environmental and economic factors. Environmental factors include the amount and timing of rainfall, minimum and maximum temperatures and soil type. A key economic factor is the price paid for different types of agricultural produce. For example, since the late 1980s the number of sheep in Australia has fallen, while the area planted with crops has increased, reflecting lower wool prices and a switch in land use from sheep grazing to cropping. However, the area planted with grain crops is forecast to decrease between now and 2004–05 in response to lower prices for grain crops, while sheep numbers may increase (Turner et al. 2000).

In some cases declining prices for particular commodities are offset by increased yields. For example, prices paid for wheat have declined from a global high of over US$600 per tonne in the mid-70s to just over US$100 per tonne today, but this has been accompanied by increased yields (from 1.6 to 2.6 tonnes per hectare) (Turner et al. 2000).

Forest clearing

The farmland of today was once native vegetation, and significant changes in the flora and fauna of Australia have taken place since European settlement. In New South Wales, Victoria, South Australia, Tasmania and the Australian Capital Territory, half or nearly half of the native forests have been cleared. A large amount of clearing of vegetation has occurred since 1980. Between 1980 and 1997 the largest percentage of native forest cleared (39%) was in South Australia (mostly in the 1980s), while the largest area cleared (around 6 million hectares) was in Queensland (table 2.9). The location of clearing between 1990–91 and 1995 is shown in map 2.10.

2.9 AREA OF NATIVE FORESTS—1788 to 1997

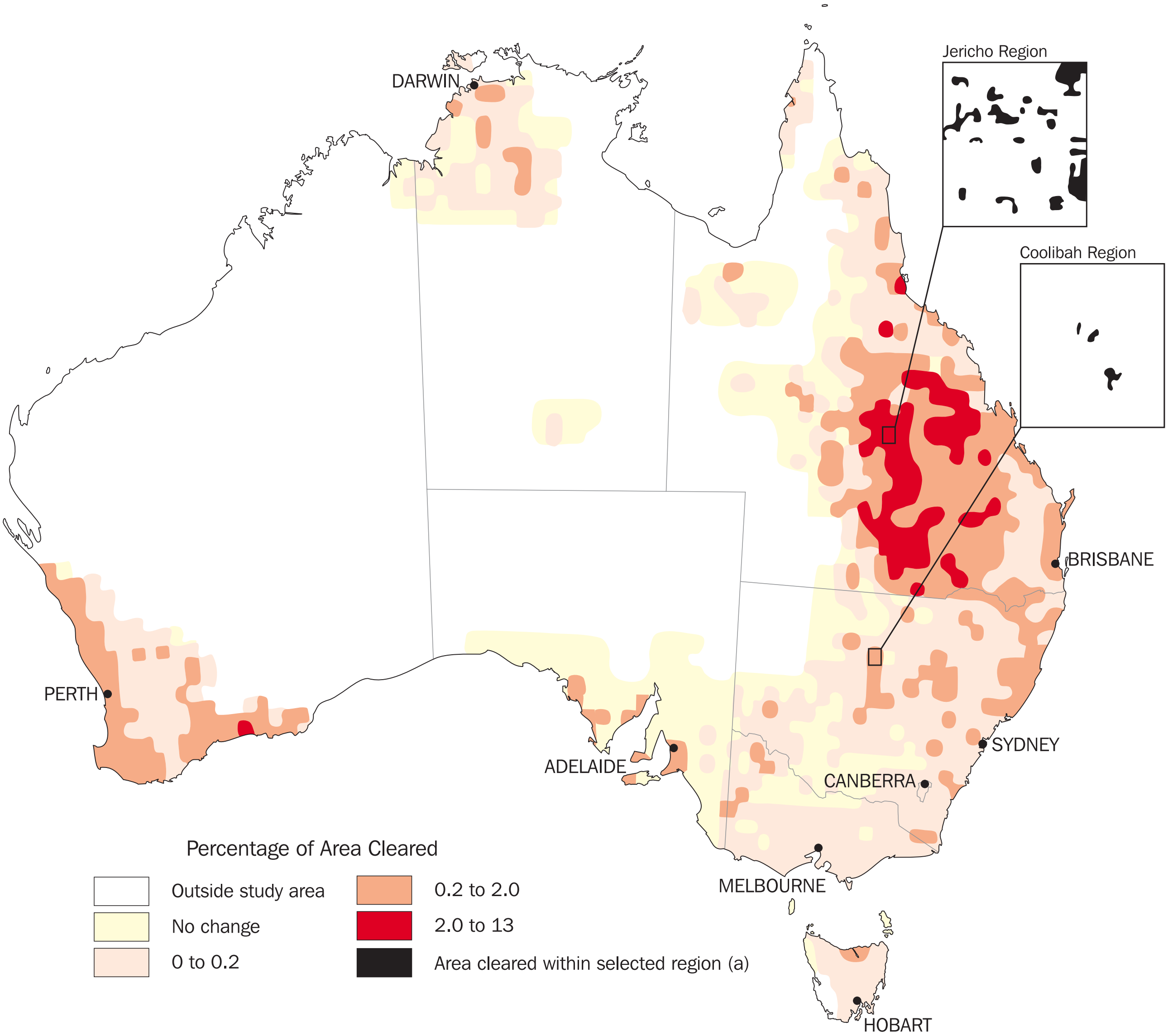
	1788	*1980*	*1997*	*1788–1997*	*1980–1997*
State/Territory	'000 ha	'000 ha	'000 ha	% reduction	% reduction
NSW	54 710	22 910	20 787	62	9.2
Vic.	18 513	7 538	7 285	61	3.3
Qld	80 609	55 963	49 056	39	12.3
SA	18 417	9 058	5 499	70	39.3
WA(a)	46 346	32 934	34 800	25	. .
Tas.	5 604	3 871	2 904	48	25.0
NT(b)	27 565	27 474	35 385	. .	. .
ACT	236	124	120	49	3.2
Australia	**252 000**	**159 872**	**155 835**	**38**	**2.5**

(a) Differences in definitions of forests used had led to the area of forest increasing in WA between 1980 and 1997.

(b) Due to differences in definitions of forests used at different times the area of forests is shown to have increased between 1788 and 1997 in the NT.

Source: NFI 1998.

2.10 WOODY VEGETATION, Location of Clearing for Agriculture, Grazing and Development—1990–91 to 1995



(a) Boxes show the area actually cleared in two regions between 1990–91 to 1995.

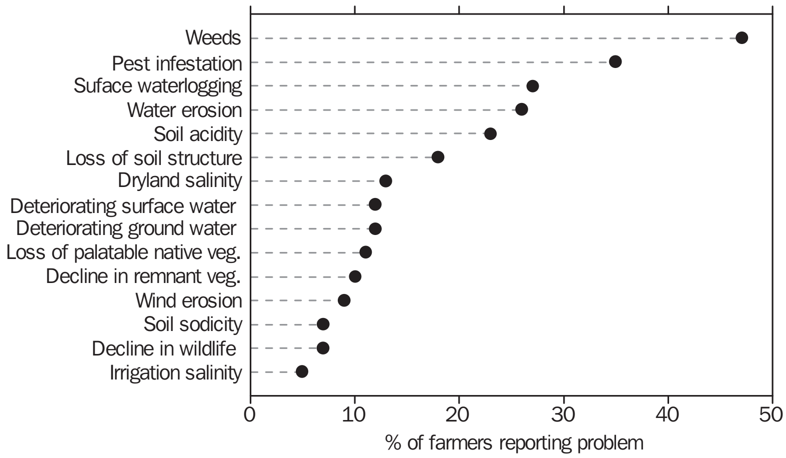
Source: Barson et al. 2000.

Land degradation

Australia is covered by shallow and old soils, susceptible to degradation by agricultural activities which deplete soil nutrients and damage soil structure. Soil degradation has resulted in losses to agricultural production and declines in the health of many native animal and plant populations. Three types of land degradation—soil acidity, sodicity and salinity—have been estimated to cost the Australian economy $2.4b annually (CRC for Soil and Land Management 1999). Estimates of the costs of land degradation vary greatly because of the difficulties involved in measuring the costs and the range of costs considered. Studies have estimated one or a combination of land degradation problems and have included assessments of one or more of the following costs: damage caused to public and private assets; expenditure needed to rehabilitate degraded land; and the value of production that could have been gained from the land, were it not degraded.

Land degradation *continued*

2.11 LAND DEGRADATION PROBLEMS REPORTED BY FARMERS—1997



Source: Mues et al. 1998.

Around 20% of Australian farms experience some form of land degradation (Kemp and Alexander 2000). A 1997 ABARE survey asked farmers to report on 15 land degradation problems (graph 2.11). Variation in the reporting rates of problems probably reflects the spatial distribution of the problems, with larger reporting rates equalling larger affected areas. For example, weed infestation is evident throughout much of Australia, but dryland salinity affects only some areas in some States.

Weeds

Weeds were the most common problem reported by farmers in 1997 (graph 2.11). They were estimated to cost the Australian economy $3.3b annually in lost production and control costs (NSW 1999). Another estimate has put these costs at around $1.2b annually for winter crops (Jones et al. 2000).

Weeds can be native or foreign to Australia and can be broadly defined as plants that have established themselves outside of their natural range and are reproducing. Most weeds were imported from other countries since European settlement for use in agriculture or as ornamental plants in gardens. Of the more than 200 weeds examined by Panetta (1993) 31% were 'garden escapes' and 15% were for use in agriculture. Many early explorers distributed the seeds of fruit and vegetables so that those who followed would have food (Low 1999). Some weeds were probably introduced before European settlement. For example, the Macassans are believed to have introduced the tamarind (*Tamarindas indicus*) to northern Australia on their visits, which occurred after 1700 (Adair and Grovers 1998).

Weeds *continued*

2.12 WEEDS OF NATIONAL SIGNIFICANCE, Current and Potential Distribution—1999

Common name	Origin of weed	*Current distribution* '000 km²	*Potential distribution* '000 km²
Alligator weed	Argentina	30	500
Athel pine	North Africa, Arabia, Iran and India	80	3 646
Bitou bush/Boneseed	South Africa	231	1 258
Blackberry	Europe	691	1 425
Bridal creeper	South Africa	385	1 244
Cabomba	USA	35	181
Chilean needle grass	South America	14	242
Gorse	Europe	233	870
Hymenachne	Central America	73	415
Lantana	Central America	389	1 052
Mesquite	Central America	410	5 110
Mimosa	tropical America	73	434
Parkinsonia	Central America	950	5 302
Parthenium	Caribbean	427	2 007
Pond apple	North, Central and South America and West Africa	27	181
Prickly acacia	Africa	173	2 249
Rubber vine	Madagascar	592	2 850
Salvinia	Brazil	383	1 376
Serrated tussock	South America	171	538
Willows	Europe, America and Asia	63	135

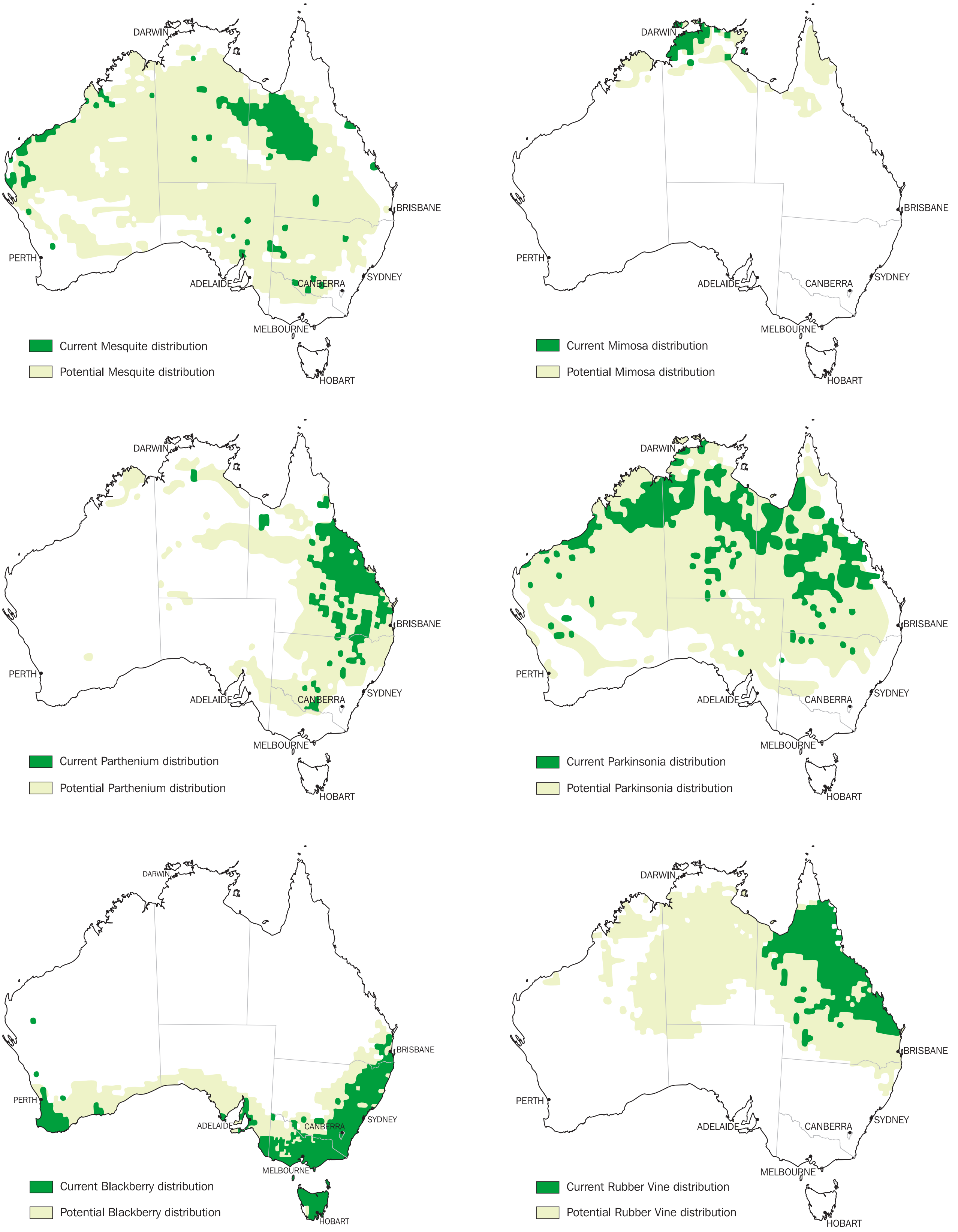
Source: NWS 1999; Thorp and Lynch 2000.

Today there are around 3,000 weed species in Australia, of which over 370 species have been declared noxious (Weeds Australia 2000a & b; Lazarides et al. 1997). To help focus national efforts addressing the weed problem, a 'Top 20' list of 'Weeds of National Significance' has been compiled (table 2.12). One aim of the list is to improve coordination among land managers around Australia.

Some weeds impose substantial economic losses (e.g. Annual ryegrass, *Lolium rigidum*. See Jones et al. 2000), while others cover very large areas. For example, Blackberry currently infests 9% of Australia, and has the potential to nearly double this area (table 2.12 and map 2.13). Some weeds have the potential to affect regions of national and international conservation importance. For example Mimosa threatens the Kakadu World Heritage Area (map 2.13). Mimosa is prickly, can grow to a height of six metres, and produces so many seeds that it is capable of doubling in area every year, turning species-rich tropical wetlands of northern Australia into a Mimosa monoculture (Lonsdale 1999).

A number of weeds are known or suspected to threaten native species (Adair and Grovers 1998). For example, in Victoria 16 plant species (many of them orchids) and six animals are threatened or potentially threatened by weeds. Extensive efforts are occurring to determine ways to reduce the ecological and economic damage being done by weeds.

2.13 DISTRIBUTION OF SELECTED WEEDS(a)



(a) Six of the 20 Weeds of National Significance.

Source: *Thorp and Lynch 2000.*

Salinity

Salinity is a measure of the amount of salt in surface soil or groundwater. Many areas of Australia have naturally saline (salty) soils, and salinity problems in particular areas may predate land clearing (Dent et al. 1999). In agricultural areas the level of salinity can increase through the removal of trees, the use of irrigation or both. Salinity accelerates the decay of plumbing, roads and buildings, and increases the risk of flooding, in addition to stopping plants from growing and hence reducing agricultural production (MDBC 1999; Wilson 2000). It can also increase the extent of soil erosion and collapse of stream banks.

2.14 DRYLAND SALINITY, Estimates of the Area Affected(a)

	Current area	*Potential area(b) 2000*	*Potential area(b) 2050*
State(c)	ha	ha	ha
NSW	120 000	181 000	1 300 000
Vic.	120 000	670 000	3 110 000
Qld	10 000	. .	3 100 000
SA	402 000	390 000	600 000
WA	1 804 000	4 363 000	8 800 000
Tas.	minor	54 000	90 000
Total	**2 476 000**	**5 658 000**	**17 000 000**

(a) The quality, quantity and scale of data on which the estimates are based varies between States.

(b) Area with a high potential to develop dryland salinity due to shallow water tables (see NLWRA 2001).

(c) Data for the NT and ACT are not presented as the problem is minor (see NLWRA 2001).

Source: PMSEIC 1999; NLWRA 2001.

Salinity has been known in Australia for more than 100 years, and it now affects a large part of the continent (MDBC 1999; table 2.14). The amount of area affected by salinity is not known precisely, but the best estimate is that 2.5 million hectares are currently affected, representing about 0.6% of all agricultural land, while the area with a high potential to develop salinity is around 5.6 million hectares or about 1.2% of agricultural land. National data mask variation between water catchments. Some areas are more severely affected (or potentially affected) than others. For example, the areas near Wagga Wagga (NSW) and Bunbury (WA) have salinity problems greater than the areas near Mt. Gambia (SA) and Orbost (Vic.) (See NLWRA 2001).

Western Australia has the largest area affected or potentially affected by salinity. The nature of groundwater flows, which are discussed in more detail in Chapter 3, are important for assessing the areas at risk. In brief, the groundwater flows in Western Australia are such that salinity resulted soon after the introduction of agriculture. This is in contrast to New South Wales and most of the Murray–Darling Basin, which have water flows such that it takes far longer (up to 100 years) for agricultural activities to cause salinity problems (See MDBC 1999 & NLWRA 2001). One of the implications of this is that improvements to current land use practises in the Murray–Darling Basin may take decades to have an impact on salinity levels.

Salinity *continued*

There are two types of salinity—dryland and irrigation salinity. Dryland salinity occurs where trees are cleared from land. Irrigation salinity typically occurs when the amount of water applied through irrigation is greater than the amount needed by the crops. The fundamental cause of salinity is changes in the flows of water entering and leaving the underground water supply. If the amount of water entering the ground increases or the amount of water leaving the ground decreases, then underground water gets closer to the surface. This is called a rising water table. As the water rises it carries dissolved salts with it. This saline soil and the water stop some plants growing and kill others outright. Many crops cannot be grown in saline soils. Where salinity is severe, salt is deposited on or near the surface as water evaporates. Run-off from saline areas can carry the salt to rivers where it is transported to other areas.

Estimates of the cost of salinity, in terms of the value of production forgone, are in the range $130m to $330m per annum (MDBC 1999; CRC Soil and Land Management 1999). The variation in the estimates reflects the difficulties and different approaches used in valuing the cost of production forgone as well as the damage to public and private infrastructure. For example, saline water causes damage to water pipes, hot water systems, rainwater tanks, roads, municipal water treatment plants, dams and sewers (Wilson 2000). The cost of restoring saline land to an agriculturally productive condition depends on the severity of the problem, and in many cases it is uneconomic to do so. In some cases land affected by salinity can be used for agriculture. For example salt tolerant plants can be grown as feed for livestock.

Estimates of the cost of salinity generally neglect the benefits to agricultural production that are achieved through land management activities, such as irrigation, land clearing and pasture improvement, that contribute to salinity. An exception was a cost-benefit analysis by the Productivity Commission (Gretton and Salma 1996). This analysis demonstrated that the economic benefits derived from the practices that contributed to salinity can sometimes be greater than economic losses. When this occurs, there are positive incentives for farmers to move towards farming activities associated with higher levels of salinity.

New survey techniques will help land managers identify salinity sources and salinity-prone areas which will enable more effective intervention (Dent et al. 1999). While problems are being identified and risk assessments are being undertaken, the most appropriate ways to manage salinity are still being developed and discussed. One area of debate is whether assistance should be given to private landowners in order to prevent damage to public assets and to improve the long term productivity of private land (see Pannell 2000, for example). Planting trees, growing salt tolerant, perennial or more deeply rooted crops and reducing the amount of water used in irrigation, are measures already used in combating salinity.

Other soil degradation issues

Other land degradation problems include soil acidity, sodicity and structure decline (also known as compaction). The same study which found that there were economic reasons for causing land to become saline also found that there were economic reasons to cease practices that lead to soil structure decline and acidity (Gretton and Salma 1996). Increasing levels of soil acidity can reduce greatly the productivity of agricultural land (LWRRDC 1995). Many Australian soils are naturally acidic, but applying acidic nitrogen fertilisers or growing sub-clover pastures can increase soil acidity. The problem of soil acidity is greater where soils are sandy and rainfall is below 500 mm per year.

Soil sodicity is often found in conjunction with other land degradation problems, particularly waterlogging and gully erosion. Around 30% of the soils in Australia are sodic. Like salinity, sodicity is caused by high levels of salt in soils, but the problems are different and require separate solutions. Soils are classed as sodic when the level of exchangeable sodium (Na) exceeds 6% and begins to affect the soil structure (Charman and Murphy 1991). Sodium is attached to clay in soil and when wet it weakens the bonds between the soil particles, causing the clay to swell, and sometimes the particles become detached. Once they are detached, clay can move through the soil, clogging pores. The clogging and swelling hinder the ability of water to enter or drain from soil (causing waterlogging). The fine detached particles also make the soil more susceptible to erosion by wind and water (CRC Soil and Land Management Technical Note No. 1, June 1994).

Loss of soil structure is less obvious than some other land degradation problems, but it reduces plant growth rates. Soil compaction is one of the most common and serious forms of loss of soil structure. It typically occurs when machinery is driven over wet soil. This compresses the soil, making it difficult for water and plant roots to penetrate.

To reduce or limit the impact of agriculture on the environment a range of activities has been undertaken by farmers, such as revegetation with native plants. Spending on environmental protection by the agricultural sector was $191.7m in 1996–97 (ABS 1999b). This represented around 2% of total expenditure on environmental protection and 0.7% of total turnover of the sector. However, the figure does not include the value of activities deemed to be undertaken primarily for the production of agricultural products, but which may also benefit the environment. For example, the cost of weed control in crops is not counted, even though this helps stop the spread of weeds to non-agricultural areas; in 1995 spending on herbicides was $452m (NWS 1999).

FORESTRY

Native forests cover around 1.56 million square kilometres of Australia (see table 2.9). Forests are used for a wide variety of purposes including recreation, biodiversity conservation, honey production, scientific research, water catchment protection and timber harvesting. All of these uses have impacts, but it is the extraction of timber that has attracted the most attention.

Australia's forestry sector is based on the extraction and processing of wood from native forests and plantations. Timber harvesting is permitted in 133,510 km^2 of public 'multiple-use' native forest, although only a fraction of this area (1,100 km^2 or 0.8% on average) is harvested in any one year. An increasing proportion of timber comes from plantations, which currently cover 13,372 km^2 of Australia (table 2.15).

2.15 ESTIMATED AREA AVAILABLE FOR TIMBER HARVESTING

Tenure	*Area* km^2
Native forests	
Public 'multiple-use' forest(a)	(b)156 080
Other crown land(c)	29 150
Private(d)	31 460
Total area	*216 690*
Plantations	
Public	6 155
Private	6 146
Joint	1 071
Total area	*13 372*
Total area available for harvesting	**230 062**

(a) Multiple-use forest incorporates forestry reserve (see table 2.2) and other land tenure categories.

(b) Only about 86% of this area is actually forested as it contains rock outcrops, lakes and swamps etc. The area available for harvesting is further reduced by about 45% by factors such as distance to mills, rough terrain, low productivity and/or high environmental, conservation, scenic and cultural values.

(c) No data available for ACT, NT, Vic. and WA.

(d) No data available for ACT, NT, Qld, Vic. and WA.

Source: NFI 1998 & 2000.

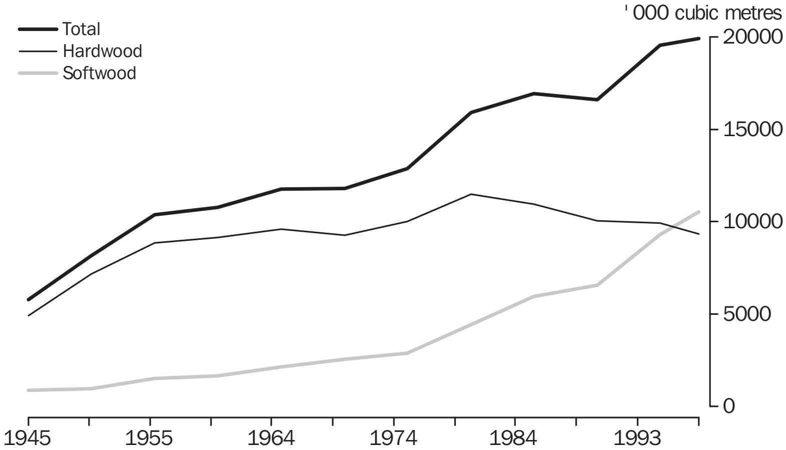
Forests are diverse, containing many different plant and animal species. What is considered a forest depends on the definition used. That used by the National Forest Inventory is:

An area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding 2 metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20% (NFI 1998).

Volume of timber

The volume of timber removed from Australia's forests has increased steadily since the end of World War II (graph 2.16). Since 1970, the volume of hardwood timber removed has been around 10 million cubic metres per year. In 1996–97 the volume of softwood removed was greater than that of hardwood, a result of more timber coming from plantations than from native forests.

2.16 WOOD REMOVED FROM FORESTS(a)



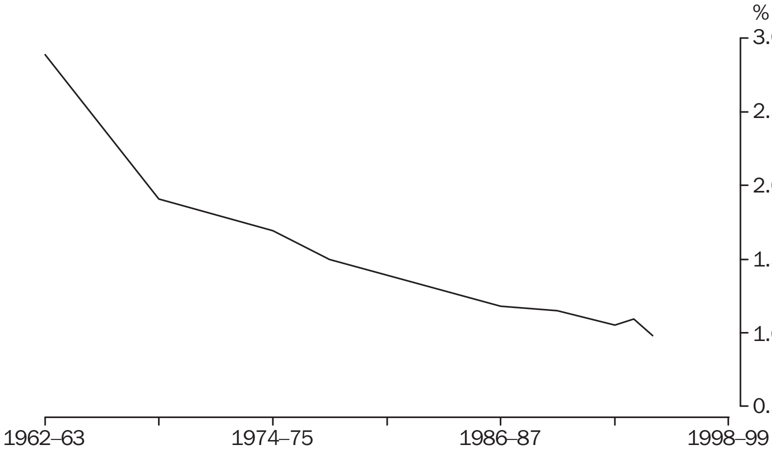
(a) Total volume of logs removed including plantation timber.

Source: ABARE 1986 & 1999a.

Contribution to the economy

The forestry sector (forestry and wood product manufacturing industries) currently contributes around 1% to GDP. This contribution has fallen from almost 3% in 1962-63 (graph 2.17).

2.17 FORESTRY SECTOR, Contribution to GDP

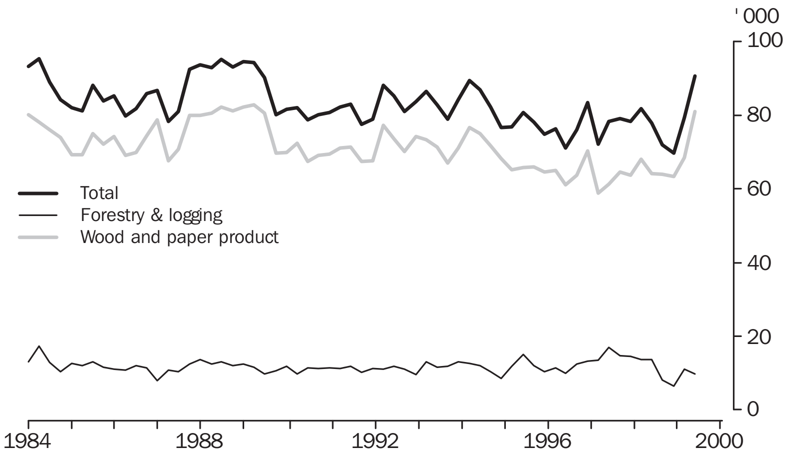


Source: ABS 1973–1999.

Contribution to the economy *continued*

The number of persons employed in the forestry sector has been around 80,000 in recent times, although the current level of employment is not far from the peaks of 95,000 persons employed at February 1985 and May 1989 (graph 2.18). Employment in the forestry sector has been around 1% of total employment for most of the 1990s, after falling in the late 1980s from a high of 1.4% at February 1985. Of the 90,000 persons employed in the sector at May 2000, most were employed in the manufacture of wood and paper products, and an estimated 16,000 were employed in plantation management and associated wood processing (Burns et al. 1999).

2.18 FORESTRY SECTOR(a), Employment—1984 to 2000(b)



(a) Industry subdivisions are Forestry and logging (03) and Wood and paper product manufacturing (23). ANZSIC code in brackets.

(b) A change in the methodology of the labour force survey between the November quarter 1999 and the January quarter 2000 is estimated to have increased by around 5% the estimates of the level of employment for the Wood and paper product manufacturing industry (see ABS1999c, pp. 3–9). The actual extent of the change in level may be higher or lower, and hence the recent figures should be interpreted cautiously.

Source: ABS unpub. (Labour Force Survey).

Forestry is important to particular communities of Australia. Forest dependency is measured by the number of people employed in forest-related industries as a proportion of the total working population. In Australia, 186 towns have a forest dependency above 5% and five towns have a forest dependency greater than 50% (NFI 1998). The perceived dependence on forestry in these towns can be much greater. The Social Report for the Regional Forest Agreement process in East Gippsland found that 66% of workers in all industries felt that they were dependent on the forestry industry to some extent (DNRE 1996).

Environmental impacts of timber extraction

The environmental impacts of forest harvesting are issues of strong concern in all Australian forests, and are greatest for native forests. In particular, the practice of clearfelling and associated fire regimes frequently results in major changes in the species composition and structure of forests (Mackey et al. 1998). Other impacts of forestry can include damage to the soil structure, siltation of streams and rivers, loss of aesthetic value and introduction of weeds and feral animals.

One major impact of timber extraction is on animals that live in tree hollows. Approximately 14.5% of Australia's vertebrate fauna depend on tree hollows (table 2.19). Hollows are also used by a large but unknown number of invertebrates (Gibbons et al. 2000).

2.19 VERTEBRATE ANIMALS THAT USE TREE HOLLOWS

Animal group	*Species* (a) no.	*Using hollows* no.	*Using hollows* %
Terrestrial mammals(b)	268	86	32.1
Birds(c)	777	111	14.3
Reptiles(d)	770	78	9.9
Frogs	203	29	14.3
Total species	**2 018**	**304**	**15.1**

(a) The number of known species is dependant upon, amoung other things, source material and definitions of inclusive taxa.

(b) Excludes marine mammals.

(c) Excludes seabirds and migratory species.

(d) Excludes marine turtles and sea snakes.

Source: Gibbons and Lindenmayer in press.

Hollows suitable for vertebrate species typically appear only in very old trees (older than 150 years). Recruiting new hollow-bearing trees into logged sites is difficult because logging operations typically occur every 55–120 years, which is insufficient time for new hollows to form (Gibbons et al. 2000). In an effort to accommodate wildlife that needs hollows, forest management agencies retain habitat trees in logged areas. In many cases, trees that do not have hollows, but are likely to form them in the future, are also retained. The number of trees left has increased in recent years as a result of changes to the Codes of Forest Practice during the Regional Forest Agreement process. For example, in south-east NSW 0.3 hollow-bearing trees per hectare were left in 1991, but by 1997 this had risen to 5 trees per hectare plus recruitment trees (Recher 1996; NSW NPWS and SFNSW 1996).

Forest management

A significant recent change in the management of Australia's forests has been the Regional Forest Agreement (RFA) process. This was designed to achieve a major goal of the National Forest Policy of establishing a comprehensive, adequate and representative reserve system for the biological diversity of Australian forests.

The RFA process attempted to balance conservation with social and economic concerns and to make decisions based on scientifically credible criteria. Some conservationists and industry groups have questioned the effectiveness of the process and are dissatisfied with the outcomes. The RFA process is not yet complete in all States.

RFAs are between the Commonwealth Government and the State Governments. In most regions, there is a reduction in resource supply and concurrently an increase in conservation reserve (table 2.20). The agreements are in place for 20 years and create greater certainty of access to forest resources for the forestry industry. Combined with RFA funding, this is expected to encourage greater investment in value-adding projects, increasing regional employment.

2.20 INCREASE IN CONSERVATION RESERVES, By RFA Region(a)

RFA region	*Year agreement was signed*	*Increase in area* ha
Tasmania	1997	442 140
East Gippsland	1997	9 460
Central Highlands (Vic)	1998	116 200
Eden (NSW)	1999	105 700
South west WA	1999	114 600
North east Victoria	1999	196 600
Gippsland	2000	278 700
Western Victoria	2000	195 600
North east NSW (upper)	2000	461 200
North east NSW (lower)	2000	619 900
Total Area		**2 540 100**

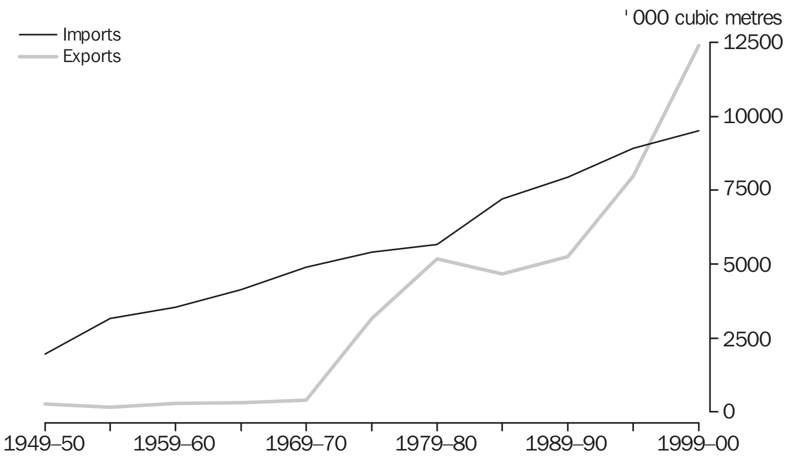
(a) These are areas reserved for conservation purposes where logging is no longer allowed. Updated figures will be released by NFI during 2001.

Source: RFA 2000.

Imports and exports

In the mid–1990s, Australia went from being a net importer of roundwood to a net exporter (graph 2.21), making Australia's wood and wood products industry self-sufficient in volume terms with annual harvests greater than the apparent consumption. However, the value of imports is nearly three times that of exports (graph 2.22). Australia imported about $3.3b of forest products in 1998–99, creating a trade deficit of $1.9b in these products (ABARE 1999b).

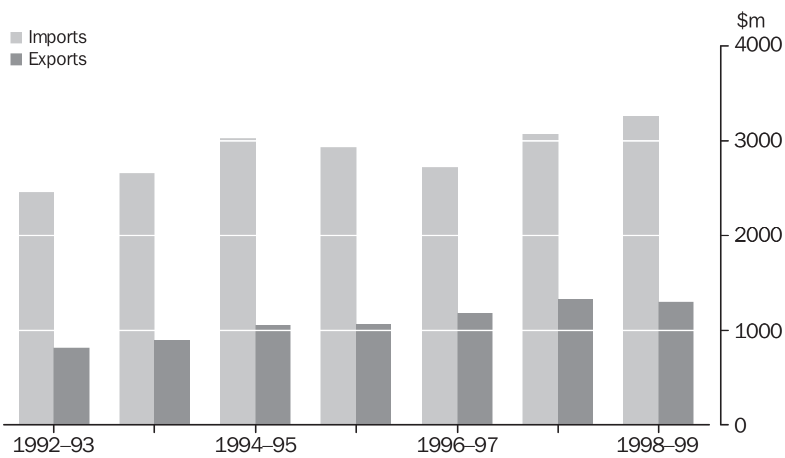
2.21 IMPORTS AND EXPORTS OF ROUNDWOOD(a)—1949–50 to 1999–00



(a) Calculated roundwood equivalent (includes processed wood and paper products).

Source: ABARE 1986, 1999a & 2001.

2.22 IMPORTS AND EXPORTS OF FOREST PRODUCTS—1992–93 to 1998–99



Source: ABARE 1999a.

Imports and exports *continued*

The trade deficit in wood products is caused by the structure of the industry and its productive capacity, especially in pulp and paper products (ABARE–Jaakko Poyry Consulting 1999). Restrictions to competitiveness include higher labour costs compared with Asian countries and cost of freight from Australia to export markets. The forest industry in Australia is also expected to meet environmental standards for waste disposal and land degradation, which can contribute to the cost of production.

Pulp and paper products account for 70% of the value of Australia's imports of forest products. Australia currently imports printing and writing papers, principally from Finland and Indonesia (Jaakko Poyry Consulting 2000).

Processing woodchips into pulp prior to exportation is not a new idea; since the 1920s the forest industry has aspired to add more value and provide more employment by processing wood through further stages of manufacturing. However, Australian producers currently operate older, smaller machines than their international competitors. The development of a large scale mill to supply pulp is impeded by resource availability, wood price (in particular competition from the Japanese export pulpwood market), and market uncertainty and volatility. A world-scale mill would require an input of 2.5 million tonnes of wood per year (Jaakko Poyry Consulting 2000). Currently there is no region in Australia with this level of resource availability.

An opportunity for improving Australia's trade balance would come from a mill based on recycled paper. The waste paper recovery rate in Australia is just over 40%, consisting of old newsprint and magazines, corrugated cardboard, office waste paper, mixed paper and other recovered paper grades. In 1996 Australia produced 1.3 million tonnes of recovered paper, imported 25,000 tonnes and exported 130,000 tonnes, making the apparent consumption 1.2 million tonnes (Margules Poyry Pty Ltd 1998). A mill based on recovered paper could supply the domestic paper and paperboard industry and export the surplus to the Asia Pacific region.

Visy is currently constructing a $400m unbleached pulp and paper mill at Tumut in NSW. It is scheduled to begin operation in July 2001 and will produce 240,000 tonnes of high quality pulp and paper annually. The inputs from pine plantations will be 450,000 tonnes of pulp wood from thinnings and harvest by-product (timber that cannot be used to produce sawlogs) and 350,000 tonnes of sawmill residue. There will also be a waste paper component of 50,000 tonnes. The pulp and paper produced by this mill will replace products currently imported, helping to reduce Australia's trade deficit (Visy Industries 2000).

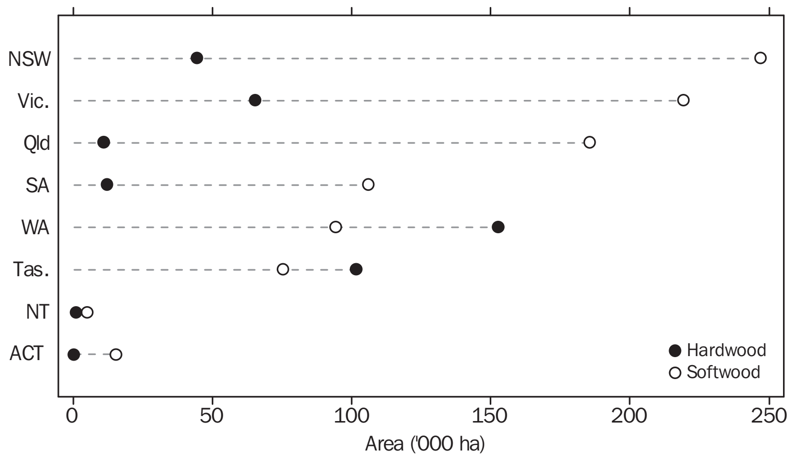
Plantations

Plantations are an important source of timber. They make up about 3% of the world's forest area, but supply around one third of the wood used in industry (Love et al. 2000). In Australia, plantations constitute less than 1% of the total forest area but supply over 50% of wood requirements. The domestic industry now uses more plantation-grown wood than native forest timber. Of $6b worth of forest products produced during 1996–97, 65% was derived from plantation wood, including 58% of logs used for sawnwood, plywood and veneer, 96% of logs used for wood based panels and 62% of wood used for paper and paper board in Australia (Burns et al. 1999).

Plantations are defined in the National Forest Policy Statement as "intensely managed stands of trees of either native or exotic species, created by the regular placement of seedlings or seeds" (NFI 1998).

Australia has a total plantation area of 1,337,283 hectares. Most of this is softwood (948,255 ha). The largest areas of plantations occur in New South Wales, Victoria and Western Australia (graph 2.23). All States and Territories except Tasmania and Western Australia have a greater area of softwood plantation than of hardwood.

2.23 AREA OF PLANTATIONS, By State/Territory —1999

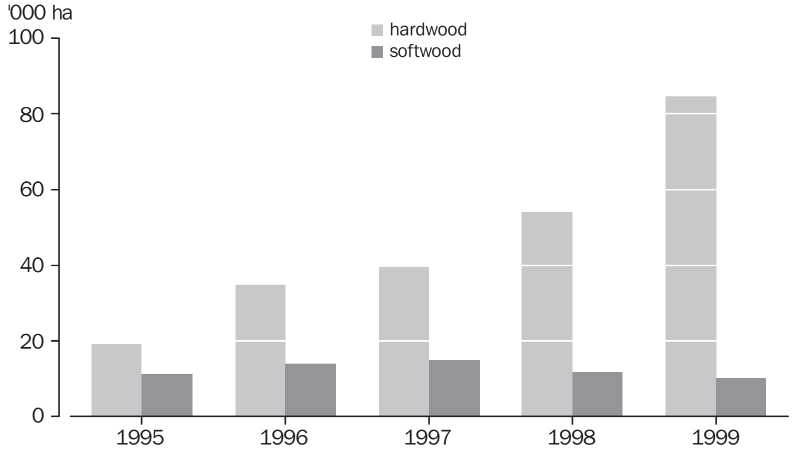


Source: NFI 2000.

The area of hardwood plantations is expanding rapidly (graph 2.24). During 1999, some 84,600 hectares of hardwood were planted, compared with only 19,100 hectares in 1995. During the same five year period, the area of softwood planted annually decreased slightly. While a substantial area of hardwood plantations has been established in recent years, it has not yet been harvested. Softwood plantations still account for over 70% of the total plantation area (NFI 2000).

Plantations *continued*

2.24 AREA OF NEW PLANTATIONS ESTABLISHED(a)



(a) Area of new plantations established annually up to September each year.

Source: NFI 2000.

The environmental impact of a plantation depends, to a large extent, on the previous use of the land and the choice of site. Compared with a natural forest, plantations have vastly simplified ecosystems, with fewer species of plants and wildlife. If the land was previously agricultural land, a plantation may increase the diversity of species by providing habitat for native animals.

Another important factor is the tree species selected. For example, exotic species may not support the understorey of native vegetation, fauna and micro-organisms that is common in natural forests.

Plantation design and management are important for avoiding environmental damage. On steep slopes and unstable soil, the harvesting of plantations is likely to cause erosion. Plantations can also increase the risk of pest and disease infestation and exotic species can spread into nearby areas of natural forest.

Plantations established on cleared land can have environmental and agricultural benefits, such as providing shelter and fodder for livestock, wildlife habitat, improving soil structure and fertility, stabilising or lowering water tables, limiting wind and water erosion, and maintaining water quality.

Commonwealth government policy

The structure of the forestry industry in Australia is changing. Plantations are already a major source of timber and more are being established, particularly hardwood plantations. The Commonwealth Government is encouraging this change in order to provide a strong base for secondary industries. With a more secure resource base, there are possibilities for value-adding before exportation, thereby reducing Australia's trade deficit in these products. Table 2.25 identifies the main policy statements made by the Commonwealth Government since 1988 and summarises their key features.

2.25 COMMONWEALTH GOVERNMENT FORESTRY POLICIES AND INITIATIVES

Policy	*Year*	*Key points*
National Forest Inventory	1988	Produced State of the Forests Report which describes the forest resource, discusses its use and management and examines social forces framing public opinion on these issues.
National Plantation Inventory		Describes in detail Australia's plantation resource. Figures updated and released annually.
National Farm Forest Inventory		Compiles data on the farm forest plantation resource.
National Pulp Mills Research Program	1989	Environmental guidelines for development of pulp mills.
National Forest Policy Statement	1992	Signed by Commonwealth Government and the State and Territory Governments, this policy statement provides a framework for the future management of Australia's public and private forests.
Farm Forestry Program (FFP)		Promotes commercial wood production on cleared agricultural land.
Tropical Forest Conservation and Sustainable Land Use Policy		Sets target for all tropical timber exports to be derived from sustainably managed forests.
Forest and Wood Products Research and Development Corporation	1994	Assists forest industries to improve their international competitiveness (jointly funded by industry and the Commonwealth).
Wood and Paper Industry Strategy	1995	Aims to facilitate development of wood and paper industry.
Regional Forest Agreements (RFA)	1996	Framework and process for carrying out comprehensive assessments of the economic, social, environmental and heritage values of forest regions. Blueprint for future management of forests and basis for an internationally competitive and ecologically sustainable forest products industry.
Framework of regional criteria and indicators		For assessing sustainable forest management in the RFA process. Based on the internationally agreed Montreal Process criteria and indicators.
Forestry Industry Structural Adjustment Program		Allocated $98.6m to assist businesses and workers involved in native forest industries to adjust to changes as a result of the Interim/Deferred Forest Agreements and Regional Forest Agreements.
Plantations for Australia: The 2020 Vision	1997	Aims to increase the area of Australia's plantations in an effort to convert the current trade deficit in wood and wood products to a surplus.
First Approximation Report of the 'Montreal Process' Working Group	1997	Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests.
Australian Forestry Standard	currently being developed	Intended to provide a performance standard for sustainable forest management, capable of independent third party verification and certification.

Source: AFFA 2000; ABS 2001.

MINING

The raw materials produced by mining underpin much of modern Australian life. Oil fuels our vehicles, coal is burnt to supply most of our electricity, and metals are used to make a wide range of goods used in everyday life (e.g. household appliances, food containers, televisions, communications equipment).

Environmental impacts

Mining has a range of environmental impacts, of which the main ones are summarised in table 2.26. The direct impacts of mining affect a small proportion of land. Less than 1% of Australia's total land area is used for mining, while petroleum production takes place in a number of offshore areas. There can also be disruptions to the earth surface at mine sites from activities such road building and site preparation. In the case of open-cut mining, surface disturbance can be very severe.

2.26 ENVIRONMENTAL ISSUES FOR THE MINING INDUSTRY

Mining issue	*Description*
Air quality	Dust is the main air quality issue. It can be a health hazard, exacerbating respiratory illnesses. Dust deposits and the resulting loss of environmental amenity is also a problem. Dust deposition rates above 2 g/m^2/month will noticeably reduce environmental amenity.
Noise and vibration	The 24 hour operation of most mines means that noise is continually generated. Noise is measured in decibels (dBL). 130 dBL are harmful to health, while 115 dBL are intrusive. Vibrations greater than 50mm per second can damage buildings and other structures, but at lower levels can be annoying.
Water management	Water is used in a range of ways. Of particular importance is the management of water which contains mine tailings—a mixture of rock, metal and chemicals that may be harmful to people and the environment. The waters are dammed and the heavy elements allowed to settle out. Dams must be designed so that they do not flood or leak.
Water quality	Contamination of water can occur by sediment, heavy metals, cyanide, fuels, acid and radioactive particles.
Soil conservation	Topsoil is often removed before mining begins, to be returned once mining is finished to assist rehabilitation of the site.
Flora and fauna	Surveys are carried out prior to mining, and mine planning must consider the conservation of species and the ecological integrity of the site.
Archaeology and cultural heritage protection	Mining may damage or disturb sites with cultural values, such as burial grounds. The planning process considers these factors and aims to eliminate or minimise disturbance of these sites (e.g. by undertaking surveys prior to mining and avoiding sensitive areas).
Transport	Mining can increase the amount of traffic on nearby public roads. Planning must consider the impacts of increased noise levels, congestion, safety and wear and tear of roads caused by mine traffic.
Subsidence	Underground mining can cause subsidence which can damage buildings and other structures on the surface. It can also cause land to become more flood prone or waterlogged.
Rehabilitation	Once mining has ceased, mine sites should be returned to an acceptable state. What is an acceptable state should be determined prior to mining and through negotiations involving mining companies, land owners, local community and various government agencies.
Visual impacts	Mines and especially open-cut mines, can be very ugly. Removal of vegetation, industrial and office buildings and large holes contribute to this. Screens of trees and care in the layout of mine operations can minimise these impacts.
Waste management	Mines generate a variety of wastes. Waste rock, tailings, mud, sewage, chemicals used in processing, oil and grease are all produced. Careful disposal strategies are required to minimise risks to the environment.

Source: EPA 1995.

Environmental impacts *continued*

Apart from the direct physical impacts, pollution from mining operations can contaminate the air, water and land. Of particular concern are some of the toxic compounds and elements used to extract minerals at mines. For example, sodium cyanide is used to recover gold from gold-bearing ore. Cyanide ions can kill animal and plant life, so cyanide should not be released into the environment, although accidental spills and releases do occur from time to time. What remains of the ore after the gold is extracted, and the water used in the treatment, is called 'tailings'; in gold mining they usually contain some cyanide. The tailings are deposited into tailings dams; there, over a period of several weeks, the cyanide ions oxidise or form solid compounds. This makes the cyanide non-toxic (Hore-Lacy 1992).

Minimising impacts

Mining operations in Australia are regulated strictly and companies make efforts to minimise various environmental impacts. Environmental protection expenditure by the mining sector has risen steadily since 1991–92. Spending totalled $369m in 1996–97, representing 1% of total turnover in the mining industry for that year (ABS 1999b). Spending covers a variety of activities, including rehabilitating mine sites after mineral deposits were exhausted (Horey-Lacy 1992). In 1998–99 spending on mine site rehabilitation totalled $275m (MCA 2000a).

Forward planning is important for minimising the environmental impacts of mining, and companies wishing to develop new mines are required to complete an environmental impact statement or similar environmental assessment of their proposed development site. These detail the wildlife, historical and natural features of the areas to be mined and outline what measures will be taken to preserve them, as well as plans for mine site rehabilitation. Most States also require companies to lodge a bond for mining leases; like a bond for a leased house, this can be forfeited if the mine site is not returned in a satisfactory condition. Lease conditions can include landscaping, rehabilitation of acidic, saline and alkaline areas, revegetation, removal of roads and buildings, and management of surface soil (storage of soil prior to mining and its replacement at the completion of mining) (SoE 1996).

An Australian Minerals Industry Code for Environmental Management was developed by the mining industry to foster increased awareness of the environmental and social issues in the industry. The code is a voluntary commitment to a range of environmental management principles. It requires the production of public reports outlining implementation of the code. By June 2000, 26 companies had committed to the year 2000 version of the code (MCA 2000b). The code and the companies that have subscribed to it can be found at the web site of the Minerals Council of Australia (www.mineral.org.au).

Size of resource and economic benefits

Despite the small area used, Australia's mineral reserves are voluminous and support a large mining industry. Australia is the world's largest producer of bauxite, diamonds, lead, tantalum and the mineral sand concentrates ilmenite, rutile and zircon (AGSO 1999). Mining accounted for 35% of Australia's exports of goods and services in 1998–99 and is the nation's second largest export earner (ABS 2000c). Total turnover in the mineral sector of the economy was $37.5b in 1998–99, contributing 4% to GDP and paying royalties totalling around $2.2b to governments and others. The percentage contribution of mining to Australia's GDP has fluctuated around 4–5% for most of the 1990s, a decrease from the 6–7% shares attained in the mid 1980s. The volume and value of production of selected minerals are shown in table 2.27.

2.27 MINERALS PRODUCTION, Quantity and Value—1998–99

	Units	*Quantity*	*Value*
Mineral or fossil fuel			$m
Metallic minerals			
Bauxite	'000 t	58 005	1 083.2
Copper concentrate(a)	'000 t	1 835	1 397.3
Gold bullion (dore)	kg	310 378	4 522.0
Iron ore(b)	'000 t	162 224	4 310.0
Lead concentrate	'000 t	927	524.5
Mineral sands			
Beneficiated ilmenite	'000 t	557	297.0
Ilmenite concentrate	'000 t	2 035	212.3
Leucoxene concentrate	'000 t	38	12.7
Rutile concentrate	'000 t	240	182.4
Zircon concentrate	'000 t	325	178.5
Zinc concentrate	'000 t	1 767	739.4
Zinc-lead concentrate(c)	'000 t	376	233.7
Other metallic minerals	n.a.	n.a.	1 981.4
Coal			
Bituminous coal	'000 t	208 176	9 276.4
Semi-anthracite coal	'000 t	3 564	158.2
Sub-bituminous coal	'000 t	20 844	752.9
Lignite	'000 t	65 880	328.3
Oil and gas			
Crude oil(d)	ML	30 306	4 435.7
Natural gas(e)	GL	30 352	3 459.8
Propane	ML	1 509	215.9
Butane	ML	1 993	265.0
Total value			**34 566.5**

(a) Includes precipitate.

(b) Commodity codes 507, 513, 515 and 520 (iron ore pellets).

(c) Includes lead–zinc concentrate.

(d) Includes condensate.

(e) Includes ethane and liquified natural gas.

Source: ABS 2000c.

Size of resource and economic benefits *continued*

Mining is a large employer. In 1998–99 there were 529 mining establishments; these employed about 47,300 people, about 3,700 fewer than the previous year (ABS 2000c). Western Australia had the largest number of mining establishments (178) and Tasmania the least (9). This is reflected in the distribution of the major ore bodies, which can be viewed on maps at the Australian Geological Survey Organisation web site (www.agso.gov.au). Employment in the mining industry has fallen from around 7% of all people employed at the beginning of the 20th century to less than 1% in 1999. The percentage contribution of mining to total employment has declined since the early 1980s (graph 2.28). Factors contributing to the decline in employment in mining are company restructures and downsizing, and greater use of contract employment over direct employment. People are also employed in manufacturing mineral and fossil fuel products (around 315,000 in May 1999).

There is a perception within some parts of the community that some minerals and oil are in short supply. This is understandable as minerals, oil and gas are finite resources—the amount in the ground does not change. What does change, however, is the amount of different minerals found and the amount which can be extracted profitably.

2.28 EMPLOYMENT IN THE MINING SECTOR—1980–81 to 1998–99

Source: ABARE 1999a; ABS 2000c.

The net present value of known reserves of minerals, oil and gas, and their average resource life, are presented in table 2.29. The average resource life is an estimate of how long the known reserves of a particular mineral will last given current rates of production.

The estimated resource life varies greatly between minerals and fossil fuels. For example, the resource life of crude oil is 10 years, while that of brown coal is about 700 years. This does not mean that in nine years crude oil stocks will be exhausted, as new crude oil reserves are found each year. Since 1989 the rate of discovery of new reserves of crude oil has kept pace with the rate of production, which has meant that the estimated resource life has changed little in the past 10 years, fluctuating between 9 and 11 years.

Size of resource and economic benefits *continued*

2.29 SUB-SOIL ASSETS, Value and Resource Life—1998–99

Mineral or fossil fuel	Net present value $m	Estimated resource life(a) years
Metallic minerals		
Bauxite	3 886	72
Copper concentrate	8 292	43
Gold	224	15
Iron ore	9 731	103
Lead	409	32
Mineral sands		
Ilmenite	1 013	78
Rutile concentrate	1 019	79
Zircon concentrate	1 546	51
Coal		
Black coal	39 063	246
Brown coal	839	701
Oil and gas		
Crude oil	13 341	10
Natural gas	28 314	45

(a) 5 year lagged moving average of resource life.

Source: ABS 2000d.

Australia's mineral reserves support most of our domestic needs, as well as a large export industry. The discovery of new reserves of some minerals and fossil fuels for which the known reserves are less than 20 years (e.g. gold and oil) is important if current rates of production, consumption and export are to be maintained. Mineral exploration is therefore very important.

The amount spent on mineral exploration has decreased since mid-1997, when it was nearly $300m per quarter, to around $187m in the December Quarter 2000 (ABS 2000e). Spending on mineral exploration varies across the States and Territories, with Western Australia spending the most (upwards of $400m a year between 1996–97 and 1999–00). Despite a recent downturn in spending on mineral exploration, technological advances in mineral exploration and mining technology have meant that new resources continue to be found. The average cost of finding additional reserves of base metals has fallen by about 50% (Allen and Waring 2000). Advances in technology also make it possible to mine more of the identified mineral resources because they can be recovered more efficiently.

Downturns in mineral exploration are attributable to economic and social factors. Increasing minerals prices are generally followed by increases in exploration expenditure, the latter lagging the former by 1–3 years. The downturn witnessed in recent years can be linked to declines in the prices paid for gold, petroleum and base metals. Additionally, uncertainty over land tenure created by the recognition of Native Title and increased environmental protection requirements are also thought to have been involved in the downturn (Allen and Waring 2000).

Metal recycling

In addition to the discovery of new resources, there has been a worldwide increase in the use of recycled metal. Virtually all of the increases in the supply of lead are due to recycling. For example, 55% of lead used in 1998 by the western world was obtained from recycling (table 2.30) (Hogan and Rose 2000).

2.30 METAL RECYCLING IN THE WESTERN WORLD, Proportion of Total Consumption(a)

Metal	%
Aluminium	41
Copper	13
Gold	28
Lead	55
Zinc	28
Steel	33

(a) Data are for 1998.

Source: Hogan and Rose 2000.

The increase in recycling and the voluntary adoption of a code of environmental management by 26 mining organisations are indications that environmental issues are becoming more prominent in the business considerations of the mining industry. Depletion of mineral resources is an important environmental issue, but the known reserves of key resources (e.g. coal, iron, bauxite) will last for decades or even hundreds of years. The discovery of new scarcer resources (e.g. oil and gold) has kept pace with production in recent years.

NATURAL AND CULTURAL HERITAGE AND TOURISM

The expansion of agriculture in Australia has put pressure on native habitats and species. One measure of the pressure caused by agriculture and other human activities is the profound decline in many of Australia's native species. A large number of plants and animals are found only in Australia (table 2.31). These are called endemic species. The decline and extinction of plant and animal species (often called biodiversity loss) has been the subject of great deal of public and scientific concern, particularly since Australia's record of mammal extinctions is one of the poorest in the world, with 19 species extinct since 1788.

2.31 AUSTRALIAN PLANT AND ANIMAL SPECIES

Species group	*No. of species*	*No. of endemic species*	*No. extinct since 1788*
Animals			
Terrestrial mammals	268	225	19
Birds	777	350	(a)20
Frogs	203	189	3
Reptiles	770	685	—
Flowering plants	(b)20000	(b)17000	76

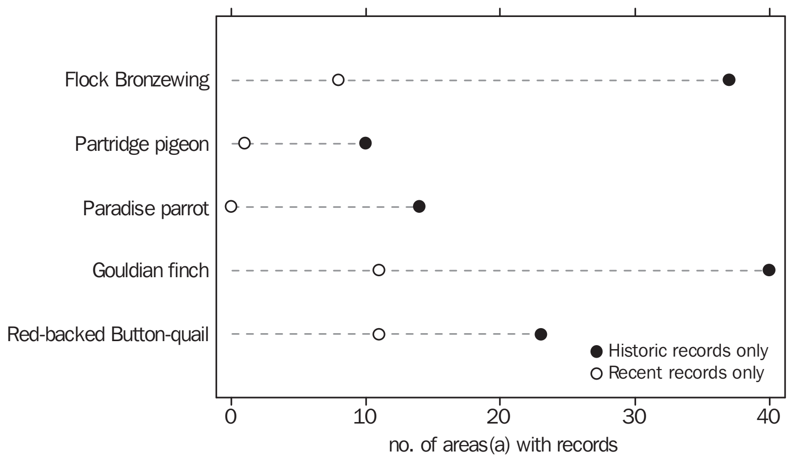
(a) Only one bird extinction is from the mainland Australia; the other 19 were from Norfolk Island.

(b) Estimated numbers.

Source: SoE 1996.

Declines in wildlife have occurred in most parts of Australia, even where tree clearing for forestry and agriculture is limited. For example, a study in northern Australia has found a significant decline in the range of five grain-eating birds (graph 2.32). As this part of Australia is more sparsely settled and has less agricultural and industrial activity than southern Australia it is often portrayed as being in good environmental condition. However, while the level of land clearing has been low to date, the extent of cattle grazing is great and fire regimes have been altered. These factors are possible reasons for the decline in abundance of grain eating birds, suggesting that threats to biodiversity may also result from less intensive uses of land.

2.32 DECLINE OF GRAIN EATING BIRDS IN NORTHERN AUSTRALIA



(a) Areas are cells of one degree of latitude and longitude.

Source: Franklin 1999.

Protection of natural and cultural heritage

In Australia, the chief responsibility for the conservation of natural heritage lies with the Commonwealth Government and the State and Territory Governments. Conservation reserves are central to conservation strategy; some 524,100 km^2, around 6.8% of land, is in public conservation reserves (table 2.33). An additional 10,800 km^2 is in Aboriginal freehold National Parks. Including other types of crown land dedicated at least in part to nature conservation, the area in conservation reserves is 597,527 km^2 or 7.8% of the area of Australia (Cresswell and Thomas 1997). The area and percentage of land in conservation reserves vary across States/Territories. The State with the largest area of land in conservation reserves is South Australia with 203,700 km^2. The Australian Capital Territory has the smallest area (1,200 km^2), but the highest percentage of land in reserves (50%). The Northern Territory has 2.1% in nature reserves, the lowest percentage, but has an additional 0.8% in Aboriginal freehold-National Parks and is the only State or Territory with this type of National Park.

2.33 AREA OF CONSERVATION RESERVES—1993

State/Territory	*Total land area* '000 km^2	*Conservation reserve area* '000 km^2	*Conservation reserve area* %
NSW	801.6	38.1	4.8
Vic.	227.6	30.6	13.4
Qld	1 727.0	54.2	3.1
SA	984.0	203.7	20.7
WA	2 525.0	155.0	6.1
Tas.	67.8	13.5	19.9
NT	1 346.2	(a)27.8	(b)2.1
ACT	2.4	1.2	50.0
Total		**524.1**	**6.8**

(a) The NT has a further 10.8 thousand km^2 in Aboriginal freehold National Parks.

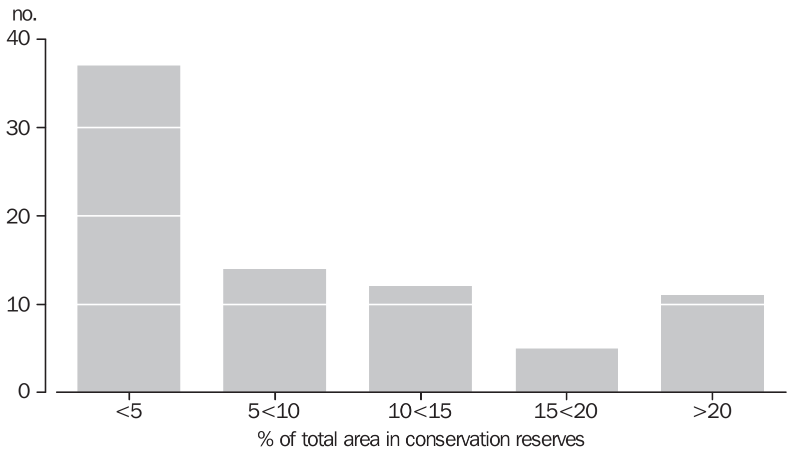
(b) The NT has a further 0.8% of land in Aboriginal freehold National Parks.

Source: AUSLIG 1993.

Not all environments are represented equally within conservation reserves. For example, of 80 Interim Biogeograhic Regions of Australia (IBRA, see Thackway and Cresswell 1995), 37 have less than 5% of their area in conservation reserves, 12 have less than 1% and two have no area in reserves (graph 2.34). Similarly, the percentage of each forest type within public conservation reserves varies: only 2.2% of Acacia forests are in reserves compared to 22.7% of Rainforests (table 2.35).

Protection of natural and cultural heritage *continued*

2.34 IBRA(a), Number by Proportion of Area in Conservation Reserves



(a) Interim Biogeographic Regions of Australia (IBRA) were developed in 1994 to identify gaps and to assist in allocating priorities for funding to projects for biodiversity conservation. It divides Australia into 80 biogeographic regions representing major environmental units, and is the only continent-wide regionalisation agreed to by all States and Territories. See Thackway and Cresswell (1995) for more details.

Source: Environment Australia CAPAD database 1997.

2.35 NATIVE FOREST TYPES, Total Area and Conserved Area

Forest type	*Total area* '000 ha	*Conserved area* '000 ha	*Conserved area* %
Acacia	12 298	276	2.2
Melaleuca	4 093	424	10.4
Rainforest	3 583	812	22.7
Casuarina	1 052	39	3.7
Mangrove	1 045	231	22.1
Callitris	867	69	8.0
Other	8 435	770	9.1
Eucalypt			
tall	6 543	1 469	22.5
medium	91 450	9 232	10.1
low	14 700	658	4.5
unknown	6	—	0.0
mallee	11 764	3 602	30.6
Total Eucalypt	*124 463*	*14 961*	*12.0*
Total	**155 835**	**17 580**	**11.3**

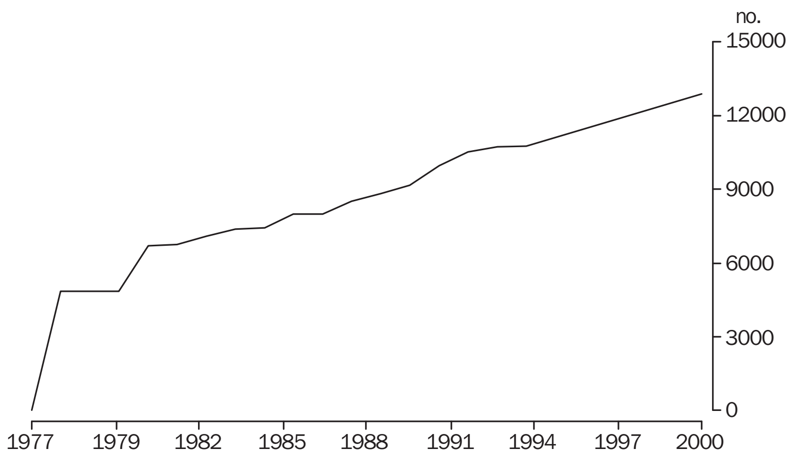
Source: NFI 1998.

Register of the National Estate

Special features of the natural, indigenous and historic environments were recognised in Australia by placing them on the Register of the National Estate. The Register has grown since its inception in 1977 to include 2,163 natural environments, 9,808 historic places and 911 Aboriginal places (AHC unpub.) (graph 2.36). Vegetation communities (totalling 423) and flora habitats (319) are the most common entries on the natural environment list (table 2.37). Listing on the Register means that the Commonwealth Government must consider the heritage value of a place before undertaking actions which will or may have significant adverse affects. The Commonwealth Government has recently changed its heritage protection regime and will compile a list of places of national heritage significance protected under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC*).

No new heritage places will be added to the Register of the National Estate, although Commonwealth actions which may significantly affect a listed place will still trigger a statutory response under section 28 of the *EPBC Act 1999*. The Register of the National Estate will be integrated into a Heritage Places Inventory, incorporating State and Territory heritage lists, and be accessible to the public through the Internet. The *EPBC Act 1999* also creates a Commonwealth Heritage list, which will comprise places managed by the Commonwealth Government.

2.36 ENTRIES ON THE REGISTER OF THE NATIONAL ESTATE—1977 to 2000



Source: Purdie 1997; AHC (unpub.).

2.37 NATURAL PLACES LISTED ON THE REGISTER OF THE NATIONAL ESTATE—2000

Type of place	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*External*	*Total*
Geological sites and areas	65	24	25	70	17	37	—	8	—	*246*
Landform sites and areas	20	11	38	3	13	17	6	2	—	*110*
Palaeontological sites	15	6	7	4	5	2	—	—	—	*39*
Vegetation communities	119	32	67	78	68	40	14	3	2	*423*
Wilderness	16	4	2	—	1	6	1	—	—	*30*
Coastal environments	38	14	30	23	14	11	1	1	2	*134*
Island environments	18	3	16	20	16	20	2	1	1	*97*
Marine environments	8	2	3	2	12	2	—	—	3	*32*
Alpine environments	4	18	—	—	—	10	—	—	—	*32*
Antarctic and Subantarctic environments	—	—	—	—	—	1	—	—	1	*2*
Arid environments	3	—	3	11	9	—	—	—	—	*26*
Semiarid environments	2	5	—	6	6	—	—	—	—	*19*
Subtropical environments	4	—	28	—	1	—	—	—	—	*33*
Temperate environments	8	50	—	11	14	16	—	2	—	*101*
Tropical environments	—	—	26	—	—	—	—	—	—	*26*
Wetlands and rivers	42	24	16	40	56	25	14	1	—	*218*
Soil sites	2	—	—	1	—	1	—	—	—	*4*
Fauna habitats	55	24	29	66	45	32	10	2	9	*272*
Flora habitats	85	23	26	50	74	30	20	10	1	*319*
Total number listed	**504**	**240**	**316**	**385**	**351**	**250**	**68**	**30**	**19**	**2 163**

Source: AHC unpub.

World heritage

Natural and cultural sites of 'outstanding universal value' may be entered on the list compiled by the World Heritage Committee. Places listed must meet strict criteria laid down in the World Heritage Convention. As of December 2000 there were 690 places listed on the World Heritage List. Australia has 14 of these (table 2.38), the last added in November 2000.

Countries that subscribe to the World Heritage Convention are required to protect and conserve the natural and cultural properties entered in the World Heritage List, for the benefit of current and future generations. The Australian Government is obliged to act in accordance with its international obligations to conserve World Heritage properties. This does not, however, prevent all activity: existing land uses can continue so long as they do not threaten the natural and cultural values of the property. For example, grazing occurs in the Willandra Lakes Region and Shark Bay, and fishing in the Great Barrier Reef.

Responsibility varies for the management of Australia's World Heritage properties. State agencies manage the Willandra Lakes Region, the Central Eastern Rainforest Reserves, Lord Howe Island, Shark Bay, the Australian Fossil Mammal Sites, and Fraser Island. Joint Commonwealth/State management is used for the Tasmanian Wilderness, the Great Barrier Reef and the Wet Tropics of Queensland. Uluru-Kata Tjuta and Kakadu National Parks are on Aboriginal land, with the day-to-day management of the Parks carried out by an agency of the Commonwealth Government (Environment Australia). Tourism is promoted at all of Australia's World Heritage properties.

World heritage *continued*

2.38 AUSTRALIAN WORLD HERITAGE SITES—2000

Place	*Year added to list*	*Values*	*State or Territory*
Kakadu National Park	1981	natural and cultural	Northern Territory
Great Barrier Reef	1981	natural	Queensland
Willandra Lakes Region	1981	natural and cultural	New South Wales
Tasmanian Wilderness	1982	natural and cultural	Tasmania
Lord Howe Island Group	1982	natural	External Territory
Central Eastern Australia Rainforest Reserves	1987	natural	Queensland and New South Wales
Uluru-Kata Tjuta National Park	1987	natural and cultural	Northern Territory
Wet Tropics	1988	natural	Queensland
Shark Bay	1991	natural	Western Australia
Fraser Island	1992	natural	Queensland
Fossil Mammal Sites (Riversleigh & Naracoorte)	1994	natural	Queensland & South Australia
Herald and McDonald Islands	1997	natural	External Territory
Macquarie Island	1997	natural	External Territory
Blue Mountains	2000	natural	New South Wales

Source: AHC 2000.

Conservation by non-government organisations

Conservation by individuals and non-government organisations is being encouraged by the various governments and a number of schemes encourage the use of private land for conservation. Most Australian States and Territories have a system whereby the government and landowners can enter into an agreement regarding the use of a particular area for conservation. In some cases landowners are rewarded financially for entering into land use agreements. The system and area covered by land use agreements, often called covenants, varies from State to State (table 2.39). The total area covered by covenants is around 0.1% of the total area of Australia.

2.39 AREA COVERED BY CONSERVATION COVENANTS ON PRIVATE LAND

	Covenants	*Area of covenants*	*Legal mechanism*	*Covenants negotiated per year*
	no.	ha		
NSW	40	5 000	National Parks and Wildlife Act	10–15
Vic.	230	8 000	Victorian Conservation Trust Act	20–30
Qld	11	—	Nature Conservation Act	Less than 10
SA	1 050	550 000	Native Vegetation Act	Less than 10
WA	—	—	Soil and Land Conservation Act	Program still developing
Tas.	—	—	National Parks and Wildlife Act	Program still developing
NT	2	11 000	Leasehold conditions	—
ACT	Unknown	Unknown	Leasehold conditions	Unknown
Total	**1 333**	**774 000**		**30–65**

Source: Binning and Young 1999.

Private conservation initiatives are few in Australia, but there are some companies and community groups that operate zoos or conservation reserves on private land. For example, Birds Australia has two reserves (Gluepot and Newhaven) with a combined area of around 316,990 hectares (Birds Australia 2000a & b). The public company Earth Sanctuaries Limited has 91,000 hectares in seven areas devoted to conservation (Earth Sanctuaries Limited 2000).

Tourism

Nature reserves provide opportunities for recreation and for tourism. The economic value of reserves for tourism is difficult to assess, but much of the tourism in Australia is based on natural and cultural heritage. Tourism is often promoted as an environmentally benign land use. There are, however, some impacts on the environment resulting from tourism. The infrastructure needed to support tourists—hotels, roads, sewerage works, walking trails—can have direct impacts on the landscape (e.g. loss of habitat, soil disturbance and increases in air and water pollution). For wildlife, frequent contact with people may alter the behaviour of wildlife, increasing risks to both people and animals.

The tourism sector makes a large contribution to Australia's economy. For 1997–98, the ABS Tourism Satellite Account shows that tourism contributed 4.5% of GDP. The 512,900 persons employed in tourism related activities at June 1998 represented 6% of all employed persons. In 1998, spending by domestic tourists totalled $43b, while international tourist spending was $17.3b, representing 15.1% of total export earnings (ABS 2000f). On average, each Australian undertook five trips per year, mostly for holidays (47%) or to visit friends and relatives (30%), and stayed away four nights on each trip. Residents of the ACT went away the most often (eight times) and those from Western Australia and South Australia the least (four times).

In 1999, there were 4,459,500 international visitors to Australia, with 16% coming from each of Japan and New Zealand. In 1999, average spending per person was about $4,000. Most international visitors (59%) intended to stay less than two weeks and only around 10% stayed more than two months (ABS 2001). Holidays were the main purpose of visits for over half (56%) of all international visitors.

2.40 VISITOR NUMBERS FOR SELECTED NATURAL ATTRACTIONS—1995

Natural attraction	*No. of international visitors*	*State/Territory*
The Blue Mountains	699 900	NSW
Great Barrier Reef	516 600	Qld
North Queensland Tropical Rainforests	272 800	Qld
Phillip Island/Penguin Parade	266 400	Vic.
Uluru (Ayers Rock)	209 300	NT
Green Island	193 300	Qld
Twelve Apostles/Great Ocean Road	130 900	Vic.
Kakadu National Park	99 400	NT
The Pinnacles	91 400	WA

Source: Blamey and Hatch 1998.

Tourism and recreation are important to Australia, but few areas are primarily dedicated to this land use. Most often tourism is a secondary benefit derived from natural areas, such as National Parks, dedicated primarily to the conservation of flora, fauna or other natural features. A number of natural attractions are of great interest to international tourists (table 2.40). National Parks, other natural attractions and favourable perceptions of rural and outback areas are factors considered when tourists decide to visit Australia. Tourism also occurs in some agricultural areas, such as wine growing districts (Dowling and Carlsen 1999).

Tourism *continued*

Nature based tourism is a significant component of the activities of international visitors. In 1995, 50% of international tourists visited a National Park or similar reserve during their stay (Blamey and Hatch 1998). Bush walking was also popular, with 19% of international visitors taking part in this activity while in Australia. The Blue Mountains (NSW) was the most visited natural attraction, with 699,900 international visitors in 1995.

In 1995 about 5% of international visitors indicated that their primary motivation for coming to Australia was to visit rural or outback areas (table 2.41). For about 7%, taking part in outdoor activities was the primary motivation. Visitors from Germany, the United Kingdom and Ireland had the highest percentage (16%) of people indicating that the primary motivation of their visit to Australia was to go to rural or outback areas, while Japanese visitors (28%) were the most likely to be motivated primarily by their desire to take part in outdoor activities.

2.41 PRIMARY MOTIVATION OF INTERNATIONAL TOURISTS—1995

	Visit rural or outback areas	*Outdoor activity*	*Total no. of visitors*
	%	%	'000
USA	13	12	287.9
Canada	3	3	55.0
UK and Ireland	16	12	335.4
Germany	16	10	119.8
Scandinavia	4	4	47.6
Switzerland	4	3	34.0
Other Europe	14	9	177.2
Japan	8	28	737.9
Other Asia	15	15	962.1
New Zealand	5	3	490.7
Other Countries	2	2	174.4
All nations	**5**	**7**	**3 422.0**

Source: Blamey and Hatch 1998.

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CHAPTER 3 THE USE AND QUALITY OF AUSTRALIA'S WATER RESOURCES

INTRODUCTION

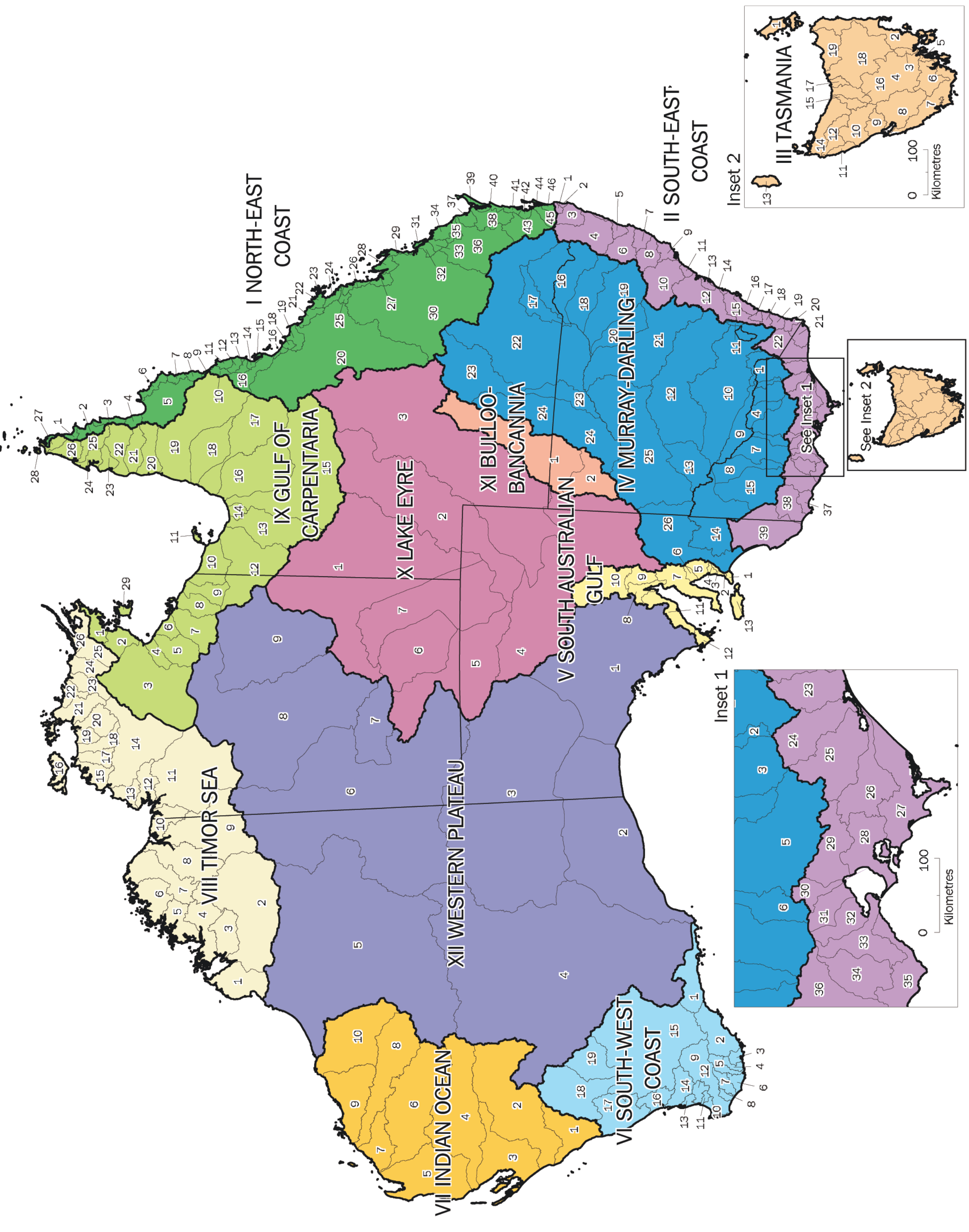
Inland waters, which include rivers, groundwater and wetlands, are an important resource in a dry continent such as Australia. There are many water related issues which could be covered. This chapter discusses the extent of Australia's water resources, their use and issues of river health degradation including changes to natural flow patterns, algal blooms, salinity and impacts on native freshwater fish populations. Most of Australia is classed as semi-arid or arid, with 80% of the continent receiving an annual rainfall of less than 600 millimetres and 50% of it receiving less than 300 millimetres. Parts of the northern, eastern, south-eastern and south-western regions of mainland Australia and areas of Tasmania receive much greater amounts of rainfall and run-off (McMahon et al. 1992). Differences in regional climate are due to elevation, precipitation and temperature. Upland areas (elevation greater than 500 metres) are characterised by lower temperatures and greater rainfall compared to lowland areas (elevation less than 300 metres, for inland systems) which have high temperatures and low annual rainfall (Thoms and Sheldon 2000a).

As a result of the predominantly flat nature of the continent, lowland rivers are dominant, covering a distance of 3,127 kilometres or 97% of the total length of Australian rivers (Thoms and Sheldon 2000a). About 83% of the lowland rivers are inland and occur in semi-arid areas. Semi-arid environments such as Australia are characterised by highly variable rainfall patterns. These patterns mean that the volume of water flowing through Australia's semi-arid rivers can change dramatically within and between years, resulting in large but infrequent floods. The highly variable nature of these river systems is an essential characteristic of the functioning of the ecosystem, as plants and animals have adapted their life cycles to changes in aquatic habitat related to the inundation of floodplains and wetlands.

As Australia's population and agricultural production have increased, so too has the development of water sources to ensure a reliable, stable water resource. Many dams and weirs have been constructed which regulate the flow in our inland rivers and wetlands. The extraction of groundwater also became a lifeline for many rural communities and groundwater is a major source of water in Perth, the capital city of Western Australia.

The inland water resources of Australia are an important economic resource. In 1996–97, 15,502 gigalitres of water were extracted for agricultural purposes. This represented 70% of net water use in Australia in that year. The Murray–Darling Basin, which contains a number of Australia's largest river systems, supports 42% of all Australian farms, with around 75% of Australia's irrigated agriculture located in the basin (MDBC 2000a). In 1996–97 the produce from the Murray–Darling Basin contributed around 43% of the total value of agricultural production. Based on average global values it has been estimated that ecosystem services of rivers, wetlands and floodplains in the Murray–Darling Basin alone are worth $187–302m per annum (Thoms and Sheldon 2000a).

3.1 DRAINAGE DIVISIONS AND RIVER BASINS



Source: AUSLIG and ARMCANZ

I NORTH-EAST COAST

1 Jacky Jacky Creek
2 Olive–Pascoe Rivers
3 Lockhart River
4 Stewart River
5 Normanby River
6 Jeannie River
7 Endeavour River
8 Daintree River
9 Mossman River
10 Barron River
11 Mulgrave–Russell Rivers
12 Johnstone River
13 Tully River
14 Murray River (Qld)
15 Hinchinbrook Island
16 Herbert River
17 Black River
18 Ross River
19 Haughton River
20 Burdekin River
21 Don River
22 Proserpine River
23 Whitsunday Island
24 O'Connell River
25 Pioneer River
26 Plane Creek
27 Styx River
28 Shoalwater Creek
29 Water Park Creek
30 Fitzroy River (Qld)
31 Curtis Island
32 Calliope River
33 Boyne River
34 Baffle Creek
35 Kolan River
36 Burnett River
37 Burrum River
38 Mary River (Qld)
39 Fraser Island
40 Noosa River
41 Maroochy River
42 Pine River
43 Brisbane River
44 Stradbroke Island
45 Logan–Albert Rivers
46 South Coast

II SOUTH-EAST COAST

1 Tweed River
2 Brunswick River
3 Richmond River
4 Clarence River
5 Bellinger River
6 Macleay River
7 Hastings River
8 Manning River
9 Karuah River
10 Hunter River
11 Macquarie–Tuggerah Lakes
12 Hawkesbury River
13 Sydney Coast–Georges River
14 Wollongong Coast
15 Shoalhaven River
16 Clyde River–Jervis Bay
17 Moruya River
18 Tuross River
19 Bega River
20 Towamba River
21 East Gippsland
22 Snowy River
23 Tambo River
24 Mitchell River (Vic)
25 Thomson River
26 Latrobe River
27 South Gippsland
28 Bunyip River
29 Yarra River
30 Maribyrnong River
31 Werribee River
32 Moorabool River
33 Barwon River
34 Lake Corangamite
35 Otway Coast
36 Hopkins River
37 Portland Coast
38 Glenelg River
39 Millicent Coast

III TASMANIA

1 Flinders–Cape Barren Islands
2 East Coast
3 Coal River
4 Derwent River
5 Kingston Coast
6 Huon River
7 South–West Coast
8 Gordon River
9 King–Henty Rivers
10 Pieman River
11 Sandy Cape Coast
12 Arthur River
13 King Island
14 Smithton–Burnie Coast
15 Forth River
16 Mersey River
17 Rubicon River
18 Tamar River
19 Piper–Ringarooma Rivers

IV MURRAY-DARLING

1 Upper Murray River
2 Kiewa River
3 Ovens River
4 Broken River
5 Goulburn River
6 Campaspe River
7 Loddon River
8 Avoca River
9 Murray–Riverina
10 Murrumbidgee River
11 Lake George
12 Lachlan River
13 Benanee
14 Mallee
15 Wimmera–Avon Rivers
16 Border Rivers
17 Moonie River
18 Gwydir River
19 Namoi River
20 Castlereagh River
21 Macquarie–Bogan Rivers
22 Condamine–Culgoa Rivers
23 Warrego River
24 Paroo River
25 Darling River
26 Lower Murray River

V SOUTH AUSTRALIAN GULF

1 Fleurieu Peninsula
2 Myponga River
3 Onkaparinga River
4 Torrens River
5 Gawler River
6 Wakefield River
7 Broughton River
8 Mambray Coast
9 Willochra Creek
10 Lake Torrens
11 Spencer Gulf
12 Eyre Peninsula
13 Kangaroo Island

VI SOUTH-WEST COAST

1 Esperance Coast
2 Albany Coast
3 Denmark River
4 Kent River
5 Frankland River
6 Shannon River
7 Warren River
8 Donnelly River
9 Blackwood River
10 Busselton Coast
11 Preston River
12 Collie River
13 Harvey River
14 Murray River (WA)
15 Avon River
16 Swan Coast
17 Moore–Hill Rivers
18 Yarra Yarra Lakes
19 Ninghan

VII INDIAN OCEAN

1 Greenough River
2 Murchison River
3 Wooramel River
4 Gascoyne River
5 Lyndon–Minilya Rivers
6 Ashburton River
7 Onslow Coast
8 Fortescue River
9 Port Hedland Coast
10 De Grey River

VIII TIMOR SEA

1 Cape Leveque Coast
2 Fitzroy River (WA)
3 Lennard River
4 Isdell River
5 Prince Regent River
6 King Edward River
7 Drysdale River
8 Pentecost River
9 Ord River
10 Keep River
11 Victoria River
12 Fitzmaurice River
13 Moyle River
14 Daly River
15 Finniss River
16 Bathurst and Melville Islands
17 Adelaide River
18 Mary River (WA)
19 Wildman River
20 South Alligator River
21 East Alligator River
22 Goomadeer River
23 Liverpool River
24 Blyth River
25 Goyder River
26 Buckingham River

IX GULF OF CARPENTARIA

1 Koolatong River
2 Walker River
3 Roper River
4 Towns River
5 Limmen Bight River
6 Rosie River
7 Mcarthur River
8 Robinson River
9 Calvert River
10 Settlement Creek
11 Mornington Island
12 Nicholson River
13 Leichhardt River
14 Morning Inlet
15 Flinders River
16 Norman River
17 Gilbert River
18 Staaten River
19 Mitchell River (WA)
20 Coleman River
21 Holroyd River
22 Archer River
23 Watson River
24 Embley River
25 Wenlock River
26 Ducie River
27 Jardine River
28 Torres Strait Islands
29 Groote Eylandt

X LAKE EYRE

1 Georgina River
2 Diamantina River
3 Cooper Creek
4 Lake Frome
5 Finke River
6 Todd River
7 Hay River

XI BULLOO—BANCANNIA

1 Bulloo River
2 Lake Bancannia

XII WESTERN PLATEAU

1 Gairdner
2 Nullarbor
3 Warburton
4 Salt Lake
5 Sandy Desert
6 Mackay
7 Burt
8 Wiso
9 Barkly

INTRODUCTION *continued*

Water resources are important for both economic and domestic purposes. Changes in land use and the economic development of river systems have degraded the health of many inland water bodies. Changes in land use for urban and agricultural purposes have reduced riparian vegetation and increased sedimentation and pollutants. The construction of dams has altered the physical and biological characteristics of many inland rivers, floodplains and wetlands. Changed flow regimes have had detrimental effects on the flora and fauna which inhabit freshwater ecosystems, reducing the abundance of some species and causing the extinction of others. For example, there has been a reduction in the abundance and diversity of native fish (Gehrke et al. 1995), and a reduction in populations of crayfish and mussels (Boulton 1999). In the Murray River, species of aquatic snails have become extinct as a result of changes to their food supply following the stabilisation of river levels (Sheldon and Walker 1997).

The water reforms of the Council of Australian Governments (COAG) have been a recent response to the deteriorating health of inland waters. These reforms seek to ensure that the State and Territory Governments manage water resources wisely and in the national interest. An important aspect of the COAG water reforms is the introduction of a cap on water diversions in the Murray–Darling Basin. This step is an effort to balance the socioeconomic and environmental goals of water management, and is discussed later in the chapter. Other issues discussed are water resources, consumption patterns and the impacts of water resource development on inland water ecosystems, with a particular focus on freshwater fish.

WATER RESOURCES

Surface water resources

Rainfall or water entering inland waters from a catchment is called run-off. There are 245 river basins which make up the twelve drainage divisions (map 3.1). Mean annual run-off in each of Australia's drainage divisions is detailed in table 3.2. Climate, vegetation and relief of the terrain are more important determinants of mean annual run-off than the surface area of drainage divisions. For example, the largely arid Western Plateau covers approximately 32% of Australia and produces only 0.38% of the total mean annual run-off. In contrast, temperate Tasmania represents 0.89% of Australia's drainage division surface area and produces 12% of the total mean annual run-off. Australia's low annual rainfall, combined high evaporation rates and the flat terrain of the country, produces a low annual run-off by world standards (Davies et al. 1994; Thoms et al. 1994).

Surface water resources *continued*

3.2 SURFACE WATER RESOURCES OF AUSTRALIA(a)

		Area	*Mean annual run-off*	*Mean annual outflow*
Drainage Division		km^2	GL	GL
i	North-East Coast	451 000	73 411	n.a.
ii	South-East Coast	274 000	42 390	40 591
iii	Tasmania	68 200	45 582	45 336
iv	Murray-Darling	1 060 000	23 850	5 750
v	South Australian Gulf	82 300	952	787
vi	South-West Coast	315 000	6 785	5 925
vii	Indian Ocean	519 000	4 609	3 481
viii	Timor Sea	547 000	83 320	81 461
ixi	Gulf of Carpentaria	641 000	95 615	24 748
x	Lake Eyre	1 170 000	8 638	n.a.
xi	Bulloo-Bancannia	101 000	546	—
xii	Western Plateau	2 450 000	1 486	n.a.
	Total	**7 680 000**	**387 000**	**208 000**

(a) Totals have been rounded.

Source: NLWRA 2001; ABS 1996b.

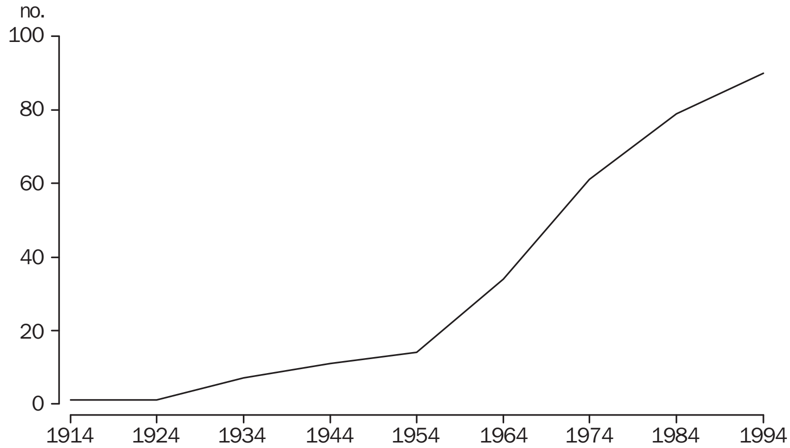
Dams

As human settlements and agriculture increased in the nineteenth century, so did the need for a reliable water resource. Australia's unpredictable climate produced substantial variability in river flows which could not support intensive settlement (MDBC 1990; McMahon et al. 1992). The construction of dams allowed the regulation and storage of flow and therefore a reliable water resource. Dams have many purposes, but they are built mainly to supply water for domestic, industrial and agricultural use. Other uses include flood mitigation, hydro-electricity generation, and recreational activities such as fishing and water skiing.

The period between 1914 and 1994 saw a large increase in the number of dams, and today Australia has around 90 major dams (those with a capacity of greater than 100 gigalitres). One hundred gigalitres is approximately the volume of water contained in 100,000 Olympic-size swimming pools (pools 20m x 50m x 1m deep). The 1950s began a period when the construction of major dams increased rapidly (graph 3.3).

Dams *continued*

3.3 NUMBER OF DAMS GREATER THAN 100 GL—1914 to 1994



Source: ANCOLD 1990; ABS 1996.

Groundwater resources

Groundwater is a vital water resource in Australia. In New South Wales alone, one million megalitres are consumed each year for agriculture and stock purposes, as well as industry, mining, urban and recreational purposes (DLWC 1997). A total of 791 Aboriginal and Torres Strait Islander communities in Australia (61%) use bore water as their main source of drinking water (ABS 1999). Groundwater underlies 60% of Australia (5,226,440 km ^{2}) and comes from geological formations called aquifers. The area of groundwater aquifers for each of Australia's twelve drainage divisions is shown in table 3.4. In 1987, around 29% of Australia's groundwater resources (including major and minor resources) was fresh, i.e. had a low amount of salt (less than 500 milligrams per litre) and 41% was marginal (500–1,500 mg/L of salt). Brackish (1,500–5,000 mg/L of salt) and saline (greater than 5,000 mg/L of salt) groundwater made up 19% and 11% respectively (AWRC 1987). Groundwater with salt concentrations less than 1,500 mg/L is suitable for human consumption and crop irrigation. Livestock prefer groundwater with low saline levels, but some stock can tolerate saline levels of up to 15,000 mg/L (ABS 2000). The salinity of groundwater has altered since the 1987 assessment, and a new assessment by the National Land and Water Resources Audit has been released in 2001. Salinity is discussed later in this chapter, as well as in Chapter 2.

Groundwater resources *continued*

3.4 GROUNDWATER RESOURCES OF AUSTRALIA

			GROUNDWATER RESOURCES		
		Area of Aquifer(a)	*Major resource(b)*	*Minor resource(c)*	*Total*
	Drainage Division	km²	GL	GL	GL
i	North-East Coast	114 250	2 010	865	2 875
ii	South-East Coast	71 660	1 860	1 490	3 350
iii	Tasmania	7 240	124	429	553
iv	Murray-Darling	908 500	2 160	1 520	3 680
v	South Australian Gulf	2 500	85	321	406
vi	South-West Coast	328 000	1 220	1 790	3 010
vii	Indian Ocean	487 400	508	1 160	1 668
viii	Timor Sea	328 900	2 820	3 410	6 230
ix	Gulf of Carpentaria	340 250	1 930	1 280	3 210
x	Lake Eyre	834 030	619	1 590	2 209
xi	Bulloo-Bancannia	90 100	100	67	167
xii	Western Plains	1 706 700	944	1 830	2 774
	Total(d)	**5 219 530**	**14 400**	**15 900**	**30 300**

(a) Includes surficial, sedimentary and fractured aquifers.

(b) A major groundwater resource is defined as a groundwater aquifer system capable of supplying sufficient water (500 ML per annum or more) to sustain a small town or irrigation development.

(c) A minor groundwater resource is an aquifer system not able to supply 500 ML of water per annum.

(d) Totals include Island Territories Drainage Division.

Source: AWRC 1987.

Wetlands

Wetlands are an important water resource for plants and animals (Environment Australia 2001). Wetlands can be of fresh or saltwater; they play a significant ecological role, providing habitats for various species as well as recycling nutrients. They also have important aesthetic, recreational and cultural values. As table 3.5 shows, there are 851 nationally important wetlands, covering just over 57.8 million hectares in Australia (Environment Australia 2001). These figures include freshwater, saline and coastal wetlands. Nationally important wetlands can have conservation, historical or cultural significance. To be considered nationally important for conservation, a wetland must support at least 1% of the national abundance of a particular plant or animal and play a significant ecological or hydrological role in the functioning of the ecosystem (Environment Australia 2001). Of the nationally important wetlands, approximately 21% are found in both Queensland and New South Wales, a further 19% are found in Victoria.

Wetlands *continued*

3.5 NATIONALLY IMPORTANT WETLANDS(a)

	Sites	*Area (approx.)*
Location	no.	ha
NSW(b)	178	2 334 734
Vic.(b)	159	557 888
Qld(b)	181	42 875 159
SA(b)	69	4 223 988
WA(b)	120	2 583 325
Tas.	89	51 514
NT(b)	33	4 033 230
ACT	13	1 257
External territories(b)	9	1 168 427
Total	**851**	**57 829 522**

(a) Includes freshwater, saline and coastal wetlands.

(b) Includes sites on Commonwealth lands.

Source: Environment Australia 2001.

WATER USE

Some 68,703 gigalitres of freshwater were extracted from Australia's environment for use in 1996–97. However, 49,480 GL (72%) were discharged back into the environment (directly to surface waters), as they were used in-stream, mostly for hydro-electric purposes. Net water consumption, which refers to the amount of water used and not discharged back to existing water bodies, was estimated at 22,186 GL in 1996–97. Around 70% (15,503 GL) of net water consumption was used for agricultural purposes (table 3.6).

Net water consumption between 1993–94 and 1996–97 changed little for most sectors of the Australian economy. However, the overall net water consumption of 22,186 GL in 1996–97 had increased from 18,575 GL in 1993–94 (table 3.6). A large portion of the increase in net water consumption can be attributed to the pasture industry, which includes the livestock, pasture, grains and other agricultural industries (ABS 2000). There were also notable increases in the use of water in the rice and cotton industries with smaller increases in use in the grapevine, fruit and vegetable industries.

A greater focus on efficient use of water has led to an increase in the volume of waste water reused. In 1996–97 approximately 134 GL of water was reused. Sectors using the most waste water were mining (31% of reused water) and agriculture (28%), while watering of parks and gardens accounted for 24% of reused water (ABS 2000).

WATER USE *continued*

3.6 NET WATER CONSUMPTION, By Sector—1993–94 and 1996–97

	NET WATER CONSUMPTION	
	1993–94	*1996–97*
Sector	GL	GL
Livestock, pasture, grains and other agriculture	6 525	8 795
Vegetables	536	635
Sugar	1 377	1 236
Fruit	570	704
Grapevines	446	649
Cotton	1 355	1 841
Rice	1 349	1 643
Services to agriculture, hunting and trapping; Forestry and fishing	21	19
Mining	591	570
Manufacturing	736	728
Electricity and gas	789	1 308
Water supply; Sewerage and drainage services	2 065	1 707
Other	511	523
Household	1 704	1 829
Total	**18 575**	**22 186**

Source: *ABS 2000.*

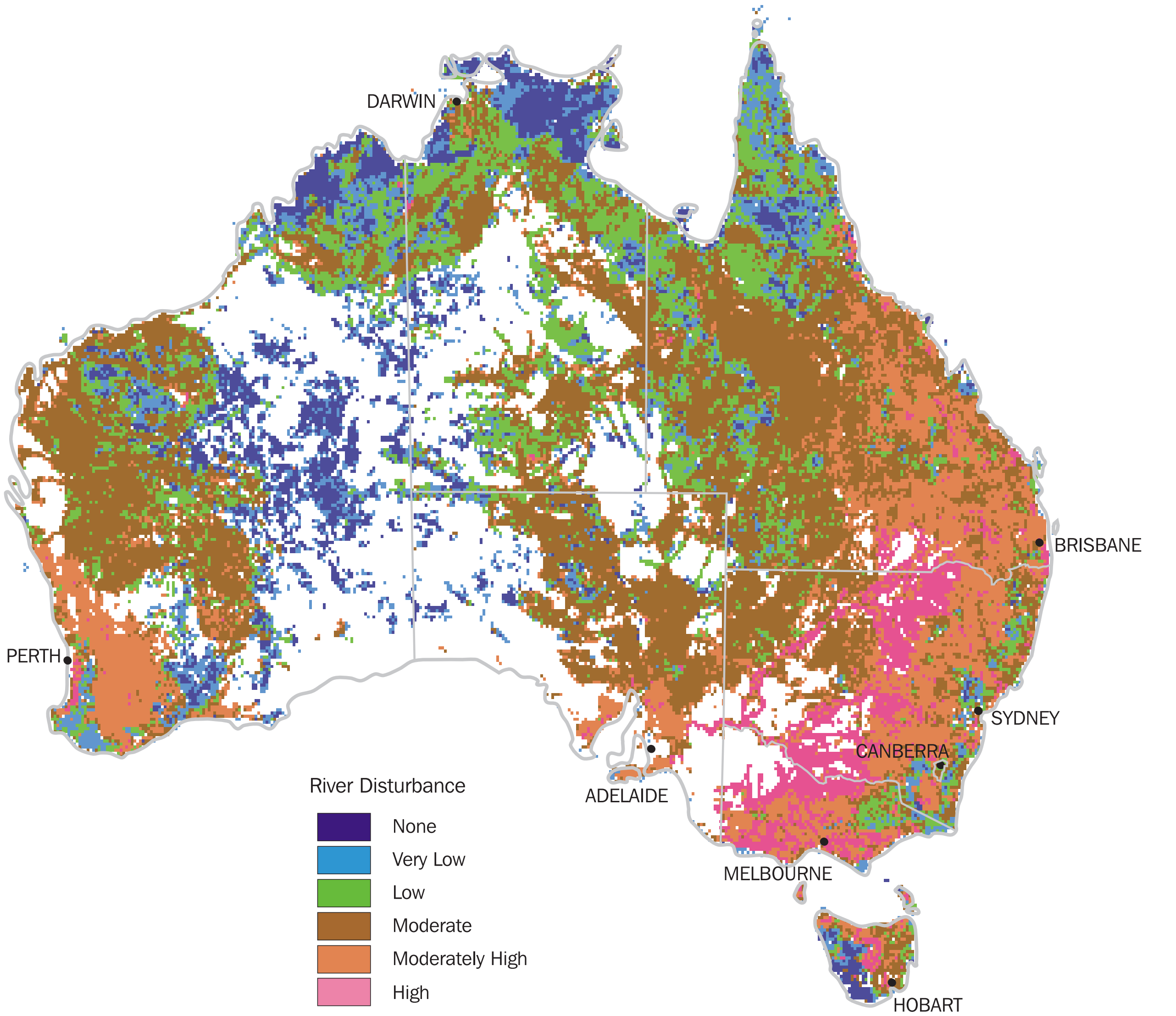
DEGRADATION OF AUSTRALIA'S RIVERS

Since European settlement, the rate at which Australia's varied landscapes and freshwater ecosystems has changed has accelerated. The development of water resources has led to changes in physical and biological characteristics of inland waterways and systems and to an overall decline in river health. These changes include the removal of riparian vegetation, degradation of river banks, sedimentation, the addition of pollutants and nutrients, the spread of exotic fish and aquatic weeds, and a loss of biodiversity. Excessive nutrient loads into waterways have contributed to severe algal bloom outbreaks, while irrigation and clearing for agriculture have worsened salinity problems on land and in our inland waters.

DEGRADATION OF AUSTRALIA'S RIVERS *continued*

The extent of river disturbance in Australian inland waters is illustrated by the Australian River and Catchment Condition Database (ARCCD) of Environment Australia (map 3.7). The ARCCD takes into account the main causes of disturbance, including nearby settlement, infrastructure, noted sources of pollution, land use, diversions of river flow, impoundments and levee banks. A large population is located in the Murray–Darling Basin. Its river systems are heavily regulated, and around 75% of Australia's irrigated crops are located in the basin (MDBC 2000a). The river systems in the Murray–Darling Basin are highly disturbed. Moderate to high levels of river disturbance occur around most State capital cities. Areas of minimal disturbance occur in the middle and upper regions of Western Australia and the Northern Territory, as well as in the western regions of Tasmania.

3.7 DISTURBANCE OF INLAND RIVERS



Source: Environment Australia 2000.

Changes in flow patterns and environmental effects

The operation of dams and water diversions has had an adverse effect on many Australian river systems. One of these effects is human-induced changes to flow patterns, which can degrade aquatic habitats and interfere with the life cycle of aquatic species. This section discusses the ecological effects of changing flow patterns on lowland rivers, which make up 97% of the total length of Australian river systems (Thoms and Sheldon 2000a).

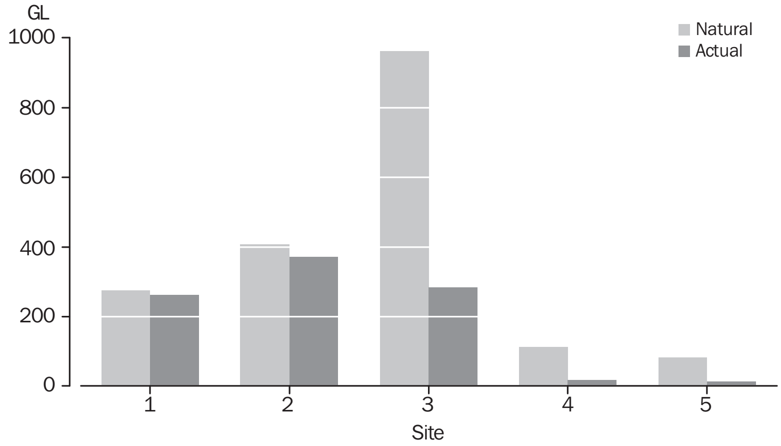
Around 83% of lowland rivers are inland systems, occurring in semi-arid and arid environments (Thoms and Sheldon 2000a). Native species have adapted to semi-arid lowland rivers. These are characterised by large infrequent floods, which create a highly variable flow pattern (McMahon et al. 1992). Important factors in the flooding characteristics of these systems include the timing, duration and magnitude of annual floods, time between floods and droughts over longer periods (i.e. from 1 to 100 years), and the overall characteristics of river flow, such as mean annual flows and the predicability of floods. Regulation of flow in lowland rivers has changed annual patterns of inundation from large, infrequent floods to smaller, more frequent floods. Flows in lowland rivers have become more predictable, an unnatural characteristic of semi-arid environments. This change has lowered the survival rate of some species and has affected the reproduction of others (Sheldon et al. 2000). For example, many of Australia's native fish species have been affected by stable flooding levels, which limit the availability of their habitats as well as migration and spawning cues. The changes to patterns of flooding have also helped the successful establishment of many exotic fish populations (Harris and Gehrke 1997). This is discussed later in this chapter.

Reductions in annual flows have also been found in other river systems across Australia. For example, under natural conditions the mouth of the Murray River would discharge 12,000 GL a year (Lewis 2000). By 1995, under regulated conditions, flows to the mouth of the Murray River were only about 20% of natural flows. Reduced river flows are also seen in a number of tributaries of the Murray (graph 3.8). At all sites actual flows are smaller than natural flows, but the magnitude of the difference varies. The difference in flows was minimal at Bandiana on the Kiewa River and at Wangaratta on the Ovens River, which are in the upper reaches of the Murray River. However, at McCoys Bridge on the Goulburn River, Rochester on the Campaspe River and Appin on the Loddon River the difference was great.

A reduction in flows has a number of environmental impacts. Wetting and drying of river channels are important in a semi-arid environment as they provide many and varied habitats (Boulton 1999). Dry periods are essential for nutrient regeneration, which occurs after the channel has been freshly inundated. Flooding events are important in the redistribution of leaf litter and woody matter, which is then trapped in aquatic plants to provide important food and shelter for aquatic species (Boulton 1999). A decrease in the size of flood events decreases the areas inundated in-stream, on the floodplain and in wetland areas. As a result, the types and availability of habitats are limited and the reproductive cues for some aquatic species are altered. A reduction in flows also leads to increased salinity levels and enhanced occurrences of algal blooms as stagnation occurs in low flows (MDBC 1995).

Changes in flow patterns and the environmental effects *continued*

3.8 NATURAL AND ACTUAL FLOWS, Selected Victorian Sites—1997–98



Sites: 1. Kiewa River at Bandiana; 2. Ovens River at Wangaratta; 3. Goulburn River at McCoys Bridge; 4. Campaspe River at Rochester; and 5. Loddon River at Appin.

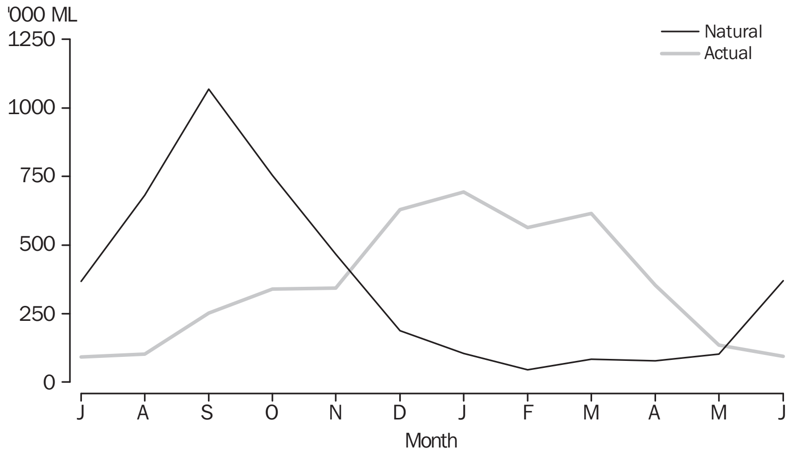
Source: MDBC 1999; 1997–98 Water Audit Monitoring Report.

Changes in seasonal flows are apparent in a number of river systems. For example, under natural conditions at Albury on the Murray River, peak flows occurred in September and were at a minimum level in February (MDBC 1995). Actual peak flows are somewhat reduced and occur in December and January, with minimum flows in July (graph 3.9). Changes in seasonal flow patterns and their effects differ from basin to basin. The main cause of their change is the storing of winter and spring flows to allow peak flows in summer when the need for water for irrigation purposes is increased (MDBC 2000b).

The combination of peak flows in summer and low flows in winter and spring not only affects the in-stream environment, but also floodplains and wetlands. It has resulted in a reduction in the diversity of aquatic organisms, together with reduced floodplain and wetland productivity (MDBC 1995; Kingsford 2000). This is a result of many wetland and floodplain systems becoming permanently inundated, upsetting the natural wetting and drying cycles. Water releases from storages are increased in summer and are quite often at a lower temperature than the water would be naturally, affecting the reproductive cycle of aquatic species (MDBC 2000b). For example, the Trout Cod, Macquarie Perch and Murray Cod, which are suited to warmer waters, have disappeared downstream of Dartmouth Dam on the Mitta Mitta River. The release of cold water during the spawning season of these species is thought to be implicated in their decline (Koehn et al. 1995).

Changes in flow patterns and the environmental effects *continued*

3.9 NATURAL AND ACTUAL FLOWS PER MONTH, Murray River at Albury—1998–99



Source: MDBC 2000.

There are many environmental effects of changing flow regimes resulting from the development of water resources. Changes in inundation patterns of floodplains and wetlands have altered biological and ecological processes, decreasing overall biodiversity and affecting the breeding patterns of wetland water birds (Kingsford 2000). Changes to river flow have affected the abundance of native fish (Gehrke et al. 1995), exacerbated bank erosion, decreased channel complexity and the available habitat for aquatic species (Thoms and Sheldon 1997).

Algal blooms

Algae are naturally occurring single-celled organisms. Only a few microns in size, the blue-green alga is a member of the plant *Phylum cynabacteria*. It is an important part of the food chain in both freshwater and marine environments. However, algal blooms are often indicative of a decline in the ecological health of freshwater systems. Outbreaks of algal blooms in Australian waters have been recorded as far back as 1878 (Flett and Thoms 1994). However, in the late twentieth century they became more abundant. Outbreaks are not caused by a single factor. They generally occur in calm waters such as lakes, reservoirs and rivers during droughts, when water storage and diversion practices have produced sustained periods of low flow rates. The addition of nutrients (i.e. nitrogen and phosphorus) from run-off containing fertiliser and stock manure, combined with low winds, bright sunlight and warm water temperatures, promotes the growth of algal blooms (Crabb 1997). High turbidity levels of Australian rivers mean that a large addition of nutrients does not always result in algal blooms (MDBC 2000b).

Algal blooms *continued*

Algal blooms can alter the physical and chemical characteristics of water, which can be dangerous for humans, livestock and wildlife. Three levels of algal blooms are generally reported in Australia: low (500–2,000 cells per millilitre); medium (2,000–15,000 cells/mL) and high (exceeding 15,000 cells/mL). Some algal species are non-toxic and pose relatively little threat to drinking or recreational water supplies. However, algae organisms such as *Microcystis*, *Anabaena*, *Nodularia*, and some cyanobacteria, can contain toxins such as hepatoxin, neutoxin and endotoxins (Flett and Thoms 1994). These toxins can cause liver damage or tumour growth, acute poisoning and paralysis in animals, and skin and eye irritation (Flett and Thoms 1994). More than one species can be involved in algal blooms. For example, in Tasmania a bloom in the Craigbourne Dam involved high concentrations of the toxic *Microcystis* algae (up to 440,000 cells/mL) as well as lower concentrations (97,000 cells/mL) of a non-toxic minor strand of *Anabaena circinalis* (DPIWE unpub.).

The location and frequency of algal blooms varies across Australia. All water storages in New South Wales have been affected to varying degrees (table 3.10). Four New South Wales storages played host to algal blooms for more than 70% of the time between October 1995 and August 1998. In a further six water storages, algal blooms occurred in 40–69% of the same period. Algal blooms are widespread in Victoria. In the 1999–2000 summer, approximately 23 different algal organisms contributed to blooms found in Victorian freshwater bodies (DNRE unpub.). The number of algal blooms changed from year to year and affected irrigation and recreational waterbodies more than town water supplies (graph 3.11).

3.10 ALGAL ALERTS IN NSW DLWC(a) STORAGES—October 1995 to August 1998

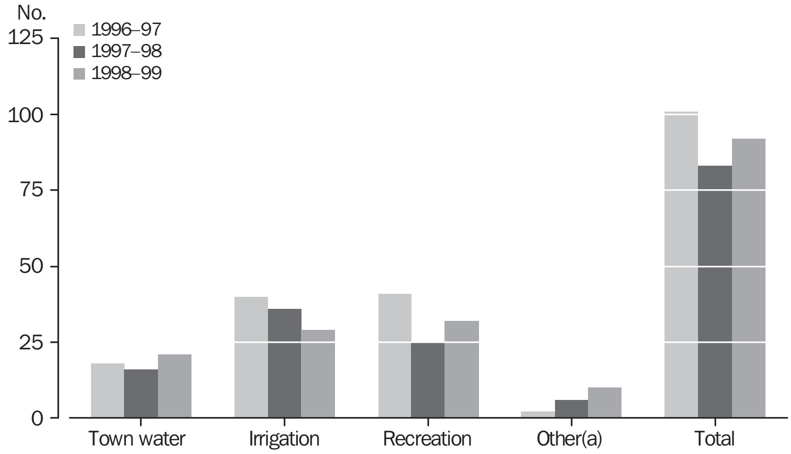
DLWC Storage	% of time with low concentration of algae (%)	% of time with medium concentration of algae (%)	% of time with high concentration of algae (%)	Total % of time with algae (%)
Windamere	9	13	66	88
Toonumbar	11	16	39	66
Carcoar	19	20	32	71
Lostock	23	20	28	70
Burrinjuck	15	18	25	58
Wyangala	22	9	18	49
Copeton	34	12	13	59
Pindari	13	6	13	33
Chaffey	50	16	12	79
Burrendong	26	13	10	48
Split Rock	24	8	9	40
Glennies	16	5	8	29
Lake Cargelligo	5	11	8	24
Keepit	18	11	5	34
Glenbawn	16	11	—	27
Tantangara	2	7	—	9
Hume	1	—	—	1
Average	18	11	17	46

(a) Department of Land and Water Conservation.

Source: LWRDCC 1999.

Algal blooms *continued*

3.11 VICTORIAN WATERBODIES AFFECTED BY RECORDED BLOOMS—1996–1999



(a) Other includes: domestic, stock, ornamental, industrial and wastewater.

Source: LWRRDC 1999.

Queensland has recorded algal blooms in approximately 45 dams and weirs since 1997 (DNR unpub.). In South Australia only algal blooms with a concentration greater than 20,000 cells/mL above the recreational guideline were reported. Eight such outbreaks were reported in 1999 and 2000, most lasting for entire summers (Australian Water Quality Centre unpub.). There were no algal bloom outbreaks in the ACT in 1999 (Environment ACT unpub.). This may be partly attributed to the tertiary treatment of wastewater at the Lower Molonglo Treatment Control Centre in Canberra, which removes 98% of phosphorus before the discharge reaches the river (Smith 1998). There were no major algal blooms in the Northern Territory in the last two years. Minor blooms in small impoundments on floodplains built to contain saltwater inundation were reported (NT DLPE unpub.). The small population of the Northern Territory (which constitutes about one sixth of the continent by area) has ensured that the Territory has remained relatively undisturbed by algal blooms.

Algal blooms incur a significant economic cost to the community, industry and government in both urban and rural areas. For example, the total management costs of freshwater algal blooms in Australia in the late 1990s were estimated at between $180m and $240m (table 3.12).

Algal blooms *continued*

3.12 COST OF FRESHWATER ALGAL BLOOMS IN AUSTRALIA—Late 1990s

Type of cost	*$m/year*
Joint management costs	9
Costs to extractive users	
Urban water supplies	35
Rural water supplies	
Stock and domestic water from farm dams	30
Stock and domestic water from rivers, storages and irrigation channels	15
Irrigation water supply	15
Total costs to extractive users	*95*
Costs to non-extractive users	76–136
Total	**180–240**

Source: LWRRDC 1999.

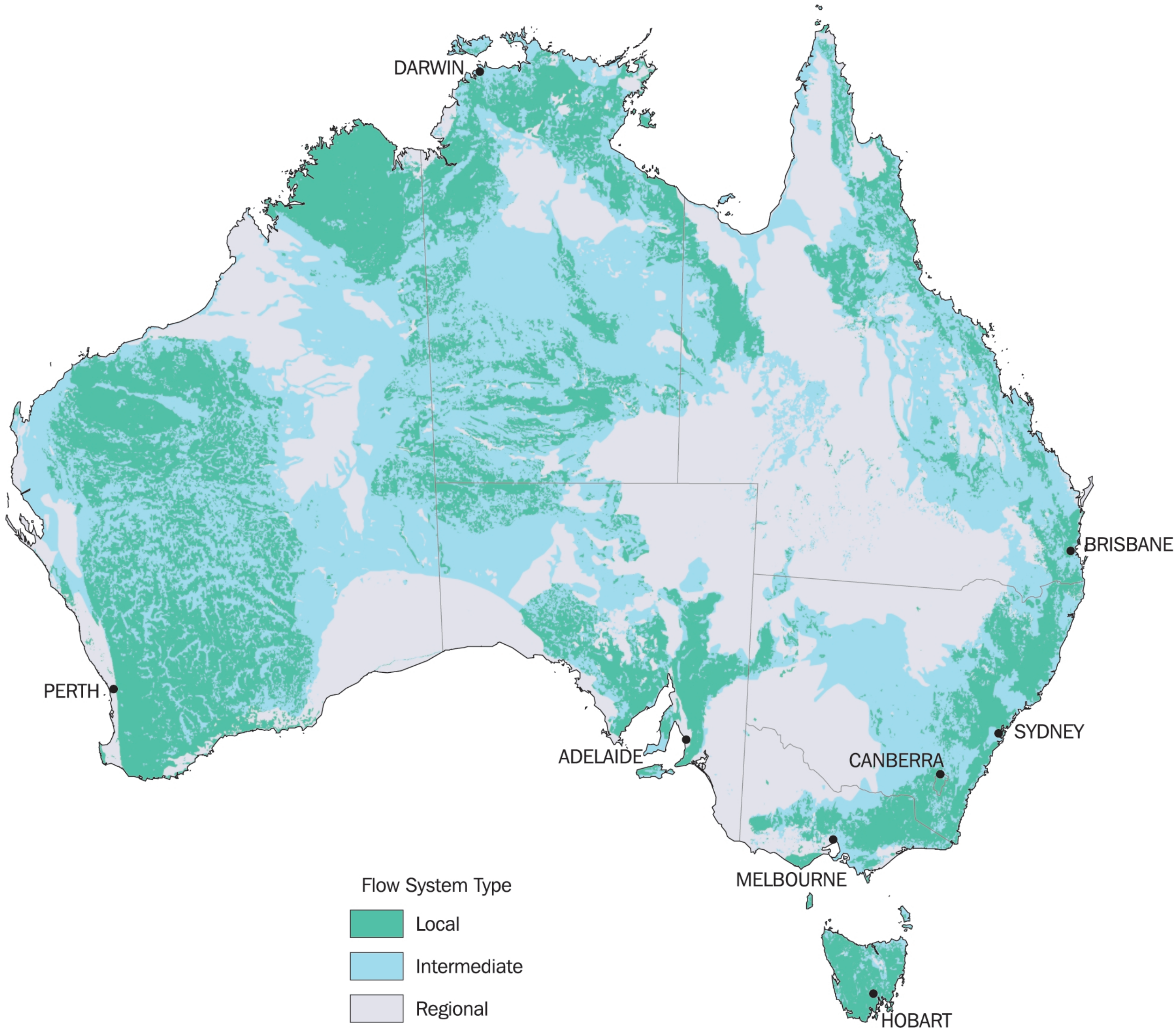
Salinity

About 60% of Australia's total area (454 million hectares) was used for agricultural production in 1999 (see Chapter 2). Since European settlement, water resource development and farming practices have contributed to a decline in the quality of our water resources. Increasing salinity is one of the major issues for Australia's land and freshwater environments.

In some parts of Australia, soils, geology, surface water and groundwater are naturally saline. However, the clearing of native vegetation and prolonged irrigation have caused the groundwater levels to rise and the naturally occurring salt loads to come to the surface (MDBC 1999b). This affects plant growth and results in excess salt loads being washed into the rivers with loose top soil or through direct seepage into the river system (MDBC 1999b). As a result of increased salinity levels in waterbodies, diversity of aquatic life can decrease and fringing vegetation can be adversely affected. This allows the successful invasion of salt-tolerant species such as the Tamarisk Tree, an environmental weed of semi-arid environments (Griffin et al. 1989).

Map 3.13 shows the character of groundwater flow systems in Australia (NLWRA 2000). Groundwater flows have been classified into three broad types of systems: local, intermediate and regional. These systems respond differently to agricultural and salinity practices. In areas where local groundwater flow systems are prominent (Western Australia, Tasmania and parts of South Australia and eastern New South Wales), water tables and saline discharges could be expected to rise within 20–30 years of initial agricultural development (NLWRA 2000). In areas which are dominated by intermediate groundwater flow systems, such as the Murray–Darling Basin and throughout Western Australia and the Northern Territory, it typically takes 50–100 years after initial agricultural practices for salinity to become evident. Finally, in areas with regional systems, saline discharges are not expected until 100 years after agricultural practices commence in that area.

3.13 AUSTRALIAN GROUNDWATER FLOW SYSTEMS(a)



(a) Groundwater flows significantly contribute to the risk of areas developing salinity. Local flow systems are more likely to develop salinity before regional flow systems.

Source: NLWRA 2000.

Salinity *continued*

South-west Western Australia is a good example of the impact of land clearance on the salinity of rivers (table 3.14). Prior to land clearance, rivers in this region were fresh to marginally saline during low flow periods (Government of Western Australia 1998). High levels of salinity occur in catchments where a large proportion of land has been cleared. For example, 24% of the Collie River catchment has been cleared, and the salinity levels in the Collie River are 790 milligrams per litre of Total Soluble Salts (TSS). The rate of salinity increase has been about 24 mg/L per year since 1965. In contrast, 56% of the Frankland River catchment is cleared, and it has a high level of salinity (2,760 mg/L TSS) and rate of increase of salinity (74 mg/L per year since 1965). The Waters and River Commission of Western Australia is working closely with the landowners to encourage reforestation in an effort to reduce salinity (Government of Western Australia 1998).

3.14 SALINITY LEVELS OF RIVERS IN CLEARED REGIONS OF WESTERN AUSTRALIA

River	*Proportion of catchment cleared (% in 1986)*	*Current Salinity in 1998*	*Trend rate of salinity increase since 1965*
	%	mg/L TSS	mg/L/yr
Frankland	56	2 760	74
Kent	40	2 087	58
Swan-Avon	75	5 835	(a)
Greenough	50	4 908	(a)
Blackwood	85	1 760	58
Collie	24	790	24
Murray	75	2 260	93

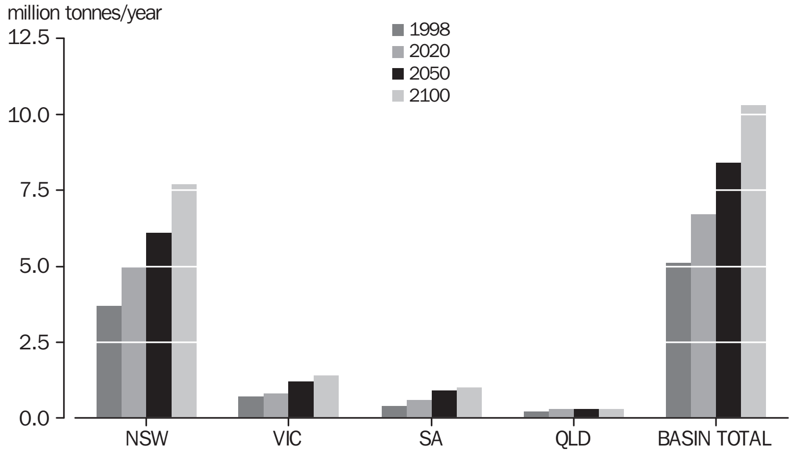
(a) Insufficient data to form trend.

Source: Government of Western Australia 1998; Water and Rivers Commission, WA.

The Murray–Darling Basin Commission has carried out a salinity audit of the basin which includes predictions to 2100 (MDBC 1999b). Graph 3.15 shows the estimated quantity of salt mobilised in the Murray–Darling Basin. In 1998 around 5.1 million tonnes of salt were mobilised for the whole basin, with just under 60% of this salt retained in the landscape. A steady increase in mobilised salt is predicted for all States with catchments located in the basin (MDBC 1999b). Over the next 100 years this is predicted to increase the salinity levels of some rivers of the Murray–Darling Basin (MDBC 1999b). The percentage of rivers with salinity levels that will exceed World Health Organization standards for drinking water (average salinity levels greater than 800 electrical conductivity units—see footnote (b) to graph 3.16) is expected to grow over the next 100 years.

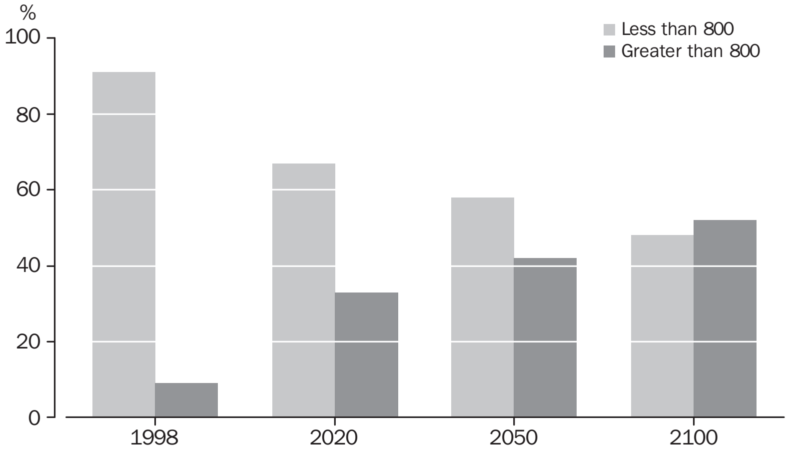
Salinity *continued*

3.15 ESTIMATED QUANTITY OF SALT MOBILISED, Murray–Darling Basin



Source: MDBC 1999b.

3.16 AUDITED RIVER SITES WITH SALINITY ABOVE OR BELOW 800EC(a)(b)



(a) The World Health Organization standards set the upper limit of salinity for drinking water at 800 EC units (see (b) below and glossary for more details of an EC unit). At 1,500 EC units, irrigation of rice, maize and grain crops should not take place and irrigation of leguminous pasture and forage crops is also risky. A waterbody which registers a salinity level of 5,000 EC units is classified as saline.

(b) EC = Electrical conductivity unit. 1 EC = 1 micro-Siemens per centimetre, measured at 25°C. It is used as a measure of water salinity.

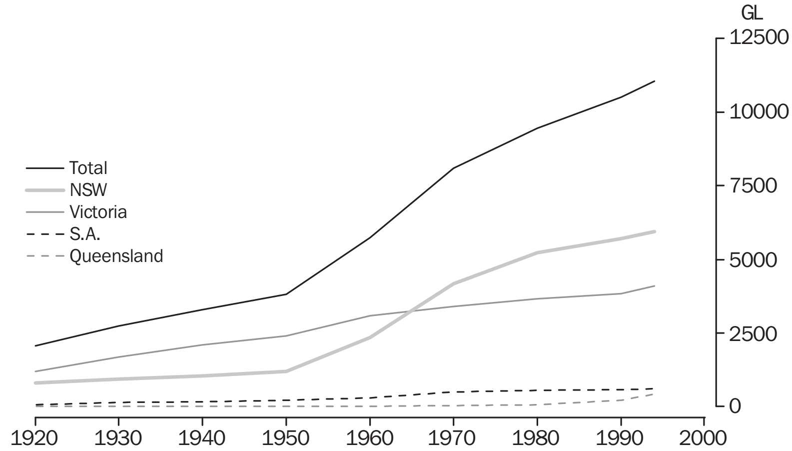
Source: MDBC 1999b.

WATER REFORMS: THE CAP

Since 1920 water diversions have steadily increased in the Murray–Darling Basin (graph 3.17). Simulated data show that water diversions substantially increased in the early 1950s. Between 1988 to 1994 there was an 8% or 792 GL/year increase in diversions. The greatest increases in diversions were in New South Wales (311 GL/year) and Victoria (240 GL/year) (MDBC 1995).

The Murray–Darling Basin is an important centre of agricultural production. In 1996-97, produce from the Murray–Darling Basin contributed 43% of the total value of agricultural production. About $3–4b of this is derived from irrigated commodities (MDBC 2000c). The river system is, however, showing signs of environmental stress: increased salinity levels in both land and water, loss of fish species and algal blooms.

3.17 GROWTH IN DIVERSIONS IN THE MURRAY–DARLING BASIN—1920 to 1994(a)



(a) ACT figures are included in NSW totals.

Source: MDBC 1995.

Development of water resources, which includes both the construction of dams and water diversion, has degraded the ecological and physical health of our river systems. The national scale of these problems led to the establishment of the Council of Australian Governments (COAG) water reform framework in the mid 1990s. This framework was designed to achieve the efficient and sustainable reform of water resources while allowing flexibility in the individual frameworks of each State. The water reforms focused on the following key areas: cost and pricing reforms; allocations and trading; institutional changes; environment and water quality; public education; and consultation.

To reduce the continual increases in water diversions and lessen the consequent environmental stress, a cap was placed on the volume of water that could be taken from the river systems in the Murray–Darling Basin (MDBC 1997, 1999c, 2000a). The Cap allocates different amounts of water to different States. For Victoria and New South Wales, the level was set at the volume of water that would have been used in 1993–94 given the infrastructure in place at that time. This is not the volume of water extracted in 1993–94, but a set percentage of this amount depending on the prevailing rainfall conditions during that year.

WATER REFORMS: THE CAP *continued*

In years of high rainfall, greater volumes of water can be used and vice versa. South Australia was permitted a slight increase over the 1993–94 level, while caps are yet to be set for Queensland and the Australian Capital Territory. The long-term cap, 1998–99 cap and actual water diversions in 1998–99 are shown for Victoria, New South Wales and South Australia in table 3.18.

States in which diversions have exceeded the long term cap by 20% on a cumulative basis trigger an independent audit of their water resource management. If the audit confirms that the long term cap has been exceeded by 20% that State is required to develop an action plan to reduce its water use to comply with the cap (MDBC 2000d).

The proportion of annual cap targets diverted each year varies between river systems across the basin. Diversions from the Lachlan and Murrumbidgee River systems exceeded the cap target in all years (graph 3.19). In the Namoi/Peel River system diversions exceeded the annual cap target by 43% in 1996–97, were 14% below it in 1997–98, and exceeded it by 3% in 1998–99 (graph 3.19).

3.18 CAP TARGET AND DIVERSIONS, Selected States—1998–99

State and river	*Long term diversion cap* GL	*Cap target* GL	*Diversion* GL
New South Wales			
NSW Murray	1 871	1 872	2 022
Murrumbidgee	2 186	(a)1 970	2 122
Lowbidgee	n.a.	n.a.	416
Lachlan	254	(a)276	282
Macquarie	464	n.a.	336
Namoi/Peel	251	(a)230	237
Gwdyir	403	n.a.	295
Border Rivers	195	n.a.	166
Barwon-Darling	177–192	n.a.	246
Lower Darling	86	236	153
Victoria(b)(c)			
Goulburn/Loddon/Broken	2 084	1 633	1 660
Murray/Kiewa/Ovens	1 656	1 732	1 742
Campaspe	122	78	73
Wimmera-Mallee	162	n.a.	n.a.
South Australia			
Adelaide			
Current year	n.a.	n.a.	152.9
Rolling 5 years	650	n.a.	599.4
Country towns	(d)50	n.a.	36.5
Irrigation(e)	524	n.a.	476.8
Total(f)	*(g)704*	*n.a.*	666.2

(a) Data calculated by climate-diversion model.

(b) Victorian data calculated by Annual Climate-adjusted Cap target.

(c) Does not include unregulated stream diversions.

(d) Under review.

(e) Includes private industrial, recreational, environmental, and stock and domestic.

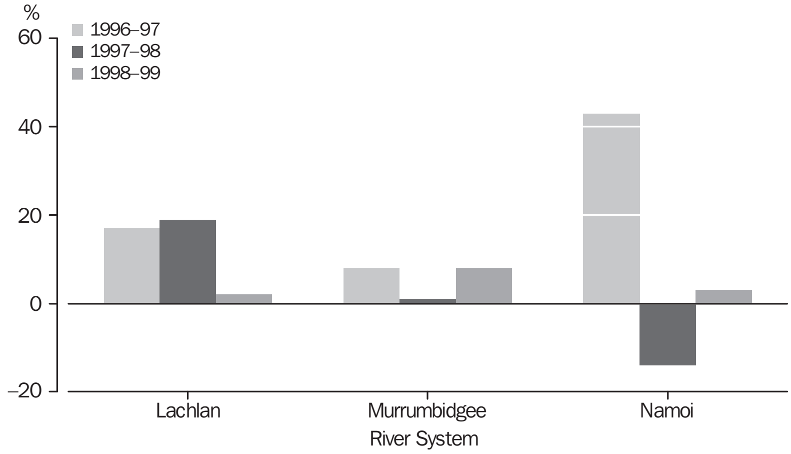
(f) Totals for SA do not include rolling 5 year figures.

(g) Total includes an approximate volume of 130 GL per year based on the rolling 5 year average.

Source: MDBC 1999c.

WATER REFORMS: THE CAP *continued*

3.19 EXTENT TO WHICH CAP TARGET IS EXCEEDED, Selected River Systems (a)(b)



(a) Cap Target=100%.

(b) Calculation: (Diversion/Cap Target x 100) – 100.

Source: MDBC 1998, 1999a, 1999c.

The development and implementation of the cap have slowed the increases in diversions and helped in the development of interstate water trading (MDBC 2000d). However, the current diversions and level of infrastructure on which the current cap targets are set contributed to environmental degradation in the past. It has been suggested that in order to evaluate the appropriateness of the cap there needs to be an investigation into the ecological impacts of the current cap. Information from this assessment could then be used to determine a cap that balances ecological and economic considerations (Whittington et al. 2000).

IMPACTS ON NATIVE FRESHWATER FISH POPULATIONS

Australia has around 195 native freshwater fish species, 90% of which are endemic (SoE 1996). A number of native fish species are threatened due to the pressures which human activities have placed on their populations and the environment (Davis et al. 2000). Forty-two freshwater species are listed as vulnerable, endangered and rare in Australia. There are 47 listings in total as the conservation status of some species varies between States (table 3.20). Seventeen species are endangered, 14 are rare and 12 are vulnerable (NFA 2000). The list includes four fish species whose conservation status is largely unknown.

Six major threats to our native freshwater fish species have been identified: habitat degradation; pollution; reduced environmental flows; barriers to fish migration; introduced species; and fishing pressures (Davis et al. 2000). The extent of each threat varies from State to State, with differences in water resources and urban development. While fishing pressures have played a role in the decline of fish populations, the modification and degradation of fish habitats have had the most substantial effect on fish populations.

3.20 CONSERVATION STATUS OF AUSTRALIA'S FRESHWATER FISH SPECIES

Family	*Species*	*Common Name*	*Distribution*	*Conservation Status*
MORDACHIDAE (SHORT HEADED LAMPREYS)	*Mordacia praecox*	Non-parasitic Lamprey	NSW	Poorly known (Aust.)
CLUPEIDAE (HERRINGS)	*Nematalosa erebi*	Bony Bream	Vic., NSW, Qld, NT, WA, SA	Rare (Vic.)
	Potamalosa richmondia	Freshwater Herring	Vic., NSW	Endangered (Vic.)
APLOCHITONIDAE (WHITEBAIT)	*Lovettia sealii*	Tasmanian Whitebait	Tas., Vic.	Rare (Vic.)
GALAXIIDAE (GALAXIAS OR NATIVE MINNOWS)	*Galaxias brevipinnus*	Climbing Galaxias	SA, Tas., Vic., NSW	Rare (Vic.)
	Galaxias cleaveri	Tasmanian Mudfish	Tas., Vic.	Endangered (Aust., Tas.)
	Galaxias fontanus	Swan Galaxias	Tas., Vic.	Endangered (Aust., Vic.)
	Galaxias fuscus	Barred Galaxias	Vic.	Endangered (Aust.)
	Galaxias johntoni	Clarance Galaxias	Tas.	Endangered (Aust., Tas.)
	Galaxias olidus	Mountain Galaxias	SA, Vic., NSW, ACT	Insufficiently known (Vic.)
	Galaxias pederensis	Pedder Galaxias	Tas.	Endangered (Aust., Tas.)
	Galaxias tanycephalus	Saddled Galaxias	Tas.	Vulnerable (Aust., Tas.)
	Galaxias truttaceus	Spotted Mountain Trout	WA, Tas., Vic	Rare (Vic.)
	Galaxiella pusilla	Dwarf Galaxias	SA, Tas., Vic	Vulnerable (Aust., Vic.), Rare (Susceptible (Tas.))
	Paragalaxias mesotes	Arthurs Paragalaxias	Tas.	Rare (Aust.)
PROTOTROCTIDAE (SOUTHERN GRAYLINGS)	*Prototroctes maraena*	Australian Grayling	Vic, Tas., NSW	Vulnerable (Aust., Vic., Tas.)
PLOTOSIDAE (EEL-TAILED CATFISHES)	*Tandanus tandanus*	Freshwater Catfish	SA, Vic., NSW, Qld	Vulnerable (Vic.)
ATHERINIDAE (HARDYHEADS OR SILVERSIDES)	*Craterocephalus eyresii*	Murray Hardyhead	SA, Vic., NSW	Vulnerable (Aust.), Rare (Vic.)
MELANOTAENIIDAE (RAINBOWFISHES)	*Melanotaenia eachamensis*	Lake Eacham Rainbowfish	Qld	Endangered (Aust.)
	Melanotaenia fluviatilus	Crimson-Spotted Rainbowfish	SA, Vic., NSW, Qld	Rare (Vic.)
	Melanotaenia pygmaea	Pygmy Rainbowfish	WA	Rare (Aust.)
PSEUDOMUGILIDAE (BLUE-EYES)	*Pseudomugil mellis*	Honey Blue-eye	Qld	Vulnerable (Aust.)
	Scaturiginichthyes vermeilipinnis	Red-Finned Blue-eye	NT	Endangered (Aust.)
SYNBRANCHIDAE (SWAMP EELS)	*Ophisternon candidum*	Blind Cave Eel	WA	Vulnerable (Aust.)
PERCHICHTHYIDAE (FRESHWATER BASSES AND CODS)	*Maccullochella macquariensis*	Trout Cod	Vic., NSW	Endangered (Aust., Vic.)
	Maccullochella peelii peelii	Murray Cod	SA, Vic., NSW, ACT, Qld	Vulnerable (Vic.)
	Maccullochella peelii mariensis	Mary River Cod	Qld	Endangered (Aust.)
	Maccullochella ikei	Eastern Cod	NSW	Endangered (Aust.)
	Macquaria ambigua	Golden Perch	SA, Vic., NSW, Qld, NT	Rare (Vic.)
	Macquaria australasica	Macquarie Perch	Vic., NSW	Endangered (Aust., Vic.)
	Macquaria novemaculeata	Australian Bass	Vic., NSW, Qld	Rare (Vic.)
TERAPONIDAE (GRUNTERS)	*Bidyanus bidyanus*	Silver Perch	SA, Vic., NSW, Qld	Vulnerable (Vic.)
NANNOPERCIDAE (PYGMY PERCHES)	*Edelia obscura*	Yarra Pygmy Perch	Vic.	Vulnerable (Aust., Vic.)
	Nannoperca oxleyana	Oxleyan Pygmy Perch	NSW, Qld	Endangered (Aust.)
	Nannoperca variagata	Ewen's Pygmy Perch	SA, Vic.	Vulnerable (Aust.), Endangered (Vic.)
ELEOTRIDIDAE (GUDGEONS)	*Hypseleotris compressa*	Empire Gudgeon	Vic., NSW, Qld, NT, WA	Rare (Vic.)
	Hypseleotris ejundida	Slender Gudgeon	WA	Poorly known (Aust.)
	Hypseleotris kimberleyensis	Barnett River Gudgeon	WA	Poorly known (Aust.)
	Milyeringa veritas	Blind Gudgeon	WA	Rare (Aust.)
	Mogurnda adspersa	Southern Purple-Spotted Gudgeon	Vic., NSW, Qld	Rare (Aust.), Endangered (Vic.)
	Mogurnda sp.2	Flinders Range Gudgeon	SA	Vulnerable (Aust.), Endangered (Vic.)
GOBIIDAE (GOBIES)	*Chlamydogobius micropterus*	Elizabeth Springs Goby	NT	Endangered (Aust.)

Source: Data compiled by Native Fish Australia with reference to the Endangered Species Protection Act 1992 Schedule 1 and the Deakin University Threatened Species list.

IMPACTS ON NATIVE FRESHWATER FISH POPULATIONS *continued*

Studies have shown that there is reduced species diversity in rivers where development of water resources and related modification of habitats have taken place (Gehrke et al. 1995). The construction of dams alters fish habitat by creating a barrier to fish movements, altering flow patterns and reducing in-stream environmental flows. For example, changes to stable flooding regimes and inundation patterns have allowed exotic fish species such as European Carp to dominate or outcompete native fish species, as native fish are less able to adjust to stable flooding. This has contributed to the decline of native fish populations in the lowland regions of the Murray and Murrumbidgee Rivers (Gehrke et al. 1995).

This section discusses introduced fish species in Australia, the effectiveness of fishways in dams, the characteristics of aquaculture production, commercial and recreational fishing as well as fish restocking in Australia's inland waters.

Freshwater aquaculture and environmental impacts

In 1997–98 freshwater aquaculture produced just under 4,000 tonnes of freshwater finfish and around 400 tonnes of freshwater crustaceans (table 3.21). These catches were worth $34m and $6m respectively. In 1997–98 freshwater finfish production comprised 23% of the total tonnage of aquaculture finfish and 18% of its value (Austasia Aquaculture 2000). Production of freshwater crustaceans comprised 17% of the total volume of production of aquaculture crustaceans and 14% of its value. Around 70% of the volume and 50% of the value of freshwater finfish production comprised the introduced Rainbow Trout (*Oncorhynchus mychiss*). Yabbies were the dominant crustacean produced.

Freshwater aquaculture takes a variety of forms, and the impacts on the environment vary with the scale, type and location of aquaculture. The most significant environmental impact from freshwater aquaculture is effluent from farms being released into natural waterways. This is because effluent from farming trout and salmon contains uneaten food and waste excreted by the fish, and is high in nutrients. The effects of these nutrients on water quality and aquatic life in rivers and streams are adverse and similar to the effects of effluent from a sewage treatment plant, though usually less severe (Metzeling et al. 1996). For example, increases in nutrients and suspended solids can lower dissolved oxygen levels and affect other aspects of water quality, and a net reduction in the number of invertebrate species in polluted sites may also occur. The scale of these effects will depend on the quality of the effluent released and a host of environmental factors, such as ambient water temperature and the nature of the waterway receiving the effluent. Effluent quality from aquaculture varies with stocking density (the number of animals kept per unit of area), and farming practices, such as the extent to which waste water is treated and diluted before being released. The high protein pellets fed to finfish also contain fish meal from bait fish (e.g. mackerel and pilchards), contributing to pressure on wild caught fisheries (see Chapter 4).

Freshwater aquaculture and environmental impacts *continued*

Some forms of freshwater aquaculture are more or less enclosed systems, with little release of waste water to the environment. In these cases, impacts from waste water will be minimal. Control and prevention of disease in freshwater farms and hatcheries sometimes entail the use of toxic therapeutics and/or antibiotics. The impacts on the environment from these practices are largely unknown. Like most farming activity, freshwater aquaculture also generates solid waste from packaging, such as plastics and foam.

Freshwater aquaculture has contributed valuable knowledge of Australia's native fish and has enabled managers to produce large numbers of native fish for restocking in waterways. This knowledge and practice may help prevent the loss of some native fish species. Display of native fish in aquariums also contributes to a broader understanding and appreciation of native freshwater fish as an important component of biodiversity.

3.21 FRESHWATER AQUACULTURE PRODUCTION—1997–98

	Commercial production	*Hatchery production(a)*	*Total value*
Species	tonnes	'000(b)	$'000
Finfish			
Chinook Salmon	n.a.	n.a.	n.a.
Brook Trout	1.3	—	8.7
Brown Trout	4.0	844.4	520.3
Rainbow Trout	2 736.1	457.2	17 445.8
European Carp	0.5	—	0.5
Australian Bass	—	396.5	111.0
Eel-tailed Catfish	—	18.1	19.0
Golden Perch	87.1	1 174.8	1 683.5
Silver Perch	165.3	678.9	1 773.1
Murray River	1.5	301.8	299.5
Eastern Cod	—	40.0	20.0
Short Finned Eels	200.3	. .	2 103.0
Long Finned Eels	18.3	. .	237.0
Barramundi(c)	633.4	—	6 999.1
Native aquarium fish	. .	129.6	307.8
Exotic aquarium fish	. .	5 081.1	2 477.3
Total freshwater finfish(d)	**3 847.8**	**9 122.4**	**34 005.6**
Crustaceans			
Marron	48.1	—	1 159.7
Redclaw	62.0	—	810.3
Yabbies	295.7	55.4	2 974.6
Brine Shrimp	3.5	. .	897.4
Freshwater Shrimp	—	10.0	3.0
Freshwater Prawns	—	58.9	7.3
Total freshwater crustaceans(d)	**409.3**	**124.3**	**5 852.3**

(a) Hatchery production not for sale to commercial farms (i.e. fingerlings sold to stock private dams and public waterways).

(b) Number of fingerlings ('000).

(c) Includes both freshwater and saltwater production.

(d) Totals have been rounded.

Source: Austasia Aquaculture 2000.

Commercial and recreational freshwater fisheries

Five Australian States (New South Wales, Victoria, South Australia, Tasmania and Western Australia) have commercial freshwater fisheries. In 1998–99 Western Australia freshwater fisheries took place only in the Ord River where an estimated 102–142 tonnes of Silver catfish were caught (WA Fisheries unpublished). South Australia had the largest catch, around 2,400 tonnes worth $6.3m (table 3.22). In Victoria and New South Wales, European Carp comprised about 72% and 49% respectively of the total catch (by weight) for each State. European Carp also featured strongly in South Australia, making up 23% of the total catch; the catches of Bony Bream and Pipis were larger, making up 29% and 27% respectively of the total catch. In Tasmania the short-finned eel made up a large portion of the freshwater catch for the 1998–99 season.

3.22 COMMERCIAL FRESHWATER FISHERIES—1998–99(a)

	NEW SOUTH WALES		VICTORIA		SOUTH AUSTRALIA		TASMANIA	
	Catch	*Value*	*Catch*	*Value*	*Catch*	*Value*	*Catch*	*Value*
Species	*kg*	*$*	*kg*	*$*	*kg*	*$*	*kg*	*$*
Murray Cod	20 600	427 100	—	—	8 000	165 000	—	—
Black Bream	—	—	—	—	3 000	30 000	—	—
Bony Bream	17 900	n.a.	—	—	687 000	608 000	—	—
Golden Perch	41 900	n.a.	1 600	17 800	155 000	1 971 000	—	—
English Perch	—	—	1 600	7 200	—	—	—	—
Silver Perch	—	—	100	1 500	—	—	—	—
Redfin Perch	2 700	15 500	—	—	—	—	2	Unknown
Yellow Eye Mullet	—	—	—	—	139 000	579 000	—	—
European Carp	108 600	167 800	283 700	219 700	552 000	807 000	—	—
Mulloway	—	—	—	—	95 000	570 000	—	—
Flounder	—	—	—	—	28 000	132 000	—	—
Australian Salmon	—	—	—	—	3 000	4 000	—	—
Pipi (Cockles)	—	—	—	—	635 000	1 068 000	—	—
Eel, short-finned	—	—	72 100	n.a.	—	—	59 809	323 425
Eel, long-finned	—	—	27 900	n.a.	—	—	—	—
Yabbie, freshwater	28 600	269 200	3 500	21 700	—	—	—	—
Fish unspecified	10	70	—	—	—	—	—	—
Mudeye (dragonfly larvae)	—	—	—	—	—	—	5 628 dozen	Unknown
Other(b)	20	n.a.	4 600	12 800	50 000	324 000	—	—
Total(c)	**220 300**	**879 600**	**395 100**	**280 700**	**2 355 000**	**6 258 000**	**(d)59 810**	**n.a.**

(a) NSW data relate to 1997–98.

(b) Other species for Victoria included Bony Bream, Murray Cod, Freshwater Goldfish, Gudgeons, Minnow, Mudeyes (Dragonfly larvae), Freshwater Mussel and Tench.

(c) Where figures have been rounded discrepancies may occur in totals.

(d) Excluding Mudeye.

Source: NSW Fisheries; Department of Natural Resources (Victoria); SARDI aquatic sciences (South Australia); Inland Fisheries Commission (Tasmania).

Recreational fishing is a popular pastime for many Australians and overseas visitors. Nationally 27% of recreational fishing expenditure is in freshwater bodies (McIlgorm and Pepperell 1999). There are differences in the percentage participation in freshwater and saltwater fishing between States. In New South Wales, Queensland, South Australia and Western Australia, greater than 72% of recreational fishing takes place in saltwater bodies. A Queensland study showed that 30% of around 640,000 fisherman participated in freshwater fishing (QFMA 1999). In Victoria, the Northern Territory and Tasmania, 40–45% of recreational fishing takes place in freshwater bodies.

Commercial and recreational freshwater fisheries *continued*

Recreational fishing in Australia's inland waters targets both native and exotic fish species (McIlgorm and Pepperell 1999). In New South Wales, Victoria and Tasmania a licence is required to fish in freshwater bodies. In Western Australia a licence is only needed to catch trout. Freshwater species fished for by recreational anglers vary from State to State (table 3.23). Crayfish (including both yabbies and marron), Brown Trout, Rainbow Trout, Black Bream and Murray Cod were among the most popular species caught by people participating in recreational fishing across Australia in 1998–99. In South Australia, nine of the eleven species caught by recreational fisheries are also caught by commercial fisheries. In New South Wales, Murray Cod and yabbies are targeted for both recreational and commercial fisheries. European Carp and Golden Perch are also popular species for both commercial and recreational fisheries in Victoria.

3.23 RECREATIONAL FISHERIES(a)

	NSW(b)	Vic(c)	Qld(d)	SA(e)	WA(f)	NT(g)	Tas(h)
Number of species caught by freshwater recreational fishing	6	5	>25	11	6	10	5
Number of anglers	>300 000	171 000	193 900	n.a.	33 236	14 566	29 690
Main targeted species	Murray Cod Golden Perch Australian Bass Rainbow Trout Brown Trout Yabby	Trout (49%) Redfin (38%) Murray Cod Golden Perch European Carp	Golden Perch Australian Bass Barramundi Catfish Crayfish/Yabbies Silver Perch Murray Cod Sooty Grunter Black Bream European Carp Trout	Golden Perch Murray Cod Bony Bream European Carp Redfin Mullet Mulloway Yabby Goolwa Cockle Flounder Black Bream	Marron Rainbow Trout Brown Trout Catfish Redfin Perch Black Bream	Archer Fish Catfish Barramundi Garfish Mouth Almighty Mullet Saratoga Sooty Grunter Spangled Perch Yabby	Brown Trout Rainbow Trout Brook Trout Atlantic Salmon Tiger Trout
Species targeted by both recreational and commercial fisheries	Murray Cod Yabby Golden Perch	European Carp Golden Perch	. .	Golden Perch Murray Cod European Carp Bony Bream Black Bream Mullet Mulloway Flounder Cockle	. .	. .	. .

(a) Includes some estuarine species.

(b) NSW Freshwater Recreational Fishery Report, data for 1998.

(c) Department of Natural Resources and Environment Victoria, data for 1996.

(d) QFMA 1999, data for 1998.

(e) SARDI, data for 1998/99.

(f) Western Australia Fisheries, data for 1996–1999, angler data for 1999.

(g) Coleman 1998.

(h) Inland Fisheries Commission, Tasmania, data for 1998–99.

Source: see footnotes.

Fish restocking programs

Fish stocking occurs in all States to help maintain freshwater fisheries and native fish. Fish restocking is monitored to manage three key aspects: native fish populations, exotic fish populations, and where native and exotic fish coexist. Although some stocking does occur directly in-stream, a large portion of stocking occurs in artificial impoundments where the management of fish populations can be monitored closely. This helps manage the risk to native fish from exotic fish populations. Exotic fish species may be spread without the permission of fisheries authorities, for example, as people fishing move about between fishing locations.

Of the total number of fish species stocked in the 1998–99 season, around half were native species. Over three million Golden Perch were collectively stocked in New South Wales, Victoria, Queensland and the Australian Capital Territory in the 1998–99 season. Australian Bass, Silver Perch and Murray Cod were also restocked with the addition of around 880,000, 540,000 and 396,700 fish respectively for each species (table 3.24). The remaining 50% of fish stocked were exotic trout and salmon species. Trout fishing is a very popular recreational activity in Australia. Many of the popular trout fishing areas are stocked to enhance the quality of recreational fishing. In the 1998–99 season over five million trout and salmon were stocked in Australian waters.

In South Australia stocking has taken place to re-establish two native species, the Southern Purple-Spotted Gudgeon (*Mogurnda adspersa*) and Agassiz's Chanda Perch (*Ambassis agassizii*). Apart from these activities, stocking was limited in South Australia in recent years due to recent flooding sequences, which proved beneficial for fish breeding (SARDI unpub.).

3.24 NUMBER OF FISH STOCKED IN INLAND WATERS—1998–99(a)

Species	*NSW(b)*	*Vic.(c)*	*Qld(d)*	*WA(e)*	*Tas.(f)*	*NT (Manton Dam)(g)*	*ACT(h)*	*Total*
Golden Perch	1 513 000	556 000	1 017 200	—	—	—	120 000	3 206 200
Silver Perch	459 900	17 000	64 500	—	—	—	—	541 400
Macquarie Perch	—	50	—	—	—	—	—	100
Murray Cod	210 000	161 600	15 100	—	—	—	10 000	396 700
Mary River Cod	—	—	48 200	—	—	—	—	48 200
Australian Bass	281 900	10 000	590 100	—	—	—	—	882 000
Saratoga	—	—	200	—	—	—	—	200
Sleepy Cod	—	—	11 600	—	—	—	—	11 600
Sooty Grunter	—	—	118 100	—	—	—	—	118 100
Barramundi	—	—	291 700	—	—	50 000	—	341 700
Trout Cod	129 000	30 700	—	—	—	—	—	159 700
Trout	3 041 500	(i)720 300	—	1 142 000	665 400	—	20 000	5 589 200
Chinook Salmon	—	(i)11 200	—	—	—	—	—	11 200
Atlantic Salmon	—	—	—	—	200	—	—	200
Total(j)	**5 635 300**	**1 506 900**	**2 156 800**	**1 142 000**	**665 700**	**50 000**	**150 000**	**11 306 500**

(a) 1999 data for Victoria, Western Australia, Northern Territory.

(b) NSW Fisheries.

(c) Department of Natural Resources and Environment Victoria.

(d) QFISH Freshwater Impoundment Management Systems, Queensland Fisheries Management Authority.

(e) Fisheries WA.

(f) Inland Fisheries Commission, Tasmania.

(g) Department of Primary Industries and Fisheries, NT.

(h) Environment ACT.

(i) Ainsworth 2000.

(j) Totals may not add to columns due to rounding.

Source: see footnotes.

Introduced fish species

A number of fish species have been introduced into Australia for ornamental or fishing purposes. Introduced fish species in Australian river systems are widely distributed with *Salmonidae* and *Cyprinidae* species prominent (table 3.25). Most other species are limited to one State or Territory, with some exceptions such as the Mosquito Fish and Redfin Perch (table 3.25).

Introduced fish species *continued*

3.25 INTRODUCED FISH SPECIES IN AUSTRALIA

Species	*Common name*	*Distribution*
SALMONIDAE (SALMONS, TROUTS & CHARS)		
Oncorhynchus mykiss	Rainbow Trout	SA, Vic., Tas., NSW, ACT, WA
Oncorhynchus tsawytscha	Chinook Salmon	Vic.
Salmo salar	Atlantic Salmon	Tas., NSW
Salmo trutta	Brown Trout	SA, Vic., Tas., NSW, ACT, WA
Salvelinus fontinalis	Brook Char	Tas., Vic., NSW
CYPRINIDAE (CARPS AND BARBS)		
Carassius auratus	Goldfish	SA, Vic., Tas., NSW, ACT, Qld, WA
Cyprinus carpio	European Carp	SA, Vic., Tas., NSW, ACT, Qld
Punius conchonius	Rosy Barb	Qld
Rutilus rutilus	Roach	Vic.
Tinca tinca	Tench	SA, Vic., Tas., NSW
CYPRINODONTIDAE (KILLIFISHES)		
Jordanella floridae	American Flagfish	Qld
POECILIIDAE (LIVEBEARERS)		
Gambusia holbrooki	Mosquitofish	SA, Vic., NSW, ACT, Qld, NT, WA
Gambusia dominicus	Domingo Mosquitofish	NT
Phalloceros caudimaculatus	One-spot Livebearer	WA
Poecilia latipinna	Sailfin Molly	Qld
Poecilia reticulata	Guppy	Qld
Xiphophorus helleri	Swordtail	Qld
Xiphophorus maculatus	Platy	Qld
PERCIDAE (PERCHES)		
Perca fluviatilis	Redfin	SA, Vic., Tas., NSW, ACT, Qld
CICHLIDAE (CICHLIDS)		
Cichlasoma nigrofasciatum	Convict Cichlid	Vic.
Cichlasoma octofasciatum	Jack Dempsey Cichlid	Vic.
Tilapia mariae	Black Mangrove Cichlid or Tilapia	Vic., Qld
Sarotherodon mossambica	Mozambique Cichlid	WA, SA, Vic., NSW, Qld
COBITIDAE (LOACHES)		
Misgurnus anguillicaudatus	Oriental Weatherloach	WA, SA, Vic., NSW, ACT, Qld

Source: Native Fish Australia.

Agricultural and water resource development practices have encouraged the spread of exotic fish populations in Australia. In some cases the introduction of an exotic species has seen the disappearance of particular native species in the area (Cadwaller 1996). Australia's native freshwater fish have adapted to the variable flow conditions which are characteristic of semi-arid environments (Davis et al. 2000). In a survey of fish species in NSW, it was found that the percentage of native fish was greater in unregulated rivers, ranging from 27% (Murray River region) to 100% (South Coast region). Results showed that flow regulation had lowered the resistance of native fish communities to competition from invading fish (Harris and Gehrke 1997).

Introduced fish species *continued*

In recent years studies have highlighted the detrimental effects of European Carp (*Cyprinius carpio*) on the native fish of Australia. The introduction of carp was documented in Sydney in the 1850s and 1860s and by the Geelong and Western District Acclimatisation Society in the 1870s (Barnham 1998). Under the *Fisheries Act 1958,* it became illegal to stock exotic fish species, and eradication programs were implemented. However, an illegal release of carp into Lake Hawthorn, Mildura, in the late 1960s undermined this initiative. Carp now make up 70–90% of fish species in the Murray–Darling River system (Crabb 1997). The appearance of carp is a sign of habitat degradation within the river system. Carp feeding strategies involve uprooting and killing aquatic plants which are important for native fish diets. In this process the carp disrupt the structure of the river bank and stir up sediments which free blue-green algae, enhancing nutrients. They also contribute to outbreaks of blue-green algae by preying on the species which feed on the algae (Crabb 1997). Increased sediments in the rivers disrupt the visual feeding patterns of native fish such as the Trout Cod (*Maccullochella macquariensis*) (Crabb 1997). To counteract carp numbers they are commercially fished in South Australia, Victoria and New South Wales (table 3.22).

Five species of the Salmonidae family have been introduced into Australia (table 3.25). The Brown Trout (*Salmo trutta*), which is distributed in all States and Territories except Queensland and the Northern Territory, was introduced to Tasmania from Europe in 1864 (Cadwaller 1996). The Rainbow Trout (*Oncorhynchus mykiss*), which is native to the Pacific coast of North America, was brought into the rivers of New South Wales from New Zealand in 1894. The Rainbow Trout also has a wide distribution, with established populations in every State except Queensland and the Northern Territory (table 3.25). The third salmonid species, the Brook Trout, originates from the north-east of North America and was introduced unsuccessfully in 1883 and again in 1962 to Tasmania. It is now distributed in Tasmania, Victoria and New South Wales. The Chinook Salmon, which is native to the west coast of North America and North-Eastern Asia, was introduced from California via New Zealand to be established in Victoria around 1877 (Cadwaller 1996). The Atlantic Salmon, which was released in Tasmania, Victoria and New South Wales in 1864, is distributed in Tasmania and New South Wales (table 3.25).

The introduction of trout species has had an adverse effect on many members of the Galaxidae family (Cadwaller 1996). Nine species of this family are considered to be at risk (table 3.20). Predation on galaxids by the larger sized adult trout, and competition for food when galaxids and trout are juveniles, has resulted in fragmented Galaxidae populations (Jones et al. 1990; Cadwaller 1996). In some studies the galaxids have been found higher upstream in areas which are inaccessible to trout, suggesting that isolation from trout increases the viability of their populations. This was thought to be a result of natural barriers in waterways (Cadwaller 1996). In summer low discharges, and abundant in-stream vegetation choking the channel, have also disadvantaged trout in some areas (Jones et al. 1990). However, trout remain a dominant introduced species in our freshwater systems due to the self-sustaining nature of their populations, as well as fish stocking, which takes place in areas lacking spawning conditions and where recreational pressures are great (Cadwaller 1996).

Effectiveness of fishways

Fishways have been put in place to counteract the barriers which dams and weirs have created. Dams and weirs restrict the movement of fish species upstream, interrupting their life cycles and limiting their distribution. For example, in the past, Golden and Silver Perch migrated extensively throughout the Murray–Darling Basin. However, with the construction of 2,900 barriers across the basin their migration patterns have been severely limited and they have disappeared completely between Yarrawonga Weir and Hume Dam in the Murray River (Crabb 1997). The main aim of fishways is to allow the movement of native fish between water bodies which have been separated by barriers. To achieve this aim it is necessary to provide a gently sloping structure with a low gradient which reduces flow speed and allows the fish to rest while climbing the structure (Crabb 1997). While a number of different fishway designs suit individual flow characteristics and fish species, all have disadvantages and advantages.

Within each State many of the fishways which have been constructed are ineffective and disadvantage native species (Crabb 1997). Table 3.26 shows the number of fishways in the inland rivers of Queensland, and their effectiveness. Around 32% of fishways in Queensland inland waters are effective. A further 16% are only partly effective, with 42% being ineffective. The effectiveness of a further 10% of Queensland fishways is unknown (DPI 2000).

3.26 EFFECTIVENESS OF FISHWAYS IN THE INLAND RIVERS OF QUEENSLAND

Fishway type	*Ineffective*	*Partly effective*	*Effective*	*Unknown*	*Total*
Vertical slot	1	2	5	1	9
Lock	—	1	2	—	3
Pool and weir	10	2	—	2	14
Submerged orifice	1	—	—	—	1
Rock ramp	1	—	3	—	4
Total	**13**	**5**	**10**	**3**	**31**

Source: DPI 2000.

Within the Murray–Darling Basin 22 fishways were constructed. However, due to their ineffectiveness they are being reconstructed to make them more suitable for native fish (Crabb 1997). In South Australia there are many fishways in rivers, estuaries and small tributaries. A major fishway on Lock 6 on the Murray River is indicative of problems with fishways. This fishway passes only one in 1,000 fish, being too steep for both exotic and native species (SARDI unpub.). In Victoria 1,100 potential barriers have been identified on inland rivers. There are only seven vertical slot fishways in these barriers, funding is available for the construction of a further eight fishways in 2000 (DNRE unpub.).

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CHAPTER 4 PRESSURES ON THE MARINE ENVIRONMENT

INTRODUCTION

As an island nation, Australia is economically dependent on its estuaries and seas for a number of important uses, including shipping and trade, offshore oil production, fishing, tourism and the disposal of waste. The coastline is about 32,000 km long, with an Exclusive Economic Zone (EEZ) covering approximately 200 nautical miles from Australia's shores (IMCRA 1997). It is beyond the scope of this chapter to comprehensively discuss all of the environmental presssures which affect this vast area. What is discussed includes production and management in Australia's Commonwealth fisheries, illegal fishing, aquaculture, shipping and ballast water discharges and selected aspects of marine pollution.

Australia's coastal and marine regions support some of the largest range and number of endemic marine species in the world (IMCRA 1997). Many of these marine and estuarine species are adversely affected by human activities occurring within the coastal region of Australia. Four out of 30 major Commonwealth managed commercial fisheries are overfished, with the status of another 15 uncertain (Caton et al. 2000a). Each year up to 90,000 tonnes of marine fauna and flora are caught unintentionally, and then often discarded, as a consequence of fishing gear and method of catch used in commercial fisheries (Harris and Ward 1999).

Shipping is an integral part of Australia's economy, with around 97% of the volume of trade carried by ships. As the majority of trade is carried by foreign vessels, the introduction of exotic marine organisms occurs in Australian waters, with 250 known species already introduced (Thresher 1999).

Marine pollutants are responsible for much of the degradation of Australia's coastal and marine environment. Pollutants include nutrients and pathogens from waste water discharges, marine debris, hydrocarbons and tributyltin from ships. Excessive nutrients cause the degradation of Australia's coastal wetlands system, with only half of Australia's 1,000 estuaries considered near pristine (NLWRA 2000). Hydrocarbons are sourced from shipping vessels, offshore drilling and stormwater discharges; around 3.2 million tonnes of hydrocarbons enter international waters each year (Minerals Council of Australia 1999).

Protection of Australia's marine species is vital to retain species diversity. Protection measures to reduce the impact of human activities on Australia's marine environment include the designation of marine protected areas, of which 38.9 million hectares had been listed by 1997 (Cresswell and Thomas 1997). Other protection measures include the introduction by the Commonwealth Government of the *Environment Protection Conservation Biodiversity Act 1999* and the development of threat abatement plans to manage species at risk of extinction.

FISHERIES MANAGEMENT

Fisheries production in Australia is a combination of commercial wildstock fisheries and farmed production (aquaculture). Australia has had mixed success with sustainably managed fisheries, four Commonwealth managed fisheries experiencing low fish stocks (Caton et al. 2000a). For many other fisheries, the detailed information to support accurate assessments of fish stocks is unavailable. Recreational and illegal fishing add to the pressure imposed by commercial fishing on fish populations in the Australian fishing zone.

Aquaculture is seen as supplementing wildstock fisheries, and contributed $602m or one third of the total value of fisheries production in 1998–99 (ABARE 2000). However, a number of negative environmental impacts are associated with aquaculture production. These include: the high demand for coastal foreshores, in direct competition with tourism, recreation and wetlands; increases in nutrient loads due to waste production; the high demand for wild capture fisheries such as pilchards and anchovies for aquaculture food stock; use of chemicals and antibiotics to control disease; the reduction of genetic diversity; and an increased risk of introducing exotic species and diseases through intentional mariculture introductions and the use of imported fishmeal (Zann 1995).

Fisheries production

Australia's Fishing Zone covers approximately nine million square kilometres, which ranks as the third largest fishing zone in the world, although Australia is ranked fiftieth in fisheries production in tonnes of fish landed (Caton et al. 2000a). Australia's commercial fisheries are generally classed as either wild stocks or aquaculture (farmed) stocks.

The State and Commonwealth fisheries produced 228,819 tonnes of fish in 1998–99 at a value of $2.04b (table 4.1). Western Australia accounted for the largest share of the value of fisheries production at $592m (29%) and people employed in the industry (20%). Victoria and the Northern Territory had the smallest share of the value of production with 4% each, and the smallest number of people employed (10% and 1% respectively). Commonwealth managed fisheries accounted for 20% of the total market share of the value of fisheries production, with the Northern Prawn Fishery the most valuable Commonwealth fishery. A significant proportion of Australia's fishery production (edible and non-edible) is exported and was valued at $1.5b in 1998–99 (ABS 2001). In the same financial year, 22,390 people were employed in the fishing industry, encompassing the fishing, aquaculture, seafood processing and fish wholesaling industries (ABARE 2000). The contribution of the fishing industry to GDP in 1996–97 was 0.16%, employment in the fishing sector accounting for just 0.001% of total employment (ABS 1999).

Fisheries production *continued*

4.1 FISHERIES PRODUCTION, VALUE AND EMPLOYMENT, By State—1998–99(a)(b)

	Production	*Value*	*Employment(c)*
	tonnes	$m	no.
New South Wales	21 777	121.5	3 950
Victoria	7 531	80.3	2 250
Queensland	29 652	241.6	4 254
South Australia	26 862	348.0	2 717
Western Australia	39 652	592.2	4 585
Tasmania	27 203	214.0	2 714
Northern Territory	4 107	82.0	292
Commonwealth	(d)77 052	(d)408.1	(e). .
Total	(f)**228 819**	(f)**2 038.5**	**22 390**

(a) State totals include estimates of aquaculture production but exclude hatcheries.

(b) Estimates.

(c) Employment figures at September 1998; they include employment in the fishing, aquaculture, seafood processing and fish wholesaling industries.

(d) Totals include all fisheries under federal jurisdiction.

(e) Commonwealth fisheries employment figures included in State totals.

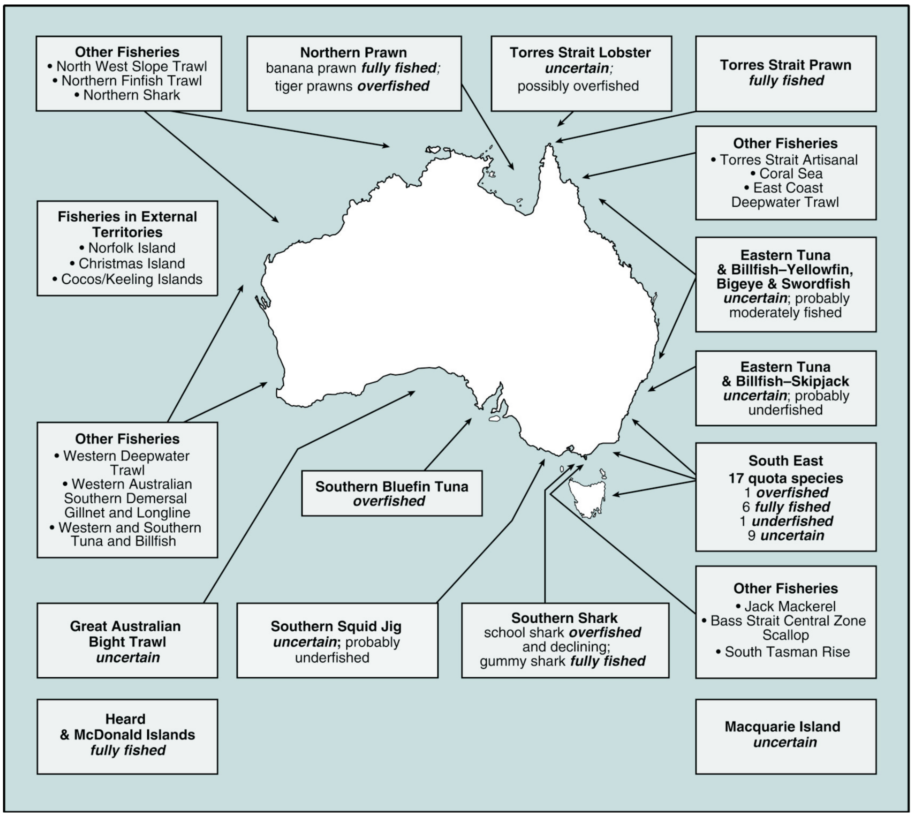
(f) Total has been adjusted to allow for southern bluefin tuna caught in Commonwealth Southern Bluefin Tuna Fishery, as an input to farms in South Australia.

Source: ABARE 2000.

Status of Commonwealth managed fisheries

Overfishing can occur when the catch rate exceeds the capacity of the natural population to renew itself through reproduction. This is commonly associated with the reproductive age of target populations or the targeting of populations at critical reproductive times (e.g. during spawning aggregations). Overfishing has occurred for some fish species such as southern bluefin tuna, eastern gemfish and tiger prawn in the Northern Prawn Fishery and the school shark. The Southern Bluefin Tuna Fishery and Southern Shark Fishery are explored in further detail in this section. In 1999, of the fish species caught by the major Commonwealth managed fisheries in Australia's fishing zone, 10 were fully fished, 1 was underfished, 4 were overfished and the status of 15 other fisheries was unknown (map 4.2) (Caton et al. 2000a).

4.2 LOCATION AND STATUS OF COMMONWEALTH MANAGED FISHERIES



Source: BRS 2000.

Combined production levels for Commonwealth managed fisheries have been increasing each year since 1995–96 (graph 4.3). This is in contrast to the Southern Shark Fishery for example, which has had declining production levels. Overfishing of the Southern Shark Fishery and the Southern Bluefin Tuna Fishery has required the implementation of total allowable catch limits and individual transferable quotas. This has been done to assist in the increase of fish stocks and achieve future economic return from these fisheries.

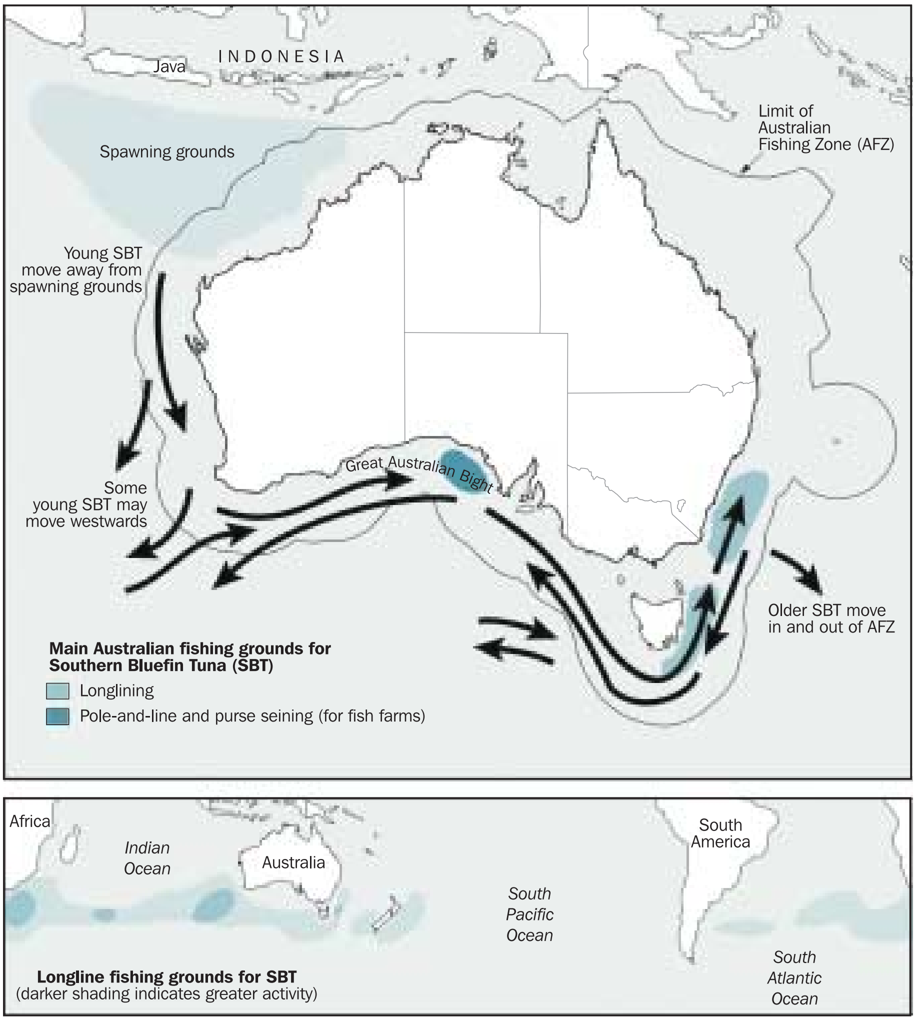
4.3 COMMONWEALTH MANAGED FISHERIES PRODUCTION

Source: ABARE 2000; ABS 1999.

Status of Commonwealth managed fisheries *continued*

A key example of the decline of a fish stock due to unsustainable fishing practices is the Southern Bluefin Tuna Fishery. Southern bluefin tuna are long-lived, slow growing and late maturing (8–12 years) which influences their ability to renew stock levels after commercial fishing. This fish species is highly migratory in the Southern hemisphere and is assumed to come from a single population. Southern bluefin tuna have only one spawning ground, located off the north-west coast of Australia, between Australia and Indonesia (map 4.4). This area is currently fished by Indonesian fishermen catching southern bluefin tuna as non-target catch during longline operations for other tunas (Robins et al. 2000).

4.4 SOUTHERN BLUEFIN TUNA FISHERY—1998

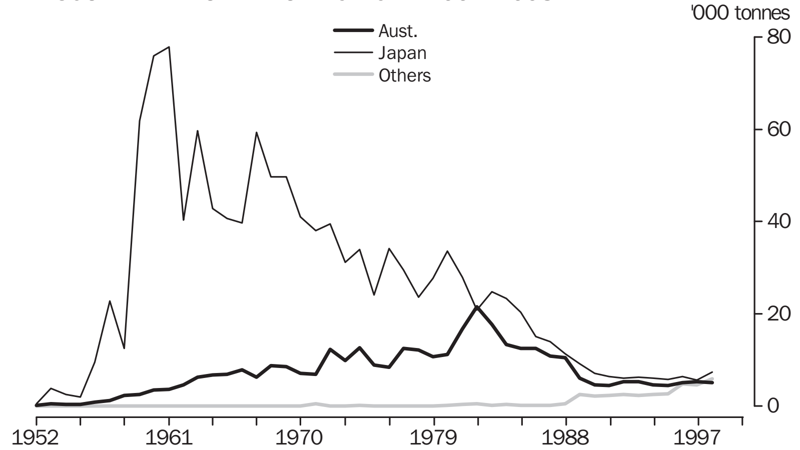


Source: BRS 2000.

Status of Commonwealth managed fisheries *continued*

The decline of southern bluefin tuna since the late 1950s saw the introduction of total allowable catch limits in 1983–84 in an attempt to increase fishery stocks (graph 4.5). The decline in the Southern Bluefin Tuna Fishery was highlighted in 1986–87, when the total allowable catch for Japan of 23,150 tonnes was not achieved and only 15,522 tonnes were caught (Robins et al. 1998). The period of lower catch since 1990 is due to the total allowable catch limits enforced by the signatories (Australia, Japan and New Zealand) under the Convention for the Conservation of Southern Bluefin Tuna (CCSBT). The increase of southern bluefin tuna catch by other fishing countries not bound by the convention (estimated at 6,270 tonnes in 1998) and increased catches by Japan under its experimental fishing program, has been seen by some parties as undermining the restrictions set for southern bluefin tuna catch (Robins et al. 2000). Australia recently lifted (May 2001) a ban on Japanese tuna vessels entering Australian ports, in place since 1998, due to a dispute over Japan's experimental fishing program. Australia and Japan have agreed not to proceed with any experimental fishing programs contrary to decision procedures of the CCSBT. The implementation of a scientific research program for SBT is to enable a stock assessment and to set preliminary total allowable catch targets by October 2001 (Tuckey 2001).

4.5 SOUTHERN BLUEFIN TUNA CATCH—1952–1998



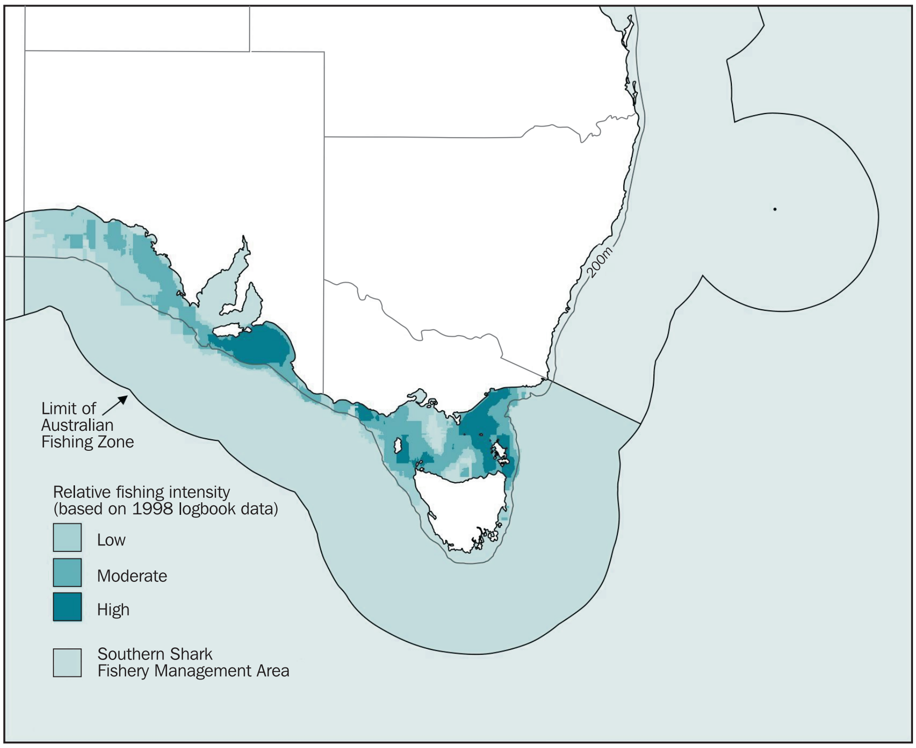
Source: BRS 2000.

In the Southern Shark Fishery (map 4.6), production from 1995 to 1997 was similar to production in the 1970s, yet required two to three times the fishing effort for the same amount of catch (graph 4.7). A slight increase in production levels after 1985 reflected the lifting of bans on larger school sharks. Bans were in place due to the accumulation of mercury in larger adults. A decrease in production levels is most likely related to the biology of the species. School sharks do not reach sexual maturity until 8–10 years of age and have a lifespan of over 50 years (McLoughlin et al. 1998).

The introduction of individual transferable quotas in 2000, to be phased in over five years, aims to reduce the catch of current fishing vessels and aid in the recovery of school shark stocks in Australian waters (McLoughlin et al. 1998; AFMA 2000). It is estimated that school shark catches need to be reduced by 20–30% to stabilise breeding stock to a healthy level in the next 15 years. Total allowable catch limits will apply to the complete Southern Shark Fishery to ensure that a reduction in catch limits of school sharks does not result in an increase in the gummy shark catch (AFMA 2000).

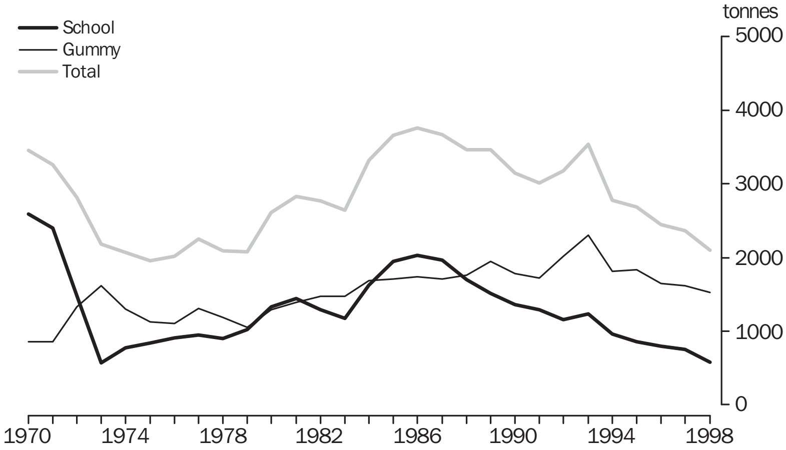
Status of Commonwealth managed fisheries *continued*

4.6 SOUTHERN SHARK FISHERY—1998



Source: BRS 2000.

4.7 SOUTHERN SHARK FISHERY CATCH—1970–1998



Source: BRS 2000.

Non-target catch

The composition of non-target species in Commonwealth managed fisheries is outlined in table 4.8. It is estimated that 50,000 to 90,000 tonnes of non-targeted catch are discarded (Harris 1998). The adverse ecological impacts of the catching and discarding of non-target species in Commonwealth managed fisheries are considerable, especially for the Northern Prawn and South-East Trawl Fisheries. These two fisheries are estimated to account for around 85% of the total non-target catch among Commonwealth fisheries. The Bass Strait Central Zone Scallop Fishery did not have any non-target species listed as of concern, with amount and composition of non-target catch unknown, but there may still be significant ecological effects on the environment due to the fishing gear used (dredging) and disruption of benthic (sea floor dwelling) communities (Harris and Ward 1999).

The composition of non-target catch includes a variety of plant and animal species including seaweed, seagrass, fish, sharks, crustaceans, molluscs, marine mammals, birds and reptiles. For example, fishing methods such as longlining have impacted on seabird populations, with an estimated 44,000 albatrosses caught in 1989 in Southern Oceans (Harris and Ward 1999). The catch of non-target species can change the ecological balance through the removal of predators, prey or competitors from the food chain. Discarding non-target species can change the ecological balance of marine ecosystems, redistributing food at different trophic levels and thereby changing the ecological relationships among species (Harris and Ward 1999).

Management methods being used in Australia's fishing zone to ensure no further degradation of fish stocks include limited entry to and closures of fishing areas, gear restrictions, restrictions to vessel size and allowable fishing area, the setting of individual transferable quotas, total allowable catch limits and restrictions on bycatch (Caton et al. 2000a). The formulation of the National Bycatch Policy, released in June 2000, aims to provide the framework to assist in the assessment and reduction of impacts of fishing on the marine environment. The Commonwealth Bycatch Policy builds on the national framework with the commitment to prepare bycatch action plans for all major Commonwealth Fisheries, these plans to be completed by March 2001 (AFFA 2000).

4.8 NON-TARGET CATCH IN COMMONWEALTH MANAGED FISHERIES(a)

Fishery	Amount (tonnes)	Composition (No. of species)	Discards (%)	Non-target species	Wastage	Ecological effects
Main						
Northern Prawn	30,000–60,000	~200	95	Turtles, snakes, sawfish,	***	***
Southern Bluefin Tuna	1,460	~50	83	Seabirds (albatrosses), sharks	*	**
South-East Trawl	25,000	~300	50–86	Seals, sharks	***	***
Medium						
Bass Strait Central Zone Scallop	?	?	High	None?	**	***
Torres Strait	4,000–8,000	~200	99	Turtles, snakes, sawfish, dugong	**(Trawling)	*** (Trawling)
Southern Shark	500–1,000	?	?	White shark, sea lions, seals	*	*?
Eastern Tuna and Billfish	1,520	~60	60 (longline)	Seabirds, sharks, turtles (low level)	*	*?
South-East Non-Trawl	?	?>67	?	Seals	*	*?
Great Australian Bight Trawl	?	?>52	?	None?	*	**
Minor						
Southern Squid Jig	Low, <18?	Few	—	Seals	—	?
Western Tuna and Billfish	?	? ~60	? >50	Seabirds, sharks, turtles (Low concern)	*	?
Jack Mackeral	Low, <10?	Few	—	Seals (Low concern)	—	**?
Western Trawl	?	? ~400	?	None?	*?	*
Macquarie Island	Low ? (tentative)	? >23	Little	Albatrosses, seals and penguins	—	***(#)

~ Approximate.

*** Substantial.

** Some.

* Few.

? Uncertain.

Precautionary concern because of closeness to a unique island reserve.

(a) Data mainly from 1995, although other periods between the mid-1980s and mid-1990s (Torres Strait) or 1970s (Southern Shark Fishery) have been used, depending on available data.

Source: Harris and Ward 1999.

Threatening processes—longlining

Longlining has been recognised as a process threatening to the non-target species of seabird populations and more specifically to albatrosses. For pelagic (mid-water set) longlining, a single longline can be up to 100 km in length, holding between 600 and 3,500 branch lines, each with a baited hook (Environment Australia 2000). Seabirds are attracted to the fishing vessels to scavenge bait from hooks, as well as offal and discarded catch. Often the seabirds become caught on submerging lines or hooks and are drowned.

In 1995, observers on longline vessels in the Southern Bluefin and Eastern Tuna and Billfish Fisheries sector recorded the number of marine species caught and discarded from these vessels. Of the 27 albatrosses caught in the Southern Bluefin sector, only 10 survived to be released (table 4.9). Of the petrels and other seabirds caught in both longline sectors, 29 birds were discarded from a total of 34 caught.

Threatening processes—longlining *continued*

4.9 MARINE WILDLIFE CATCH AND DISCARDS, Tuna Fisheries—1995(a)

	Southern Bluefin Tuna Fishery		*Eastern Tuna and Billfish Fishery*	
Marine wildlife	*Total*	*Discard*	*Total*	*Discard*
Albatross	27	17	4	—
Petrel	9	7	1	—
Other seabirds	4	3	20	19
Turtles	—	—	2	2
False Killer Whale	—	—	1	1
Seals	—	—	1	1

(a) Only includes total and discarded catch of non-target species in the longline sector of the Southern Bluefin Tuna and the Eastern Tuna and Billfish Fisheries.

Source: Harris and Ward 1999.

A threat abatement plan has been developed to reduce the number of seabird bycatch by longline fisheries to less than one bird per 20,000 hooks set. This would be a reduction by 90% of 1997 bycatch fishing levels. Fishing practices are being modified, particularly setting baits at night when seabirds are least active, and equipment changes such as hook modifications (Environment Australia 2000).

Recreational fishing

Commercial fisheries are not the only source of pressure on sustainable fishing practices in Australia. Recreational fishing is also very popular in Australian marine waters. Nationally, about 73% of recreational fishing occurs in marine waters (McIlgorm and Pepperell 1999).

The removal of fish and invertebrate species targeted by recreational anglers puts increased burden on fish stocks that are already targeted by commercial fisheries. Some fish species that are targeted by both recreational anglers and commercial fisheries include snapper, mackerel, whiting, shark, tuna, reef fish, lobster, abalone, mussel, crab and prawn (Caton et al. 2000b; McIlgorm and Pepperell 1999). The southern bluefin tuna is a prized catch by recreational anglers in the waters off Victoria, South Australia and Tasmania, but tends only to be available intermittently (McIlgorm and Pepperell 1999).

Difficulties in determining quantities of catch taken by recreational anglers have implications for fisheries management when calculating the sustainability of fish resources. Home production of fish caught in 1996–97 was estimated at 30,000 tonnes, which equated to 11% of total fisheries production in Australia for that year (ABS 1999).

The diverse array of fish species caught by recreational anglers needs to be monitored to ensure that overlap between commercial and recreational fishing does not reduce fish stocks to unsustainable levels. To assist in better management of the recreational and commercial fishing sectors, the Commonwealth Government has contributed $1.8m to the National Recreational Fishing Survey (Department of Environment and Heritage 1998).

Illegal fishing

Foreign fishing vessels in Australia's maritime zone can impact on the sustainability and management of Australia's wildstock fisheries, through illegal catch. Illegal fishing has the potential to deplete current fish stocks and interfere with catch limits set for specific fisheries in Australia's fishing zone. Protection of Australia's Exclusive Economic Zone is coordinated by Coastwatch, a division of the Australian Customs Service. Coastwatch coordinates a civil surveillance and response service covering Australia's coastline and maritime zone of nine million square kilometres. Customs vessels, Royal Australian Navy vessels, Customs Coastwatch aircraft and Royal Australian Air Force aircraft assist in responses to illegal incursions (Australian Customs Service 2000).

Illegal fishing has been detected in Antarctic waters, with a high level of illegal fishing posing a threat to the Patagonian toothfish and being responsible for the deaths of large numbers of seabirds (Australian Maritime Digest 1998a). In 1998–99, 299 foreign fishing vessels were identified as possibly in breach of Australia's fishing laws (table 4.10). An increase in funding (by $16m over four years) was allocated in 1998 for patrolling sub-Antarctic waters against illegal fishing (Australian Maritime Digest 1998b). Increased surveillance of this area may have acted as a deterrent to illegal fishermen, resulting in the reduction of potential fishing breaches from 1997–98.

4.10 COASTWATCH ACTIVITIES—1997–98 and 1998–99

	1997–98	*1998–99*
	no.	no.
Surveillance		
Flights	3 391	3 505
Flying hours	15 358	15 460
Patrolling days (RAN)	1 725	1 868
Flying hours (RAAF)	241	401
Australian Customs Vessels sea days	831	831
Vessel sightings	125 273	119 331
Foreign fishing vessels		
Total boarded	480	366
Potential breaches of fishing laws	980	299

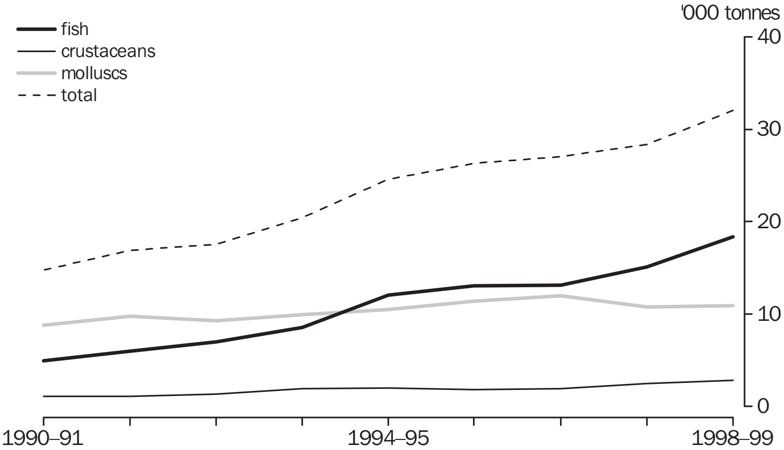
Source: Australian Customs Service 2000.

Aquaculture

Aquaculture is an emerging market for supplementation of wild fisheries in response to the global demand for seafood. Globally, the production and value of aquaculture have more than doubled in the past decade (Preston and Rothlisberg 2000). There are, however, a number of environmental concerns associated with aquaculture development in Australia. Very few coastal sites are suitable for aquaculture development, key requirements being pristine areas and good water quality. These areas are often near regions of high conservation value, conflicting with their use for environmental and recreational purposes (Cordover et al. 2000).

The majority of the aquaculture industry is near shore or on land-based sites within the coastal zone, with only around 10% of aquaculture derived from freshwater species (Preston and Rothlisberg 2000). In Australia, total aquaculture production and value have increased from 14,773 tonnes and $221m in 1990–91 to 32,080 tonnes and $602m in 1998–99. The value of production in 1998–99 represents around 30% of the total value of fisheries production in Australia (ABARE 2000). The increase in production (graph 4.11) and value since 1990–91 has been mainly due to farming of pearl and edible oysters, tuna, salmon, prawns and southern bluefin tuna (ABS 2000a).

4.11 TOTAL AQUACULTURE PRODUCTION(a), Australia



(a) Excludes hatchery production, crocodiles, microalgae and aquarium worms.

Source: derived from Brown et al. 1997; ABARE 2000.

Australia's aquaculture production is low compared to its coastal area and to global aquaculture production (Preston and Rothlisberg 2000). For example, prawn farming in Australia produced around 2,400 tonnes in 1999, compared with Thailand where prawn farming production has increased from 20,000 tonnes in 1984 to the present level of 200,000 tonnes. The problems associated with nutrient discharges from farming ponds and the possible degradation of coastal areas, as have occurred overseas, have reduced the likelihood of uncontrolled aquaculture expansion in Australia, with greater restrictions being imposed on aquaculture development.

The area leased by the aquaculture industry is larger than the area productively used, and varies from year to year. In 2000, 48,828 hectares (488 km^2) were leased for the use of marine or estuarine aquaculture (mariculture) farming in Australia (table 4.12). The species farmed vary by State. In Tasmania, coastal areas leased for aquaculture had the highest monetary return from salmon and oyster farming (ABARE 2000).

Aquaculture *continued*

In Queensland, farming areas consist of pearl and edible oysters and the production of prawns (Queensland Department of Primary Industries pers. comm) with prawns being the most profitable (ABARE 2000). Pearl oysters and shellfish are the primary species farmed in Western Australia (Fisheries Western Australia pers. comm.) although pearls are the most profitable (ABARE 2000). Coastal aquaculture is concentrated around southern bluefin tuna in South Australia (Knight et al. 2000), pearl oysters in the Northern Territory (NT Department of Primary Industries pers. comm.), and mussels and other shellfish in Victoria (State of Victoria 2000). In New South Wales, 4,500 hectares of the 4,538 hectares leased for aquaculture are designated for the farming of native and pacific oysters (NSW Fisheries pers. comm.).

4.12 AQUACULTURE LEASE AREAS(a), By State—February 2000

	NSW	*Vic.*	*Qld(b)*	*SA*	*WA*	*Tas.(c)*	*NT*	*Aust.*
	ha	ha	ha	ha	ha	ha	ha	ha
Area	4 538	812	4 001	2 260	17 360	8 469	11 388	48 828

(a) Area does not include freehold land.

(b) This figure does not include 5.7 km of coastline designated to oyster farming in the Northern Queensland region.

(c) Does not include land-based marine farming operations.

Source: New South Wales Fisheries; Victorian Department of Natural Resources and Environment; Queensland Department of Primary Industries; Aquaculture South Australia; Fisheries Western Australia; Tasmanian Department of Primary Industries, Water and Environment; Northern Territory Department of Primary Industries and Fisheries.

The aquaculture industry is heavily reliant on fishmeal as a protein feed for farmed species. The high cost of protein feed required by aquaculture farms accounts for around 60% of farm production costs for most species (Cordover et al. 2000). In 1996, 90% of feed required for Australian prawn farms was imported, at a cost of around $6m (CSIRO 1999). Fishmeal is a blend of sardines, anchovies, pilchards and other low value fish. It has been calculated that 2 kg of fishmeal are required to produce 1 kg of farmed fish or shrimp (prawns)(World Resources Institute et al. 2000). Aquaculture farms can make a profit from the use of low value fishmeal to produce high value fish products such as atlantic salmon. The quantity of fishmeal required for these high value fish products places pressure on the fisheries used to meet the demand for fishmeal.

Reliance on fishmeal, often a product of non-target catch from wild fishery stocks, can impact on fishery resources. Peru supplies 50% of the world's supply of fishmeal, from an area heavily influenced by El Niño effects. Limited supplies of fishmeal would invariably increase costs associated with fishmeal supplies, and reduce the economic net value of aquaculture production in Australia (CSIRO 1998).

At present, only 20–30% of protein in aquaculture feed is retained by the fish; the rest is not eaten or is excreted, adding to the increased nutrient load in coastal waterways. The development of alternative feed is being trialled in Australia to reduce reliance on fishmeal and to produce a better quality food source with less wastage (CSIRO 1999).

SHIPPING AND BALLAST WATER DISCHARGES

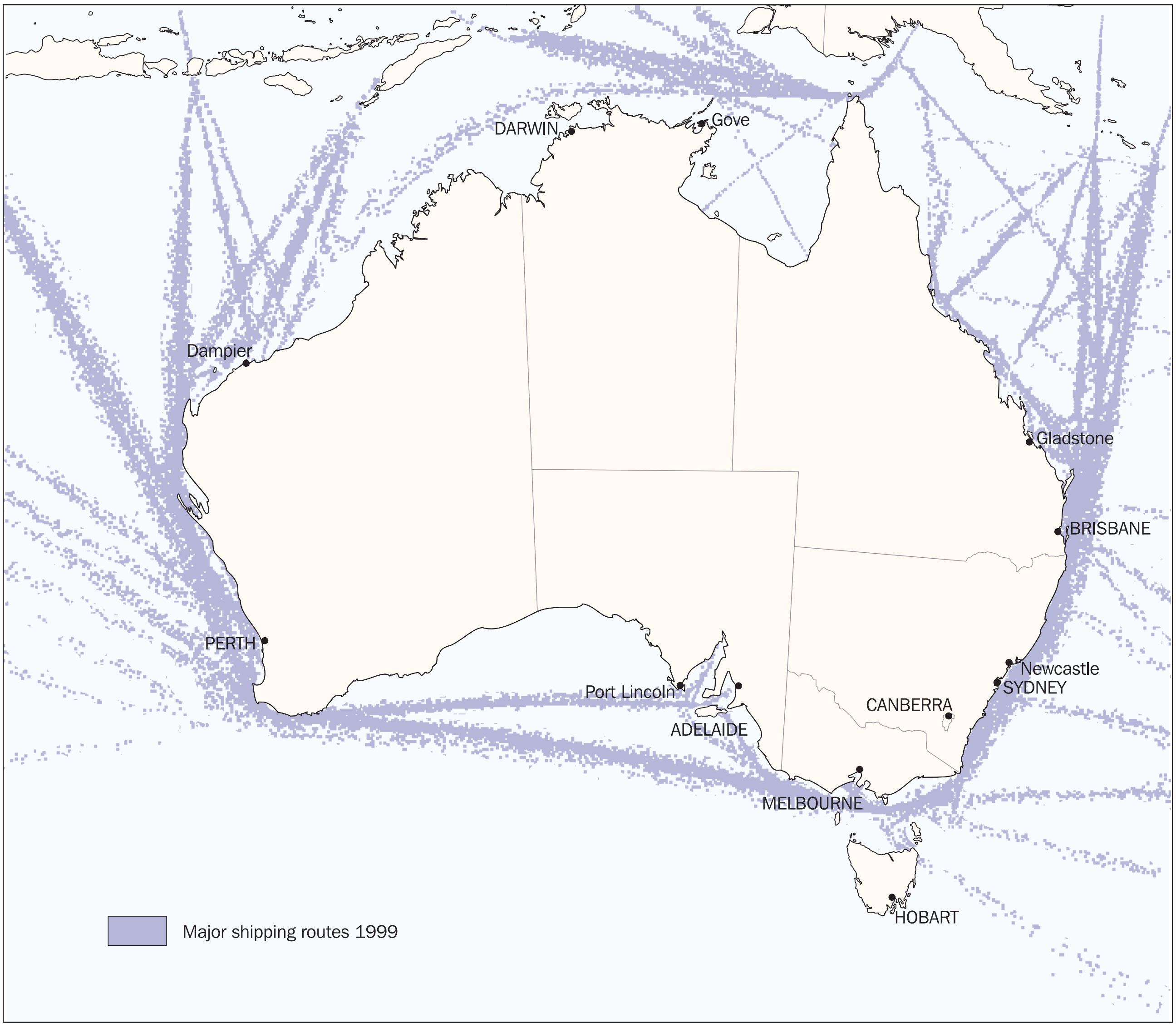
Adverse impacts on and risks to marine fauna and flora arise from the reliance on shipping in Australian waters. Australia is economically dependent on shipping and, as a consequence of geographic location, it is dependent on foreign shipping operating in Australian waters. The discharge of ballast water in Australian waters has introduced exotic marine species that have impacted adversely on the marine environment. Risks associated with the introduction of exotic species include reduction in commercial fishing catches in affected areas and displacement or localised extinction of native fauna and flora.

Shipping

Australia's shipping industry provides a national investment of about $2.5b in assets, directly employing 3,550 Australians in 1997 (AMISC 1997). Australia's trading fleet in 1997 totalled 76 vessels, a fall from 82 vessels in 1996 (ABS 1998 & 2000b). The decrease in Australia's trading fleet corresponded to an increase in the number of foreign vessels visiting and trading in Australian waters. Total permits issued to foreign vessels increased from 572 in 1996–97 to 779 in 1997–98 (Department of Transport unpub.).

The risk of an oil spill from shipping activities is high. In 1991 it was estimated that the risk of a major oil spill in any five year period was 49%, and 84% in any 20 year period (Zann 1995). Some sections of the major shipping routes (map 4.13) are near areas of high conservation value such as Shark Bay and Ningaloo Reef in Western Australia, the Southern Whale Sanctuary in the Great Australian Bight and a number of marine protected areas along Australia's coastline. Increased shipping activity near these areas of high conservation value puts them at risk from environmental damage, not only from oil spills, but also from the introduction of exotic marine species and physical damage to marine habitats or organisms. Steps to reduce the risk have been implemented in the Great Barrier Reef region, a marine protected area of international importance, with strict shipping guidelines enforced (AMSA 1998). However, strict guidelines do not always protect areas from shipping accidents. An example was the grounding of the Malaysian shipping vessel *Bunga Teratai Satu* on the Sudbury Reef off Cairns in November 2000. The environmental toll due to the grounding included damaged coral, dead fish, sedimentation and the threat of contamination from anti-hull fouling paint (Herald Sun 21 November 2000).

4.13 AUSTRALIAN SHIP REPORTING RECORDS—1999



Source: AMSA unpub.

The extent of shipping in Australian waters is also reflected by the number of port visits by trading vessels in Australia (table 4.14). In 1999, 22,077 visits were made nationally to Australian ports, only marginally greater than in 1998 but less than port visits made in 1997. Queensland was the State with the highest number of port visits. The ports with the most visits in 1999 were Melbourne (2,812), Brisbane (2,224), Fremantle (1,678) and the New South Wales ports of Newcastle (1,259), Botany Bay (1,247) and Sydney (1,225) (Bureau of Transport Economics unpub.). The large number of port visits in Australian waters increases the likelihood of marine organisms being introduced and greater chance of interstate transmission of marine organisms.

Shipping *continued*

4.14 PORT VISITS BY TRADING SHIPS, By State(a)

	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*Aust.(b)*
	no.	no.	no.	no.	no.	no.	no.	no.
1997	4 337	3 824	6 457	1 066	4 454	1 670	992	22 881
1998	4 485	3 566	5 700	1 138	4 503	1 343	913	21 726
1999	4 388	3 743	6 097	1 154	4 277	1 493	846	22 077

(a) A trading ship is defined as a commercial vessel over 200 gross tonnes. Many vessels make more than one port call per voyage.

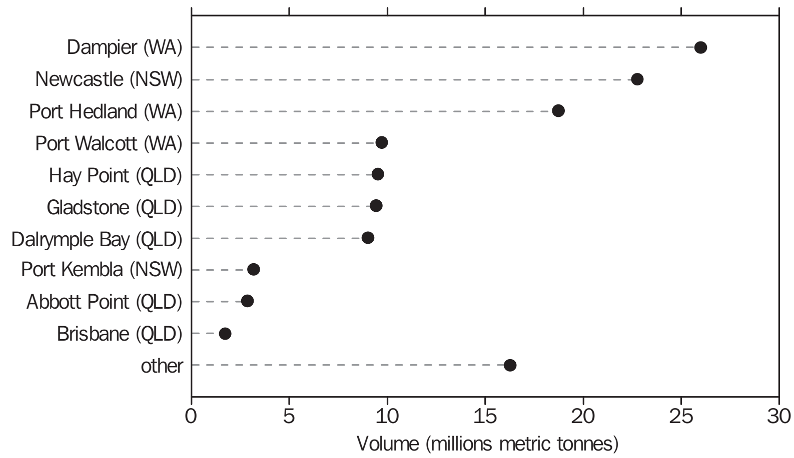
(b) Includes port visits made in Australian waters but not declared at which port.

Source: derived from Bureau of Transport Economics (unpub.).

Ballast water

Shipping can impact on water quality and biodiversity by the discharge of ballast water into Australian waters when vessels take up their cargo. Ballast water is the volume of water taken on board to balance the ship when cargo holds are empty. The ballast water is discharged when the ship takes on cargo at a port. As Australia is one of the largest users of shipping in the world (AMISC 1997), ballast water discharges pose a major environmental threat. In Australia, about 97% of trade by volume is carried by ships, with 95% carried by foreign vessels (Department of Environment and Heritage 1998). Organisms present in sea water taken up as ballast by vessels in foreign waters have been introduced into Australian waters. From October 1998 to October 1999, over 129 million metric tonnes of ballast water were discharged at 61 ports around Australia. The ten ports receiving the greatest amount of ballast water are shown in graph 4.15. The Western Australian ports of Dampier and Port Hedland received 35% of all ballast water discharged in Australia.

4.15 BALLAST WATER DISCHARGES, Australian Ports—Year ending October 1999



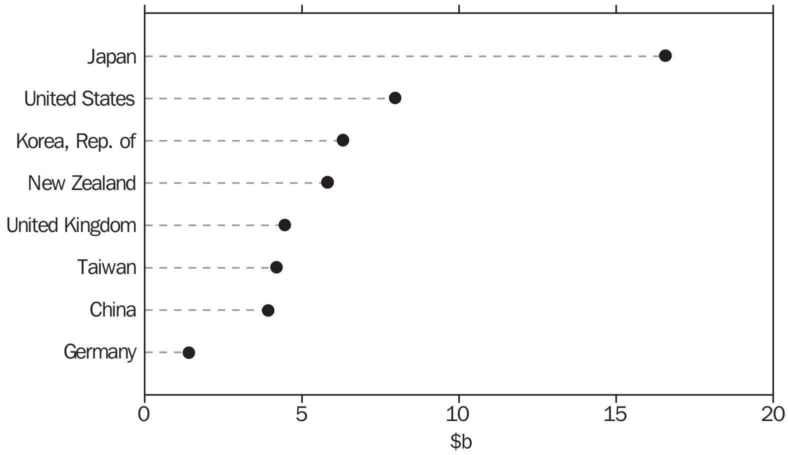
Source: Australian Quarantine Inspection Service (unpub.).

The potential for organisms to survive in ballast water has increased with improved shipping technology leading to quicker transport times between locations. Similar temperate waters in other regions also enhance the likelihood of organisms adapting to and surviving in Australian waters.

Ballast water *continued*

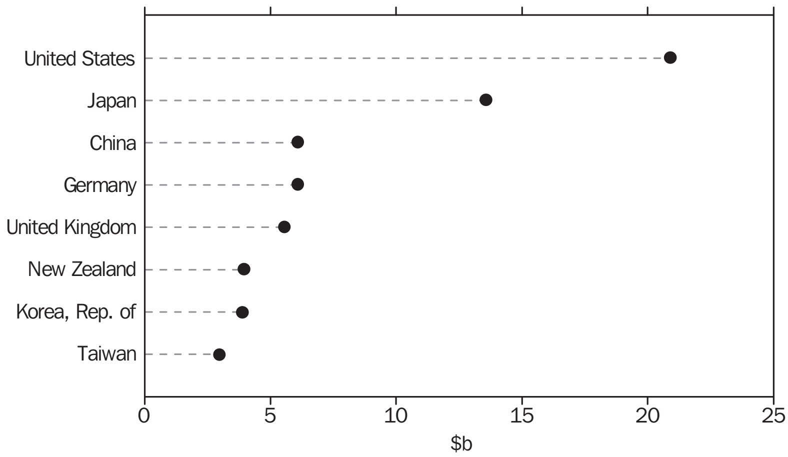
The majority of ballast water received in Western Australia originates from the Asia Pacific region, with Japan the greatest single contributor (State of the Environment Reference Group 1998), reflecting trade links with this region. The economic importance of international trade is highlighted in the international merchandise trade statistics for Australia (graphs 4.16 and 4.17). Australia's largest export destination in 1998–99 was Japan, with exports to Japan valued at $16,568m; the largest source of imports was the United States, with imports from the US valued at $20,893m. The largest share of Australian merchandise trade is with countries of the Asia Pacific Economic Cooperation (APEC) forum, with $61,359m in exports and $68,128m in imports in 1998–99. Of the countries listed in graphs 4.15 and 4.16 only Germany and the United Kingdom are not included in the APEC group.

4.16 AUSTRALIA'S MERCHANDISE TRADE, Exports—1998–99



Source: ABS 2000c.

4.17 AUSTRALIA'S MERCHANDISE TRADE, Imports—1998–99



Source: ABS 2000c.

Strong trade links with the countries of the APEC group increase the likelihood of ships carrying ballast water from this region into Australia and introducing exotic marine species. A number of species targeted by the Australian Ballast Water Management Advisory Council have originated from the Asia Pacific region. For example, the Japanese kelp *Undaria pinnatifida* and the Northern Pacific Sea Star (*Asterias amurensis*) are now established in south eastern temperate waters (Hewitt unpub.).

MARINE POLLUTION

Marine pollution is one of the key causes of the degradation of Australia's coastal wetland systems. Healthy estuarine and marine environments support biodiversity and have direct socioeconomic benefits through tourism and recreation. Pollution has a deleterious effect on the coastal environment, affecting wetlands, fish communities, visual amenity for recreation and tourism, and viability for aquaculture development. Australia has over 1,000 estuaries, approximately half in near pristine condition. Of the remainder, 22% are considered largely unmodified, 17% modified and 11% severely modified (NLWRA 2000).

The coast is used as a waste disposal area, the majority of waste consisting of sewage from treatment plants and ocean outfalls, stormwater run-off, industrial waste and waste from shipping vessels. With around 85% of Australia's population connected to a sewage treatment system (AWWA 1999), the disposal of treated sewage and waste into the marine environment is of concern. Nutrient discharges, often associated with treated sewage and stormwater discharges, have accounted for up to 97% of seagrass losses in some areas of coastal Australia (Kirkman 1997). Another pollutant of concern is the discharge of disease-causing microorganisms from low level treated sewage and stormwater.

The key contributors to the discharge of hydrocarbons into the marine environment are marine transport (in the form of oil spills) and coastal run-off. The problem, however, is not necessarily how much oil is spilt but the geographic location and seasonality of local fauna populations in the vicinity of the spill. Shipping not only impacts on the marine environment through ballast water discharges (as discussed earlier), but also through marine debris and anti-fouling paints, used to minimise the attachment of marine organisms to the hulls of ships.

Waste water

Sewage is generally treated in three stages. The objective of primary sewage treatment is to remove settlable solids, i.e. screening sewage by grit removal and sedimentation. Secondary treatment generally removes 85–95% of biodegradable material by biological oxidation, for example, by activated sludge digestion and disinfection. Tertiary treated sewage involves further reduction of biodegradable material and significant nutrient removal. The majority of treatment plants treat waste water to secondary level (table 4.18). An exception is the Sydney Water Corporation, which has the highest percentage in Australia of treatment plants only treating waste water to primary level (80% in 1999). The level of waste water treatment required depends on the ecological balance of the receiving waters. Areas that have poor mixing of treated discharge and receiving waters, require higher levels of treatment than ocean discharges with deep waters and strong currents (WSAA 1999).

Waste water *continued*

4.18 LEVEL OF SEWAGE TREATMENT, Major Authorities—1999(a)

	LEVEL OF TREATMENT		
	Primary	*Secondary*	*Tertiary*
Water business	%	%	%
ACTEW Corporation	—	—	100
Gosford City Council	—	100	—
Hunter Water Corporation	—	58	42
Sydney Water Corporation	80	8	12
Barwon Water	—	100	—
Central Gippsland Water	—	64	36
Central Highlands Water	—	100	
CityWest Water	—	100	—
Coliban Water	—	44	56
Goulburn Valley Water	—	100	—
Melbourne Water Corporation	—	100	—
South East Water Limited	—	93	7
Yarra Valley Water	—	—	100
Brisbane Water	—	63	37
Gold Coast Water	—	89	11
S.A. Water Corporation	—	100	—
Water Corporation (WA)	39	61	—
Power and Water Authority (NT)	37	63	—

(a) The level of treatment is not a performance measure and is a reflection of the level of treatment needed to meet discharge targets of receiving waters.

Source: WSAA 1999.

Nitrogen and phosphorus are essential nutrients found in our inland and coastal water systems, but in large quantities they are likely to contribute to the increase in algal blooms in our estuaries. The list of sewage treatment facilities discharging nitrogen and phosphorus into Australia's coastal regions is not complete as not all facilities are required to report to the National Pollutant Inventory (NPI). Only those plants above the threshold 15 tonnes per year of nitrogen and 3 tonnes per year of phosphorus are required to report discharges of nutrients into coastal and inland waters. Below this threshold, reporting of nutrient discharges is voluntary.

Of the sewage treatment plants and industry bodies reporting nitrogen discharges into coastal waters in 1998–99, the smallest discharge volume reported was 292 kg (Queensland); the largest reported discharge (7.3 million kg) occurred at the Malabar Ocean outfall, New South Wales. The smallest reported phosphorus discharge was 444 kg (Tasmania); the largest was 1.7 million kg (Victoria) (NPI 2000).

Effects of nutrients

Excess nutrients are responsible for increases in algal bloom occurrence. Toxic algal blooms cause fish kills and the death of plants due to reduced sunlight. They also risk human health by making seafood (such as shellfish) unsafe to eat and water unsafe for recreational purposes (NSW EPA 1997). For example, in February 2000 an inundation of freshwater, following heavy rains in Western Australia, caused the closure of the Swan–Canning estuary to human activity (including recreation and fishing) from toxic blue-green algal blooms. Samples tested found 7,000 micrograms of toxins per litre of water, 700 times the level allowed in water used for recreational purposes (South Australian Centre for Water Research as cited in The Australian 15 February 2000). Algal blooms in freshwater systems are discussed in Chapter 3.

Excess nutrients are a major source of pollutants affecting Australia's seagrass beds. Of the known seagrass species in the world (less than 70), Australia has more than half (Walker et al. 1999). Seagrass habitats provide food for many marine organisms including green turtles, swans and many invertebrates, and are the sole source of food for the dugong. Seagrasses are also an important breeding ground and nursery area for many fish and prawns (Environment Australia 1999). These breeding areas are vital for the sustainability of commercial fisheries in Australian waters.

A number of seagrass areas in Australia have been affected by pollution. It is estimated that approximately 50% of seagrass beds off NSW have been lost in recent decades (Zann 1995). At Cockburn Sound in Western Australia, 97% of seagrass beds have been lost due to increased nutrients from sewage disposal and trade waste (Kirkman 1997). Nutrient discharges can cause an increase in algal levels, restricting the light to seagrass meadows below. The engineering cost to reduce algal growth at Cockburn Sound in WA totalled $170m. This highlights the economic and environmental costs associated with pollution inputs into estuarine environments (Zann 1995).

For many areas of seagrass beds, baseline data are not available to determine what area of seagrasses has been lost. Recovery and regrowth of seagrass beds are poor, especially in temperate regions (Zann 1995). In tropical regions, seagrasses can take over 10 years to recover, and most attempts to replant seagrass beds have been expensive and ineffective (Environment Australia 1999).

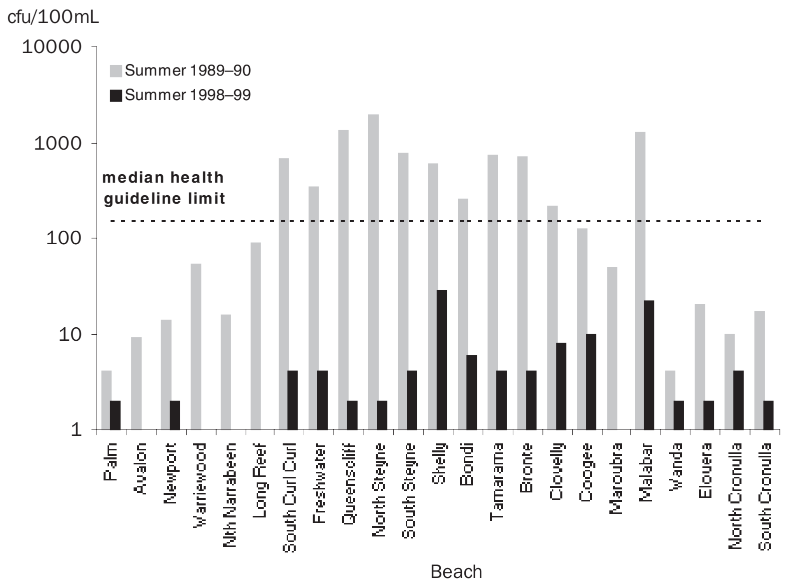
Pathogens—bacteria

Sewage discharged into our seas and estuaries releases not only nutrients but other contaminants such as disease-causing micro-organisms. These pathogens, in sufficiently high densities, can be detrimental to human health through the recreational uses of polluted waters such as swimming and surfing, or the consumption of fish caught in areas of high pollution.

A measure of water quality to determine whether beaches are suitable for recreational activities is the testing for bacteria (faecal coliforms and enterococci) in water. Faecal coliforms are only a useful indicator of recent pollution events as they die off quickly in the marine environment. Enterococci are believed to be a better indicator of residual events, as these bacteria are more tolerant of marine environments and reflect similar lifespans to other pathogens. The health problems associated with high levels of disease-causing bacteria and viruses in sewage are gastroenteritis (including diarrhoea and abdominal pain), food poisoning (salmonellosis), fever, colds, respiratory infections and hepatitis (NSW EPA 1999).

Beaches around Sydney often experience higher faecal coliform densities after periods of heavy rain associated with stormwater run-off and sewer overflows. This poses a greater human health risk during summer when there is higher beach usage. The improvements to disposal and treatment of sewage at Sydney's sewage outfalls have seen a reduction in median faecal coliform density detected in 1998–99 compared to 1989–90 (graph 4.19). These improvements have resulted in outfalls discharging pathogens at levels below median health guideline limits.

4.19 MEDIAN FAECAL COLIFORM DENSITY(a)— Summer 1989–90 and 1998–99



(a) Sites showing one cfu/100mL experienced one or less than one cfu/100mL.

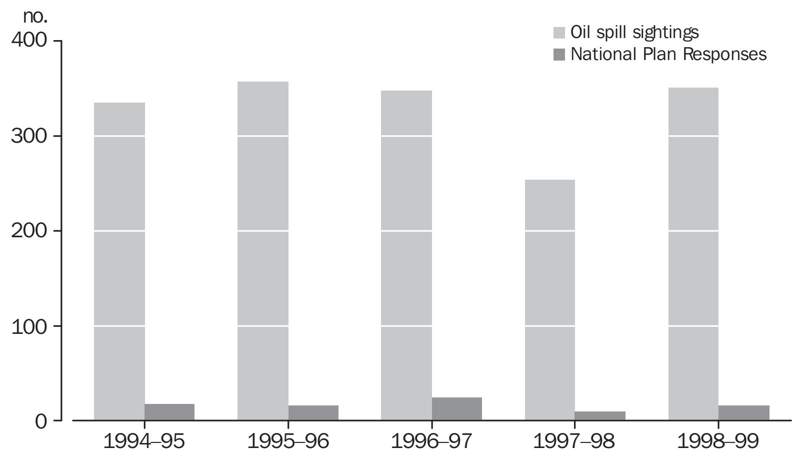
Source: NSW EPA 1999.

Hydrocarbons

Hydrocarbons occur in estuaries and marine waters from oil spills from tankers and other ships, offshore drilling associated with petroleum production, and urban stormwater run-off. It has been estimated that between two and eight million tonnes of oil enter the world's oceans each year. A total of 3.2 million tonnes per year of oil are estimated to occur in international waters, with 45% attributable to marine transport, 38% to coastal, urban, municipal and river run-off wastes, 8% to natural seepage, 6% to atmospheric fallout and 3% to offshore production (Minerals Council of Australia 1999).

In Australia, there were 1,645 oil spill sightings from 1994–95 to 1998–99, of which 84 required a nationally coordinated clean-up response team (graph 4.20). In 1998–99, of the 351 oil spill sightings, 16 required a National Plan Response (see below). Details of oil spill sightings are compiled from discharge reports, the AMSA Search and Rescue Centre, National Plan expenditure records, State/Territory monthly incident reports and other sources such as the Department of Primary Industries and Energy (AMSA 2000a). A National Plan Response involving the Commonwealth Government, the State and Territory Governments and the shipping, oil and exploration industries, has been put in place to maximise Australia's capability to respond to oil spills. A National Plan Response is a nationally coordinated clean-up plan to assist in large or environmentally damaging oil spills. This is managed by the placement of pollution response equipment stockpiled at locations around Australian ports. Australia has enough equipment to control an oil spill of up to 10,000 tonnes (Zann 1995).

4.20 OIL SPILL SIGHTINGS AND NATIONAL PLAN RESPONSES



Source: AMSA 2000a.

Hydrocarbons *continued*

The environmental impact of oil spills depends largely on the geographic location of the spill. Oil spills close to the coast or near areas of high conservation value are likely to cause greater damage than those offshore. For example, the oil spill from the *Iron Baron* in 1995, located in the mouth of the Tamar river in Launceston, Tasmania, caused extensive environmental impact on wildlife in the area due to the location of the spill and the prevailing weather conditions, in comparison to larger tanker spills such as from the *Kirki* off Western Australia (17,280 tonnes). An estimated 300 tonnes of bunker fuel oil escaped when the *Iron Baron* grounded (AMSA 2000b). Strong winds and high seas caused oil to cover the shoreline of the Tamar River Estuary, part of the northern Tasmanian coast and some eastern Bass Strait islands.

It is estimated that between 7,000 to 17,000 Little penguins were killed due to the resulting oil pollution in south eastern Bass Strait. Of the Little penguins brought in for treatment (2,060), 95% survived to be released. Of the other bird life brought in for treatment, all 6 pelicans and half of the 54 Little Pied cormorants were released in a healthy state (DPIWE 1999).

Monitoring of the damaged reef from the hull's impact revealed that fish species had recovered to stable levels within two years of the spill, although recovery of invertebrate and macroalgal populations was slower. Two breeding seasons after the oil spill, oil rehabilitated birds and their fledging chicks had lower body mass than control populations, and seal populations had a decreased number of pups compared to previous years. The effect on beaches, rocky shores and subtidal reefs is difficult to gauge as insufficient baseline data were available to determine natural variations of organisms in the area (DPIWE 1999).

Since 1994–95, all accidents from offshore petroleum sites that discharge over 80 litres of oil have to be reported. Prior to 1994–95, offshore oil spill accidents of over 320 L were required to be reported. A comparison of the offshore oil basins shows that the largest total volume of oil spilt in any given year occurred in the Western Australian region in 1994 (table 4.21). This was mainly caused by the parting of a floating hose and 34,980 L of crude oil was released (DISR unpub.). Although this volume of oil appears large, it is small in comparison to tanker accidents such as that of the *Iron Baron* in 1995.

4.21 OIL SPILLS/ACCIDENTS, Offshore Production(a)

	1991	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*
Location	L	L	L	L	L	L	L	L	L
Vic.	1 000	1 695	680	127	620	238	6 750	—	—
WA	2 890	2 399	5 627	35 440	—	—	1 398	—	1 030
NT	300	15 100	6 600	220	1 300	1 669	100	100	1 000
Total	**4 190**	**19 194**	**12 907**	**35 787**	**1 920**	**1 907**	**8 248**	**100**	**2 030**

(a) Amounts do not include discharges of synthetic muds released from offshore accidents.

Source: DISR (unpub.).

Although major oil spills and tanker accidents are more publicised and cause greater concern for our marine environment, urban run-off of hydrocarbons by land-based sources contribute a greater amount of pollution and cause a large amount of damage to our estuaries (Zann 1995).

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CHAPTER 5 ENERGY AND ATMOSPHERIC POLLUTION

INTRODUCTION

Energy consumption underpins Australia's standard of living. Energy is used in all facets of our lives, from domestic to industrial uses. It heats our homes, provides us with hot water, cooks our meals, drives our washing machines and powers our cars. It also powers the industries that build our homes, and make our hot water heaters, food, washing machines and cars. Although government policy can influence energy consumption, the rate at which energy is consumed is ultimately determined by decisions made by individuals when they purchase and use products.

Over the past decade the issues surrounding energy production and consumption have received increasing attention because of the link between greenhouse gases, the waste products of fossil fuel consumption, and global climate warming.

The emission of greenhouse gases is a major environmental concern related to energy consumption. In 1998, 80% of greenhouse gas emissions in Australia were attributable to the energy sector. Strategies are now in place to re-evaluate energy use in Australia in an attempt to minimise greenhouse gas emissions.

This chapter discusses the major dimensions of Australia's consumption of energy. It goes on to discuss the consequences, particularly regarding atmospheric pollution, of Australia's dependence on non-renewable energy sources.

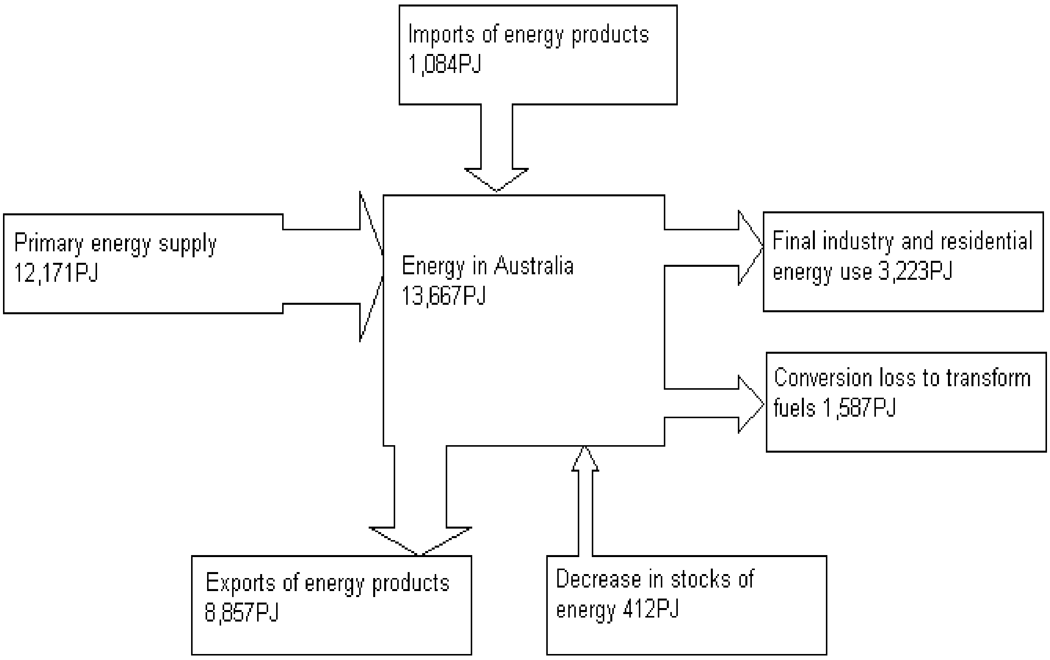
THE ENERGY MODEL

The fuels mined in Australia are either consumed here, stockpiled (for future consumption or export), or exported to other countries. In some cases, consumption takes place in Australia to produce another kind of fuel for export (e.g. coke, LPG). Some fuels are imported into Australia, mainly crude oil.

The relationships involved in the sources and uses of energy are illustrated in figure 5.1, the energy model for Australia for 1997–98, which sets out the quantities (petajoules) of energy imported, produced, used, stockpiled and exported.

As can be seen from the model, in that year Australia exported 73% of the energy it produced. The export of coal, petroleum, gas and uranium earned Australia $15,700m in 1997–98, representing 18% of the value of all exports in that year. However, the main focus of this section is on the consumption of energy within Australia.

5.1 ENERGY MODEL, Australia—1997–98

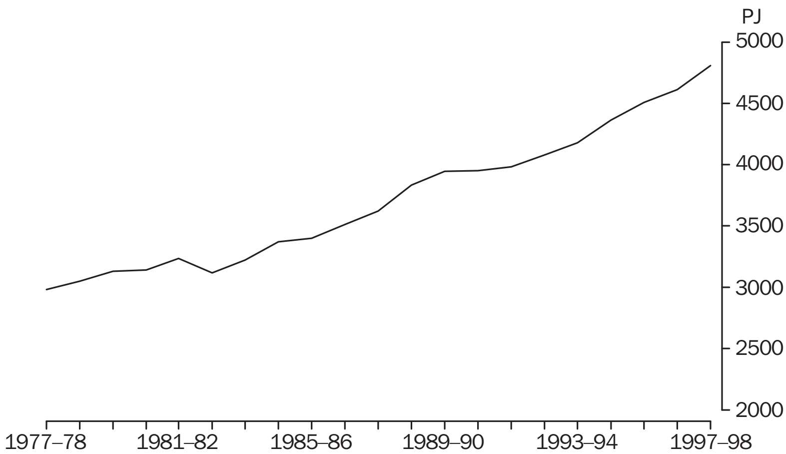


Source: *Australian Energy: Market Developments and Projections to 2014–15 (ABARE).*

ENERGY CONSUMPTION

The total amount of energy consumed per annum in Australia (the sum of the two right hand boxes in figure 5.1) was 4,810 petajoules (PJ, or J x 10^{15}) in 1997–98, a rise of 61% from 2,985 PJ in 1977–78 (graph 5.2). This reflects the growth of both the Australian population and the economy.

5.2 ENERGY CONSUMPTION—1977–78 to 1997–98

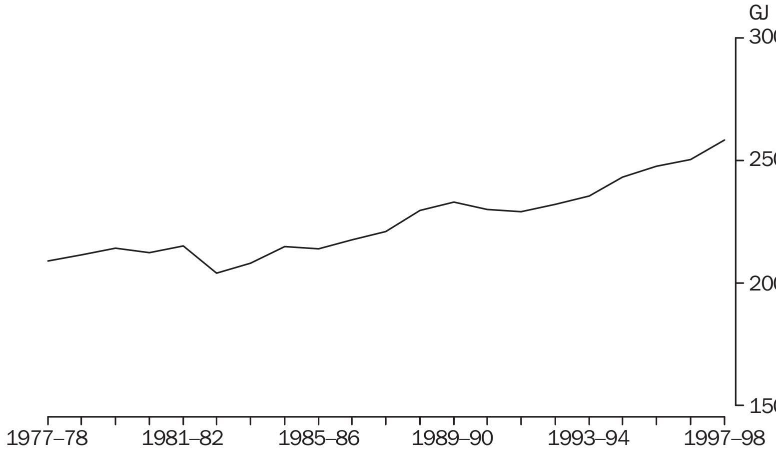


Source: *Bush et al. 1999; ABARE historical spreadsheets.*

ENERGY CONSUMPTION *continued*

The amount of energy used per capita increased by 24% over this period, from 209 gigajoules (GJ, or J x 10^9) per person in 1977–78 to 258 GJ in 1997–98 (graph 5.3). Australian's energy consumption per capita is above the average for OECD countries, most of which are comparatively affluent. In 1995–96, based on International Energy Agency methodology, Australia's total energy consumption was estimated at 230 GJ per capita, compared with an OECD average of 192 GJ. To place these figures in perspective, two less affluent OECD countries, Mexico and Turkey, consumed 61 GJ and 44 GJ per capita respectively (IEA 1998).

5.3 ENERGY CONSUMPTION PER CAPITA

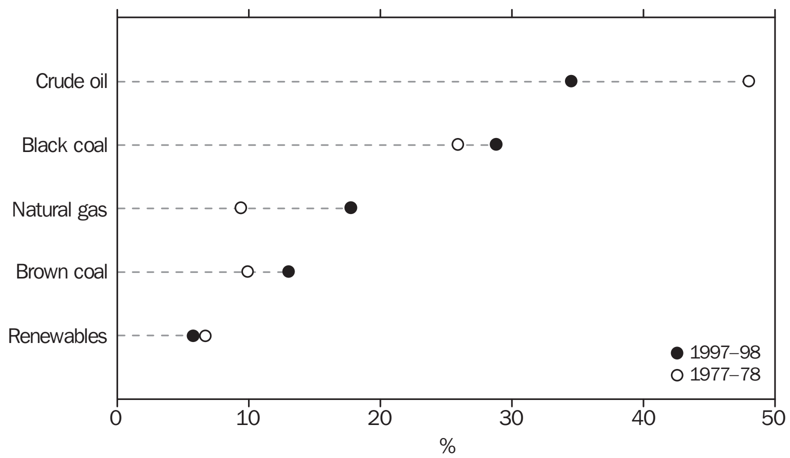


Source: Bush et al. 1999; ABARE historical spreadsheets.

Many factors can influence a country's energy consumption. They include the availability and cost of energy; climate; population size; and the level of development and industrialisation. Australia is a resource-rich country with considerable reserves of fossil fuels. These resources enabled Australia to become an industrial nation. Although Australia's increasing energy consumption is linked to population growth, economic growth is also an important driver of energy demand.

Primary fuels consumed

5.4 PRIMARY ENERGY SOURCES CONSUMED, Proportions by Fuel Type



Source: Bush et al. 1999; ABARE historical spreadsheets.

Primary fuels consumed *continued*

Australia's dependence on fossil fuels is readily apparent when the primary fuels consumed are ranked in order of use (graph 5.4; table 5.5). In 1997–98, fossil fuels accounted for 94% of energy consumed in Australia. Crude oil and black coal were the main fuels, representing 35% and 29% of energy consumed respectively. Natural gas represented 18% of energy consumed, followed by brown coal (13%) and renewable fuel sources (6%). Comparison of these figures with those for 1977–78 shows a decline of 14 percentage points in the proportion of energy derived from crude oil and an increase of eight percentage points in the proportion of energy derived from natural gas. These shifts reflect the increase in oil prices over this period and the development of natural gas fields and the gas pipeline network.

5.5 PRIMARY ENERGY SOURCES, Proportions by Fuel Type

	1977–78	*1982–83*	*1987–88*	*1992–93*	*1997–98*
	PJ(a)	PJ	PJ	PJ	PJ
Crude oil	1 438.3	1 262.7	1 369.2	1 491.7	1 672.0
Black coal	7 76.8	869.6	1 035.6	1 195.6	1 396.2
Brown coal	297.4	329.4	424.9	466.8	631.6
Natural gas	283.0	466.2	610.5	707.0	860.0
Wood, woodwaste	80.9	85.1	90.6	104.8	109.7
Bagasse	68.3	71.9	73.9	78.0	112.1
Hydro-electricity	52.0	46.5	53.9	61.0	55.5
Solar energy	0.4	1.6	2.4	2.4	3.7
Net coal byproducts etc.(b)	–12.0	–10.3	–37.9	–25.8	–30.7
Total primary energy	**2 985.1**	**3 122.7**	**3 623.1**	**4 081.5**	**4 810.1**

(a) Petajoules.

(b) The difference between production and consumption of derived fuels, includes net thermal electricity and statistical discrepancies.

Source: Bush et al. 1997 & 1999; ABARE historical spreadsheets.

Energy consumption by State

Despite the overall dependence on fossil fuels, the types of fuel consumed vary considerably by State. These differences primarily reflect the availability of resources. Coal is the main fuel consumed in the eastern States, while natural gas is the main fuel in Western Australia. Renewable energy, in general, plays a minor role in energy production. However, nearly half of the energy consumed in Tasmania comes from a renewable source because of its history of hydro-electricity development. In Queensland 12% of the energy consumed is sourced from renewable resources, mainly by burning bagasse (sugar cane waste) (Bush et al. 1999).

Energy consumption by State *continued*

5.6 ENERGY CONSUMPTION, Total and Per Capita by State

Year	NSW(a)	Vic.	Qld	SA	WA	Tas.	NT	**Australia**
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	**PJ**
1977–78	1 011.2	823.3	461.2	247.7	328.2	78.4	35.1	**2 985.1**
1982–83	1 002.5	896.5	541.5	254.6	304.6	82.3	40.8	**3 122.7**
1987–88	1 143.4	1 014.5	642.4	291.1	391.1	89.5	51.1	**3 623.1**
1992–93	1 249.3	1 104.7	758.5	300.1	522.0	90.1	57.2	**4 082.0**
1997–98	1 427.3	1 280.3	966.8	309.9	660.1	95.5	70.2	**4 810.1**
	GJ/capita	GJ/capita	GJ/capita	GJ/capita	GJ/capita	GJ/capita	GJ/capita	**GJ/capita**
1977–78	192.8	213.7	214.4	191.7	269.6	188.2	328.4	**209.0**
1982–83	180.2	223.4	220.4	190.3	224.8	191.0	307.3	**204.2**
1987–88	192.7	239.6	237.6	208.1	258.4	199.0	321.3	**221.0**
1992–93	198.9	247.4	247.3	205.7	313.0	191.3	337.0	**232.2**
1997–98	216.0	276.7	282.3	209.0	364.4	202.1	372.7	**258.4**

(a) Includes ACT.

Source: Bush et al. 1997 & 1999.

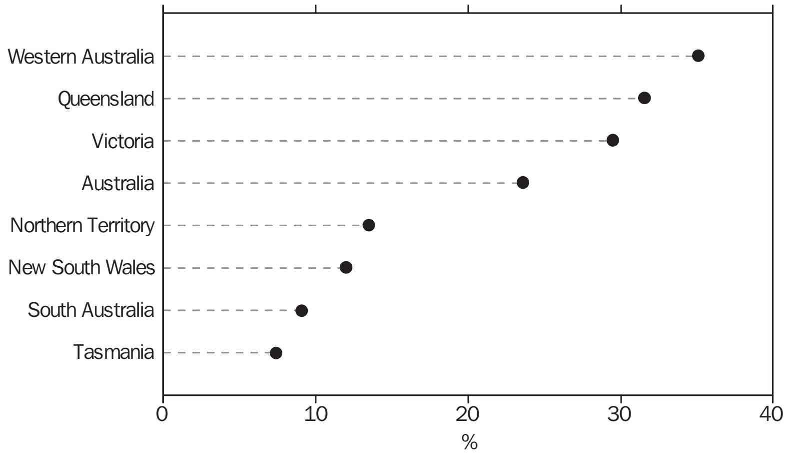
The energy consumed in a State generally reflects its population size: the ranking of the States, ordered by population size, matches that for energy consumption. In 1997–98 New South Wales, the most populous State, had the highest total energy consumption at 1,427 PJ (table 5.6). The Northern Territory had the smallest population and the lowest total energy consumption at 70 PJ.

Although energy consumption generally increases with population size, a comparison of the energy consumption and population size of each State shows that the per capita energy consumption varies considerably by State (table 5.6). In 1997–98, States with per capita energy consumption greater than the average for Australia (258 GJ per capita) were the Northern Territory (373 GJ/capita), Western Australia (364 GJ/capita), Queensland (282 GJ/capita) and Victoria (276 GJ/capita). New South Wales, South Australia and Tasmania had lower than average per capita rates of 216 GJ, 209 GJ and 202 GJ per capita respectively. The particularly high per capita rates in the Northern Territory and Western Australia reflect energy consumption by industry, particularly in the minerals processing sector (Bush et al. 1997 & 1999).

Over the period 1978 to 1998, the per capita energy consumption of all Australians increased by 24%. However, the increase varied across States, ranging from a 35% increase in Western Australia to 7% in Tasmania (graph 5.7). In Victoria, Queensland and Western Australia the increase in per capita consumption was more than the national average, while in the other States and the Northern Territory it was less.

Energy consumption by State *continued*

5.7 ENERGY CONSUMPTION, Per Capita Increase—1978 –1998



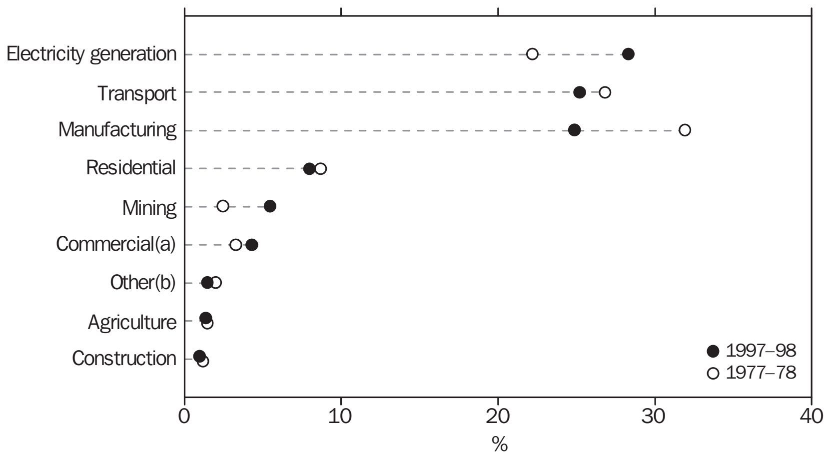
Source: ABS data for Estimated Resident Population and Bush et al. 1997 & 1999.

Energy consumption by industry

Industry is the major consumer of energy in Australia. In 1997–98, 78% of total energy consumption in Australia was by three sectors: electricity generation, transport and manufacturing.

Comparison with data for 1977–78 reveals shifts in the shares of energy consumed by different sectors (graph 5.8). Manufacturing was the largest consumer of energy in 1977–78, accounting for 32% of domestic consumption, but by 1997–98 its share had declined to 25%. The electricity generation industry's share of total energy consumed increased by 6 percentage points, and by 1997–98 energy generation had become the industry with the largest share of energy consumption. This energy consumption represents mainly the energy cost of the conversion of coal and natural gas to electricity (the energy consumed does not include the electrical energy produced).

5.8 ENERGY CONSUMPTION BY INDUSTRY, Percentage Shares—1997–98



(a) Includes ANZSIC Divisions F, G, H, K, L, M, N, O, P, Q and the water, sewerage and drainage industries.

(b) Includes consumption of lubricants and greases, bitumen and solvents, as well as energy consumption in the gas production and distribution industries.

Source: Bush et al. 1999; ABARE historical spreadsheets.

Energy consumption by industry *continued*

The energy consumption of all sectors has increased with the growth of Australia's population, though not at the same rate. Analysis of industry sector energy consumption on a per capita basis highlights differences due to factors other than population increase. Most sectors had higher per capita energy consumption in 1997–98 than in 1977–78 (table 5.8). The Mining sector showed the largest increase, its energy consumption increased from 5 GJ per capita in 1977–78 to 14 GJ in 1997–98, a growth of 173%. The Commercial and Services industries and the Electricity Generation industry also both increased their per capita energy consumption by 58% and 62% respectively. Manufacturing was the only sector to experience a decline, decreasing its per capita energy consumption from 67 GJ in 1977–78 to 64 GJ in 1997–98. The construction sector experienced fairly constant per capita energy consumption during the 20 year period from 1977–78. Changes in per capita use of energy within a sector may be due to a range of factors, such as increasing domestic efficiency, increases in the size of a sector, or relocation of certain economic activities off-shore.

5.9 ENERGY CONSUMPTION BY SECTOR, Shares and Consumption Per Capita

	1977–78	*1982–83*	*1987–88*	*1992–93*	*1997–98*
Sector	%	%	%	%	%
Electricity generation	22.2	26.5	26.5	26.8	28.3
Transport(a)	26.8	26.8	26.7	25.7	25.2
Manufacturing	31.9	27.3	27.3	26.1	24.9
Residential	8.7	8.7	8.2	8.5	8.0
Mining	2.5	2.4	3.3	4.7	5.5
Commercial and services(b)	3.3	3.6	3.7	4.0	4.3
Agriculture	1.5	1.6	1.5	1.5	1.4
Construction	1.2	1.1	1.1	1.0	1.0
Other(c)	2.0	1.9	1.8	1.6	1.5
Total (%)	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Total (PJ)	**2 985.1**	**3 122.7**	**3 623.1**	**4 082.0**	**4 810.1**
	GJ/capita	GJ/capita	GJ/capita	GJ/capita	GJ/capita
Electricity generation	46.3	54.2	58.6	62.3	73.0
Transport(a)	55.9	54.7	58.9	59.7	65.0
Manufacturing	66.7	55.8	60.3	60.7	64.3
Residential	18.3	17.9	18.1	19.8	20.7
Mining	5.2	5.0	7.2	10.8	14.2
Commercial and services(b)	6.8	7.3	8.2	9.4	11.0
Agriculture	3.0	3.3	3.4	3.4	3.7
Construction	2.5	2.3	2.4	2.4	2.5
Other(c)	4.3	3.9	3.9	3.7	4.0
Total	**209.0**	**204.2**	**221.0**	**232.2**	**258.4**

(a) Includes all transport activity, including private motor vehicle use.

(b) Includes ANZSIC Divisions F, G, H, K, L, M, N, O, P, Q and the water, sewerage and drainage industries.

(c) Includes consumption of lubricants and greases, bitumen and solvents, as well as energy consumption in the gas production and distribution industries.

Source: Bush et al. 1999; ABARE historical spreadsheets.

Renewable energy

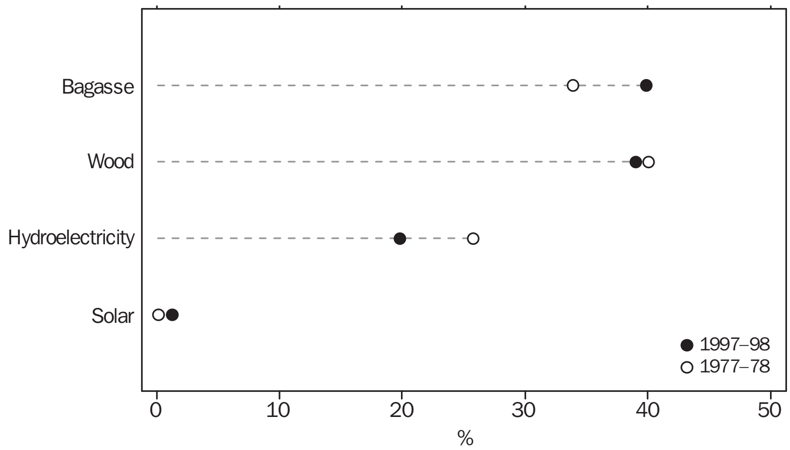
Renewable energy resources are those that can be used at a rate that can in theory be sustained indefinitely. The main forms are hydro-electricity, solar heaters or photovoltaic cells, wind generators, geothermal plants, ocean or tidal generators and biomass generators, which use organically based fuel sources such as wood, bagasse, landfill gases and ethanol.

In 1997–98, 6% of the energy consumed in Australia came from renewable sources. Australia has the resources to increase the proportion of energy contributed from solar, wind, biomass and other sources, and so decrease or slow the expansion of our consumption of greenhouse gas emitting fossil fuels. In 1997 the Prime Minister's Statement *Safeguarding the Future: Australia's response to climate change*, set a target of an additional 2% of electricity generation from renewable or specified waste product sources by 2010.

Over the two decades prior to 1997–98 the contribution of renewable sources to Australia's energy consumption increased by 39%, from 202 PJ in 1977–78 to 281 PJ in 1997–98. However, as a proportion of Australia's total energy consumption the contribution is small, and has declined slightly, from 7% to 6%.

Over those two decades the proportion of renewable energy derived from wood has remained similar while that from bagasse has increased by six percentage points (graph 5.10). The proportion of renewable energy sourced from hydro-electricity has decreased by six percentage points.

5.10 RENEWABLE ENERGY CONSUMPTION, By Source—1977–78 and 1997–98



Source: Bush et al. 1999; ABARE historical spreadsheets.

The expansion of renewable energy will have economic benefits as well as environmental ones. In 1995–96 an estimated 6,400 people were employed in the production of renewable energy and related goods and services. The value of these was $850m and exports were valued at $100m. The main export commodities were photovoltaic panels and cells, solar water heaters and consultancy services. The largest employers in the area of renewable energy were in wood stove manufacturing and related areas and in hydro-electricity generating plants and authorities (DPIE 1997).

Renewable energy *continued*

Cost is the main reason for the limited use of renewable energy sources. Energy from renewable sources is generally more expensive than energy derived from fossil fuel. However, small scale renewable energy sources are commonly used in remote locations that are not serviced by major gas or electricity networks.

Renewable technologies are most cost effective where production takes place close to the point of consumption (DISR 1999). The increasing use of bagasse is a good example: sugar mills burn the bagasse to produce steam and electricity for their own use, and more recently, for sale into the national electricity market—a process often referred to as co-generation. Bagasse is discussed further below.

Other relatively recent renewable energy innovations in Australia are the use of gases produced by the decomposition of organic wastes in landfill sites to power small electrical generators; the establishment of windfarms and small hydro-electricity turbines; and the use of photovoltaic cells to produce electricity.

Landfill gas is mainly a mix of about 55% methane and 40% carbon dioxide, produced by the decomposition of organic materials deposited in landfill sites. The high methane content enables the gas to be burnt on-site to power small electricity generators. This use of landfill gas has the additional advantage of reducing the potential greenhouse impact of gas emitted from the landfill, since burning methane produces mainly water vapour and carbon dioxide; the latter has a smaller global warming potential than methane (see table 5.17). In 1997 the electricity generating capacity of landfill gas in Australia was 72 megawatts. Generally, landfill gas generation occurs within weeks of deposition, but can continue at a gradually decreasing rate for over twenty years after filling is completed (DPIE 1997). Emission estimates result from waste disposed of over the preceding 20–25 years, so recent changes in waste management practices, population growth and per capita quantities of waste, do not immediately impact on methane emission levels. Recovered methane equalled 10% of methane generated from solid waste disposal at municipal landfill sites in 1997 (AGO 1999).

5.11 OPERATING WINDFARM INSTALLATIONS—1999

Location	*State*	*Capacity* MW
Crookwell	New South Wales	4.80
Esperance	Western Australia	2.00
King Island	Western Australia	0.75
Koorangang Island	New South Wales	0.60
Thursday Island	Queensland	0.45
Denham	Western Australia	0.23
Malabar	New South Wales	0.15
Coober Pedy	South Australia	0.15
Flinders Island	Tasmania	0.10
Breamlea	Victoria	0.06
Murdoch	Western Australia	0.03
Aurora	Victoria	0.01
Coconut Island	Queensland	0.01

Source: DISR 1999.

Renewable energy *continued*

Although windmills are a common feature of the Australian landscape, they are generally used to pump groundwater to holding tanks. Small wind-powered generators have also commonly been used in remote areas to generate electricity. More recently, large scale wind generators have been connected into the electricity grid and are capable of supplying approximately 20 MW of electricity in total. The largest windfarm in Australia, located at Crookwell in New South Wales, has eight 600 kilowatt turbines that together can generate up to 4.8 MW of electricity (DISR 1999) (table 5.11).

Currently Australia has the capacity to generate about 7,580 MW from large scale hydro-electricity generators, most of which are located in Tasmania and in the Snowy Mountains of New South Wales. These large scale installations can have a detrimental effect on river flows and result in large-scale flooding of river valleys (see Chapter 3). They can also displace people and fauna, and destroy flora (DPIE 1997; DISR 1999).

More recent development since the mid 1980s has centred on small-scale hydro-electricity schemes. These can either make use of existing structures (dams, weirs, pipelines etc.) and harness energy that was previously wasted, or use diversion pipes that return flows to the river. In 1999 there were 13 small hydro-electricity installations operating in Victoria, New South Wales and Western Australia, with a generating capacity of about 200 MW (Redding Energy Management 1999).

Biomass energy is derived from plant or animal material. Commonly used sources in Australia include wood, bagasse, landfill gas and sewage gas.

Bagasse is the largest contributor of renewable energy in Australia, producing about 112 PJ of energy in 1997–98, or 40% of renewable energy produced in that year (Bush et al. 1999). The sugar mills, mainly located in Queensland and New South Wales, have an estimated capacity of 250 MW. The industry has been assessed as having the potential to supply considerably more electrical energy into the grid—as high as 1,000 MW (DPIE 1997).

Photovoltaics, or solar cells, can directly generate electricity from light. In Australia they are extensively used in remote regions to power settlements and homes, pumps, and automatic navigation and communications systems. More recently, large arrays have been constructed to generate directly into the electricity grid, such as the 50 kW solar array at Queanbeyan, New South Wales. Currently, photovoltaic technology is expensive, but its cost is projected to decrease as global demand increases (DPIE 1997).

Greenpower schemes

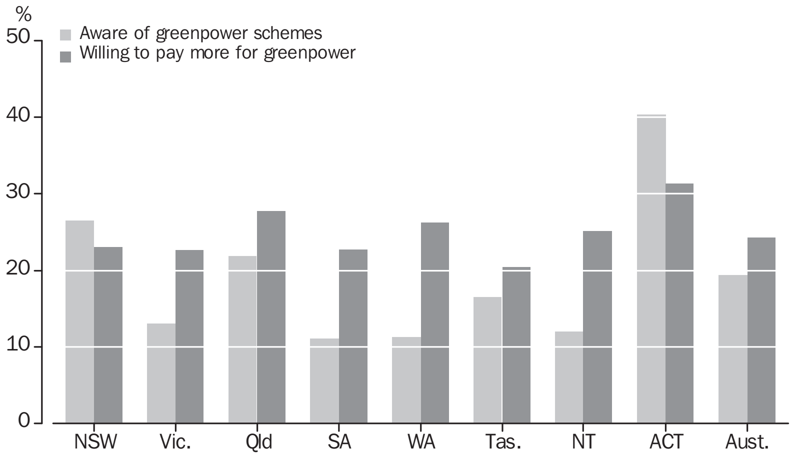
Another recent renewable energy initiative is the development of Greenpower schemes, whereby consumers undertake to increase their payment for their electricity supply to support the development of renewable energy sources. The innovator of these schemes was the New South Wales Sustainable Energy Development Authority (SEDA), which commenced its program in 1997. The Authority has developed an accreditation program for Greenpower schemes to ensure that consumers receive what they pay for. In June 2000, seventeen electricity retailers in New South Wales, Victoria, Queensland, the Australian Capital Territory and Western Australia were offering accredited schemes, with about 68,000 customers (SEDA 2000).

Greenpower schemes *continued*

An example of a Greenpower scheme is that run by the New South Wales electricity supplier, Great Southern Energy. Its 'earthsaver' Greenpower scheme was accredited in April 1997. Customers can nominate a maximum contribution per billing period in addition to normal charges. Customers pay a premium of around 2.5 cents per kilowatt hour on peak and 1 cent per hour off-peak (an average of 2.0 cents per kilowatt hour). The scheme had 2,660 customers in June 2000, and sources its Greenpower from the Crookwell windfarm, a photovoltaic array in Queanbeyan, a hydro-electric generator at Wyangla Dam and a number of smaller facilities (SEDA 2000).

In 1999 an estimated 3% of households (228,000 households) were connected to a Greenpower scheme. This exceeds the number reported by SEDA, the Greenpower accreditation agency, primarily because an estimated 88% of Tasmanian households (164,100 households) reported that they were connected to a Greenpower scheme. Tasmania does not have an accredited Greenpower scheme, but does source nearly all of its electricity from hydro-electric power stations.

5.12 AWARENESS OF GREENPOWER SCHEMES, By Households Not Connected—1999



Source: ABS 1999.

An ABS household survey in 1999 found that 79% of the households not connected to a Greenpower scheme were unaware of these schemes (graph 5.12). Nearly a quarter (24%) of the households not connected to a Greenpower scheme stated that they would be prepared to pay more for this form of electricity. The remaining households not connected to a scheme were not prepared to pay more (56%), or thought they should not have to pay more for this form of energy (5%), or were not sure (15%). Of those households willing to pay more for Greenpower, 54% were prepared to pay between $50 and $150 more per year for their electricity.

Although the proportion of households aware of Greenpower schemes varied widely across States, these variations tended to reflect the state of accredited Greenpower schemes.

ENERGY WASTE PRODUCTS AND CONSEQUENCES

The first part of the chapter discussed the main dimensions of Australia's consumption of energy. The remainder of the chapter considers the consequences of our dependence on non-renewable energy sources, particularly fossil fuel combustion. The main consequences relate to the release of pollutants into the atmosphere, including greenhouse gases.

The atmosphere

The atmosphere is essential to the survival of all life on Earth. It provides the oxygen animals need to breathe, the carbon dioxide plants need to photosynthesise and the water required by both animals and plants. The atmosphere also provides protection from harmful rays of sunlight and from asteroids and other space debris which occasionally collide with the Earth (most asteroids are burned up in the upper atmosphere).

The Earth's atmosphere is divided into several layers and the amounts of different gases change from layer to layer. Near the surface of the Earth the approximate makeup of the atmosphere (by volume) is nitrogen (78%) and oxygen (21%), with carbon dioxide (0.03%) and other gases present in small quantities (Linacre and Hobbs 1977). Even though carbon dioxide and other gases (nitrous oxide, methane) account for only a fraction of a percentage point of the atmosphere they are important because of the heat retaining properties these gases have, relative to oxygen and nitrogen.

Air pollution

While many pollutants are released directly into the air, photochemical smog and ozone (O_3) are the products of chemical reactions in the atmosphere. Both are produced from reactions involving oxides of nitrogen (NO, NO_2), volatile organic compounds (e.g. aldehydes), water, other airborne chemicals and sunlight. The amount of smog formed increases with increasing levels of volatile organic compounds, sunlight and air temperature.

Table 5.13 lists some of the major air pollutants and their sources. Cars and trucks are a major source of air pollution and in the early 1990s accounted for around 80% of carbon monoxide and oxide of nitrogen emissions, 50% of volatile organic compounds and 10% sulfur dioxide in Australia's capital cities (AATSE 1997). While Australia's motor vehicles are the greatest source of air pollution, the introduction of unleaded petrol and the use of catalytic converters has led to significant reductions in the amount of lead pollution (AATSE 1997). For example, lead concentrations at Mascot (inner Sydney) have fallen from an average level of 330 nanograms per cubic metre in the year prior to 1994 to around 130 nanograms per cubic metre in 1996 (Cohen 1996). Lead pollution levels are expected to keep falling as older cars leave service.

5.13 SELECTED AIR POLLUTANTS AND THEIR MAJOR SOURCES

Pollutant	*Description and major source*
Carbon monoxide (CO)	Produced by cars and industrial processes which use fossil fuel driven engines. Other sources include burning vegetation, cigarette smoke, defective heaters and stoves.
Sulfur dioxide (SO_2)	Emitted by cars, during coal burning, oil combustion and industrial processes such as wood pulping, paper manufacture, metal refining and melting, particularly from ore containing sulfide. Small textile bleaching and food preserving facilities, wineries and fumigation activities can also emit sulfur dioxide. Hot springs, volcanoes and decaying vegetation are natural sources of sulfur dioxide.
Oxides of nitrogen (NO, N_2O, NO_2)	Combustion of fossil fuel, in cars and at power plants, burning vegetation and intensive use of fertilisers are some of the human activities which produce oxides of nitrogen. Oxides of nitrogen are produced naturally in soil and in the air during lightning storms. Nitrogen oxide is also a greenhouse gas and depletes stratospheric ozone.
Lead (Pb)	Major sources include engines that use leaded petrol, lead smelters, refineries, combustion of recycled sump oil and battery manufacture.
Volatile organic compounds (VOC)	Major sources in Australian cities are car exhausts, petrol refining plants, petrol stations and manufacturing industries. Industrial processes involving solvents, paints or the use of chemicals are likely to be significant sources. VOCs are also released by painted surfaces, fabrics, carpets, printed paper and material and fibreboard products. There are significant natural sources of VOCs. Most Australian State capitals are adjacent to areas of native vegetation which emit volatile oils. In the Brisbane area, for instance, 60% of the VOCs are believed to originate from natural sources.
Particulate matter (PM 10)	These are very small particles of any substances that are less than 10 micrometres diameter. Particles can be of a range of substances, including sea salt, sulfates, sulfur dioxide, carbon, and silica from soil and pollen. Releases are from a variety of industrial sources—bulk material handling, combustion and minerals processing e.g. refineries, cement works, iron and steel making, quarrying, fossil fuel and power plants. Vehicles also generate particles directly by burning fossil fuels (especially diesel) and by the action of tyres or vehicle-generated air turbulence on roadways.
Ozone (O_3)	Ozone is formed near the Earth's surface by photochemical reactions of a range of air pollutants.

Source: ABS 1996; NPI 2000; CSIRO 2000.

Measuring or estimating the amount of different substances released into the environment has been the task of the National Pollutant Inventory (NPI). The NPI was initiated by the National Environment Protection Council in 1996. The NPI represents the first attempt to quantify the amount of pollution released into the environment at a national level. Data from the first reporting period are available on the Internet (www.environment.gov.au/npi); while it is not a complete picture of pollution in Australia it provides an indication of scale of emissions and a base for future assessments.

The data from the first reporting period contain information on nearly 70 substances emitted by 7,385 operations from 23 industry sectors between 1 July 1998 and 30 June 1999. A total of 1.1 million tonnes of polluting substances was recorded by the NPI, with air pollution accounting for over 95% of all pollution (by weight). Three substances—sulfur dioxide, oxides of nitrogen and carbon dioxide—accounted for more than 90% of all atmospheric pollution recorded by the NPI.

5.14 RISKS TO PEOPLE AND THE ENVIRONMENT FROM AIR POLLUTANTS(a)

Substance	*Human health hazard*	*Environmental hazard*	*Total hazard score*	*Description of human health problems*
Oxides of nitrogen	1.5	3.0	4.5	Causes inflammation in the lungs and increases the risk of lung infections, especially in young children. Effects of exposure may not be immediate.
Chromium (VI) compounds	2.5	3.0	5.5	Usually highly toxic. Inhalation can damage the nose, throat, lungs, stomach and intestines. It may lead to asthma, other allergic reactions, stomach upsets, ulcers, convulsions, kidney and liver damage. Long-term exposure can adversely affect the respiratory and immune systems and can cause cancer.
Carbon monoxide	2.0	0.8	2.8	Reduces the oxygen carrying ability of the blood. May cause poor concentration, memory and vision problems, loss of muscle coordination, and, at high levels, headaches, fatigue and nausea. At very high levels the symptoms intensify and are life threatening. Long-term exposure at low levels may produce heart disease and damage the nervous system. Exposure of pregnant women may cause low birthrates and nervous system damage to offspring.
Sulfur dioxide	1.5	1.3	2.8	Causes irritation of the eyes, nose and throat, choking and coughing. Exposure of the eyes to liquid sulfur dioxide can cause severe burns, resulting in the loss of vision. Other effects include headache, general discomfort and anxiety. Those with impaired heart or lung function and asthmatics are at increased risk.
Dichloromethane	1.5	1.3	2.8	Can be inhaled and absorbed through the skin. High concentrations may cause loss of consciousness and death. Exposure may irritate the lungs, cause a buildup of lung fluid and the heart to beat irregularly or stop. Low doses may cause headaches, fatigue, and behaviour similar to being drunk. Long-term exposures at high levels may damage the liver and brain. It is a suspected human carcinogen.
Cadmium and compounds	2.0	2.3	4.3	Linked to prostate and kidney cancer in humans and also to lung and testicular cancer in animals. Smoke from burning cadmium or cadmium oxide can also damage the respiratory system. Long-term exposures can cause anaemia, fatigue and loss of smell.
Particulate matter (PM 10)	1.2	1.3	2.5	The health effects are many because of the varied composition of particles. General effects include aggravation of existing respiratory illnesses and decrease in lung function. Long-term decline in lung function causing increased death rates and sickness in sensitive people.
Sulfuric acid	3.2	1.3	4.5	A corrosive chemical that can severely burn skin and cause blindness on contact with eyes. Exposure to mist can irritate the eyes, nose, throat and lungs, and at higher levels can cause a buildup of fluid in the lungs. Asthmatics are particularly at risk. Is carcinogenic.
Xylenes (individual or mixed isomers)	1.3	1.0	2.3	Irritates eyes, nose and throat and may cause stomach problems, drowsiness, loss of memory, poor concentration, nausea, vomiting, abdominal pain and loss of coordination. High doses may cause dizziness, passing out and death. Repeated exposures may damage bone marrow. Xylenes may damage a developing foetus.
Arsenic and compounds	2.3	1.7	4.0	Poisonous and carcinogenic. Large doses can cause death. Some arsenic compounds will harm a foetus. Lower level exposure may cause nausea, vomiting, diarrhoea, abnormal heart rhythm, damage to the blood vessels, decreased production of blood cells, and 'pins and needles' in the hands and feet. Long term exposure to contaminated water has resulted in stomach disorders, anaemia, skin lesions, and liver and kidney damage.

(a) The ten pollutants given the highest priority by the National Pollutants Inventory.

Source: NEPC 1998; NPI 1999.

Air pollution *continued*

Air pollution can have adverse effects on human and environmental health. Photochemical smog and airborne particles (particulate matter) are the most serious urban pollutants from a human health perspective (AATSE 1997). Australian studies are consistent with overseas reports which show that high pollution levels increase daily mortality, hospital admissions and emergency room visits for respiratory and cardiovascular disease. For example, a recently published study found that air pollution in Melbourne, and in particular ozone and nitrogen dioxide pollution, were associated with increases in daily death rates (Victorian EPA 2000).

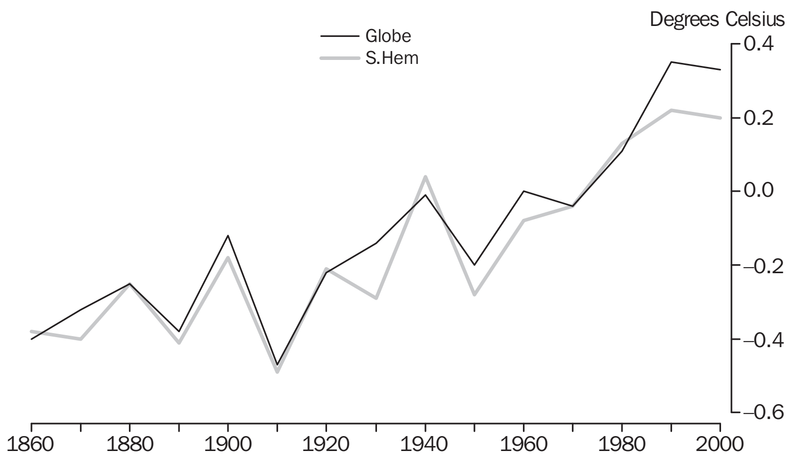
Different substances released into the air cause varying degrees of harm to people and the environment (table 5.14). Some substances are very harmful and can cause problems even in small quantities. A system of assessing the risk to human and environmental health was developed by the NPI Technical Advisory Panel. In this, health and environmental risks were each scored on scale of 0–3, with zero being no risk and three a very high risk (NPI 1999). The scores for health and the environment were then summed to evaluate the overall risk. These scores and the health effects of the ten substances given the highest priority by NPI are shown in table 5.14.

Climate change

The world's climate has gone through many climatic cycles. These cycles have occurred since the formation of the Earth more than four billion years ago, and the temperature of the Earth has fluctuated significantly over time. There have been several ice ages, the first around 2,300 million years ago lasting tens of million of years (Frakes 1979 cited in Lewis 1995). In the context of geological time, current global temperatures are in the middle range of those experienced by the Earth. When viewed in a shorter time frame a different picture can be seen.

The World Meteorological Organization reported that the temperatures of the 1990s were the warmest since records began in the 1860s, and that 1999 was the fifth warmest year on record (www.bom.gov.au/climate/c20thc). The rise in temperature in the southern hemisphere was less than that in the northern hemisphere and the world as a whole (graph 5.15).

5.15 TEMPERATURE TRENDS, World and Southern Hemisphere—1860 to 2000(a)



(a) Trend expressed as the departure from 1961–1990 mean.

Source: Meteorological Office (UK) 2000.

Climate change *continued*

In Australia temperatures have increased since 1910 (graph 5.16), although the amount of the increase has varied from place to place. In general, minimum temperatures have increased by the largest amount, particularly in the eastern half of Australia where they have increased by around one degree Celsius (BoM 2000). The rise of minimum temperatures in winter cropping areas of New South Wales and Queensland has led to fewer frosts and is thought to be partly responsible for increased wheat yields (Nichols 1997; BoM 2000). As with temperature changes, the increase in wheat yields was not uniform, with a few areas reporting low or negative growth in yields (BRS 2000).

5.16 ANNUAL MEAN TEMPERATURE TREND, Australia—1910—2000(a)

(a) Trend expressed as the departure from 1960–1991 mean, as calculated January 2000.

Source: BoM 2000.

Climate change has been implicated in changes to the range (area used) or behaviour of several animals in the northern hemisphere (Wuethrich 2000). In Australia changes are yet to be fully documented, but several species are threatened (Dexter et al. 1995; SoE 1996; Chapman and Milne 1998). For example, two species of flying-fox have undergone significant range changes in the past 30 years (Tidemann 1999). The Black and Grey-headed Flying-foxes have both shifted their range south, with the Black Flying-fox now common in Brisbane, while the Grey-headed Flying-fox has established a camp (colony) in Melbourne. Increased temperatures and loss of native vegetation are the proposed causes of the range changes. The range changes of these species have been reasonably well documented because both flying-foxes are relatively abundant, form obvious camps, and occur in the densely population regions of eastern Australia. Other Australian species, and particularly those that are less mobile, uncommon or hard to find, may also have undergone changes in their range over time.

The effects of increased temperatures are also evident in the marine environment. For example, in 1998 sea surface temperatures in the Coral Sea were the highest recorded in 95 years. These temperatures resulted in widespread coral bleaching on the Great Barrier Reef off the coast of Queensland. Coral bleaching results when corals lose symbiotic algae which live in their tissue, turning them from tan to white. The algae provide their coral hosts with oxygen and other nutrients. The extent and intensity of coral bleaching of the Great Barrier Reef in 1998 were variable.

Climate change *continued*

Some places were largely unaffected (e.g. near the Whitsunday Islands), but in the worst affected places most staghorn and other fast growing corals were killed. Most very old corals survived in these areas. It appears that many corals of the Great Barrier Reef are living close to the limits of survival in terms of sea surface temperature, so any increase in sea temperature is likely to be detrimental (Lough and Done 2000).

There is widespread national and international concern that it is the activities of people that have caused temperatures to increase worldwide (Watson 1999). This has been termed the greenhouse effect or enhanced greenhouse effect. The gases involved, namely carbon dioxide, methane, nitrous oxide, perfluorocarbons, etc., have been called greenhouse gases. Table 5.17 lists the main greenhouse gases produced in Australia by human activity and their greenhouse warming potential (GWP) expressed as their carbon dioxide equivalent (CO_2-e).

5.17 NET GREENHOUSE GAS EMISSIONS, Australia—1998(a)

Greenhouse gas	*Volume emitted* Mt	*Global warming potential(GWP)(b)* CO_2-e	*Volume as CO_2-e* Mt CO_2-e	*Percent of total* %
Carbon dioxide (CO_2)	312.100	1	312.1	68.4
Methane (CH_4)	5.500	21	114.9	25.2
Nitrous oxide (N_2O)	0.089	310	27.5	6.0
Oxides of nitrogen (NO_x)	2.600	—	—	—
Carbon monoxide (CO)	18.600	—	—	—
NMVOC	1.900	—	—	—
Perfluorocarbons (PFCs)	0.002	(c)	1.4	0.3
Sulfur hexafluoride (SF_6)	— (d)	23 900	0.004	0.0
Sulfur dioxide (SO_2)	1.800	—	—	—
Total(e)			**455.9**	**100.0**

(a) Excluding forestry and grassland conversion.

(b) GWP is a measure of the heat retaining properties of gases. Different gases have different GWP. For example, one tonne of CH_4 will cause the same amount of warming as 21 tonnes of CO_2.

(c) CF_4 has a GWP of 6500 and C_2F_6 has a GWP of 9200.

(d) Excludes SF_6 emissions from electricity transmission and distribution but includes emissions from magnesium production. Hydrofluorocarbons (HFCs) are not shown because of very high levels of uncertainty associated with the data.

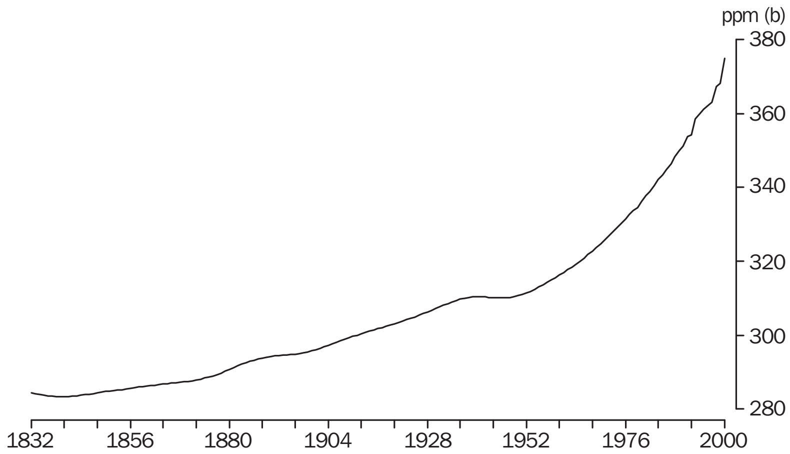
(e) Totals may not add due to rounding.

Source: AGO 2000a.

Globally the concentration of carbon dioxide and other greenhouse gases has risen significantly since around 1800 (graph 5.18). In the southern hemisphere, the concentration of carbon dioxide has been measured in ice cores taken from Antarctica (Etheridge et al. 1996), at the South Pole and at the Cape Grim Research Station in Tasmania (Francey et al. 1996).

Climate change *continued*

5.18 CONCENTRATION OF CO_2 IN THE ATMOSPHERE(a)—1832—2000



(a) Southern Hemisphere only.

(b) Parts per million.

Source: Etheridge et al. 1996; Francey et al. 1996; CSIRO unpublished.

Different sectors of Australian society emit different amounts of greenhouse gases, and the amounts contributed changed between 1990 and 1998 (table 5.19). The energy generation sector is the biggest contributor of greenhouse gases, accounting for 80% of all emissions in 1998, with the generation of electricity (mainly from coal fired power stations) and heat the biggest contributors to the sector (258.7 megatonnes of CO_2 equivalents). This was a 21% increase on 1990 levels. Within the energy sector, transport was responsible for producing 72.6 Mt CO_2-e, road transport accounting for most emissions. Fugitive emissions, mostly methane from coal mining and oil and gas operations, totalled 31.5 Mt CO_2-e. The agriculture sector was the second largest emitter of greenhouses gases with 92.2 Mt CO_2-e (20%), most of these made up of methane emissions from livestock. Forestry is a net consumer of carbon dioxide because the growing trees are storing more carbon dioxide than is released through the trees being cut down. In 1998, 24.5 Mt CO_2-e were stored by trees and vegetation (e.g. through pasture improvement). Growing trees and other activities that store carbon are known as carbon sinks, which are discussed briefly later in the chapter.

Table 5.19 excludes emissions resulting from land clearing (the main greenhouse gas emitted is carbon dioxide). Emissions from land clearing result from the burning and decay of vegetation on the land surface following clearing and soil disturbance which releases carbon (AGO 2000b). Carbon sinks (which reduce net emissions) associated with land clearing result from the regrowth of vegetation following clearing and the build up of carbon in the soil from management practices such as pasture improvement. Estimates of net carbon dioxide emissions from land clearing are very uncertain and they do not fall into the existing reporting framework. Rough calculations have suggested that in 1998 this sector emitted 81.5 Mt CO_2-e, but removed 17.5 Mt CO_2-e, producing a net emission of 64.0 Mt CO_2-e (AGO 2000c). The estimate of emissions from this source will be refined in coming years.

Climate change *continued*

5.19 GREENHOUSE GAS EMISSIONS, By Sector—1990 and 1998

Sector	*1990* Mt CO_2-e	*1998* Mt CO_2-e	*Change* Mt CO_2-e	*Percentage change* %
Energy	299.6	362.9	63.3	21.1
Industrial processes	12.0	(a)9.8	–2.2	–18.4
Agriculture	90.6	92.2	1.6	1.8
Forestry and other(b)	–27.2	–24.5	2.7	10.1
Waste	14.9	15.5	0.6	4.2
Net emissions	389.8	455.9	66.1	16.9

(a) Includes PFCs and SF_6 used in magnesium production.

(b) This sector is a net remover of CO_2, hence a negative contribution.

Source: AGO 2000c.

While the total emissions of carbon dioxide and other greenhouse gases by Australia are low by world standards, representing about 1% of world emissions, on a per capita basis emission levels are very high. Table 5.20 shows carbon dioxide emissions per capita for major world regions and Australia in 1996. Australian carbon dioxide emissions per capita were higher than the averages for selected world regions. Australia's emissions were more than four times the world average and around 30% higher than the average for the countries belonging to the Organisation for Economic Co-operation and Development (OECD). Two of the more important reasons are our reliance on coal fired power stations and our dependence on road transport.

5.20 CO_2 EMISSIONS FOR FUEL COMBUSTION, Australia and Selected Regions—1997

Selected regions/countries	*CO_2* Mt	*CO_2/pop* t CO_2/capita
World	22 981.1	3.97
OECD	12 235.0	11.18
Europe	3 477.8	7.73
Middle East	955.9	6.12
Former USSR	2 257.2	7.74
Non-OECD Europe	309.1	4.95
Asia	2 034.1	1.12
Latin America	878.8	2.22
Africa	729.4	0.99
Canada	477.4	15.76
United States	5 470.5	20.50
China	3 162.0	2.56
Australia	**306.1**	**16.52**

Source: *IEA 1999*.

Reducing greenhouse gases

Reducing the amount of greenhouse gas emissions has become a focus of most recent energy-related policies of the Australian Government, as well the subject of major international negotiations. In December 1992, Australia ratified the United Nations Framework Convention on Climate Change. The Convention came into force in March 1994 and 186 countries are now signatories to it. The main objective of the convention was to achieve a stable level of greenhouse gas concentrations in the atmosphere, and so prevent dangerous human interference with the climate system (AGO 1999). A principal commitment resulting from the Convention was that East European and OECD countries would aim to restore their emissions to 1990 levels by the year 2000.

In 1995 the adequacy of the developed countries' commitments was reviewed and the resulting negotiations led to the Kyoto Protocol of December 1997. This protocol has been signed by 84 nations, including Australia, but has only been ratified by 33 of these nations. Within the Kyoto Protocol Australia successfully argued for differential emissions targets depending on circumstances in each country. On this basis, Australia was allocated a target of restricting emissions to a maximum of 8% above the 1990 level in the period 2008–2012. This contrasts with the overall target set for developed countries of an average 5% reduction. The Australian target is, however, significantly below the projected growth rate of Australian emissions if no actions were taken. Factors considered in setting Australia's targets were its current dependence on fossil fuels and its relatively high economic and population growth rates.

The 1997 Kyoto Protocol included provisions that allow countries to offset emissions by taking into account carbon that has been stored in carbon sinks, such as trees. A proviso was that the storage was to result from a direct human-induced change in land use. Other provisions allowed countries to invest in projects in other countries to acquire 'carbon credits' to meet their obligations, while a clean development mechanism permitted developed countries to invest in emission-reducing projects in developing countries to earn credits.

The main objective of carbon credit trading is to minimise the costs of meeting reduction targets. For example, emitters reducing emissions in excess of their target could sell the excess credits, perhaps to emitters that do not or cannot reduce their emissions cost-effectively. The system provides a degree of flexibility for meeting targets. An emissions trading system could also incorporate carbon sinks based on the mass of carbon stored in the sink. The practical details of these mechanisms are yet to be finalised. The Sixth Conference of the Parties to the United Nations Framework Convention on Climate Change held at The Hague in November 2000 was unable to reach agreement on these issues, but resolved to meet in July 2001 to consider them further.

Additional issues of the Kyoto Protocol that are still to be resolved include precise definitions relating to forestry activities, how changes in land use are to be incorporated, and how carbon sinks are to be measured. Under the protocol, by 2007 Australia must have a national system to estimate emissions and removals into sinks due to human-related activity. A National Carbon Accounting System is being established to fulfil that obligation. Many nations, including Australia, have yet to ratify the Kyoto Protocol, with some nations indicating they may not do so.

Reducing greenhouse gases *continued*

The National Greenhouse Strategy (Commonwealth of Australia 1998) is the main mechanism for meeting Australia's international greenhouse commitments. This strategy is an extension of the National Greenhouse Response Strategy of 1992. The limiting of greenhouse gas emissions has already led to reforms in energy production and the promotion of renewable energy sources, as discussed earlier in this chapter.

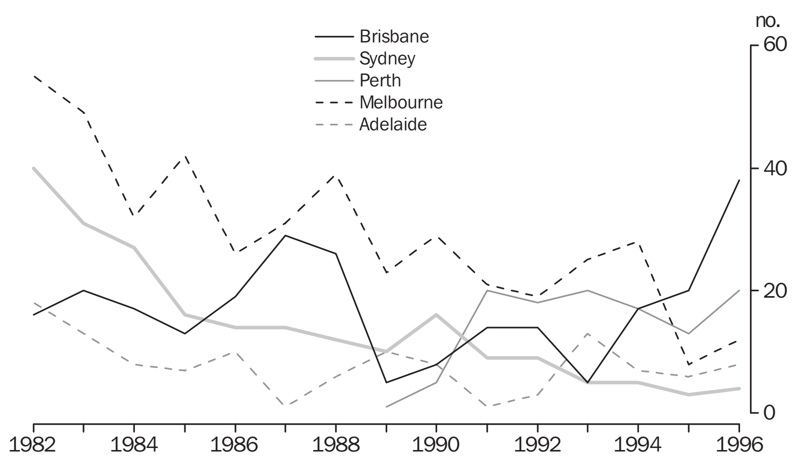
Measuring air quality

Where air quality in the capital cities has been measured, there has been no significant change for a decade or so (AATSE 1997). Hindering the interpretation of results is the lack of data on air quality for 95% of Australia (SoE 1996). Most of the pollution monitoring networks were established around 20 years ago. Long term information on air quality in the outer suburbs is lacking for all of Australia's capital cities, except Brisbane and Perth. Some cities have recently expanded their monitoring networks to rectify this problem (Katestone Scientific 1997).

Another factor confounding the interpretation of pollution trends is the effect climate has on pollution. Particular weather patterns are more likely to produce higher levels of air pollution than others. These days are known as pollution conducive days. While the nature of pollution conducive days varies from city to city, they typically occur in summer and spring in all of Australia's coastal capital cities, except Brisbane which experiences them in late winter as well. Off-shore winds and high inland temperatures are a feature of most pollution conducive days. Australia's capital cities typically have around 20–40 pollution conducive days per year (Katestone Scientific 1997).

The trends in air quality shown by the amount of ozone and smog pollution for five capital cities are shown in graphs 5.21 and 5.22. While the level of pollution has not changed greatly since the early 1980s, the number of cars and level of industrial activity have. This is an indication that emission control technologies and strategies have countered the increases which would be expected given no action and increases in pollution sources (AATSE 1997).

5.21 MAXIMUM HOURLY OZONE GREATER THAN 6 PPHM(a), Days Per Year



(a) Particals per hundred million.

Source: Katestone Scientific 1997.

Measuring air quality *continued*

5.22 MAXIMUM HOURLY SMOG GREATER THAN 10 PPHM(a), Days Per Year

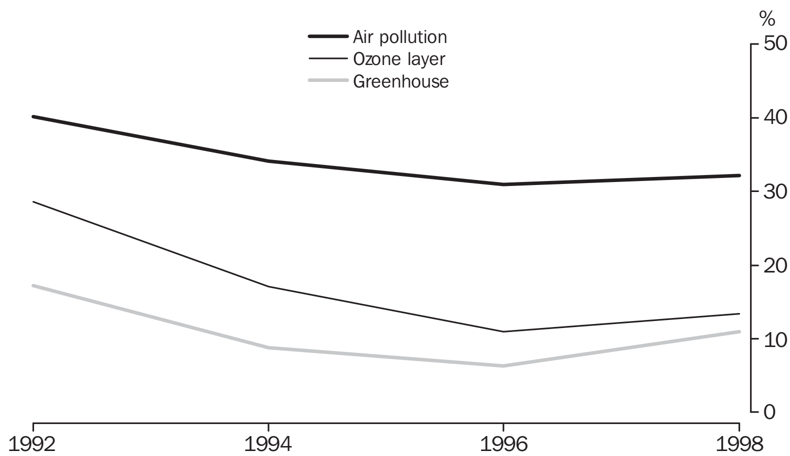
(a) Particals per hundred million.

Source: Katestone Scientific 1997.

Attitudes to atmospheric problems

Air pollution has been the environmental problem of greatest concern to Australians for nearly a decade. Concern about atmospheric problems: air pollution, the ozone layer and the greenhouse effect, has diminished slightly since 1992 (graph 5.23). Atmospheric problems were more likely to be of concern to people living in metropolitan areas than people in other areas (table 5.24). This is to be expected since people in metropolitan areas are more likely to be affected by pollution from industry and motor vehicles.

5.23 CONCERNS ABOUT ATMOSPHERIC PROBLEMS, By Type of Problem—1992–1998



Source: ABS 1999.

Attitudes to atmospheric problems *continued*

5.24 ATMOSPHERIC ENVIRONMENTAL CONCERNS, By Area—1999

Environmental issue	*Metropolitan areas* %	*Non-metropolitan areas* %	*Australia* %
Air pollution	33.9	20.0	29.1
Ozone layer	13.4	10.1	12.3
Greenhouse effect	9.6	7.2	8.7

Source: ABS 1999.

The decrease in concern about air pollution may be due to improvements in air quality resulting from new emission control laws, or part of an overall downward trend in concern for environmental issues.

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ABBREVIATIONS AND SYMBOLS

AATSE	Australian Academy of Technological Sciences and Engineering
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AFFA	Agriculture, Fisheries, Forestry–Australia
AFMA	Australian Fisheries Management Authority
AGO	Australian Greenhouse Office
AGSO	Australian Geographic Survey Organisation
AHC	Australian Heritage Commission
AMISC	Australian Marine Industries Science Council
ANCA	Australian Nature Conservation Agency
ANCOLD	Australian National Committee of Large Dams
ANZSIC	Australia and New Zealand Standard Industry Classification
APEC	Asian Pacific Economic Cooperation
ARCCD	Australian River and Catchment Condition Database
AUSLIG	Australian Surveying and Land Information Group
AWRC	Australian Water Resources Council
AWWA	Australian Water and Wastewater Association
BHP	Broken Hill Petroleum
BIEC	Beverage Industry Environment Council
BoM	Bureau of Meteorology
BRS	Bureau of Rural Sciences
CAPAD	Collaborative Australian Protected Area Database
cfu	coliform faecal units
COAG	Council of Australian Governments
CRCSLM	Cooperative Research Centre for Soil and Land Management
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DISR	Department of Industry Science and Resources
DLPE	Department of Lands, Planning and Environment (Northern Territory)

DNR	Department of Natural Resources (Queensland)
DNRE	Department of Natural Resources and Environment
DPI	Department of Primary Industries
DPIE	Department of Primary Industry and Energy
DPIF	Department of Primary Industry and Fisheries
DPIWE	Department of Primary Industry, Water and Environment
EA	Environment Australia
EEZ	Exclusive Economic Zone
EPBC	Environment Protection and Biodiversity Conservation
EPA	Environment Protection Agency
EDR	Economic Demonstrated Resources
ESD	Ecological Sustainable Development
GDP	Gross Domestic Product
GL	gigalitres (10^9 litres)
GWP	Greenhouse Warming Potential
ha	hectares
IBRA	Interim Biogeographic Regions of Australia
IEA	International Energy Agency
IMCRA	Interim Marine Regionalisation of Australia
IRSED	Index of Relative Socioeconomic Disadvantage
IUCN	World Conservation Union (formerly the International Union for the Conservaton of Nature and Natural Resources)
kg	kilograms
kL	kilolitres (1,000 litres)
km^2	square kilometres
kW	kilowatts (1,000 watts)
L	litres
LWRRDC	Land and Water Research and Development Corporation
MDBC	Murray Darling Basin Commission
mL	millilitres
ML	megalitres (10^6 litres)

MPA	Marine Protected Area
Mt	megatonnes (10^6 tonnes)
MW	megawatts (10^6 watts)
n.a.	not available
NEM	National Electricity Markets
NEPC	National Environment Protection Council
NFA	Native Fish Australia
NFI	National Forest Inventory
NGS	National Greenhouse Strategy
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
no.	number
NPI	National Pollutant Inventory
NSWEPA	New South Wales Environment Protection Agency
NSWNPWS	New South Wales National Parks and Wildlife Service
NWS	National Weed Strategy
OECD	Organisation for Economic Co-operation and Development
PJ	petajoules (10^{15} joules)
PMSEIC	Prime Minister's Science, Engineering and Innovation Council
pphm	Parts per hundred million
QFMA	Queensland Fisheries Management Authority
RAAF	Royal Australian Air Force
RAN	Royal Australian Navy
SARDI	South Australian Research and Development Institute
SEDA	Sustainable Energy Development Authority
SoE	State of the Environment
t	tonnes
TPES	Total Primary Energy Supply
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Protection

UK	United Kingdom
WHO	World Health Organization
WRC	Water and Rivers Commission
WSAA	Water Services Association Australia

$b	billion (one thousand million) dollars
$m	million (one thousand thousand) dollars
—	nil or rounded to zero (including null cells)
. .	not applicable

GLOSSARY

Algal blooms A sudden proliferation of microscopic algae in water bodies, stimulated by the input of nutrients such as phosphates.

Anthropogenic Of human origin or human induced; can be used in the context of emissions that are produced as a result of human activities.

Aquaculture Commonly termed fish farming, but it broadly refers to the commercial growing of marine (mariculture) or freshwater animal and aquatic plants.

Australian Fishing Zone (AFZ) Australia has proclaimed a zone 200 nautical miles wide around its mainland and territories coasts, within which it controls domestic and foreign access to fish resources.

Ballast water Water carried in tanks to maintain stability when a ship is lightly loaded; it is normally discharged to the sea when a ship is loaded with cargo.

Benthos (benthic) All marine organisms living upon or the bottom of the sea.

Biodiversity Biological diversity; variability among living organisms—including genetic diversity, diversity within and between species and diversity within ecosystems (see also ecosystems).

Bycatch Species taken incidentally in a fishery where other species are the target; bycatch species may be of lesser value than the target species and are often discarded ('trash' species). In many cases, bycatch species have some commercial value and are retained for sale (see also non-target species).

Carrying capacity The maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a given region without progressively impairing the functional integrity and productivity of relevant ecosystems.

Coastal The region extending seaward and inland from the shoreline that is influenced by, and exerts an influence on, the seas and their resources and biota.

Coastal zone Numerous definitions exist. Taken here as the area of land and sea, extending landward to the edge of the coastal-draining rivers, and seaward to the edge of the 200 mile EEZ.

Coliform A group of bacteria originating from animal (including human) intestines and used as an indicator of the sanitary quality of water.

Diversion Volume of water diverted from a stream or aquifer on a sustained basis to supply water for rural, urban and industrial usage. Includes diversions undertaken by a water authority, a private company or a group of individuals authorised to act as a water supply industry.

Ecological footprint An estimate of the area of land a population uses to produce the natural resources it consumes and to assimilate the waste it generates.

Ecosystem A complex of plant, animal and microorganism communities which, together with the non-living components, interact to maintain a functional unit.

Ecosystem services The role played by ecosystems in creating a healthly environment for human beings, from production of oxygen to soil formation and maintenance of water quality. Ecosystem services for rivers, wetlands and floodplains include: habitat or refugia, water regulation and supply, waste treatment, food production, recreation and cultural services.

El Ñino A warm water current which periodically flows southwards along the coast of Ecuador and Peru in South America, replacing the usually cold northwards flowing current; occurs once every five to seven years usually during the Christmas season. Occasionally (e.g. 1925, 1972–73, 1982–83 and 1990–1994) the occurrence is major and prolonged.

Endangered species Under endangered species protection legislation, a species in danger of extinction because of its low numbers or degraded habitat; or a species likely to become so unless factors affecting its status change (see also vulnerable species).

Endemic/Endemism Species that are confined to a particular region; for example, a species endemic to Australia is only found in Australia.

Environment protection expenditure Expenditure on actions and activities that are aimed at the prevention, reduction and elimination of pollution as well as any other degradation of the environment.

Estimated resident population Population estimates based on Census counts and then augmented using records of births, deaths, immigration and emigration.

Estuary Area of an inlet or river mouth that is influenced by the tides and also by fresh water from the land; area where fresh and salt waters mix.

Eutrophication Process by which waters become enriched with nutrients, primarily nitrogen and phosphorous, which stimulate the growth of aquatic flora and/or fauna.

Exclusive Economic Zone (EEZ) 200 nautical mile zone declared in August 1994 by Australia in line with the provisions of the United Nations Convention on the Law of the Sea. Australia has the right to explore and exploit, and the responsibility to conserve and manage, the living and non-living resources within this area: see also: Australian Fishing Zone.

Exotic organisms An animal or plant that has been introduced to a region (compare with native species).

Extinct When there is no reasonable doubt that the last individual of a species has died.

Fauna The entire animal life of a region.

Filament line Type of fishing line used in commercial fishing gear, such as gillnets.

Fishmeal Protein rich animal feed product based on fish.

Fishway A structure installed to provide fish with a passage through dams and weirs.

Flora The entire plant life of a region.

Fossil fuels Any natural fuel derived from decomposed or partly decomposed organic matter. Common fossil fuels include, coal, oil and natural gas.

Fully fished A fish stock for which current catches are close to optimum sustainable levels (the definition of which may vary between fisheries: for example, catches are close to maximum sustainable yield, or fishing effort is close to an agreed biological reference point). Categorising a species as 'fully fished' suggests that any increase in levels of fishing effort or catches above current levels (allowing for annual variability) may lead to overfishing.

Gigalitre One thousand million litres.

Gross Domestic Product (GDP) The total market value of goods and services produced in Australia after deducting the cost of goods and services used up in the process of production (intermediate consumption), but before deducting allowances for the consumption of fixed capital (depreciation).

Groundwater provinces Areas where the broad uniformity of hydrogeological and geological conditions with reasonably uniform water bearing characteristics. The provinces are split into zones of predominantly sedimentary or fractured rocks.

Hardwood Timber produced from broadleaved species such as eucalypts, predominantly found in native forests. An increasing area of hardwood plantations is being established.

Individual transferable quota (ITQ) A management tool by which the total available catch quota is allocated to individual fishers or companies. These individuals or companies have long-term rights over this quota and are able to trade quota with others (see also quota).

Interim Marine and Coastal Regionalisation of Australia (IMCRA) Regions which define the major coastal regions around Australia, which do not necessarily conform to State or physical boundaries.

Joule Unit of energy.

Life expectancy The average number of additional years a person of a given age and sex might expect to live if the age-specific death rates of the given period continued throughout their lifetime.

Longline A fishing gear in which short lines carrying hooks are attached to a longer main line at regular intervals. Pelagic longlines are suspended horizontally at a predetermined depth with the help of surface floats. The main lines can be as long as 100km and have several thousand hooks. Demersal longlines, set at the seabed with weights, usually have closer spaced hooks.

Mariculture Fish farming or aquaculture of marine animals or plants.

Marine protected area Any area of estuarine, intertidal or sub-tidal terrain, together with its overlaying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment (Kelleher and Kenchington 1992).

Megalitre One million litres. Approximately equal to the volume of water contained by an Olympic swimming pool (i.e. 20m x 50m x 1m).

Multilateral An agreement or other instrument in which three or more parties (e.g. nations) participate.

Natural increase The difference between the number of children born and the number of deaths in a population.

Net overseas migration The difference between the number of settlers and long-term overseas arrivals and the number of permanent or long-term departures of Australian residents.

Net water consumption Net water consumption is equal to mains water use plus self-extracted water use minus mains water supply. (see Water Account for Australia 1993–94 to 1996–97, (Cat. no. 4610.0) for more details.)

Non-target species Species that are unintentionally taken by a fishery or not routinely assessed for fisheries management.

Nutrients Elements or compounds essential as raw materials for organic growth and development such as carbon, oxygen, nitrogen and phosphorus.

Outfalls Pipe or conduit used to carry either raw sewage or treated effluent to a final point of discharge into a body of water.

Overfished A fish stock for which levels of fishing or catches are excessive, or which still reflects the effects of prior excessive fishing. In the former case, yields may be higher in the long term if the fishing level is reduced in the short term. A classification of 'overfished' may continue after reduction of fishing levels while the stock rebuilds to a desired level or until resumption of fishing is acceptable.

Pathogen Agent causing disease.

Pelagic Inhabiting surface waters rather than the sea floor. This term is usually applied to free swimming species such as tunas and sharks.

Petajoule 10^{15} Joules.

Pollution 1. presence of substances and heat in environmental media (air, water, land) whose nature, location or quantity produces undesirable environmental effects; 2. activity that generates pollutants.

Primary energy The forms of energy obtained directly from nature. They include nonrenewable fuels such as black coal, crude oil and natural gas as well as renewable fuels such as wood and hydro-electricity.

Quota Amount of catch allocated; could refer to a fishery as a whole (total allowable catch) or to that amount allocated to an individual or company (see individual transferable quota).

Regulated river A river declared under Section 22 of the New South Wales Water Act that has its flow or supply of water augmented by a dam.

Renewable energy Renewable energy resources are those that can be theoretically used at a rate that can be sustained indefinitely. The main forms are hydro-electricity, wood, solar heaters or photovoltaic cells, wind generators, geothermal plants, ocean or tidal generators and biomass generators.

Run-off The amount of rainfall which actually reaches a storage or stream.

Seagrass Flowering plant adapted to living wholly submerged in seawater; not true grasses, but many have a grass-like form.

Secondary energy Energy source derived from the conversion of a primary energy fuel. For example, the production of electricity by burning coal.

Semi-arid climate Receives between 250 and 500 mm annual rainfall.

Sewage Organic waste and waste water produced by residential and commercial establishments.

Softwood Timber produced from conifers, predominantly grown in plantations. The most common species grown is the introduced Pinus radiata (radiata or Monterey pine). There are also a number of Gondwanan conifer genera that still survive in native forests.

Species Group of animals or plants having common characteristics and able to breed together to produce fertile (capable of reproducing) offspring, so that they maintain their 'separateness' from other groups; for example, yellowfin tuna and bigeye tuna are two distinct tuna species, whereas general terms like 'tuna' and 'trout' each represent groups of species.

Stock (fish) A group of individuals of a species occupying a well-defined spatial range independent of other stocks of the same species. Random dispersal and directed migration due to seasonal or reproductive activity can occur. Such a group can be regarded as an entity for management or assessment purposes. Some species form a single stock (for example, southern bluefin tuna) while others are composed of several stocks (for example albacore tuna in the Pacific Ocean belong to separate Northern Pacific and South Pacific stocks). The impact of fishing on a species cannot be determined without knowledge of this stock structure.

Stormwater A sudden, excessive run-off following a storm.

Subsistence (catch) Catch of marine wildlife taken by traditional fishing peoples and practices for the purpose of food or ceremony.

Surface water resources (assets) Volume of water that could be diverted from a basin each year on a sustained basis.

Sustainable fishing A management goal in which the rate of harvesting or use does not exceed the rate of renewal of the resource over a prescribed time.

Threat abatement plan A plan formalised under endangered species legislation to counter the effects of a listed key threatening process.

Total allowable catch (TAC) For a fishery, a catch limit set as an output control on fishing.

Total fertility rate Represents the number of children one woman would bear if the age-specific birth rates of the year shown continued during her child-bearing lifetime. It is obtained by summing age-specific birth rates.

Underfished A fish stock that has potential to sustain catches higher than those currently taken. The classification is not applied to stocks that are subject to limited catches while rebuilding from overfishing.

Vulnerable species Under endangered species protection legislation, a species that within 25 years will become endangered unless mitigating action is taken; see also endangered species.

Wastewater Water discharges from domestic effluent, industrial (trade waste, industrial waste) and other sectors.

Wetlands Wetlands are shallow bodies of water which can be freshwater, saline or brackish and periodically or permanently inundated.

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