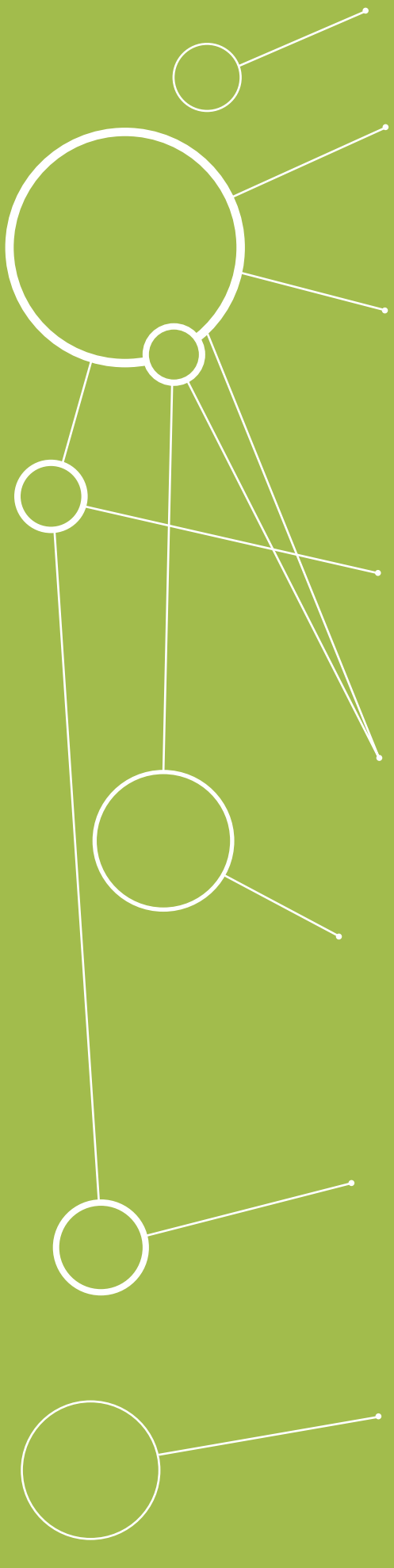
Australia State of the Environment 2006



Australia State of the Environment 2006

Independent report to the Australian Government Minister for the Environment and Heritage

2006 Australian State of the Environment Committee

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Disclaimer
This report was prepared by the 2006 Australian State of the Environment Committee and was guided by 8 theme commentaries, 10 integrative commentaries and 33 papers on current and emerging issues. The views it contains are not necessarily those of the Commonwealth or of state and territory governments. The Commonwealth, which includes the 2006 Australian State of the Environment Committee, does not accept responsibility in respect of any information or advice given in relation to or as a consequence of anything contained herein.

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Australia State of Environment 2006 is the work of many people, starting with the foundations laid by the 1996 and 2001 committees. Expert authors wrote the various commentaries and short reports (see Appendix 2), based on data provided by Commonwealth, state and territory agencies. These sources were used by the Australian State of the Environment Committee to prepare this report. The Department of the Environment and Heritage (DEH) has provided secretariat support, the web-based product and the Data Reporting System. This system was adapted by DEH from a system that was developed by the Tasmanian Government.

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Letter of Transmittal

Dear Minister

It is with great pleasure that I, on behalf of the Australian State of the Environment Committee, submit the *Australia State of the Environment 2006* report and all the supporting material to you as Minister for the Environment and Heritage and through you to the Parliament and people of Australia.

Prepared by an independent committee, the report is required to cover the environment as defined by the *Environment Protection and Biodiversity Conservation Act 1999* and the *Environment and Heritage Legislation Amendment Act 2003* to include:

(a) ecosystems and their constituent parts, including people and communities

(b) natural and physical resources

(c) the qualities and characteristics of locations, places and areas

(d) heritage values of places, and

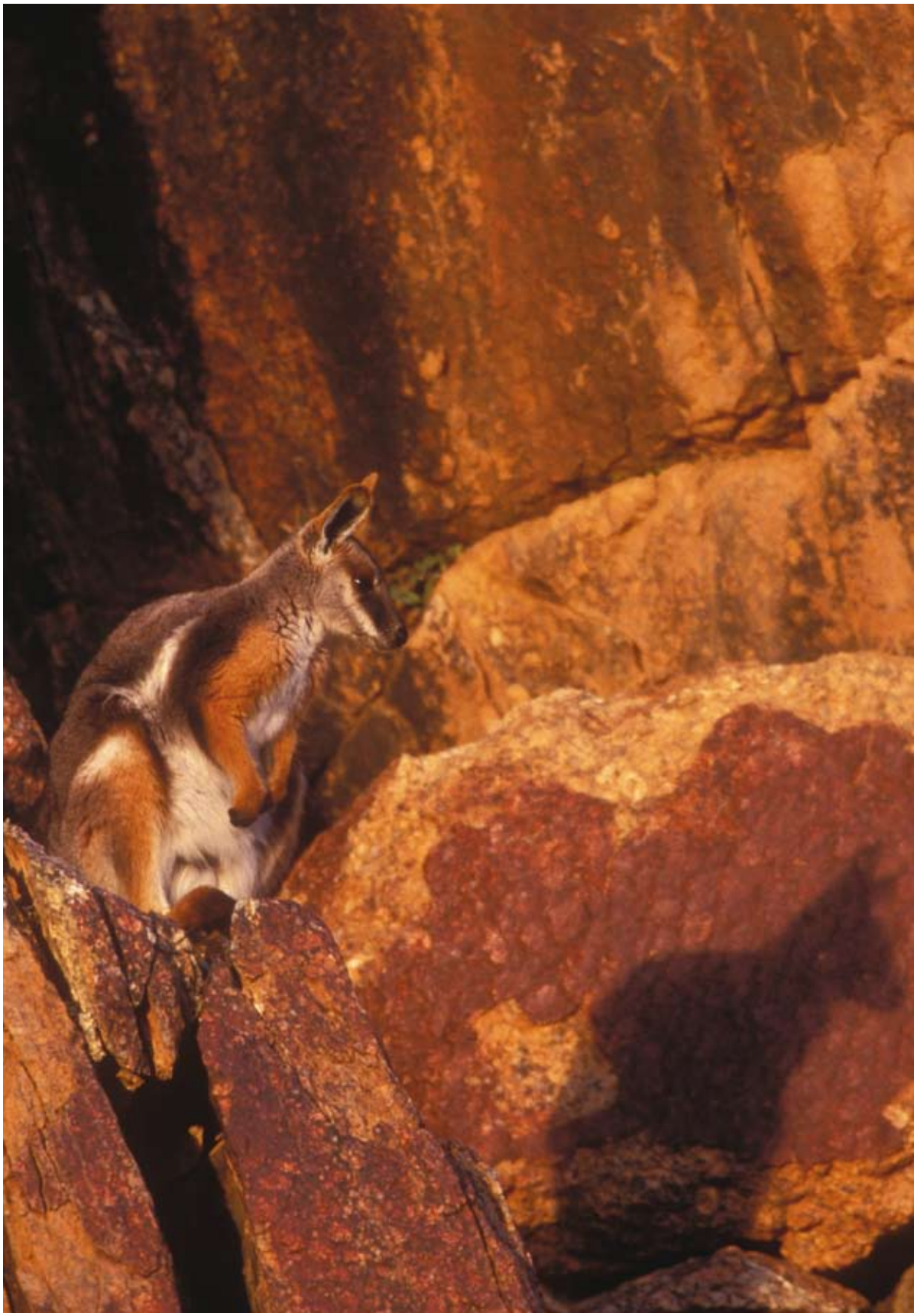
(e) the social, economic and cultural aspects of a thing mentioned in paragraph (a), (b) or (c).

The legislation requires a report on Australia's environment every five years.

Australia State of the Environment 2006 is published as a dynamic, web-based system that is designed to be continuously updated through an enduring environmental reporting system. The nation needs such a system, the environment deserves it and policy development and evaluation cannot occur without it. But only the foundation has been laid; much more needs to be done to make it an enduring system.

The future role of a state of the environment committee should be one of data interpretation and commentary, with ready access to up-to-date, relevant, national data. The *Australia State of the Environment 2006* report should be the last one that is prepared from a committee-initiated process of ad hoc data collection.

Bob Beeton
Chairman
2006 Australian State of the Environment Committee



The vulnerable yellow-footed rock wallaby (South Australia and New South Wales). Photo: D Watts, DEH.

1

Introduction

Australia is blessed with a mega-diverse continent and seas. Increasingly, our attention is directed at managing and sustaining it. *Australia State of the Environment 2006* (*SoE2006*) is the third independent national stocktake of the Australian environment. It covers the five-year period 2001 to 2006, and reports on all aspects of the environment through the themes of human settlements, atmosphere, biodiversity, coasts and oceans, inland waters, land, natural and cultural heritage, and the Australian Antarctic Territory, and a number of commissioned integrative commentaries.

Since 1996, three Australian state of the environment (SoE) reports have been prepared. Yet because of the lack of accurate, nationwide environmental data, the Committee is still not in a position to give a clear national picture of the state of Australia's environment.

Within the limitations of the available data, this report sets out to objectively and accurately describe the reality of the circumstances, to recognise what has been achieved, and to identify future options. This is no easy task. It is far more demanding than just listing everything that is wrong or lost, or celebrating everything that has been saved or restored. This report acknowledges the long sequence of human occupation and interaction with the natural environment of Australia that has shaped and layered the landscape—a natural and cultural heritage that is valuable and worth conserving in its own right. The report also recognises the profound impacts of people on Australia's natural ecosystems.

The relationships between environmental pressures, conditions and responses are diverse, and environmental management is a complex process. Nevertheless, there is a rising level of debate about Australia's environment, how it should be managed and how the public is informed and involved in its management. This has significant implications for policy and practice. Nevertheless, there is an increasingly mainstream debate about Australia's environment and how it should be managed. The environment is everybody's business.

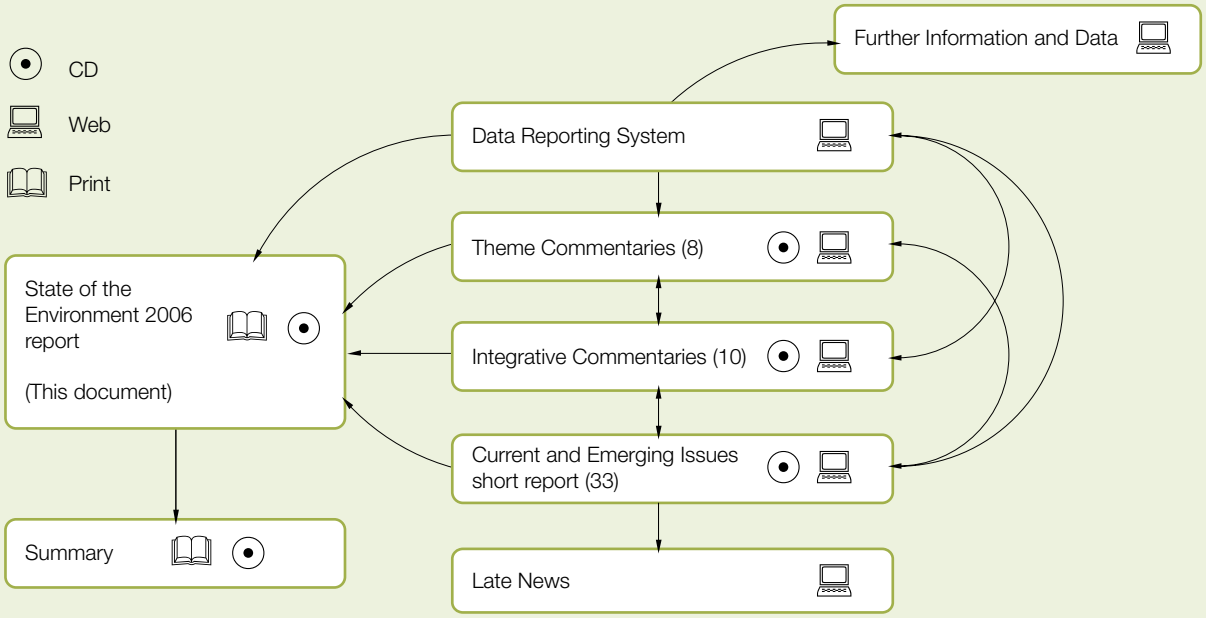
SoE2006 is a key contribution to the ongoing process of environmental reporting. It is the only mandated national reporting process for which data from different aspects of the environment are brought together and assessed by independent experts. The process of state of the environment reporting focuses attention on environmental problems and progress. It provides access to data and it is a basis for all Australians, and people interested in Australia, to evaluate, comment and act on environmental issues.

To assist with the independence of the reporting process, the Australian State of the Environment Committee commissioned commentaries on each of the major themes: human settlements, atmosphere, biodiversity, coasts and oceans, inland waters, land, natural and cultural heritage, and the Australian Antarctic Territory. Additionally, the Committee commissioned commentaries on associated issues that were seen as critical to understanding the state of Australia's environment and improving the debates that surround it. All commentaries were peer reviewed and are published on the website as the authors' own works. An additional series of short reports on current and emerging issues was also prepared (see Appendix 2). These all support *SoE2006* but they are not formally part of it.

SoE2006 reflects the diversity of views that can arise from the differing ways of interpreting the same data and drawing out messages. In preparing this report, the Australian State of the Environment Committee has looked at all the available data and interpretations, with a view to contributing to a healthy environmental debate. The Committee does not expect that this report will be the last word and has designed a total product that will allow progress to be debated and monitored.

The *SoE2006* product comprises seven elements, all of which are available in a fully integrated website at <http://www.deh.gov.au/soe>. The main *SoE2006* is available in printed form and on CD-ROM as well, and it is this component that is provided to the Minister for the Environment and Heritage for tabling in the Australian Parliament. A printed summary document that includes a CD-ROM is also available. Other elements of *SoE2006* include the data reporting system, theme commentaries, integrative commentaries and short reports, and numerous data links in an organised system that includes a late news section (see diagram below). The content of the main report is built upon these elements. Those who want further information than is presented here, including the source data and analysis, should look to these other elements.

The report that follows provides the key findings of *SoE2006* along with an overview of the issues associated with each theme. Those interested in pursuing these issues can, by CD-ROM and Internet, access commentaries, short reports and data systems through a search engine and links system that attempts to make all relevant information available to all who are interested in Australia's environment.



2

Key findings

This section presents key findings drawn from the data and other information available to the Australian State of the Environment Committee. It is an assessment of Australia's environment in terms of the pressures on it, the state it is in, and the responses that Australia has made. In addition, the Committee presents suggested future directions on the basis of its experience of assembling *SoE2006*. Collectively, all these findings are important for future policy, but they are not intended to be prescriptive.

This is the third independent state of the environment report for Australia since 1996, but it is still impossible to give a clear national picture of the state of Australia's environment because of the lack of accurate, nationally consistent, environmental data. This has particularly serious consequences for identification and management of Australia's biodiversity, coasts and oceans, and natural and cultural heritage. Better time-series and spatial data are needed across almost every environmental sector.

The biggest improvements in condition are seen in relation to atmosphere. There is evidence to suggest that the global response to reduce the use of ozone-depleting substances 18 years ago is having an effect. The size of the Antarctic ozone hole has not changed in the last ten years and the overall amount of ozone in the stratosphere appears to have increased from 2000. Also, air quality in both urban and regional areas, in most cases, is meeting agreed national standards. There are some concerns for air quality in some cities where serious air pollution episodes still occur.

Climate change is an important issue for Australia. While there is debate about scientific predictions, it is almost universally accepted that temperatures are rising. The extent of rise is uncertain and continuous adaptation of environmental and sectoral policies, in an uncertain environment, is the key.

The recent drought was particularly severe because it was hotter than previous droughts, and because it affected almost the entire continent. It demonstrated that some of the water resources for our cities and irrigation-based industries, which are already stressed and over-allocated, are particularly vulnerable to 'natural' climate variability, let alone the increased climate variability that is expected over the coming decades. One result is that Australian governments, companies and citizens have started to recognise the issues around climate variability far more than they did in 2001.

There has been a major shift in the approach by governments and the community towards environmental management during the last decade. This is seen in an increasing financial investment in Australia's environment by all levels of government; for example, the Australian Government spent more than $10.3 billion during 2001–05 to address environmental problems through a variety of programmes. Tangible evidence of this shift includes:

- steps were taken to bring an end to broad-scale vegetation clearing between 2001 and 2006 in most states and territories
- changes to oceans and fisheries management, with a major industry restructure to reduce the total catch in Commonwealth-managed fisheries, the increase in no-take zones in the Great Barrier Reef Marine Park and Queensland's nearshore waters, and the creation of a number of marine protected areas in some state and territory waters
- increasing cooperation between governments and the community in environmental stewardship through regional environmental management arrangements, such as regional natural resource management entities; there are concerns about the differences in the capacity of local government and regional groups to adequately undertake and fund their responsibilities

- since *Australia State of the Environment 2001* (*SoE2001*), the Council of Australian Governments has further advanced its water reform agenda, with its National Water Initiative using market-based reforms and agreed policy platforms to seek improvements in water use and allocation, by humans and the environment
- clarification of the responsibilities of the three levels of government, improved protection of Commonwealth-owned heritage assets, establishment of a National Heritage List and promotion of a holistic view of heritage as part of the environment through amendments to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- the establishment of the National Collections Council in 2001 and the establishment of significance assessment methods for collections — important response measures for conserving cultural heritage
- an increasingly cooperative approach between most states and territories and the Australian Government in developing a consistent approach to threatened species listing and the protection of threatened species and ecological communities
- the increasingly active role in environmental stewardship by the philanthropic and business sectors, with several organisations actively managing large areas of land to either restore or manage for biodiversity outcomes.

Many of the pressures that were reported in *SoE2001* still exist, and some have intensified. The demands this places on the broader environment, through increases in use of energy, land, water and other materials, are also significant, particularly because individual consumption of most resources is increasing to support the Australian lifestyle. The advances in recycling some forms of urban waste, such as paper and glass, are positive but they do not offset the environmental costs of net consumption. Australia has to do better in recycling and in the reuse of critical resources such as water, energy, construction materials and organic waste from gardens, sewage, residual food, industrial and livestock sources.

Of continuing concern for Australia's immediate future is continued population growth along the coastline. The formation of mega-metropolitan centres with increasing population density on Australia's coasts has the potential to displace much valuable biodiversity and 'high-value' agricultural land.

Much urban environmental progress can be achieved by adopting strategies that reduce the harmful impacts of unsustainable consumption on the environment and nationally recognising that urban form and liveability have a powerful influence on human settlements. The development and implementation of an Australian Government policy on cities would provide leadership and guidance to the other two levels of government, as well as to developers, producers and consumers so as to achieve a common approach to the creation of sustainable settlements.

Future directions

The following points are derived from the Committee's insights from preparing this report. They are the opinions of the Committee, and are offered as a contribution to the policy debate in Australia.

This report initially used 263 indicators to establish the data reporting system. They were selected by the Committee from the original 500 indicators that were proposed for state of the environment reporting in 1999 (DEH 2006i). Their selection was on the basis of measurability and usefulness of information. There are useful national data for 37 per cent of them, some data for 51 per cent and no data for 12 per cent. Each of land, biodiversity, coasts and oceans, inland waters, and natural and cultural heritage lacks more than half the data needed to make a comprehensive national assessment.

It is the emphatic opinion of the 2006 Australian State of the Environment Committee that the future role of a national state of the environment committee should be to provide data interpretation and commentary, using accessible, up-to-date, relevant national data. The year 2006 must be the last state of the environment report that starts with a committee-initiated process of indicator and data selection. Environmental data should be continuously updated and made publicly available on the web. This will require strategic responses that are tailored to national, state and territory and regional needs, and that are sufficiently understood and accepted to be sustained into the future.

Such a system will equip Australia with a national capacity to monitor and assess the condition of the environment on an ongoing basis, not just every five years. It will also illustrate the returns on investment in the environment and changes to environmental governance. This knowledge will allow Australia to measure, for example, the anticipated improvements in river systems from existing and foreshadowed investments. It will allow greater leverage of private sector inputs, including capital, information and knowledge, to better integrate production systems with natural resource management.

The capacity of some environmental sectors and rural communities, including local government, needs urgent attention. They need equipping to meet the new challenges posed by new monitoring systems. Another very significant issue is the continuing national decline in Australia's capacity in biological taxonomy. A third is the need to improve the quality of environmental education in general.

Environmental stewardship by Indigenous Australians is of increasing importance, and governments have a lot more to do to support the capacity of Indigenous communities in this respect. The very poor health and employment prospects of many Indigenous Australians significantly affect their ability to contribute to their culture and country, and to manage Australia's environment. This is especially the case in remote areas, many of which do not meet minimally acceptable standards for human settlements.

Community perceptions of heritage, and the relationships between cultural and natural heritage, and Indigenous and non-Indigenous stories, are likely to continue to change. Better outcomes for Australia's heritage will require a shift in the emphasis by governments on statutory responses to a better alignment between heritage and environment policies and programmes. They will also need greater focus on the development of effective and efficient measures for resourcing heritage conservation, including through better integration of heritage investments and outcomes with regional environmental investments.

The Committee supports systems that encourage stewardship by accreditation, certification and, where appropriate, markets for environmental services. Regulations work best when either dealing with common property resources or situations where market failure occurs. Incentives work best when a private good is involved, provided they do not mask disincentives and providing their performance is measured and their use is adapted in light of their effectiveness. Regulation and incentives are appropriate tools for environmental management.

Adaptive management will make a significant contribution to Australia's environment and long-term sustainability. It requires further investment in improving the capture of successful examples of its application and environmental monitoring and data availability. This will come from a national environmental reporting system that is coordinated in its timing, reporting and has improved data management, sharing and aggregation protocols across all jurisdictions.

Fire illustrates the need for adaptability. The debate following the major 2001 and 2003 bushfires in south-eastern Australia has challenged approaches based on reasoned, adaptive science. The development of appropriate fire regimes remains a national priority. This is because fire is a risk to public life and property, a critical factor in the survival of many plant communities, an important variable in the adaptive set of many species and the one manipulative management tool over vast areas of Australia.

A further illustration of the need to better adapt is in Australia's urban areas, in which a reduction in net individual consumption and waste is required. This will involve greater population densities in our cities and major urban areas than currently is the case, significant increases in building material recycling, the capture and use of stormwater, the recycling of wastewater and biological waste, and improved urban form and urban structures.

Benefits derived from Australia's investments in the development and deployment of environmental technologies (such as better urban systems, water management, water and land restoration, and recycling) will require increasing emphasis so that they are in proportion to the investment in environmental policy and management.

The Australian State of the Environment Committee has drawn attention to significant issues, to which responses cannot occur without government leadership and public support. Australia's collective sense of national stewardship and shared responsibility requires a recognition that environmental services are needed and valued by all and so must be paid for by all. This can occur only from a strong economic base and in a social context of individual and collective responsibility.

3

Human settlements

Australia's human settlements take a variety of forms. The large capital cities dominate in population terms, but many Australians live in smaller towns and remote areas. All are part of the environment and, as Australia's population continues to increase, all are a source of pressure on Australia's environment. Because the majority of people live in cities and towns, the environment within them also has a direct effect on people's quality of life, including health and access to services and opportunities such as education, employment and health care.

A major pressure on and of Australia's human settlements is in coastal regions near the capital cities, where the population is growing faster than the national average. This pressure is accentuated by increasing consumption of energy, land, water and other products dependent on natural resources. Wastes are increasing despite efforts at recycling. A sustainable human environment requires greater attention to urban design and a reduction in net consumption. In some areas of Australia where pressures are high, progress has been made in recognising the importance of urban form and infrastructure; the challenge is implementing this insight.

3.1 Population changes

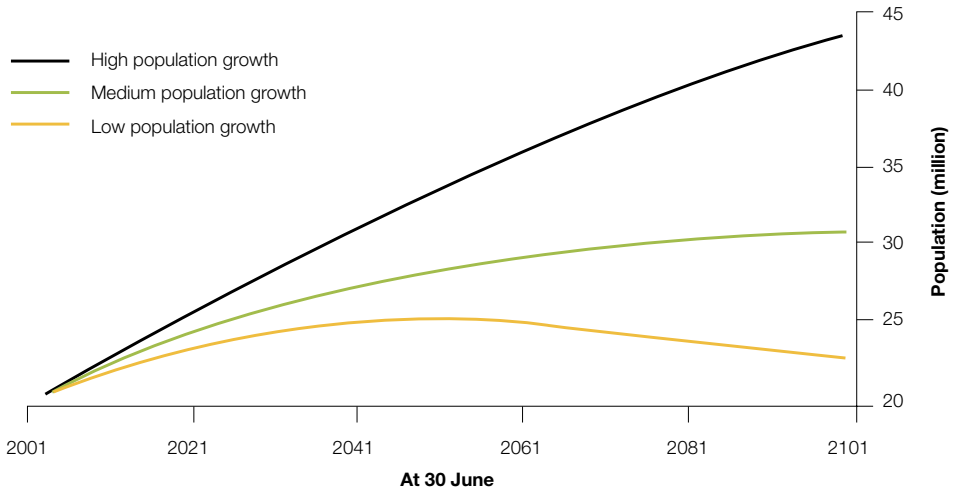
In the five years since *SoE2001*, Australia's population has increased by about 0.9 million people to reach the current estimated population of 20.3 million people (30 June 2005). This is an annual growth rate of 1.2 per cent. As in *SoE2001*, this is an estimate because the national census is done just before this report is published and up-to-date data were not available.

Australia's overall population growth comes roughly equally from natural increase (births) and migration from overseas. Projections by the Australian Bureau of Statistics suggest that Australia's population will increase to 28 million people by 2050 (the moderate population growth shown in Figure 1), with the number of people aged over 65 doubling from 13 per cent to 26 per cent. This moderate forecast assumes net immigration levels of 110 000 people per year (slightly below the current level), fertility rates of 1.7 (about the current level) and an average life expectancy of 85 years for males and 88 years for females. The assumptions on migration levels could be optimistic with increasing competition for skilled migrants.

These changes to Australia's demography could see a slowing in population growth and economic growth, which in turn could reduce the growth in pressures on the environment, although this depends on producer and consumer behaviours.

The main street of Taree on the mid north coast of New South Wales. Increasingly coastal settlements are changing with demographic and lifestyle shifts. Photo: J Baker, DEH.

Figure 1: Projected population for Australia



Source: ABS (2003c)

Local population trends are more complex. Rural areas are generally declining while larger cities continue to grow in area and population. The reason is that most of the growth in coastal regions is from internal migration, as people from inland areas and from larger cities move to the coast to retire or, more commonly, for a 'sea change'—79 per cent of people who moved to 'sea change areas' during 2000–01 were younger than 50 years of age (ABS 2004a). Overseas migrants have tended to stay in the larger cities, with half of them settling permanently in Sydney or Melbourne—this presents a challenge to the state governments trying to manage growth in already populous areas. Commonwealth, state and territory government policies aiming to encourage immigration to rural and regional Australia have seen a decrease in the number of overseas migrants settling in the capital cities—from 78 per cent in 1996 to 67 per cent in 2004.

The greatest population growth in larger cities continues to be in the outer suburbs—greenfield developments around the city fringes. There has also been an increase in the number of people choosing to live in high-rise buildings in city centres, particularly in 'beachfront' suburbs. Residential densities have always been highest in the inner suburbs, but they are now increasing across middle suburbia under compact city policies of state governments and the relatively recent process of infill housing. Population density in all of Australia's larger cities has increased, with more high-rise, medium density, infill and smaller lot greenfield developments (Table 1), which have also increased dwelling density. Paradoxically, occupancy rates—the number of people per dwelling—have declined.

These changes are fundamentally altering the centres of Australian cities. Apartment living has acquired a certain cachet amongst some sectors of the population, and the demand is being met by recycling of old buildings and construction of new high-rise buildings. It is partly because of high city-centre land values, and partly in response to planning policies that encourage more vibrant city centres (by mixing uses and bringing more people in over longer periods).

The outer suburbs of Australia's largest cities continue to be population growth hotspots and contribute significantly to urban pressures. Photo: A Mostead, DEH.

In Australia's regional areas, there is some growth in the larger regional centres at the expense of small towns within easy driving distance (ABS 2005a). Rural decline generally has both economic and environmental flow-on effects. Sixty-three percent of all rural municipalities lost population between 1991 and 2001 (Shepherd 2003).

Table 1: Selected occupied private dwellings* in Australia, 2001

Population centre (grouped by size)	Separate houses		High density housing		Total dwellings#
	Percentage of dwellings	Change in number of dwellings (%)	Percentage of dwellings	Change in number of dwellings (%)	('000)
	2001	1991–2001	2001	1991-2001	2001
Capital cities	72.4	16.1	26.7	36.2	4453.4
Sydney	63.7	10.2	35.5	36.5	1438.4
Melbourne	74.5	13.9	24.7	36.0	1243.4
Brisbane	80.6	25.9	18.3	73.5	601.1
Adelaide	75.5	13.5	24.0	13.9	430.2
Perth	77.9	26.1	21.5	30.5	511.2
Hobart	83.1	15.4	16.2	8.2	76.1
Darwin	62.6	32.8	29.8	55.4	38.2
Canberra	76.9	18.0	22.8	49.6	114.7
Other large cities	76.8	40.0	20.8	71.5	1257.9
Country areas	86.5	7.0	8.5	-0.1	1361.0
Australia	75.9	17.5	22.2	37.2	7072.2

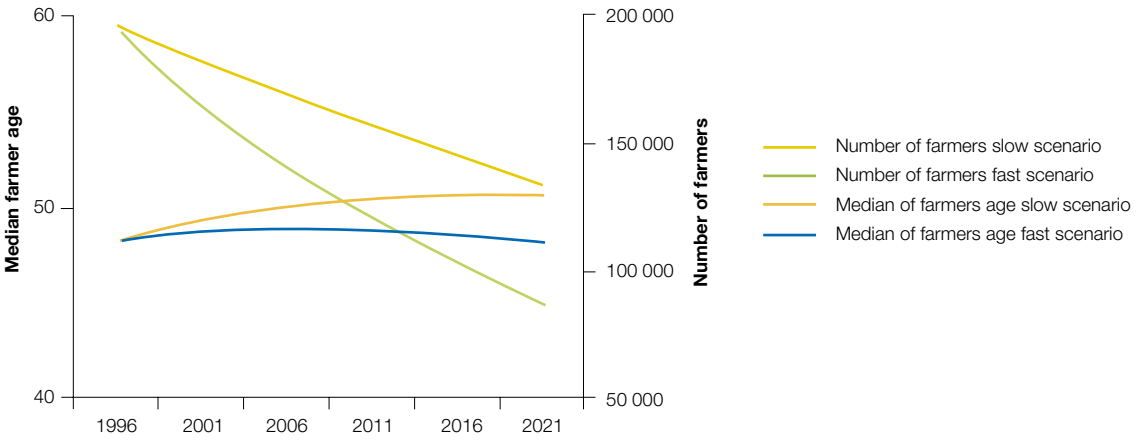
Note: * dwellings where the dwelling structure was not stated were excluded prior to the calculation of percentages;
includes other dwellings.

Source: Australian Bureau of Statistics (1991 and 2001) Censuses of population and housing, cited in ABS (2003a).

The National Land and Water Resources Audit (NLWRA) forecasts a decline of between 30 and 55 per cent in farmer numbers by 2020 (Figure 2) and a continued increase in the age of the farming population (NLWRA 2002a). Median farmer age increased from 48 years to more than 50 years between 1996 and 2001 (Barr 2004). Together, these two trends directly affect the viability of rural communities. Regions experiencing the greatest threat are the dryland (grains and sheep) farming regions (Hugo 2002), some of which are highly vulnerable under future climate change scenarios of reduced rainfall (Fisher 2005). The trend with respect to small towns is likely to continue apart from those associated with mining and tourism.

Overall, the loss of people from rural areas has left a raft of small towns and some Indigenous communities struggling because of depopulation and welfare dependency, which raises doubts about their ability to maintain their efforts to manage their own natural and cultural environments.

Figure 2: Projected age and number of Australian farmers 1996–2021 using fast and slow adjustment scenarios



Source: NLWRA (2002a)

3.2 Population pressures

From an environmental perspective, the key issue arising from human settlements is the pressure they impose on the environment in terms of the demand for land, water, energy and other resources. As this section demonstrates, a long-term but immediate change in materials and energy balances is needed to give more efficient urban systems, and this requires a decoupling of resource use from economic progress.

Australians are consuming more resources. The trends of the past five to ten years indicate that during a period of relatively high employment and sustained high consumer confidence, per capita household consumption expenditure has increased in real terms by 25 per cent from 1995–96 to 2003–04. This puts more pressure on the environment and on cultural heritage.

Realising a sustainable human environment requires a reduction in net consumption and waste. This will involve greater population densities than currently is the case, significant increases in building and material recycling, the capture and use of stormwater, the recycling of wastewater and biological waste, and improved urban form and urban structures. It also requires changes in behaviour by individuals, so education and awareness-raising are important factors. The challenge is to implement this insight.

Water presents particular issues for human settlements. A huge contribution to resolving Australia's 'water crisis' could be made by using existing technologies to improve the yield of water supply catchments; better utilise runoff from urban stormwater; and greatly increase water reuse and recycling.

Urban development

Urbanisation is an increasing pressure on some areas of Australia's land resource. At most risk is the coastal strip, which is experiencing an increasing demand for housing by a growing population (Table 2). Most Australians live within 50 kilometres of the coast, and most tourism occurs there. At greatest risk are areas close to capital cities where high-quality arable land and many coastal low-key holiday settlements near the capital cities are being replaced by low-density suburban forms. The result of these trends is that many coastal cities are merging to form 'mega-metropolitan' regions—systems of interlinked cities. The regions of greatest development are:

- south-eastern Queensland and northern New South Wales (Hervey Bay to Byron Bay)
- Sydney mega-metropolitan region (Newcastle to Wollongong)
- the Port Phillip region (Queenscliffe to Portsea)
- north of Perth in the City of Wanneroo to south of Perth in the City of Mandurah (Figure 3).

The spread of urban development is placing pressures on coastal habitats through loss of vegetation and hence biodiversity, and increased pressures on wetland environments. Photo: Great Lakes Council.

The risk for the eastern seaboard is that, if left unchecked, this coastal development will soon give rise to a largely contiguous urbanised east coast seaboard stretching from Hervey Bay to the Surf Coast in Victoria. Only protected areas along the coast such as national parks and other reserves will not be urbanised. At risk are highly productive agricultural lands, areas of heritage significance and unprotected ecologically significant remnant habitats. In other areas, coastal development is encroaching into fire-prone areas of coastal heath, forest and shrubland.

Figure 3: Urban development along the Perth coast

Source: ERIN (2006a)

Table 2: Size and density changes in estimated resident population of coastal areas in Australia, 1996–2004

Coastal areas (as defined by Statistical Local Areas)[a]	Area[b] ('000 km²)	Estimated resident population ('000s)			Average annual population change (%[c])	
		1996	2001	2004	1996-2001	2001-04
All coastal areas	2163.1	7482.0	7971.7	8283.5	1.3	1.3
Coastal areas excluding capital cities	2149.2	2977.7	3193.4	3339.6	1.4	1.5
Coastal areas within capital cities	13.8	4504.4	4778.3	4943.9	6.1	3.5
Australia	7705.3	18 310.7	19 413.2	20 111.3	1.2	1.2

Notes: a. coastal areas are all Statistical Local Areas (SLAs) with a boundary adjoining the sea, including those with boundaries adjoining harbours and rivers such as Leichhardt (A) in Sydney Harbour and South Perth (C) on the Swan River in Perth. Note that many SLAs extend inland for large distances (for example, East Pilbara Shire in Western Australia has a coastline of roughly 80 kilometres and an area of over 350 000 square kilometres). b. based on 2004 Australian Standard Geographic Classification (ASGC) boundaries. c. average annual growth rate.
Source: ABS (2005a)

In New South Wales, coastal urban expansion has been limited because the state government has bought strategic areas of land, and continues to do so. Between March 1995 and May 2006, approximately 37 000 hectares of coastal national parks were created. In total, some 140 000 hectares of land in New South Wales is protected and managed in coastal national parks. Combined with Queensland's efforts, this protects more than 600 kilometres in the Nowra to Noosa coastline from urbanisation.

The challenges the mega-metropolitan regions create for planning and governance are complex. The public costs associated with these lifestyle choices and the demand for infrastructure are significant. For example, agricultural production from peri-urban regions is estimated to be a quarter of Australia's total gross value of agricultural production (Houston 2005), yet there is no national mechanism in Australia for monitoring the loss and its impacts. National monitoring of biodiversity loss through urban expansion has been similarly neglected. It is encouraging that emerging long-term development strategies are starting to define limits to urban expansion and protect and conserve rural land and conservation areas (for example, Melbourne 2030, Sydney Metropolitan Strategy, Southeast Queensland Regional Plan, Planning Strategy for Adelaide).

In several major urban areas of Australia where urban growth pressures are high, progress has been made in recognising the importance of urban form. The pace and scale of redevelopment and outward expansion in many Australian cities provides opportunities for changing urban form to increase urban efficiency.

Energy use

Across Australia, total energy use has continued to increase (Table 3). This is a result of Australia's increasing population as well as more industries and more people using more energy, despite a small offset as a result of improved energy efficiency. Growth in use of renewable energy sources is slow, amounting to less than 6 per cent of energy used in Australia (Table 4). Use of liquid gas is increasing in some areas, such as in Brisbane and Canberra public buses (Table 5), but the full potential is not being realised.

Table 3: Energy use per capita and per unit GDP in Australia, 1997–98 to 2003–04

Year	Energy consumption[a] (PJ)	Estimated resident population[b] ('000)	GDP*[c] $million	Energy use per capita (GJ per capita)	Energy use per unit GDP (GJ per $million)
1997–98	4777.6	18 711.3	633 353	255.3	7543.3
1998–99	4884.7	18 925.9	666 921	258.1	7324.3
1999–00	4971.0	19 153.4	692 264	259.5	7180.8
2000–01	5034.1	19 413.2	706 109	259.3	7129.4
2001–02	5110.8	19 641.0	733 647	260.2	6966.3
2002–03	5215.1	19 872.6	756 170	262.4	6896.7
2003–04	5345.7	20 111.3	783 593	265.8	6822.0

Note: PJ - petajoules; GJ - gigajoules *Reference year 2002–03
Sources: column a. Donaldson (2004), column b. ABS (2005b), column c. ABS (2004b)

Table 4: Energy end-use by source and by sector in Australia, 2001–02

	Petroleum products	Electricity	Natural gas	Biofuels	Solar	Total
Total final energy consumption (PJ)	1530.0	689.9	649.3	1.5	4.4	3307.5

Note: PJ - petajoules
Source: Donaldson (2004)

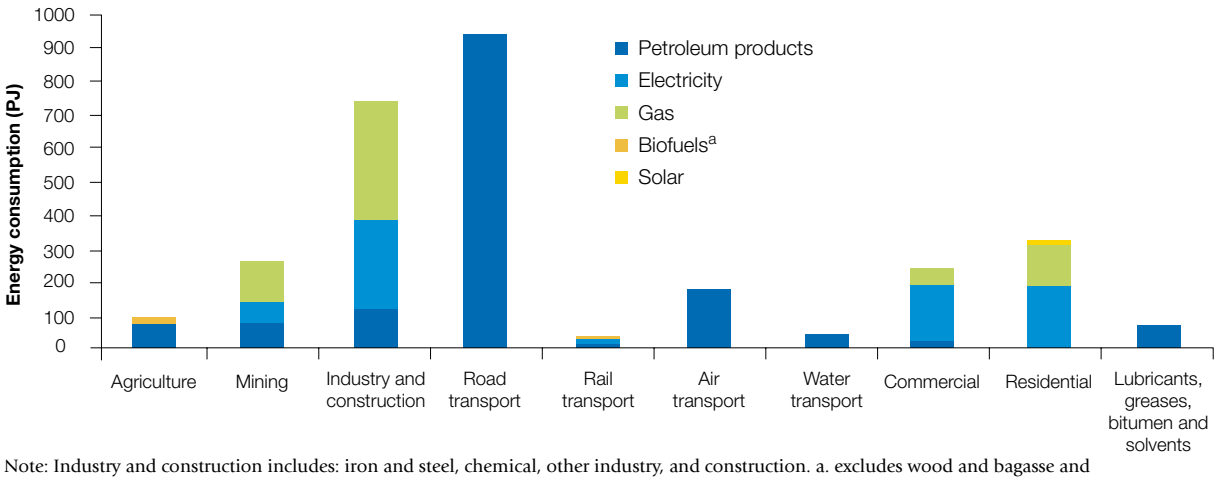
Table 5: Energy consumption by Canberra's public bus fleet, 2002–03 to 2004–05

Fuel type	Energy Use (GJ)		
	2002–03	2003–04	2004–05
Automotive diesel	315 674	321 869	302 183
Electricity	7871	8379	8995
Greenpower	2332	2602	2749
Liquid petroleum gas	-	12	17
Natural gas	9561	19 764	43 281
Petrol	2466	2570	2581
Total	**337 904**	**355 196**	**359 807**

Note: GJ - gigajoules
Source: ACTION Authority (2005)

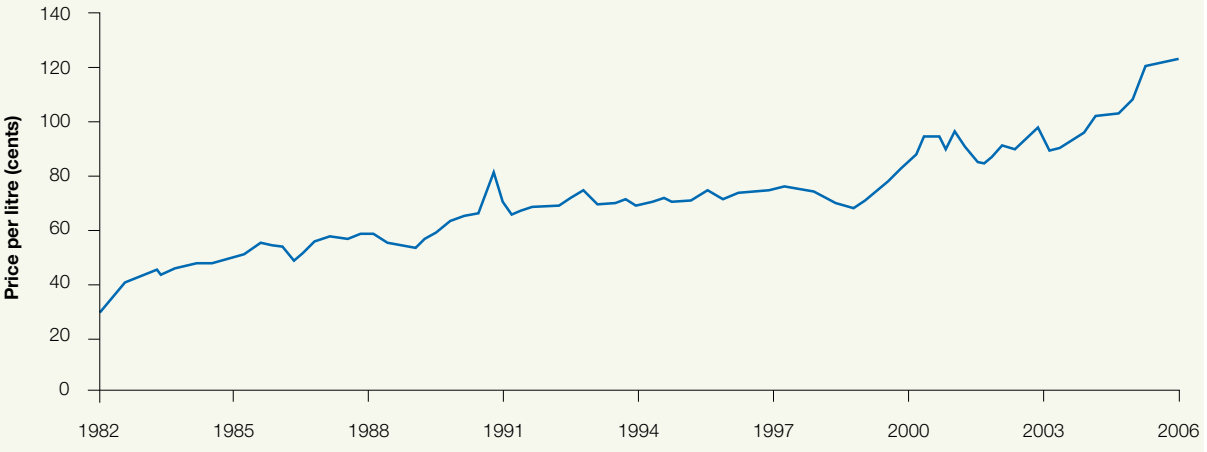
Road transport is the single biggest user of energy, consuming almost 40 per cent of the energy used in Australia (Figure 4). On roads, private passenger vehicle travel represents three-quarters of total road travel, and although total petrol consumption continues to increase, there are signs of household consumption stabilising. This would be influenced by higher petrol prices and more fuel-efficient cars (see Figure 5).

Figure 4: Energy end-use by source and by sector Australia, 2001–02



Note: Industry and construction includes: iron and steel, chemical, other industry, and construction. a. excludes wood and bagasse and includes recyclables.
Source: Donaldson (2004:43)

Figure 5: Quarterly average retail price of petrol in Australia's eight capital cities, 1982–2006

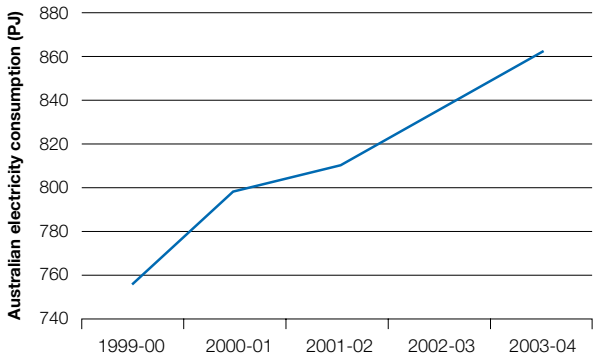


Note: from 1994, figures are for unleaded petrol. Leaded petrol is approximately 2 cents per litre more expensive.
Source: after various ABS catalogues 6403.0

The rate of growth in share of road travel is greatest in the category of light commercial vehicles servicing intra-urban freight needs. Growth in volume of freight transported by road, both within and between cities, has also continued at rates more closely aligned to rates of economic growth than population growth.

Electricity consumption has been steadily increasing, and this is a direct result of economic growth. The rate of growth in electricity consumption is also expanding, from an increase of 1.9 per cent in 2001–02, to 3.4 per cent in 2002–03 and 5 per cent in 2003–04 (ESAA 2005). The main users of electricity are the industry and construction, residential and commercial sectors. The changing patterns of electricity consumption are partly linked to the growth in commercial and residential air conditioning load of 20 per cent a year for the last five years (Figure 6). Improved thermal design of Australia's buildings is needed to reduce the need for air conditioning, particularly given the increases in temperatures in the last 30 years (page 25), and thereby mitigate this pressure on the environment.

Figure 6: Australian electricity consumption



Note: PJ - petajoules
Source: ABARE (2005a)

Increasing energy use is of concern because it directly affects environmental quality. Much of Australia's energy use is based on non-renewable fossil fuels such as coal and oil and, aside from the direct environmental impacts of extraction, the emissions from burning these products impact on air quality and on climate change through greenhouse gas emissions. For example, the use of petroleum products in the road transport sector is directly associated with high levels of particulates, carbon monoxide and other pollutants (see 'Ambient air quality' pages 30-31).

All Australia's major dams are at record low levels as a result of the current drought. At only 9 per cent capacity in April 2003, Wyangala Dam, south-east of Cowra in New South Wales, exposes the old dam structure. Photo: J Boshier.

Water use

Water use continues to increase across Australia. In 2000–01, just over two-thirds of water consumed in Australia was used by irrigated agriculture, with only about 5 per cent of water used by other rural sectors. Domestic use accounted for only 9 per cent of water use. Industrial and commercial use accounted for the rest. The impacts of Australia's water use on inland waters is discussed elsewhere (see 'Inland waters' pages 59-68).

Water reuse has increased, albeit slowly. In 2001-02, 516.5 gigalitres of water was reused, which is a substantial increase from the 134.4 gigalitres reused in 1996–97. Some 82 per cent (423.3 gigalitres) of that was reused by irrigated agriculture, and 23.1 gigalitres was reused in other rural sectors.

Only 9 per cent of Australia's sewage effluent was being recycled in 2001–02, which is an improvement from the estimated 7 per cent during 1996–99. The extent of wastewater reuse increased in all Australian states, except Queensland, from the late 1990s to early 2000s (Table 6); however, the rate of recycling varies greatly between states, with South Australia being the leader and the Northern Territory being well behind.

Table 6: Water discharge and reuse from water utility sewage treatment plants in Australia, 1996–99 and 2001–02

State or territory	1996–99			2001–02		
	Effluent (GL/yr)	Recycled (GL/yr)	%	Effluent (GL/yr)	Recycled GL/yr	%
Qld	328	38	11.6	339	38	11.2
NSW	548	40.1	7.3	694	61.5	8.9
ACT	31	0.25	0.8	30	1.7	5.6
Vic	367	16.9	4.6	448	30.1	6.7
Tas	43	1	2.3	65	6.2	9.5
SA	91	9	9.9	101	15.2	15.1
WA	109	5.5	6.1	126	12.7	10
NT	21	1	4.8	21	1.1	5.2
Aust.	1538	112.9	7.3	1824	166.5	9.1

Note: GJ - gigalitre
Source: Radcliffe (2003)

Strategies for the capture, treatment and use of stormwater—the realisation of 'city as catchment' —are poorly developed. Urban stormwater from the many hard surfaces in cities is essentially not used, even though the area of the combined 'catchment' is equivalent to that of most urban water supply catchments. The exception is the increasing use of rainwater tanks; some 17 per cent of Australia's households had rainwater tanks (1 340 700 tanks) in 2004; an increase from 15 per cent of households since 1994. This reflects better government and community acceptance of the need to reduce water use. Even though more Australians are now reporting that they use water conservation measures, it is too early to assess whether the change in attitude is reflected in the water use data. As much as 44 per cent of household water is still used outside the house, although water restrictions in the major metropolitan areas have had some effect on use of water on gardens.

Water Futures Project – Toowoomba

Toowoomba's water supply dams were at about 25 per cent capacity in April 2006, and the city was on severe water restrictions. The Council proposed a Water Futures programme to look at ways to better use the available water. The most significant aspect of the programme was to treat wastewater to a high degree and to mix it with water in the supply dams. The mixed water would then be further treated before being used for drinking water, and would have supplied about a quarter of Toowoomba's total water needs in 2025. There would also have been more water available for coal washing, irrigation, power generation and industrial use. Irrespective of the science, these issues will always be controversial. A Toowoomba Water Futures Poll was held on Saturday 29 July 2006 to determine whether the proposal to use recycled and treated wastewater as a water supply option for the city and surrounding industry would be accepted. The residents rejected the proposal in July 2006.

Source: Toowoomba City Council (2006)

Waste

The amount of waste generated in Australia has increased with population. Around one tonne per person per year is disposed into landfill (Table 7), but the amount is decreasing in some states (ABS 2003b).

Most households in Australia's cities recycle some waste, especially newspapers and green waste, and waste recycling and reuse rates in general have increased to an average of 36 per cent across Australia (WCS Market Intelligence 2001). In areas outside the capital cities, the recycling rate is lower because of the logistics and costs associated with collection and transport from rural areas to processing plants. Reuse of waste, in contrast, is higher among rural and regional households.

Most states and territories have implemented waste reduction policies with a view to reducing the amount of waste to municipal landfills. These have been broadly successful. For example, of the waste generated from building activity on an annual basis in the Sydney region approximately 10 million tonnes are now recycled or reused, 2.5 million tonnes are reprocessed into building materials off-site, and 1 million tonnes are disposed of annually to landfill (DEC NSW 2003).

In Australia, product stewardship schemes are being used by industry and governments to bring the key players together to understand and correct market failures in the life cycle of products and materials, such as packaging, newsprint, plastic bags, refrigerants, farm chemicals, motor oil and polyvinyl chloride.

A new used oil collection facility at Maryborough in Queensland. Schemes to collect used oil have been implemented largely through government and industry partnerships with a total of 80 per cent now collected and reused. Photo: Maryborough City Council.

Table 7: Solid landfill waste quantities in Australian states and territories[a], 2002–03

Sector	Amount of waste to landfill ('000 tonnes)[b]							
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Domestic and municipal	1657	2133	1108	na	741	na	na	82
Commercial and industrial	2358	2790[c]	522	na	420	na	na	98
Construction and demolition	1193		200	na	1525	na	na	27
Other	–	545	986	na	–	na	na	–
Total (b)	5208	5467	2815	1252	2696	na	na	207

Note: na - not available.
(a) data as reported by state and territory government departments and environment protection authorities across all industries.
(b) caution should be exercised when making state comparisons due to scope differences across states and territories.
(c) Victoria reports commercial, industrial, construction and demolition waste as a combined amount.

Source: Australian Bureau of Statistics (2004c: 15)

Schemes are also being developed for tyres, televisions and computers. The schemes are implemented largely through voluntary and co-regulatory arrangements involving the Australian Government, state governments and industry.

Despite these efforts, it is clear that almost all (96 per cent) of Australia's waste ends up in landfill. This compares with 70 per cent in the United States (approximately 16 per cent is incinerated) and 50 per cent in Sweden (where 45 per cent is incinerated) (Batten 2002). Although the potential is far from being realised, a small amount of the methane generated from landfill sites is recovered, mainly for electricity generation, increasing from a negligible amount in 1990, to 24 per cent in 2003 (DEH 2005a). Many of Australia's landfill waste disposal sites do not incorporate measures for the collection and treatment of landfill gas. An estimated 80 per cent of Australia's municipal solid waste is available for this purpose, representing a source of approximately 50 gigajoules annually excluding the total potential from existing landfill sites (ABS 2003b, Aquatech 1997).

The Productivity Commission (2006a) released its draft report on Waste Generation and Resource Efficiency on 23 May 2006. The report focuses solely on the downstream environmental impacts of waste disposal and does not investigate outcomes from implementation of more resource efficient practices or cleaner technologies. In summary, the Commission found that waste management policy in Australia needs to be refocussed, and the attitudes of both policy makers and the community need to be guided by rigorous analysis of costs, benefits and risks in order to secure the best returns for the community. While recycling can be good up to a point, returns diminish when it is pushed too far.

3.3 The condition of human settlements

The condition of Australia's human settlements is closely connected to the broader environment. In Australia, the overall condition is good. Most Australians live reasonably well, enjoying clean air and water, more than enough to eat, and ready access to employment, housing and a range of high quality services such as health and education. There are some notable exceptions, such as in many remote Indigenous communities. These require continuing and positive attention.

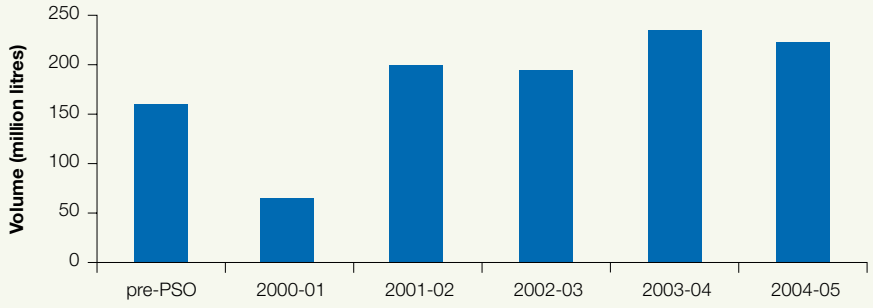
Community wellbeing

Wellbeing is a broad concept that includes factors such as family and social networks, neighbourhood amenity, access to services, as well as more individual issues such as employment, economic resources and health (OECD 1976, ABS 2001, Eckersley 1998). Wellbeing is not spread evenly through Australia's human settlements.

The most disadvantaged group in Australia is remote Indigenous communities, in terms of almost every measure of wellbeing, including health, disability, housing, employment and education (ABS 2005c). For example, infant mortality in remote Indigenous communities is double the Australian average and average life expectancy is around 17 years lower (Productivity Commission 2005). Housing conditions for 9 per cent of Indigenous households do not support good health, largely because of overcrowding. Despite modest gains in some aspects, such as employment and education levels (ABS 2005c), it is patently obvious that much more needs to be done before some settlements will meet minimally acceptable standards for human settlements. In this context, governments have a lot more to do to support the capacity of Indigenous

The amount of used oil being recycled under the Product Stewardship for Oil programme has increased dramatically. Of an estimated 280–300 million litres of potentially recoverable used oil, more than 220 million litres were recycled and reused in 2004–05, a large increase from the estimated 160 million litres of used oil recycled before the introduction of the programme in 2000 (Figure 7).

Figure 7: Volume of used oil recycled under the Product Stewardship for Oil programme, 2000-01 to 2004-05



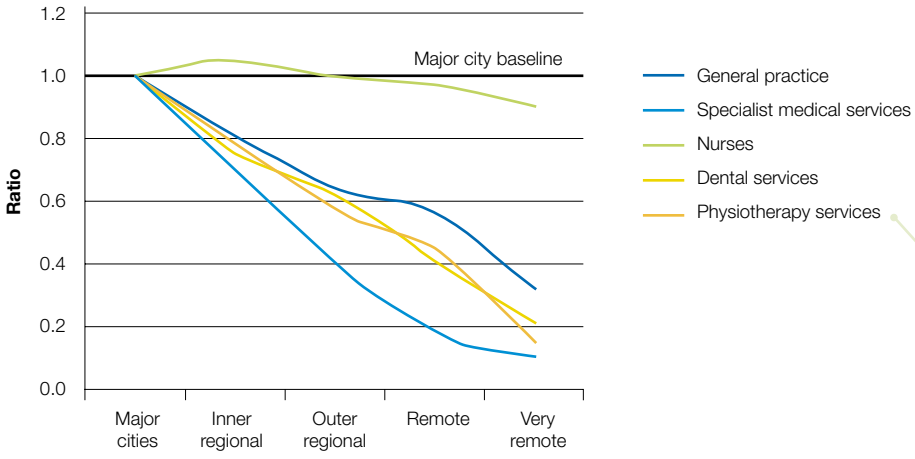
Note: 2000–01 data are for six months, from the start of benefits from the Product Stewardship for Oil programme in January 2001.
Source: DEH (2006a)

A family walks home after Sunday mass in Wadeye, 2005. Photo: G Hunt, Fairfaxphotos.

communities to be able to take a more active role in stewardship of Australia's natural and cultural heritage.

The disparity in wellbeing across the rest of Australia is less significant, but it does exist. For example, rural and remote areas in general are poorly served in terms of health outcomes. Compared with the major cities, the number of deaths per thousand people is on average 10 per cent higher in regional Australia, and 50 per cent higher in very remote regions. Access to health services is of increasing concern because of a shortage in the number of health practitioners, which is worse in outer metropolitan, rural and remote areas and especially in Indigenous communities (Figure 8). Areas of special need such as mental health, aged care and disability services particularly suffer significant shortages in the face of growing demand (Productivity Commission 2005). Major regional centres and inner city areas have not experienced the same shortage in the supply of health professionals.

Figure 8: Availability of medical practitioners in regional and remote areas compared with availability in Australia's major cities

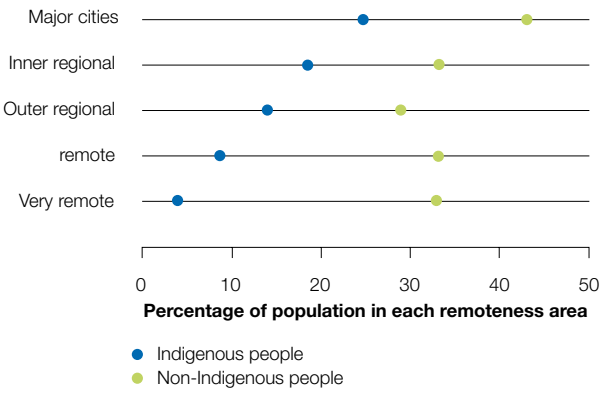


Source: Productivity Commission (2005:205)

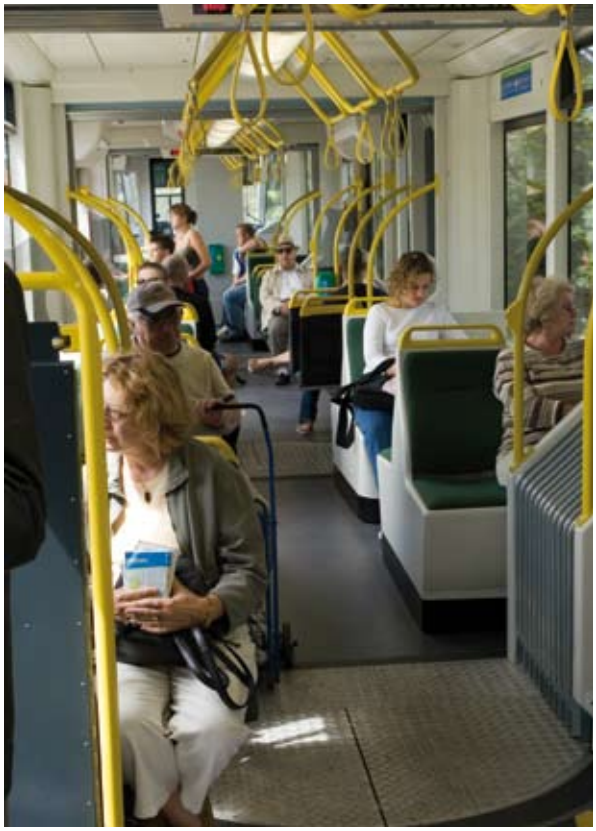
Continuing disparities in the wellbeing of urban Australians are seen in wealth in the last two decades. Some 20 per cent of households in Australia control almost 40 per cent of the nation's total disposable income. One consequence of this gap is the concentration of welfare recipients in areas where housing is more affordable, but where there is little chance of finding work, such as in some areas in Melbourne (Birrell et al 1999, Borland et al 2001). The concern is that an intergenerational pattern of welfare dependency could be reinforced by a combination of poor family and neighbourhood experiences in relation to employment.

Computer literacy is a key skill that is required to access the growing knowledge economy, but the availability of the resources needed—computers and Internet access—varies with income and geography (Figure 9). There are significant concentrations of information and knowledge workers within cities linked to high income —high amenity suburbs (Gipps et al 1996, Florida 2002, Newton 1991, Reich 1991).

Figure 9: Levels of Internet use across Australia, 2001



Source: ABS (2004d)



In the past five years, greater attention is being paid to urban planning issues, including public transport; however more work needs to be done. Photos: J Baker, DEH.

Liveability: urban design and planning

Concerns with the growth of Australia's larger cities have led to a greater attention to urban design and planning in the past five years, with most state governments producing strategic plans for their capital cities. These include policies that are designed to minimise the sprawl of outer suburbia and to encourage higher density residential development around key activity centres and routes served by public transport. Despite this, billions of dollars have been spent on freeway construction in Sydney and Melbourne in recent years (Newman 2006), and relatively little has been spent on improving public transport infrastructure, particularly to connect new outer suburbs.

As urban sprawl continues, the lack of integration of residential development, employment location and transport systems across capital cities could result in two city types: service rich, higher income inner and middle suburbs; and service poor, lower income outer urban areas. The type and location of sprawling residential areas will inevitably lead to increased car use, particularly across town. Inner city areas experience a decline in liveability due to the replacement of open space with built form, increases in traffic, parking difficulties, noise and air emissions. Communities in inner-urban areas are now recognising the character of their neighbourhoods as a value to be protected; this is in addition to historic heritage. New developments, including 'urban consolidation' or 'urban renewal', are often resisted if they are seen to impinge on these values. If not managed well, these factors combined will inevitably cause strategic city plans to fall short of their goals.

Open space is increasingly seen as a major issue for the liveability of cities, but there were no national data available for this report. The amount and quality of

public open space affects both mental and physical health. People are more likely to walk or cycle in areas with well-designed and accessible public open space. In Australia, a disproportionately large amount of public open space is allocated to organised sport rather than to informal activities such as walking. Neighbourhoods characterised by low-density, poorly connected street networks, and poor access to shops and services are associated with low levels of walking (Giles-Corti 2006).

With increases in the extent and density of urban areas, there is a concern that some open space has been lost, particularly in areas of infill and in smaller-lot greenfield developments. A planning approach that incorporates aspects of the natural environment into the evolving urban form would not only improve urban liveability and wellbeing, but it may also broaden and heighten the experience of the relationship between urban change and its effects on the natural environment.

A shift in governance is needed, with more cooperation between all levels of government, to be more involved in planning processes and work with large housing companies, road planning agencies and construction companies to determine the shape and functioning of Australian cities. Only then will the potential of changes to urban form lead to more efficiently functioning cities in Australia. That sustainable urban design and development is possible, has recently been demonstrated in Rouse Hill (New South Wales), Christie Walk (Adelaide) and Aurora (Victoria). The New South Wales BASIX (Building Sustainability Index) scheme has also achieved some performance improvements on issues such as energy and water, by requiring developers to achieve sustainability targets as a condition of gaining development approval.

The Sustainable Cities report by the House of Representatives Standing Committee on Environment and Heritage provides useful guidance (HRSCEH 2005). Recommendations cover a broad range of urban sustainability issues, including that the Australian Government take a strong leadership role in urban sustainability issues in the areas of policy and governance, planning and settlement patterns, water, building design and management, energy, and research.

Sustainable human settlements require a reduction in resource consumption. A stronger emphasis on environmentally responsible behaviour by developers, governments, producers and consumers is needed to achieve this. Intervention by governments, at all three levels, can foster changes in behaviour. The development and implementation of an Australian Government policy on cities would provide leadership and guidance to the other two levels of government, as well as to developers, producers and consumers, so as to achieve a common approach to the creation of sustainable settlements.

Adelaide's Christie Walk development is an environmentally sympathetic mixed density community housing project. Design and photo: Ecopolis Architects Pty Ltd.

Key points

- Population growth and urban expansion, particularly in coastal areas and capital cities, are placing increasing pressure on the environment.
- In the ten years to the last census (2001) there was a small but significant increase in the amount of high density housing in capital cities and regional cities.
- The quality of human settlements is generally good, with remote Indigenous settlements being the notable exception.
- In the past five years, the per capita consumption of energy has increased, with only a slow take-up of renewable energy.
- The design of urban areas has a significant impact on their efficiency and environmental impact and some progress has been made towards recognising this fact in new developments, but the legacy of past urban and building design will continue to impact on the environment.
- The rate of population growth is expected to slow, so pressures on the environment from this source may also grow at a slower rate, but this will be affected by future producer and consumer behaviour.

4

Atmosphere

For many people, the state of the atmosphere is a measure of the state of the environment, and in Australia the immediate impression is good. Because of its isolation, air quality in Australia is not substantially influenced from outside its borders and, apart from the effects of bushfires, dust storms and localised industrial pollution, outdoor air quality in Australia's cities continues to improve and usually meets agreed national standards. The quality of indoor air is unknown due to a lack of data, but bans on smoking in public places by most jurisdictions hold promise.

Australia is meeting its global responsibilities in reducing its consumption of ozone-depleting substances. The benefits of this global action can be seen in the increase in the amount of ozone in the upper atmosphere in recent years. The size of the hole in the ozone layer over Antarctica appears to have stabilised.

Climate change is undoubtedly a threat to Australia's environment. Although Australia's climate is so variable that the extent of change is uncertain, there is clear evidence for some warming and changes to rainfall distribution. The so-called millennium drought of the last five years was not the driest period on record in all parts of Australia, but the combination of low rainfall and warm temperatures exacerbated its effects. In the same period, rainfall over central west Australia has been higher than average. These trends are consistent with overall rainfall trends for the last 100 years.

The air quality in Australia's human settlements continues to improve, although bushfires and dust storms can cause serious localised pollution for short periods of time. Photo: P Olsen, DEH.

4.1 Australia's variable climate

There is no doubt that Australia has always had a highly variable climate and that Australians are still learning to adapt to it. Paleo-climate data alone show that there have been more extreme wet and dry periods than the relatively few that have been seen in only two centuries of European settlement, and that more can be expected.

Most of Australia was settled before long-term climate data were collected. The result is that agricultural and urban land use patterns were fixed well before there was any understanding that Australia's climate is highly variable, with a high occurrence of widespread extreme wet and dry years. For example, eastern Australia has experienced several sequences of wet years since the late 1880s (early 1890s, 1916–18, early 1920s, mid-1950s, early 1970s and late 1990s). Dry conditions in various rural regions followed these wet sequences (1896–1902, 1919–20, 1926–31, mid-1960s, early 1980s, 2001 to present) (Power et al 1999, Mantua and Hare 2002). Temperatures have been equally variable.

Rainfall

The direction and magnitude of rainfall trends for the last one hundred years over the continent vary regionally, with increases in north-western Australia and decreases in south-western Australia. Given the influence of decadal and multidecadal variability in the climate system on Australian rainfall, the start and finish year of analysis also affect the reported magnitude and direction of the trends (1900–2005 compared with 1950 to 2005 and with 1970 to 2005 – see Figure 10). The choice of period for analysis has been determined by either scientific need (accuracy of records, behaviour of climate system) or practical application (recent resource management issues).

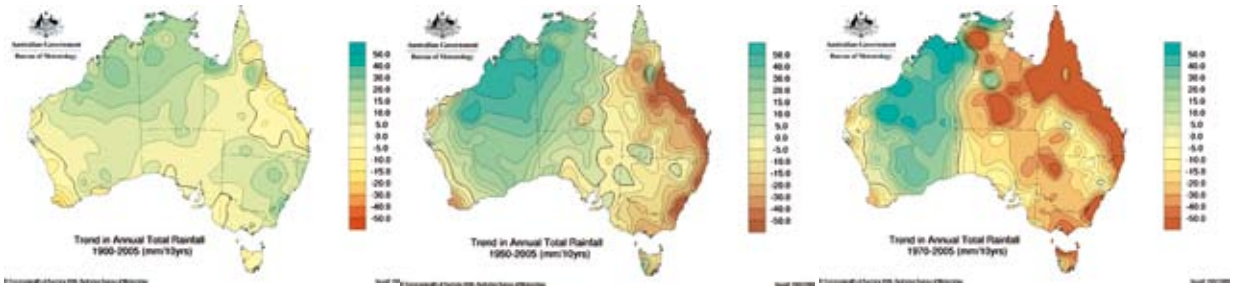
Rainfall is highly variable across Australia and from year to year (Figure 11). In recent years, rainfall has increased over much of northern Australia, especially in the north-west. South-eastern Australia has been drier than average. Winter rainfall in the south-west of Western Australia has also decreased substantially since the mid-twentieth century, and since the mid-1970s in particular (IOCI 2002). Some areas have experienced eight consecutive years of below-average rainfall (BoM 2005a). Long-term records show that dry sequences are not unusual. For example, Lake George in New South Wales showed a 17-year dry spell in the 1930s and 1940s (Singh and Geissler 1985). More recent data show the trend may be continuing, but a statistical conclusion cannot be reached.

For some areas, such as north-east Queensland, reconstructed rainfall records from coral records suggest that the driest and wettest years in the 230 years from 1754 to 1985 occurred in the twentieth century (Lough 2003:33). The year 1902 was the driest and 1974 was the wettest for this period, and the recent drought of 2002–03 was almost as extreme. The coral records show that the driest 10 and 30-year periods occurred at the end of the eighteenth century (1766–75 and 1770–99, respectively), which was well before the period of northern settlement and instrumental record-keeping (post-1860).

It is increasingly clear that the last 50 years of experience with rainfall patterns is not a sufficient time span to plan and design an adequate response to climate variability and change. Planning and adaptation must include the dry periods of 1890–1950 as well as extraordinary events such as the Sydney hailstorms of 1999, 2004 and 2005, the Katherine floods of 1998 and 2006, and numerous storm and cyclonic events, including Cyclone Larry in 2006.

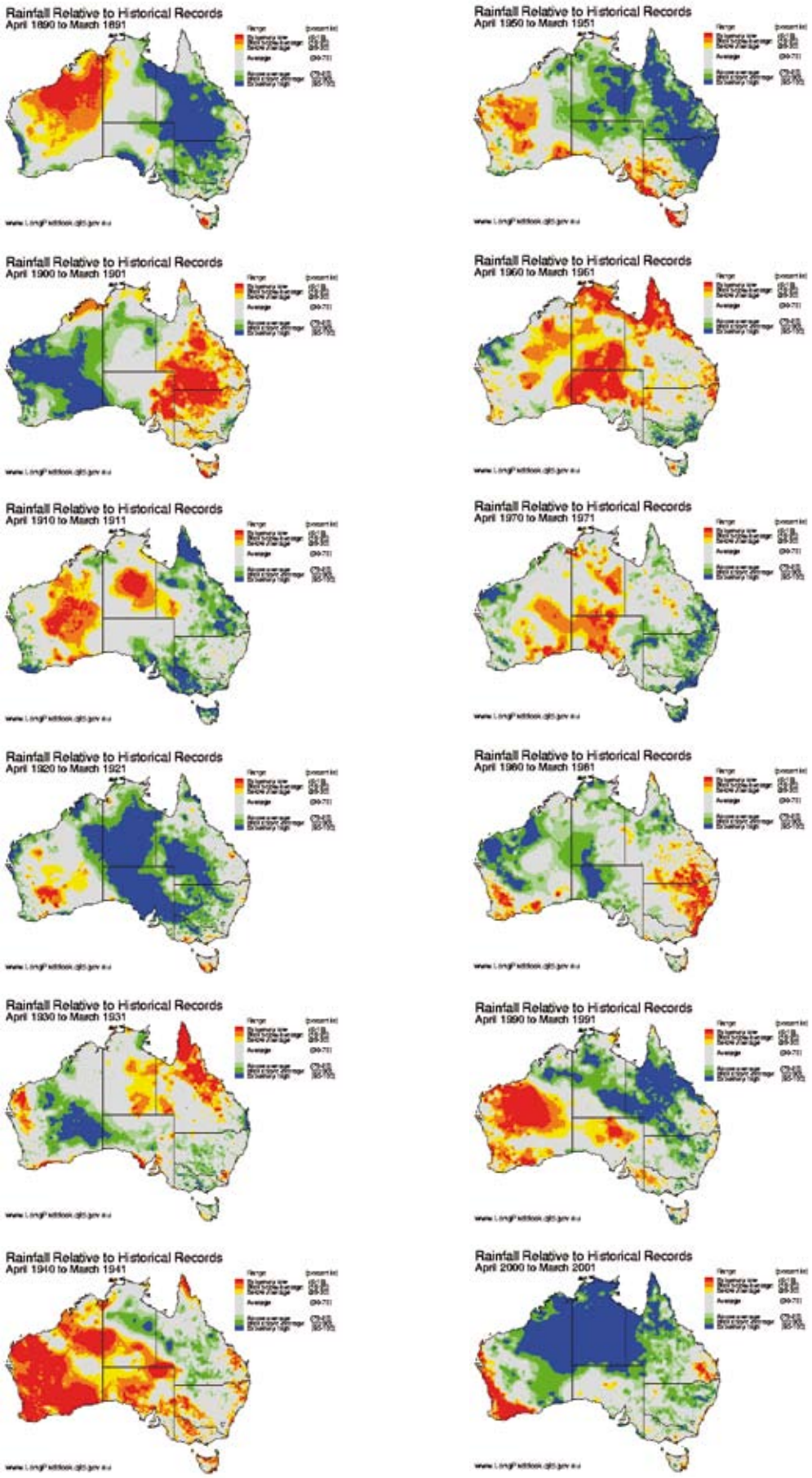
Are extreme events becoming more extreme? The best data are for rainfall, which can be measured in terms of the amount of rain falling in a 24-hour period. Australia's rainfall is so variable over time that the trends in extreme rainfall during 1910–2005 differ from those during 1970–2005. From 1910 to 2005, for example, the only statistically significant trend in extreme rainfall was in the south-west region, which experienced a decline in the intensity of the most extreme 1 per cent of storms for each year. Apart from the central arid region and the New South Wales tablelands, most regions in Australia show a decline in total and extreme rainfall since the mid-1970s (Figure 10).

Figure 10: Trends in annual total rainfall for three time periods, 1900–2005, 1950–2005 and 1970–2005



Source: BoM (2006b)

Figure 11: Australia's variable rainfall



Source: Queensland DNRMW (2006)

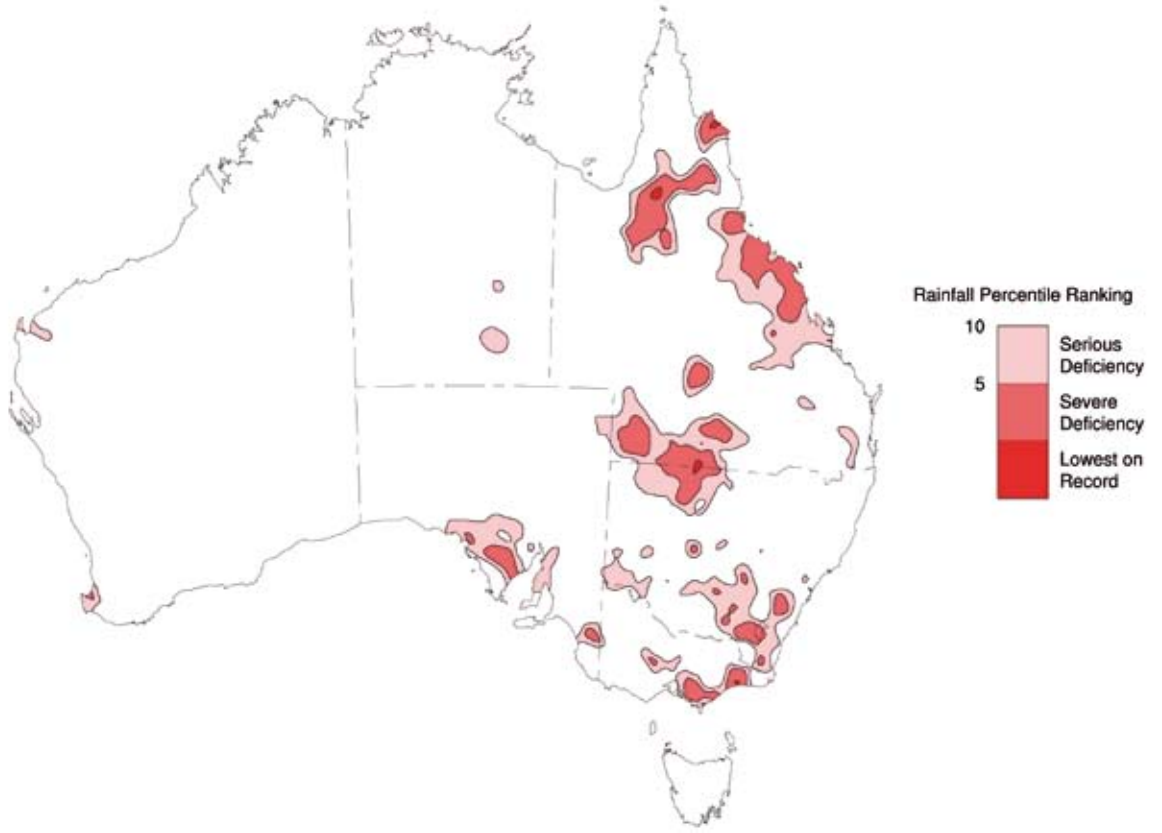
Droughts

Although drought is seen as an extreme event, long periods of low rainfall are common in Australia (Figure 11), as are periods of high rainfall. For example, a series of wet years preceded *SoE2001*, while the reverse is true for *SoE2006*. Understanding this aspect of Australia's climate variability is critical for future environmental policy. The problem is one of scale, both over time and across the landscape. This is illustrated by two stories.

The most recent drought story begins in 2001–02, when drought began in areas of south-western Queensland, western New South Wales, eastern South Australia, north-western Victoria and the Gascoyne region of Western Australia. In 2002–03, an El Niño year (see Glossary), extreme drought occurred across much of eastern Australia and areas of Western Australia, further exacerbating drought conditions in those areas (McKeon et al 2004). Following average conditions in 2003–04, severe drought returned in many regions in 2004–05 (a year with marginal El Niño conditions). For many regions of Australia, the overall five-year period from April 2000 to March 2005 represents extremely low rainfall compared to the historical records commencing in 1890.

A similar but more cautionary story emerges from an analysis of the last 40 years of rainfall records. In much of Australia, this recent drought started after a sequence of above-average years of rainfall from the second half of 1998 to the first half of 2001. Central coastal Queensland and south-west Western Australia had already experienced drier conditions for at least 15 years. For example, eastern Australia received significantly less rainfall during the three years from 2002 to 2005 than during 1961–90 (the current international standard reference period). Coastal areas experienced the greatest rainfall deficits (the difference between actual rainfall in a year and the long-term average) (Figure 12). In contrast, during the same 2002–05 period, rainfall in the north of the Northern Territory and in parts of north-western Western Australia was significantly greater than that experienced from 1961–90 (BoM 2005b). The recent drought may be unusual in that it has been warmer than previous droughts in the last 50 years (the length of temperature records).

Figure 12: Rainfall deficiencies, August 2002 to July 2005



Source: BoM (2005b)

Both stories acknowledge drought as a regular occurrence; both have been used in the debate about climate change, and both acknowledge the importance of drought as a driver of Australia's natural systems. Despite this, both urban and rural communities appear to have been as surprised by each succeeding drought as all the others. Lovett (1973) wrote that the notion of 'drought' may be meaningless in an environment in which extremes are the norm, as did others some 30 years later (Botterill 2003).

It is likely that the variability in Australia's climate is at least partly responsible for this national optimism. The wet periods (Figure 11) were likely to have led to unrealistic expectations of long-term agricultural production, livestock-carrying capacity, and water availability. The result has been government and community support for inappropriate land uses, such as cropping of marginal areas and small grazing property sizes (Heathcote 1965, Russell 1988, Condon 2002). The more marginal land uses have suffered during the inevitable dry episodes, and there have been major re-examinations of appropriate land use as well as a public call for major infrastructure development to 'drought-proof' regions.

The recent drought was particularly severe because:

- it was accompanied by record high average maximum temperatures (see page 25)
- it affected virtually the entire continent, with 35 per cent of the continent having rainfall below the tenth percentile
- it was followed by a series of relatively dry years (BoM 2005a).

Extreme events have always had a profound influence on policy in Australia. A feature of the current drought has been a renewal of the debate on drought-proofing agriculture and rural Australia.

Drought-proofing is the changing of management practices and infrastructure to reduce the impact of drought on production and communities. At the core of the debate is the clash between two opposing approaches to managing for drought. On one hand, it is argued that technical advances and financial support are needed to maintain a high level of agricultural production and to protect the stability of rural communities in periods of rainfall deficit. On the other hand, there is a general call for recognition that Australia has a relatively high frequency of drought in many regions and that better individual climate risk management and more appropriate land use would be less environmentally damaging and require less financial support.

The current debate on drought raises two major questions:

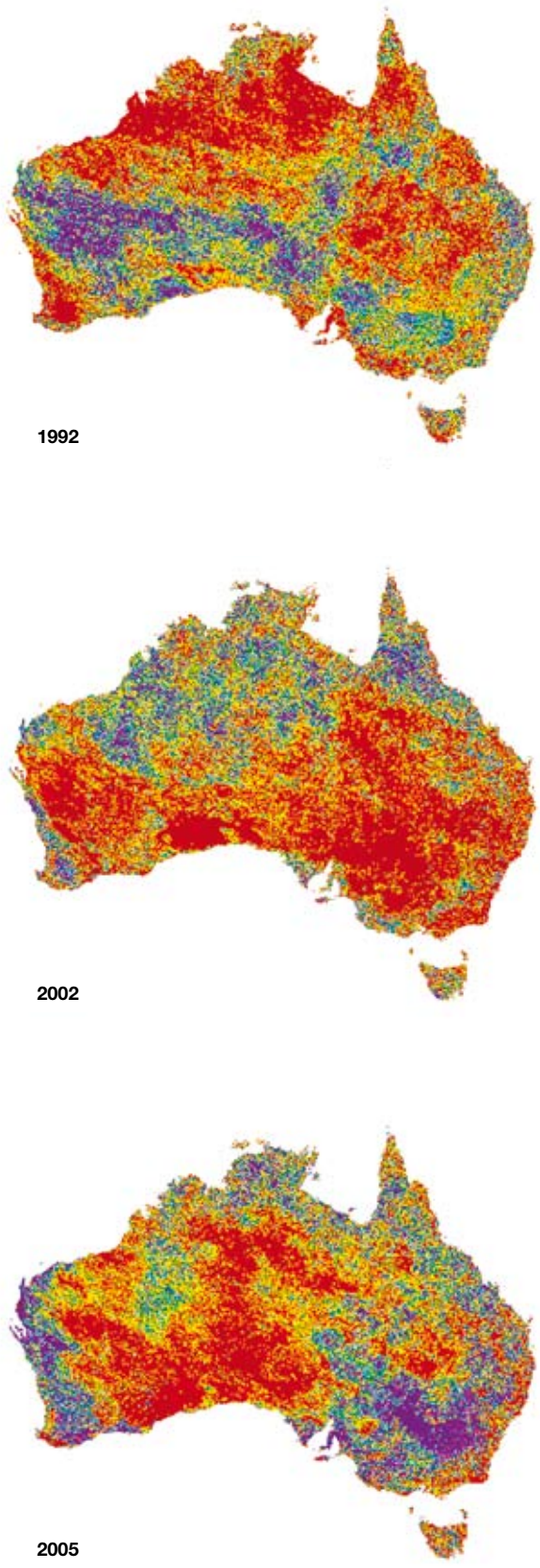
1 How much of the current variability is due to human-induced effects (climate change, stratospheric ozone depletion, aerosol concentrations, land use change, and land clearing) in contrast to expected variability resulting from natural fluctuations of the global climate system?

2 What planning and infrastructure investment should occur?

These questions can be answered only by increasing our 'climate literacy' (Botterill 2003:197). It requires our emerging understanding of how the climate systems work, knowledge of historical climate variability, and plausible projections of future climate variation. It also requires longer-term climate data, to better understand that cycles of high and low rainfall should be part of our expectations and built into decision-making and planning.

Australia's current difficulties may well be because the nation is entering a dry period similar to that experienced in the first half of the last century, and planning has not made adequate provision for this. Further, the dryness may also be influenced by the hotter and more extreme climate that is predicted to result from climate change. The bottom line should surely be that the impact of the demand for water and other resources from increasing population together with a move to drier sequences in southern Australia will place further stress on already stressed rivers and landscapes. There are indications that, if there were a return to the 1900–50 rainfall patterns, the Murrumbidgee River could not supply the current extraction demand (Khan 2006).

Figure 13: Season quality in Australia, based on a comparison of years of Normalised Vegetation Difference Index anomalies



The 1992 image (Figure 13) shows a very poor growing season across most of northern Australia as indicated by the dominance of red values in the north. Conversely, the 2002 image shows a very poor growing season across most of southern Australia, while the 2005 image shows a good growing season in most of the major agricultural areas, as indicated by the purple values.

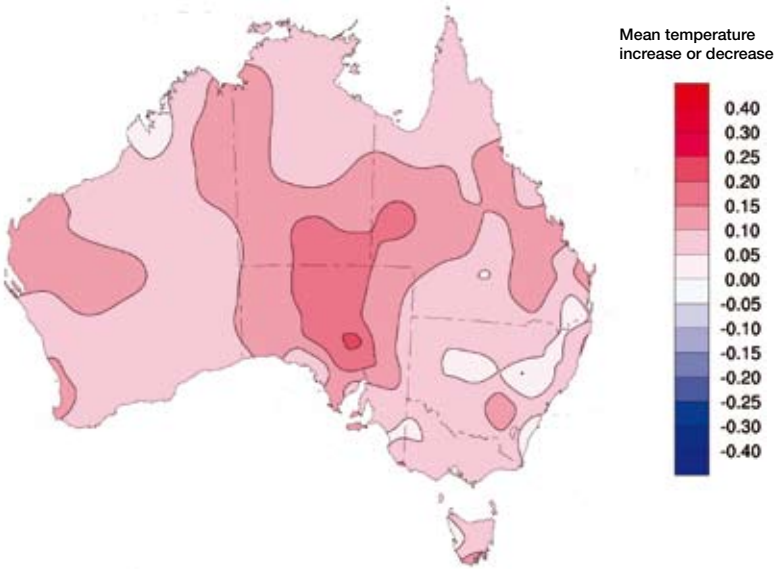
The analysis is based on the hypothesis that the cover of green vegetation will increase over the growing season, and better seasons show greater greenness. In this analysis, the amount of greenness is estimated from Normalised Difference Vegetation Index data collected by the US National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (NOAA AVHRR) satellite. In the images, season quality is estimated from the relative increase in greenness for each year scaled against the long-term data (1992 to 2005). Zero per cent is the minimum 'increase in greenness' recorded and 100 per cent is the maximum recorded. Each pixel is thus scaled against its own measured ability to become greener following rainfall.

Source: ERIN (2006a)

Temperature

The average temperature across Australia has risen by 0.82°C between 1910 and 2004 (Figure 14), with much of the warming occurring in the second half of the twentieth century (Figure 15). The warmest year on record is now 2005. Until 2004, the warmest year had been 1998, with all of the ten warmest years since 1910 occurring in the last 32 years (1973–2004).

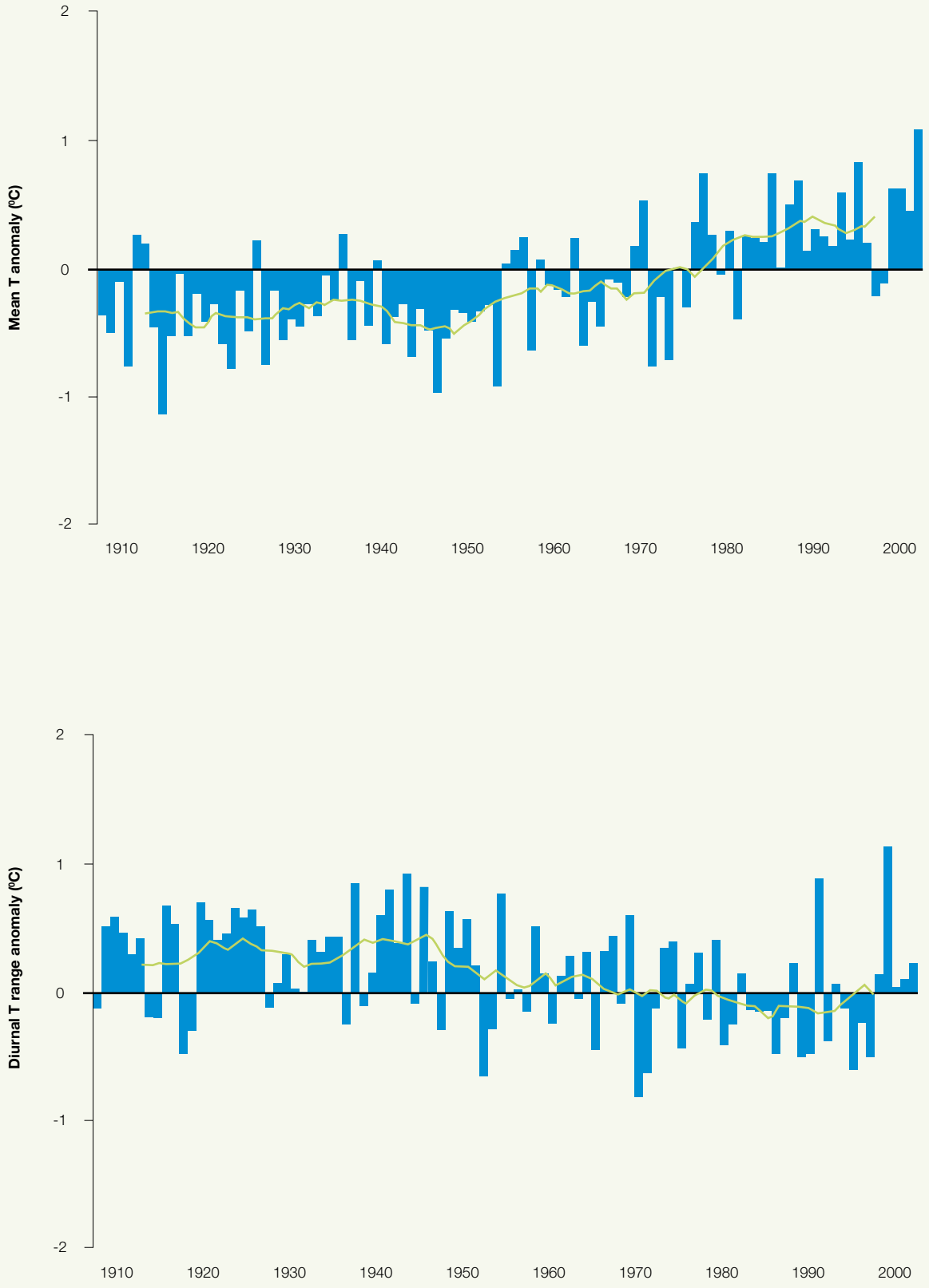
Figure 14: Trend in mean temperature, 1910–2005 (°C/10 yrs)



Source: BoM (2005c)

Torquay Beach on Victoria's Surf Coast attracts holidaymakers when temperatures rise in the summer.
Photo: J. Baker, DEH

Figure 15: Trends in temperatures, as shown in annual mean temperature anomalies, 1910–2005



Source: BoM (2005d)

More recently, temperature records show that the year 2005 was 1.09°C warmer than the Australia-wide annual mean temperatures for 1961–90, and 2002 was 0.63°C warmer (Figure 14). Australian temperatures have increased slightly more rapidly than the global average (CSIRO 2005a). The warming in Australia since 1950 has been almost 0.2°C per decade.

Although all of Australia has become warmer, the amount of warming has not been uniform across Australia (Figure 14 and BoM 2006a). Greatest temperature increases, of 0.15°C to 0.20°C per decade, have occurred in inland South Australia and in western Queensland. Other regions have warmed by only 0.05°C per decade, including south-eastern New South Wales, western Tasmania, north-western Western Australia and a large swathe inland from south-eastern Queensland to central New South Wales. Increases in annual mean minimum and in annual mean maximum temperatures have resulted in more of Australia experiencing extremely hot temperatures (above the ninetieth percentile) and less of Australia with temperatures below the tenth percentile. Diurnal temperature ranges also show a similar change.

Evaporation

Evaporation affects water availability, and it is determined by humidity, wind, air temperature and radiation. Despite the higher temperatures recorded across much of Australia, the data show a small decline in potential evaporation of around 5 per cent over 30 years, but with some regions experiencing increases or remaining constant (Roderick and Farquhar 2004). The continued monitoring of trends in potential evaporation, and understanding of the contributing factors, will be important in estimating future water availability and demand for rural and urban use.

4.2 Atmospheric gases

Greenhouse gas equivalents

In 2002, Australia changed the method used to estimate greenhouse gas emissions to include land clearing, as specified in the Kyoto Protocol. The procedures also follow the Intergovernmental Panel on Climate Change reporting guidelines. All previous emissions estimates were revised, and the increase in carbon dioxide equivalents (CO_2-e) between 1990 and 1998 is much less than the figure quoted in *SoE2001*.

Australia's greenhouse gas emissions are increasing. Net emissions are estimated to have increased by 2.3 per cent to a total of 564.7 million tonnes (Mt) CO_2-e from 1990 to 2004 (DEH 2006b). While this overall increase is partly a result of population increase, the per person contribution to Australia's greenhouse gas emissions has declined during 1990 to 2004—from 32.3 to 28.2 tonnes CO_2-e. Emissions per dollar of gross domestic product (GDP) have also declined from 1.1 to 0.7 kilograms CO_2-e per dollar of GDP (DEH 2006b). This is largely a result of the large decline in emissions from land use and land use change during the period, improved emissions management, and structural changes in the economy, with the services sector growing faster than the manufacturing sector. While these data could be used to claim that Australia has become more 'greenhouse gas efficient', the overall increase in net emissions is still of concern.

Australia signed the UN Framework Convention on Climate Change in June 1992 and ratified it in December 1992. Although not formally bound by the Kyoto Protocol, Australia has committed to meeting a target of less than an 8 per cent increase on 1990 levels by 2012.

Sources of greenhouse gas emissions

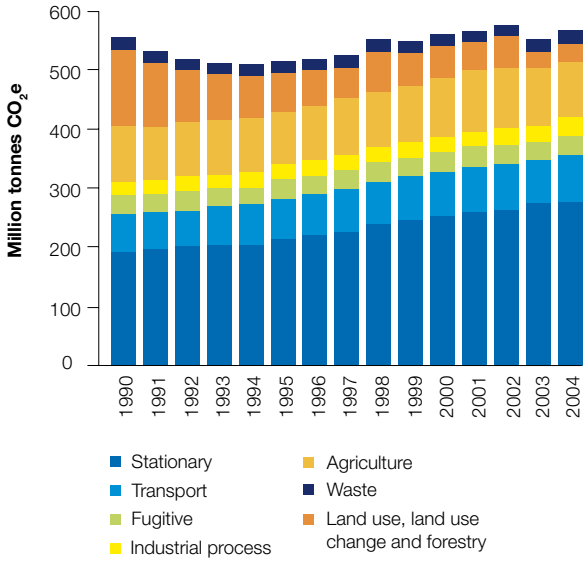
The largest and fastest growing source of greenhouse gas emissions in Australia is the energy sector, contributing 68.6 per cent of Australia's net emissions (Figure 16). Much of the total can be attributed to the stationary energy subsector (the main source, at 49.6 per cent of net emissions) and the road transportation subsector (12.5 per cent of net national emissions). Increasing household incomes have contributed to the increase in both sectors, with stationary energy emissions also driven by growing population and export increases from the resources sector; and transport emissions affected by the numbers of vehicles. These two sectors are responsible for much of the increase in greenhouse gas emissions since 1990.

Greenhouse gas emissions from road transport account for 12.5 per cent of Australia's net emissions. The interaction of atmospheric quality, time spent travelling, loss of land, and other urban pressures emphasise the complexity associated with critical decisions Australia must make in altering urban form. Photo: J Baker, DEH.

The agriculture sector is responsible for 16.5 per cent of Australia's net emissions. Another 6.3 per cent of net emissions comes from the land use, land use change and forestry sector. This last sector includes land clearing, which was a major source of Australia's net greenhouse gas emissions in the early 1990s, but is now much reduced. This reduction offsets most of the increase in emissions in all the other sectors. Other relatively minor sources include emissions from industrial processes, such as from the manufacture of mineral products, and emissions from waste disposal (DEH 2006b).

Emissions for 2020 are projected to reach 122 per cent of the 1990 level, reflecting the impact of ongoing growth in emissions in the energy sector. This emphasises the need to focus on lowering Australia's greenhouse emissions over the longer term, while maintaining a healthy and competitive economy (DEH 2005b).

Figure 16: Greenhouse gas emissions from major Australian sectors (net carbon dioxide equivalents), 1990–2004



Source: DEH(2006b)

Carbon dioxide

Globally, carbon dioxide concentrations have risen from 330 parts per million in the mid-1970s to more than 375 parts per million by the mid-2000s. This constitutes a long-term growth rate of about 1.5 parts per million per year (Francey 2005). It is largely a result of the burning of fossil fuels, and this has increased because of economic growth, accentuated by increasing global population and the industrialisation of the developing world. Australia's contribution to that proportion of the increase attributable to anthropogenic sources has been around 1.5 per cent.

Methane

Methane concentrations increased from 1450 parts per billion in the mid-1970s to 1700 parts per billion by the mid-2000s; however, the concentration is no longer increasing as rapidly as it once did. Although methane has not yet had the impact on climate that carbon dioxide has, some researchers believe that methane release from cold wetlands could be a climate change accelerator.

The long-term growth *rate* of methane emissions has declined to zero over the last six years, from a high of 15 parts per billion per year in the mid-1980s (CSIRO 2005b). The reason for the trend is uncertain, but it may be because the oil and gas industry is emitting less, or the same amount, of methane than previously. As well as showing a long-term decline, the methane emission growth rate shows significant variability, the cause(s) of which remain elusive. It has recently been demonstrated that assumptions about the relationship between greenhouse and vegetation require re-examination (Keppler et al 2006). The full implications of this are yet to be tested, but this discovery demonstrates the need for flexible and adaptation-driven policy.

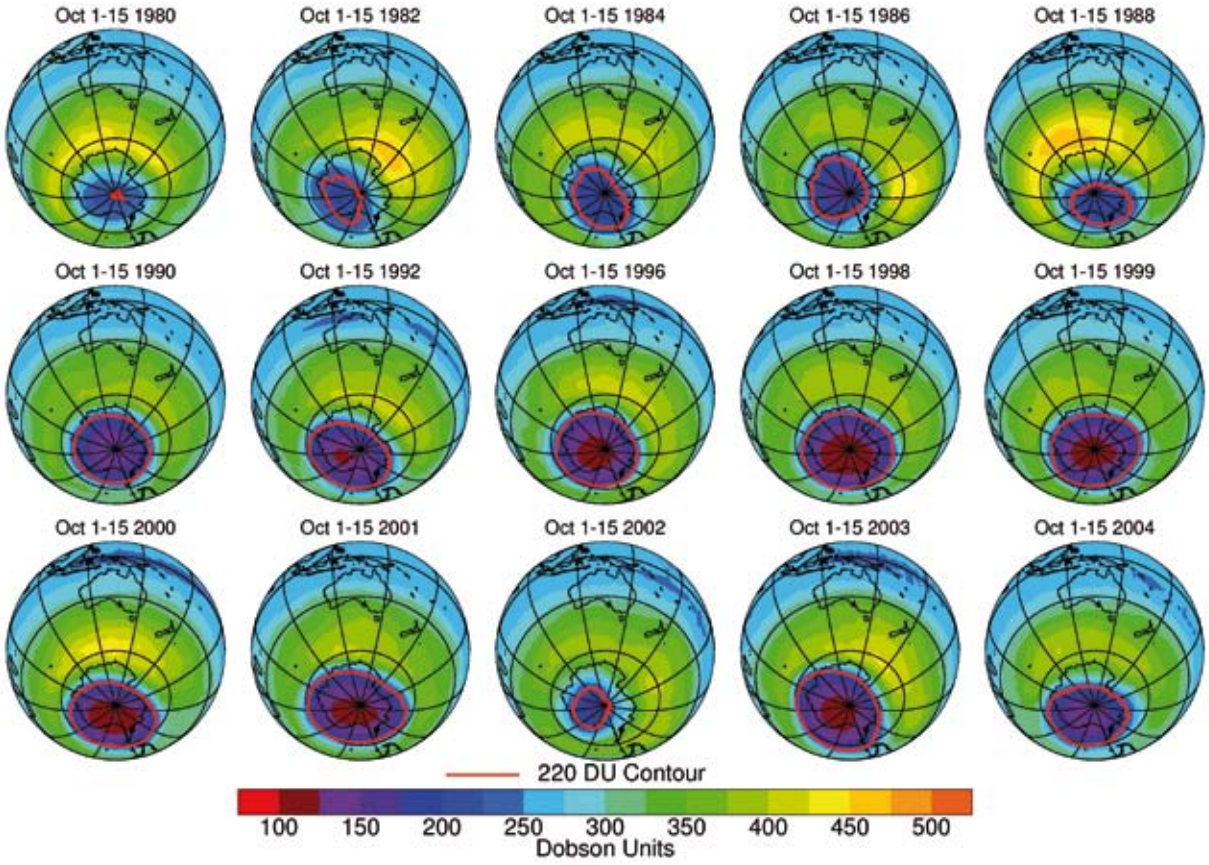
Ozone

The amount of ozone in the stratosphere (upper atmosphere) matters because it absorbs most of the sun's harmful ultraviolet B radiation. Overall, the concentration of ozone in the stratosphere over Australia and New Zealand may have started to increase since the year 2000 (Figure 17 and Figure 18). The ozone 'hole' over Antarctica has been at its current size of 25 million square kilometres since the mid-1990s, following two decades of rapid growth. At the same time, there has been a 1 per cent a year decrease in the erythemal ultraviolet index (a measure of skin cancer potential) over the southern part of Australia since 1998 (CSIRO 2005c). These datasets show marked variability, making interpretation difficult.

These positive trends may be associated with the decline of about 1 per cent each year in the concentration of total stratospheric chlorine (a measure of ozone-depleting substances) since the late-1990s (CSIRO 2005b). Australia has met all Montreal Protocol targets for reducing its consumption of ozone-depleting substances, setting accelerated phase-out requirements in some cases.

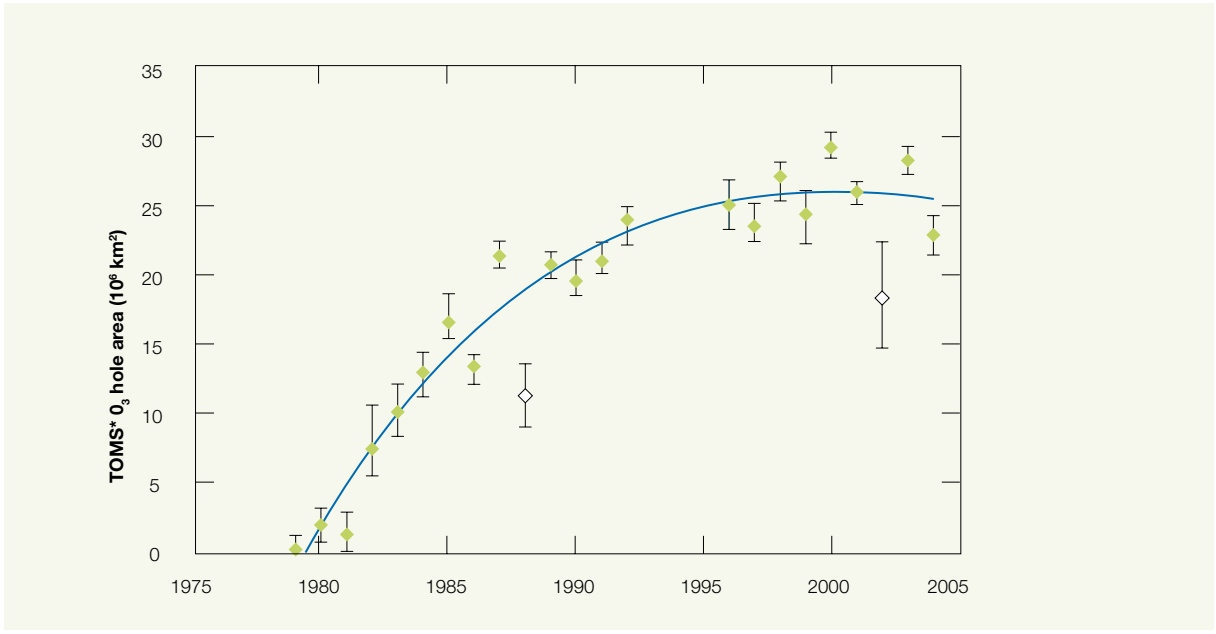
Skin cancer rates for Australians showed a steady increase from the early 1980s to the late 1990s but have since stabilised (AIHW and AACR 2003). This could be a result of improved awareness and behavioural changes in the Australian community.

Figure 17: Total ozone levels over the southern hemisphere in spring (average over 1–15 October)



Source: CSIRO (2005c)

Figure 18: Maximum ozone hole area (area within the 220 Dobson Unit contour)



Note: The polynomial fit does not include the unusual data seen in 2002 and 1988.

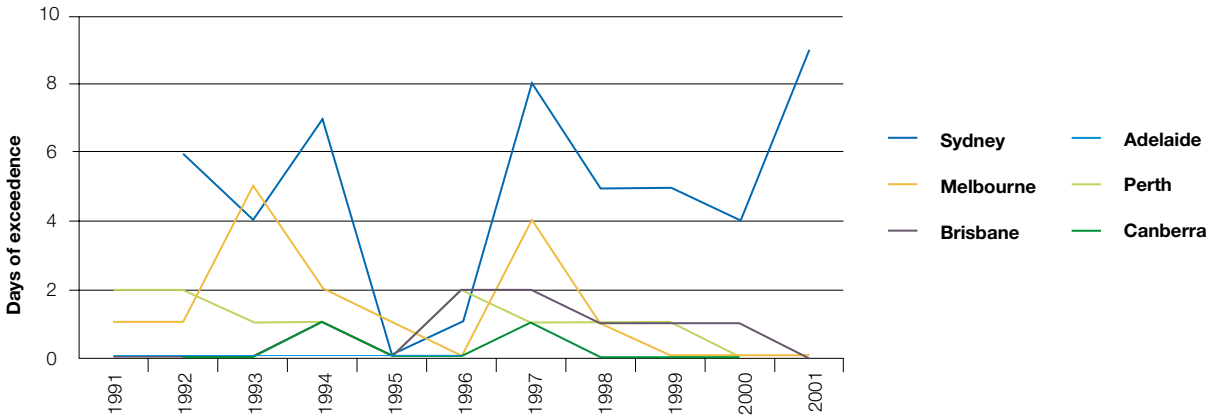
Source: CSIRO (2005c)

* TOMS: Total Ozone Mapping Spectrometer

Ambient air quality

Urban air quality continues to improve. Concentrations of sulphur dioxide, nitrogen dioxide and lead are not of concern in any urban area (DEH 2004). Carbon monoxide has not exceeded the National Environment Protection Measure (NEPM) standard in any Australian city. Photochemical smog is still an issue in some urban areas, as indicated by high ozone levels. This is especially the case in Sydney, where the most recently available data show that maximum ozone concentrations in the lower atmosphere increased (Figure 19).

Figure 19: Number of days in capital cities with daily maximum one-hour ozone concentrations above the National Environment Protection Measure standard



Source: DEH (2004)

The main pressure on air quality in urban areas is the continued increase in population—more people are driving more cars. The data show this as an increase in the number of vehicles per head of population and in the total vehicle kilometres travelled (ABS 2004e). The controls on carbon monoxide, nitrogen oxide and volatile organic compounds through fuel quality standards indicate that total motor vehicle emissions in 2020 will probably be below those of 2006 (DoTARS 2003), but this is unlikely to be the case with total particulate matter emissions.

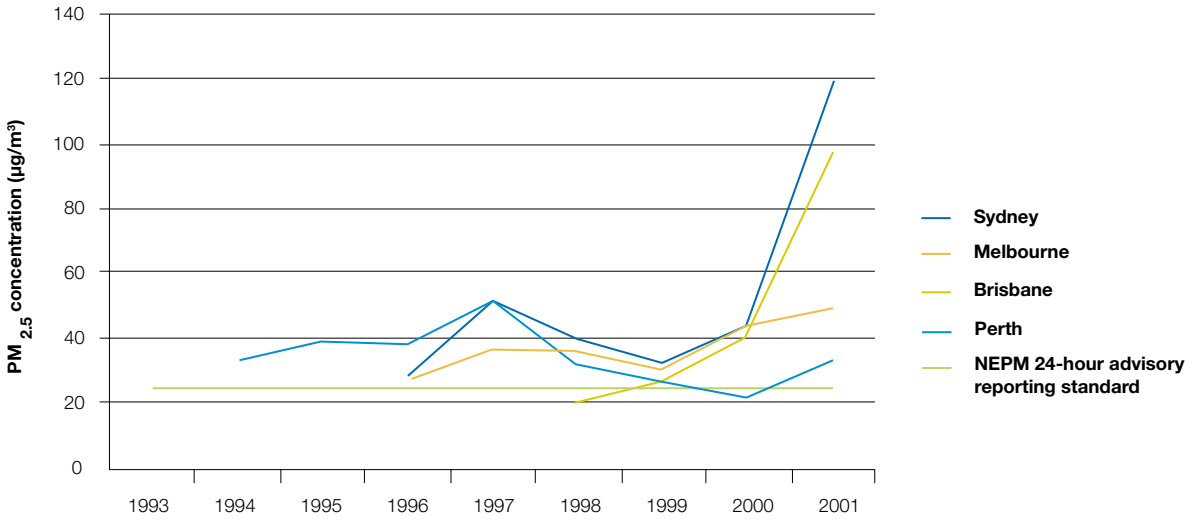
In rural and regional Australia, levels of most pollutants are well below actual or proposed standards (DEH 2004). Sulphur dioxide and lead emissions continue to be of concern in a few limited localities (for example, lead and sulphur dioxide in Port Pirie, South Australia and Mount Isa, Queensland). Particular pollutants, such as benzene in the Pilbara, may be of local concern in specific regions. Despite the probable existence of such rural air pollution hotspots, there is insufficient monitoring to identify other areas of concern and insufficient monitoring of air toxics at such sites (Manins et al 2001).

Dust and other fine particles, including wood-smoke, are of concern in regional areas such as Armidale and Beresfield in New South Wales, Bunbury in Western Australia and Launceston in Tasmania. Concentrations

Extreme air quality events can occur in a few inland cities where temperature inversion and wood-burning heating can lead to rapid declines in air quality for short periods. Launceston, Canberra (pictured) and Armidale are notable examples. Photo: Environment ACT.

of very fine particles, smaller than 2.5 microns in diameter ($PM_{2.5}$), have increased threefold in Sydney and Brisbane in the last five years (Figure 20). Some very high levels in 2001 may have been a result of bushfires. $PM_{2.5}$ is of concern because the smaller particles have a greater effect on health, particularly respiratory illnesses, than the larger particles (PM_{10}) that have been monitored in the past. Some of these health effects may arise from pollen or seeds, but Australia still does not have a systematic pollen monitoring system.

Figure 20: Highest daily average of $PM_{2.5}$ for Australia's capital cities



Note: µg/m³ - micrograms per cubic metre

Source: DEH (2004)

Issues of air quality across Australia continue to be addressed through various measures, including NEPMs, Australian Design Rules for motor vehicles, national fuel quality standards, and wood-heater replacement programmes. It is hoped that issues around air toxics at rural hotspots will be addressed with the implementation of the NEPM on air toxics, with states and territories commencing monitoring of air toxics from the end of 2006.

Indoor air quality

Although Australians spend 90 per cent or more of their time indoors, relatively little research has been done on the quality of indoor air. A major concern with respect to indoor air quality is the use of gas cookers and un-flued gas heaters. These two sources can often contribute a large percentage of the pollutants found in domestic dwellings.

Tobacco smoke is an important aspect of indoor air quality for some households and in some workplaces. The World Health Organisation states that 'there is no safe level of exposure to environmental tobacco smoke' (WHO Regional Office for Europe 2000). This position is supported by the National Occupational Health and Safety Commission's Guidance Note on the Elimination of Environmental Tobacco Smoke in the Workplace (Commonwealth of Australia 2003).

States and territories have taken various actions to ban smoking in public places, with total indoor bans in force in Tasmania, Queensland and Western Australia, and partial bans in the Australia Capital Territory and Victoria.

4.3 Adapting to climate change

Climate change has always been a reality. The challenge is to predict how much an already variable world climate system will change as a result of human activity. While scientists debate the relative contribution of human activity to climate change, it is generally considered that continued increases in the levels of greenhouse gases, such as carbon dioxide, methane and nitrous oxide, are expected to lead to an enhanced greenhouse effect and regional climate change.

The question, then, is not 'if' but 'how much'. Predictions from models of temperature increases suggest a wide range of uncertainty—ranging from 0.4–2.1°C by 2030, to 6.8°C in 2070 (CSIRO 2001, Lindesay 2003) (Figure 21); others suggest an increase of 5.8°C by 2100 (Steffen 2006). The largest increases are projected to occur in summer (CSIRO 2001). There have clearly been significant increases in sea surface temperatures of up to 0.28°C in the Australian region since 1950 (Figure 22).

It is likely that rainfall may become even more variable across the seasons and across Australia. Southern and eastern Australia may receive less rainfall in winter and spring than it does now (CSIRO 2001, Whetton and Suppiah 2003). The situation for other areas in Australia is not as well understood. Even though some of the projected changes in rainfall appear relatively small, they should not be dismissed as unimportant.

Figure 21: Climate change projections for Australia, 2001

Figure 1: Ranges of average annual warming (ºC) for around 2030 and 2070 relative to 1990. Coloured bars show changes for areas with corresponding colours in the map.

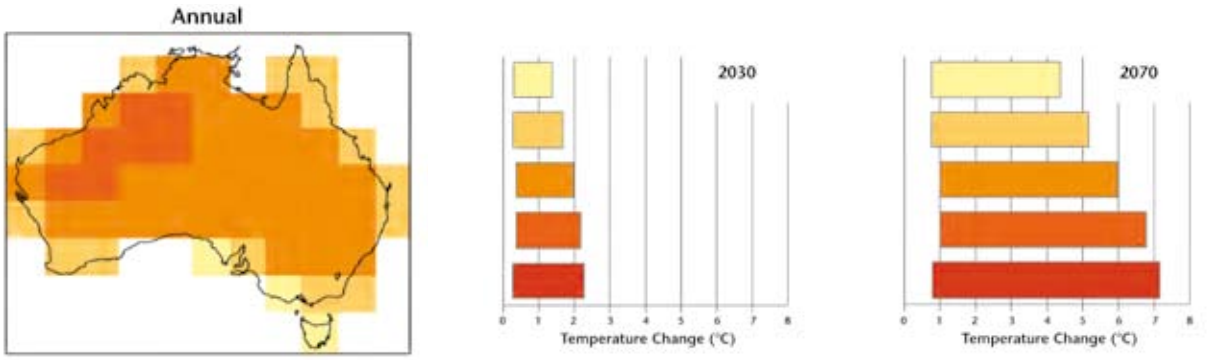
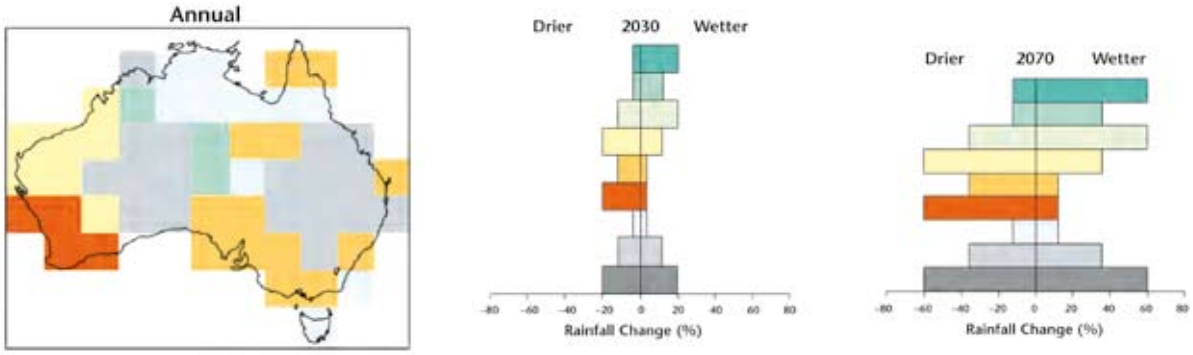


Figure 2: Ranges of average annual rainfall change (ºC) for around 2030 and 2070 relative to 1990. Coloured bars show changes for areas with corresponding colours in the map.



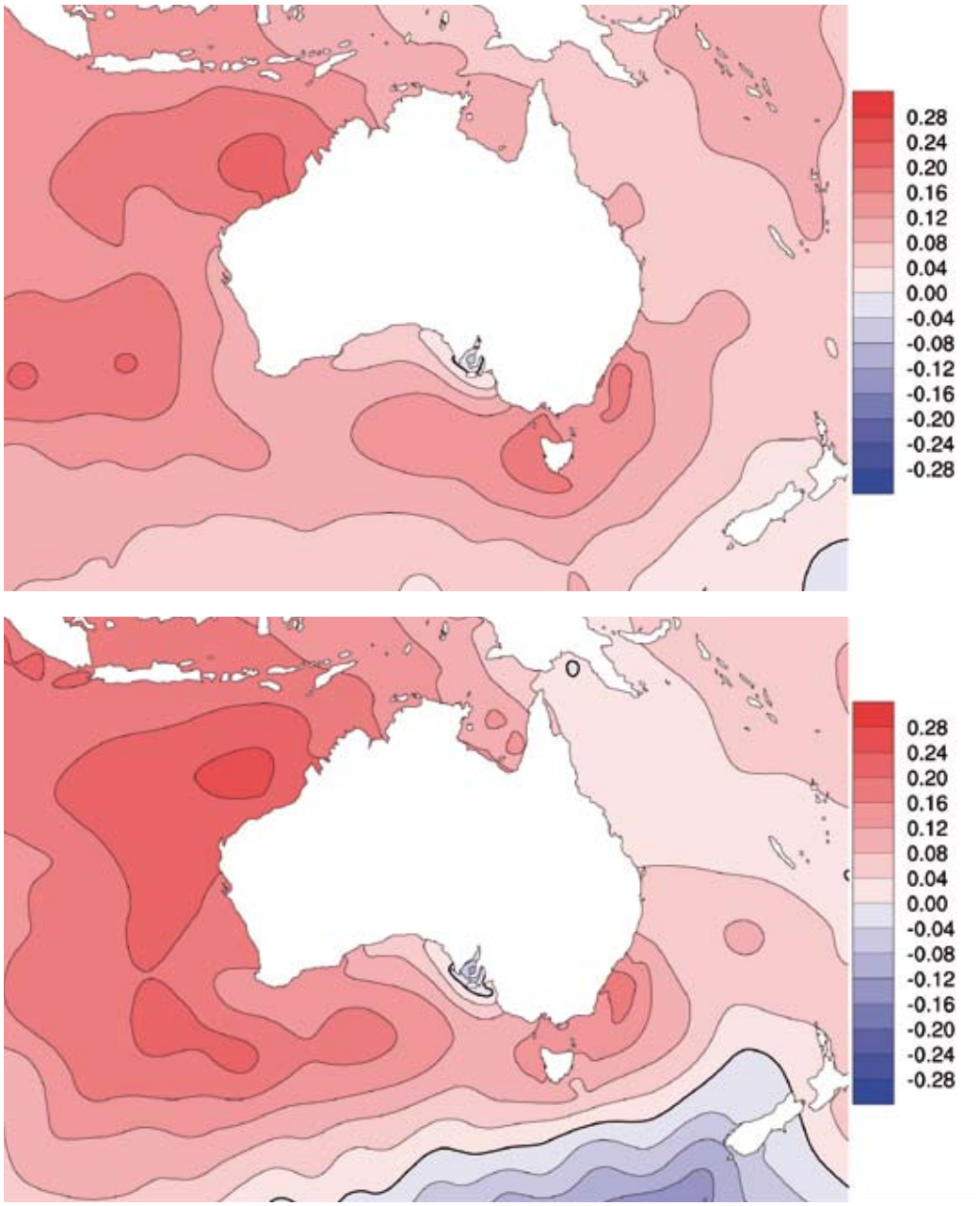
Source: CSIRO (2001)

In the face of such variability, and because global climate systems are not completely understood, it is impossible to be more certain about Australia's future climate. For example, it is only recently that there has been recognition of the influence on Australia's rainfall of decade-long, large-scale fluctuations of ocean surface temperature and pressure across the north Pacific Ocean (Mantua et al 1997, Power et al 1999, Lindesay 2003), although it is still the subject of intense debate. Variously called the Pacific Decadal Oscillation or the Inter-decadal Pacific Oscillation, it modulates the impact of El Niño and La Niña on Australia's climate. In other words, data suggest that the Pacific Decadal Oscillation accentuated the low rainfall influence of the recent El Niño. It means that the Southern Oscillation Index is no longer seen as the only predictor of Australia's climate. The increase in tropical storms in recent years is probably a result of changes to sea surface temperatures, but no one can yet predict the future direction of these changes.

The likely effects of climate variability and change on Australia's urban and rural communities are well recognised. Both must adapt to survive. The history of agriculture in Australia demonstrates much success in adapting agricultural practices and technologies to better manage for a variable and dry climate in a semi-arid land (Pestana 1993, Burroughs 2003). Crop production has been improved through plant breeding, and better crop and water management. Livestock enterprises have developed better-adapted animal breeds, improved pasture species and animal husbandry, and improved drought management. These practices have sometimes resulted in resource damage, such as increased soil erosion (due to loss of soil protection) and increased salinity risk (due to loss of perennial plants). Urban Australia is being similarly challenged to conserve its limited water resources and invest in alternative water sources, especially where increasing demand is outstripping supply. Australia's water use efficiency and water reuse and recycling rates would have to increase from their current low levels.

Equally significant is the impact on Australia's biodiversity. Recent Australian (Howden et al 2003) and international (Thomas et al 2004) assessments suggest that climate change is among the significant emerging pressures on biodiversity. Changes in the extremes and timing of the components of climate in coming decades will further compound and intensify pressures

Figure 22: Trends in sea surface temperature for the Australian region, 1950–2002 and 1970–2002 (°C/10 yrs)



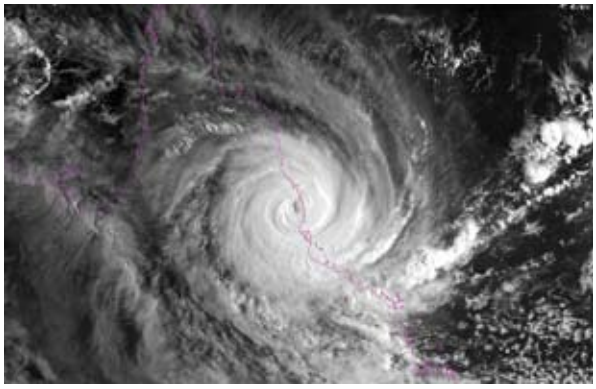
Source: BoM (2006b)

on biodiversity, especially by affecting rainfall patterns (hence fire regimes), regeneration of vegetation, and where plants and animals can live. In the oceans, it will affect sea level and sea temperatures, with potential impacts on marine ecosystems and ocean currents.

A possible impact of climate change is a change in how often coral bleaching events occur. In 1998, and again in 2000, there was large-scale bleaching of the Great Barrier Reef, raising concerns about its long-term health. Sea surface temperatures are certainly a factor, as are other stressors in coastal and ocean systems. If maximum summer temperatures increase, an increase in the frequency of major bleaching events is very likely. The future of tropical coral reefs is causing worldwide concern (Reef Futures 2003).

If management and conservation strategies do not begin to take climate-driven variability and the likely long-term shifts into account, it may be difficult to mitigate or manage impacts effectively. The National Biodiversity and Climate Change Action Plan 2004–07 is one small step in the right direction (Natural Resource Management Ministerial Council 2004).

Many of Australia's species and ecological communities are especially vulnerable because they are highly fragmented and many of the remnants are on areas of naturally poor soil quality. Their resistance to change and resilience to shock are likely to decline as the worst seasons or events become more extreme or more frequent. Increasing extremes, for example, of climate, fire events, total grazing pressure, intra- and interspecies



Severe Tropical Cyclone Larry crossed the tropical north Queensland coast near Innisfail on 20 March 2006 causing major damage to homes and other buildings as well as extensive damage to local crops. Photo: J Davidson, Bureau of Meteorology. Satellite image: Japan Meteorological Agency and Bureau of Meteorology.

competition, predation, disease, gross soil loss, soil nutrient and carbon loss, soil acidity, soil salinity or soil toxicity brought about by changing acidity can further complicate the issue. This means systems that are apparently in reasonable condition can suddenly change without hope of recovery.

Overall changes in Australian climate variability cannot be accurately predicted. What can be said is that adapting for conditions outside of people's experiences and encouraging better management on a national and international scale is needed to secure Australia's environmental future.

Key points

- The air quality in Australia's human settlements continues to improve and, apart from bushfires, dust storms and localised industrial pollution, mostly meets agreed national standards.
- Australia's greenhouse gas emissions remain high by global standards but the growth in net emissions has reduced over the last five years primarily because of reduced vegetation clearing.
- The last five years have seen lower than average rainfall over much of eastern Australia (especially Queensland) and south-west Western Australia, and higher than average rainfall over central west Australia. This is consistent with rainfall trends over the last 100 years.
- The use of ozone-depleting substances has continued to decline, the amount of ozone in the upper atmosphere has increased, and the size of the hole in the ozone layer over Antarctica has clearly stabilised.
- Although Australians spend more than 90 per cent of their time indoors, relatively little research has been done on the quality of indoor air. The banning of smoking in public places by most jurisdictions would have had a positive impact.

5

Biodiversity

Australia's biodiversity is distinctive because of the country's size, isolation, naturally fragmented landscapes and long-term climate variability. For example, about 80 per cent of vertebrate species and plant species are found nowhere else in the world. Many of Australia's ecological communities have a low resilience to external pressures, particularly those that have already been extensively modified, such as in the wheat–sheep belt and semi-arid areas, where many species have suffered a significant decline in numbers and range and even extinction.

Australia's most vulnerable ecosystems have been the first to suffer massive biodiversity decline but this does not mean that other systems will not follow. It is only a question of how long it will be before pressures will overwhelm the resilience of the remaining ecosystems. This issue of decline is now recognised by Australian farmers and others in the community, and it is increasingly being incorporated into the evolving natural resource management response.

The value being placed on Australia's biodiversity is seen in the community's recognition that it is part of the nation's natural heritage. People are starting to value biodiversity for its own sake. This is reflected in the large response by governments in protecting Australia's biodiversity through the EPBC Act and through the Natural Heritage Trust (NHT) and other funding.

Loss of biodiversity is continuing to have a significant impact on the traditional practices and beliefs of Indigenous people. Traditional customs place great emphasis on 'caring for country' and maintaining its biodiversity. Decline and loss of species are having an effect on Indigenous culture and heritage, and it is reducing the amount of bush tucker available in many areas (see 'Natural and cultural heritage' page 77).

The endangered spotted-tailed quoll lives in forest areas and is one of the many quoll species that have declined in numbers since European settlement. Most recent pressure on the group of animals is occurring in the Northern Territory and the Kimberley in Western Australia where the spread of cane toads is dramatically reducing numbers. Photo: D Watts, DEH.

The definition of an ecological community in the EPBC Act is: 'an assemblage of native species that: (a) inhabits a particular area in nature; and (b) meets the additional criteria specified in the regulations (if any) made for the purposes of this definition'.

5.1 Condition

As reported in *SoE2001*, biodiversity continues to be in serious decline in many parts of Australia (Williams et al 2001). This legacy effect represents the consequence of past actions and it will be some time before responses to recent actions can be seen. Recognising change is difficult because of the imperfect knowledge of the condition and trend of biodiversity at a range of scales. Also unknown are the implications of change for sustaining Australia's natural systems and heritage.

It is only for some iconic groups that estimates of condition can be made. For example, analysis of the 1977–81 and 1998–2001 Bird Atlas surveys showed that 29 species (out of 497 species) had significantly decreased reporting rates over the 20-year period. Grassland, woodland and ground-nesting guilds were particularly affected (Garnett et al 2002). In the oceans, key habitats and groups of species, including kelp, seagrass and a range of fish and seabirds are showing changes in distribution. In addition, there is little doubt that a number of fish species have also declined. Expert opinion in 2001 was that a large proportion (39 per cent) of Australia's 85 bioregions have more than 30 per cent of their ecosystems described as threatened (NLWRA 2002b).

A new approach to assessing the condition of ecological communities has been proposed by the Threatened Species Scientific Committee (DEH 2006e). This approach recognises the impact of degradation through the use of condition classes that describe areas of an ecological community that have a similar conservation value. The definition of an ecological community listed under the EPBC Act will now include information on the condition classes. This new approach is for areas of land that contain degraded examples of listed ecological communities may still be rehabilitated. This approach adds to the credibility of the listings and will assist regional bodies in developing appropriate management responses (DEH 2006e).

Many of Australia's threatened species are in the Murray-Darling Basin, south-west Western Australia, populated coastal regions, and in the Tasmanian Midlands. Some areas contain more than 150 threatened species. More than half of the ecosystems in the developed coastal areas and the Murray-Darling Basin are under severe pressure and significant declines are likely (NLWRA 2002b, Olsen et al 2006, Tyler 2006).

Across Australia the condition of nationally important wetlands varies: those in northern Australia are generally in good condition; those in southern Australia need significant management actions for their recovery. Of 901 (as at 2006) nationally important wetlands in Australia, 64 are protected under the Ramsar Convention. An assessment in 2001 found that a total of 231 nationally important wetlands were under pressure from changes to water regimes (Table 8).

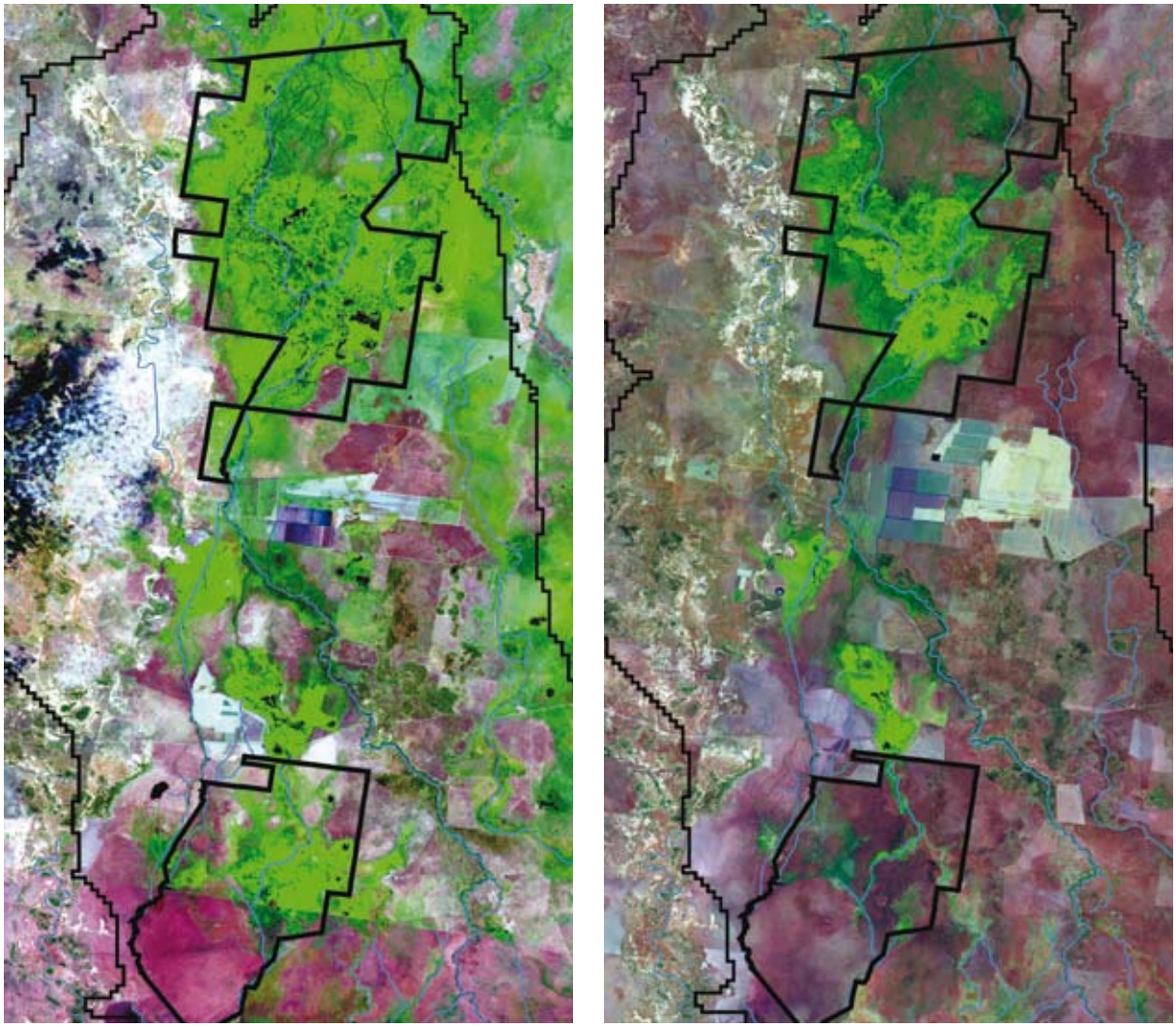
Changes to Australia's wetlands and floodplains have caused a decline in the number of waterbirds dependent on floodplains in areas that have been permanently flooded (for example, the Macquarie Marshes and Lowbidgee wetlands). Waterbird numbers across eastern Australia have declined since 1983, with the most significant decline occurring between 1984–86, and with further declines after 1991 (Kingsford and Porter 2005). Overall, annual average bird numbers have fallen from 1.1 million in 1983 to 0.2 million in 2004. Waterbird breeding grounds depend on regular flooding for their replenishment; a decrease in the frequency of flooding inevitably decreases the frequency of breeding and hence the numbers of birds. Should flooding be prevented altogether, there can be little or no breeding (Frith 1967).

Some important aquatic indicator species have also declined, including many species of aquatic macro-invertebrates, freshwater fish, and frogs. In Australia, four species of frog are extinct, 15 are endangered and another 12 are listed as vulnerable; in total about 14 per cent of frog species are threatened and there are an increasing number of sites in Australia in which frogs are no longer found. While some of this decline may be attributed to the Chytrid fungus, nobody knows whether, if, or to what extent, human activities have exacerbated the problem.

Table 8: Number of nationally important wetlands and number with threatened water regimes as at 2001

State or territory	Total number of sites	Number of Commonwealth owned or managed sites	Number of wetlands with threatened water regimes*
Australian Capital Territory	13	0	4
New South Wales	178	6	38
Northern Territory	33	4	7
Queensland	181	8	42
South Australia	69	1	19
Tasmania	89	0	13
Victoria	159	4	57
Western Australia	120	8	51
External Territories	9	9	-
Total	**851**	**40**	**231**

Note* Source is Davis et al (2001)
Source: DEH (2001)



The 1989 image (left) shows that the vegetation in and around the Macquarie Marshes is green and growing vigorously indicating that a good rainfall event occurred prior to the capture of the image. The 2003 image (right) is much drier by comparison, particularly in the southern part of the marshes. This illustrates the interaction of natural variance with human induced variance. Produced by the DEH Environmental Resources Information Network (ERIN) for the National Land and Water Resources Audit: Remote Sensing Products Addressing National Matters for Target (NLWRA July 2006).

5.2 Pressures on biodiversity

Pressures on Australia's terrestrial biodiversity have been operating over long periods of time and have a legacy (often called an 'extinction debt') that will continue for decades to come, even with remedial action. While clearing has been one of the main pressures, it is likely that climate change and urban development, infrastructure, and water extraction will soon dominate. For aquatic systems, the two main pressures are water extraction and habitat loss (see 'Inland waters' page 59).

Clearing

Loss of native vegetation continues to be one of the greatest threats to Australia's biodiversity. Historically, most clearing has been for agricultural production (see 'Land', page 69), with the result that around 13 per cent of the original vegetation has been removed since European settlement. Just for forest alone (see 'Land' page 69), some 17 million hectares have been cleared since 1973, with 1.5 million hectares of that deforestation between 2001 and 2004. With broadscale clearing controls in most states and territories, the threat is an increase in clearing for urban development on Australia's richly diverse escarpment and coastal ecosystems.

These broad statistics mask some important trends. For example, some vegetation systems such as hummock grassland are relatively unmodified, while others such as eucalyptus woodlands have 66 per cent of their systems left (Table 9). Natural temperate grasslands have been even more severely affected (Table 10). Apart from limitations to the data, such as the scale of mapping,

there is also the continuing inconsistency of vegetation classification systems used across states and territories. This makes it very difficult to consider finer-scale changes in vegetation type across the continent. Clearing statistics also give no indication of the condition of various ecosystems. For example, the ecosystems in many arid systems appear to be relatively unmodified, but other pressures, such as grazing, have significantly changed their structure and condition.

Nevertheless, it is possible to say that some species and ecological communities have declined more than others, some regions are being cleared more than others, and the condition and connectivity of vegetation as habitat have declined in many areas. In cleared landscapes there has been a general decline of ecological community functionality and processes. A major concern is that old trees in these landscapes are not being replaced as they die. All of these changes in vegetation condition and extent have major implications for biodiversity.

Loss of vegetation in riparian zones has been significant for both terrestrial and freshwater biodiversity, with 56 per cent of Australia's riparian vegetation having disappeared from 172 river basins (ERIN 2005b) (See 'Inland waters' page 59).

Some regions are being cleared more than others - of major concern is that older trees in landscapes are not being replaced. Photo: P Matthews, DEH.

Loss of vegetation caused by salinity has been significant for both terrestrial and freshwater biodiversity. Photo: J Baker, DEH.

Table 9: Estimated changes in vegetation in Australia from pre-1750 to the present (2001–04)

Major vegetation group	Estimated pre-1750 area (km^2)	Area remaining (km^2)	Percentage remaining	Percentage of remaining vegetation in reserves
Rainforest and vine thickets	53 469	35 200	65.8	54.4
Eucalyptus tall open forest	40 801	35 344	86.6	33.6
Eucalyptus open forest	394 280	272 121	69.0	22.7
Eucalyptus low open forest	4726	3952	83.6	35.1
Eucalyptus woodlands	1 362 263	892 920	65.5	8.1
Acacia forests and woodlands	495 059	408 632	82.5	8.8
Callitris forests and woodlands	40 278	32 296	80.2	6.1
Casuarina forests and woodlands	166 303	149 262	89.8	18.5
Melaleuca forests and woodlands	106 057	99 561	93.9	10.1
Other forests and woodlands	80 772	72 414	89.7	9.9
Eucalyptus open woodlands	498 663	458 905	92.0	6.2
Tropical eucalypt woodlands–grasslands	115 503	112 481	97.4	12.8
Acacia open woodlands	320 981	314 040	97.8	7.6
Mallee woodlands and shrublands	387 230	271 529	70.1	36.8
Low closed forest and tall closed shrublands	25 819	16 278	63.0	30.5
Acacia shrublands	865 845	851 274	98.3	10.0
Other shrublands	157 530	123 464	78.4	18.7
Heath	9256	8071	87.2	44.1
Tussock grasslands	559 850	525 888	93.9	3.0
Hummock grasslands	1 368 861	1 367 973	99.9	9.9
Other grasslands, herblands, sedgelands and rushlands	67 977	64 810	95.3	17.2
Chenopod shrublands, samphire shrubs and forblands	447 239	436 801	97.7	12.6
Mangroves	9664	9325	96.5	33.1
Total	**7 578 427**	**6 562 541**	**86.6**	**11.5**

Note: National Vegetation Information System Stage 1, Version 3.0, Major Vegetation Groups

Sources: DEH (2006h)

Table 10: Changes in the area of natural temperate grasslands

Bioregion	Pre-1750 (ha)	Area in 2003 (ha)	% remaining
Brigalow Belt South	270 000	25 000	9.26
Flinders Lofty Block	1 500 000	5 000	0.33
Murray-Darling Depression	440 460	1244	0.28
Riverina	2 750 000	26 871	0.98
South East Coastal Plain	60 000	25	0.04
South Eastern Highlands	450 000	<22 500	<5.00
Tasmania	80 098	13 617	17.00
Victorian Volcanic Plain	220 073	2291	1.04
Total	**5 770 631**	**96 548**	**1.67**

Note: ha - hectare

Source: Carter et al (2003)

Changed fire regimes

Australia's fire regimes have been profoundly changed by loss of pre-European Indigenous fire regimes. For example, in most of Australia's northern savannas there are now more large-scale, late dry season fires (Russell-Smith et al 2003). These fires are hotter and cover larger areas than the early to mid dry season fires that were typical of traditional Indigenous burning practices. In contrast, there are now fewer fires in the Wet Tropics because grazing has removed fuel. The resulting habitat changes have been widespread. For example, shrubs and trees have replaced grasslands, and rainforests have significantly invaded wet sclerophyll communities. In the 1500+ millimetre rainfall zone there have been widespread and massive habitat changes in the last 100 years, largely related to decreasing fire incidence, with demonstrable change in the last 30 years (Stanton 1995) (see 'Living in a land of fire' page 46).

Bushfires will occur at some time in most parts of the Australian continent, although they may be very infrequent in some climatic zones, such as those dominated by rainforest or wet eucalypt forest. Between 4 per cent and 10 per cent of the continent (c32-80 million ha) might be burnt in a typical year thereby suggesting an average interval between fires for the continent of about 15 years: in the severe fire season of 1974-75, about 15 per cent of the land area of Australia was burnt (Luke and McArthur 1978), and in 2002-03, a severe fire year in south-eastern Australia, 7 per cent (54 million ha) was burnt. Years in which bushfires cause the most serious threats to lives and property in Australia are typically serious drought years in southern Australia (Figure 23).

Adopting appropriate fire regimes could be one of the most cost-effective tools for biodiversity management across large parts of Australia. Research has provided fire guidelines for vegetation types that specify, for example, fire should be avoided in New South Wales rainforest, alpine complexes and estuarine and saline wetlands. The guidelines also recommend periods between fires, such as a 25–60 year interval in wet sclerophyll forests, with the period between crown fires being closer to 60 than 25 years.

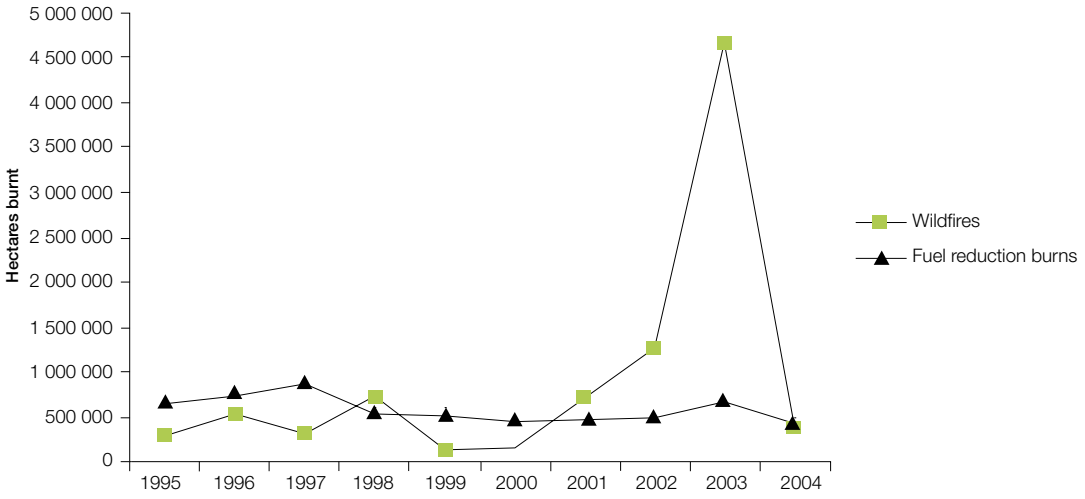
Total grazing pressure

Total grazing pressure is the combined effect of grazing by all animals. It includes domestic livestock such as sheep, cattle and horses, feral livestock (including goats and camels), native grazing animals (including kangaroos), and at times, locust populations.

Total grazing pressure is one of the main pressures on biodiversity in Australia. It dramatically reduces the standing biomass of grasses and forbs, and changes the species composition, with the most palatable species suffering the most. In systems where the decline has been significant, even low total grazing pressure can prevent system recovery (Page and Beeton 2000). This is particularly the case in parts of Australia where a combination of extreme overstocking and a 50-year rabbit plague has probably shifted the ecosystem to a new state. Grazing and various agricultural improvement strategies have modified vast areas of grassland and open grassy woodland so that in temperate ecosystems, less than 2 per cent of the original grasslands remain. The changes have altered populations of native animals because the changed environment favours some species to the disadvantage of others.

The proliferation of watering points across many landscapes, especially rangelands, has exacerbated the impacts of total grazing pressure because it allows native animals, feral animals and livestock to survive where

Figure 23: Area of forest burnt in Australia due to bushfires and fuel reduction burns, 1995–2004



Source: DEH (2005b)

Sheet erosion near Molong in Central New South Wales. Photo: D Eastburn, DEH.

they would otherwise die of thirst. The bore-capping programme in the Great Artesian Basin is a positive step in this regard, because it has reduced the number of watering points, and given ecosystems that can withstand only a very light grazing pressure the chance to recover (Fisher et al 2004). The effectiveness of the programme is so far measured in terms of groundwater pressure, which has increased in New South Wales, South Australia and the Flinders Zone of northern Queensland. The ecological benefits for rangelands ecosystems are yet to be comprehensively measured and reported, but there is evidence that the 334 mound springs in the Great Artesian Basin will benefit from the demonstrated increases in groundwater pressures (Fensham 2006).

Weeds and feral animals

It is estimated that Australia gains around 20 new pests or diseases each year (CSIRO 2004). Some well-known examples include Cane Toad (*Bufo marinus*), rabbits, willows and, more recently, the Black Striped Mussel (*Mytilopsis sallei*) and Fire Ants (*Solenopsis invicta*). Historically, feral cats, foxes and rabbits have been a cause of local extinctions and significant reductions in range for native species, through a combination of habitat modification and predation. They are a major ongoing pressure. Weeds are an equally significant pressure on ecosystems, with more than 2500 species of introduced plants now established in the wild in Australia. They have invaded every part of the landscape—bushland, rangelands, coasts, rainforests, deserts and farms. About 65 per cent are escaped garden plants, and nurseries still routinely sell many.

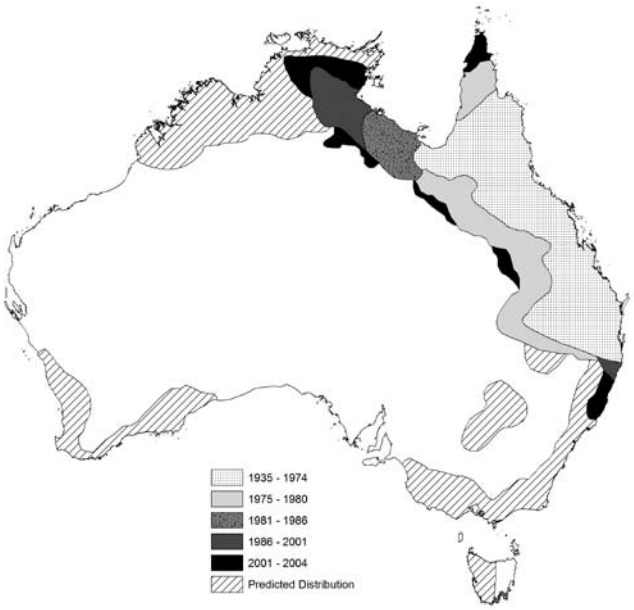
Weeds are not necessarily the primary cause of species decline. In many cases, land clearing resulting in habitat destruction, degradation and fragmentation has caused the initial reduction in species numbers and abundance. Environmental weeds then become a threat when invading remaining habitats, especially where these are already fragmented or degraded. Environmental weed invasion is a constantly increasing pressure on these vulnerable ecological communities.

The annual cost of weeds and feral animals has been estimated many times. The most recent estimates indicate that the annual cost probably greatly exceeds the current annual investment in management and control. The cost of weeds to Australian agriculture now exceeds $4 billion a year and almost all the plants involved are foreign (Sinden et al 2004). Half a million dollars a year, for example, is spent trying to keep just one woody weed species (*Mimosa pigra*) out of the Kakadu National Park (McLeod 2004). Other woody weed species such as Athel Pine (*Tamarix aphylla*), Parkinsonia (*Parkinsonia aculeata*), Prickly Acacia (*Acacia nilotica* ssp *indica*) and Rubber Vine (*Cryptostegia grandiflora*) in Australia's north and Bitou Bush (*Chrysanthemoides monilifera*), Blackberry (*Rubus fruticosus* agg), Boxthorn (*Lycium ferocissimum*), Broom (*Cytisus* spp and *Genista monospessulana*), Gorse (*Ulex europaeus*), olives, *Radiata* pine and willow in Australia's south are also expanding in range and they are difficult and costly to control (NLWRA 2001a).

Many animal species and plants listed under the EPBC Act are threatened by at least one invasive organism. For example, the invasion of Yellow Crazy Ants

(*Anoplolepis gracilipes*) on Christmas Island has led to the reduction in numbers of native Red Land Crabs (*Geocarcoidea natalis*), and this has resulted in changes to the rates of seedling recruitment and litter breakdown and the recruitment dynamics of rainforest trees. It has almost certainly changed patterns of nutrient availability. This leads to a rapid shift in forest structure and composition or a 'state change' in the rainforest ecosystem (Commonwealth of Australia 2005) The expansion of Cane Toads is similarly of concern (Figure 24).

Figure 24: Distribution (1935 to 2004) and predicted spread of Cane Toads in Australia



Source: DEH (2006f)

Changes to the aquatic environment

The combined effect of 50 years of changes to river flows, land use change, water use, over-allocation of water for irrigation, draining of wetlands, and habitat modification have left a legacy of decline in freshwater aquatic biodiversity. Arthington (2002) has reported that altered flow regimes have resulted in the loss of 90 per cent of floodplain wetlands in the Murray-Darling Basin, 50 per cent of coastal wetlands in New South Wales and 75 per cent of wetlands on the Swan Coastal Plain in south-west Western Australia.

The issue is not just the total amount of water, but also the timing and quality of water that stresses aquatic ecosystems. High concentrations of nitrogen and phosphorus can lead to algal blooms, oxygen depletion, fish kills, and depleted aquatic invertebrate populations. Changing groundwater levels, which contribute to salinity, also affect groundwater-dependent species such as wetland species that rely on groundwater during key phases of their lifecycles, as well as a range of life that exists in aquifers and about which little is known (Sinclair Knight Merz 2001).

Changes to the physical environment—through dams, weirs and 'de-snagging' programmes—have also been a significant pressure. Weirs and dams change the natural frequency and magnitude of floods, they change water temperature, and they are a physical barrier to movements of fish and other species. The response has been to construct fish-ways and to 're-snag' (drop in dead trees), but the scale and scope of these programmes are generally small compared to the scale of the problem (see 'Inland waters' page 59).

5.3 Responses

The increasing value many Australians place on biodiversity is reflected in the large increase in community action and investment in recent years. The NHT and the National Action Plan for Salinity and Water Quality (NAP), for example, have driven more conservation than ever before. Although they have sometimes struggled to focus enough on the underlying causes of biodiversity decline (PMSEIC 2002) the value of these programmes is that they have brought biodiversity management into broader natural resource management processes. Although this has been occurring slowly, initiatives such as conservation advice from the Threatened Species Scientific Committee is providing information links for natural resource management regions. Resource management programmes, such the National Reserve System and the National Water Reform Framework have shared similar stories. Many states and territories offer some type of financial incentive, based on the merits of agreed management plans and relative conservation value of the land. Collectively, these schemes are generating significant governance issues that remain to be resolved.

From 2000 to 2004, Australia's terrestrial protected areas increased by approximately 19 million hectares and now extend across almost 81 million hectares or 10.5 per cent of Australia (Table 11) (Cork et al 2006).

Despite this coverage, the protected area system is only partly representative of the biodiversity of nearly half of Australia's bioregions (NLWRA 2002b). Creative ways are required to fill this gap, and they must include whole-of-continent and whole-of-landscape management as a means of protecting Australia's biodiversity.

Large areas of land of high conservation potential are found on private property. For example, 50 per cent of Victoria's threatened vegetation types are found almost entirely on private land. As this report is being prepared, various off-reserve schemes, such as Bush Tender Victoria, Property Vegetation Planning in New South Wales, and the Nature Reserve System in Queensland, are being trialled as mechanisms for engaging private landholders in biodiversity conservation. In New South Wales, the community-based New South Wales Murray Wetlands Working Group has been managing 30 000 megalitres of environmental water on behalf of the New South Wales Government. The programme has so far extended a natural flood event through the Barmah-Millewa Forest and ensured successful bird-breeding of more than 30 000 waterbirds, watered a remnant stand of Common Reeds (*Phragmites australis*) within the Werai Forest, and watered approximately 120 isolated floodplain wetlands on private properties within southern-central New South Wales.

Dome Rock in South Australia's 63 000 ha Boolcoomatta Reserve, west of Broken Hill which was purchased in 2006 with funds from the Australian Government's Natural Heritage Trust and from the Nature Foundation of South Australia. Photo: W Lawler, Australian Bush Heritage/Copix.

Table 11: Australian terrestrial protected areas 1997–2004

1997		2000		2002		2004	
Number	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
5645	59 752 783	5251	61 438 611	6755	77 461 951	7720	80 895 099

Note: ha - hectare
Source: DEH (2005c)

The regional forest agreements have also been important in conserving forest values. The result of the 2005 Tasmanian Community Forest Agreement is that more than 156 000 hectares of forest were added to formal and informal reserves and, of that, some 121 000 hectares were old growth forest.

There is an increasingly cooperative approach between states and territories and the Australian Government in developing a consistent, national approach to biodiversity management. This is seen in the listing and the protection of threatened species and ecological communities (DEH 2006c). Also, three states – Victoria, New South Wales and Western Australia – and the Australian Capital Territory have agreed national objectives and targets for biodiversity conservation. Although progress towards these targets is encouraging, it has so far improved only policy, regulatory and planning processes (Griffin NRM Pty Ltd 2004). Biodiversity outcomes will take longer.

A potentially positive response for aquatic biodiversity may be the 2003 Living Murray Initiative, in which the Council of Australian Governments agreed to promote ecosystem health by implementing environmental flow regimes at a whole-of-basin, aquifer or catchment scale. It involved an historic commitment of $500 million over five years to return up to 500 gigalitres of environmental flow to six iconic sites along the river, including the Barmah forest, Hattah and the Coorong. Despite the recent and growing acceptance by governments and the community of the need for water reform in Australia (See 'Inland waters' page 59), no jurisdiction has as yet provided environmental water allocations for all of its river systems.

An innovative programme of the Australian Government to improve the conservation of biodiversity hotspots followed identification of such hotspots by the Threatened Species Scientific Committee in 2003. Biodiversity hotspots are areas that are both rich in plant and animal species, particularly many endemic species, and under immediate threat from impacts such as land clearing, development pressures, salinity, weeds and feral animals. The Australian Government allocated about $36 million to improve the conservation of these biodiversity hotspots on private and leasehold land.

Attempted restoration is not, in itself, the solution to poor environmental condition. Some ecologists are doubtful that restoration can ever be considered successful because of the poor understanding of most ecological communities and because of the lack of benchmarks against which to measure the success of most restoration projects. Also, restoration projects are subject to the same vagaries of climatic variability as fully natural systems. Consequently, it is extremely difficult to set time limits on environmental restoration, but restoration will often be the only way to give some elements of biodiversity a reasonably secure future. This will require that absolute concepts of naturalness be abandoned in favour of management for specific objectives.

The ecological community of White Box, Yellow Box and Blakely's Red Gum was listed as nationally critically endangered in May 2006. This remnant in Woodstock Cemetery is of high ecological quality; however less than 5 per cent of the overall ecological community remains in good condition. Photo: E Higginson.

The nationally critically endangered orange-bellied parrot whose range has been decreased due to habitat loss. The species is unique as it requires habitats on both sides of Bass Strait and is Australia's only parrot with an annual cross-border migration. The recovery of the species depends on concerted cross-jurisdictional action. Photo: D Watts, DEH.

For example, although it is possible to revegetate, reintroduce native animals, or mitigate threats such as weeds and feral animals, these activities cannot restore all the processes in an entire ecosystem. Furthermore, many elements of ecological communities and the way they function are poorly understood, and they can shift to a new state with little warning. These natural shifts can be a threat to some ecological communities when they are added to the extreme disruption that has occurred in recent history. For example, the rapid spread of native shrubs in the semi-arid zone and their apparent 'locking up' of the system in a state of low grass basal area, could be seen as an ongoing threat to biodiversity recovery across large areas of Australia's rangelands (Page et al 2000). Similarly, the absence of fire and the subsequent spread of wet forest types are placing some ecological communities under threat (Stanton 1995).

It should never be assumed that any cause and effect sequence involving biodiversity is simple or linear. It is for these reasons that preservation and adaptive management of what is left are much more effective.

Key points

- Australia has a legacy from past actions, and biodiversity will continue to decline in some areas before current investments either arrest or reverse change.
- Biodiversity has become increasingly vulnerable because of both loss of extent, and ecosystem resilience, aggravated by current climatic variability and possibly by enhanced variability.
- Pressures on biodiversity are uneven and reflect the level of development and at times the spread of novel biota.
- The future reduction in land clearance represents a reduction in pressures on biodiversity.
- Much needs to be done to increase the sophistication of biodiversity management and its integration into natural resource management.
- Biodiversity management needs to continue to move to a landscape-based model with adaptive management applied equally to productive and protected lands. This is because while the national reserve system could expand, it cannot ever fully conserve all of Australia's biodiversity.

The twin roles of fire as an ecological factor and as a threat to life and property are exemplified by these images of Mount Stromlo and Tidbinbilla in the ACT after the January 2003 bushfires.

The gutted historic Mt Stromlo Observatory. Photo: M Mohell, DEH

Ablaze. Photo: A Mostead, DEH.

Regeneration. Photo: J Baker, DEH.

Burnt forest, farmland and bush. Photo: M Mohell, DEH.

Living in a land of fire

Fires are an inherent part of the Australian environment. They cannot be prevented. Fires have a fundamental and irreplaceable role in sustaining many of Australia's natural ecosystems and ecological processes, and are a valuable tool for achieving many land management objectives. If they are too frequent or too infrequent, too severe or too mild, or mistimed, they can erode ecosystem 'health' and biodiversity, and compromise other land management goals—just as uncontrolled fires can threaten life, property, infrastructure and production systems.

Over the past 40 years, fires have claimed more than 250 peoples' lives, making fires the most hazardous natural event in Australia. Their financial cost, around $2.5 billion over the same period, represents about 10 per cent of the costs of natural disasters in Australia (Ellis et al 2004). Fires also typically release smoke particles, carbon monoxide, air toxics and volatile organic carbons in the air, and can raise the concentration of ground-level ozone. Both low-intensity cool-season fires and intense uncontrollable fires can affect human health.

Although bushfires occur at some time in most parts of the Australian continent, they may be very infrequent in some vegetation systems such as rainforest, and very frequent in others, such as the savannas of northern Australia. Fires in wet sclerophyll forests are infrequent, but are often of spectacularly high intensity when they do occur. Fires in temperate heathlands typically occur at intervals of between 7 and 30 years and some species may become locally extinct if fire intervals are shorter, whereas fires in tropical savanna woodlands and grasslands can occur every second year.

Bushfires do not destroy the bush, but burning can cause changes—some species may be lost from a burned area, temporarily or even permanently. Because not all species respond the same way, there are a variety of responses to an individual fire as well as to the fire regime. An inappropriate fire regime for some species may be frequent fires, whereas lack of fires, high intensity fires, or low intensity fires may be inappropriate for others. A common misconception is that all Australian species are unaffected by fires. Research clearly shows that the flora and fauna may be adapted to certain fire regimes

The bridled nail-tail wallaby — while remaining vulnerable to extinction — has been the subject of a moderately successful recovery programme. The species is easy to breed in captivity but difficult to reintroduce into altered natural habitats. Photo: D Watts, DEH.

but not to others. Some plants die, others re-sprout, and others appear little affected. Some *Xanthorrhoea* species flower abundantly soon after a fire. Other species that were not obvious before a fire appear on burnt ground following germination of buried seed, stimulated by heat or smoke, or as a result of the reduced competition. Some of these differences are due to the individual species, some are due to the characteristics of the fire, and some may be due to the particular environmental conditions before and after the fire.

Strategic management

There is increasing interest in engaging Indigenous people in contemporary fire management, especially in northern Australia where Indigenous people are major landowners and much traditional ecological knowledge persists (Horstman and Wightman 2001, Hill and Nowakowski 2003). For example, reintroducing fire to Boggy Plain in 2001 transformed the wetlands from a dense thicket of grass into a mosaic of habitats that is rich in biodiversity and of greatly enhanced cultural value to Indigenous people. This issue remains contentious because of uncertainty over the ecological impacts of traditional fire management and its relevance to contemporary conservation values. Russell-Smith et al (2003) show that the breakdown of traditional burning practices in northern Australia has led to a far higher incidence of large-scale wildfires late in the dry season.

Most Australian states and territories are managing fire by developing various forms of landscape and fuel management planning and zoning. Fuel reduction burning, although widely used throughout Australia because it is the only feasible means of fuel reduction on a landscape scale, will never prevent fires completely (Kanowski et al 2005). It is easier to protect adjacent property from lower intensity fires. Interface zones—between rural and urban land uses, and between primary production and conservation reserves—are usually the parts of the landscape in which fire poses the greatest risks to lives, property and economic values. Such interface zones are a high priority for fuel management as well as for other preparedness activities, especially where land uses and management objectives preclude wide-scale fuel reduction across the landscape.

Institutional arrangements must also be addressed. There is a need for better coordination of all aspects of fire mitigation and management among all levels of government, and between agencies in each jurisdiction (Ellis et al 2004). A second requirement is the adoption of a structured risk-management process for effective planning, preparedness and appropriate responses to fires. A risk-management approach focuses attention on the context in which fires occur—the local community and its assets, the environment, and the available resources for mitigation and response—as well as on the threats bushfires can pose.

6

Coasts and oceans

As an island continent, Australia is responsible for 14.7 million square kilometres of ocean and about 36 000 kilometres of mainland coastline. It extends from tropical systems in the north to Antarctic systems in the south. The resulting diversity of ocean and coastal systems means that Australia is probably the world's most important jurisdiction for marine biodiversity.

Australia's oceans comprise those marine areas for which Australia has responsibility. The 'coasts' encompass a much smaller area and include only the beaches, estuaries, near shore islands, reefs and the waters around them. They are at risk of serious degradation because of the pressures on them, including fishing, population growth and urbanisation, pollution, mining, tourism, species invasion from ballast waters, and climate change. There is also an alarming lack of knowledge because there is no systematic national monitoring of many important aspects of Australia's coastal and ocean systems.

There are no surprises or new issues since 2001. There is still a pressing need to respond to previously identified pressures in order to prevent the continuing slow and cumulative decline in environmental quality. The decline in the status of Commonwealth managed fisheries is one example. Furthermore, the current forecasts of climate change suggest that changing ocean circulation patterns and sea level changes are likely to have significant effects, for example, on cold water aquaculture. Planning for adaptation to climate variability should be a priority.

The pelicans, so intimately associated with Australia's coasts, have limited breeding habitats. The most extensive of these are inland Australia's ephemeral desert lakes and coastal wetlands associated with the Murray River mouth. This illustrates the species connectedness across large distances of many key Australian wildlife habitats. Photo: D Watts, DEH.

6.1 Marine biodiversity

Australia's vast and varied coasts and oceans are largely unexplored. There is very little information about Australia's marine biodiversity, much of which might not yet have even been discovered (Ponder et al 2002). This is especially the case for species and ecosystems in more remote, deeper oceanic areas. The risk is that small, but cumulative changes might not be detected because of a lack of knowledge of these vast and varied systems. The recently discovered loss of shell (mollusc) species over the past 150 years in shallow, sheltered estuarine waters of south-eastern Tasmania is just one example (Samson and Edgar 2001).

The limited information that does exist is generally for coastal biodiversity, with some species and systems showing mixed trends and others in apparent decline:

- of the limited number of bird species studied in a narrow range of monitored habitats, seven species appear to be stable, seven are declining, four have declined but appear to be rising or stabilising again, and five have expanded either their population or their range in at least one location
- mangroves are declining in some places as they are cleared for coastal development, and expanding in certain areas, especially northern Australia; but the extent to which they are expanding into other ecosystems is unclear
- monitoring in the Great Barrier Reef and in Ningaloo Reef shows considerable local damage and changes in resident species from cyclones, bleaching, fishing, sedimentation and pollution (see 'Natural and cultural heritage' page 77)
- major seagrass losses have been documented in Queensland, Victoria, South Australia and Western Australia

Australia's seagrass meadows are important habitats for species ranging from the dugong to many commercially important marine species. The biggest threat to seagrass beds are the processes leading to excessive sedimentation in coastal rivers. Photo: D Harasti, DEH.

- giant kelp declined, both in overall area and in number of beds in some places, until the 1990s with only slight recovery since then
- there is very little systematic monitoring of fish populations except in the commercial fisheries and many fisheries have no biomass reference points, little reliable data and no fully independent assessment of stocks. Reports on Commonwealth commercial fisheries by the Bureau of Rural Sciences show a steady increase in the number of species considered to be overfished. As researchers have found out more about these fisheries' resources, they have rated more species as overfished.

Further information about marine biodiversity is available through the Ocean Biogeographic Information System database <http://www.obis.org.au>.

Up to mid-2005, 18 marine species had been listed as threatened under the EPBC Act, and the number is likely to increase. It is not yet possible to predict whether protection alone will allow some of these species to recover. An emerging issue is that some species that have apparent niche overlaps are recovering differently. For example, Australian fur seals are increasing rapidly while sea lions are not showing such a recovery. The reasons for this difference are not well understood and are at the moment only speculative.

Overall, the lack of knowledge makes it difficult to predict the impact of climate change on Australia's oceans. Even the effects of a small change in water acidity due to increasing carbon dioxide concentrations are not known.

6.2 Pressures on Australia's coasts and oceans

Urban development

Australia's coasts are under increasing pressure as existing towns and cities spread to accommodate Australia's growing population (see 'Human settlements' page 7). Australia-wide, most of the coastal development—some 77 per cent of it—has been there since 1980. Moreover, the rate of urbanisation has slowed since 1989. If these trends continue, 42.3 per cent of the Nowra to Noosa coastline will be urbanised by the year 2050, with the resulting loss of much of Australia's temperate and tropical coastal systems and stress on existing infrastructure. For the Australian coastline as a whole, the proportion will be 9.2 per cent. In addition, the Tasmanian coastline has been under increasing pressure during the reporting period (Figure 25).

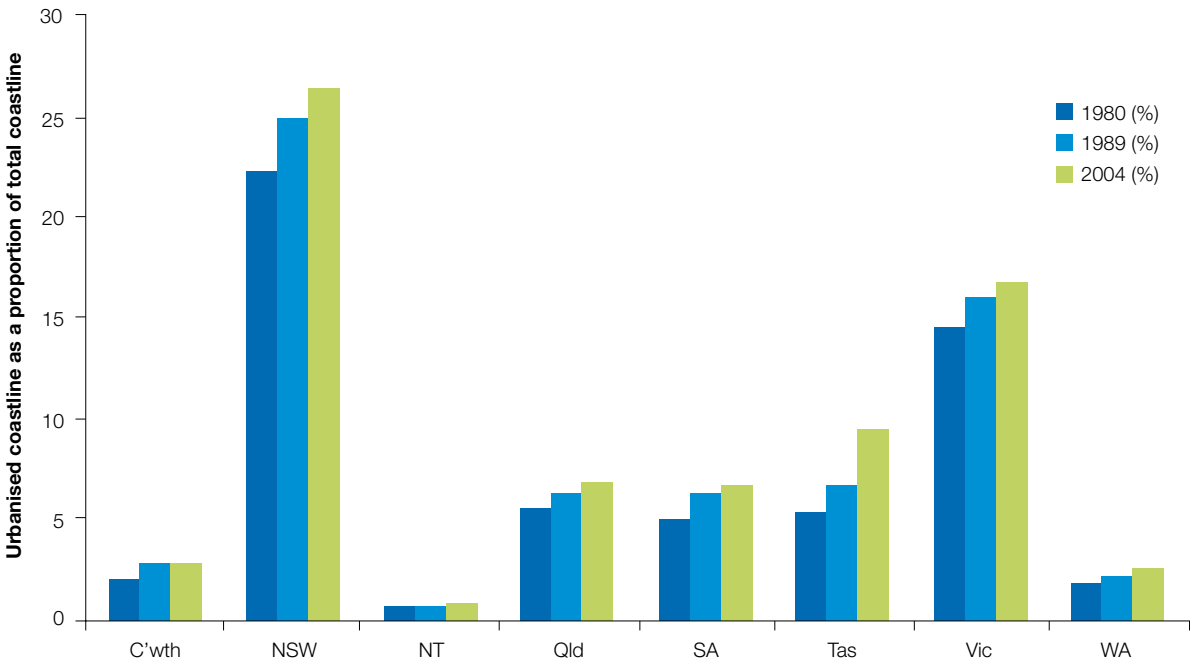
Pressure on Australian coasts is leading to critical loss of habitats. In some coastal locations there could be a future need for engineering protection from the effects of storms and cyclones. Photo: J Boshier.

Although 9.2 per cent may seem like a small proportion of the massive Australian coastline, urban development along the coastal strip is one of the main pressures on Australia's coastal environment. Replacing ecological communities with urban infrastructure threatens much of the temperate coast and tropical systems, especially near existing centres of population. All existing threats and pressures are intensified; this is in addition to the complete loss of habitat in the newly urbanised areas and the loss of many significant coastal Indigenous heritage places. The heritage landscapes of small coastal towns are similarly threatened by population increases and by urban development that is often unsympathetic or poorly planned.

The impact of continued urban expansion on coastal water quality could be a serious issue, particularly when combined with nutrients, chemicals and sediments entering the sea from rivers draining agricultural catchments. The effect has been the creation of localised and increasing 'pollution halos' around these areas, such as the contamination in Port Phillip (Victoria) and the toxic sediments at the bottom of Sydney Harbour (New South Wales). Dioxin levels in some fish and seafood have been high enough to suspend all commercial fishing in Port Jackson and its tributaries (NSW Food Authority 2006). Further areas are not expected to develop (Turner et al 2004) because much of the Australian coast is now subject to significantly better management practices than in even the 1970s and 1980s, but improvements are not keeping pace with pressures. With the increased urban spread, a realistic fear is that pollution halos will begin to link up and form bodies of polluted water that are not easily dispersed, which would affect many types of marine life.

Halting and reversing the decline in coastal water quality is a long, slow process. For example, the Swan River Trust began its efforts to improve water quality in the Swan-Canning river system in 1994 with a study of the problems caused by increased algal blooms.

Figure 25: Extent of urban development along Australia's coastline



Source: ERIN (2006b)

A few local councils, such as Noosa in Queensland and Surf Coast Shire in Victoria, have attempted to limit growth to a rate at which they can provide essential infrastructure, such as water supply. It is local government, after all, that bears most of the burden of managing the impacts, and some outside the capital cities have found that they do not have the financial and other resources to adequately manage the cumulative adverse impacts on the natural environment (Wild River 2006). On the other hand, many councils find it hard to justify forgoing the perceived benefits of the 'sea change' phenomenon and have actively supported surges in migration and tourism.

Table 12: Number of coastal-based facilities reporting emissions to the NPI

Number of facilities	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04
0–10 km from coast	400	686	826	956	1090	1142
10–50 km from coast	297	551	691	906	1047	1123
Total number coastal NPI facilities	**707**	**1260**	**1550**	**2039**	**2173**	**2297**

Note: NPI - National Pollutant Inventory
Source: NPI website <http://www.npi.gov.au> accessed May 2005

Agriculture

Intensive agriculture is a pressure on Australia's coasts and oceans, particularly estuaries and near shore environments. Modelling predictions estimate that each year almost 19 000 tonnes of total phosphorus and 141 000 tonnes of total nitrogen are discharged to rivers flowing to the coast (NLWRA 2001c). The highest nutrient loads are expected to be in the Far North of Australia, northern Queensland, Moreton Bay and coastal New South Wales.

Large quantities of total nitrogen have been discharged into rivers within ten kilometres of the coast since 1998 (the year when reporting nutrient emissions through the National Pollutant Inventory began). Total phosphorus discharges have also been significant. The number of facilities reporting discharges to water within ten kilometres of the coasts has increased from 400 in 1998–99 to 1142 in 2003–04 (Table 12); most of these are sewerage treatment plants and there are some intensive agricultural operations. These discharges are likely to be having at least a localised affect on fish, marine life, ecosystems and biodiversity, but despite this increase there are no national-level data on the impacts of these discharges.

Many eastern coastal lakes are suffering from land use change and forest clearing in their catchments, suburban development, alteration of freshwater inflows, storm and waste water discharges, over-fishing and resource development of various kinds. All are showing some kind of human impact (DEH 2006d, Harris 2006).

Fishing

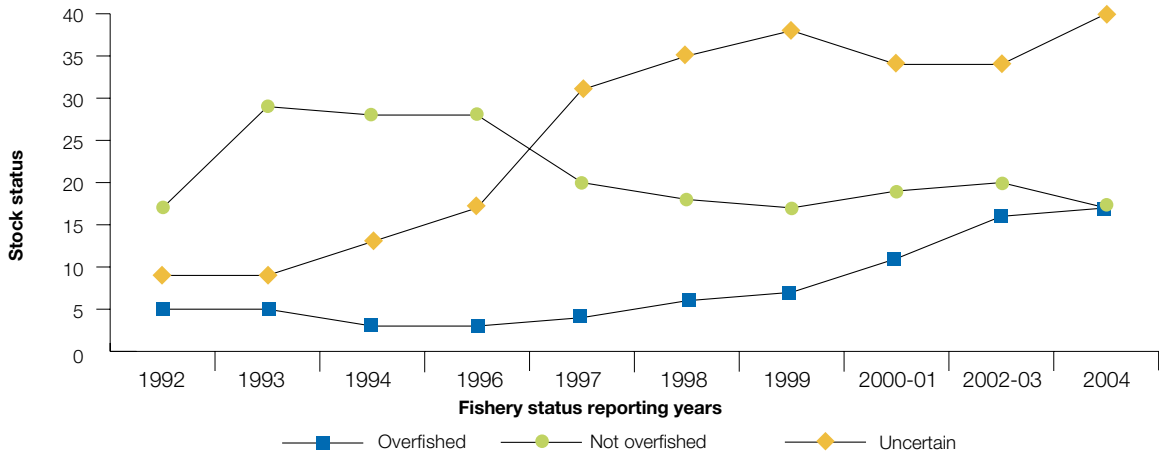
Fishing is a continuing pressure on marine ecosystems. While Australia's fisheries are limited compared to those of some other countries, they are also an important source of recreation, livelihood and wealth in many coastal areas of Australia. The pressure of overfishing generally and the consequent depletion of stocks, and increasing regulation will have an accelerating effect on traditional Indigenous subsistence activity in some areas.

Australia's commercial fisheries are amongst the most diverse in the world, exploiting more than 300 species—including fish, cephalopods (such as octopus and squid) and shellfish. In 2003–04, Australia's commercial fisheries (including aquaculture) produced about 267 000 tonnes of seafood valued at about $2.2 billion (ABARE 2005b). In terms of tonnage, 70 per cent of Australia's fish are caught in state-managed waters. Although some states and territories assess the status of their fisheries, these assessment processes are different from those used for Commonwealth-managed fisheries, and so a meaningful nationwide assessment is difficult, if not impossible.

The data that are available show a decline in Commonwealth-managed fisheries (Figure 26). Among the 74 species that are Commonwealth-managed, the number of stocks that are overfished has increased in the last 12 years and is now at a record-high level of 17 species. The highly migratory Southern Bluefin Tuna (*Thunnus maccoyii*) is considered to be overfished, but it has not been listed as vulnerable because this would not necessarily lead to a good conservation outcome (Caton and McLoughlin 2005, TSSC 2005). The strong management regime provided by the Commission for the Conservation of the Southern Bluefin Tuna (CCSBT) is seen to be the better way to go. At least some of the additional 40 species for which status is uncertain, are likely to be overfished as the trend to higher numbers of overfished stocks has followed more or better information becoming available on those resources. It is likely that similar trends would be seen across all Australian fisheries, and so these data can be taken as a case study with national implications.

Icefish is the first Australian fin fishery, and the second Australian fishery, to achieve certification by the Marine Stewardship Council. Photo: D Skinns, Austral Fisheries.

Figure 26: Trends in Commonwealth-managed fish stocks



Note: Classification categories used in *Fishery Status Reports 2004* differ from those of previous reports. Species previously classified underfished or fully fished are combined in the figure as not overfished. Overfishing counts for previous years are not available.
Source: Caton and McLoughlin (2005)

Recreational fishing

Recreational fishing also places significant pressure on fish populations, particularly for the onshore and near shore resources. In the 12 months prior to 2000, recreational fishers were estimated to catch approximately 136 million aquatic animals (Henry and Lyle 2003). While many recreational fisheries are managed through size and bag limits for individual fishers, this often does not limit the total catch in the fishery or adequately link the catch to a level that can be sustained by the fish population.

Illegal fishing

Illegal fishing places further pressure on some fish species—Patagonian Toothfish (*Dissustichus eleginoides*) in the Southern Ocean and shark (for fins) in northern Australian waters being the worst affected. The number of vessels apprehended for illegally fishing in Australian waters more than trebled (from 60 to 210) between 1999 and 2005 (Table 13). This gives some indication of the policing effort required to protect Australia's fishing stocks.

Table 13: Apprehensions for illegal fishing

Annual apprehensions	1999	2000	2001	2002	2003	2004	2005
Total/year	60	77	80	111	139	161	210

Source: Data supplied by Australian Fisheries Management Authority (2005)

Indirect impacts of 'wild catch' fishing

The impact of fishing extends beyond the direct harvesting of fish. In Australia's oceans, some of the most significant impacts are related to bycatch, which includes the accidental catching of other species, such as marine turtles, birds or non-target species of fish. There is still limited reporting of bycatch. Bycatch of marine turtles is one of the two key marine threatening processes that have been declared under the EPBC Act. In the Northern Prawn Fishery, the introduction of turtle exclusion devices dramatically reduced marine turtle bycatch from a high of 883 turtles in 1999, to only 27 turtles in the year 2003. Bycatch includes ghost fishing, which occurs when lost and discarded fishing gear continues to catch marine species indefinitely. Ghost fishing is also one source of marine debris: coastal surveys of northern Australia over recent years (Kiessling 2003) recorded 2566 abandoned fishing nets.

Ghost fishing occurs when lost and discarded fishing gear continues to catch marine species indefinitely. This is a particular problem in Australia's northern waters where Australia's jurisdictional reach is limited. Photo: J Dermer, Carpentaria Ghost Nets Programme.

Nanum Wungthim Land and Sea Management Centre Rangers based in Napranum, Queensland, tug a ghost net wedged in sands near Weipa. Photo: G Luchi, Carpentaria Ghost Nets Programme.

Other examples of indirect impacts of fishing are the disruption that trawling causes to ecosystems on the seabed, and the effects on the overall structure of marine ecosystems from removing key prey or predator species. These changes have been observed in the fisheries data that are available. For example, deep water trawling since the south-east fishery started in 1915 has greatly altered the biodiversity of the continental shelf and deeper water ecosystems, with one result being that the principal target species has changed over time. The mix of other, non-target species has altered substantially as the ecosystems have changed (Klaer 2001).

Aquaculture

The Australian aquaculture industry is small by global standards, contributing less than 0.1 per cent of global production by volume (ABARE 2005b). In Australia, the industry is gaining importance as, in 2003–04, it produced nearly 20 per cent of the tonnage of the wild fishery and nearly 50 per cent of the value. About 99 per cent of the Southern Bluefin Tuna catch is now 'ranched'. As wild-catch fisheries decline, aquaculture is expected to become an increasingly important feature of the fishing industry and of Australia's coastal regions.

The industry is expected to continue to grow rapidly (Love and Langenkamp 2003), particularly in sea-cage and other in-water operations that require protected shallow coastal sites of high water quality. As the competition for these sites intensifies, local, state and national planning and management processes will have to improve, as will monitoring of the pressures and impacts. Environmental risks from aquaculture include nutrient loading of estuarine systems, exotic diseases and possibly threats to wild populations through genetic alteration and disease.

Coastal and marine pollution

Shipping, and oil and gas exploration and extraction are sources of marine and coastal pollution in Australia's oceans. In the Great Barrier Reef World Heritage Area alone, some 6000 large ships pass through each year and three-quarters of them use the inner route along the land side of the reef, carrying a wide range of cargoes, including bauxite and alumina, manganese, iron ore, coal, sugar, silica sand, general container freight and petroleum products. The main pollutants from boats and shipping include ballast water discharges, marine debris and oil spills.

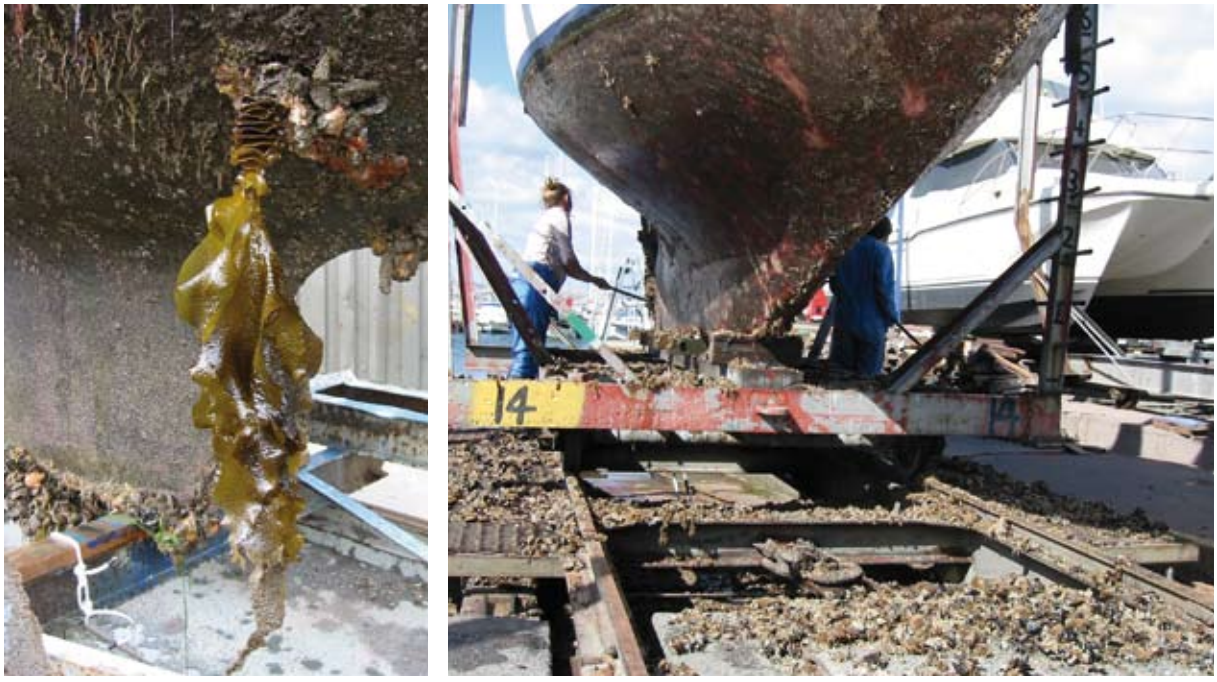
Waste from marine vessels is a localised pressure for marine ecosystems. Of the total 13 800 tonnes of waste generated each year in Australian waters, 70 per cent is off-loaded at ports and disposed to landfills. There are requirements for waste disposal by vessels traversing the Great Barrier Reef World Heritage Area as well as for tertiary treatment of sewage on offshore Great Barrier Reef islands.

There is little pollution from offshore extraction activities, which include tanker accidents, oil rig spills, and wellhead failures, as well as routine emissions from offshore facilities.

Introduced marine species

Ballast water discharges are of concern because of their potential to transport species from their native habitat to new habitats where they may become invasive. Ballast water from shipping has been responsible for introducing more than 250 species, and possibly as many as 500 species, into Australian waters. Australia has introduced mandatory ballast water management requirements to reduce the risk of introducing more unwanted marine species. More than 99 per cent of the approximately 12 500 annual voyages that arrive in Australia comply with these requirements.

The transfer of exotic organisms from the hulls of ships and boats also remains a threat to Australian waters. Two well-known examples include the Asian Green Mussel (*Perna viridis*), which almost certainly entered at Cairns on the hull of a vessel, and the Black Striped Mussel (*Mytilopsis sallei*) in the Northern Territory. The Northern Territory now has a hull inspection protocol in place for vessels entering the marinas, which has detected species of concern, including mussels. Even with inspections, there is always the chance that niche areas, such as the internal waterway systems of vessels, will harbour pests but be missed during inspections (Neil et al 2005).



The transfer of exotic organisms from the hulls of ships and boats remains a threat to Australian waters. Photo: K Hayes, CSIRO Division of Marine and Atmospheric Research.

6.3 Responses to pressures

Great Barrier Reef Marine Park

One-quarter of Queensland's land area drains directly into the Great Barrier Reef Marine Park through some 26 major river catchments. These catchments are largely agricultural, and 80 per cent of the coastal strip facing the Great Barrier Reef World Heritage Area supports dryland agricultural production. Most of the rest is used for intensive agriculture, which involves high levels of fertilisers and pesticides. With the added effects of urban development and aquaculture, water quality in the marine park is under considerable pressure.

Raised concentrations of sediment and nutrients have long been regarded as the principal water quality threats to the Great Barrier Reef. The threat from other pollutants such as persistent pesticides has been more recently recognised. Agriculture is the major human-induced source of excess nutrients, sediments and pesticides on the Great Barrier Reef.

Urban waste and stormwater discharges, and the impacts of aquaculture, are locally important. These threats are compounded by high rainfall and erosion rates in the wet tropics region of the North Queensland coast.

The potential impacts of pollution on the Great Barrier Reef range from reduced growth and reproduction in reef animals and plants, to major shifts in the community structure and functioning of coral reef and seagrass ecosystems. Coastal and nearshore coral reefs and seagrass communities adjacent to human settlement are most at risk from pollutants contained in runoff from the mainland. Declining ecosystem health in estuarine and nearshore areas will affect the biodiversity and other values of the Great Barrier Reef (see 'Natural and cultural heritage' page 77) (GBRMPA 2004).

There are many local and regional initiatives to reduce the pressures of urban development on the coast; many of them are partnerships between local community, local government, non-government organisations, state or territory governments and the Australian Government. For example, coastal management planning activities in some of the states have given rise to in-depth inquiries and strategies (such as the New South Wales Inquiry into Infrastructure Provision in Coastal Growth Areas and the Victorian Coastal Spaces Initiative). The sign-on of the majority of the states and the Northern Territory to the national coastal framework, developed by the Intergovernmental Coastal Advisory Group, and facilitated by the Australian Government, is also evidence of a coordinated attempt to manage the impacts on Australia's coastal areas.

The National Sea Change Taskforce is one example of a regional initiative that is facing the challenge of managing the pressures that come with increased coastal development. Made up of 70 local government councils, the taskforce has already identified the key social, economic and environmental planning issues facing coastal 'sea change' communities; documented the range of governance, environmental and other challenges; and reviewed current responses to the issues (National Sea Change Taskforce 2005).

The Moreton Bay Waterways and Catchment Partnership aims to develop a coordinated regional strategy to protect Queensland's waterways (see <http://www.healthywaterways.org/index.html>). This is one of the best available examples of local governments, with the help of the state and Australian governments, working with community, research organisations, Indigenous communities and industry.

The Australian Government has responded to marine environmental issues in several ways, including developing Australia's Oceans Policy, further implementing the National Representative System of Marine Protected Areas, and supporting programmes of the NHT. In total, Australia's current marine protected area estate, including state and territory protected areas and the Great Barrier Reef Marine Park, comprises more than 360 individual areas covering more than half a million square kilometres.

Australia's Oceans Policy is designed to improve outcomes in marine conservation and sustainable use in the Commonwealth-managed, offshore regions.

The Healthy Waterways partnership works to protect Queensland's waterways and reflects the potential of well-managed community government partnerships. Photo: courtesy Healthy Waterways.

South-east Queensland catchment. Courtesy Healthy Waterways.

Fur seals rest near Big Ben in the Heard and McDonald Islands Marine Reserve. Photo: K Green, DEH.

Ningaloo Reef, Western Australia – is Australia's largest fringing reef and one of the nation's Marine Protected Areas. Photo: C Bryce.

Its force is seen in the process of regional marine planning, which is occurring progressively across each of the major marine regions of Australia. One plan has already been completed for the South-East Marine Region (in May 2004), and two more are underway, one in northern Australia and the other in south-west Western Australia.

As a result of the marine planning process, the South-East Marine Protected Area network was proposed in December 2005 to give Australia about one third of the world's marine protected regions by area. The network contains representative examples of the major seafloor habitats across 2 million square kilometres of offshore waters in the South-East Marine Region. It is the first temperate waters system of its kind. In 2004, the area of highly protected zones of the Great Barrier Reef was increased from 4 per cent to 33 per cent of the Great Barrier Reef Marine Park. This makes the Great Barrier Reef one of the world's largest marine protected areas, reflecting its global significance as a high-diversity coral reef system. In addition, a Reef Water Quality Protection Plan has been agreed to by both the Australian and Queensland governments.

These moves are to be applauded, but cooperation in marine management between all levels of government is crucial. All the states and the Northern Territory manage vast coastal marine areas with exceptional biodiversity values. For example, Western Australia's marine jurisdiction comprises 18 bioregions covering about 126 000 square kilometres of mainly shallow coastal waters along 13 000 kilometres of coastline. This area hosts marine components of extreme global biodiversity value, including about 20 000 square kilometres of the world's most diverse seagrass beds, about 2500 square kilometres of mangrove forests, one of the world's largest fringing coral reef ecosystems (Ningaloo Reef is some 300 kilometres long) and one of the world's most southern, high-diversity coral reef systems in the Abrolhos Islands.

In conjunction with protection of marine areas, the Australian Government has introduced a $220 million structural adjustment programme that aims to take a large percentage of the fishing effort permanently out of several Commonwealth-managed fisheries, so that stocks have the opportunity to recover from their currently overfished condition. Combined with state moves to address overfishing, this programme will phase-out a large portion of the fishing industry, which will have a significant effect on coastal lifestyles and associated heritage values. Also, efforts to secure the future of the Patagonian Toothfish stocks around Australia's Macquarie Island were boosted in early 2006 through a management plan that limited the total allowable catch to 380 tonnes, but illegal foreign fishing operations continue to place this species under pressure on a global scale.

There have been some major, positive steps in the last few years, with many state and territory governments declaring marine protected areas (Figure 27). In 2004, the Queensland Government created a zoning plan in the nearshore waters adjacent to the Great Barrier Reef Marine Park. Around 14 per cent of the state's marine park is no-take, but the exact area has not been quantified. Western Australia has declared a third of Ningaloo Reef as highly protected. In 2002, Victoria became the first state in Australia to create a representative system of marine national parks. Covering 5.3 per cent of Victoria's waters, the parks are all fully protected from fishing and mining.

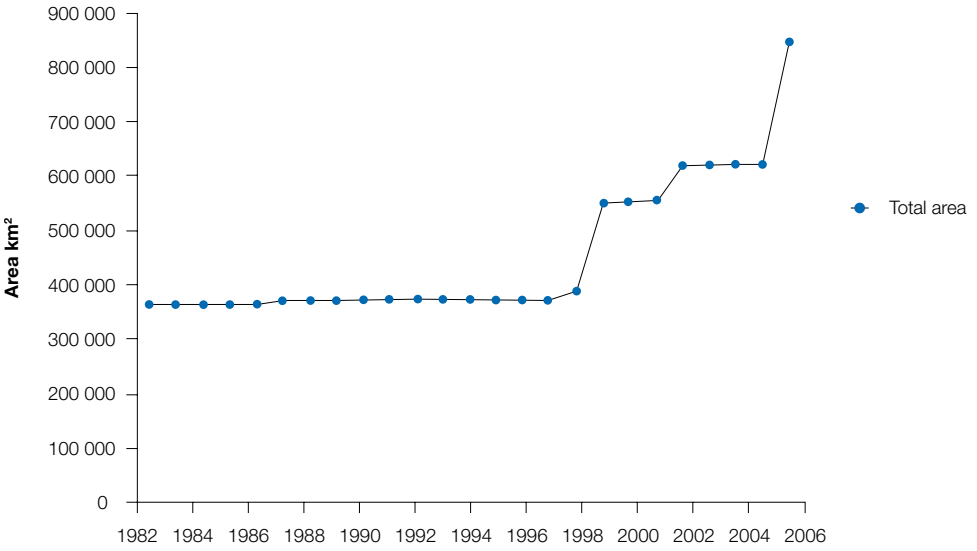
New South Wales has also expanded its marine protected area estate with the declaration of the Batemans Marine Park in 2006. This is the third in a series of new marine parks established since 2001, and there is now a chain of six multiple-use marine parks stretching along the state's coastline, incorporating one third of its waters. During this same period, extensive public consultation has informed the successful development and establishment of zoning plans for four of these marine parks, and a process has been put in place to finalise zoning for the remaining two in 2006.

Tourism, fishing and shipping are closely regulated in marine parks and sensitive areas such as the Great Barrier Reef. The increase in the adoption of environmental management systems by sections of the fishing industry since 2001 is a positive trend that should be encouraged.

Key points

- Australia still does not have a comprehensive, nationally consistent system for measuring the condition and trends of its coasts and ocean ecosystems and the key resources they support.
- While still uncertain, the current forecasts of climate change suggest that increasing ocean temperatures will cause major impacts on coral reefs and that changing ocean circulation patterns are likely to affect cold water, and thus planning for adaptation to climate variability should be a priority.
- Because Australian marine ecosystems remain at risk from exotic species being brought into Australian waters on ships' hulls and discharged in ballast water, measures to restrict transfer must continue both internationally and domestically.
- Trends in the status of fisheries' resources and in the bycatch are negative, and efforts to reverse these trends, such as improving management plans and introducing environmental management systems, should be enhanced and then communicated to the public to ensure progress is measured and evaluated.
- While there are no surprises or new issues since 2001, the need to resolve existing problems remains as strong as ever in order to stem the slow decline of environmental quality.

Figure 27: Increase in area of Commonwealth marine protected areas, 1982-2006



Source: DEH (2006g)

7

Inland waters

Australia is characterised by extremely variable rainfall and river flow regimes. Most lowland rivers are not only occasionally dry, but also flood from time to time and have large floodplains, with connected wetlands and billabongs. Rivers in Australia's south have been dammed extensively to provide a reliable water supply for agriculture and urban use. In contrast, rivers in Australia's tropics and subtropics, where two-thirds of Australia's surface water is located, are largely unmodified by water resources development schemes apart from coastal Queensland and the Ord River in northern Western Australia.

The increasing demand for water is placing significant pressure on Australia's inland water systems. The situation has been exacerbated by the recent drought, with uncontrolled growth in groundwater use in many catchments. Integrated management of surface water and groundwater is urgently needed in many catchments. This extra pressure on already stressed river systems has had serious impacts on biodiversity in some regions. Rivers, wetlands, lakes and billabongs were, and still are, sites of significant activity and value for Indigenous people—an important heritage value that is often overlooked. Significantly more needs to be done to monitor, preserve and protect important natural, cultural and aesthetic values of Australia's inland waters.

There have been some positive moves in the past five years with environmental flow allocations, habitat restoration, and invasive species control programmes in many river systems. Controls on point-source nutrient and chemical pollution have also been reasonably successful over the past decade, though some concerns remain. Community attitudes to water are beginning to change, with water 'left in the river' no longer seen as wasted water, but as a valuable resource for Australia's riverine ecosystems. Evidence of this is the increasing attention that is being paid to the development of a national system of freshwater aquatic reserves to ensure that those river and wetland ecosystems that are still largely 'pristine' can be protected into the future, especially those in northern Australia (Nevill 2006).

Integrated management of surface water and ground water is urgently needed in many catchments. The shift from flood irrigation to micro sprays and centre pivot irrigation is only part of the journey to a much improved water use efficiency. Photos: J Baker, DEH.

In 2004, the Australian, state and territory governments initiated the second stage of a national water policy reform process that started in 1994. When fully implemented over the next decade, the National Water Initiative will revolutionise the way water is owned, used and reused in Australia's cities and inland regions, whether for human consumptive purposes or for protection of the aquatic environment. This is a significant shift in water resources policy, and the impact on the aquatic environment of specific policies, such as extensive water trading, needs to be carefully monitored.

7.1 Water availability and use

Australia's rainfall and river flow have always been naturally variable and could become more variable, especially in southern Australia, as a result of changes in climate and seasonal river flows (Thresher et al 2004). While the recent drought has reduced water supplies across much of the country, in some regions the decline appears to have occurred during the past three decades. The situation in Western Australia is particularly severe, with Perth water supply catchments yielding 50 per cent less water than in the years before the mid-1970s, as a result of changes to rainfall as well as revegetation of the catchment. The extent to which this signifies a longer-term drying trend for Australia is uncertain, but the run of dry years experienced in the early 1900s could occur again, but this time for a longer period as a result of climate change. Australia should heed the warning signs, especially in view of climate change forecasts.

Apart from Darwin, all major Australian cities have been on water restrictions during recent years, with many now permanently on at least the minimum level of restrictions as water storages have emptied (Figure 28). Some larger rural cities have even had to enact emergency plans to provide essential water supplies. There are very few cities in Australia where planners are not considering strategies for dealing with issues of long-term water availability. Already there have been enormous changes, for example, in the public acceptance of the need for reduced water use in city and rural regions. The days of lush, green lawns in every Australian backyard may well be gone forever.

Regardless, demand for water is increasing across the nation, and in spite of trends to more efficient and careful water use, the pressure to build new dams and to exploit additional groundwater and river systems (especially in northern Australia) is growing. Australia is now the third largest per capita user of water in the world (Radcliffe 2004). In 2004, the Australian Bureau of Statistics published the Australia Water Account for 2000–01, which was effectively a census of Australian water use and the first since 1996–97. It showed that irrigated agriculture is the main user of water, accounting for 67 per cent of water used in 2000–01. This is a slight decrease from the level of use by that sector in 1996–97. Urban and industrial consumption accounts for only 9 per cent of water use, which is a slight increase since 1996–97 (Table 14).

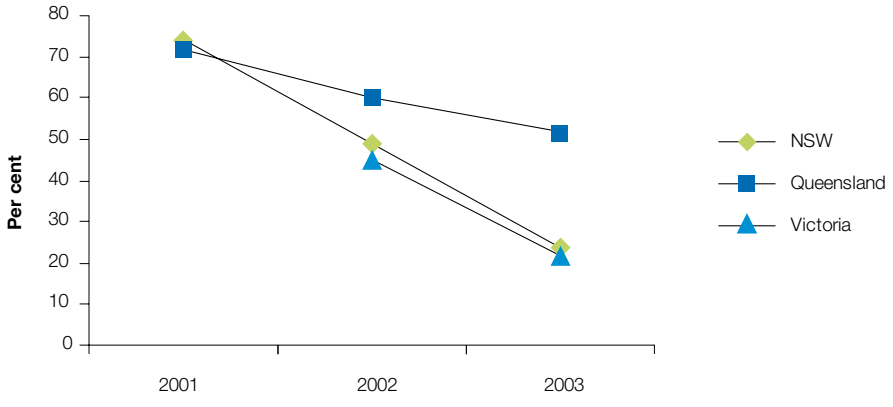
Table 14: Water consumption* by selected industries and sectors, 1996–97 and 2000–01

Sector	Australia's annual water consumption (GL)			
	1996–97	%	2000–01	%
Irrigated agriculture	15 503	70	16 660	67
Forestry and fishing	19	<1	23	<1
Mining	570	3	401	2
Manufacturing	728	3	866	3
Electricity and gas supply	1308	6	1688	7
Water supply, sewerage, drainage	1707	8	1794	7
Household	1829	8	2181	9
Environmental flows	–	0	459	2
Other	523	2	837	3
Total	**22 187**		**24 909**	

Note: GL - gigalitre.
*Water consumption definition as in the Water Accounts

Source: Adapted from ABS (2000, 2004f)

Figure 28: Per cent capacities of selected storages in eastern Australia, 2001–03



Source: Adapted from Hanna (2003, Table 1: 398)

Overall, total consumption of water has increased by more than 10 per cent in the five-year period from 1996 to 2001. If this trend continues, the gap between supply and demand will have to be addressed. Australia's water use efficiency and water reuse and recycling rates will need to increase from the current low levels to at least those of other developed countries (Radcliffe 2004). This is not just a technical issue because public perceptions are very important for reuse to succeed, as seen in the debate around water reuse in Sydney and the current experience of some country towns such as Toowoomba (see 'Water Futures Project—Toowoomba' page 14). Other, more expensive solutions include building new dams or desalination plants, or using aquifer storage and recovery methods. All are controversial.

With the increasing pressure to reuse wastewater, water quality is likely to become a greater issue, as recycled water 'fit for purpose' will be required for many agricultural, industrial and domestic purposes. While water of poorer quality may be used for many industrial purposes (such as cooling water), other uses (such as drinking water) require high-quality water. A recent debate has focused on the technique of 'indirect potable supply'. Under this scheme, highly treated sewage effluent would be added back into dams, where it would be further treated naturally before returning to the drinking water treatment plant for reticulation to household consumers. This has inadvertently been the practice for decades in some river systems. It is a proposal being considered by the cities of Toowoomba and Goulburn, and increasingly will be on the agenda for discussion by the rest of Australia. The environmental aspects of this technique will have to be closely considered as well as the human issues. The risk of toxic algal blooms may be increased if the recycled water is not first treated to remove the majority of the nitrogen and phosphorus that it contains.

Widespread reforestation, either through plantation forestry or through smaller scale agroforestry activities, will change the hydrology of catchments to further reduce water availability. A contentious issue is that young, rapidly-growing trees and shrubs use much more water than mature 'bush', leaving less to flow into rivers, lakes and dams (Zhang et al 1999, Best et al 2003, Dovers 2006).

Groundwater use is becoming the greatest challenge to sustainable water use in Australia (Table 15). There are now large areas of Australia, both urban and rural, where groundwater is being used above a sustainable level, although limited data mean that it is difficult to accurately monitor groundwater use and calculate sustainable yields. Many irrigators in the Murray–Darling Basin have switched from using surface water to groundwater since the surface water cap was introduced in 1995 (MDBC 2003). In combination with other groundwater uses, and the drought, this increase has caused groundwater levels to decline over large areas of the Murray–Darling Basin over the last decade (MDBC 2004).

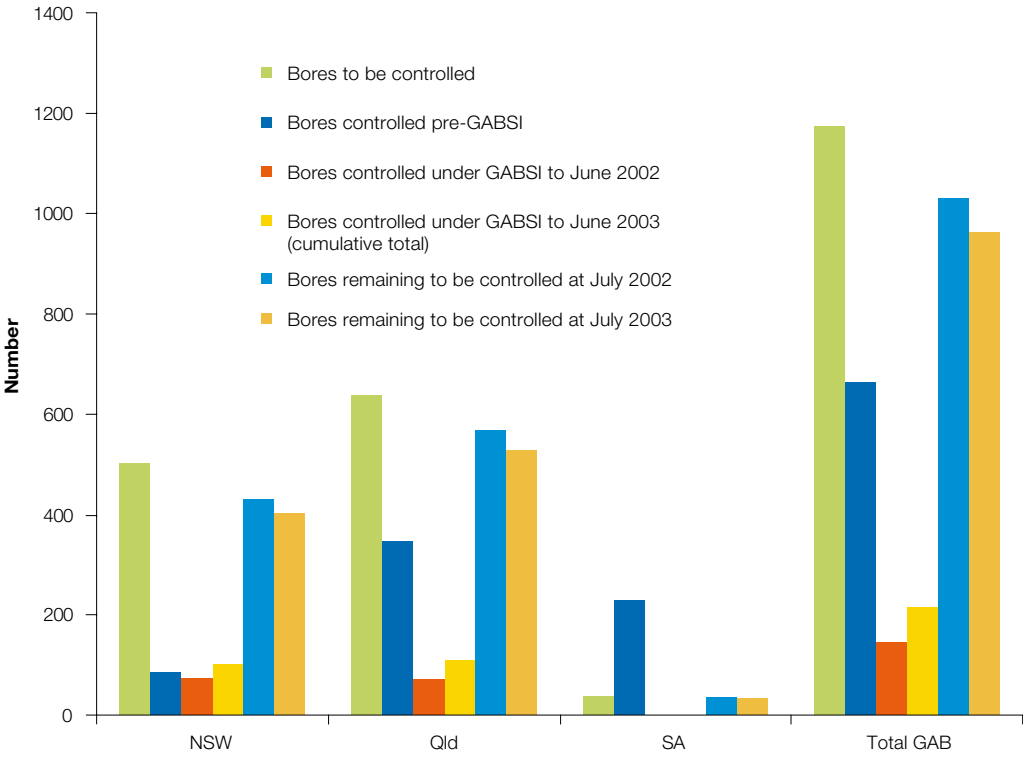
There are, however, positive signs in some regions. In response to declining pressures and water levels in the Great Artesian Basin, for example, many bores have been capped (Figure 29), drainage canals have been piped, and some spring wetlands restored.

Table 15: Change in mean annual groundwater use between 1983–84 and 1996–97

State or territory	Annual groundwater use (GL)		Per cent change between 1983–84 and 1996–97
	1983–84	1996–97	
New South Wales	318	1008	217
Victoria	206	622	202
Queensland	1121	1622	45
Western Australia	373	1138	205
South Australia	542	419	–22
Tasmania	9	20	122
Northern Territory	65	128	97
ACT	no data	5	–
Total	**2634**	**4962**	**88**

Note: GL – gigalitre
Source: NLWRA (2001b)

Figure 29: Number of artesian bores controlled under the Great Artesian Basin Sustainability Initiative



Note: GABSI - Great Artesian Basin Sustainability Initiative; GAB - Great Artesian Basin
Source: Adapted from Hassall and Associates Pty Ltd (2003)

7.2 Assessments of river health

During the nineteenth and twentieth centuries, major changes to Australia's land and water resource use led to altered flow regimes, increases in sediment and nutrient loads, habitat destruction, the introduction of exotic species and the consequent loss of aquatic biodiversity. Whether river health has been getting better or worse or has been stable at a national scale over the last five years is difficult to assess because of a lack of data.

There is some evidence that the management interventions over the past decade may have stabilised the decline in river health in some regions. In 2005 the Victorian Government provided the first scientifically robust assessment of trends in river health across an entire state. It concluded that there had been no broad change in Victoria's rivers during 1999–2004, and that the previous deterioration in stream condition had been arrested. The study did report that local changes were likely, with improvements in river health in some places and deterioration in a few others (DSE 2005). While far from scientifically or nationally conclusive, these results do provide some cause for optimism. However, the observations in Victoria make it clear that if there are to be improvements in river health, they will be hard-earned and a long time coming. Along the way, some rivers will continue to decline in health while others improve.

Aquatic biodiversity

Aquatic biodiversity is particularly sensitive to changes in river health, and it has declined in many river systems since European settlement. For example, one-third of river length in Australia has lost 20–100 per cent of the various kinds of aquatic invertebrates that should live there. Conversely, many rivers or river reaches, perhaps the majority, may not be significantly degraded due to a lack of development (Table 16). Many of them are not suitable for dam construction, or they are located in less populated mountain areas or in the northern tropical regions of Australia. Indeed, there is growing concern that many of these rivers, especially the larger pristine rivers in tropical Australia, will come under increasing pressure as sources of water to support irrigation development are exhausted in southern Australia.

Table 16: Sites assessed using AusRivAS, all states and territories, 1990–2004

Period of assessment	Number of sites at each level of diversity compared with reference sites					
	More diverse	Similar to reference condition	Significantly impaired	Substantially impaired	Severely impaired	Total number of test sites
1990–2004	195	2465	1556	433	56	4705
1994–99 (in *SoE2001*)	154	1702	963	254	39	3112

Source: Australian River Assessment System (AusRivAS)

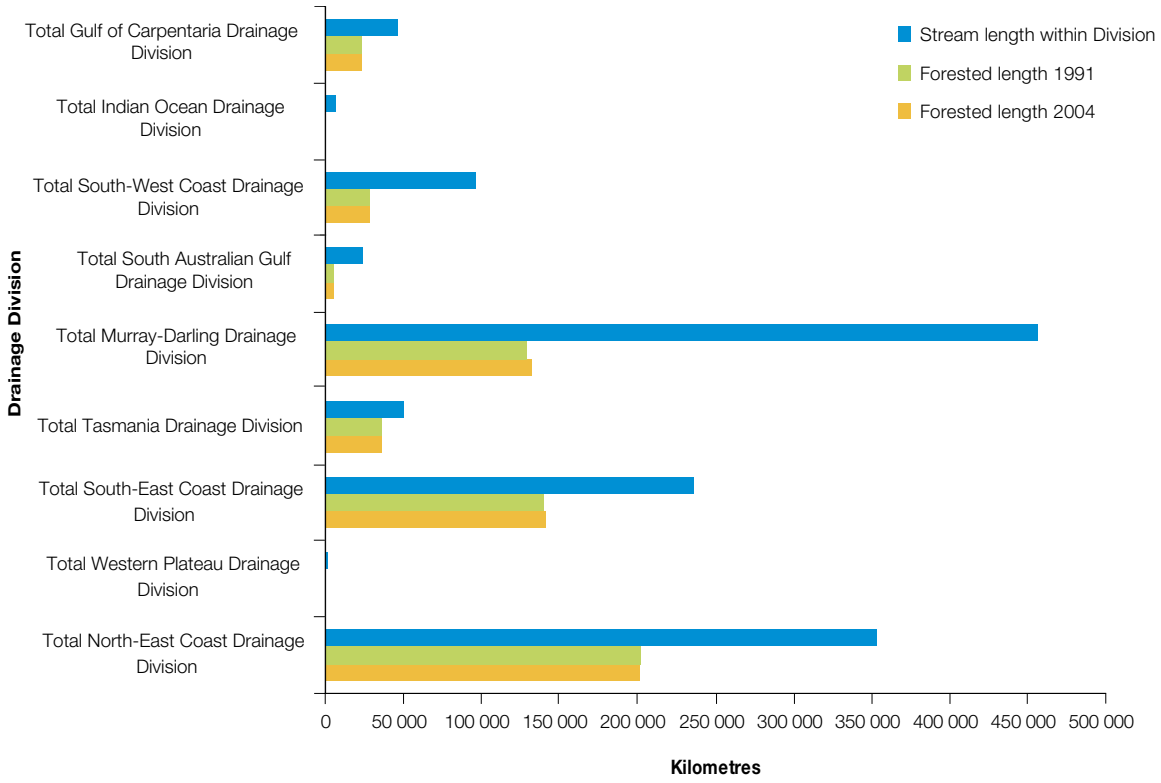
Frogs are very sensitive indicators of aquatic ecosystem health and extent. Their populations have decreased markedly in the last decade or so, with 27 species of frog listed as endangered or vulnerable (Tyler 2006).

Riparian vegetation, a key part of riverine ecology, has also declined. Extensive revegetation is required to improve river health, and many areas remain under significant pressure due to the combined impacts of human activity and the drought. For example, in 2003, 80 per cent of remaining River Red Gums on the Murray River floodplain in South Australia were stressed to some degree in 2003, and 20–30 per cent of them were severely stressed; this severe decline had occurred in the previous 12 months. In lowland rivers, 'de-snagging' and loss of water plants has also modified much instream habitat. While important locally, the scale and scope of recovery programmes are small compared to the scale of the problem. For example, in a sample of river basins, there was only a small increase of some 3700 kilometres in the extent of riparian vegetation between 1991 and 2004 (Figure 30). There have also been some limited projects aimed at bringing snags, which are essential habitat, back into some rivers.

The threatened green and golden bell frog at Kioloa on the New South Wales south coast. Across Australia frogs tend to be in decline. Photo: F Lemckert, Forests NSW.

The physical river environment has also been extensively modified as dams and weirs have been built. Not only do these structures physically restrict the movement of native animals, but they also regulate river flow, so there are fewer floods and fewer dry periods, and they divert

Figure 30: Forested stream length in all drainage divisions of the intensive land use zone



Note: ILZ – intensive land use zone
Source: ERIN (2005c)

Fish ladder on Broken River weir, Nathalia, Victoria. In some river systems fish ladders can overcome a range of problems. However other issues such as river flow and temperature profile remain problems. Photo: J Baker, DEH.

water out of the river. In New South Wales alone, there are over 4300 weirs and dams. Only 28 have fishways constructed that are effective for native fish.

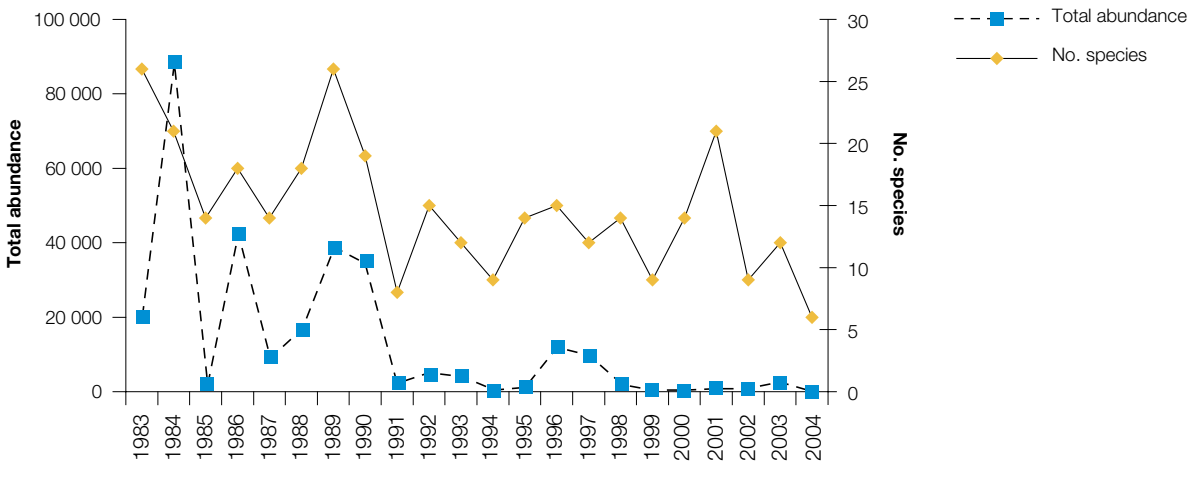
The impact on wetlands has been dramatic. As many as 231 nationally important wetlands are under pressure across Australia. Of the 64 Ramsar wetlands, latest assessments indicate that 22 have changed in ecological character or have the potential to change (DEH 2002). In the Macquarie Marshes, for example, there has been a significant long-term decline in river flows as a result of river regulation and subsequent diversions upstream. There are now fewer waterbirds, and fewer species of waterbird, than ever before (Figure 31). In the Lowbidgee floodplain, at least 76 per cent of the area has been destroyed by dams, diversions and floodplain development, reducing the amount of water reaching the floodplain by at least 60 per cent. Waterbird numbers in that area have decreased by 90 per cent. Breeding success has been improved in local experiments in the Macquarie Marshes, by allocating water for bird breeding through environmental flows (Kingsford and Porter 2005).

While much attention is being paid to restoring degraded rivers, there is also a growing movement to develop a system of state and national river 'reserves' to protect rivers that remain in a healthy, near-pristine condition.

River and wetland salinity

With so much of Australia's land affected by dryland salinity and with so much more at risk (see 'Land' page 69), it is not surprising that a third of catchments assessed by the NLWRA (2001b) showed signs of increased salt loads in rivers and streams. The problem is particularly severe in the southern Murray–Darling Basin, along the south-east coast of Australia and in catchments in south-west Western Australia. In other areas, such as the Lower Murray River,

Figure 31: Estimates of numbers of waterbirds and numbers of species of up to 50 different taxa counted during aerial surveys in October each year 1983–2004 at Macquarie Marshes



Source: Kingsford and Porter (2005)

salt interception schemes are helping to ameliorate instream salinity levels. Whether river salinity has improved is not yet certain because, with only 8 to 10 years of data in most places, there has not been enough time for any significant trends to emerge from the effects of climate variability and variations in flow.

There is little evidence that increased salt concentrations have yet had a broad-scale impact on aquatic plants and animals, but some wetland ecosystems have shown signs of salt degradation. Impacts on sensitive species should be expected if the salt concentration in Australia's lakes and rivers increases. While adult Australian fish, for example, are generally believed to be quite salt tolerant, recent research shows that the larval and juvenile stages of certain fish, such as Murray Cod (*Maccullochella peelii peelii*), are particularly sensitive to salt.

Effects of salinity on riparian vegetation, near Lyrup South Australia. Photo: J Baker, DEH.

Soil erosion and sedimentation

Throughout Australia, soil erosion has significantly increased sediment loads to rivers and estuaries (see 'Land' page 69). River water from forested catchments, or from catchments with large areas of relatively unmodified native vegetation, tends to be clearer than river water from agricultural and urban catchments. Extensively cleared catchments, such as large areas of the wheat and sheep zones of eastern and south-western Australia, are worst affected. In many parts of Australia, because much of the eroded material has still not yet worked its way through the bigger river systems, large amounts of sediment are stored in river channels in low-gradient areas (Wasson et al 1996, Martin and McCulloch 1999, Prosser et al 2001). Sand slugs in the lowland reaches have smothered various instream habitats, which has had significant impacts on aquatic plants and animals. Rehabilitation techniques for sand slugs are being explored, including placing railway sleepers across a riverbed to increase the natural scouring process (Bond et al 2004).

Erosion of sediments is dramatically increased after fire. The large-scale fires that burned across the Victorian and New South Wales high country and the Australian Capital Territory in 2001 and 2003 caused greatly increased erosion in these areas, leading to poor water quality and the deposition of large amounts of soil and other materials in stream beds and lakes downstream of the fires (DSE 2003). In the Australian Capital Territory, a storm shortly after the 2003 fires washed debris and the equivalent of 27 years' worth of sediments into the water supply dams (Carey et al 2003). Erosion and sedimentation rates were still high in 2005, especially after rainfall, and the territory has had to upgrade its water treatment facilities to maintain drinking water quality to the city (ACTEW 2005). For all of these areas, the risk of further deterioration will remain until the vegetation recovers.

Nutrient levels

Excess nutrients were a major water quality issue in about 60 per cent of basins assessed by the NLWRA in 2001. For most rivers, the largest source of increased phosphorus loads is gully and stream bank erosion, rather than farm fertilisers (Martin and McCulloch 1999, Prosser et al 2001). In contrast, increases in nitrogen levels are typically from fertiliser use, animal wastes and sewage discharges (Caraco and Cole 1999). Nearly 19 000 tonnes of total phosphorus and 141 000 tonnes of total nitrogen were estimated to be transported down rivers to the coast each year from areas of intensive agricultural activity.

Table 17: Exceedance of water quality guidelines for Australia (number of river basins)

	Major exceedances	Significant exceedances	Number of basins assessed
Nutrient: total nitrogen	19	19	50
Nutrient: total phosphorus	40	20	75
Salinity: electrical conductivity	24	18	74
Turbidity	41	10	67
pH	7	6	43

Source: NLWRA (2001b)

Blue-green algal blooms

Blue-green algae have become more widespread as changes to instream habitat and catchment land use have altered the stream metabolism of inland waters. All the changes seem to favour increased toxic algal blooms, and more frequent periods of oxygen depletion in the bottom waters of pools, weirs and dams. The current cost of algal blooms is in the range of $180 million to $240 million per year (Atech 2000). Between 2001 and 2005, SA Water recorded the occurrence of 19 algal blooms in 12 freshwater bodies in South Australia. Most blooms occurred during the summer–autumn months and some lasted several months (Baker 2006).

Exotic species

Introduced species appear to be favoured by the large-scale landscape and waterscape management practices found across large areas of the continent. Introduced pests—such as carp (*Cyprinus carpio*), mosquito fish (*Gambusia holbrooki*), and oriental weatherloach (*Misgumus anguillicaudatus*), and weeds—have continued to expand their range. In the Lower Murray–Darling catchment, for example, exotic species make up 56 per cent of the total biomass of fish (Gilligan 2005). There has been a corresponding decline of native species, with little evidence of effective control of invasive species. Species such as carp not only compete with native species but also alter habitats, and their management is not straightforward. Native fish are more successful in breeding in wet years, and the reintroduction of environmental flows and overbank flows is needed for ongoing improvement.

There are some possible solutions being developed, such as a research programme aimed at producing 'daughterless carp' to help reduce carp numbers and distribution. Another technique uses the ability of carp (unlike most native fish) to 'jump' over instream barriers. This 'capture' technique is proving effective in preventing carp from moving into some floodplain lakes and wetlands.

7.3 Investments in inland waters

Investments such as the NHT and the NAP at a national and regional scale, the Living Murray (MDBC), Healthy Waterways Partnership (south-eastern Queensland), and the Clean Up the Swan Programme (Western Australia) are important to future progress. These programmes have addressed local and regional needs, but Australia needs a systemic approach that develops sustainable systems of land management that address fundamental environmental problems.

The National Water Initiative represents a significant shift in this regard, with much support for the initiative having been galvanised by the recent drought. Whether these reforms will be sufficient to restore the rivers to an acceptable level and redress the evident loss of biodiversity remains to be seen. Indeed, there is concern in some quarters that the environment may not necessarily benefit from changes such as extensive interstate water trading (Jones 2005).

Much progress is being made with programmes such as the recovery and restoration of environmental flows, riparian vegetation and snags, and aquatic pest control and removal (such as of carp and willows). Habitat management programmes are underway in all states and territories, as part of 'Healthy Rivers' programmes, although they are often underpinned by a view that isolated local action can remedy the problem. The most widely publicised and known of these river restoration programmes is the Murray–Darling Basin Commission's 'Living Murray' programme. In 2004, the Murray–Darling Basin Ministerial Council agreed to recover 500 billion litres of water for the Murray River environment. Other less well-publicised environmental flow agreements have been, and continue to be, struck elsewhere.

As important as these programmes are, they provide little ground for complacency—the magnitude of human impact often exceeds the scale of restoration programmes. For example, the 500 billion litres to be recovered for the Murray River represents only a small percentage of the water consumed every year by the people living along the river. It is likely that the Murray River will require at least three times this volume of water if there are to be significant improvements in the entire river environment, rather than just improvements to the parts that are targeted to receive environmental flows (Jones et al 2003).

Moreover, analysis shows that so-called 'best management practices' might not achieve sustainability

Before (left) and after (right) riverbank repair at Mulloon Creek east of Bungendore, New South Wales - funded by the Natural Heritage Trust through Envirofund and implemented by the Reedy Creek Landcare Group. Restoration ecology will continue to be an important component in Australia's natural resource management toolkit. Photo: P Hazell, DEH.

Banrock Station in South Australia is an internationally important wetland site on private land which its owners have rehabilitated. Photo: J Baker, DEH.

or the desired catchment management targets. This is partly a product of the small scale and fragmented nature of various investments in inland water, riparian and catchment management. Past investments in these programmes addressed local needs, but did not often address the larger, strategic needs for improved practices and sustainable solutions. Investments in individual programmes must be coordinated from a whole-of-catchment perspective that is underpinned by strong principles and models of landscape hydrology and ecology.

Without criticising the efforts of extremely dedicated volunteers, it should be noted that the success of many excellent, small-scale habitat and species restoration programmes is easily compromised by unsustainable large-scale land and water use patterns.

Similarly, Commonwealth, state and territory programmes continue to address many of the issues, but in a fragmented manner and with a range of responses, although there are some signs that this is changing. In Victoria, the Murray–Darling Basin Salinity Management Strategy, for instance (MDBC 2001) has been used as a framework for basin communities and governments to control salinity and protect natural resources. The strategy establishes end-of-valley salinity targets for each tributary catchment and a basin target at Morgan in South Australia. Implementation is a shared responsibility between valley communities and governments and there is a commitment to the principles of the Integrated Catchment Management Policy Statement.

There are some heartening stories. One example is the broader water reform process in Australia, which has led to improvements in allocation mechanisms, water use efficiencies and more use of water for environmental purposes. Water use efficiencies in the irrigation sector are increasing, with improved irrigation practices and crops that yield greater returns per megalitre of water used (in the case of rice growing in the Murray Irrigation Area, see <http://www.rga.org.au/environment/water.asp>). It is hoped that the National Water Initiative will continue to add incentives to positive reform in this area.

Controls on chemical pollution have been reasonably successful over the last decade, as shown by improvements in water quality in Port Phillip Bay (Harris 1996). Many state regulatory and licensing programmes have focused on eliminating industrial, agricultural and other chemicals from the aquatic environment. While some cases still exist where action is required, it can be said that, overall, such programmes have been reasonably successful in the last decade and that instances of problematic concentrations of such chemicals are not frequent. For example, during the 1990s, the Australian cotton industry undertook a coordinated programme to reduce the impact of pesticides on rivers and wetlands. They have made significant steps to reduce pesticide use and to improve the techniques by which it is applied and managed on-farm (Schofield et al in press).

Exceptions to this positive trend include waterways downstream of some irrigation areas, some industrial and mining sites, disused sheep dip sites and old waste dumps that continue to pollute groundwater. Increased emissions to inland waters have been reported to the NPI for a number of substances between 2001 and 2004,

notably sulphuric acid, manganese, copper, ethanol, zinc and total volatile organic compounds, while reported emissions from facilities have declined for ammonia, total phosphorus, total nitrogen, fluoride and chlorine. Total nitrogen is the greatest NPI-reported pollutant of inland waters, followed by sulphuric acid, ammonia, manganese, total phosphorus and oxides of nitrogen.

Key points

- River and wetland management activity has increased in the past five years, with environmental flow allocations, habitat restoration, and invasive species control programmes in many river systems. Nevertheless, Australia's inland waters remain under significant development pressure and much remains to be done before the health of *all* Australian waterways is sustainable in the long term.
- Increasing attention is being paid to the development of a national system of freshwater aquatic reserves to ensure that those river and wetland ecosystems that are still largely undisturbed can be protected into the future. Many of these 'near-pristine' rivers are in northern tropical Australia, and there is growing pressure for their agricultural and industrial exploitation.
- The recent drought has placed additional pressures on already stressed river systems, leading to impacts on biodiversity in some regions. The recovery of rivers and wetlands will need to be closely monitored as part of the process of adapting to known and anticipated variability.
- Increasing demands on surface water sources, combined with impacts of the drought, have led to often uncontrolled growth in groundwater use in many regions. Not only is this cause for serious concern from a water resources perspective, but the impact on groundwater-dependent ecosystems is uncertain and little studied.
- Controls on point-source nutrient and chemical pollution have been reasonably successful over the past decade, with a few remaining areas of concern. The 2001 and 2003 bushfires in south-eastern Australia also led to massive inputs of sediment and nutrients to rivers and reservoirs in affected catchments, with consequent diminution of water and instream habitat quality; recovery from this natural disaster could take many years.
- The National Water Initiative is set to revolutionise the way water is used, reused and managed in Australia. The impact on the aquatic environment of specific policies, such as extensive water trading, needs to be carefully monitored.

Discharge of irrigation water into Victoria's Barr Creek. The challenge is to integrate systems so that water once discharged is treated and becomes available for other uses. Photo: J Baker, DEH.

8

Land

Australia's land use has and is being fundamentally shaped and influenced by thousands of years of Indigenous use and two centuries of European settlement. Changes in vegetation and patterns of settlement and land use continue to be significant sources of pressure on Australia's natural and cultural environment.

Agriculture is still the main use of land in Australia, occupying some 62 per cent of the continent (Table 18), with much of that in the rangelands. Sheep and cattle grazing and cropping continue to return high economic benefit to Australia, but contribute to habitat loss, surface soil loss, salinity, and soil and water quality issues, and there are ongoing concerns about sustainable farming and land use management. Surface soil loss was exacerbated by the 2002–03 drought, leading to the highest national dust storm activity since measurements began in the 1960s.

Increasing uptake of a 'landscape' view by governments, regional management groups and farmers is boosting the prospects for sustainable land management. As part of this, landscape objectives that integrate local actions are expected to be a key management tool over the next decade. In this context, the regional NAP and NHT programmes remain important in funding and guiding catchment and bioregional planning and management. It is expected that the benefits of extensive Australian, state and territory government investments in land and resource management will emerge during the coming years.

Table 18: Land use in Australia (National Land Use 1996-97 Summary Statistics)

Land use	% of total
Agriculture	61.5
Grazing natural vegetation (rangelands)	56.0
Dryland grazing (improved pastures)	2.5
Cropping	2.8
Horticulture	<1.0
Irrigation	<1.0
Minimal use	15.0
Traditional Indigenous uses	12.0
Biodiversity conservation	6.1
Forestry	2.0
Water	1.7
Managed resource protection	1.4
Urban uses	<1.0
Mining	<1.0
Total	**100**

Source: DAFF (2006)

8.1 Vegetation

The most visible indicator of land condition is the extent and quality of vegetation cover. Nationally the picture is deceptive—about 87 per cent of Australia's original native vegetation cover remains, but its condition is variable and masks an underlying issue of the decline of many ecological communities. Some ecological communities occupy less than 1 per cent of their original extent as a result of clearing for agriculture, and many others are highly fragmented. In addition, the components of many ecosystems, especially the understorey in forests and woodlands, have been severely disrupted.

Some regions, such as agricultural areas in south-eastern Australia and the south-west Western Australian wheat belt, have particularly suffered from over-clearing. The result in those areas is a landscape with ageing mature trees that have a radically changed, or non-existent, native grass and shrub understorey. Many trees are affected by dieback, and continued grazing of the understorey means they are not being replaced. The legacy of these effects further reduces the capacity of the environment to recover from a range of pressures associated with its use (see 'Biodiversity' page 35).

Australia's rangelands occupy more than 75 per cent of the continent and include a diverse group of variably disturbed ecosystems such as tropical savannas, woodlands, shrublands and grasslands. They are home to a significant number of rare, threatened and endangered fauna and flora species, and include a number of World Heritage sites. The rangelands are extensively grazed, but there is evidence that some pastoral rangelands have improved over the last decade (Watson 2006).

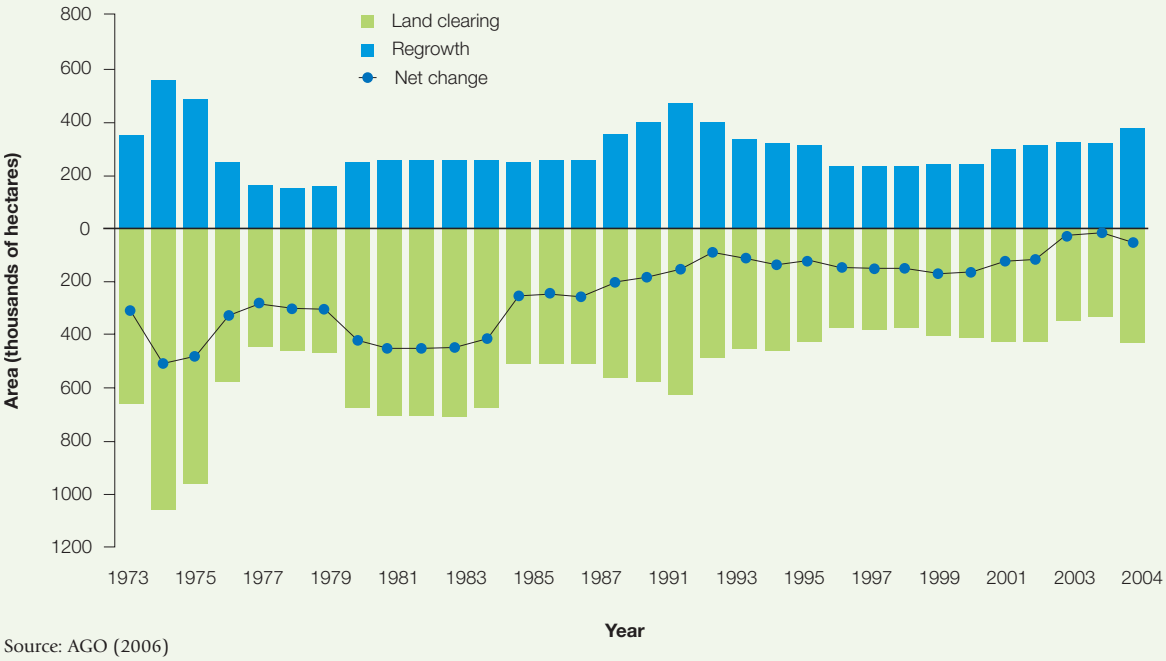
Clearing of native vegetation is an ongoing threat to Australia's environment. Between 2000 and 2004, 1.5 million hectares of forest (which includes native and non-native vegetation) was cleared across the continent. After forest regrowth, the net change was a loss of 287 000 hectares (Figure 32). The rates of deforestation and forest regrowth vary across the states and territories (Figure 33), but there has been a recent increase in some states in advance of stronger clearing legislation. It is expected that most states will be clearing less native vegetation in the future as clearing regulations are progressively applied.

The concern about vegetation change extends beyond the number of hectares cleared or replanted each year. It is often the case that the replacement vegetation, whether natural regeneration or planted trees, is not like the communities that were previously cleared. For example, dense woody shrubs may form a monoculture in place of a naturally occurring, complex ecosystem. It is not possible to derive ecosystem complexity data from the data provided, however desirable this information may be, because the data are collected to monitor national-scale trends through time.

The picture is also confused by definitional issues. The area of forest discussed in this report corresponds to the international definition of forest and is the native and non-native vegetation that has at least 20 per cent canopy cover and could grow to at least two metres tall with a minimum of 0.2 hectares. Other systems of vegetation measurement, such as that used to assess key threatening processes, include all native vegetation across the entire continent, including sparse woody vegetation and non-woody vegetation such as grasslands. The states and territories also have variable definitions in the legislation they use to manage and protect vegetation. Despite its deficiencies from an ecological viewpoint, the forest (international definition) dataset is the only nationally consistent, long-term dataset available.

Left: sparse woody vegetation (less than 20 per cent canopy cover).
Right: forest (more than 20 per cent canopy cover).
Photos: J Lyons-Reid.

Figure 32: Net forest change in Australia (using forest regrowth and deforestation data) 1973–2004



Source: AGO (2006)

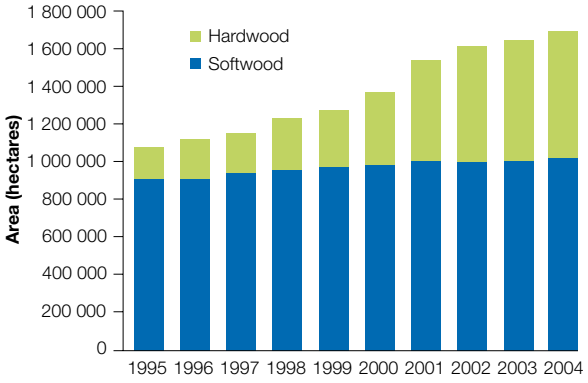
Figure 33: Area of deforestation and forest regrowth in Australia, by state and territory, 2001 to 2004

Source: AGO (2006)

Historically, almost all clearing in Australia has been for agricultural production. It was initially driven by a condition in many early leases to clear a specified number of hectares each year. Later came financial support from government agencies and new land clearing technologies developed by CSIRO. While community and government attitudes have changed, most clearing is still for agricultural production.

Clearing for commercial plantation forestry has also been significant. The plantation estate is still expanding—from 1.66 million hectares in 2003 to 1.72 million hectares in 2004 (Figure 34). Although this is only 2 per cent of the Australian continent, the issue with this activity is that it occurs in sites of high forest production value, which often have high biodiversity values as well. From this perspective, the trend towards establishing plantations on former agricultural land rather than on native forest land, especially over the last 11 years, can be seen as positive (Figure 35). In some areas, however, social dislocation and loss of previous agricultural heritage landscapes can accompany such developments when entire farming communities are replaced with a private plantation that is managed by one person.

Figure 34: Change in area of hardwood and softwood plantation 1995–2004

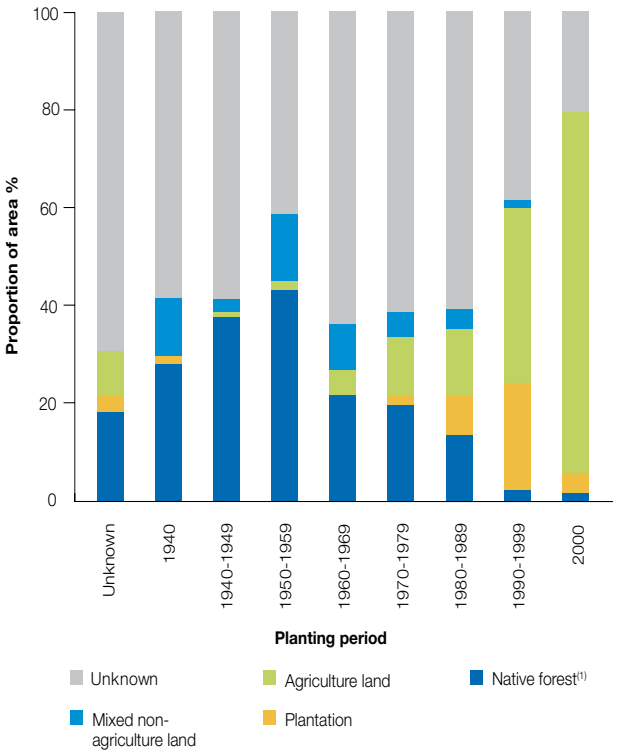


Source: National Forest Inventory (2005)

Urban clearing for housing and infrastructure continues in biologically rich habitats along the Australian coast; it is a consequence of the continued urbanisation of the Australian coastline. Clearing in these areas is of concern because it often occurs in already fragmented habitats, some of which are quite small in extent, and many of which were ice age species refugia and hence have high conservation value. In aggregate, urban areas occupy about 24 per cent of the coastal fringe between Hervey Bay (Queensland) and Queenscliffe (Victoria).

Land clearing is not the only cause of vegetation and habitat loss. Major habitat changes have occurred in both northern and southern Australia due to a range of pressures, including grazing and changed fire regimes (see 'Biodiversity' page 35). A 2005 analysis of grazing

Figure 35: Previous land use of commercial forestry plantations



Note: Data include industrial plantations only; (1) includes approximately 1 per cent of native grassland

Source: Wood et al (2001) and National Forest Inventory (2005)

pressure relative to biomass showed that 62 per cent of the continent consists of areas where biomass is low and is therefore at risk from any level of grazing intensity—the rangelands and areas of minimal use.

Although grazing animals have different impacts, the combined impact of all domestic and non-domestic herbivores is significant. Total grazing pressure is one of the leading causes of vegetation changes (especially to grasses) and soil erosion. Australia has an estimated 28.5 million cattle and 103.1 million sheep in 2005-06 (ABARE 2006). The number of cattle has increased by an estimated 0.6 million from 2001-02 to 2005-06, and sheep numbers have decreased by 3.1 million over the same period. There were major reductions in the national flock during the previous decade. Kangaroo numbers have decreased because of the drought. The situation with other grazing species is unknown.

8.2 Land condition

One legacy of changes in native vegetation is often a decline in soil quality. Changes to ecosystem structure and complexity, species composition, groundwater levels, soil salinity, rates of soil loss, soil acidity and levels of carbon and other nutrients in the soil are all significant problems in varying ways across Australia. Some of these are discussed below (but see also 'Biodiversity' page 35).

There are some areas, especially those with high-quality soils, where farming practices have improved fertility through the use of fertilisers or lime. In addition, minimal tillage techniques have improved soil organic matter levels, which in turn has improved the functionality of soils. Regardless, the issue of 'leaky landscapes' remains and much needs to be done to further improve the condition of Australian soils.

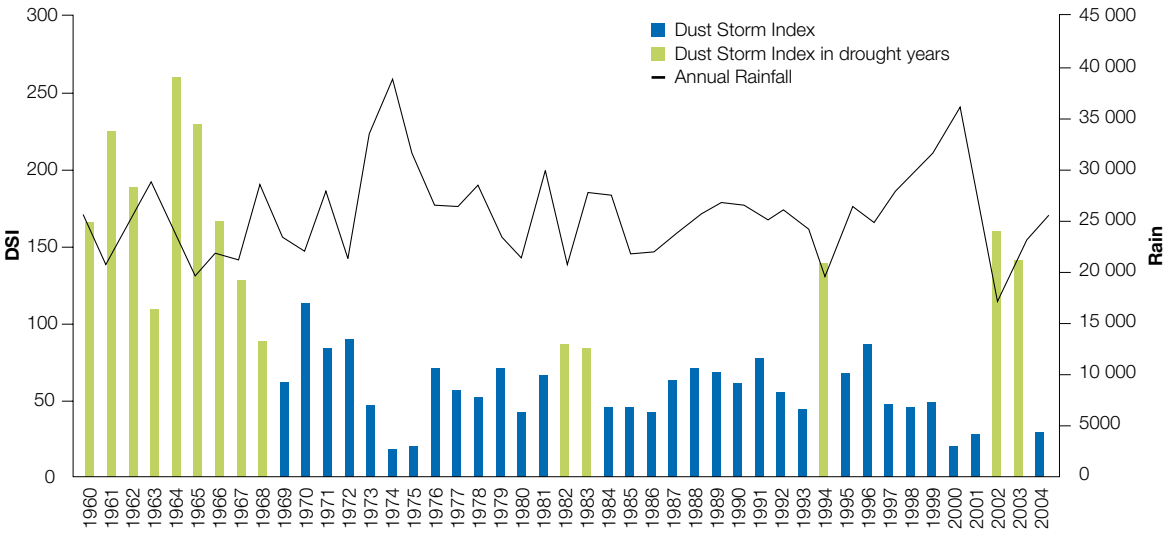
Soil loss and dust storms

Prior to European settlement, there was little bare soil in Australia apart from the sparsely vegetated arid regions. Australia's agricultural land uses and practices have caused an increase in erosion through vegetation clearing and total grazing pressure. The situation has been exacerbated by low rainfall and changes to fire regimes. The rate of erosion in pasture lands has doubled from the rate under natural conditions, and there has been a fivefold increase for improved pastures. On average, sheet wash erosion from hillslopes has accelerated to three times the natural rate (NLWRA 2001a). There has been no attempt to assess gully erosion at the national scale since 2001. This gap in environmental reporting is surprising because gully erosion is recognised to be one of the most significant sources of sediment to streams and can severely impact on river health.

Overall, the number and intensity of dust storms suggest that wind erosion in Australia has varied considerably since 2000 (Figure 36). Measurements of airborne dust (measured as a Dust Storm Index) show that 2002 and 2003 were the worst years since the nine-year run of high dust storm activity during the dry years of the 1960s. Interestingly, dust storm activity during the 1982–83 drought, which is widely remembered as 'the

Domestic livestock such as cattle contribute to total grazing pressure on fragile ecosystems. The resultant lack of vegetation, together with the effects of drought, can lead to dust storms. Top photo: Greening Australia.

Figure 36: Total annual Dust Storm Index in relation to total annual rainfall at 46 stations across Australia.



Note: Bars are DSI; lines are rainfall. DSI – Dust Storm Index
Source: McTainsh et al (2006)

worst drought', was not as nationally significant as would be expected. Indeed, there were big dust storms in the 1880s and the 1940s before monitoring even began.

Soil carbon

Soil organic matter levels, measured as the amount of soil carbon, are an index of soil health. Although it is likely that large amounts of soil carbon are exported each year—as crops and livestock products—the best long-term, nationally consistent estimates available are from modelling by the Australian Greenhouse Office. Soil carbon levels vary from one year to the next, but the models suggest that, as a result of clearing for agriculture, soil carbon has declined from slightly more than 675 million tonnes in 1990 to about 643 million tonnes in 2004.

Salinity

The area of land affected by salinity across Australia is difficult to estimate. The states and territories all have different definitions of 'salinity' and have mapped it at different times, and in some areas the data have been reviewed in the intervening period.

The most recent estimate from a survey of farmers is that about 2 million hectares on 20 000 farms across Australia showed some signs of salinity (ABS 2002). The NLWRA in 2001 estimated that a total of 2.4 million hectares were saline, of which 1.6 million hectares were in Western Australia, with a total of 5.4 million hectares predicted by models to be at risk of salinisation (NLWRA 2001d), although some interests challenge the predicted increases (Keogh 2005). Approximately 30 per cent of Western Australia's south-west is considered to be at risk of becoming saline by 2050. It has been suggested that the value of environmental assets should be considered alongside the area affected, so that large areas of low-value grazing land would not receive more attention than horticultural land, an environmentally significant wetland, or a town building (Pannell 2005).

In 2003–04, the NAP and the regional component of the NHT invested $33 million in actions that have a major focus on land salinity. The majority of these funds were disbursed in New South Wales, Victoria and South Australia, to be used primarily for on-ground activities. Their effectiveness is yet to be evaluated.

Soil acidity

Soil acidity is a serious concern across large areas of rural Australia, largely because of agricultural practices. After many years of acidification under legume-based pastures, such as clovers, and related cropping rotations, approximately 50 million hectares of Australia's agricultural land (around half the total area) have a surface soil pH value less than 5.5. At this level most commercial agricultural plants suffer reduced yields. The problem is easily remedied by applying lime (Hamblin 2001); however, while it may be good agricultural practice to do this, it is not financially viable for pasture-based industries. In contrast, lime application in cropping systems is a necessary and increasingly routine operation.

The NLWRA estimated in 2001 that, if current practices were to continue, the area of land with surface pH below 5.5 would double to over 90 million hectares in the next 10 years with a concomitant need for the use of lime. This raises one of many environmental conundrums: the manufacture of the amount of lime needed would produce CO_2 in significant amounts. In addition, the use of lime improves soil performance and reduces soil nutrient loading, but this leads to leaky landscapes and, possibly in the long term, soil carbon accumulation.

In 2003-04 the National Action Plan for Salinity and Water Quality and the regional component of the Natural Heritage Trust invested $33 million in activities that have a major focus on land restoration, such as saltbush plantations. Photo: J Baker, DEH.

8.3 Institutional pressures

A major pressure on Australia's land has been the slow recognition and acceptance of the fact that landscapes are used and valued for more than one thing at a time. Products that have a dollar value (such as crops, minerals or forestry products) have generally been given primacy over 'products', such as landscape function, biodiversity, carbon balancing, water quality or heritage, with a value that is difficult to measure. This has been the case for generations, but it nevertheless must change in the context of a wide range of macro-economic, competition and other generic policy settings that affect land management practices.

Agriculture, with the large area of land it uses, is the most obvious and dominant example. Many past and some present public policies and programmes contribute to landscape decline. These include the advocacy of land clearing and intensive grazing systems, certain forms of drought assistance, and land tenure arrangements, all of which promote or enable practices that impact adversely on the natural resource base.

While it is becoming more widely accepted that land management is the responsibility of all Australians, much policy is still targeted at single sectors and single issues. For example, environmental legislation tends to focus on one issue, such as vegetation cover or water or chemical use, leaving land managers to decipher and apply apparently unconnected regulatory requirements across a range of highly connected activities. Support, when it does come, has historically been transient, not integrated and costly, and has failed to fully exploit landholder motivations and capabilities. In this regard, governments need to support regulatory frameworks with education, training and compliance-monitoring efforts that address the interconnectedness of landscapes.

There is also a fear that mandating environmental practices or outcomes will constrain trade between countries, and thus may disadvantage Australia as a trading nation. Others subscribe to the alternative view that failure to sign up to mandatory environmental outcomes may jeopardise Australia's position as a trading nation.

The management of Australia's landscapes requires three things. Firstly, institutional arrangements are needed that recognise the multi-industry nature of most Australian farms. Secondly, support is needed for systemic and revolutionary innovations to improve landscape sustainability. Thirdly, incremental innovations directed towards the needs of existing operators in existing businesses must continue (Corrish 2005).

Coastal rehabilitation, Cambridge Coastcare, Western Australia. Photo: M Heller.

The paucity of relevant time series data sets has inhibited the development of more effective responses. Biophysical data are needed to assess the condition of the environment and the pressures acting on it. Such data are also needed to inform the beliefs and values governing the design and operation of the institutional arrangements that drive the pressures and inhibit the responses.

8.4 Institutional responses

Some positive initiatives are emerging. Natural resource management has become much better integrated into the thinking of land management agencies and farmers' organisations during the last five years, with many engaging professional staff to help them develop appropriate science and policy. It is likely that these developments will lead to improvements in land condition, provided that appropriate adjustments to farming as an economic pursuit can be achieved. One such adjustment that is already taking place is the recent push for the development of farming accreditation and environmental assurance systems.

There have been significant investments in natural resource management since 2000, at both the national and the state and territory levels. Within regions, the NAP and NHT programmes are driven by an integrated plan to improve natural resources on a regional scale. The plan was developed by natural resource

management entities and is supported by state and territory government. Like all evolving systems, this has attracted its share of criticism (Lane 2006).

Fifty-six NHT regions have been established and a natural resource management plan has been developed for each. In most cases, regions are defined based on catchments or bioregions and, where possible, are consistent with those established for the NAP.

Each region has at least one regional body formed to manage the region's natural resources. It is too early in the life of these regional plans to report on the results of their investments in improving the condition of their land and water (although for an early indication, see Green 2006), and there are some concerns about their longevity because most have no long-term funding.

Key points

- At the national level, the rate of vegetation clearing has decreased in recent years in many states. Nevertheless, declines in vegetation extent and condition, and further fragmenting of vegetated habitat in some areas and regions, are a cause for ongoing action and vigilance.
- Sheep and cattle grazing derives high economic value for Australia but, in doing so, continues to place heavy pressures on soils, vegetation, and terrestrial and wetland habitats, especially in sensitive areas.
- The ongoing decline in soil quality is of concern. Despite a lack of definitive data, it is clear that soil acidity, soil salinity, soil erosion and nutrient loss all remain a major threat to the long-term sustainability of Australia's agricultural environment. The actual extent of the current salinity problem across Australia is currently under review and re-analysis.
- The need to take a landscape-wide view of land and vegetation management is increasingly being recognised by governments, regional management groups and farmers. Tools that allow local on-ground actions to be integrated into broad-based landscape plans will become increasingly important over the next decade.
- The regional NAP and NHT programmes remain important in funding and guiding catchment- and bioregion-based planning and management actions. It is too early in the life of most of these regional plans to report on the value that is being derived from the extensive community and government investments in natural resources management.

9

Natural and cultural heritage

Australia's heritage—the landscape layered with places and associated objects—tells the story of who we are, our histories and our relationship to the environment. Heritage includes places with natural, Indigenous and historic values. It also includes objects, collections and intangible aspects such as community values, customs, languages, beliefs, traditions and festivals. Heritage forms part of Australia's cultural identity.

Generally, much of Australia's heritage is well protected. Some heritage places and values are under threat through a range of pressures, including environmental decline, shifts in land use, or social change (for example, demographic changes in inner city areas, rural towns and coastal areas), or a lack of understanding, skills or resources. The condition of many aspects of Australia's heritage is unknown. Knowledge and management of Indigenous cultural heritage are particularly limited, but there are some promising emerging approaches to integrating Indigenous cultural values and community participation into natural resource management programmes.

Since *SoE2001*, there have been significant legislative changes by the Australian, state and territory governments to improve systems for natural and cultural heritage identification and management. Most states and territories have revised their statutory or policy frameworks for historic heritage places since 2001. In addition, new national heritage legislation came into effect in 2004, establishing a National Heritage List and improving protection for the heritage values of Commonwealth-owned and managed properties. The changes to the EPBC Act to include heritage as part of the environment at the national level represent a shift in the scope and operation of heritage legislation.

Despite the high levels of activity in terms of statutory arrangements, and increasing levels of community interest in heritage, resourcing of heritage conservation and management has not increased to the same extent. Australian Government funding for heritage is now largely confined to places of national significance, and levels of state and territory funding are largely unchanged. Of particular concern is the ongoing, and large, discrepancy between natural and cultural heritage in the areas of resourcing and national policy (see 'Biodiversity' page 35).

9.1 Defining Australia's heritage

Reporting on the state of Australia's heritage is a particular challenge because heritage is selected, and the selections are often contested (Aplin 2002). In contrast, many other components of the environment, for example air or water, are not subject to this process of selection.

The community's understanding of heritage has continued to expand as people have come to realise that cultural and natural heritage are closely integrated. Heritage *is* still regarded as consisting of 'special places', but there is an emerging recognition by Indigenous and non-Indigenous Australians of intangible heritage and cultural landscapes, and of the importance of heritage as a part of people's locality and identity. It is encouraging that some states have introduced the concept of cultural landscapes as a heritage listing and protection device. The rise of community groups to protect their local area and the continuing involvement of National Trust organisations in defending the heritage values of suburban areas are evidence of the strength of community feeling.

People's understanding of heritage changes over time. A good example is the improving recognition of the importance of Indigenous languages in sustaining cultural heritage, which was a result of surveys for national state of the environment reporting completed in 2000 (McGonville and Thienberger 2001) and again

Budj Bim National Heritage Landscape was the first Indigenous place on the National Heritage List. It dates back thousands of years and bears evidence of a large, settled Aboriginal community systematically farming eels for food and trade in what is considered to be one of Australia's earliest and largest aquaculture ventures. Photos: top left – eel traps; bottom left, hut remains; right, eel smoking tree. Photos: J Baker, DEH.

in 2004 (AITSIS and FATSIL 2005). Another example is the shift in thinking observed in catchment management plans over the last 10 to 15 years (Johnston 2006). The shift has been from a narrow definition of natural resources towards a values-based and more integrated approach, particularly during the reporting period for *SoE2006*.

All of the environment is part of Australia's natural heritage, but the term has special meanings that include internationally recognised natural places, such as World Heritage sites and Ramsar wetlands (see 'Aquatic biodiversity' page 62). In addition, Australia's role as a mega-diverse, first-world continent is seen by many to make an important contribution to national heritage and to the world's natural heritage. Other parts of this report indicate how Australia is discharging these responsibilities. The increasing recognition of the landscape as the relevant unit for natural resource management is creating a framework in which better integration of natural and cultural heritage can be expected.

From a cultural heritage perspective, there is currently strong interest in recognising intangible heritage, gaining a better understanding of how Indigenous people value land and landscape, and involving communities in identifying strong and special associations with place. For natural heritage, an important challenge is to develop ways to assess aesthetic significance.

Tensions can arise in the recognition of heritage values. For example, reservation of public land to protect its natural heritage values often restricts traditional uses such as hunting, grazing of stock, and riding horses. While these uses may conflict with natural heritage conservation, the long associations between particular communities and these activities may be of cultural heritage significance. New approaches to this issue are starting to emerge, including as a recent example the revised management plan for Kosciuszko National Park (NSW National Parks and Wildlife Service 2006).

More than 1100 native plant species are found in Alpine National Park, Victoria's largest national park. Many of these are especially adapted to survive the severe winter climate. Twelve species are found nowhere else in the world. Photo: T Lerino, DEH.

9.2 Knowledge of heritage

Governments throughout Australia tend to use statutory registers to identify and manage heritage places and values. These registers are a useful way of monitoring Australia's knowledge of its own heritage, and because they appear to offer a definitive list of heritage places, they are easy to incorporate in environmental management planning. A disadvantage is that heritage registers will never be able to capture all heritage values and places. Problems include limitations in their scope and coverage.

At the national level:

- a total of 16 Australian properties are on the World Heritage List, two of which have been added since 2001. These are Purnululu National Park (Western Australia) and the first Australian property inscribed for its non-Indigenous cultural heritage values—the Royal Exhibition Building and Carlton Gardens (Victoria)
- a National Heritage List came into effect on 1 January 2004 as a result of amendments to the EPBC Act. As at 31 December 2005, 23 places were entered on the National Heritage List. Recent additions include the Melbourne Cricket Ground, South Australia's Parliament House and the Tree of Knowledge in Barcaldine, Queensland
- a Commonwealth Heritage List of places owned, managed or leased by the Australian Government is a new statutory list established by the amendments to the EPBC Act since *SoE2001*. Launched in July 2004, this list had 339 places entered as of 31 December 2005, 87 per cent of which are listed for their historic values. The remainder are places of natural or Indigenous significance
- there were few additions to the Register of the National Estate between 2001 and 2006; only 342 places were added because of the commencement of the new national heritage system
- since 2001, approximately 130 ships have been added to the Historic Shipwrecks Register, which is maintained cooperatively by the Australian, state and territory governments

The Melbourne Cricket Ground, entered the National Heritage List on 26 December 2005. Photo: M Munro, DEH.

The Royal Exhibition Building and Carlton Gardens in Melbourne was inscribed on the World Heritage List in July 2004. Photo: D Bishop, DEH.

The stern gun of the Liberty Ship, the SS Iron Knight which a Japanese submarine sank off the New South Wales coast in 1943. The sunken vessel was declared an historic shipwreck under the Historic Shipwrecks Act in August 2006. Photo: S Alhafith.

- a new Australian Government programme, *Distinctively Australian*, which was launched in December 2003, aims to identify, manage and promote Australia's national heritage places.

At the state and territory level, the number of historic places listed increased from 13 160 in 2000 to 14 148 in 2005. The state and territory listings of historic heritage places continue to grow at a slow but steady pace as thematic and regional surveys are completed. For example, South Australia has almost finished the comprehensive surveying that has been going on since 1981, and so is identifying fewer places to add each year. Cultural landscapes are beginning to be added to heritage registers, particularly in Victoria, South Australia and New South Wales. The number of listings in this category has increased slowly because the pressures from competing land uses require specialised management tools, which currently do not exist. Urban expansion, wind farm construction, marina development, rural subdivision and new rural land uses all compete with heritage values as new landscapes develop.

In some states and territories, significant objects associated with registered historic buildings can be included in statutory registers. Amendments made in 2004 to the Victorian Heritage Act allow heritage objects to be included in the Victorian Heritage Register in their own right. As of April 2006, three objects of cultural significance to Victoria have been included in the Victorian Heritage Register, including the Ballarat Reform League Charter (held by the Public Records Office), the 8-Hour Day Trade Union Banners (held by the Museum of Victoria), and the Eureka Flag (held by the Ballarat Fine Art Gallery).

At the local government level, a survey of local councils in 2005 found that their statutory lists collectively cover more than 76 000 individual historic places and 1770 historic heritage areas. Not all local councils have a statutory list of historic heritage places. The survey found, for example, that more than 90 per cent of responding councils in New South Wales and Victoria had a statutory heritage list, but in Queensland fewer than half of the responding councils had a list of this kind (Productivity Commission 2006). Local government listing of heritage places is a good indicator of Australia's recognition of heritage because it reflects community appreciation of and activity in identifying and protecting heritage places. The provisions for

The Sydney Opera House was nominated for World Heritage listing in January 2006. Photo: Department of Foreign Affairs and Trade.

statutory identification and protection of natural heritage, Indigenous heritage and heritage objects at the local level are less consistent than at other levels of government. Examples of local government heritage initiatives are given elsewhere (Sullivan 2006).

The community is interested in connecting with and experiencing Australia's heritage, especially through people's stories that can bring places and the past to life. A recent survey revealed that 93 per cent of the community see heritage as forming part of Australia's identity (Allen Consulting Group 2005a). In 2004 alone, some 5.2 million Australians did at least one activity that was related to Australia's heritage. About 27 per cent of international tourists visited heritage places, with the Sydney Opera House, The Rocks, the Blue Mountains and the Great Barrier Reef being among the top ten destinations (Allen Consulting Group 2005a).

Knowledge of Indigenous heritage is particularly limited outside Indigenous communities, especially in relation to the recognition of the full range of cultural values (including intangible and contemporary aspects). A growing body of work now documents Indigenous intangible heritage, and current guidelines (Commonwealth of Australia 2004) encourage its recognition in natural resource planning. Additional Indigenous heritage places are being recorded through new reporting arrangements in Queensland, through surveys in all states associated with environmental impact assessments, and through surveys in south-eastern Australia after the 2003 bushfires (Gill et al 2004). The Department of Defence has recently begun systematic surveys of Indigenous places in association with local Indigenous people on the large areas of land it controls.

Indigenous languages are an intrinsic part of Indigenous cultural heritage. Fewer people are speaking Indigenous languages than at the time of *SoE2001*. Of an original number of over 250 known Indigenous languages, about 145 are still spoken in Australia, but about 110 are in the severely and critically endangered categories, which means that they are spoken only by small groups of people who are mostly older than 40 years of age (AIATSIS and FATSIL 2005).

Only a limited amount of work has been done in Australia on traditions and practices of non-Indigenous peoples in relation to heritage values and places, although there is increasing public debate about the heritage significance of cultural traditions. For example, after the 2003 bushfires in south-eastern Australia, there were surveys of historic high-country huts to assess their social significance and to improve future management (Godden Mackay Logan 2005, Graeme Butler and Associates 2005).

9.3 Condition of Australia's heritage

Despite this expansive and increasing knowledge of heritage, there are few systematic efforts to monitor the condition of Australia's heritage, and no agreed measure for assessing the 'condition' of either natural heritage places or Indigenous heritage. Progress has been made in summarising the natural values and environmental condition of natural heritage places by the Victorian, New South Wales and Australian government agencies, through State of the Parks reporting processes. Aside from the periodic reporting requirements of the World Heritage Convention, there has not been much monitoring of impacts to assess the condition of the iconic World Heritage places, nor have there been surveys to evaluate whether visitors learnt about the heritage values of these places, despite the identification of the need for these surveys in *SoE2001*. The State of the Tasmanian Wilderness World Heritage Area Report is an exception.

The results of two national surveys assessing the condition of a sample of historic heritage places carried out in 2000 and 2004 show that there were minor changes in the condition and integrity of the surveyed historic heritage places over that period (Table 19). The practicability of assessing these places remains a challenge for reporting on historic heritage condition.

Table 19: Changes in integrity and condition of historic heritage places, 2000–04

Integrity and condition categories	2000		2004	
	Number of places	%	Number of places	%
High integrity	510	41.9	477	37.9
Medium integrity	603	49.5	690	54.9
Low integrity	105	8.6	90	7.2
Good condition	538	44.2	561	44.6
Fair condition	611	50.2	608	48.4
Poor condition	69	5.7	88	7.0
Total number surveyed	**1218**		**1257**	

Source: Pearson and Marshall (2006)

Heritage Victoria undertook a survey of owners about the condition of a proportion of properties on the Victorian Heritage Register in 2002–03. Its self-selecting sample led to subjective interpretations of condition, but positive outcomes have resulted, with more detailed information about the places, and good relations with their owners and managers.

While the subjective method of the survey is acknowledged, the results suggest that as many as '30 per cent of heritage places could be considered at risk either now or in the future if no remediation works are done'. The survey also found that 64 per cent of funds for conservation work were from private sources, and 22 per cent were from the funding programmes of the Heritage Council.

Source: Heritage Council of Victoria, Annual Report 2002-03, pages 26-27, Melbourne.

9.4 Managing for heritage values

Although all states and territories now have historic heritage listing in their statutory planning systems, state and territory legislation is not uniform in including all aspects of heritage in one statute. There are also gaps in the coverage of certain types of heritage, such as historical archaeology and cultural landscapes. As noted above, a significant disadvantage of heritage lists and registers is that they will never be able to capture all heritage values and places.

There has been much legislative change since 2001 at all levels of government in Australia. At the national level, the changes to the EPBC Act have created a more coherent, three-tier heritage system. The changes fulfil a long-identified need for Australian Government agencies to identify and conserve their significant heritage places. The changes also mark a move away from a National Estate model (which provided some level of protection to places at a national, state or local level), but without the mechanisms and joint arrangements needed to implement the legislation. There are also still some inconsistent legislative provisions throughout the states and territories. As a result, many types of heritage places, especially natural heritage places, might be unprotected at the state, territory and local levels.

Opportunities to develop a cross-agency or whole-of-government approach to integrating heritage values and environmental management have recently been demonstrated. In Victoria, for example, the Department of Sustainability and Environment, and Aboriginal Affairs Victoria have developed a Strategy for Aboriginal Managed Lands in Victoria with support from the state and Australian governments, to create a framework for Indigenous land and water management across Indigenous lands (SAMLIV 2003).

Most states and territories have reviewed or updated their historic heritage legislation since *SoE2001*. Legislation for natural heritage has changed less, although some states made changes to national park and protected areas legislation to transfer state forests to park reservations. The trend to separate legislation for nature conservation and for parks and reserve management continued, with the *National Parks and Reserve Management Act 2002* in Tasmania.

Government responses to conserve cultural heritage (both Indigenous and historic) over the reporting period included:

- the Australian Government's Cultural Heritage Projects Programme; from 2000–01 to 2005, this programme disbursed $10.6 million, which included $1 million for Indigenous projects. In 2005, this programme was replaced by the National Heritage Investment Initiative, which will disburse $10.5 million over three years to provide financial incentives for conservation of places of national significance
- the community-based programmes for Indigenous cultural heritage management, for which Victoria has allocated $2.1 million annually

Successful restoration projects undertaken through the Australian Government's Cultural Heritage Project Programme – clockwise from top left: Bustard Head Lightstation, Qld; North Bundaleer Homestead, SA; the first school at Angurugu, NT; Cascades Convict Site, Tas.

- the handing back to Indigenous ownership of two long-contested islands in Bass Strait by the Tasmanian government in March 2005
- the doubling of funds to $2 million, by Western Australia, to heritage agencies for Indigenous places.

The level of investment in heritage conservation goes well beyond the funds delivered by government programmes and includes a substantial level of private investment and volunteer support.

Data in relation to levels of private investment were not readily available to report, although the Productivity Commission (2006b) has reported some information.

Responses to conserve natural heritage over the reporting period included:

- an increase in the area of protected land in Australia to 81 million hectares over 7720 protected area reserves in 2004, an increase of more than 21 million hectares since 1997
- the establishment in 2000 of a new category of Indigenous Protected Areas – at March 2005 there were 19 Indigenous Protected Areas, totalling 13.2 million hectares, ranging from Ngaanyatjarra (Western Australia) covering 9.8 million hectares to Chappell and Badger Islands (Tasmania) covering 1270 hectares. These lands now account for 18 per cent of Australia's protected areas

Mount Chappell Island, off the north-east coast of Tasmania, is one of the most recent of Australia's 19 Indigenous Protected Areas. Photo: D Boyd, DEH.

- an increase in Indigenous involvement in natural resource management groups since *SoE2001*.

There has also been an increase in private conservation reserves (see Table 20 and Parker and Fitzhardinge 2006).

The establishment of the National Collections Council during the reporting period and the development of significance assessment methods for collections are important response measures. Repatriation of Indigenous cultural property has continued during the reporting period—from overseas to Australia; and from national institutions to Traditional Owners—although there are a number of complexities associated with repatriations being successfully concluded (Truscott 2006).

Local government also plays an important role in the recognition and protection of heritage values and places, and in local environmental management. In Victoria, for example, it is estimated that more than 100 000 cultural heritage places (primarily historic) are protected through local planning schemes, compared to around 2000 on the state government register (Allen Consulting Group 2005a, 2005b). Local government can also act through statutory controls, advice and incentives, direct land and property management, community development, and environmental education.

The Productivity Commission has reported that heritage identification and protection at the local level vary considerably. The Inquiry into the Conservation of Australia's Historic Heritage pointed to inconsistencies in approach, expertise and resources at the local level (Productivity Commission 2006). Submissions made by local councils and local government associations commented on the increasing responsibilities for heritage identification and management, and the frequent lack of adequate resources. On the other hand, there is also a growing trend for councils to actively use their heritage as a basis for social, economic and tourism benefits, particularly in rural Australia (Sullivan 2006).

Tourism supports public enjoyment and understanding of heritage, but it is also a pressure on heritage that must be managed carefully to retain vital heritage values and minimise impacts such as congestion, fluctuating demands on local infrastructure and resources, displacement of local services, and physical impacts on, and degradation of, properties and landscapes (Productivity Commission 2006). For local governments, especially in depressed areas, the economic value and tourism potential of authentically conserved places are well recognised (Sullivan 2006). The Environment Protection and Heritage Council has agreed to develop policy to better integrate heritage into tourism, and has produced papers that outline key opportunities and actions as input to the Australian Government's tourism industry planning (NTHT 2003).

Verandah restoration on Sully's Building in Broken Hill. The building in 1911, 1992 and c2004. Photo: Broken Hill City Council.

In recent years, many popular natural heritage areas have benefited from the installation of paths and boardwalks through fragile environments such as wetlands or Aboriginal middens. Conservation works have improved the condition of some historic heritage properties, such as the restoration of the original 1859 Cardwell Post Office in North Queensland and the reinstatement of verandahs on many buildings in Broken Hill and Mudgee. This work is being done through heritage trails programmes or programmes for the conservation of buildings in the main streets of country towns. Repairs to dry-stone walls are enhancing their condition in the landscape at Kiama and in the Melton Shire in Victoria. The condition of Indigenous heritage places has improved as a result of increased involvement of Indigenous people in site management, but there are huge variations in resources, intergenerational involvement and available skills.

Improvements and revisions to Indigenous heritage legislation have allowed for a more integrated concept of heritage in some cases. Indigenous knowledge is increasingly accepted as a valid and necessary information input to biodiversity management, alongside scientific information (Brown and Creaser et al 2006). In Queensland, New South Wales and Western Australia, for example, legislative changes have improved the recognition of contemporary (social) significance and strengthened the roles of local and regional Indigenous bodies. Increasingly, Indigenous rights to continue practices and to manage their traditional areas are being recognised.

Indigenous land use agreements have gradually gained in popularity, increasing from six agreements in 2000 to 135 agreements in September 2004. Eighty of these were in Queensland, and 55 per cent included cultural heritage provisions. These voluntary agreements between one or more native title groups and other parties—such as miners, pastoralists and governments—about the management of an area of land or water include detailed arrangements about financial payments, employment and training, Indigenous involvement in environmental management, and cultural heritage provisions that exceed legislative requirements (O'Faircheallaigh 2004).

However, the survey of Indigenous organisations conducted for *SoE2006* (Open Mind Research Group 2006) reported that community involvement, particularly with Indigenous Elders and outside agencies, is often insufficient to ensure the protection of heritage. Consultation with communities often does not happen at all, or happens too late. Funding is, in many cases, inadequate and uncertain for legal representation to fight inappropriate developments, for long-term planning of heritage maintenance and

for cultural centres and computer databases. There are also widespread and complex problems created by overlapping native title claims and consequent lack of clarity about which group legitimately speaks for heritage in a particular area.

In 2002, the former Australian Heritage Commission produced a guide to assist planners and developers in consulting with Indigenous communities. Titled *Ask First: A guide to respecting Indigenous heritage places and values*, the guide has been widely distributed.

9.5 Building capacity

There is a shortage of qualified and experienced people who can identify and manage Australia's heritage. Despite its responsibilities in environmental management, local government, particularly in remote and rural areas, has had the greatest difficulty. In this light, the provision of historic heritage advisors by state and local government in most states is a positive move that has resulted in cost-effective delivery of heritage conservation outcomes to local councils, property owners and managers.

The number of Indigenous people employed by governments in heritage conservation activities—partly a measure of use of skills and expertise—has shown little increase from the very small numbers reported in 2001, with the exception of Aboriginal Affairs Victoria.

The continuing decline in practical conservation skills in both the trades and the professions and the lack of training programmes (particularly in rural areas) are of concern because heritage values will be recognised and effectively managed only if properly trained staff are available to do so. It requires capacity building through training, through formal, multidisciplinary courses at universities, and through volunteers.

The use of volunteers has increased in recent years, but opportunities for volunteer participation in cultural heritage are still more limited than in environmental management. The greatest increase has been in museum and historic house management in cataloguing collections and guiding visitors to heritage places. This trend is also observed in physical conservation works such as those undertaken by Hands on Heritage teams (Heritage Council Victoria 2004).

Key points

- Community interest in Australia's heritage has continued to grow. There is increased appreciation of the relationships between natural and cultural values, and increased recognition of intangible cultural heritage and cultural landscapes.
- There is some capacity to measure the condition and trends of Australia's historic heritage, and minor changes have been identified since 2001. The lack of data remains a chronic problem for reporting on Australia's heritage. Inter-governmental cooperation and resourcing are urgently needed to enable regular measurement of the condition of natural or Indigenous heritage, or of heritage objects.
- Knowledge and management of Indigenous cultural heritage are limited. The number of 'endangered' Indigenous languages has increased since 2001. Some promising approaches are emerging to integrate Indigenous cultural values and community participation into natural resource management programmes.
- New national heritage legislation came into effect in 2004, establishing a National Heritage List and improved protection for the heritage values of Commonwealth-owned and managed properties. Most states and territories have also revised the statutory frameworks for historic heritage since 2001. In terms of both resourcing and the development of policies and programmes, there is a continuing disparity between government provisions for natural and cultural heritage.
- The growth in the role of local government has continued (particularly for historic heritage), although the outcomes and the capacity of councils to take on this role are patchy across Australia.

10

The Australian Antarctic Territory

The Australian Antarctic Territory is 'that part of the territory in the Antarctic seas that comprises all the islands and territories, other than Adélie Land, situated south of the 60th degree south latitude and lying between the 160th degree east longitude and the 45th degree east longitude'. This includes Australia's sub-Antarctic Territory of Heard Island and the McDonald Islands, and Macquarie Island.

Icebergs near Davis Station. Photo: K Rollings, Australian Government Antarctic Division.

Antarctica and the surrounding Southern Ocean are important to Australia because of their historic associations, influence on regional and global climate processes, and contribution to biodiversity, as well as the economic value of the Southern Ocean fisheries. Data from long-term monitoring provide a platform for better understanding the functioning of global systems, and predicting climate and other atmospheric trends. Antarctica and its surrounding oceans are dominated and shaped by the global climate.

Five main areas of local human activity have the potential to impact adversely on the Antarctic environment, although the intensity of impact is low. These are the conduct of scientific research, logistic support operations, tourism, construction of buildings and infrastructure, and commercial harvesting of living resources. Australia has nine permanent scientific stations; an extremely low density when considered in the context of the almost 6 million square kilometres of the Australian Antarctic Territory (AAT). Nevertheless, there is a local environmental impact of the day-to-day operation of the stations. Tourist visits to the Australian sub-Antarctic islands and the AAT have not increased, in contrast with an increase in visitors of 10 per cent a year to other parts of Antarctica outside Australia's jurisdiction.

A variety of marine and terrestrial species and ecosystems are found in the territory, and their vulnerability to human pressures is not fully known. Some species have been exploited over the last 200 years, and a number of those have not yet recovered.

There are also difficult practical challenges in the long-term conservation of historic sites and objects. Despite these difficulties, scientists need to find ways of conducting research and sharing and aggregating data that will give a better overall picture of the state of the Antarctic environment.

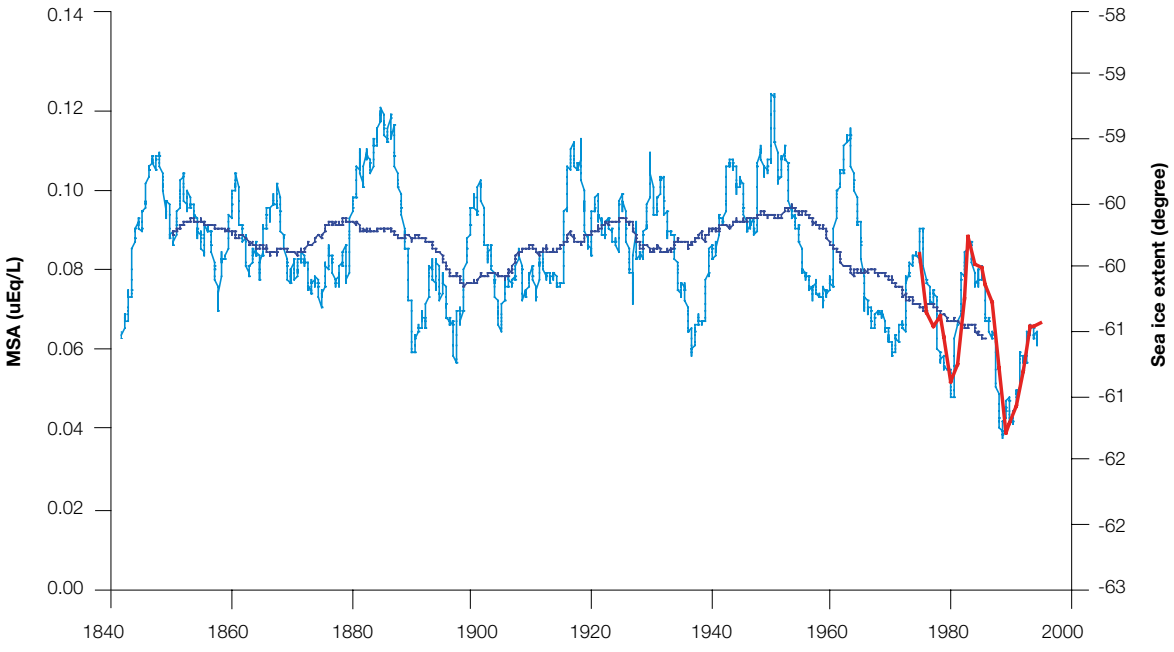
10.1 Climate, atmosphere and the ice

Two salient features of Antarctica are its remoteness from human settlements and the dominance of ice. These characteristics give Antarctica, as well as many other isolated areas, a valuable role in monitoring global climate change.

Ultraviolet radiation values at Australian stations are elevated, relative to expectations for sites at comparable northerly latitudes, and this is directly attributable, to stratospheric ozone depletion (the 'ozone hole'). However, ozone loss over Antarctica appears to have stabilised during the 1990s (see 'Atmosphere' page 19).

In the territory, temperatures have neither increased nor decreased, which is consistent with records from across most of Antarctica. The area of sea ice has varied from year to year (Parkinson 2004), with the only significant increase since the 1970s being in the Ross Sea area. The total volume of continental ice has actually increased, but not consistently. The ice volume in east Antarctica has increased while large parts of west Antarctica have experienced decreases. In contrast, the Antarctic Peninsula (which is not part of the Australian

Figure 37: Change in the extent of sea ice, 1850–2000



Note: Methanesulphonic Acid (MSA) records from an ice core from Law Dome in East Antarctica and inferred northern most latitude extent of winter sea ice (SIE) off East Antarctica between 80°E and 140°E. The MSA record covers the period 1841 to 1995. The light blue line is the three-year running mean MSA measurement and the purple line is the 20-year running average. The red line is the maximum winter sea ice extent measured by passive microwave between 1973 and 1994 (Jacka unpublished data).

Source: Curran et al (2003)

Glaciologists in the field on a climate change programme, Brown Glacier, Heard Island. Photo: S Goldsworthy, Australian Government Antarctic Division.

Antarctic Territory) appears to have become warmer, and accordingly has a smaller area of sea ice and a lower volume of ice overall (Zwally et al 2002).

A recent study of proxies for sea ice extent derived from analysis of coastal ice cores, indicate however, that there may have been consistent decline in sea ice extent around East Antarctica in the last 50 years, despite large annual variations (Curran et al 2003, Figure 37). Similar changes in sea ice extent have been inferred also from analyses of historical whaling records (de la Mare 1997) and penguin populations (Wilson et al 2001, Barbraud and Weimerskirch 2001).

Sub-Antarctic glaciers tell a more consistent story. Heard Island's glaciers have retreated in extent since 1947, and the total land area covered by glaciers has decreased from 288 square kilometres in 1947 to 253 square kilometres in 2000 (Ruddell 2006). Thirty-five square kilometres of new terrain, including several large lagoons, have been exposed by ice retreat. This represents nearly 10 per cent of the total area of the island. Areas of vegetation are increasing as a consequence.

Some signals are starting to emerge from the study of Australia's Antarctic Territory. Recent surveys of the Southern Ocean off East Antarctica have revealed that the deep ocean water is markedly fresher and less dense than expected and has become progressively so over the last 30 years. The exact causes of these changes are not yet resolved, but the results indicate that the Southern Ocean is changing much more rapidly than previously considered likely (Rintoul, in press).

These changes are significant. Variations in the winter extent of sea ice have a key role in global oceanic circulation, they are thought to have effects on the productivity of algal growth under the ice and the reproduction of Antarctic Krill (*Euphausia superba*), a small, highly abundant crustacean which is a major component of the Antarctic food chain.

10.2 Marine ecosystems

The ecosystems of the Southern Ocean have been subjected to human pressure for more than 200 years. Historically, sealing, whaling and fishing have had significant effects on populations of marine species. Climate change is an additional pressure that may affect the rates of upwelling of nutrients and the melting rate of the pack ice in spring. Increases in levels of carbon dioxide may increase the acidity of the ocean and affect the health and normal function of marine organisms.

Seal populations have not yet recovered from the eighteenth century exploitation, but there is some evidence of improvement. Land-breeding seals have increased from the low levels at Heard, McDonald and Macquarie Islands in the nineteenth century, but the status and trends of ice-breeding seals are far less certain due to difficulties in surveying. Whales were severely over-harvested in the middle of the twentieth century and although some species, such as the humpback whale (*Megaptera novaeangliae*) are recovering, the status of others, such as blue whales (*Balaenoptera musculus*), is uncertain. The minke whale (*Balaenoptera acutorotrata*) has been harvested less than other species but there is still debate over its numbers.

Fish have been harvested commercially in the Southern Ocean since the 1960s and many stocks have never recovered from the initial phase of overexploitation (see page 52). Current finfish fisheries have suffered greatly from illegal, unregulated and unreported fishing.

The breeding population of King Penguins on Heard Island is thought to be doubling every five years. Photo: S Goldsworthy, Australian Government Antarctic Division.

While fisheries in the Antarctic region today are focused on Patagonian Toothfish (*Dissostichus eleginoides*), Mackerel Icefish (*Champsocephalus gunnari*) and Antarctic Krill (*Euphausia superba*), the focus may shift to other species in the future. The position of Antarctic Krill in many critical food webs suggests that their increased utilisation could be a significant issue and so, despite their relative abundance, catch limits will need to take this into account.

Antarctic waters are highly productive, with a complex plankton-driven food chain. The zooplankton composition changed in the year 2000, accompanied by a substantial change to the composition of smaller zooplankton. It is too early yet to determine if this is a permanent regime shift or part of a cyclic pattern.

Many of the flighted seabird colonies are in remote areas and their status is largely unknown. Of the large number of flighted seabirds in the Antarctic, Heard Island cormorants and Macquarie Island shags are listed as vulnerable. Of the seabirds that breed at Macquarie Island, albatrosses and petrels are probably the most threatened birds worldwide. The Wandering Albatross (*Diomedea exulans*) is the most critical, with less than 15 breeding pairs. The numbers of Southern Giant Petrels (*Macronectes giganteus*) at Macquarie Island have doubled since the 1970s and appear to be stable. More generally, Giant Petrel (*Macronectes* species) populations appear to have decreased since their discovery some 40 years ago (Woehler et al 2003).

Due to the overlap of commercial fishing areas with foraging ranges of seabirds, the two interact directly. It is believed to be here that most of the mortality among seabirds occurs, particularly various species of albatrosses and medium-sized petrels, as birds drown either by swallowing baited hooks or by being entangled in fishing gear.

Of the 17 species of penguin world-wide, seven are known to breed regularly in, or occasionally use, the ice-free areas of the Australian Antarctic Territory, including the islands, and forage in the oceans surrounding these areas. Estimates of populations from about three decades of research show trends for two species at three sites. Gentoo Penguin (*Pygoscelis papua*) breeding populations at Heard Island were estimated at 10 000 pairs in 1950 and 16 600 pairs in 1987. Breeding populations of King Penguins (*Aptenodytes patagonicus*) are difficult to estimate, but at Heard Island, data collected between 1963 and 1993 suggest that the population is doubling every five years (Woehler 2006). At Macquarie Island, the population has recovered rapidly from harvesting in the last century and is thought to be still expanding. Royal Penguins (*Eudyptes schlegeli*) have been estimated at approximately 850 000 breeding pairs at Macquarie Island, but no information on trends is available.

10.3 Antarctic and sub-Antarctic cultural heritage

The Australian Antarctic Territory contains some important heritage sites. Located on the Antarctic continent and on Heard and Macquarie Islands in the sub-Antarctic, they are:

- sites associated with the sealing industry and shipwrecks on Heard and Macquarie Islands
- sites associated with early (1911–14) scientific endeavour and exploration, notably Mawson's Huts (added to the National Heritage List in 2005) and Cape Denison
- evidence of the British Australian New Zealand Antarctic Research Expeditions of Douglas Mawson between 1929 and 1931
- sites associated with the Australian National Antarctic Research Expeditions (ANARE) and agencies of other nations that established research stations after World War II (Atlas Cove at Heard Island, Buckles Bay at Macquarie Island, and Mawson, Davis and Wilkes stations on the Antarctic continent).

In addition to these sites, a lot of material related to cultural heritage in Antarctica is held in collections in and outside of Australia.

The condition of Antarctica's heritage sites varies. For example, the ANARE station at Atlas Cove on Heard

Island is mostly dismantled, while elements of the site associated with Mawson's Huts are relatively well preserved. Some structures are maintained as part of permanently occupied research stations, like Mawson. Monitoring and regular maintenance are essential for the continued survival of standing structures, including standing ruins, such as the transit and absolute magnetic huts at the site associated with Mawson's Huts.

Many of the portable artefacts associated with these sites are slowly deteriorating and have only a limited lifespan due to the high cost of conservation of artefacts in situ. Because their significance could be compromised by removal, managed decay has been adopted as a strategy for moveable heritage objects at most sites. There is debate about this approach and it should be monitored to ensure that as little cultural significance as possible is lost. There is limited time to preserve and document these sites because of deterioration, and an appropriate policy response will be needed in the near future. The changes to the EPBC Act impose new requirements on the Australian Government Antarctic Division in its management of this historic heritage.

Collections of material associated with sub-Antarctic and Antarctic cultural heritage are housed in a number of museums and other institutions in Australia, including private collections. Some material is held in overseas collections, for example, the Canterbury Museum in Christchurch, New Zealand houses the magnetometer used for Mawson's 1911–14 expedition.

Historic places and objects, such as Mawson's Hut, are subject to significant pressures from climatic conditions, and a conservation policy of 'managed decay'. Photos: D Killick, Mawson's Huts Foundation.

These collections are generally not at risk, although conservation assessments are required on some. As much of the material held privately was collected opportunistically, it is impossible to assess quantity or condition. An unknown quantity of material was also collected by early expeditioners and is now owned by descendants.

Key points

- Antarctica plays a key role in regulating the world's weather, climate and oceanic processes. Antarctica serves as an early warning system for the rest of the world.
- No significant changes are reported in overall Antarctic sea ice extent since the 1970s, although significant regional changes are evident, particularly around the western Antarctic Peninsula.
- The ecosystems of the Southern Ocean have been subjected to considerable human-induced pressure for over 200 years. Sealing, whaling and fishing have had significant effects on the stocks of marine species, and while some are recovering, illegal and unregulated fishing is impacting other species.
- Tourist visits to Australian sub-Antarctic islands and the Australian Antarctic Territory are a small proportion of Antarctic tourism, with 100 tourists on four vessels visiting the site of Mawson's Huts since 2002–03. However, the environment and heritage of Antarctica are very vulnerable to visitor pressure, and close monitoring is warranted.
- Historic heritage places and objects are subject to significant pressures from climatic conditions. The current levels of conservation activity—including the policy of managed decay—could lead to the loss of significant material.
- Changes in the Antarctic environment are inevitable due to global factors such as climate change and atmospheric and oceanic pollutants.

11

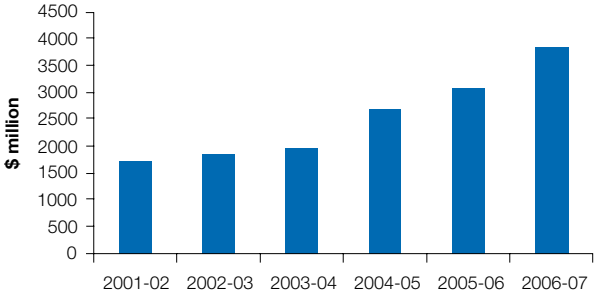
Environmental governance

The role of institutions in Australia's environmental governance is a crucial one, but it receives little public analysis. Governments at all levels, public and private sector organisations, volunteer organisations, and regional boards and committees have all been mentioned throughout this report for their contribution to addressing environmental issues. The increase in spending on the environment by the Australian Government justifies an examination of these issues in a national report (Figure 38).

This is the first time that the national state of the environment report has examined the role of local government in environmental management. Particular attention is paid in this section to the shift of responsibility for natural resource and heritage management to a regional or municipal scale, and the increasing role of local government. The success of the EPBC Act in contributing to Australia's environmental protection is also assessed.

Roles played by the business sector, the philanthropic sector, and conservation organisations in Australia have evolved over time and have intersected with the established conservation organisations that provided environmental activism and political energy to conservation during the past two decades. These new developments have been made possible because of an increasingly urbanised population in Australia which is receptive to newly articulated values for conservation management. Australia's environment and heritage management will be enhanced by building partnerships among all levels of government and the community.

Figure 38: Estimated Australian Government environment-related expenditure, from budgets 2001–07



Source: ABS (2004g, 2004h)

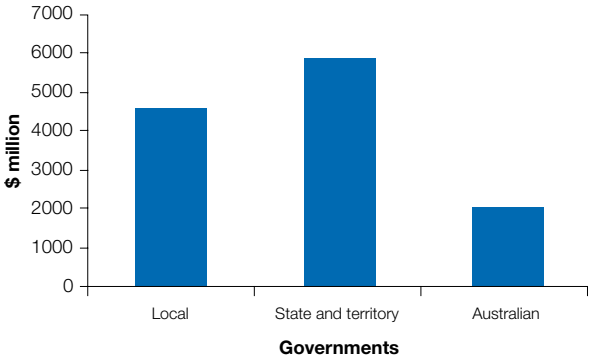
The Brooklyn Wildlife Sanctuary (right) was purchased by the Australian Wildlife Conservancy with support from the Australian Government. The property is now formally protected under Queensland legislation through a conservation agreement signed by the owners of Brooklyn, the Australian Wildlife Conservancy and the Queensland Government. Photo: R Waldendorf, Australian Wildlife Conservancy.

11.1 Role of local government

Local government is the most diverse of Australia's three levels of government. It is an important player in the area of environment and heritage management in Australia, and has responsibility for protecting the environment, planning future landscapes, providing infrastructure, managing natural resources, and conserving or managing cultural heritage through a variety of mechanisms. Many local governments work in areas beyond statutory requirements, such as Local Agenda 21 and Cities for Climate Protection.

In 2002–03, local government collectively accounted for about $4.1 billion of spending on environmental management (Figure 39), which is about 32 per cent of the total environmental expenditure by the three levels of government across Australia. Most of this expenditure is for solid waste management and wastewater treatment. The income is funded primarily from rates (some 83 per cent of total local government funding in 2000–01), which can be inflexible in some of the poorer and smaller rural local government areas. The most extreme and poorly resourced examples are Indigenous councils.

Figure 39: Government expenditure on the environment, 2002-03

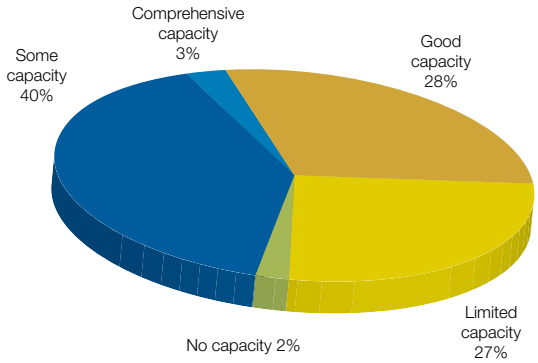


Source: Wild River (2006)

The mechanics of local environmental governance are complex. Local government has many environmental and heritage roles and responsibilities, and carries these out according to legislation or policies or programmes (Sullivan 2006). This can create tensions because councils and the staff they hire consider themselves to be creatures and servants of the local areas. Instead of being driven by any specific statute, local governments use state and territory laws as toolkits to fix local problems, rather than as the instruction manuals intended by state governments.

This gap between the expectation and the reality is only one of a raft of pressures faced by local governments. Others include local government amalgamations, enhanced general roles and responsibilities, devolution, unfunded mandates and cost shifting, an increasing need to work with regional organisations, and population pressures from 'sea change' and 'tree change' movements (see 'Human settlements' page 7). For some, the pressure is sufficient to limit what they can do. A 2005 survey found that only 31 per cent of councils considered that they had a comprehensive or good capacity to take up natural resource management initiatives; 29 per cent said they had either a limited capacity or none (Figure 40). An April 2004 report, (Making Heritage Happen), found that on the basis of partial evidence offered at the local level, it is possible that current trends could lead to the loss by 2024 of 10-15 per cent of the heritage places that are extant in 2004 (National Incentives Task Force 2004). More recently, a Productivity Commission survey of the role of local governments in the conservation of historic heritage showed that around half of responding councils provided assistance (ranging from 15 per cent of councils in Queensland to more than 80 per cent in New South Wales) with free heritage advisory services and grants being the main forms of assistance (Productivity Commission 2006b).

Figure 40: Local government capacity for natural resource management planning



Source: Shepherd (2005)

Local governments in the Northern Territory and Queensland face these problems and more. Many govern largely Indigenous communities, and play an important role in helping to manage the cultural heritage of their local populations. A total of 93 Indigenous local councils have been established in the Northern Territory (as at October 2005) and, overall, 650 of the 815 elected members are Indigenous people.

The increasing need to work with regional organisations is a challenge for local governments. One reason is that various organisations have different boundaries, depending on their needs, and they rarely coincide with each other or with local government boundaries. The challenge is greater for local governments that straddle regional borders because they can find themselves having to work with more than a dozen regional organisations. This can create barriers to effective long-term local-regional partnerships. The problems also include both the transience of regional bodies and their frequently unclear roles in relation to local government (Dore and Woodhill 1999; Bellamy et al 2003).

11.2 Indigenous participation in environmental management

In recent times, the percentage of Indigenous owned and managed land has been slowly rising. In addition, there is a growing recognition and appreciation of Indigenous knowledge of the land and the sea and their biodiversity.

For *SoE2006*, the Australia State of the Environment Committee has sought information on Indigenous involvement in environment and heritage management in a novel way. Case studies were sought to illustrate a diversity of approaches to land and sea management. They were not intended to be fully representative of the ways Indigenous people are involved in environmental and heritage management.

The case studies illustrate the complexities of the ongoing engagement of Indigenous people with management of their country. For example, the South Australian Aboriginal Lands Indigenous Natural Resource Management Group is the first to be managed by a board of entirely Indigenous people. In this area of South Australia, Indigenous people's knowledge of the land and its biodiversity is being captured with technology, such as the use of handheld computers to record species sightings. This knowledge is being connected directly to scientific information and to policy for improving the condition of the land resources and the ability of the Indigenous people to gain economic benefit from their land.

The Lake Victoria Advisory Committee, with financial and resource support from the Murray-Darling Basin Commission, has advanced the protection of Indigenous burial sites on the shores of an operational water storage area on the Murray River. The process has not always been straightforward and has required goodwill and understanding from all participants to achieve both cultural heritage protection and water management results.

The deep commitment of the Waignayu people in the Daly River region in the Northern Territory to their river and the surrounding catchment is affirmed directly by one of the participants in the Community Reference Group. She tells of the struggle to understand the technical language and to incorporate Indigenous knowledge into the Daly River Catchment Land Use Plan. Her experience illustrates the very different ways people have of seeing the world. The group's report is now public and a new round of consultation is underway.

Rock art in the newly proclaimed Anindilyakwa Indigenous Protected Area on Groote Eylandt. Photo: S Strike.

11.3 Role of the philanthropic sector in environmental stewardship

The role of the philanthropic sector and conservation organisations in environmental stewardship has changed over the last 5 to 10 years. During this time approximately 400 perpetual philanthropic bodies have emerged in response to environmental and other issues. An annual total of $5.7 billion from individuals and $3.3 billion from businesses is donated in all fields of the Australian community including the environment, arts and culture, health, Indigenous people, medical research, community development, social justice and education (FaCS 2005). Australia-wide, the results have been more on-ground environmental work in partnership with second-generation environmental organisations.

The environment is a relatively new concern for philanthropic organisations, as they have traditionally supported social issues such as medicine, education, and welfare. A notable exception is the Ian Potter Foundation, which signed up other philanthropic organisations, and the government to implement the Potter Farmland Plan. Its values and mission later emerged through components of the subsequent Landcare movement.

Australians have become more interested in philanthropy for two main reasons. The first is wealth. More than 200 000 Australians have liquid assets of over a million dollars and several thousand Australians have a net worth of more than $20 million. The second reason is that changes in taxation policy encourage the establishment of foundations and provide incentives for giving.

The Australian Wildlife Conservancy's Mornington Wildlife sanctuary in north-west Western Australia is the nation's largest non-government protected area. Photo: Ecopix, Australian Wildlife Conservancy.

Voluntarism is a major component of this new investment, much of which is directed to communities in which this new wealth has been gained and in which volunteers live. This trend is clearly seen in an increase of 16 per cent in volunteer hours since 2000, reaching 836 million hours per year in 2004. The environment is a major recipient (FaCS 2005). The National Trust of Australia alone manages a volunteer workforce of 7000 people.

An important role for philanthropic organisations is to help bridge the gap between public expectation and environmental reality. For example, urban dwellers have started to form strong views on how Australia's environment should be used and protected (Witt et al 2006), but the diminishing rural sector and local governments are the ones who live in and manage that same environment. Economic, social, intellectual, environmental and other forms of 'capital' have been transferred over time from the countryside to urban centres (Beeton et al in prep.) and there is little indication that a reverse flow has seriously begun, although the 'tree change' and 'sea change' movement of people to regional centres may stimulate the reversal.

An Australian Wildlife Conservancy wildlife ecologist releases a mala in the Scotia Wildlife Sanctuary, western New South Wales. Photo: Freeswimmers, Australian Wildlife Conservancy.

The formal conservation estate will always be too small to meet the goals for conservation sought by the urban population. In response, several task-focused environmental organisations have brought in private sector investment to support a parallel, private conservation estate, which is receptive to activities that are not easily accommodated in the traditional national

Table 20: Areas of land managed by some conservation organisations as at May 2006

Organisation	Area of land (hectares)	No of reserves	Status
Australian Bush Heritage Fund	372 156	19	Own and manage
Australian Wildlife Conservancy	917 000	14 locations	Own and manage
Australian Landscape Trust	340 000		Research, restore and manage
Trust for Nature	35 000 hectares of natural bush	56 bush properties in Victoria	Own and manage

Source: Data from ABHF, AWC, Trust for Nature and ALT (May 2006)

park model. As with philanthropy more generally, voluntarism plays a key role in enabling investment in this alternative conservation model. Two of these organisations are the Australian Bush Heritage Fund and the Australian Landscape Trust. There are, as well, a number of other active organisations with similar characteristics, including the Australian Wildlife Conservancy.

These organisations tend to rely on contributions from significant donors and on grants from governments and other donors, which provide opportunities for a variety of investments in land and biodiversity conservation. Many of them are learning organisations —evolving programmes and testing ideas within a private sector culture that recognises the 'deal making' approach of business culture and the give and take that is essential between donors, volunteers of services, and the management of the organisations. The organisations attempt to involve local communities in their operations, and seek to extend their influence beyond reserve boundaries. Because of the significant private investment that is required for their operations, performance milestones and accountability are high priorities.

11.4 Role of the business sector in environmental stewardship

The business sector has played an increasingly important role in environmental stewardship during the last few decades as it has become more aware of environmental issues and their consequences. While progress in environmental stewardship is variable across business and industry sectors and across large and small sized enterprises, some managers realise that environmental stewardship contributes to profitability by decreasing costs and providing a competitive advantage. Many businesses have incorporated the principles of sustainability into their operations to increase their competitiveness and decrease their costs. The benefit most often perceived by companies from producing a sustainability report is reputation enhancement (CAER et al 2004).

In Western Australia, for example, many environmental issues are addressed by industry and mining groups at a standard that exceeds that of public sector groups. In some instances, the corporate knowledge base is higher in the private sector than in the public sector. In the longer term, this will cause problems in environmental reporting unless the environmental reporting systems are adapted to include these sectors.

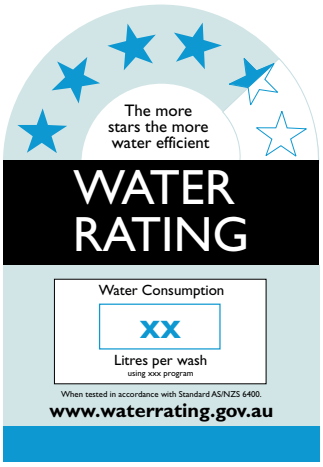
Key roles for the business sector are as follows:

- Ensuring protection—historically this has generally related to compliance with emission controls on industrial facilities as a result of government regulations. This role has expanded with community expectations, seeing the introduction of (for example) paints and glues with reduced toxicity and lower levels of volatile organic compounds. Other examples include voluntary agreements to reduce packaging and plastic bag use, reducing or offsetting greenhouse gas emissions, cultural heritage conservation and including biodiversity considerations before clearing.

Some industries are reducing the environmental impacts of their operations through innovative technological and management solutions. Photo: J Baker, DEH.

Significant progress has been made on recycling some forms of urban waste such as timber beams. Much more progress is required on difficult recycling such as water, buildings, and organics. Photos: Salvage <http://www.salvage.com.au>.

- Disclosing information—an increasing number of publicly listed companies in the private sector are beginning to release public sustainability reports, in addition to their traditional annual reports to shareholders. These exceed the statutory obligations to report details of breaches of environmental laws and licences (*Corporations Act 2001*). Companies in the manufacturing and mining sector are the most likely to produce sustainability reports, but the overall reporting rate of the top 100 publicly listed companies is still low by international standards (KPMG 2005). Product labelling schemes, such as water efficiency labelling on fittings and appliances (WELS 2005), are being implemented with strong support from industry.



- Supporting research and innovation—the business sector continues to play a role, along with universities and research organisations, in contributing to sustainability through research and innovation. The collaborative nature of innovative research efforts in Australia is demonstrated, for example, by the winner of the 2005 Prime Minister's Prize for Science, who collaborated with the mining industry to improve the transport of mineral slurries. This project substantially decreased the amount of liquid waste produced, and saved the industry millions of dollars.
- Implementing financial sector initiatives—the potential to promote sustainability is being increasingly recognised by the financial sector in Australia through initiatives such as socially responsible managed investment funds, socially responsible superannuation funds, individual portfolios invested using socially responsible criteria, lending policies that take account of environmental and social issues, green loans that reward sustainable choices, and green bank accounts.

The business sector plays a role in most areas of environmental protection and heritage conservation. A growing number of Australian businesses are coming to recognise the opportunities as well as the challenges in achieving sustainability.

11.5 Critical issues in regional natural resource management

The way Australians are managing natural resources is changing. The traditional 'top-down' model of centralised natural resource management that relies on governments for planning and implementation is no longer in favour. It is being replaced with 'civic regionalism', an approach that relies on participation by citizens through regional citizen boards and statutory committees in their own regions. There are many examples of this shift at the national level (under the NHT) and in the states and territories (particularly South Australia, New South Wales and Queensland). A similar shift in governance is also underway in some aspects of social and economic policy.

As a new approach, civic regionalism is being pursued in different ways in different parts of Australia. There are three reasons given for adopting this model of natural resource management:

1. management needs to be scaled-down to the regional level so that management efforts can be focused on a single geographic unit
2. government has failed to secure environmental sustainability (or, at least, government action has proven ineffectual) and so alternative ways of managing need to be found
3. citizen participation should be central to the development and implementation of natural resource management strategies. Instead of being treated as stakeholders, the citizens of any given region should be directly engaged in policy development and implementation.

These reasons do not always hold in Australian natural resource management. Reviews of the NHT (for example, Lowe 2004) have highlighted the ephemeral character of groups receiving financial assistance, the short-term benefits of their work, the lack of scientific information combined with local knowledge as it is replaced with citizens' views and experiences, and the lack of a wider strategic direction in their work. There are also questions around the potential parochialism of regional management, the capacity of new regional groups to acquire the skills and knowledge needed to address urgent environmental problems in time, and the ability of regional boards to be truly democratic rather than entrenching the power of local elites (see 'Future directions' page 101).

Civic regionalism will not necessarily enhance the integration of policy and management. The allocation, use and management of natural resources is a complex, multi-jurisdictional domain in which many non-government players (from market and civil society) jostle with diverse government players to determine

After

Before

Rehabilitation of a salt scalded gully in South Australia's Bremer Hills – part of the significant expansion of natural resource management investment over the past five years. Photos: B Munday.

environmental policy at different scales. Furthermore, because many of the causes of environmental problems are extra-regional, regional bodies will be required to coordinate the activities of more powerful government and market forces operating at broader scales.

11.6 The EPBC Act

The EPBC Act has made important contributions to environmental protection and sustainable development in Australia during its first five years of operation. Despite concerns by some community sectors about the inability of the EPBC Act to deal with cumulative environmental impacts, there is evidence that it has achieved its principal objective: the protection of matters of national environmental significance. It appears to be achieving at least some good, though mixed, results in terms of environmental outcomes beyond what would otherwise be achieved under state and territory laws.

The substantial amendments to the EPBC Act in 2003, to incorporate Australia's new national heritage system, came into effect in 2004 (see 'Natural and cultural heritage' page 77). Because these changes are new, it is too early to evaluate their outcomes. This will be an important consideration for the *Australia State of the Environment Report 2011*.

The statistics reveal the EPBC Act has been well-used during its first five years of operation. A total of 1591 referrals were received covering a very broad range of sectors; 1528 controlled action decisions were made; 354 referrals were determined to be controlled actions; and 212 referrals were determined to be not-controlled actions if taken in a particular manner. Determinations under the Act for which the environmental outcome is regarded as 'good' (McGrath 2006) have included Iluka Resources Mineral Sands Mine, Western Australia; the Koolyanobbing Iron Ore Expansion Project, Western Australia; and the Coral Sea Pearls Ltd aquaculture development, Queensland. In addition, some non-government organisations have used the expanded standing provisions in the EPBC Act to achieve good environmental outcomes.

An important aspect of the operation of the EPBC Act has been a comprehensive assessment of fishery operations and management, including the effects of fishery operations on non-target species and ecosystems. By the end of 2005, 113 fisheries had been assessed under the Act, and one result has been a move towards ecosystem-based management in Commonwealth-managed fisheries. Also significant is the role of the Act in the process it has established for assessing the conservation status of species and ecological communities. The listing process is scientifically

rigorous and, despite concerns in some sectors about delays in listing, several extensive ecological communities have been listed, including some on private land.

In attempting to assess the effectiveness of the EPBC Act there is a danger of oversimplifying both the nature of problems the Act seeks to address and the nature of the solutions it offers. Environmental policy is a truly messy thing (Bartlett 1994), and merely ascribing 'success' or 'failure' on narrowly defined grounds is rarely useful for improving policy-making in spite of the messiness. The EPBC Act deals with what has been described in other contexts as 'patently tangled, wicked complex policy problems' (Bartlett 1994) for which there are no simple solutions.

Public accountability

The EPBC Act has improved public accountability and access to information about proposed developments. Public access to information on the EPBC Act web site contributes to improved scrutiny of major developments that are likely to have impacts on matters of national environmental significance at the environmental impact stage. In addition, the reasons for each listing recommendation are publicly listed on the threatened species web site of the Department of the Environment and Heritage.

It is difficult to quantify what has been achieved 'on the ground' by the EPBC Act but there are indications that it is achieving some positive results. Two important test cases were the Greentree Case and the Flying Fox Case (McGrath 2006). In the latter example, the Australian Government Minister for the Environment and Heritage refused approval of the operation of the electric grid to kill Spectacled Flying Foxes (*Pteropus conspicillatus*), which stopped a major source of mortality that was severely impacting on the species. Without the EPBC Act, an action to halt the operation of the grids would have faced a great hurdle under Queensland law for lack of standing (although the state laws have since been amended to bring them in line with the widened criteria for standing provided in the EPBC Act). In response to this case, the Queensland Government has announced that it would no longer issue permits for the operation of electric grids, thereby effectively outlawing their operation. This represents a major contribution to protecting a threatened species and the World Heritage values of the Wet Tropics World Heritage Area to which the species contributes.

Despite the positive outcomes of these examples, the 'on the ground' results of the Act should not be overstated. State and territory laws and local government planning schemes continue to provide the bulk of environmental regulation in the Australian environmental legal system. The Act is only one component, albeit an important one, of an overall system responding to many strong pressures on the environment. Over the last four years, six of the eight Australian states and territories have collaborated in the listing of threatened species and the alignment of those efforts with ecological communities, but more needs to be done (DEH 2006c).

Flow-on effects

The Act was ground-breaking in imposing a new layer of Commonwealth decision-making and requiring higher levels of integrity and rigour in environmental impact assessment than were required under previous state, territory or Commonwealth laws. These requirements have a great practical significance for development assessment nationally, and they are also directly influencing state and territory assessment processes. In Queensland, for example, the desire to accredit state environmental impact assessment processes in a bilateral agreement under the Act has led directly to major legislative improvements in development assessment laws for the state. Western Australia also amended its laws to achieve accreditation of a bilateral agreement under the Act.

12

Future directions

The 2006 Australian State of the Environment Committee makes the following suggestions to the Australian Government, Parliament and people. These are based on the insights the Committee has gained from the discussions held in preparing *SoE2006*.

The 2001 Committee identified six key issues fundamental to the sustainability of Australia's environment, and its economic and social interests. These issues were:

- research and monitoring
- the protection of natural and cultural heritage
- barriers to implementing environmental sustainability
- adaptive management
- data and information management
- widespread adoption of sustainability in Australian society.

In addition, *SoE2001* pointed firmly to the need to integrate environmental, economic and social policy in the future.

While there has been considerable progress on a number of these issues since 2001, the 2006 Australian State of the Environment Committee believes that the issues identified in 2001 require continuing attention and investment and so they are integrated into the advice that the 2006 Australian State of the Environment Committee offers as to the future directions for Australia.

Measuring environmental progress

In preparing this report, the Committee used 263 indicators selected from the original 500 environmental indicators proposed in 1999. They were chosen on the basis of measurability and usefulness of information. There are good national data for 37 per cent of these, some data for 51 per cent and no data for 12 per cent. Land, biodiversity, coasts and oceans, inland waters, and natural and cultural heritage are each more than 50 per cent data deficient.

It is the emphatic opinion of the 2006 Australian State of the Environment Committee that the future role of a national state of the environment committee should be to provide data interpretation and commentary, using accessible, up-to-date, relevant national data. The year 2006 must be the last state of the environment report in which the Committee initiates the process of indicator and data selection. Environmental data should be continuously updated and made publicly available on the web. This will require strategic responses that are tailored to national, state and territory, and regional needs and that are sufficiently understood and accepted to be sustained.

The Committee believes that, in cooperation with the Department of the Environment and Heritage, the Department of Agriculture, Fisheries and Forestry, the Australian Bureau of Statistics, the National Land and Water Resources Audit, and many other Commonwealth and state and territory instrumentalities, it has laid the basis for Australia to adopt an enduring environmental reporting system that has the potential to track changes in environmental pressures, conditions and responses. The nation needs such a system, the environment deserves it, and policy development and evaluation cannot occur without it.

This is a critical national need. The system must be well designed and based on datasets that are collected in a nationally consistent way over a long period of time. This requires agreement on a consolidated list of important datasets, appropriate synchronicity of reporting between jurisdictions and in data collection, and agreement from data custodians to commit to data collection, aggregation and management protocols.

The need is particularly pressing because environmental systems do not respond to intervention in the same way as the economic and social systems that Australians are more accustomed to managing. Only by this action will Australians be able to identify and assess changes in the environment—whether resulting from interventions or natural causes—as well as the return on investments made, and hence be able to improve environmental decision-making processes.

The Committee is concerned that the perpetuation of current data gaps could lead to an uncoordinated response. This would not be in the interest of any jurisdiction.

Adaptation is crucial to survival

As this report and its supporting commentaries have demonstrated, Australians have altered the environment in major ways.

The Committee recognises that large-scale changes, such as natural and human-induced climate variability, have the potential to mask many other changes in condition that result from human pressure or from Australia's responses. It is neither necessary nor appropriate to wait for this conundrum to be resolved because the changes to environmental management and the development of adaptability suggested in this report are desirable of themselves, irrespective of the complexity of the interactions.

Effective adaptive management of Australia's environment requires an improved capacity to collect, synthesise and interpret key information and the consideration of any single change in the context of broader environmental change. There is a need for rigorous assessments of the performance of market-based and stewardship approaches to managing biodiversity objectives along with evaluation of other options.

Similarly, Australia's responses to other environmental problems must be addressed through urgent action. In a number of cases, the strategies have been developed to begin restoring environmental quality, but Australia's systems of government have impeded implementation, and the required monitoring, evaluation and reporting that good management requires. The key elements needed are clarity of purpose, commitment to implementation, appropriate accountability and monitoring of progress. All are essential to effect change. All are possible. All are within the technical and financial capability of the nation.

Regulation and incentives

SoE2001 pointed out that appropriate regulation works when dealing with common property resources and situations where market failure occurs. For example, there have been significant recent environmental benefits from regulating engine performance characteristics and fuel types, and from air pollution controls on heavy industry.

Governments have a continuing role in environmental stewardship through appropriate environmental investment, governance and regulation at the appropriate scale of intervention and evaluation. In Australia's multi-level system of government this is especially challenging; however, the considerable progress noted in this report should give reasons for renewed efforts to better coordinate these activities. The 2006 Australian State of the Environment Committee supports systems that encourage stewardship by accreditation, certification and, where appropriate, markets for environmental services.

It is appropriate that the changes to regulatory regimes (such as the EPBC Act) that have recently been established, be reviewed. Such an outcomes-based approach to regulation and incentives will facilitate change for the common good. Change is inevitably repercussive, and consequently, economic, social and environmental tests need to be applied when regulation is considered as a solution to an environmental problem. Alternative options to regulation should always be considered and tested in any adaptive framework.

As a first step towards improving institutional arrangements all parties need to recognise and accept the diverse role of landscapes. This will involve the rethinking of much existing environmental legislation, of the support provided to land managers to improve their management practices, and of the support provided for research and innovation. It will also require a reform in governance to move away from short-term and sectoral management towards a more systematic, integrated and planned approach to monitoring and managing almost every environmental sector covered in this report. The private sector has the potential to make a valuable contribution, including information, knowledge and wisdom. Environmental governance arrangements should support rather than impede good environmental management.

There is a tendency for local-scale decisions in the planning and management of most environmental issues to promote the complexity of regulations and fragmentation of ecosystems. Part of the governance reforms must include nationally coordinated, ongoing monitoring and assessment of the ecological, social and economic condition so that this can be avoided.

Maintaining and building a capability to manage

For Australia's innovative approach to environmental management to work, it is critical that scientific understanding of environmental issues be translated into effective action and made available in a cost-effective fashion. This means that national investment in the development and deployment of environmental technologies (such as better urban systems, water management, water and land restoration and recycling) will require increasing emphasis in proportion to investment in environmental science. The need for technological innovation was recognised in 'Backing Australia's Ability'[1], but more progress has been made on science and less on commercially useful technologies that improve environmental management and position Australia as a world leader in this field.

The success of future generations and environmental progress will depend on better technologies, knowledge, skills and investment strategies. *SoE2001* identified a shortage of skills and knowledge in interpreting data and in some core science areas. These problems remain and are of ongoing concern. One very important issue that continues to get worse is a national decline in capacity in biological taxonomy (Mather 2006). The situation in this field has become critical.

Sharing responsibility

National stewardship of the environment implies that there can be shared responsibilities by all Australians in relation to the environment. It seems evident that rural and regional Australia cannot single-handedly address all of Australia's environmental problems, because the required investment is well beyond the capability of the rural economy. National capability is being built at the scale of the whole landscape. This involves multiple land tenures of both public and private land, and integration of conservation and development. It has created a regional delivery system that places enormous demands on regional groups and local government. Building capacity in the regional and rural communities is critical to address the issues raised in *SoE2006*.

In this context, knowledge has become perhaps the most important factor in determining the standard of living. It is more important than land, tools or labour. Today's most technologically-advanced economies are truly knowledge based. For environmental progress, rural and regional communities need knowledge-building interventions in the provision of leadership. All communities, whether rural or urban, need to become learning communities dedicated to all the knowledge areas that determine long-term sustainability. Achieving this must be a national priority.

Corporations have increasingly adopted environmental standards beyond compliance, and they have made valuable philanthropic contributions to natural and cultural heritage conservation, bringing more than a million hectares under management. Both of these trends should be encouraged by governments. On the other hand, the Committee does not consider the tendency of some Australian corporations to export adverse impacts to offshore developments in less regulated countries, to constitute responsible stewardship.

Stewardship by Indigenous Australians is of increasing importance, and governments have a lot more to do to build the capacity of Indigenous communities. The very poor health and employment prospects of many Indigenous Australians significantly affect their ability to care for the land and to teach other Australians about their traditional methods of care, although this is routinely expected of them. This is especially the case in remote areas, many of which do not meet minimally acceptable standards for human settlements. It also limits their ability to use government programmes to develop businesses and to actively manage their lands.

Ethics and the future

The 2006 Australian State of the Environment Committee recognises that the environment is important in its own right. It is also practically important for a mix of food, fibre and other environmental services. If this is the position accepted by most Australians, there are some important consequences:

- The unit for environmental management of land is at the property or the appropriate government land management unit. The evaluation of success will often be at a large scale—for example, the catchment or ecological population. This means that when property owners manage for agreed outcomes they will collectively contribute to environmental outcomes on a broader landscape scale.
- It must be recognised that environmental services are valued by all and so must be paid for by all. Consumers must bear a fairer share of the costs. It cannot be a free service provided by landholders any more than any other form of essential national capital can be paid for by the small number of people who are intimately involved with it. Markets may then work in a way that improves environmental outcomes.

Governments have a role of improving environmental education in schools and the community so that better-informed national decisions can be made on these critical issues (Tilbury 2006).

[1] 'Backing Australia's Ability' is an Australian Government initiative to invest in innovation, science and technology.

Australians must also recognise the necessity to manage for the needs of future generations. Because Australia's landscapes and climate are so variable, and so little is known, perhaps the best option is to make decisions now that will allow future generations the flexibility to make their own. It is likely that they will have better technologies, knowledge, skills and investment strategies for environmental management and restoration. The critical proviso is that they still have the raw materials to achieve the environment that they desire.

Improving Australia's environment

Increasing pressure on the environment can be expected from continuing population and economic growth, and from continued urban development. These pressures will continue to increase unless there is some decoupling of growth from non-sustainable consumption of resources, particularly energy, land, water and other products dependent on limited natural resources (such as forestry and fisheries). Wastes also need to be reduced. This requires an appropriate mixture of improved public awareness, incentives, price signals that incorporate at least some of the environmental costs, improved recycling, renewal (such as forests), regulation, and investment in technologies with the potential to reduce environmental impacts. Sound urban planning and development, that takes account of environmental costs, would be another step in the right direction.

Strategies targeting threats can maximise conservation return. Modest investment can lead to significant recovery of threatened species and ecosystems in northern and central Australia. In nearly half of Australia, however, there are significant constraints to recovery due to the level of landscape change, resources, and regional and community capacity. Consequently, conservation strategies need to be integrated with other natural resource management considerations as part of a regional delivery framework.

So far, many responses to environmental decline have been reactive. Innovation is required in policy, management, science and technology; and new solutions must be found and applied in the form of new land and water use patterns that are sustainable, financially viable and acceptable to the community. In some regions, particularly those subjected to intense development for urbanisation or agriculture, major programmes of ecosystem restoration are required. Because prevention is more cost effective, anticipatory policies are required that focus on stemming ecosystem and species decline.

The state of the environment reporting process is intended to be a national stocktake of environmental progress. Australia has made considerable progress in creating a reporting process and integrating it into policy development. However, in order to capitalise on the enormous national investments that have been made, further improvements to monitoring, reporting and response systems are required. This is the final word for *Australia State of the Environment 2006*.

Appendix 1

The Committee and their terms of reference

2006 Australian State of the Environment Committee

Associate Professor Bob Beeton (chair), School of Natural and Rural Systems Management, University of Queensland

Ms Kristal Buckley, consultant and Vice-President of the International Council on Monuments and Sites

Professor Gary Jones, Chief Executive Officer e-Water CRC

Ms Denise Morgan, Senior Town Planning Consultant, HASSELL

Professor Russell Reichelt, Managing Director of the Reef and Rainforest Research Centre

Mr Dennis Trewin, Australian Statistician and head of the Australian Bureau of Statistics

Mr Geoff Gorrie, chair National Land and Water Resources Audit Advisory Council (observer from 7 October 2005)

Mr Mark Hyman (ex-officio) Assistant Secretary, Environment Protection Branch, Department of the Environment and Heritage (until 27 October 2005)

Mr Sean Sullivan (ex-officio) Assistant Secretary, Environment Research and Information Branch, Department of the Environment and Heritage (since 28 October 2005)

Ms Jenny Boshier (ex-officio) Director, Environment and Sustainability Reporting Section, Department of the Environment and Heritage

Terms of reference for the Committee

- Oversee the preparation of the *SoE2006* report to ensure its independence, credibility and quality of work
- Determine the findings of the report based on the information collected for each of the SoE themes and strategic issues
- Assist the Minister for the Environment and Heritage, on request, in the initial promotion of the *SoE2006* findings
- Advise the Minister of progress with the preparation of the report from time to time

Reviewers of the *SoE2006* report

Dr Robin Batterham, Office of the Chief Technologist, Rio Tinto, Melbourne, Victoria

Mr Michael Kennedy, Campaign Director, Humane Society International, Avalon New South Wales

Professor Michael Keniger, Deputy Vice-Chancellor (Academic), University of Queensland, St Lucia, Queensland

Professor Helene Marsh, Dean of Postgraduate Studies, Graduate Research School, James Cook University, Townville, Queensland

Dr Alan F Reid AM, consultant, Adelaide, South Australia

Dr Sharon Sullivan AO, Heritage consultant Nymboida, New South Wales

Ms Fiona Wain, Chief Executive Officer, Environment Business Australia, Kingston, Australian Capital Territory

Dr John Williams, John Williams Scientific Services Pty Ltd, Australian Capital Territory

Secretariat

Environment and Sustainability Reporting Section, SoE team

Ms Jenny Boshier, Director

Ms Frankie Seymour

Dr Tharman Saverimuttu

Ms Leigh West

Mr Gary Whatman

Appendix 2

List of commentaries and papers supporting *SoE2006*

Theme commentaries

Beer T, Borgas M, Bouma W, Fraser P, Holper P and Torok S 2006, 'Atmosphere', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/atmosphere/index.html>.

Cork S, Sattler P and Alexandra J 2006, 'Biodiversity', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/biodiversity/index.html>.

Gleeson T and Dalley A 2006, 'Land', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/land/index.html>.

Harris G 2006, 'Inland waters', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/water/index.html>.

Lazer E 2006, 'Antarctic and sub-Antarctic cultural heritage', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/antarctic-heritage/index.html>.

Lennon JL 2006, 'Natural and cultural heritage', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/heritage/index.html>.

Newton PW 2006, 'Human settlements', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/settlements/index.html>.

The Australian National Committee on Antarctic Research 2006, 'Australian Antarctic Territory, Territory of Heard Island and McDonald Islands, and observations on Macquarie Island Tasmania', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/antarctic/index.html>.

Ward TJ and Butler A 2006, 'Coasts and oceans', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/coasts/index.html>.

Integrative commentaries

Brown R and Creaser P (eds), Kevins S, Lennon J and Liddy M 2006, Indigenous involvement in environmental and heritage management case studies prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/indigenous/index.html>.

Department of the Environment and Heritage 2006, 'Progress in accessing environmental data and information', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/data/index.html>.

Greene D 2006, 'The role of the private sector in environmental stewardship', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/private/index.html>.

Johnston C 2006, 'An integrated approach to environment and heritage issues', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/heritage/index.html>.

Lane M 2006, 'Critical issues in regional natural resource management', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/nrm-issues/index.html>.

McKeon G 2006, 'Living in a variable climate', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/climate/index.html>.

Parker P and Fitzhardinge G 2006, 'Changing the delivery of environmental stewardship in Australia', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/philanthropic/index.html>.

Smith T and Doherty M 2006, 'The suburbanisation of coastal Australia', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/coastal/index.html>.

Whelan R, Kanowski K, Gill M and Andersen A 2006, 'Living in a land of fire', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/fire/index.html>.

Wild River S 2006, 'The role of local government in environmental and heritage management', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/local-government/index.html>.

Current or emerging issues

Australian Bureau of Statistics 2006, 'What do Australians think about protecting the environment?', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/peoples-views/index.html>.

Beeton RJS 2006, 'Society's forms of capital: a framework for renewing our thinking', paper prepared for the 2006 Australian State of the Environment Committee, Department of the the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/capitals/index.html>.

Birtley M 2006, 'The Collections Council of Australia', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/collections/index.html>.

Buxton M 2006, 'Urban form and urban efficiency', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/urban-form/index.html>.

Cribb J 2006, 'The Wentworth Group and the great water debate', paper for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/water-debate/index.html>.

Cribb J 2006, 'The Great Green Debate: urban myths, risks and alternative opinions', paper for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/urban-myths/index.html>.

Cutbush G 2006, 'Incentives for natural and cultural heritage conservation', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/incentives/index.html>.

Department of the Environment and Heritage 2006, 'Environmental indicators for reporting', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/indicators/index.html>.

Department of the Environment and Heritage 2006, 'SoE in an international context', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/soe-international/index.html>.

Department of the Environment and Heritage 2006, 'Species information partnerships: sharing knowledge on threatened species', paper prepared for the 2006 State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/species-listing/index.html>.

Department of the Environment and Heritage 2006, 'Coastal water quality, Western Australia's Peel-Harvey estuarine system', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra <http://www.deh.gov.au/soe/2006/emerging/coastal-wq-peel-harvey/index.html>.

Department of the Environment and Heritage and South Australian Environment Protection Authority 2006, 'Coastal water quality, Adelaide's port waterways', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/coastal-wq/index.html>.

Dovers S 2006, 'The dilemma of conflicting environmental outcomes', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/conflict-outcomes/index.html>.

Fearon R 2006, 'The coastal pollution halo', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/coastal-pollution/index.html>.

Fensham R 2006, 'Spring wetlands of the Great Artesian Basin', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/wetlands/index.html>.

Giles-Corti B 2006, 'The impact of urban form on public health', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/public-health/index.html>.

Green P 2006, 'Progress in restoring our environment' paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/nrm-progress/index.html>.

Harris G 2006, 'A dying shame — Australian coastal freshwater lakes', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/lakes/index.html>.

Humphreys W 2006, 'Groundwater fauna', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/fauna/index.html>.

McGrath C 2006, 'Review of the EPBC Act', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/epbc-act/index.html>.

Millis N 2006, 'Genetically modified organisms', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/gmo/index.html>.

Nevill J 2006, 'Freshwater protected areas in Australia', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/freshwater/index.html>.

Olsen P, Silcocks A, Weston M and Tzaros C 2006, 'Birds of woodlands and grasslands', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/birds/index.html>.

Perkins P 2006, 'The environment management services industry', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/industry/index.html>.

Rae I 2006, 'Chemicals in the environment', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/chemicals/index.html>.

Sullivan S 2006, 'Cultural heritage and local government', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/local-heritage/index.html>.

Tilbury D 2006, 'Environmental education in Australia', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/education/index.html>.

Truscott M 2006, 'Repatriation of Indigenous cultural property', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/repatriation/index.html>.

Tyler M 2006, 'The disappearing frogs', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/frogs/index.html>.

Watson A 2006, 'Property rights and the environment', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/property-rights/index.html>.

Watson I 2006, 'Monitoring in the rangelands', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/rangelands/index.html>.

Western Australian Water Corporation 2006, 'Desalinisation', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/desal/index.html>.

Wood M 2006, 'Audit of the outcomes of the National Trust's Endangered Places Programme', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/national-trust/index.html>.

Technical reports

Kingsford RT and Porter JL 2006, *Waterbirds and wetlands across eastern Australia,* technical report prepared for the Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/technical/waterbirds/index.html>.

Lennox JA and Turner GM 2006, S*tate of the environment report on human settlements: stocks and flows indicators*, technical report prepared for the Department of the Environment and Heritage, Canberra, and CSIRO Sustainable Ecosystems, Canberra, <http://www.deh.gov.au/soe/2006/technical/stocks/index.html>.

Open Mind Research Group 2005, *State of Indigenous cultural heritage — A survey of Indigenous organisations*, technical report prepared for the Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/technical/indigenous-heritage/index.html>.

Pearson M and Marshall D 2006, *Study of the condition and integrity of historic heritage places for the 2006 State of the Environment Report*, technical report prepared for the Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/technical/historic-heritage/index.html>.

References

ABARE [Australian Bureau of Agricultural statistics and Resource Economics] 2005a, *Australian energy statistics — Australian production of primary fuels by state – physical units 1960–61 to 2003–04*, Australian Bureau of Agricultural and Resource Economics, Canberra.

ABARE [Australian Bureau of Agricultural and Resource Economics] 2005b, *Australian fisheries statistics 2004*, Australian Bureau of Agricultural and Resource Economics, Canberra.

ABARE [Australian Bureau of Agricultural and Resource Economics] 2006, *Australian commodities*, 13(2), Australian Bureau of Agricultural and Resource Economics, Canberra.

ABS—*see* Australian Bureau of Statistics.

ACTEW 2005, *Annual Report 2003–04*, ACTEW Corporation, Canberra.

ACTION Authority 2005, *Annual Report 2004–05*, Australian Capital Territory Government, Canberra, <http://www.action.act.gov.au/about.cfm>, accessed May 2006.

AIATSIS and FATSIL [Australian Institute of Aboriginal and Torres Strait Islander Studies and Federation of Australian and Torres Strait Islander Languages] 2005, *National Indigenous Languages Survey Report 2005*, report submitted to the Department of Communications, Information Technology and the Arts, Canberra.

AIHW and AACR [Australian Institute of Health and Welfare and Australasian Association of Cancer Registries] 2003, <http://www.aihw.gov.au/cancer/datacubes/index.cfm>, accessed 1 February 2005.

Allen Consulting Group 2005a, *Thoughts on the 'When' and 'How' of Government Historic Heritage Protection*, research report prepared for the Heritage Chairs and Officials of Australia and New Zealand, Canberra.

Allen Consulting Group 2005b, *Valuing the Priceless: The Value of Historic Heritage in Australia*, research report prepared for the Heritage Chairs and Officials of Australia and New Zealand, Canberra.

Aplin G 2002, *Heritage: Identification, Conservation and Management*, Oxford University Press, South Melbourne.

Aquatech 1997, *Estimating Potential Methane Production, Recovery and Use from Waste*, Environment Australia, Canberra.

Arthington A 2002, 'Environmental flows: ecological importance, methods and lessons from Australia,' paper presented at Mekong Dialogue Workshop on International Transfer of River Basin Development Experience: Australia and the Mekong Region, 2 September 2002, Sydney, <http://www.mekong.es.usyd.edu.au/events/past/Conference2002/index.htm>.

Atech 2000, 'Cost of Algal Blooms,' prepared for Land and Water Resources Research and Development and Murray Darling Basin Commission, LWRRDC Occasional Paper 26/99, Canberra, <http://www.lwa.gov.au/publications_search_details.asp?id=61>.

Australian Bureau of Statistics 2000, *Water Account for Australia 1993–94 to 1996–97*, cat. no. 4610.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2001, *Measuring Wellbeing: Frameworks for Australian Social Statistics 2001*, cat. no. 4160.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2002, *Salinity on Australian Farms 2002*, cat. no. 4615.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2003a, *Australian Social Trends 2003*, cat. no. 4102.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2003b, *Australia's Environment: Issues and Trends* 2003, cat. no. 4613.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2003c, Population Projections, Australia, 2002 to 2101, cat. no. 3222.0 Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2004a, *Australian Social Trends 2004: Population Seachange—New Coastal Residents*, cat. no. 4102.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2004b, 'Table 1: Key national accounts aggregates,' in *Australian System of National Accounts 2003–04*, cat. no. 5204.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2004c, *Waste Management Services Australia 2002–03*, cat. no. 8698.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2004d, 'Use of information technology by Aboriginal and Torres Strait Islander peoples', in *Year Book Australia 2004*, cat. no. 1301.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2004e, *Survey of Motor Vehicle Use Australia, October 2003*, cat. no. 9208.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2004f, *Water Account Australia 2000–01*, cat. no. 4610.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2004g, *Environment Expenditure Local Government Australia 2002–03*, cat. no. 4611.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2004h, *Government Finance Statistics 2002–03*, cat. no. 5512.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2005a, *Regional Population Growth, Australia and New Zealand 2003–04*, cat. no. 3218.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2005b, *Australian Demographic Statistics December Quarter 2004*, cat. no. 3101.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics 2005c, *The Health and Welfare of Australia's Aboriginal and Torres Strait Islander Peoples 2005*, cat. no. 4704.0, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics, *Average Retail Prices of Selected Items, Eight Capital Cities,* cat. no. 6403.0.55.001, (various years) Australian Bureau of Statistics, Canberra.

AGO [Australian Greenhouse Office] 2006, Analysis of forest in Australia. Source of data AGO (version 2, May 2006), NCAS, Department of the Environment and Heritage, Canberra.

Australian River Assessment System (AusRivAS): National River Health Database, <http://www.deh.gov.au/erin/edd/index.html>.

Baker P 2006, pers comm, information supplied to the Department of the Environment and Heritage, 25 May 2006.

Barbraud C and Weimerskirch H 2001, 'Emperor penguins and climate change', *Nature* 411:183–186.

Barr N 2001, *Structural Change in Australian Agriculture: Implications for Natural Resource Management*, National Land and Water Resources Audit, Canberra.

Barr N 2004, *The Micro-dynamics of Occupational and Demographic Change in Australian Agriculture: 1976–2001*, Australian Bureau of Statistics, Canberra.

Bartlett RV 1994, 'Evaluating environmental policy success and failure', in Vig NJ and Kraft ME (eds), *Environmental Policy in the 1990s*, 2nd edition, CQ Press, Washington.

Batten DF 2002, *Converting Our Waste into Wealth: The Scope for Eco-efficiency in Australian Regions,* CSIRO Manufacturing and Infrastructure Technology, Melbourne.

Beeton RJS, Parker PJ, Carter RW, Harris GP, Rabb GB, Donnelley S, Barlow ERW, Pearson CJ, Kelleher G, Bosch OJH, Williams JA, Koerner RJ, McDonald GT, Ross H, Saunders CD, Strahl SD, McPhail I, Howarth NA, Williams JM, Ogorzalek K, Heltne P, Ranney G, Adelmann GW, Gleeson T, Miles RI and Reichelt RE (in prep), 'Most of nature — a framework to resolve the twin dilemmas of the decline of nature and rural communities'.

Bellamy J, Meppem T, Gorddard R and Dawson S 2003, 'The changing face of regional governance for economic development: implications for local government', *Sustaining Regions* 2(3).

Best A, Zhang L, McMahon T, Western A and Vertessey R 2003, *A critical review of paired catchment studies with reference to seasonal flows and climatic variability*, CSIRO Land and Water Technical Report 25/05, CRC for Catchment Hydrology Technical Report 03/04 and Murray-Darling Basin Commission publication 11/03, CSIRO Publishing, Canberra.

Birrell B, O'Connor K and Rapson V 1999, 'Explaining spatial concentrations of the poor in metropolitan Melbourne', *People and Place* 7(1).

BoM—*see* Bureau of Meteorology.

Bond N, Lake PS and Glaister A 2004, 'A habitat restoration in degraded rural streams: the Granite Creeks Project', presentation to Healthy Rivers Communities Conference 2004, CRC for Freshwater Ecology and School of Biological Sciences, Monash University, Melbourne, <http://www.gbcma.vic.gov.au/default.asp?ID=178>, accessed 22 June 2006.

Borland J, Gregory B and Sheehan P (eds) 2001, *Work Rich, Work Poor: Inequality and Economic Change in Australia*, Centre for Strategic Economic Studies, Victoria University, Melbourne.

Botterill LC 2003, 'Beyond drought in Australia: the way forward', in Botterill LC and Fisher M (eds), *Beyond Drought: People, Policy and Perspectives,* CSIRO Publishing, Collingwood, Victoria.

Brown R and Creaser P (eds), Kerins S, Lennon J and Liddy M 2006, 'Indigenous involvement in environmental and heritage management', case studies prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/indigenous/index.html>.

Bureau of Meteorology 2005a, *Annual Australian Climate Statement 2004*, press release, Bureau of Meteorology, <http://www.bom.gov.au/announcements/media_releases/climate/change/20050106.shtml>, accessed 11 July 2005.

Bureau of Meteorology 2005b, 'Australian rainfall anomalies: 36 months August 2002 to July 2005', <http://www.bom.gov.au/cgi-bin/climate/rainmaps.cgi?page=mapandvariable=anomaliesandperiod=36monthandarea=aus>, accessed 11 July 2005.

Bureau of Meteorology 2005c, 'Trends in mean temperature 1910–2006' <http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/trendmaps.cgi>, accessed 28 June 2006.

Bureau of Meteorology 2005d, Temperature anomalies, unpublished data supplied to the Department of the Environment and Heritage.

Bureau of Meteorology 2006a, *Annual Australian Climate Statement 2005*, press release, Bureau of Meteorology, <http://www.bom.gov.au/announcements/media_releases/climate/change/20060104.shtml>, accessed 25 January 2006.

Bureau of Meteorology 2006b, 'Trends in annual total rainfall for three time periods', Bureau of Meteorology, <http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/trendmaps.cgi>, accessed March 2006.

Burroughs W 2003, *Climate into the 21st Century*, Cambridge University Press, Cambridge.

CAER [Centre for Australian Ethical Research], KPMG, Deni Greene Consulting Services 2004, *The State of Sustainability Reporting in Australia 2004*, report prepared for the Department of the Environment and Heritage, Canberra.

Caraco N and Cole JJ 1999, 'Regional export of C, N, P and sediment: what river data tell us about key controlling variables', in Tenhunen JD and Kabat P (eds), *Integrating Hydrology, Ecosystem Dynamics and Biogeochemistry in Complex Landscapes*, John Wiley and Sons, New York.

Carey A, Evans M, Hann P, Lintermans M, MacDonald T, Ormay P, Sharp S, Shorthouse D and Webb N 2003, *Wildfires in the ACT 2003: Report on Initial Impacts on Natural Ecosystems*, Technical Report 17, Wildlife Research and Monitoring, Environment ACT, Canberra, cited in Commissioner for the Environment 2003, 'Fire', *ACT State of the Environment 2003*, ACT Office of the Commissioner for the Environment, Canberra.

Carter O, Murphy AM and Cheal D 2003, 'Natural temperate grassland', Arthur Rylah Institute for Environmental Research, Department of Natural Resources and Environment, Victoria, <http://www.deh.gov.au/biodiversity/publications/grasslands/index.html>, accessed June 2006.

Caton AE and McLoughlin K (eds) 2004, 'Southern Bluefin Tuna fishery' in *Fisheries Status Report 2004*, Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry, Canberra.

Commonwealth of Australia 2003, 'Guidance note on the elimination of environmental tobacco smoke in the workplace', NOHSC: 3019 (2003), Department of Employment and Workplace Relations, Canberra.

Commonwealth of Australia 2004, *Guidelines for Indigenous Participation in Natural Resource Management*, Natural Heritage Trust, Canberra.

Commonwealth of Australia 2005, 'Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean', in *Advice to the Minister for the Environment and Heritage from the Threatened Species Scientific Committee on Amendments to the List of Key Threatening Processes under the* Environment Protection and Biodiversity Act 1999, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/biodiversity/threatened/ktp/christmas-island-crazy-ants.html>, accessed June 2006.

Condon RW 2002, *Out of the West: Historical Perspectives on the Western Division of New South* Wales, Lower Murray–Darling and Western Catchment Management Committees, Rangeland Management Action Plan, Mildura, Victoria.

Cork C, Sattler P and Alexandra J 2006, 'Biodiversity', theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/biodiversity/index.html>.

Corrish P 2005, *Creating Our Future: Agriculture and Food Policy for the Next Generation*, Agriculture and Food Policy Reference Group, Commonwealth of Australia, Canberra, <htttp://www.agfoodgroup.gov.au/next_generation.html>, accessed 1 May 2006.

CSIRO 2001, *Climate Change Projections for Australia*, CSIRO Atmospheric Research, <http://www.dar.csiro.au/publications/projections2pp.pdf>, accessed 1 February 2005.

CSIRO 2004, submission to the Federal Senate inquiry on invasive species, <http://www.aph.gov.au/senate/committee/ecita_ctte/invasive_species/index.htm>, accessed 28 April 2006.

CSIRO 2005a, 'Global and regional surface warming—1870 to 2004', CSIRO Atmospheric Research, <http://www.dar.csiro.au/information/observedchange.htm>, accessed 11 July 2005.

CSIRO 2005b, unpublished data supplied by CSIRO Marine and Atmospheric Research and Cape Grim Baseline Air Pollution Station, Australian Bureau of Meteorology to the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra.

CSIRO 2005c, unpublished data from CSIRO Marine and Atmospheric Research based on data obtained from Downey A, Bureau of Meteorology and McKenzie R, National Institute of Water and Atmospheric Research Ltd, supplied to the Department of the Environment and Heritage, Canberra.

Curran MAJ, van Ommen TD, Morgan VI, Phillips KL and Palmer AS 2003, 'Ice core evidence for Antarctic sea ice decline since the 1950s', *Science* 302.

DAFF [Department of Agriculture, Fisheries and Forestry] 2006, *National Land Use 1996–97 Summary Statistics,* <http://www.daff.gov.au/content/output.cfm?ObjectID=24597553-446E-435F-851E067477DB1E73>, accessed May 2006.

Davis JA, Froend RH, Hamilton DP, Horwitz P, McComb AJ and Oldham CE 2001, *Environmental Water Requirements to Maintain Wetlands of National and International Importance,* Environmental Flows Initiative Technical Report No. 1, Commonwealth of Australia, Canberra, <http://www.deh.gov.au/water/rivers/nrhp/wetlands/index.html>, accessed 6 October 2005.

De la Mare WK 1997, 'Abrupt mid-twentieth century decline in Antartic sea ice extent from whaling records', *Nature* 389.

DEC [Department of Environment and Conservation] NSW 2003, *New South Wales State of the Environment 2003*, Department of Environment and Conservation, Sydney.

DEH—*see* Department of the Environment and Heritage.

Department of the Environment and Heritage 2001, *A Directory of Important Wetlands in Australia, 3rd edition, Environment Australia*, Canberra, <http://www.deh.gov.au/water/wetlands/database/directory/index.html> accessed 6 October 2005.

Department of the Environment and Heritage 2002, *Australia's National Report to the Eighth Conference of Contracting Parties to the Convention on Wetlands (Ramsar, Iran, 1971)*, Valencia, Spain, November 2002, Canberra.

Department of the Environment and Heritage 2004, *State of the Air: National Ambient Air Quality Status and Trends Report 1991–2001*, Department of the Environment and Heritage, Canberra.

Department of the Environment and Heritage 2005a, *National Greenhouse Gas Inventory 2003, Part B*, Australian Greenhouse Office, Department of the Environment and Heritage, Canberra, <http://www.greenhouse.gov.au/inventory/2003/index.html>, accessed 4 October 2005.

Department of the Environment and Heritage 2005b, *Tracking to the Kyoto Target 2005*, Australian Greenhouse Office, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/biodiversity/index.html>.

Department of the Environment and Heritage 2005c, The Collaborative Australian Protected Areas Database (CAPAD), <http://www.deh.gov.au/parks/nrs/capad/index.html>, accessed 12 July 2005.

Department of the Environment and Heritage 2006a, Product Stewardship for Oil programme, data compiled from recent annual reports, Department of the Environment and Heritage, Canberra.

Department of the Environment and Heritage 2006b, *National Greenhouse Gas Inventory 2004*, Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

Department of the Environment and Heritage 2006c, 'Species information partnerships: sharing knowledge on threatened species', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra <http://www.deh.gov.au/soe/2006/emerging/species-listing/index.html>.

Department of the Environment and Heritage 2006d, 'Coastal water quality, Adelaide's port waterways', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/coastal-wq/index.html>.

Department of the Environment and Heritage 2006e, *Ecological Communities: A Way Forward—Threatened Species Scientific Committee Advice for the Minister for the Environment and Heritage,* September 2006, Department of the Environment and Heritage, Canberra.

Department of the Environment and Heritage 2006f, map compiled from various data sources, including Williams et al 2001, and Vandervuys and Wilson 2005.

Department of the Environment and Heritage 2006g, data obtained from the Collaborative Australian Protected Areas Database (CAPAD), <http://www.deh.gov.au/parks/nrs/capad/index.html>, accessed June 2006.

Department of the Environment and Heritage 2006h, Australia's Native Vegetation: A summary of Australia's major vegetation groups 2006, Australian Government, Canberra.

Department of the Environment and Heritage 2006i, 'Environmental indicators for reporting', paper prepared for the 2006 Australian State of the Environment

Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/indicators/index.html>.

DSE [Department of Sustainability and Environment] 2003, *Report of the Scientific Advisory Panel on Fire Affected Grazing*, report prepared for Parks Victoria, Melbourne, <http://www.dse.vic.gov.au/dse/nrenfoe.nsf/FID/-0ECF67F794ED8FBACA256DE300830ABF?OpenDocument>, accessed June 2006.

DSE [Department of Sustainability and Environment] 2005, *Index of Stream Condition: The Second Benchmark of Victorian River Condition*, Department of Sustainability and Environment, Victoria.

DoTARS [Department of Transport and Regional Services] 2003, *Urban Pollutant Emissions from Motor Vehicles: Australian Trends to 2020*, draft consultancy report to the Department of the Environment and Heritage, Canberra.

Donaldson K 2004, *Energy Statistics—Australian Energy 2004*, cited in *Energy in Australia 2004*, Australian Bureau of Agricultural and Resource Economics, Canberra, <http://abareonlineshop.com/product.asp?prodid=12814>, accessed 28 July 2005.

Dore J and Woodhill J 1999, *Sustainable Regional Development—Final Report: An Australia-wide Study of Regionalism Highlighting Efforts to Improve the Community, Economy and Environment*, Greening Australia, Canberra.

Dovers S 2006, 'The dilemma of conflicting environmental outcomes', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra <http://www.deh.gov.au/soe/2006/emerging/conflict-outcomes/index.html>.

Eckersley R (ed) 1998, *Measuring Progress: Is Life Getting Better?*, CSIRO Publishing, Melbourne.

Ellis S, Kanowski P and Whelan RJ 2004, *National Inquiry on Bushfire Mitigation and Management*, Commonwealth of Australia, Canberra.

ERIN [Environmental Resource Information Network] 2005a, Analysis of forest in the intensive landuse zone, unpublished data from ERIN, Department of the Environment and Heritage. Source of data AGO version 1, July 2005, NCAS, Canberra.

ERIN 2005b, Analysis of forest extent in riparian strips in the intensive landuse zone, unpublished data from ERIN, Department of the Environment and Heritage. Source of data AGO version 1, July 2005, NCAS, Canberra.

ERIN 2006a, Season quality in Australia, unpublished data from ERIN, Department of the Environment and Heritage. Source of data is Normalised Difference Vegetation Index (NDVI) data collected by the NOAA AVHRR satellite.

ERIN 2006b, Analysis of urbanised coastline, unpublished data from ERIN, Department of the Environment and Heritage. Source of data is Australian 1:100,000 Coastline, Geosciences Australia, Canberra.

ESAA [Electricity Supply Association of Australia] 2005, *Electricity Prices 2003–04*, Electricity Supply Association of Australia, Sydney.

FaCS [Department of Family and Community Services] 2005, *Giving Australia: Research on Philanthropy in Australia*, report prepared on behalf of the Prime Minister's Community Business Partnership, Department of Family and Community Services, Canberra.

Fensham R 2006, 'Spring wetlands of the Great Artesian Basin', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/wetlands/index.html>.

Fisher B 2005, 'Predicting the impacts of climate change on agriculture—a case study of the Australian broadacre industry', presentation to ABARE Outlook 2005 Conference, 2 March 2005, Canberra.

Fisher A, Hunt L, James C, Landsberg J, Phelps D, Smyth A and Watson I 2004, *Review of Total Grazing Pressure Management Issues and Priorities for Biodiversity Conservation in Rangelands: A Resource to Aid NRM Planning*, Desert Knowledge CRC Project Report No. 3, Desert Knowledge CRC and Tropical Savannas Management CRC, Alice Springs.

Florida R 2002, *The Rise of the Creative Class*, Basic Books, New York.

Francey RJ 2005, 'Recent record growth in atmospheric carbon dioxide levels', *Environmental Chemistry* 2, <http://www.publish.csiro.au/?act=view_fileandfile_id=EN05013.pdf>.

Frith HJ 1967, *Waterfowl in Australia*, Angus and Robertson, Sydney.

Garnett ST, Crowley GM and Barrett GB 2002, 'Birds', in *Australian Terrestrial Biodiversity Assessment*, National Land and Water Resources Audit, Commonwealth of Australia, Canberra.

GBRMPA 2004, *State of the Reef Report—Water Quality Update June 2004*, Great Barrier Reef Marine Park Authority, Townsville, <http://www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/water_quality/summary.html>, accessed 12 April 2006.

Giles-Corti B 2006, 'The impact of urban form on public health', paper prepared for the 2006 Australian State of the Environment Committee, Department of the

Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/public-health/index.html>.

Gill AM, Good R, Kirkpatrick J, Lennon J, Mansergh I and Norris R 2004, *Beyond the Bushfires 2003: Environmental Issues in the Australian Alps,* Australian Alps Liaison Committee, Canberra.

Gilligan DM 2005, *Fish Communities of the Lower Murray–Darling Catchment: Status and Trends*, NSW Department of Primary Industries, <http://www.fisheries.nsw.gov.au/_data/assets/pdf_file/57700/664-Final-Report-83.pdf>, accessed 28 April 2006.

Gipps P, Brotchie J, Hensher D, Newton PW and O'Connor K 1996, *The Journey to Work, Employment and the Changing Structure of Australian Cities,* AHURI Research Monograph 3, Melbourne.

Godden Mackay Logan 2005, *Kosciuszko National Park Huts Conservation Strategy,* draft report prepared for the NSW National Parks and Wildlife Service, Sydney.

Graeme Butler and Associates 2005, *Victorian Alpine Huts Heritage Survey 2004–05,* report to Parks Victoria, Melbourne.

Green P 2006, 'Progress in restoring our environment', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/private/index.html>.

Griffin NRM Pty Ltd 2004, *Small Steps for Nature: Review of Progress Towards the National Objectives and Targets for Biodiversity Conservation 2001–05*, World Wildlife Fund and Humane Society International, Sydney.

Hamblin A 2001, *Land: Australia State of the Environment Report 2001* (theme report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra.

Hanna N 2003, 'The irrigation drought. Implications for irrigators 2003–04', ABARE *australiancommodities* 10(3), <http://www.abareonlineshop.com/product.asp?prodid=12584>, accessed 30 November 2005.

Harris G, Batley G, Fox D, Hall D, Jernakoff P, Molloy R, Murray A, Newell B, Parslow J, Skyring G and Walker S 1996, *Port Phillip Bay Environmental Study Final Report,* CSIRO Publishing, Canberra.

Harris G 2006, 'A dying shame—Australian coastal freshwater lakes', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/lakes/index.html>.

Hassall and Associates Pty Ltd 2003, *Review of the Great Artesian Basin Sustainability Initiative,* Department of Agriculture, Fisheries and Forestry, Canberra, <http://www.affa.gov.au/content/publications.cfm?ObjectID=07F7F8F9-DD6A-4E87-93BC79E638BBCDDB>, accessed 1 May 2006.

Heathcote RL 1965, *Back of Bourke: A Study of Land Appraisal and Settlement in Semi-arid Australia,* Melbourne University Press, Melbourne.

Henry GW and Lyle JM (eds) 2003, *The National Recreational and Indigenous Fishing Survey 2003*, FRDC Project No. 99/158, Department of Agriculture, Fisheries and Forestry, <http://www.affa.gov.au/recfishsurvey>, accessed June 2006.

Heritage Council Victoria 2003, *Annual Report 2003–04,* Heritage Council Victoria, Melbourne, <http://www.heritage.vic.gov.au/pages/pdfs/annualreports/annualreport0203part2.pdf>, accessed 1 May 2006.

Heritage Council Victoria 2005, *Hands on Heritage,* <http://www.heritage.vic.gov.au/page.asp?ID=165>, accessed 1 May 2006.

Hill R and Nowakowski S 2003, *Yalanji-warranga kaban. Yalanji People of the Rainforest Fire Management Book,* Little Ramsay Press, Cairns.

Horstman M and Wightman G 2001, 'Karparti ecology: recognition of Aboriginal ecological knowledge and its application to management in north-western Australia', *Ecological Management and Restoration* 2.

Houston P 2005, 'Re-valuing the fringe: some findings on the value of agricultural production in Australia's peri-urban regions', *Geographical Research* 43 (2).

Howden M, Hughes L, Dunlop M, Zethoven I, Hilbert D and Chilcott C 2003, *Climate Change Impacts on Biodiversity in Australia,* outcomes of a workshop sponsored by the Biological Diversity Advisory Committee, 1–2 October 2002, Commonwealth of Australia, Canberra.

HRSCEH [House of Representatives Standing Committee on Environment and Heritage] 2005, *Sustainable Cities: Report on the Inquiry into Sustainable Cities,* Parliamentary paper 215/2005, tabled 12 September 2005, Canberra.

Hugo G 2002, 'Population trends in South Australia', *People and Place* 10(1).

IOCI 2002, *Climate variability and change in south-west Western Australia*, report of the Indian Ocean Climate Initiative, <http://www.ioci.org.au/publications/pdf/IOCI_TechnicalReport02.pdf>, accessed 8 August 2005.

Johnston C 2006, 'Managing Australia's heritage in environmental management', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/heritage/index.html>.

Jones G, Arthington A, Gawne B, Hillman T, Kingsford R, Thoms M, Walker K and Young W 2003, *Ecological Assessment of Flow Reference Points for the River Murray System*, interim report of the Scientific Reference Panel for the Murray-Darling Basin Commission, CRC for Freshwater Ecology, Canberra.

Jones G 2005, *Watershed*, April edition, CRC for Freshwater Ecology, <http://enterprise.canberra.edu.au/WWW/www-crcfe.nsf/0/7e16e5963b71476b4a25664a004a2493?OpenDocument>, accessed June 2006.

Kanowski PJ, Whelan RJ and Ellis S 2005, 'Inquiries following the 2002–03 Australian bushfires: common themes and future directions for Australian bushfire mitigation and management', *Australian Forestry* 68.

Keissling I 2003, *Finding solutions: derelict fishing gear and other marine debris in Northern Australia,* National Oceans Office, Hobart.

Keogh M 2005, 'The National Dryland Salinity Audit five years on: is the 17 million hectare estimate still valid or useful?', *Australian Farm Institute Policy Journal* 2(4).

Keppler F, Hamilton JTG, Brar M and Rockmann T 2006, 'Methane emissions from terrestrial plants under aerobic conditions', *Nature* 439.

Khan S 2006, 'Managing climate risks in the driest continent: options for water policy and irrigation management', keynote paper in *Proceedings of the 6th Triennial Conference of the Maize Association of Australia*, Griffith, New South Wales, 21–23 February 2006, NSW.

Kingsford RT and Porter JL 2006, 'Waterbirds and wetlands across eastern Australia', technical report prepared for the Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/technical/waterbirds/index.html>.

Klaer NL 2001, 'Steam trawl catches from south-eastern Australia from 1918 to 1957: trends in catch rates and species composition', *Marine and Freshwater Research*, 52.

KPMG Global Sustainability Services™ and the University of Amsterdam 2005, 'KPMG international survey of corporate responsibility reporting 2005', <http://www.kpmg.com/Rut2000_prod/Documents/9/Survey2005.pdf>, accessed 5 December 2005.

Lane M 2006, 'Critical issues in regional natural resource management', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/nrm-issues/index.html>.

Lindesay JA 2003, 'Climate and drought in Australia', in Botterill LC and Fisher M (eds) *Beyond Drought: People, Policy and Perspectives,* CSIRO Publishing, Collingwood, Victoria.

Lough JM 2003, 'Lessons from the past: climate from corals' in Stone R and Partridge I (eds), *Science for Drought: proceedings of the National Drought Forum,* Brisbane, April 2003, Queensland Department of Primary Industries.

Love G and Langenkamp D 2003, *Australian Aquaculture: industry profiles for related species,* ABARE eReport 03.8, <http://www.abare.gov.au/publications_html/fisheries/fisheries_03/fisheries_03.html> prepared for the Fisheries Resources Research Fund, Canberra.

Lovett JV 1973, *The Environmental, Economic and Social Significance of Drought,* Angus and Robertson, Sydney,

Lowe I 2004, 'The environment', in Manne R (ed), *The Howard Years*, Black Inc Agenda, Melbourne.

Luke RH and McArthur AG 1978, *Bushfires in Australia,* Australian Government Publishing Service, Canberra.

Manins P, Allan R, Beer T, Fraser P, Holper P, Suppiah R and Walsh K 2001, *Atmosphere: Australia State of the Environment Report 2001* (theme report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra.

Mantua NJ and Hare SR 2002, 'The Pacific decadal oscillation', *Journal of Oceanography* 58.

Mantua NJ, Hare SR, Zhang Y, Wallace JM and Francis RC 1997, 'A Pacific inter-decadal climate oscillation with impacts on salmon production', *Bulletin of the American Meteorological Society,* 78.

Martin CE and McCulloch MT 1999, 'Nd-Sr isotopic and trace element geochemistry of river sediments and soils in a fertilised catchment, New South Wales, Australia', *Geochimica et Cosmochimica Acta*, 63.

Mather P, Talbot F and Archer M 2006, 'Rescuing the key to nature's databank', *Australasian Science*, January/February 2006.

McGonville P and Thienberger N 2001, *The State of Indigenous Languages in Australia,* report to the State of the Environment Section, Environment Australia, Canberra, <http://www.deh.gov.au/soe/techpapers/languages/index.html>.

McGrath C 2006, 'Review of the EPBC Act', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/epbc-act/index.html>.

McKeon GM, Hall WB, Henry BK, Stone GS and Watson IW 2004, *Pasture Degradation and Recovery in Australia's Rangelands: learning from history,* Queensland Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland.

McLeod R 2004, *Counting the Cost: Impact of Invasive Animals in Australia 2004*, Cooperative Research, Centre for Pest Animal Control, Canberra.

McTainsh GH, Leys JF and Tews EK 2006, unpublished data on wind erosion trends, prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra.

MDBC [Murray–Darling Basin Commission] 2001, *Basin Salinity Management Strategy 2001–15*, Murray-Darling Basin Commission, Canberra, <http://www.mdbc.gov.au/salinity/basin_salinity_management_strategy_20012015>, accessed June 2006.

MDBC [Murray-Darling Basin Commission] 2003, *Projections of Groundwater Extraction Rates and Implications for Future Demand and Competition for Surface Water,* Report No. 04/03, Murray-Darling Basin Commission, Canberra.

MDBC [Murray-Darling Basin Commission] 2004, *Murray-Darling Basin Groundwater Status,* Report No. 32/04, Murray-Darling Basin Commission, Canberra.

Melbourne 2030: Protecting Our Liveability Now and for the Future, Department of Sustainability and Environment, Victoria.

National Forest Inventory 2005, *National Plantation Inventory 2005 Update*, Bureau of Rural Sciences, Canberra, <http://affashop.gov.au/product.asp?prodid=12762>, accessed 23 June 2006.

National Incentives Task Force 2004, *Making Heritage Happen: Incentives and Policy Tools for Conserving Our Historic Heritage,* report prepared for the Environment Protection and Heritage Council, Canberra.

National Sea Change Taskforce 2005, 'The challenge of coastal growth: background information prepared by the taskforce on the issues associated with the "sea change" phenomenon and the challenge it poses to coastal councils', <www.seachangetaskforce.org.au>, accessed March 2006.

Natural Resource Management Ministerial Council 2004, *National Biodiversity and Climate Change Action Plan 2004–07*, Department of the Environment and Heritage, Canberra.

Neil KM, Hilliard R, Clark P and Russell BC 2005, *A Situation and Gaps Analysis of IMS, Vectors, Nodes and Management Arrangements for the Northern Planning Area*, independent report by CRC Reef, URS Perth and the Museum and Art Gallery of the Northern Territory, prepared for the National Oceans Office Branch of the Department of the Environment and Heritage, Canberra.

Nevill J 2006, 'Freshwater protected areas in Australia', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/freshwater/index.html>.

Newman P 2006, keynote address, Sydney Futures Forum, 19 May 2006, Sydney.

Newton PW 1991, 'Telematic underpinnings of the information economy', in Brotchie JF, Batty M, Hall P and Newton PW (eds), *Cities of the 21st Century,* Longman Cheshire, Melbourne.

NLWRA [National Land and Water Resources Audit] 2001a, *Landscape Health in Australia,* Commonwealth of Australia, Canberra.

NLWRA [National Land and Water Resources Audit] 2001b, *Australian Water Resources Assessment 2000*, Commonwealth of Australia, Canberra.

NLWRA [National Land and Water Resources Audit] 2001c, *Australian Agriculture Assessment 2000*, Commonwealth of Australia, Canberra.

NLWRA [National Land and Water Resources Audit] 2001d, *Australian Dryland Salinity Assessment 2000*, Commonwealth of Australia, Canberra.

NLWRA [National Land and Water Resources Audit] 2002a, *Australians and Natural Resource Management: an overview—Australia*, Commonwealth of Australia, Canberra.

NLWRA [National Land and Water Resources Audit] 2002b, *Australian Terrestrial Biodiversity Assessment,* Commonwealth of Australia, Canberra.

NSW Department of Planning 2006, *City of Cities: A plan for Sydney's future*, prepared by the NSW Department of Planning with input from state and local government, industry, interest groups, agencies and the community, NSW Department of Planning, Sydney, <http://www.metrostrategy.nsw.gov.au/dev/ViewPage.action?siteNodeId=28andlanguageId=1andcontentId=-1>, accessed 15 June 2006.

NSW Food Authority 2006, *Sydney Harbour Closure to Commercial Fishing—Overview and facts about Dioxins,* NSW Food Authority, Sydney, <http://www.foodauthority.nsw.gov.au/c-dioxins.htm>, accessed 1 May 2006.

NSW National Parks and Wildlife Service 2006, *2006 Plan of Management Kosciuszko National Park,* Department of Environment and Conservation, Sydney.

NTHT [National Tourism and Heritage Taskforce] 2003, *Going Places: Developing natural and cultural heritage tourism in Australia,* report of the National Tourism and Heritage Taskforce for the Environment Protection and Heritage Council, Adelaide, <http://www.ephc.gov.au/heritage/strat_sustain_tour_herit.html>, accessed June 2006.

OECD [Organisation for Economic Co-operation and Development] 1976, *Measuring Social Wellbeing: a progress report on the development of social indicators,* Organisation for Economic Co-operation and Development, Paris.

O'Faircheallaigh C 2004, 'Native title and agreement making in the mining industry: focusing on outcomes for Indigenous peoples', in *Land, Rights, Laws: Issues of Native Title,* volume 2, issues paper no. 25, Native Title Research Unit, AIATSIS, Canberra.

Olsen P, Silcocks A, Weston M and Tzaros C 2006, 'Birds of woodlands and grasslands', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra.

Open Mind Research Group 2006, *State of Indigenous Cultural Heritage—A Survey of Indigenous Organisations,* technical report prepared for the Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/technical/indigenous-heritage/index.html>.

Page MJ and Beeton RJS 2000, 'Is the removal of domestic stock sufficient to restore semi-arid conservation areas?', *Pacific Conservation Biology* 6.

Page MJ, Beeton RJS and Mott JJ 2000, 'Grass response to shrub removal in two semi-arid rangeland vegetation communities', *Rangelands Journal* 22(2).

Pannell D 2005, 'Leading researcher responds to claims of exaggeration', media release from the Cooperative Research Centre for Plant-based Management of Dryland Salinity, 13 December 2005.

Parker P and Fitzhardinge G 2006, 'Changing the delivery of environmental stewardship in Australia', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/philanthropic/index.html>.

Parkinson, CL 2004, 'Southern Ocean sea ice and its wider linkages: insights revealed from models and observations', *Antarctic Science* 16(4).

Pearson M and Marshall D 2006, *Study of Condition and Integrity of Historic Heritage Places,* technical report prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/technical/historic-heritage/index.html>.

Pestana B 1993, *Australian Agriculture: the complete reference on rural industry*, National Farmers Federation, Canberra.

Planning South Australia 2003, *Planning Strategy for Metropolitan Adelaide*, Department of Transport and Urban Planning, Adelaide, <http://dataserver.planning.sa.gov.au/publications/857p.pdf>, accessed 15 June 2006.

PMSEIC [Prime Minister's Science, Engineering and Innovation Council] 2002, 'Sustaining our natural systems and biodiversity', paper prepared by an independent working group for the 8th meeting of the council, < http://www.dest.gov.au/sectors/science_innovation/publications_resources/profiles/setting_biodiversity_priorities.htm >, accessed 28 April 2006.

Ponder W, Hutchings P and Chapman R 2002, *Overview of the Conservation of Australian Marine Invertebrates,* report prepared for Environment Australia, <http://www.austmus.gov.au/invertebrates/marine_overview/contents.html>, accessed 30 November 2005.

Power S, Casey T, Folland C, Colman A, Mehta V 1999, 'Inter-decadal modulation of the impact of ENSO on Australia', *Climate Dynamics* 15.

Productivity Commission 2005, *Australia's Health Workforce,* research report, Canberra.

Productivity Commission 2006a, Waste Generation and Resource Efficiency, draft report released on 23 May 2006, Canberra.

Productivity Commission 2006b, *Conservation of Australia's Historic Heritage Places,* report no. 37, AusInfo, Canberra.

Prosser IP, Rutherford ID, Olley JM, Young WJ, Wallbrink PJ and Moran CJ 2001, 'Large scale patterns of erosion and sediment transport in river networks, with examples from Australia', *Marine and Freshwater Research* 52.

Queensland DNRMW [Department of Natural Resources, Mines and Water] 2006, Climate Management Information for Rural Australia, <http://www.LongPaddock.qld.gov.au>, accessed 27 February 2006.

Radcliffe J 2003, *An Overview of Water Recycling in Australia—Results of the Recent ATSE Study*, Water Recycling Australia and National Conference, Brisbane, Australian Water Association.

Radcliffe J 2004, *Water Recycling in Australia*, Australian Academy of Technological Sciences and Engineering, Parkville, Victoria, <http://www.atse.org.au/index.php?sectionid=600>, accessed 30 November 2005.

Reef Futures 2003, *Coral Bleaching,* CRC Reef Research Centre, <http://www.reeffutures.org/topics/bleach.cfm>, accessed 18 April 2006.

Reich R 1991, *The Work of Nations*, Simon and Schuster, New York.

Rintoul S in press, *Rapid Freshening of Antarctic Bottom Water.*

Roderick ML and Farquhar GD 2004, 'Changes in Australian pan evaporation from 1970 to 2002', *International Journal of Climatology* 24.

Ruddell A 2006, 'An inventory of present glaciers on Heard Island and their historical variations', in Green K and Woehler E (eds), *Heard Island: Southern Ocean Sentinel,* Surrey Beatty, Sydney.

Russell JS 1988, 'The effects of climatic change on the productivity of Australian agroecosystems', in Pearman GI (ed), *Greenhouse: Planning for Climate Change,* CSIRO Publishing, Melbourne.

Russell-Smith J, Yates C, Edwards A, Allan GE, Cook GD, Cooke P, Craig R, Heath B and Smith R 2003, 'Contemporary fire regimes of northern Australia, 1997–2001: change since Aboriginal occupancy, challenges for sustainable management', *International Journal of Wildland Fire* 12.

SAMLIV 2003, *Draft Strategy for Aboriginal Managed Lands in Victoria,* Strategy for Aboriginal Managed Land in Victoria Steering Committee, Melbourne, <http://home.vicnet.net.au/~samliv>, accessed June 2006.

Samson CR and Edgar GL 2001, 'Use of sediment cores to document changes in coastal marine habitats since European settlement', in Heijnis H and Harle K (eds), *Australian Institute for Nuclear Science and Engineering: environment workshop on archives of human impact of the last 200 years,* Australian Institute for Nuclear Science and Engineering, Lucas Heights, New South Wales.

Schofield NJ, Williams A, Holloway R and Pyke B (in press), 'Minimising riverine impacts of endosulphan used in cotton farming — a science into practice environmental success story' Rational Methods for the Selection and us of Agrochemicals, American Chemical Society, Washington.

Shepherd A 2005, *2004–05 National NRM Survey of Local Government,* Australian Local Government Association, Canberra.

Shepherd C 2003, 'The risk/reward trade-off that is shrinking the population of rural Australia', in Vizard S, Martin H and Watts T (eds), *Australia's Population Challenge,* Penguin, Melbourne.

Sinclair Knight Merz Pty Ltd 2001, *Environmental Water Requirements of Groundwater Dependent Ecosystems*, Technical Report No. 2, Environment Australia, Canberra, <http://www.deh.gov.au/water/rivers/nrhp/groundwater>.

Sinden J, Jones R, Hester S, Odum D, Kalish C, James R and Cacho O 2004, *The Economic Impact of Weeds in Australia*, Technical Series No. 8, report to the CRC for Australian Weed Management, Adelaide.

Singh G and Geissler EA 1985, 'Late Cainozoic history of vegetation, fire, lake level and climate of Lake George', *Phil. Trans. Royal Society London* 311.

Stanton P 1995, 'A tropical Queensland perspective', in Rose DB (ed) *Country in Flames: Proceedings of the 1994 Symposium on Biodiversity and Fire in North Australia,* Department of the Environment, Sport and Territories and the North Australia Research Unit, Canberra and Darwin.

Steffen W 2006, *Stronger Evidence but New Challenges: climate change science 2001–05*, Department of the Environment and Heritage, Canberra.

The State of Queensland 2005, *South East Queensland Regional Plan 2005–26*, Department of Local Government, Planning, Sport and Recreation, Brisbane.

Sullivan S 2006, 'Cultural heritage and local government', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/local-heritage/index.html>.

Thomas CD, Cameron A, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, Erasmus BFN, De Siquiera MF, Grainger A, Hannah L, Hughes L, Huntley B, Van Jaarsveld AS, Midgley GF, Miles L, Ortega-Huerta MA, Peterson AT, Phillips O and Williams SE 2004, 'Extinction risk from climate change', *Nature* 427: 145–148.

Thresher R, Rintoul SR, Koslow JA, Weidman C, Adkins J and Proctor C 2004, 'Oceanic evidence of climate change in southern Australia over the last three centuries', *Geophysical Research Letters* 31:L07212. doi: 10.1029/2003GL018869.

Tilbury D 2006, 'Environmental education in Australia', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/education/index.html>.

Toowoomba City Council 2006, *Water Futures Toowoomba,* <http://www.toowoombawater.com.au>, accessed 8 May 2006.

Truscott M 2006, 'Repatriation of Indigenous cultural property', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/repatriation/index.html>.

TSSC [Threatened Species Scientific Committee] 2005, 'Southern Bluefin Tuna *(Thunnus maccoyii)*', in Advice to the Minister for the Environment and Heritage from the Threatened Species Scientific Committee on Amendments to the List of Threatened Species under the *Environment Protection and Biodiversity Conservation Act 1999*, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/biodiversity/threatened/species/southern-bluefin-tuna.html>, accessed 1 May 2006.

Turner L, Tracey D, Tilden J and Dennison WC 2004, *Where River Meets Sea: exploring Australia's estuaries,* Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, Brisbane.

Tyler M 2006. 'The disappearing frogs', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/frogs/index.html>.

Vanderduys E and Wilson S 2005, 'Cane toads', <http://www.qmuseum.qld.gov.au/inquiry/leaflets/>, accessed 25 November 2005.

Wasson RJ, Olive LJ and Rosewell CJ 1996, 'Rates of erosion and sediment transport in Australia', *International Association of Hydrological Sciences* 236.

Watson I 2006, Monitoring in the Rangelands, paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/rangelands/index.html>.

WCS Market Intelligence 2001, *Industry and Market Report—Australian Waste Industry,* WCS Market Intelligence, Sydney.

WELS 2005, 'Water efficiency labelling and standards scheme', Commonwealth of Australia, <http://www.waterrating.gov.au>, accessed 4 December 2005.

Whetton P and Suppiah R 2003, 'Climate change projections and drought', in Stone R and Partridge I (eds), *Science for Drought: proceedings of the National Drought Forum,* Brisbane, April 2003, Queensland Department of Primary Industries.

WHO Regional Office for Europe 2000, *Air Quality Guidelines for Europe,* 2nd edition, WHO Regional Publications, European Series, No. 91, Copenhagen, <http://www.euro.who.int/document/e71922pdf>, accessed August 2006.

Wild River S 2006, 'The role of local government in environmental and heritage management', paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/integrative/local-government/index.html>.

Williams J, Read C, Norton A, Dovers S, Burgmann M, Proctor W and Anderson H 2001, *Biodiversity: Australia State of the Environment Report 2001* (theme report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra.

Wilson PR, Ainley DG, Nur N, Jacobs SS, Barton KJ, Ballard G, Comiso JC 2001, 'Adelie penguin population change in the pacific sector of Antarctica: relation to sea-ice extent and the Antarctic Circumpolar Current', *Marine Ecology Progress Series,* 213.

Witt B, Carter B, Witt K and Gordon A 2006, 'Urban views of rural land management: a survey of Brisbane residents', preliminary report, School of Natural and Rural Systems Management, University of Queensland, Brisbane, <http://www.nrsm.uq.edu.au/survey/urbanviews/>, accessed 1 May 2006.

Woehler EJ in press, 'Status and conservation of the seabirds of Heard Island', in Green K and Woehler EJ (eds), *Heard Island: Southern Ocean Sentinel*, Surrey Beatty, Sydney.

Woehler EJ, Riddle MJ and Ribic CA 2003, 'Long-term population trends in southern giant petrels in East Antarctica', in Huiskes AHL, Gieskes WWC, Rozema J, Schorno RML, van der Vies SM and Wolff WJ (eds), *Antarctic Biology in a Global Context,* Backhuys Publishers, Leiden, The Netherlands.

Wood MS, Stephens NC, Allison BK and Howell CI 2001, *Plantations of Australia—A Report from the National Plantation Inventory and the National Farm Forest Inventory* (abridged version), National Forest Inventory, Bureau of Rural Sciences, Canberra.

Zhang L, Dawes WR and Walker GR 1999, *Predicting the Effect of Vegetation Changes on Catchment Average Water Balance,* CRC for Catchment Hydrology, Technical Report, 99/12, Canberra.

Zwally HJ, Comiso JC, Parkinson CL, Cavalieri DJ and Gloersen P 2002, 'Variability of Antarctic sea ice 1979–98', *Journal of Geophysical Research* Vol 107, No C5, 3041, doi:10.1029/2000JC000733, 2002.

Abbreviations

ABS	Australian Bureau of Statistics
ANARE	Australian National Antarctic Research Expeditions
AVHRR	Advanced Very High Resolution Radiometer
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
MDBC	Murray-Darling Basin Commission
NAP	National Action Plan for Salinity and Water Quality
NDVI	The Normalised Difference Vegetation Index
NCAS	National Carbon Accounting System
NEPM	National Environment Protection Measure
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
NOAA	National Oceanic and Atmospheric Administration (USA)
NPI	National Pollutant Inventory
SoE2001	*Australia State of the Environment 2001* report
SoE2006	*Australia State of the Environment 2006* report (this report)

Glossary

aerosol	a suspension of particles, other than water or ice, in the atmosphere that ranges in size from about 5 nm to larger than 10 µm in radius. It may be either natural or caused by human activity, and most of the latter are usually considered to be pollutants
air toxics	gaseous, aerosol or particulate pollutants (other than the six criteria pollutants) present in the air in low concentrations with characteristics such as toxicity or persistence so as to be a hazard to human, plant or animal life
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
aquaculture	commercial growing of marine (mariculture) or freshwater animals and plants in water
aquifer	an underground layer of soil, rock or gravel able to hold and transmit water. Bores and wells are used to obtain water from aquifers
arid zone	the arid and semi-arid lands are those remote and sparsely populated areas of inland Australia, defined by the presence of desert vegetation and land forms as well as by low rainfall. They are bound by median annual rainfalls of about 250 mm in the south but up to 800 mm in the north and about 500 mm in the east
average temperature	in Australia, the average (or mean) temperature is always taken as the maximum plus minimum, divided by two. For a continental-scale average, the calculation is done in two steps. The minimum temperatures from all weather stations at a point in time are averaged to get the average minimum temperature across the continent; similarly, all maximum temperatures from weather stations are averaged to get the average maximum temperature across the continent. These two averages are then averaged again to get the average temperature across Australia
ballast water	water carried in tanks to maintain stability when a ship is lightly loaded; it is normally discharged to the sea when the ship is loaded with cargo
biodiversity	variability among living organisms from all sources (including terrestrial, marine and other ecosystems and ecological complexes of which they are part), which includes diversity within species and between species and diversity of ecosystems
biomass	the quantity of organic matter within an ecosystem (usually expressed as dry weight for unit area or volume)

bioregion	an area defined by a combination of biological, social and geographical criteria rather than by geopolitical considerations; generally, a system of related, interconnected ecosystems
biota	all of the organisms at a particular locality
blue-green algae	an ancient order of algae (with characteristics of bacteria) that have become more common in water bodies due to disturbance and pollution. Some species produce toxins that can cause sickness and nerve and liver damage
bycatch	species taken incidentally in a fishery where other species are the target. Some bycatch species are of lesser value than the target species, so are often discarded but other bycatch species have some commercial value ('byproduct') and are retained for sale.
catchment	an area determined by topographic features within which rainfall will contribute to runoff at a particular point under consideration
CO_2-e	carbon dioxide equivalent
conservation	in relation to biodiversity: the protection, maintenance, management, sustainable use, restoration and enhancement of the natural environment; in relation to natural and cultural heritage: generally, keeping in safety or preserving the existing state of a heritage resource from destruction or change
conservation estate	those parts of the environment that are formally reserved for conservation of native species, ecosystems and recreation
contaminated site	a site at which hazardous substances occur at concentrations above background levels and where assessment shows this poses, or is likely to pose, an immediate or long-term hazard to human health or the environment
cultural landscape	encompasses the qualities and attributes of places that have aesthetic, historic, scientific or social value for past, present or future generations. These values may be seen in a place's physical features, but importantly can also be intangible qualities such as people's associations with, or feelings for a place.
de-snag	to remove the 'snags' (fallen trees) lying in the river channel of lowland rivers. Snags are common in Australian rivers, but they interfere with recreational uses like water skiing and look unsightly and so are often removed. In the past, they were also removed in the mistaken belief that they had a major effect on reducing the flood carrying capacity of rivers
dryland salinity	a condition wherein soil salinity levels in an area are high enough to affect plant growth
ecological community	the definition of an ecological community in the EPBC Act is as follows: 'an assemblage of native species that: (a) inhabits a particular area in nature; and (b) meets the additional criteria specified in the regulations (if any) made for the purposes of this definition'

ecosystem	a dynamic complex of plant, animal and microorganism communities and their non-living environment that interacts as a functional unit
El Niño	an extensive warming of the central and eastern Pacific Ocean that leads to a major shift in weather patterns across the Pacific. In Australia (particularly eastern Australia), El Niño events are associated with an increased probability of drier conditions
endangered	when referring to the state of Indigenous languages, there are several categories including the severely and critically endangered categories. These languages are only spoken by small groups of people mostly over 40 years old.
endemic	native to a particular area and found nowhere else
energy efficiency	the means of using less energy in doing the same amount of work
enhanced greenhouse effect	the addition to the natural greenhouse effect resulting from human activities such as the burning of fossil fuels and land clearing, which increase the atmospheric levels of greenhouse gases such as carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons (CFCs)
environment	includes ecosystems and their constituent parts, including people and communities; natural and physical resources; the qualities and characteristics of locations, places and areas; and the social, economic and cultural aspects of a thing mentioned in the previous three categories
environmental indicators	are the physical, chemical, biological or socio-economic measures that best represent the key elements of a complex ecosystem or environmental issue. Indicators can organise environmental information both spatially and over time. An example is 'surface water used for irrigation'.
exceedances	those times when a measurement of a component goes beyond a specified limit
fire regime	the pattern of fires at a location; includes the frequency, intensity and seasonality of the fires
forest	this report uses an international definition of forest. Under this definition, forest is native and non-native vegetation that has at least 20 per cent canopy cover and could grow to at least two metres tall. Only patches of more than 0.2 hectares are included. The forest change analysis used for these calculations therefore involves only deforestation and forest regrowth data that is human induced, so it does not include commercial forestry operations, or loss of vegetation due to fire or dieback. The data have been independently verified
greenhouse effect	see enhanced greenhouse effect
greenhouse gas emissions	releases of those gases that, by affecting the radiation transfer through the atmosphere, contribute to global warming
groundwater	the water beneath the surface that flows naturally to the earth's surface via seeps or springs, that can be collected with wells, tunnels or drainage galleries

heritage objects	material that is in situ at significant sites or held in collecting institutions such as archives, libraries, museums, galleries, zoos, herbaria or botanic gardens, or historic buildings
hydrocarbons	organic molecules containing hydrogen and carbon; the major components of petroleum
Indigenous	of or relating to the Aboriginal and Torres Strait Islander peoples of Australia
intensive land use zone (ILZ)	the area of Australia where intensive land use practices such as irrigated agriculture occur
intertidal	between the levels of low and high tide
invasive species	a species spreading beyond its accepted normal distribution as a result of human activities and which threatens valued environmental, agricultural or personal resources by the damage it causes
invertebrate	an animal without a backbone composed of vertebrae (eg insects, worms, snails, mussels, prawns and cuttlefish)
in-water operations	a number of methods used for farming aquatic animals, in the sea in Australia, including cages, ropes, rafts and racks.
La Niña	warming of the western equatorial Pacific warm pool, north of New Guinea, accompanied by cooling in the equatorial eastern Pacific Ocean. La Niña is often associated with above average rainfall in eastern Australia (see El Niño)
Landcare	a programme to further sustainable land management
managed decay (for cultural heritage)	involves extensive documentation, removal of hazardous material, eg poisonous chemicals, followed by minimal intervention and monitoring to enable decisions to be made to decrease the demise of artefacts, for example objects that are at risk due to exposure to a harsh environment can be relocated to more protected areas
mangrove	a plant (belonging to any of a wide range of species, mainly trees and shrubs) that grows in sediment regularly inundated by sea water
marine area	area of sea or sea bed over which a country has jurisdiction under the Law of the Sea Convention. For Australia it includes the Australian Exclusive Economic Zone around the mainland, islands and the Australian Antarctic Territory and the continental shelf off the mainland and the Australian Antarctic Territory
molluscs	a phylum of invertebrates, including snails, clams, octopuses, squids, and others
Montreal Protocol	the Montreal Protocol on Substances that Deplete the Ozone Layer, agreed in Montreal in 1987
National Environment Protection Measures	broad framework-setting statutory instruments defined in the *National Environment Protection Act 1994* (see <http://www.nepc.gov.au>)

natural places	those sites, areas or regions for which the heritage significance is based on their natural biological and physical features; may also have cultural heritage values
Natural Heritage Trust	a body established by the *Natural Heritage Trust of Australia Act 1997* to stimulate conservation, sustainable use and repair of Australia's natural environment
net consumption	the amount of natural resources used per person per year less the wastes produced that are recycled or reused. This includes household, industrial, mining and agricultural wastes of which only a small portion are recycled
old-growth forests	forests dominated by mature trees and with little or no evidence of any disturbance such as logging, road building or clearing
ozone depletion	a disturbance of the natural equilibrium between chemical reactions forming and destroying stratospheric ozone; caused by the release of manufactured chemicals
ozone layer	a region in the stratosphere where there is a small, but significant, amount of ozone
percentile (as in mathematics)	represents the relative position or rank of each priority score (along a 100 percentile band) among the scores assigned by a particular study section.
photochemical smog	air pollution caused by chemical reactions among various substances and pollutants in the atmosphere in the presence of sunlight; ozone is a major constituent
PM_{10} and $PM_{2.5}$	particles with aerodynamic diameters of up to 10 µm and 2.5 µm, respectively
point-source pollution	pollution from an easily discernable, single source such as a factory or sewage treatment plant
potable water	water pure enough for humans to drink
potential evaporation	the amount of evaporation that would occur if a sufficient water source were available. Surface and air temperatures, solar radiation, and wind all affect this
Ramsar Convention	the Convention on Wetlands, signed in Ramsar, Iran, in 1971 providing the framework for the conservation and wise use of wetlands and their resources. There are presently 122 Contracting Parties to the Convention, with 1031 wetland sites, totalling 78.2 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance. Wetlands are referred to as Ramsar wetlands if they are included in the Ramsar List
rangelands	native grasslands, shrublands and woodlands that cover a large proportion of the arid and semi-arid zones, and also include tropical savanna woodlands; regular cropping is not practised and the predominant agricultural use, if any, is grazing by sheep and cattle on native vegetation
Register of the National Estate	a national inventory of places of natural, historic and Indigenous heritage significance, deemed to be worth conserving for present and future generations
re-snag	the process of replacing natural river snags and large woody debris to encourage freshwater fish habitat rehabilitation

riparian vegetation	plant communities on the fringes of and adjacent to water bodies
river salinity	concentrations of salt in rivers and creeks caused by saline discharges from dryland, irrigation and urban salinity
runoff	the portion of rainfall not immediately absorbed into the soil and which becomes surface flow
salinisation	the process by which land becomes salt-affected
sand slug	large deposits of sand or other fine material in the beds of rivers. The material comes from gully erosion in the catchment. These sand deposits fill up the river channel, alter the original form of the riverbed and move slowly downstream if flooding occurs
salinity	the concentration of salts in water and/or soil
sea-cage	sea-cages are square or circular, floating pens used for commercial farming of marine animals such as southern blue fin tuna
sea change	a fundamental lifestyle change and accompanying relocation to certain non-metropolitan areas on the coast
seagrass	intertidal and subtidal flowering plants found mainly in shallow waters of protected coastal areas
semi-arid zone	an area where rainfall is so low and unreliable that crops cannot be grown with any reliability (see also arid zone)
soil acidity	a condition in which the surface soil pH has declined to less than pH 5.5 as a result of human activity (such as agriculture)
Southern Oscillation	a fluctuation in atmospheric circulation, in particular over the tropical areas of the Pacific and Indian oceans; in general, when atmospheric pressures are high over the eastern Pacific Ocean they tend to be low in the eastern Indian Ocean and vice versa; the fluctuation between the two produces a marked variation in parameters such as the sea surface temperature and rainfall over a wide area of the Pacific and has a cycle of two to seven years; the phenomenon is influenced by the El Niño
sustainable	with respect to an activity, able to be carried out without damaging the long-term health and integrity of natural and cultural environments
threatened	of or relating to a species or community that is vulnerable, endangered or presumed extinct (as defined in the *Environment Protection and Biodiversity Conservation Act 1999*)
threatening process	a process that threatens, or may threaten, the survival, abundance or evolutionary development of a native species or ecological community
tree change	a fundamental lifestyle change and accompanying relocation to certain non-metropolitan areas, especially localities within striking distance of the bigger cities
turbidity	the extent to which the passage of light through water is reduced by suspended matter

urban form	the pattern of development in an urban area, including urban density, land use, centres and degree of development at the edge
urban water supply	a typical urban water supply system begins at the catchment source such as a river. Water is pumped from the source to a treatment plant where sediment and contaminants are removed and chlorine disinfection kills microbiological organisms. Water is distributed via localised storage tanks and pipes to the community.
urban stormwater	urban stormwater is runoff from urban areas, including the major flows during and following rain as well as dry weather flows
volatile organic compound (VOC)	carbon-containing compounds occurring in ambient air as gases or vapour with boiling points between 50°C and 260°C. The VOCs that participate in smog formation reactions are called reactive organic compounds (ROCs) (eg benzene, xylene and toluene).
wastewater	water that has been generated or used by humans, or in industrial processes
World Heritage sites	sites of outstanding universal natural or cultural significance that are included on the World Heritage List

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