■ *Acropora* coral reef, Great Barrier Reef, Queensland

Photo by Gary Bell

Marine
environment

6

Key findings

The overall condition of the Australian marine environment is good.

Compared with the marine waters of other nations, Australia's oceans are considered as being in good condition. This is a testament to the limited pressures of the past century, combined with relatively good management of high-priority and emerging issues in recent years.

Areas near the coast are suffering.

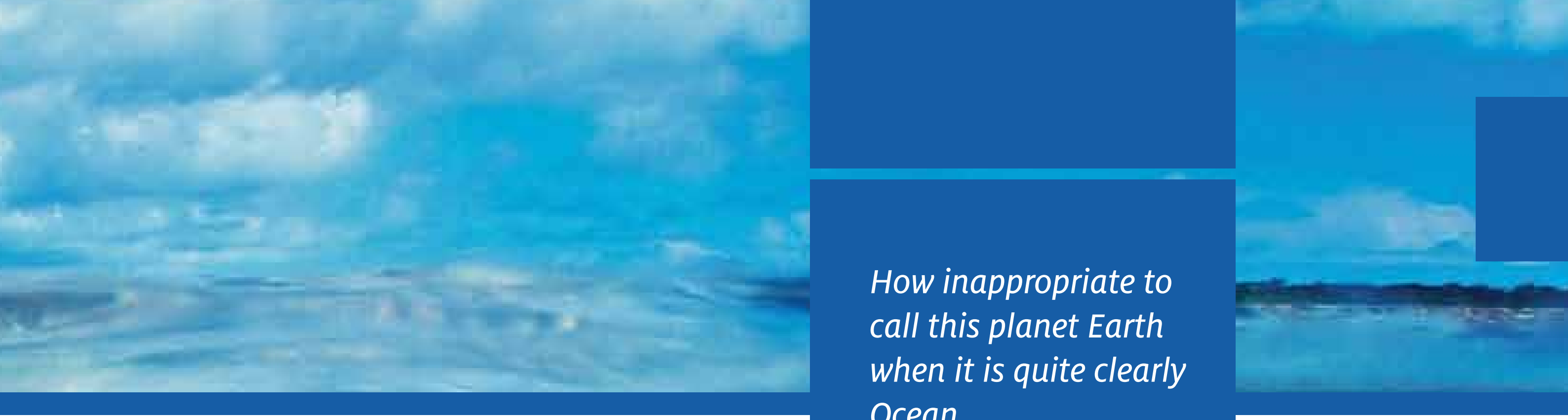
Despite the overall good condition, there is substantial degradation in the east, south-east and south-west. Ecosystems near the coast, bays and estuaries in these regions are in poor to very poor condition. Much of the impact occurred in the mid-19th and 20th centuries, and the recent impacts principally arise from unregulated human activities in river catchments, urban and coastal developments, and fishing. Aquaculture in coastal waters has resulted in major disease outbreaks that have affected the ecology of native species. Oyster reefs, which formerly occurred in many estuaries across the south-east region, were mined for lime in the 1800s and are now functionally extinct. There are also major new pressures developing for these coastal waters, including the impacts of the changing climate.

There are significant existing impacts on the oceans caused by human activities.

Fishing and offshore developments, particularly oil and gas extraction, all have local impacts on marine biodiversity. The pattern of impact is different between the north and the south, and between the east and the west—aligned with the distribution and intensity of the pressures.

An extended continental shelf has been granted.

Under the provisions of the United Nations Convention on the Law of the Sea, in 2008 Australia was granted a large (23%) increase in the seabed territory it controls. This is now 13.86 million square kilometres—the third largest national marine territory in the world's oceans.



> *How inappropriate to call this planet Earth when it is quite clearly Ocean.*
>
> Arthur C Clarke, *Nature*, 8 July 1990

The ocean climate is changing and we need to prepare to adapt.

Changes in the world's climate are affecting Australia's oceans. There are likely to be major impacts in the coming decades from increasing sea level, increased severity and incidence of extreme weather events, altered ocean currents and associated changes in productivity, increasing acidity of the oceans (resulting from higher carbon dioxide levels), and changing patterns of biodiversity and productivity in nearshore waters. Although there are currently only limited signs of changes in ecosystems, these will develop further and have important consequences for our coastal communities, wildlife and fishing. Planning to cope with these incremental impacts will require considerable strategic investment and leadership from governments working with communities and the private sector.

Our understanding of major aspects of our unique biodiversity is limited.

Our knowledge of seabed geology and topography, oceanographic systems and physical processes has increased, but our knowledge of biodiversity and ecological processes remains limited. Ongoing research programs in marine biodiversity and ecological function are a high priority and, because our existing knowledge base is dominated by information about fished species, it is particularly important to increase our understanding of non-exploited species and their roles in maintaining healthy and resilient ocean ecosystems.

The lack of a nationally integrated approach inhibits effective marine management.

The cumulative pressures on our marine ecosystems are rapidly growing. Impacts from climate change are beginning to escalate, population pressures and coastal development continue to grow, globalisation of marine industries continues, the risks to tropical waters from oil and gas developments are increasing—but our understanding of how ocean ecosystems operate is still very limited. In addition, present-day management systems lack integration among the various federal, state and local government systems that provide for planning, regulation and management of the marine and estuarine waters. These weaknesses significantly impede the design and delivery of efficient and effective policies and programs to maintain healthy and productive marine ecosystems and oceans. Foremost among the many issues is the lack of an integrated national system for assessment and reporting of marine condition. Without an integrated and genuinely national system of multilevel governance for conservation and management, it will be difficult to properly maintain the natural wealth of our oceans in the face of the challenges ahead.

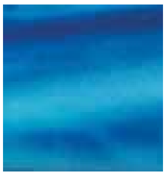
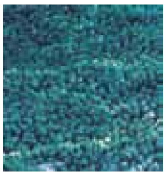
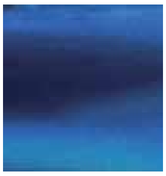
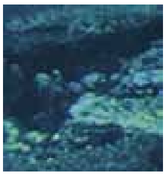
Contents

Pouring forth its seas everywhere, then, the ocean envelops the earth and fills its deeper chasms.

Nicolaus Copernicus,
On the revolutions of the celestial spheres, 1543

Australian sea lions (*Neophoca cinerea*), Hopkins Island, South Australia
Photo by Michael Patrick O'Neill



1

Introduction

Our coastal lands and waters, beaches, bays and inlets hold a special place in Australian culture—for many, the coast is a defining attribute of what it is to be an Australian. Australia's vast ocean territory offers the opportunity to generate wealth, as well as the concomitant responsibility for conservation, management and sustainable use of the environment and living resources.

The majority of our cities and smaller coastal communities rely heavily on coastal waters for economic and recreational pursuits, coastal shipping, energy production and seafood products. Land near the coast—with ocean views and breezes, and easy access to waterways, walks, swimming and surfing beaches—commands a premium value everywhere. The ocean is the inspiration for contemporary music, film, books, stories and legends. The commercial opportunities in tourism, recreational fishing, water sports and the amenity of coastal waterfront lands drive the development patterns of our coastal cities and major towns.

Outside the towns and cities, our natural treasures—such as Fraser Island and the Great Barrier Reef in Queensland; Lord Howe Island and Jervis Bay in New South Wales; the Great Australian Bight in South Australia; Shark Bay, Ningaloo Reef and the Kimberley coast in Western Australia; and many more—stand as icons of Australia's national identity.

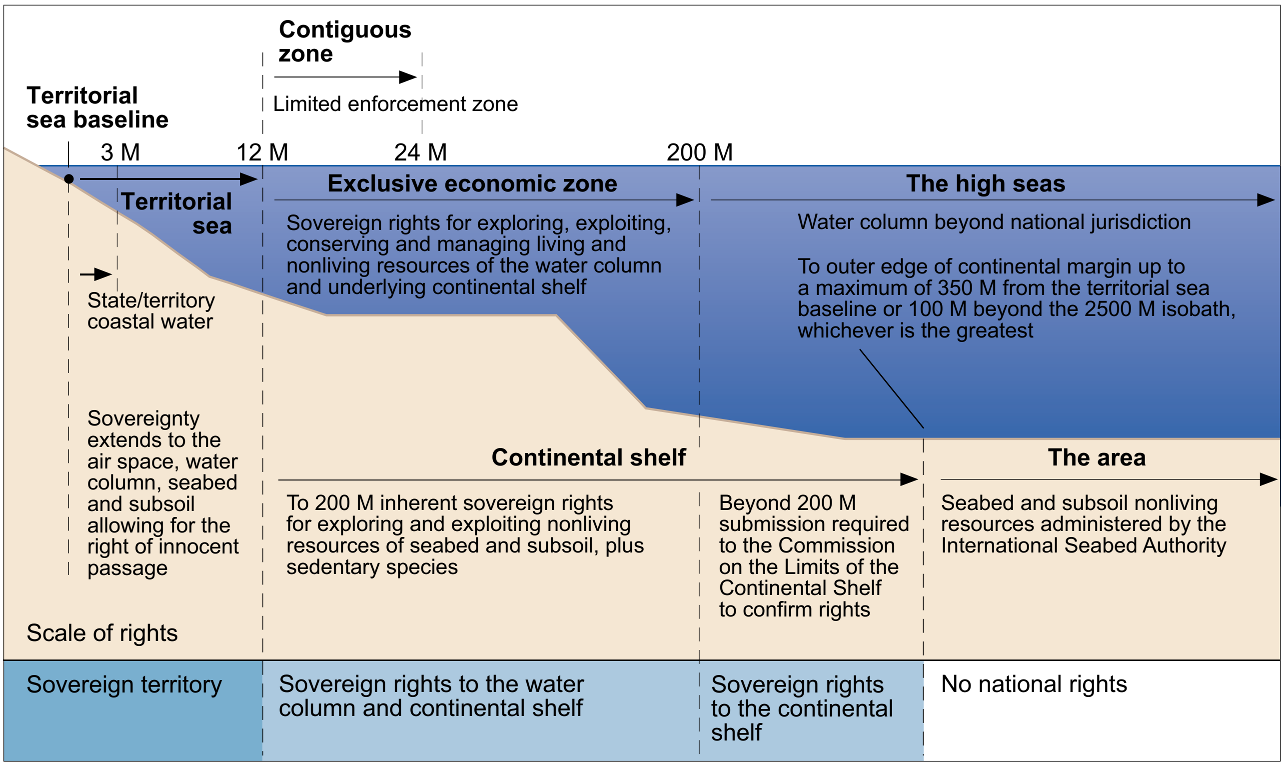
1.1 The jurisdictions

Australia's marine environment extends from the landward limit of marine waters (which, in many places, is the high tide level) along the coastline of the continent and islands to the deepwater outer limit of the continental shelf, as recognised by the United Nations Convention on the Law of the Sea (UNCLOS) in 2008. This includes parts of the Indian, Southern and Pacific oceans. The outer boundary of the Australian marine jurisdiction adjoins boundaries of other countries, mainly in the north and east, including France, Indonesia, New Zealand, Papua New Guinea, the Solomon Islands and Timor-Leste. In the west and south, Australia's outer marine boundary mainly meets international waters—the high seas.

Management of Australian waters is divided into a number of complex administrative zones, reflecting the role of state and territory governments in the nearshore waters, and the terms of international agreements and conventions, principally UNCLOS, in the offshore waters (Figures 6.1 and 6.2). The two main zones of management are the three-mile zone and the 200-mile zone. The three-mile state waters zone (which is not a zone recognised by UNCLOS) extends from near the shoreline to approximately three nautical miles offshore. In 1983, title to the seabed, rights to the water column and some legislative powers in this zone were granted to the adjacent state or territory under the Offshore Constitutional Settlement. Full responsibility for the marine seabed and the waters between the three-mile zone and the 200-mile zone—the territorial sea and the exclusive economic zone (EEZ)—remains with the Australian Government.

On 9 April 2008, the United Nations Commission on the Limits of the Continental Shelf confirmed Australia's entitlement to an area of continental shelf that extends beyond the EEZ, known as the extended continental shelf (ECS). When this is proclaimed, it will increase the size of Australia's marine jurisdiction by around 2.56 million square kilometres. Australia's marine jurisdiction (including the ECS of the mainland and islands, but not the ECS of the Australian Antarctic Territory, the claim for which is disputed by several countries) will then cover around 13.86 million square kilometres—nearly twice the size of the Australian landmass and islands. As a result, Australia will have stewardship of approximately 3.8% of the world's oceans, one of the top three in area in the world, along with the United States and France.[1] The seabed and all the living and nonliving resources of the ECS, but not the water column and its resources, will be under the control of the Australian Government.

In December 1998 the Australian Government released a national Oceans Policy for implementation through regional marine plans, to provide a basis for integrated management of Australia's oceans. This has been superseded by a series of bioregional marine plans being established under the *Environment Protection and Biodiversity Conservation Act 1999* to provide an ocean planning system with a legislative base, although the plans themselves are not legislative instruments. These bioregional plans apply to the waters of the EEZ and the territorial sea, but not to the state and territory coastal waters as was envisaged by Australia's Oceans Policy and the intended regional marine plans.[2-4]



1 nautical mile (M) = 1852 metres

Source: Adapted from Symonds et al.[1]

Figure 6.1 Jurisdiction zones for Australia's marine environment

■ Territorial sea and internal waters

■ Australia's exclusive economic zone as defined by the United Nations Convention on the Law of the Sea and certain treaties (not all in force)

■ Australia's extended continental shelf (ECS) beyond 200 nautical miles as confirmed by the Commission on the Limits of the Continental Shelf and as defined by certain treaties (not all in force)

■ Australia's ECS considered by the commission and yet to be resolved

■ Australia's ECS off Antarctica as submitted on 15 November 2004 to the commission that Australia requested not be considered for the time being

🟨 Joint Petroleum Development Area as defined in the Timor Sea Treaty between Australia and Timor-Leste

— Treaty boundary with opposite or adjacent state

AAT = Australian Antarctic Territory; FR = France; NOR = Norway; NZ = New Zealand; PNG = Papua New Guinea

Source: Symonds et al.[1]

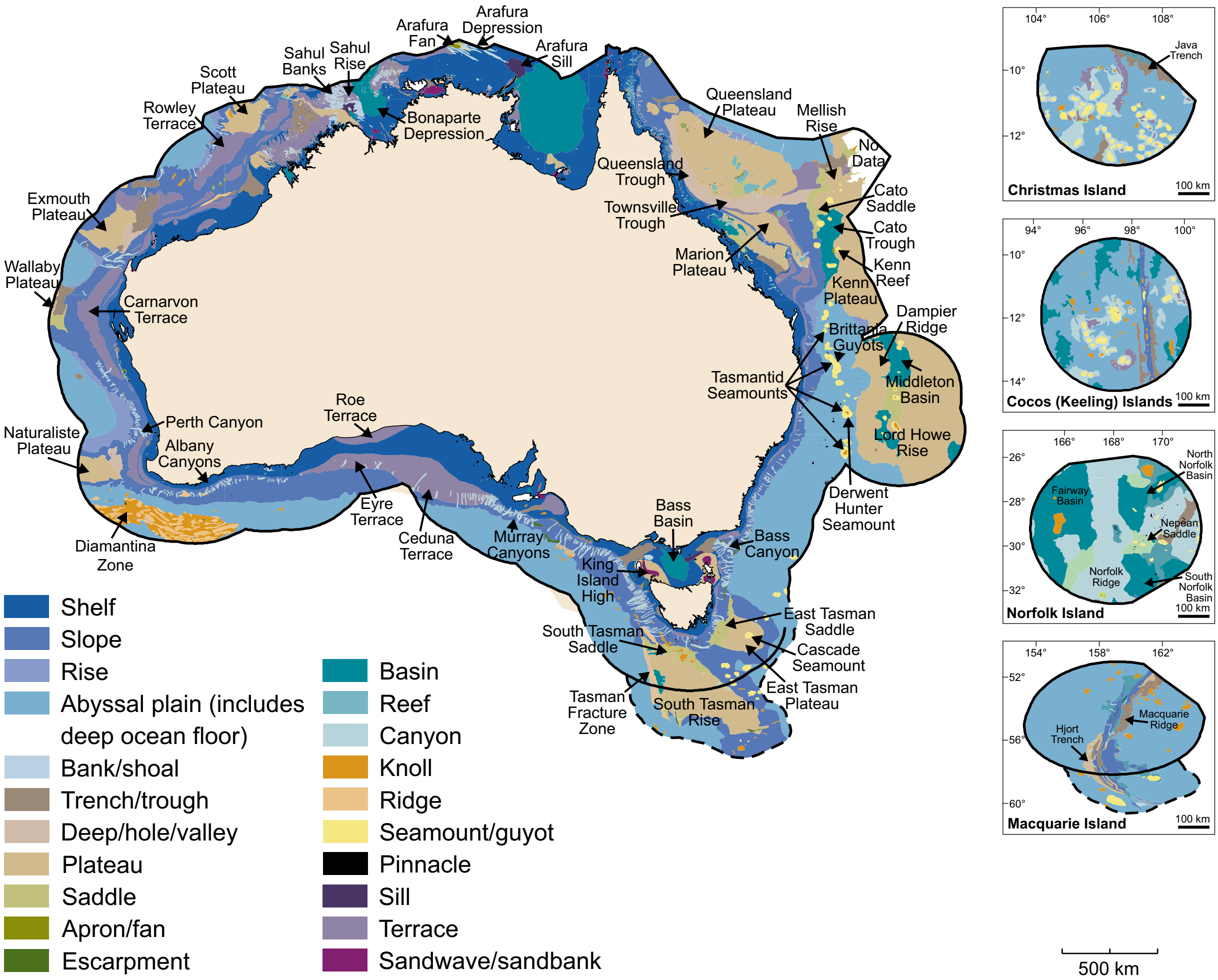
Figure 6.2 Zones and limits of Australia's marine jurisdiction

1.2 The seabed

The seabed of Australia's marine jurisdiction is diverse and complex, reflecting the large area it covers and its span from the tropics to the Antarctic, with many coastal and offshore islands and their fringing geomorphic structures. The continental mainland has a coastline of around 36 000 kilometres, and spans more than 5000 kilometres from the tropics (9°S) to temperate latitudes (47°S).

Recent mapping of nearly 50 million square kilometres of the seabed in our region has identified 21 types of geomorphic features. These include major features such as the continental shelf, slope, plateaus and abyssal plain (bottom of the deep ocean at a depth of more than 2000 metres); and smaller features such as basins, terraces, reefs and seamounts (Figure 6.3). The geomorphology at the margin of the continent is the most complex aspect of the region and includes marginal plateaus, terraces, trenches, troughs and submarine canyons. The plateaus along the Australian margin cover around 1.5 million square kilometres—20% of the total world area of marginal ocean plateaus.[5] The great diversity of geomorphic structures provides an equivalent diversity of habitat types for animals and plants that live on, or are closely associated with, the seabed.

Broadscale mapping of seabed environments into a series of 'seascapes' has uncovered great diversity in Australia's marine jurisdiction, including aspects of



Source: Heap & Harris[5]

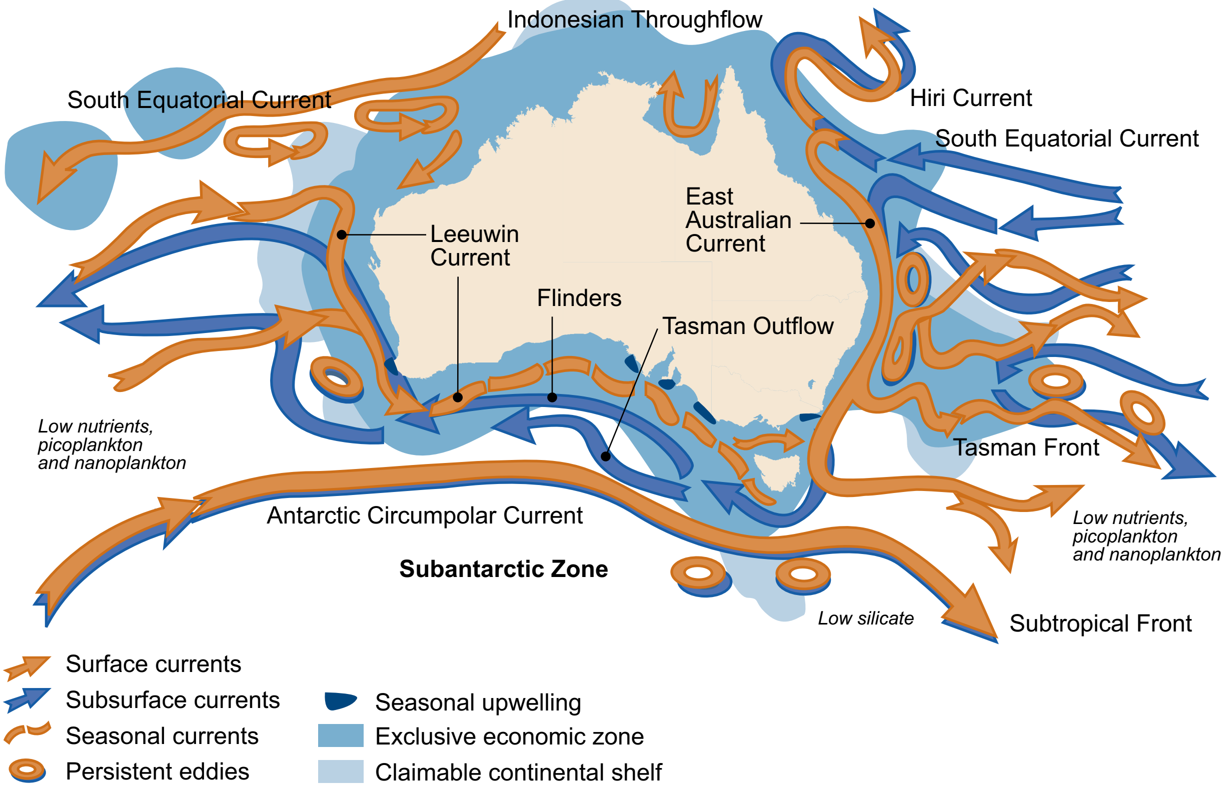
Figure 6.3 Geomorphic features of the Australian margin and adjacent sea floor the seabed that may be important for conservation and biodiversity management. These seascapes combine aspects of water depth, sediment type, geomorphology, sea-floor temperature, disturbance by tides and waves, slope of the seabed and amount of primary production. These parameters are related in complex ways to the distribution of biodiversity, so areas where there are many seascapes might also be areas with a high diversity of species or ecological communities.[6]

In coastal waters, recent studies have revealed the complex interplay between sediment types, local geomorphology and ocean conditions, producing a classification of sediment compartments that describe the structure of coastal seabed systems. The compartments broadly reflect the vulnerability of coastal seabed and beach systems to ocean-driven change, and therefore contribute to regional development planning and conservation activities.

1.3 Structure of the oceans

Australia is heavily influenced by four major ocean currents (Figure 6.4):

- The East Australian Current flows southward along the east coast of Australia from near Fraser Island in Queensland to Tasmania. It is an important feature of the Tasman Sea between Australia and New Zealand, and generates large eddies that peel off the main current as it moves south.
- The Leeuwin Current forms near the North West Shelf and breaks into a series of eddies as it travels south along Australia's west coast, eventually dissipating in the Tasman Sea and Southern Ocean. It is the longest coastal current in the world and has a major influence on the weather in Western Australia and the distribution of marine life.



Source: Adapted from CSIRO in Australian Government Department of the Environment, Water, Heritage and the Arts[7]

Figure 6.4 The major ocean currents and features influencing Australia's marine environment

- The Indonesian Throughflow is a system of currents that carries water westward from the Pacific Ocean to the Indian Ocean through the Indonesian Archipelago. Beyond Australia, the throughflow is a critical element in the global climate system because the heat it carries from the tropical Pacific Ocean into the Indian Ocean affects regional sea surface temperatures and rainfall, including the Asian and Australian monsoons.
- The 20 000-kilometre-long Antarctic Circumpolar Current is considered to be the powerhouse for global climate. It connects the Atlantic, Pacific and Indian oceans with an eastward flow equivalent to 150 times the combined flow of all the world's rivers. The current comprises merging and separating jets between different masses of water—the subtropical front and the subantarctic front. This turbulent region, well south of Australia, is characterised by high ocean nutrient levels and primary production, and typically hosts large aggregations of krill, migratory fish, birds and marine mammals.

Together, these four major currents have a driving influence on the conditions and biodiversity in our oceans and coastal environments, and on Australia's climate.

Along with the major ocean basin currents and the continental currents, there are a number of smaller and more complex current systems. All these ocean features can change from season to season, and may be more or less extensive and energetic, depending on climate factors that influence the oceans at the scale of the whole ocean basin.

1.4 Biodiversity and productivity

The coastal waters of Australia are generally low in nutrients all year round and are not highly productive (exceptions to this are the shallow waters of the tropics and the shallow shelf and gulf systems, such as Torres Strait). This means that the diverse species and ecosystems of these waters are very sensitive to the addition of even small amounts of land-derived or ocean-derived nutrients, and disturbances of the seabed that resuspend nutrients.

The low nutrient status of our waters is a result of the limited penetration of nutrient-rich deep ocean currents into shallow coastal waters where there is enough sunlight to drive primary production (where organisms such as phytoplankton use solar energy to convert carbon dioxide and nutrients into new organic materials). As a result, Australia's oceans do not support a large biomass of fish or dependent predators, as occurs in waters off South Africa and South America. However, in the high density of canyons along the edge of the continental shelf, there are areas that experience periodic small intrusions of deep, cold ocean waters. These canyons and shelf-edge features are therefore small hot spots that are rich in diversity and biomass of invertebrates, fish, and their prey and predators. For example, the line of shelf-edge canyons on the west coast of Australia and their associated production systems are thought to support the 'whale highway'—the annual migration pathway of humpback whales from the Antarctic to their calving grounds in the warm tropical waters of the Kimberley region. A cold-water upwelling system (where sea water rises from the depths to the surface, typically bringing nutrients to the surface) also regularly occurs along the west coast of Victoria and near South Australia's Kangaroo Island, extending to the Eyre Peninsula.[8]

Elsewhere, the remoteness, diversity of habitat types and low-nutrient waters have created highly diverse flora and fauna. Many areas have locally endemic (unique to the region) species, and assemblages of low species diversity that are unique and highly ecologically valued. For example, the tropical, subtropical and temperate reefs, shelves, bays and gulfs around the Australian coast are home to a rich diversity of species and ecosystems. At different times of the year, depending on river inputs and coastal run-off, these coastal features can be dominated by turbid and productive waters or, alternatively, by clear waters with low nutrient status. The flora and fauna of these areas are specialised and resilient to such variable coastal conditions. The Australian waters have a high number of endemic species, particularly in the southern regions that are most isolated from other land masses in the Pacific and Indian oceans.[9-10]

While our knowledge of the distribution and taxonomy of Australia's marine biodiversity (particularly the invertebrates) remains patchy, the recently conducted Census of Marine Life[10] summarised our knowledge of animals from the major marine biodiversity databases. The census found approximately 33 000 marine species that were confirmed to occur in Australian waters; of these, 130 species are introduced, 58 are listed as threatened, and an unknown (but likely to be large) number of species are endemic. Levels of endemism are low in the tropics because many species also occur across the broader Indo–West Pacific region but, in the temperate waters of southern Australia, endemism is likely to be high (possibly up to 90%). Although the taxonomy of marine plant species is reasonably well known, particularly for the 75 species of seagrasses and mangroves, they are not well represented in the national biodiversity database systems that describe their distributions.

The marine animal species confirmed to occur in Australian waters are dominated by molluscs (8525 species), crustaceans (6365) and fish (5184)—a pattern that is consistent across all the world's oceans.[11] A further estimated 17 000 species are likely (reported but not confirmed) to occur in our waters, including the many soft-bodied pelagic and benthic (sea-floor) invertebrate species (such as worms) that play important ecological roles. Crude estimates based on the rate of biological exploration and discovery suggest that the total number of marine species (those known to occur, likely to occur and yet to be discovered) in Australian waters is around 250 000 macroscopic species, and many more if microscopic species are included.

1.5 Uses and values

Australia's oceans inspire many of our social and cultural values, and the marine sector contributes significantly to the national economy through energy and food production, recreation and tourism. A recent evaluation of Australia's marine industries showed that the sector provides at least 4% of gross domestic product and is undergoing rapid growth, increasing by approximately 50% since 2000 and conservatively valued at $48 billion in 2007–08. This estimate did not include a number of emerging industries, such as seabed mining, carbon capture, desalination, tidal and wave power, or the use of marine organisms as the source of new materials or pharmaceuticals.[12]

1.5.1 Oil and gas

The economic backbone of the marine sector is the oil and gas industry. More than 90% of Australia's liquid hydrocarbon and 74% of the nation's natural gas production is extracted from ocean areas. The annual value of this activity was estimated at around $22 billion in 2007–08.[12] Increasing global demand for energy and fewer discoveries of new oil and gas fields are increasing the pressure for further exploration and extraction within Australia's EEZ and ECS. Associated with this challenge is the need for novel extraction technologies to increase recovery rates and safety of extraction, capture and storage of carbon; more onshore and floating processing plants; new shipping facilities; and higher standards of environmental protection.[13] Oil and gas production in Australia is concentrated in the north-western and southern regions (Figure 6.5).

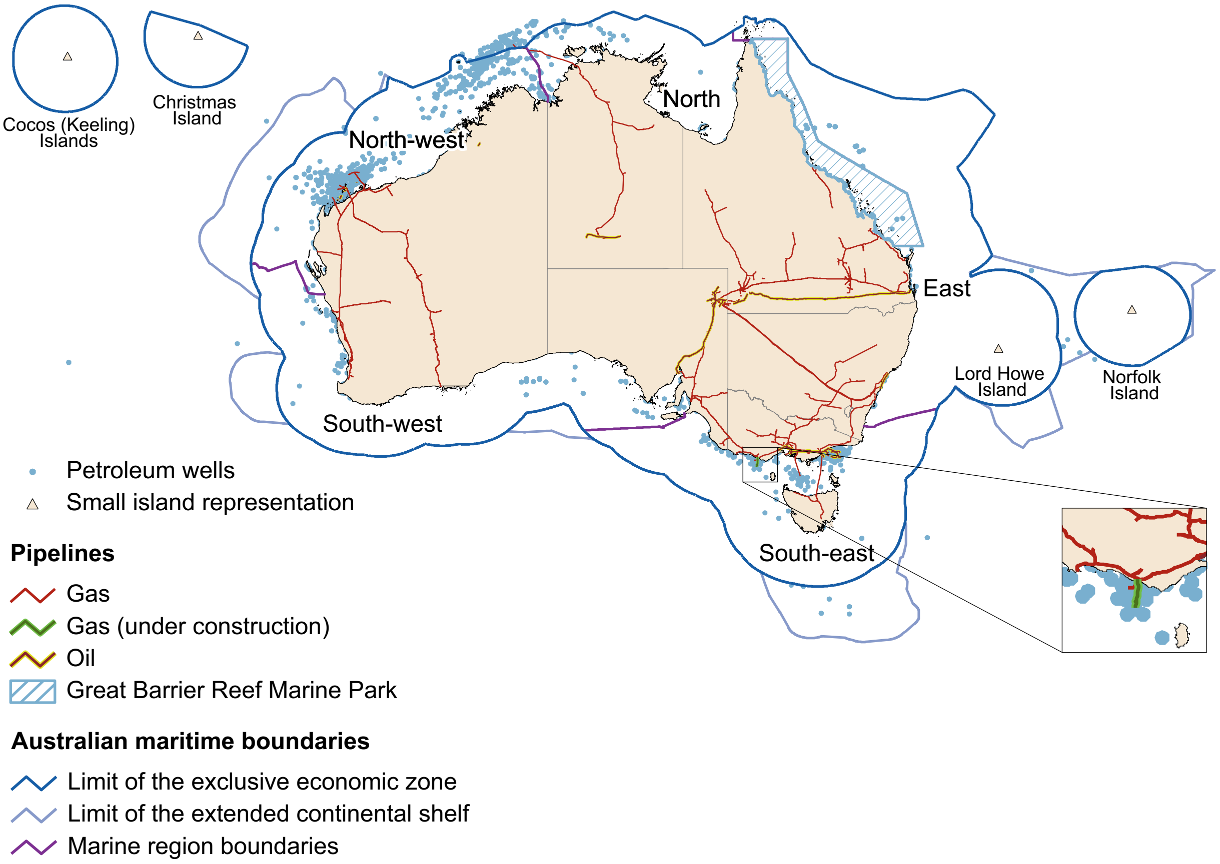
1.5.2 Fisheries and aquaculture

Although considerably smaller in economic value than oil and gas, the coastal fisheries and aquaculture sector is the mainstay of Australia's renewable marine resources. The gross value of production (GVP) in 2008–09 was $2.2 billion, from a production of 238 000 tonnes of seafood. The majority of the sector—86% of the value of commercial fisheries in 2008–09—is managed by state and territory agencies. These commercial fisheries focus on several hundred high-value, but low-yield, marine species and products. For example, the New South Wales commercial wild-catch sector in 2008–09 was valued at approximately $93 million,[16] based on around 100 species of fish and invertebrates (mostly low-volume products considered to be currently fished to their maximum capacity).[17-18] The highest value production is the Atlantic salmon aquaculture industry (GVP of $323 million; 15% of the total seafood value in 2008–09), and the largest wild-catch fishery is for Australian sardines (31 500 tonnes, 13% of the total wild catch in 2008–09),[16] much of which is used as fish food in aquaculture.

Australia's overall seafood production over the decade from 1999–2000 to 2008–09 increased steadily for the first six years, rising from 223 000 tonnes in 1999–2000 to peak at 279 000 tonnes in 2004–05. Production remained relatively stable for the period 2005–06 to 2008–09, at an average of 242 000 tonnes per year (Figure 6.6). Production from our wild-catch fisheries increased initially from 2001–02 until 2004–05, but then declined subsequently to 2008–09.[16,19-20] Similarly, global catches have remained stable,[21] but stocks in wild-catch fisheries have declined.[22] The annual GVP of Australia's fisheries declined by 30% from 1999–2000 to $2.2 billion in 2008–09 (Figure 6.7).[16] Most of this decline in value was related to the decline in the GVP of the wild-catch sector from $2.5 billion in 1997–98 to $1.4 billion in 2008–09.[16] The main reason for this trend was a fall in prices for the major wild-caught species (rock lobster, prawns, tuna), but overall wild-catch production also fell significantly, from 236 864 tonnes in 2004–05 to 173 142 tonnes in 2008–09.[16,20]

Commonwealth-managed commercial fisheries are the responsibility of the Australian Fisheries Management Authority (AFMA), either directly, indirectly through joint management authority with a state or territory, or under international agreements on the high seas. The products of AFMA-managed fisheries include some of the better known species to be found in mainland fish shops, such as banana prawns from the Gulf of Carpentaria, flathead from the continental shelf waters off Victoria and scallops from Bass Strait. In 2008, there were 20 AFMA-managed fisheries targeting 98 stocks or species groups. Catch levels vary widely, depending on the area and target species (Figure 6.8). The AFMA fisheries are becoming better understood as a result of many years of significant investment in research and management. The condition of the Commonwealth-managed fisheries is assessed and reported annually by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, an independent research agency of the Australian Government).

In 2008, AFMA applied a new harvest policy[23] that seeks to manage each fishery so that fished stocks are generally maintained between two reference points—an upper-level 'target' biomass (population size to be achieved) that is considered to be a relatively safe level of biomass for the fished stock, and a low-level 'limit' biomass that represents a minimum permitted level. The setting of these



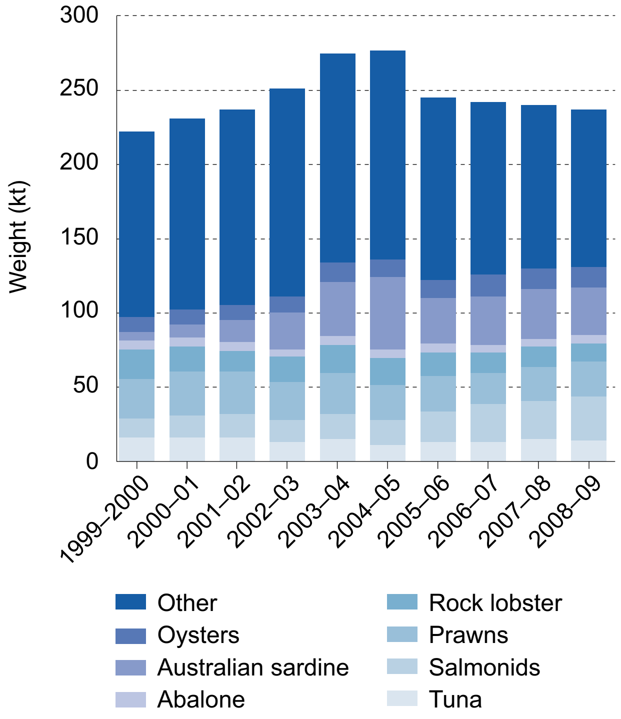
Source: Environmental Resources Information Network, Australian Government Department of Sustainability, Environment, Water, Population and Communities; Geoscience Australia[14-15]

Figure 6.5 National distribution of oil and gas facilities

The facilities shown within the Great Barrier Reef region are historical drilling sites on islands, and are not within the marine park.

target and limit reference points recognises that biomass is a central attribute of fish populations and an important metric to be tracked in management. While target and limit reference points are currently set mainly on the basis of economic yield, the stage is set for the future management of harvests so that both ecological and economic parameters can be considered simultaneously. The challenge for the wild-catch sector of all Australian jurisdictions is for ecosystem-based fisheries management to be developed and implemented in a way that protects the biodiversity values of the ocean ecosystems, as well as the harvests from fishable stocks. In particular, we need to avoid the pitfalls of 'Ludwig's ratchet',[24] in which fisheries overcapitalise in fishing technology and overexploit species to cover their debt, despite scientific evidence that stocks are declining. When the fishery is no longer economically viable, governments provide financial assistance to minimise economic hardship. When stocks increase, there is another rush to invest in yet newer technology, and the cycle repeats.

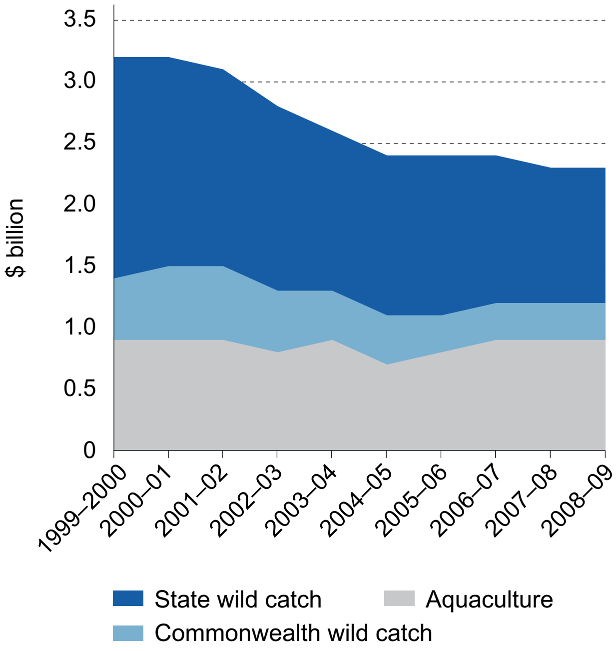
In 2009, the condition of 59 AFMA stocks was classified as not overfished, and 73 were classified as not suffering overfishing. Twelve further stocks were assessed as overfished (12%, reduced from 19% in 2004) and 10 as suffering ongoing overfishing (10%, reduced from 12% in 2004); there was too much



kt = kilotonne

Source: Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences[16]

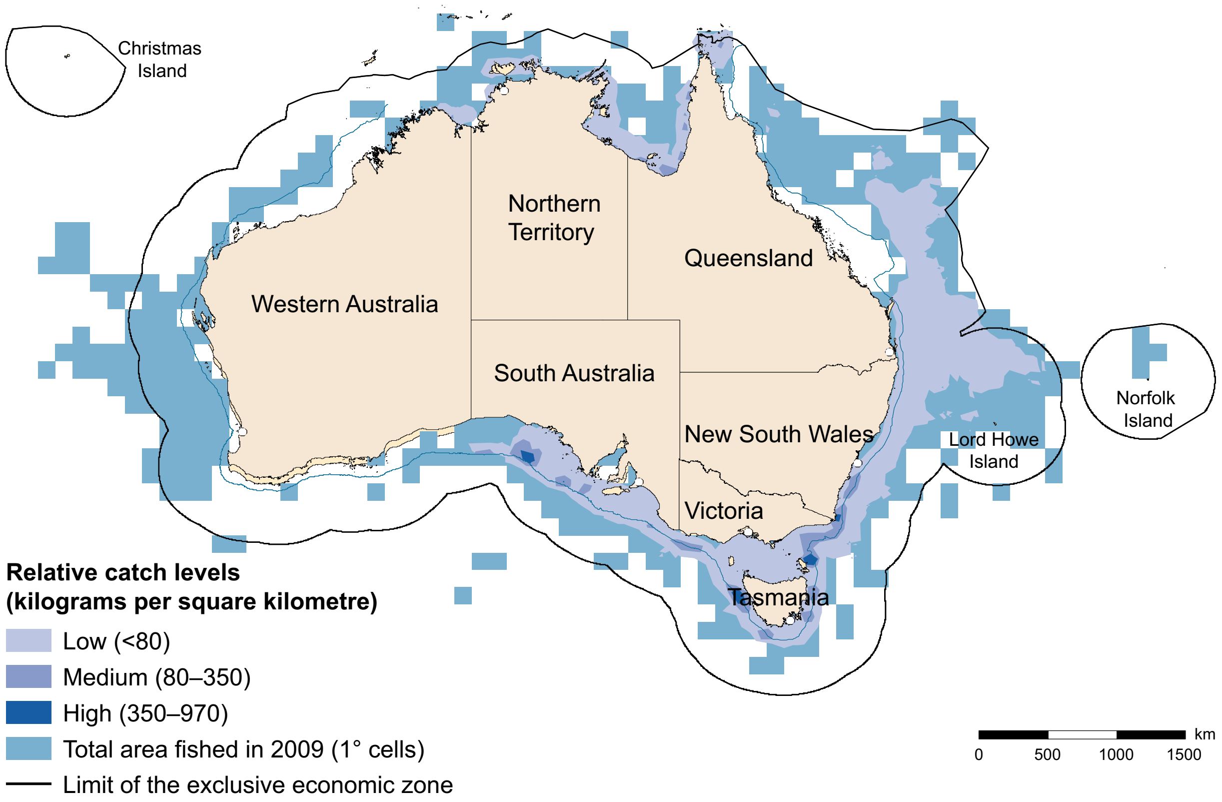
Figure 6.6 Australian fisheries production



Source: Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences[16]

Figure 6.7 Real value of Australian fisheries production by sector

The aquaculture total has been adjusted to exclude southern bluefin tuna caught in the Commonwealth Southern Bluefin Tuna Fishery that are used as stock for the tuna farms in South Australia, to avoid double counting.



Source: Wilson et al.[23]

Figure 6.8 Relative catch levels of all Commonwealth-managed fisheries, 2009

uncertainty to determine if the remaining 30 stocks were overfished or not. These figures show a steady improvement since 2004; however, some key stocks (such as school shark) remain in the overfished category and continue to require priority action.[23]

The number and identity of the AFMA stocks reported by the ABARES system have changed substantially since this form of reporting began in 1992. This has been generally positive, with new stocks being added to increase resolution of the reporting system. Updating by dropping stocks that are no longer important (two stocks reported in 1992 are no longer reported) risks confounding the capacity to assess long-term trends in fish populations and fishing activity, and is generally avoided.

1.5.3 Recreational and subsistence fishing

Beyond commercial fishing and aquaculture, recreational and subsistence fisheries form an important part of Australia's coast-focused culture and make a major contribution to the Australian way of life. The recreational amenities of many regional cities, coastal towns and (increasingly) remote communities are dominated by marine attractions and recreational fishing. No data are available for subsistence fishing, but it is likely to be difficult to separate from recreational fishing, since a significant portion of the recreational catch is consumed by fishers. For many of the highly sought-after species, recreational fish catches are likely to be larger than the commercial catches of the same species. Marine tourism and recreation, including fishing, were estimated to contribute $18.7 billion to the Australian economy in 2007–08[12]—about the same value as the oil and gas industry—and fishing is now considered to be the nation's largest participatory recreational activity.[25]

A recent study of recreational fishing in South Australian waters[25] found that approximately 16% of the population (about 240 000 people) participated in recreational fishing during the survey year (2007). Over the year, with a total fishing effort of around 1 million fishing-days, these fishers caught almost

10 million fish, crustaceans and molluscs, from 98 species. However, they also released large numbers of these fish. Release rates varied from less than 10% to more than 70%. However, there is little information about the subsequent survival rates, which may not be very high for some species. The survey also revealed that there had been a substantial decline in catches of six of the eight key recreational species since a similar survey in 2000, together with a 5% decline in participation and a 42% decline in fishing effort. Such declines in participation and effort may reflect reduced expectations of the fishers about the experience.

1.6 In this chapter

This chapter reports on the state of our vast system of marine waters and seabed. The present-day condition and trends for marine ecosystems, biodiversity and ecological health over the period 2005 to 2010 are assessed and reported in a standardised report-card system (assessment summaries), based on the expert judgement provided by a selected group of experienced Australian marine scientists at a series of national condition assessment workshops. The design, methodology and outcomes of the assessment workshop process are available on the State of Environment (SoE) website.[a] Supplementary materials for various sections of this chapter are also available on the website.

The chapter also examines the pressures for change that marine systems are experiencing and the risks they face in the near future. This information is used to project an outlook for the marine environment for the next 20–50 years. Some further important aspects of the marine environment are described and reported in Chapter 2: Drivers, Chapter 8: Biodiversity and Chapter 11: Coasts. The state of the waters of Australia's Antarctic Territory is reported in Chapter 7: Antarctic environment.

Barramundi aquaculture grow-out facility, Cone Bay, the Kimberley, Western Australia

Photo by Fran Stanley, Western Australian Department of Environment and Conservation

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[a] www.environment.gov.au/soe

2

State and trends of the marine environment

Australia's marine environment encompasses the structures of the seabed, ocean and shoreline systems, marine and estuarine waters, and their species and biological structure and function, all of which interact in a complex and interdependent web. Biodiversity and ecological health is assessed and reported here for:

- marine biodiversity
  - quality of marine habitats for marine species
  - populations of the main types of marine species
  - ecological processes that support biodiversity and habitats
- ecosystem health
  - quality of the physical and chemical processes that maintain the health of marine ecosystems
  - extent of diseases, algal blooms, pests and introduced species.

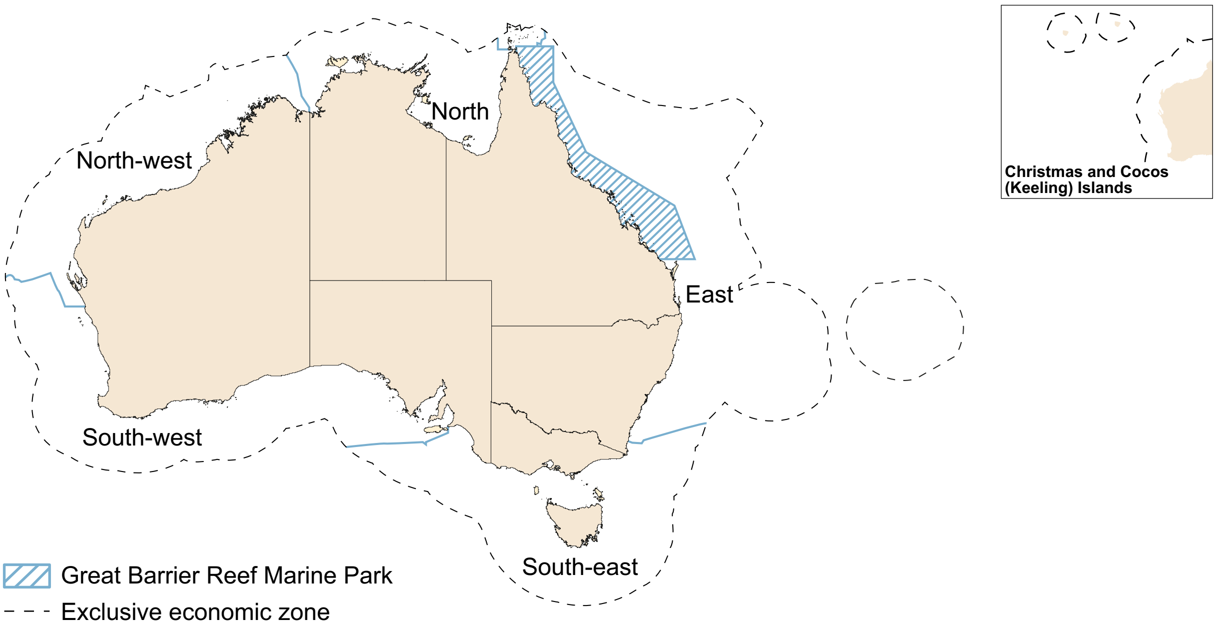
For this SoE report, the condition and trends for the main aspects of marine biodiversity and ecosystem health have been assessed within each of the major Australian marine regions (Figure 6.9). These five regions include the Australian Government's marine planning regions, the extended continental shelf, the offshore islands and territories (other than the subantarctic islands), and the state and internal waters, up to high tide level at the shoreline. The assessment of conditions reported here must be interpreted with caution, because studies and data directly relevant to the Australian marine environment are limited. The assessments reported here are derived from available data and information, and from the judgement of a limited number of experts who participated in the national marine condition assessment workshops that contributed to the analyses presented here.

At a glance

Marine biodiversity overall is in good condition, but nationally there are a number of areas on the coast, continental shelf and upper slope where the condition of some elements of biodiversity is very poor, as a result of the effects of specific human activities. Condition remains poor to very poor for a number of iconic species that have failed to recover from earlier impacts of excessive hunting and fishing, and some species continue to decline. These include Australian sea lions, which are unique to temperate southern Australian waters and are showing no substantial signs of population recovery from the hunting of previous centuries; and migratory wading birds, which appear to be continuing to decline across many of their Australian habitats. Southern bluefin tuna, formerly a major predator of our regional seas, has been fished to the edge of population survival but is now listed as conservation dependent under the *Environment Protection and Biodiversity Conservation Act 1999*; its global catch has been reduced, and a management procedure has been proposed that is intended to rebuild the population.

In addition to national-scale biodiversity problems, there are many more habitat and species issues in smaller local areas. These judgements are based on a generally low level of certainty, with most of the available knowledge linked to fished species and threatened species. A much more detailed national assessment of marine biodiversity is required to properly clarify the nature, extent and significance of the condition of our marine biodiversity.

The overall health of our marine ecosystems is good, but this finding is influenced by the good condition of the offshore waters and the remote coastlines of regions where pressures are lowest. In inshore waters near the coast of the south-west, east and south-east regions, and near urban areas and industrial developments, the ecosystems are in poor health. Algal blooms occur regularly; natural levels of freshwater, sediment and nutrient inputs have been heavily altered; and worrying levels of pesticides are found in waters near areas of intensive agriculture. The ecosystem health of some nearshore marine waters and many estuaries is poor, particularly across the temperate areas and in many parts of the south-east region. In this report, the south-east region is assessed to be in the worst condition: most places are good, but the worst 10% of the region is poor—existing values are significantly impacted, and serious further degradation is expected within 50 years.



Source: Environmental Resources Information Network, Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC); Geoscience Australia;[14–15] DSEWPaC[26–28]

Figure 6.9 State of the Environment reporting regions

These are the marine regions used for 2011 State of the Environment assessment and reporting. They are based on Australia's marine planning regions, but extend landward to the limit of the influence of marine waters.

2.1 Marine biodiversity

The status of marine biodiversity has been assessed by examining marine habitat quality, the species and populations, and the ecological processes that support the species and populations. These assessments of marine biodiversity are summarised for each region (the criteria used and detailed results are available on the SoE website[b]) and aggregated into a single national assessment and report card for biodiversity.

The overall assessment of biodiversity found that the north and north-west regions are in very good condition, the east and south-west regions are in good condition, and the south-east region is in poor condition, although bordering on good (Figure 6.10).

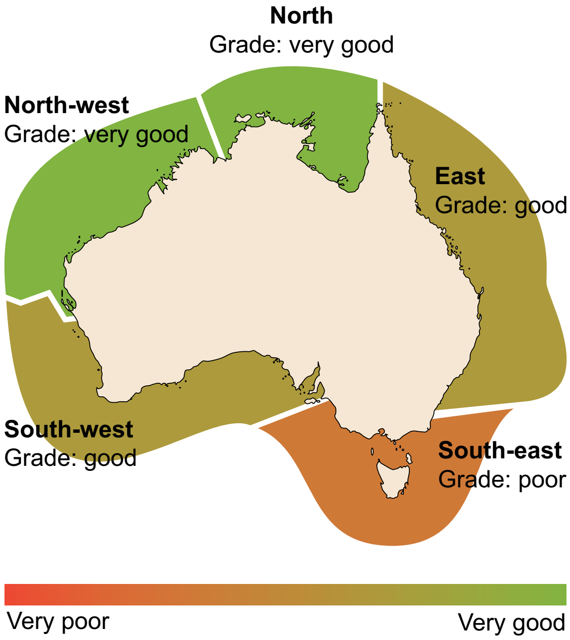


Figure 6.10 The overall condition of most components of biodiversity in each SoE reporting region

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[b] www.environment.gov.au/soe

2.1.1 Quality of habitats for species

Good-quality habitat is essential to support species populations and to allow natural ecological processes to operate. Habitat quality is defined using structural and functional intactness, relative to the conditions at the time of European settlement of Australia.

This section reports at the national level on our best understanding of the status and trends of marine habitat quality in 21 types of habitats that occur broadly and in more than one region, and 60 habitat types that occur principally in only one region.

South-west region

The habitats of the south-west region are overall in good condition. There are, however, a number of localised coastal areas of historical heavy impact where the effects remain—these include pollution and dredging of seagrass beds in Cockburn Sound, Perth; pollution-induced losses of seagrasses in Gulf St Vincent, Adelaide; and pollution of Albany harbours in Western Australia. Away from areas of coastal development or river run-off, many habitats remain in good condition. Water conditions overall are very good, particularly away from the shoreline. Conditions of habitats of the estuaries and lagoons of this region are considered overall to be very poor.

Seagrass beds are a dominant habitat in the south-west of Australia, occurring in many intertidal and subtidal areas of coastal waters and estuaries, and in offshore locations down to 50 metres depth. Seagrasses provide important habitat for many fish and invertebrate species, and they host important parts of the lifecycle of a number of fished species. Although two species of seagrass (*Posidonia sinuosa* and *P. australis*) are considered threatened or near-threatened with extinction,[29] in most places in this region seagrasses are in very good condition.

North-west region

The habitats of the north-west region are overall in very good condition. Much of this region is very remote (particularly the north) and, as a result, many habitats are considered to be very good and in nearly pristine condition. These include the large gulfs and bays, fringing coral reefs, and seagrass and algal bed systems of the Kimberley, and most of the offshore shoals and islands, canyons and shelf-break ecosystems of the region.

Some of the world's most extensive undisturbed tropical and subtropical habitats occur in the shallow waters of the Kimberley, Ningaloo Reef, Roebuck Bay and Shark Bay. Nonetheless, there are localised areas where the habitats are in very poor condition, such as near Dampier, Port Hedland and Onslow, where ports and shipping activities have heavily impacted coral and mangrove habitats. Offshore habitats are generally in good condition, although the deepwater corals and sponges of the North West Shelf are still considered to be heavily degraded and only slowly recovering from the extensive impacts of historical trawling, and some offshore islands have been heavily impacted by foreign fishing.

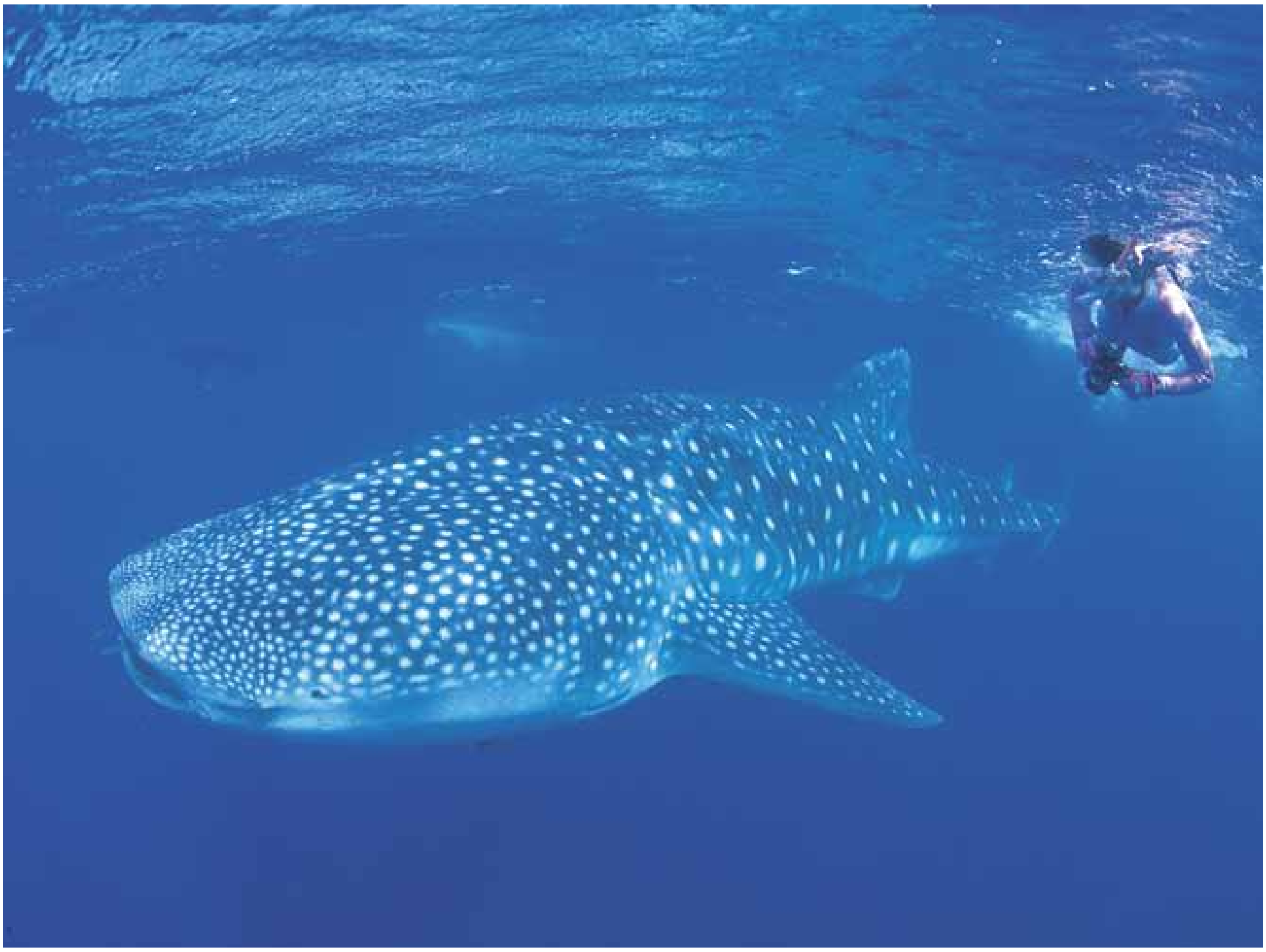
In the Kimberley, there are 343 islands with more than 20 hectares of land above mean high water, and many more smaller islands.[30] Almost all the islands have fringing reef systems of complex hard coral and algal (rhodolith) habitats. Most of these are remote from human influences and in very good and near-pristine condition.

North region

Like the north-west, the habitats of the north region are also remote and pristine tropical habitats, and most are considered to be in very good condition. These include the nearshore shallow-water marine systems, the extensive shoreline wetlands, and the bays and gulfs of the region. However, the pressures of coastal development are evident in some areas, such as Darwin Harbour and Melville Bay (Nhulunbuy, Northern Territory), where a localised, biologically dead area has been created by mining wastes. Most of the rivers are substantially unmodified. Exceptions are the Ord River, which is heavily modified by the Ord River Dam, resulting in substantial impacts on the estuarine habitats of the delta in Cambridge Gulf; and the Macarthur River, which is modified by mining.

East region

The east region includes the Great Barrier Reef, Torres Strait, the Coral Sea plateau and islands, Fraser Island, Sydney Harbour, Jervis Bay, and the many smaller islands, bays and estuaries of the New South Wales coast. Habitats of the northern part of the region are considered to be in good condition overall, despite considerable pressure from land-based sources of pollution. The Great Barrier Reef region has been considered in detail, and a condition assessment is presented in the *Great Barrier Reef outlook report 2009*.[31]



The world's largest fish—the filter-feeding whale shark (*Rhincodon typus*) with a diver, Ningaloo Marine Park, Western Australia
Photo by Tourism Western Australia

However, the habitats of the central and southern part of the region are more degraded, and many are considered to be poor. This is mainly the result of population pressures in coastal areas (such as in south-east Queensland and northern New South Wales), beach modifications, loss of major areas of seagrass and corals, historical effects of heavy trawling on the continental shelf, and major modification of rivers, some of which (such as the Tweed River) have significantly modified catchments for agriculture and altered freshwater flow regimes feeding to the estuaries and bays. Herbicides have been found in all water sampling sites in the inshore waters of the Great Barrier Reef and, in some places, are approaching levels that may have significant impacts on coral and other marine life.[32] In New South Wales, the seagrass *Posidonia australis* is proposed to be declared as an endangered species in six areas where it formerly occurred widely, because of various impacts (such as dredging and pollution) over the past decades.[33]

South-east region

The overall quality of habitat in the south-east region is poor; the pressures of population, shipping, fishing and development in many places have degraded habitats of inshore waters, bays and estuaries. This is the only region where a habitat type has been made functionally extinct by human activities—the oyster reef beds that formerly dominated a number of the estuaries and small bays were exterminated by mining and fishing practices by the end of the 1800s. Seven of the 11 formerly existing oyster reefs assessed are functionally extinct, while the remaining 4 were assessed as having more than 90% of their area lost.[34] This has had a significant impact on ecological systems, reducing habitat for many other species and probably greatly affecting the overall water filtering (purification) capacity of these affected areas and their capacity to assimilate nutrient inputs.

6.1 Assessment summary

State and trends of quality of habitats for species

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Gulfs, bays, estuaries, lagoons	South-east, south-west and east regions heavily degraded in many places; north region in very good condition			⊟		●	◒
Beaches	South-west and north regions in very good condition			⊟		◒	◒
Fringing reefs—corals, intertidal and subtidal, of coast and islands	East region in very poor condition			⊟		●	◒
Seabed inner shelf (0–50 m)	South-east and east regions in poor condition			⊟		◒	◒
Seabed outer shelf (50–200 m)	South-east and south-west regions in poor condition			⊟		◒	◒
Seabed, shelf break and upper slope (200–700 m)	South-east region in very poor condition				⊟	◒	◒
Seabed lower slope (700–1500 m)	South-east region in poor condition		⊟			●	◒
Seabed abyss (>1500 m)	Abyss depths in very good condition in all regions				⊟	◒	◒
Water column, shoreline (0–20 m), not estuaries	East region in poor condition			↙		●	◒

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Water column, inner shelf (20–50 m)	East region in poor condition				↙	◒	◒
Water column, outer shelf (50–200 m)	All regions in good or very good condition				—	◒	◒
Water column offshore (>200 m)	All regions in good or very good condition				—	◒	◒
Mangroves	East and south-east regions in poor condition			—		●	●
Seagrasses	East and south-east regions in poor condition				—	◒	◒
Algal beds	East and south-east regions in poor condition				—	●	◒
Coral reefs (<30 m)	North-west and north regions in very good condition			—		◒	◒
Deepwater corals and sponges (>30 m)	North and east regions in very good condition			—		◒	◒
Bryozoan reefs	Only assessed in the south-east region		—			◒	◒
Canyons and shelf break	South-east region in poor condition				—	◒	◒

Continued next page

State and trends of quality of habitats for species *continued*

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Seamounts (>1000 m rise from sea floor)	East region in poor condition			—		◒	◒
Offshore banks, shoals, islands	Only assessed in north-west and east regions			—		◒	◒
Regionally unique features	Assessed 60 individual habitat features that occur primarily in only one region				—	◒	◒

Recent trends

↗ Improving
— Stable
↙ Deteriorating
? Unclear

Confidence

● Adequate high-quality evidence and high level of consensus
◒ Limited evidence or limited consensus
○ Evidence and consensus too low to make an assessment

Grades

🟩	Very good	All major habitats are essentially structurally and functionally intact and able to support all dependent species
🟫	Good	There is some habitat loss, degradation or alteration in some small areas, leading to minimal degradation but no persistent, substantial effects on populations of dependent species
🟧	Poor	Habitat loss, degradation or alteration has occurred in a number of areas, leading to persistent, substantial effects on populations of some dependent species
🟥	Very poor	There is widespread habitat loss, degradation or alteration, leading to persistent, substantial effects on many populations of dependent species

2.1.2 Populations of species and groups of species

This section reports on our best understanding at the national level of the status and trends of 31 major populations and groups of marine species, including threatened species. Condition of the populations of species and groups of species is defined by the extent to which populations have declined because of human activities, relative to their condition at the time of European settlement of Australia. There has been no previous national synthesis of species condition, and the assessments reported here are derived from the national marine condition assessment workshops. The criteria used in the workshops are available on the SoE website.[c]

Species are threatened mainly by direct exploitation and by loss of, or changes in, their habitats. Future assessments of the condition of marine species will also need to consider the impacts of climate change on both the inherent biological properties of individual species and their preferred habitats. To enable accurate reporting of population conditions and trends, these future assessments will need to be conducted using more holistic ecological approaches to population condition assessment, such as those outlined for the coral trout and the butterflyfish in Box 6.5.[35]

South-west region

The populations of 16 of the 29 species and species groups assessed were found to be in poor or very poor condition in the south-west region—these were mainly the large species for which there was enough knowledge to be able to make a judgement. Species and groups considered to be in poor condition include exploited sharks and rays, whale sharks, great white sharks, exploited tuna and billfish, southern bluefin tuna, exploited species of reef fish, seabed species of the inner shelf, migratory seabirds, dolphins and porpoises, seals and sea lions, and baleen and toothed whales (although humpback whale populations are considered to be in good condition and strongly recovering from historical hunting). Invertebrate species, seahorses and their relatives, small pelagic fish, and sharks and rays that are not targeted by commercial or recreational fishers are considered to be in good condition.

Australian sea lions are endemic to this region. After intense hunting in the 1800s, their population still does not show any significant recovery. Increases have been documented only at Dangerous Reef in South Australia. Breeding colonies are substantially isolated from each other, and population recovery will continue to be a very slow process and subject to pressures of climate change and incidental mortality in fisheries.

North-west region

The populations of 15 of the 21 species and species groups assessed in the north-west region were found to be in good or very good condition. These include most of the shelf invertebrate species, the corals and shoreline species, dugongs, dolphins, humpback whales, crocodiles and sea snakes. Most of these groups that are in good or very good condition are considered to have stable populations. Nonetheless, the sea snakes at Ashmore Reef and the larger species of tuna and billfish across the region were considered to be in very poor condition. Also, across the region, large predatory reef fish (species targeted in commercial and recreational fisheries) were considered to be in poor condition overall.

Cod have been heavily fished in most of the southern parts of this region, including at Ningaloo Reef. Oral histories indicate that the populations that once existed are now largely gone, and the large, old fish no longer exist:

> ... cods were everywhere—there were hundreds of them there, and they were giving me trouble every day. One snuck up behind me and took a full bag of crayfish—and when I say a full bag I mean about eighty pounds of crayfish. When I looked around there was this big monster of a cod there and he had about a quarter of my bag in his mouth. *Farinaccio*[36]

North region

The species and their populations in the north region are considered to be overall in very good condition—14 of the 17 species and species groups were assessed as being in good or very good condition. The remoteness of the region and lack of major pressures indicate, with a high level of certainty, that many species and their populations have been only slightly changed from their likely condition at the time of European settlement. Nonetheless, a number of exploited populations could not be assessed, and their condition is likely to range

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[c] www.environment.gov.au/soe

from good to poor. Turtles and migratory seabird populations were considered to be in poor condition, mostly because of pressures on their populations outside the region, including internationally. Other species that occur in this region, such as the Indo–Pacific humpback dolphin and the Australian snubfin dolphin, are listed by the International Union for Conservation of Nature (IUCN) as near threatened.

East region

The species populations in the east region are overall in poor condition—20 of the 29 species and species groups assessed were in poor or very poor condition. The populations considered to be in the worst condition include the invertebrates and plant species of the dunes, shoreline and shallow inner-shelf waters; fish of the shallow-water reefs; migratory wading birds; sea snakes; dugongs; turtles; and whales. In some places, hard corals are considered to be in very poor condition. Within the Great Barrier Reef Marine Park, some of these populations are considered to be in good condition. The invertebrate species of the outer shelf and slope, the species of sharks and rays that are not targeted by fishing, and remote areas of the Coral Sea are considered to be in good condition across this region.

South-east region

The species populations of the south-east region are in poor condition overall—14 of the 24 species and species groups were assessed as being in poor or very poor condition. Populations considered to be in poor to very poor condition across the region include major predator species (such as great white sharks and southern bluefin tuna), species of the outer shelf and upper slope where intensive fishing was conducted in earlier years, inshore reef fish species, and species of seagrass and mangroves. The Oceania (south-west Pacific) subpopulation of humpback whales remains IUCN-listed as endangered.[37]

■ Schooling diagonal-banded sweetlips (*Plectorhinchus lineatus*), Great Barrier Reef, Queensland

Photo by Gary Bell

6.2 Assessment summary

State and trends of species populations and groups

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Sharks and rays	East, south-east and south-west in poor condition for some species (e.g. east coast population of grey nurse sharks)			—		◒	◒
Whale sharks	South-west in very poor condition		↙			◒	◒
Great white sharks	Condition continues to decline in the east		↗			◒	◒
Tuna and billfish	Condition very poor in the south-west and continuing to decline			—		◒	◒
Southern bluefin tuna	Condition very poor and stable	—				●	●
Outer shelf (>50 m)—demersal and benthopelagic fish species	Condition improving in all regions except the north-west, where the condition is generally stable but the worst areas continue to decline		↗			◒	◒
Inner shelf—demersal fish species	South-east in good condition and improving		↗			◒	◒
Slope—demersal fish species	Only south-east was assessed		↗			◒	●
Mesopelagic fish species	Only east and south-east were assessed				—	◒	◒
Small pelagics—inner shelf	South-east and south-west were assessed, with condition improving in the south-west			—		●	◒
Inner-shelf reef fish species	South-west, east and south-east were assessed, and are all in poor condition		—			◒	◒
Inner shelf—invertebrate species	East and south-east in poor condition			—		◒	◒

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Outer shelf and inner slope—invertebrate species	South-east in poor condition			—		◒	◒
Shoreline and intertidal species	East in poor condition and declining			—		◒	◒
Seabirds—resident	South-east in poor condition			—		◒	◒
Seabirds—migratory	South-west in very poor condition		↙			◒	◒
Hard coral species	East and south-east in poor condition			—		●	◒
Mangrove species	East and south-east in poor condition			—		◒	◒
Seagrass species	East and south-east in poor condition			—		◒	●
Dune and saltmarsh plant species	East in poor condition and declining			—		◒	◒
Dugongs	East in poor condition				—	◒	◒
Turtles	North and east in poor condition (greater understanding in east region)		—			◒	◒
Sea snakes	East in very poor condition and declining				↙	◒	◒
Crocodiles	Populations increasing				↗	●	●

Continued next page

State and trends of species populations and groups *continued*

Component	Summary	Assessment grade Very poor	 Poor	 Good	 Very good	Confidence In grade	 In trend
Dolphins and porpoises	Populations generally stable, although some are declining in the east and south-east			—		◒	◒
Baleen whales (not including humpbacks)	Condition and trends are poorly understood for some species, but recovery occurring generally		—			◒	◒
Humpback whales	Condition in the east and south-east remains very poor and stable			↗		◒	◒
Toothed whales	Condition and trends are poorly understood		—			◒	◒
Fur seals	Assessed only in the south-west and east		↗			◒	◒
Australian sea lions	Assessed in the south-west	↙				●	◒
Seahorses and allies (families Syngnathidae, Solenostomidae)	Assessed in the south-west and south-east				—	●	●
Regional features	Assessed nine species or population features that principally occur in only one region			—		◒	◒

Recent trends

- ↗ Improving
- ↙ Deteriorating
- — Stable
- ? Unclear

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◒ Limited evidence or limited consensus
- ○ Evidence and consensus too low to make an assessment

Grades

🟩	Very good	Only a few, if any, species populations have declined as a result of human activities or declining environmental conditions
🟨	Good	Populations of a number of significant species (but no species groups) have declined significantly as a result of human activities or declining environmental conditions
🟧	Poor	Populations of many species or some species groups have declined significantly as a result of human activities or declining environmental conditions
🟥	Very poor	Populations of a large number of species or species groups have declined significantly as a result of human activities or declining environmental conditions

2.1.3 Ecological processes

This section reports on our best understanding at the national level of the status and trends of the 15 major national-scale ecological processes that operate in the regions and the effects of human activities on them. The processes assessed here include aspects such as migration pathways (are human activities interrupting the normal migration routes of animals between their feeding and breeding grounds?), and trophic (food web) structures of the ecosystems (does the abundance and distribution of the species among primary producers, secondary producers and predators reflect the natural structure and rates of interaction?). Condition of the processes is defined by the extent to which they have declined because of human activities, relative to their condition at the time of European settlement of Australia (further details of the criteria are on the SoE website[d]).

South-west region

The main ecological processes for the south-west region are in good condition, including unimpeded physical pathways for migration, maintenance of most feeding grounds, and maintenance of the main sources of water column productivity, reef building processes and symbiotic relationships across the region. However, coastal development has had major impacts on recruitment and settlement processes for fish and invertebrate coastal species across the region; and nesting, roosting and nursery sites for seabirds. Predation as a process has been severely affected by the removal of top predators from across the region. These impacts continue to increase.

North-west region

Like the south-west, the main ecological processes in the north-west region are in good condition overall. This is partly because the two regions are closely connected by the Leeuwin Current, and because some of the same threats apply to both regions. In parts of both regions that are remote from human influences, some of the ecological processes (such as offshore benthic productivity, symbiosis and reef building) are considered to be in very good condition. However, in other areas, removal of top predators has affected predation as a process, which is considered to be in poor condition and significantly affects ecosystem function in some areas of this region.

North region

The ecological processes in the north region overall are in very good condition, and there are considered to be few significant ecological changes to the main processes of the region as a result of human activities. However, in the offshore areas, the trophic structures and relationships are considered to be poor across the region, and very poor in some areas. This has resulted from excessive fishing pressures, including illegal fishing and the extensive impact of discarded bycatch and related wastes. Top predators have been heavily fished, and impacts in international waters and adjacent areas are likely to have a flow-on effect on the trophic structures of this region.

East region

The ecological processes of the east region are considered to be in good condition overall. These include processes such as the maintenance of migration pathways; availability of nesting, roosting and feeding grounds; reef building; activities of herbivores; and algal-derived calcification processes. However, the flooding cycles of the coastal wetlands are considered to in very poor condition, with substantial changes across a wide area, resulting in serious effects on ecosystem functions. Hydrological regimes altered by land use, coastal engineering, water harvest and flood protection have substantially altered the seasonal habitat cycles in wetlands.

South-east region

The ecological processes of the south-east region are considered overall to be in very good condition. However, the reef-building process has been heavily reduced and is in poor condition. The loss of oyster reefs from shallow inshore waters is widespread (these reefs are considered to be functionally extinct), and trawling has removed much of the deepwater bryozoan reef in fishable depths.

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[d] www.environment.gov.au/soe

6.3 Assessment summary

State and trends of ecological processes

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Connectivity—spatial/physical disjunctions	South-east has been significantly affected				—	◒	◒
Connectivity—biological, migration, flyways	South-east in poor condition and continues to decline			↙		◒	◒
Connectivity—recruitment, settlement	Variable across the regions, improving in some and declining in others			—		◒	◒
Connectivity—genome structures, genetic adaptation	Knowledge base very limited and condition hard to assess			—		◒	◒
Nesting, roosting and nursery sites	Knowledge base very limited and condition hard to assess			—		◒	◒
Feeding grounds	Whale feeding grounds significantly affected by human activities in the south-west and north-west			—		◒	◒
Trophic structures and relationships	South-west and north-west are in poor condition, substantially affected by historical and ongoing fishing			—		◒	◒
Water column, pelagic productivity	Good to very good in all regions				—	◒	◒
Benthic productivity	Good to very good in all regions				—	◒	◒
Reef building	Condition poor in south-east			—		◒	◒

Component	Summary	Assessment grade Very poor	Poor	Good	Very good	Confidence In grade	In trend
Symbiosis—fish, corals, molluscs	Knowledge base very limited and condition hard to assess				—	◒	◒
Predation	Condition of the worst areas very poor in the south-west and north		—			◒	◒
Herbivory processes	Declines observed in the east				—	◒	◒
Filter feeding	Condition poor in the south-east				—	◒	◒
Microbial processes	Knowledge base very limited and condition hard to assess				—	◒	◒
Regional features	Assessed four ecological process features that principally occur in only one region			—		◒	◒

Recent trends

↗	Improving	—	Stable
↙	Deteriorating	?	Unclear

Confidence

●	Adequate high-quality evidence and high level of consensus
◒	Limited evidence or limited consensus
○	Evidence and consensus too low to make an assessment

Grades

🟩	Very good	There are no significant changes in ecological processes as a result of human activities
🟫	Good	There are some significant changes in ecological processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions
🟧	Poor	There are substantial changes in ecological processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas
🟥	Very poor	There are substantial changes in ecological processes across a wide area of the region as a result of human activities, and ecosystem functions are seriously affected in much of the region

2.2 Marine ecosystem health

The health of marine ecosystems has been assessed by examining the status and trends of the major physical and chemical processes that maintain the quality of the biodiversity and habitats in each region. Outbreaks of diseases, non-natural algal blooms and infestations by pests have been assessed as symptoms of an unhealthy marine ecosystem. The assessments of marine ecosystem health (available on the SoE website[e]) are summarised for each region, and aggregated into a single national assessment and summary.

The overall assessment of ecosystem health found that all the regions are in very good condition except for the south-east, which is in good condition (Figure 6.11).

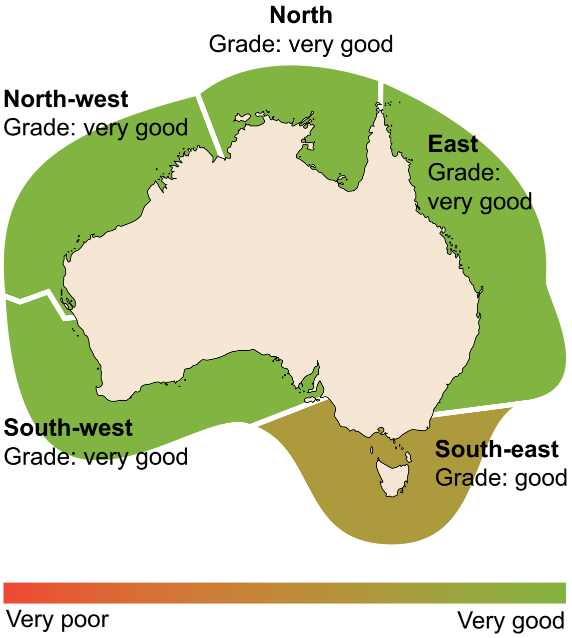

Figure 6.11 The overall health of most components of the ecosystems in each SoE reporting region

2.2.1 Physical and chemical processes

This section reports on our best understanding at the national level of the status and trends of the 14 major national-scale physical and chemical processes that operate in the regions and their interaction with human activities.

South-west region

The physical and chemical processes in the south-west region are considered to be in very good condition, with little human-induced impact. Ocean currents have broadly maintained their natural structure and dynamics; nutrient cycling (the movement and exchange of organic and inorganic matter back into the production of living matter) has been maintained at natural levels and extent in ocean waters (although it has been severely affected in estuaries and some coastal waters); and salinity and oxygen conditions remain in natural condition. However, near to the shore, the light, sediment, freshwater and nutrient regimes have been severely altered in a number of the estuaries and bays in the region, and several estuaries have a significant number of recurrent dead-zone (low oxygen) episodes. These nearshore pressures are continuing to increase, most notably the land-based sources of nutrients, and increasing changes are noted for sea level rise, frequency of storms and changes to ocean current patterns, associated with gradually changing global climatic conditions.

North-west region

Like the south-west region, the physical and chemical processes across most of the north-west region are considered to be in very good condition, with little human-induced impact. Ocean currents have broadly maintained their natural structure and dynamics; and nutrient cycling has been maintained at natural levels and extent in ocean waters. The most important process in this region that has been affected by human activities is the coastal sediment supply regime, which is considered to be in poor condition in some places. The sediment supply and dynamics of the coastal region have been heavily affected by structural developments on beaches and dunes in the southern part of this region (particularly port development and shipping channels), and by broadscale agricultural practices and mining in the central parts of the region.

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[e] www.environment.gov.au/soe

North region

The physical and chemical processes in the north region are also considered to be in very good condition, approaching pristine in most places. Although there have been extensive agricultural changes in a number of catchments, and mining has had a major impact in some localised areas, these are not regional-scale effects. The most affected process is the flow and hydrological regime, which has been affected by major modification to some of the significant rivers of the region (such as the Macarthur River).

East region

Physical and chemical processes overall are considered to be in very good condition in the east region. However, a number of processes have been degraded at a regionwide scale. These include the sediment input regime, and the freshwater inputs and hydrological cycles—these are considered to be good overall, but very poor in some areas; and the changes in sea temperatures, which are in poor condition across the region (because of increasing ocean temperature across the region). Other issues include the prevalence of pesticides in waters across the region, which may be affecting biodiversity.

South-east region

Physical and chemical processes overall are considered to be in good condition in the south-east region. However, there have been substantial changes to sediment input, the dynamics of freshwater inputs and hydrological cycles, the land-based nutrient inputs, the turbidity and light regime of inshore waters, and the dynamics of the East Australian Current that affect this region. In some areas in the region, these changes are extreme, and there have also been substantial inputs of toxicants, resulting in serious impacts on ecosystems. Taken together, this region has experienced changes in physical and chemical processes that are significantly affecting ecosystem functions. Examples include the Coorong, the Derwent River and estuary, and the Gippsland Lakes.

Australia's largest water storage, Lake Argyle, created by the Ord River Dam, the Kimberley, Western Australia

Photo by John Baker and the Australian Government Department of Sustainability, Environment, Water, Population and Communities

6.4 Assessment summary

State and trends of physical and chemical processes

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Ocean currents, structure and dynamics	Significant changes in dynamics of currents in the south-east, and changes are increasing				↙	◒	◒
Storms, cyclones, wind patterns	Wind patterns are changing in the south-west and south-east, affecting ocean ecosystems				—	◒	◒
Sediment inputs	Substantial changes to sediment input regimes in the south-east			—		◒	◒
Inshore water turbidity, transparency and colour	Substantial changes to inshore water conditions and processes in the south-east				—	◒	◒
Sea temperature	Significant changes in all regions, and changes are increasing			↙		◒	◒
Sea level	Significant changes in the south-west and south-east, and changes are increasing				↙	◒	◒
Nutrient supply and cycling—land based	Major changes in land-based nutrient inputs in the south-east				—	◒	●
Nutrient supply and cycling—ocean based	Significant changes in ocean-based nutrients in the south-east				—	◒	◒
Freshwater inflow; surface and groundwater run-off	Major changes in freshwater inflows in the south-west and south-east			—		◒	◒
Toxins, pesticides, herbicides	Significant changes in the south-west and south-east				—	◒	◒

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Dumped wastes	Significant issues with dumped wastes in the east and south-east				—	◒	◒
Ocean acidity	Acidification is a significant risk in all regions, although only limited evidence of change to date				↙	◒	◒
Ocean salinity	Significant changes evident in the south-east				—	◒	◒
Low oxygen—dead zones	Each region has one or more examples, and these have major or extreme local impacts, but limited regional consequences				—	◒	◒
Regional features	Assessed 13 regional features; impacts on river discharges in the east and changes to the East Australian Current were assessed as major changes with significant impacts on ecosystem functions				—	●	◒

Recent trends

↗ Improving

↙ Deteriorating

— Stable

? Unclear

Confidence

● Adequate high-quality evidence and high level of consensus

◒ Limited evidence or limited consensus

○ Evidence and consensus too low to make an assessment

Grades

🟩	Very good	There are no significant changes in physical or chemical processes as a result of human activities
🟫	Good	There are some significant changes in physical or chemical processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions
🟧	Poor	There are substantial changes in physical or chemical processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas
🟥	Very poor	There are substantial changes in physical or chemical processes across a wide area of the region as a result of human activities, and ecosystem functions are seriously affected in much of the region

2.2.2 Pests, introduced species, diseases and algal blooms

This section reports on our best understanding for each region of the status and trends of outbreaks of diseases, pests and introduced species (including pests listed in the National Introduced Marine Pest Information System—NIMPIS), and algal blooms in the region and their relationship with human activities. These are summarised at the national level in the assessment summary.

South-west region

The south-west region is overall in very good condition in relation to pests, introduced species, algal blooms and outbreaks of disease that can cause ecological imbalances. However, pest species have been documented from a number of the ports across the region, and have caused significant ecological impacts in their local areas. A large number of introduced species are recognised across the region whose ecological significance is unknown. The herpes-like virus that has seriously affected the region in past decades (see Box 6.8) appears to have now declined, and there are no obvious ongoing impacts on pilchard populations. However, there is only limited knowledge of the impact of the previous virus outbreaks on bird populations and other species that may be ecologically dependent on the pilchards. Blooms of toxic and nuisance algae continue to be a problem in a number of the estuaries and inshore waters across the region, creating substantial changes, fish kills (deaths of a large number of fish over a short period) and associated ecological impacts. When they occur, algal blooms in this region can cover large areas (see Box 6.1).

North-west region

The north-west region is also in very good condition overall in relation to pests, introduced species, algal blooms and outbreaks of disease. Only two pest species are known to have been established in this region, although many (likely hundreds) of species are introduced to the region as fouling on ship hulls. The intense level of shipping activity associated with the oil and gas sector in the region has probably made a big contribution to this problem. However, few data are available on the ecological impacts of such introductions and, for now, these effects are assumed to be neutral in terms of ecological function.

■ Weedy seadragon (*Phyllopteryx taeniolatus*), male with eggs attached to tail, Western Port Bay, Victoria
Photo by Michael Patrick O'Neill

There are natural algal blooms in this region, but only low levels of coastal and related development that are likely to be the source of nutrients for human-induced algal blooms of any significance. Poor catchment management in many parts of the region influences sediment and nutrient input (such as in floods), but there are no data on the relationship between catchment management and algal blooms in coastal waters. Issues associated with *Lyngbya* (a toxic alga) are noted near Broome, possibly associated with local groundwater, urban run-off and sewage management.

North region

The north region is also in very good condition overall in relation to pests, introduced species, algal blooms and outbreaks of disease. One pest species (striped mussel) has been recorded in the region, but is now thought to have been largely eliminated. Monitoring of the high-risk areas (Darwin Harbour) has not detected further pest incursions. The region is also likely to have many introduced species, as in other areas of Australia, and for the same reasons (including shipping activity, the aquarium trade, tourism and petroleum industry infrastructure). There are few ecological data on impacts.

East region

The east region overall is considered to be in good condition in relation to pests, introduced species, algal blooms and outbreaks of disease. Four species of pest have been recorded in the region, in and around the ports, shallow bays and estuaries. However, the region suffers from periodic outbreaks of crown-of-thorns starfish, and there are extensive algal bloom issues in Moreton Bay and other bays and shallow coastal northern waters, including outbreaks of *Lyngbya*. These shallow and inshore waters of the region are considered to be heavily impacted at times by algal blooms, and their condition is considered overall to be poor in this respect. When they occur, algal blooms in this region can cover large areas. The Pacific oyster (*Crassostrea gigas*, endemic to Japan) has been introduced to the region for oyster farming and has spread, with a significant ecological impact in the estuaries of the southern part of the region.

South-east region

Pests and outbreaks of disease have had major impacts in the south-east region and, overall, the regionwide condition is poor with respect to pests, diseases, introduced species and algal blooms. The pests noted in the region (some of which are widespread and have major ecological impacts at times) include starfish (*Asterias*), sea urchins (*Centrostephanus rodgersii*), plankton (toxic dinoflagellates), algae (*Undaria, Caulerpa*), molluscs (*Maoriocolpus*), crustaceans (*Carcinus*) and worms (*Sabella*). Port Phillip Bay has been described as one of the most invaded marine ecosystems in the Southern Hemisphere, but there are others of equal note, including the Derwent estuary. Outbreaks of harmful native species are also pervasive, mainly toxic algal blooms. The zooplankton *Noctiluca* (a red form of 'sea sparkle', often responsible for 'red tides') has recently become very widespread and is dominant in many parts of the region, probably displacing other forms of native species. The drivers and consequences of this phenomenon are unknown, but are of ecological concern across the region. A severe outbreak of abalone viral ganglioneuritis has affected abalone in several parts of the region, with serious ecological consequences (Box 6.8, p. 428).

Box 6.1 Surface phytoplankton blooms and phytoplankton biomass in coastal waters

Timeseries from satellite data at five coastal sites (monthly data from 2003 to 2010) have compared chlorophyll-a concentrations in the upper water column (a proxy for phytoplankton biomass) with the occurrence and extent of surface phytoplankton (or algal) blooms. The information retrieved from satellite ocean-colour remote sensing is based on the cloud-free portions of the images. Therefore some sites, such as Storm Bay or Broome, may have a more restricted spatial and temporal representation due to more frequent cloud cover.

Site 1: Darwin

The phytoplankton biomass peaks in January and then progressively declines through the rest of the year, before increasing again at the start of spring (September). The biomass level here is the highest of all the sites, and shows the greatest decline of all the sites over the period reported. There is a peak in surface phytoplankton blooms during September and October, covering a limited spatial extent (<8%) of the site.

Site 2: Burdekin River, Townsville

The Burdekin River catchment is located in the Great Barrier Reef region, and generates significant river plumes during wet-season flood events (see Box 6.10). The phytoplankton biomass peaks during the early wet season, between February and March. The biomass shows a general decline during the reporting period, although there was high phytoplankton biomass during the 2007 and 2008 wet seasons, following the large flood events in those years. Surface phytoplankton blooms, likely *Trichodesmium* spp., occur mainly between June and October, and may cover large areas (≥30% of the site).

Site 3: Storm Bay, Hobart

The phytoplankton biomass data from this site were affected by cloudy conditions (annual cloud cover 70–80%). The phytoplankton biomass peaks annually in September–October, the 'spring bloom'. However, the available satellite data and field studies confirm a decline in phytoplankton biomass during the reporting period. Surface phytoplankton blooms occur mainly in June and may cover up to 10% of the site.

Site 4: Geographe Bay, Perth

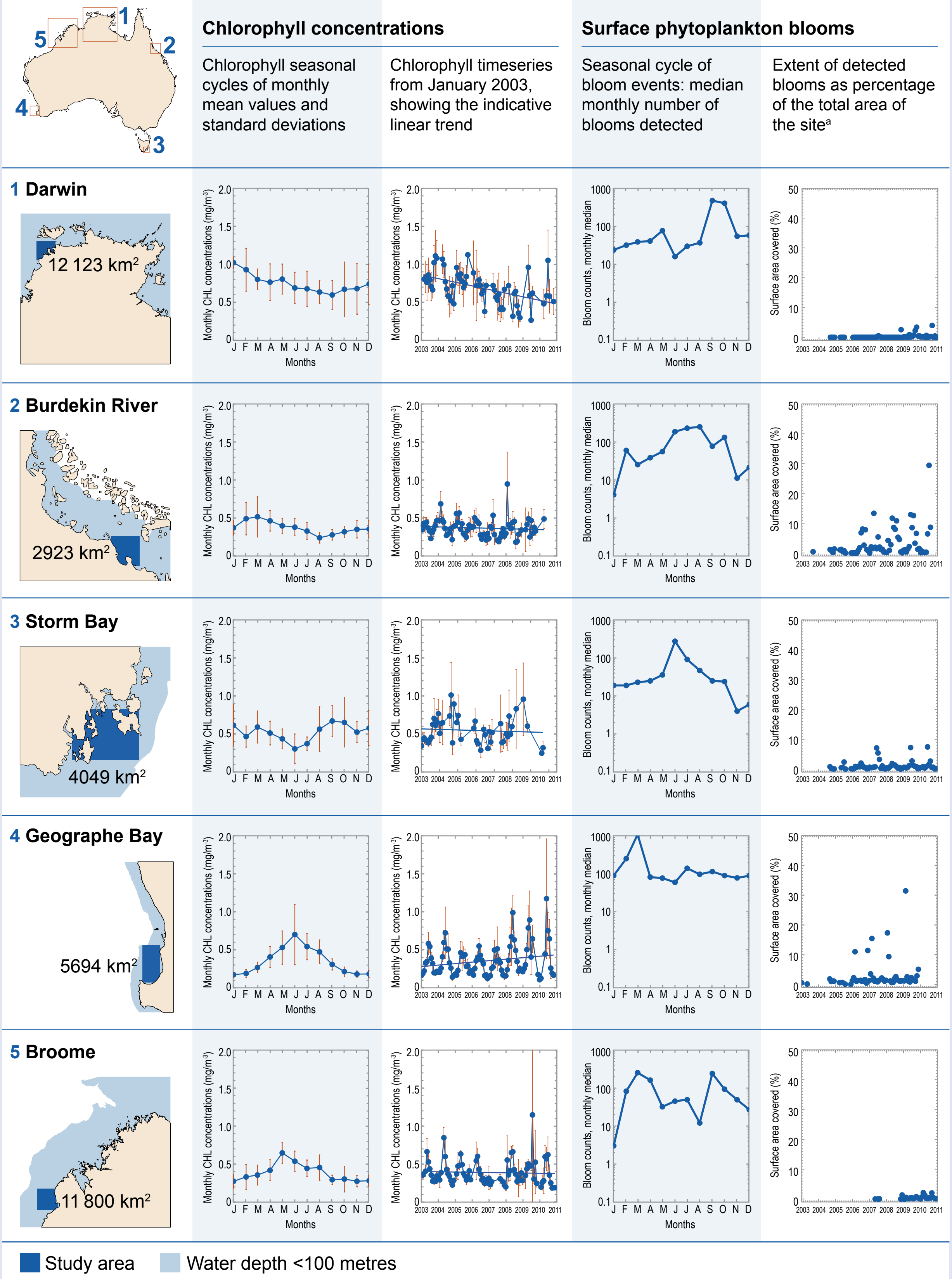
The phytoplankton biomass is localised close to the coast and is highest during winter. Nutrients supporting this biomass probably come from local river run-off and storm disturbance of sediments. Compared with the other sites, this is the only site with an apparent increasing (although not statistically significant) trend in phytoplankton biomass. Surface phytoplankton blooms were found to occur mainly in early autumn, sometimes covering large areas (>30% of the site).

Site 5: Broome, south Kimberley

There is a peak of phytoplankton biomass in May, with high variability in August. The biomass shows a significant decline over the reported period. Surface phytoplankton blooms occur mainly in March and September. They appear to be more limited in extent than those at the Geographe Bay site, covering <5% of the site.

A detailed description of the methodology and additional data can be found in Blondeau-Patissier et al.[38]

Box 6.1 *continued*



CHL = chlorophyll-a; km² = square kilometre; mg/m³ = milligrams per cubic metre
a 2003–06, incomplete satellite dataset

6.5 Assessment summary

State and trends of pests, introduced species, diseases and algal blooms

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Number and abundance of NIMPIS-listed pests	Condition in the south-east region is poor and declining			—		◒	◒
Number and abundance of introduced species	Number of introduced species is high, possibly increasing, but their impacts and trends are unknown				?	◒	○
Viral diseases, parasitic infestations, fish kills	A major disease outbreak has occurred, and condition in the south-east region is poor				—	◒	◒
Algal blooms, jellyfish blooms	Blooms of algae and other species occur regularly, and condition in the south-east region is poor				—	◒	◒
Crown-of-thorns starfish abundance and distribution	Occurs regularly across the east region, and condition there is poor			—		◒	●

Recent trends

- ↗ Improving
- ↙ Deteriorating
- — Stable
- ? Unclear

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◒ Limited evidence or limited consensus
- ○ Evidence and consensus too low to make an assessment

Grades

🟩	Very good	The incidence and extent of diseases and algal blooms are at expected natural levels, there are insignificant occurrences or outbreaks of pests, and the numbers and abundance of introduced species are minimal
🟫	Good	Diseases or algal blooms occur occasionally above expected occurrences or extent, and recovery is prompt, with minimal effect on ecosystem functions. Pests have been found, but there have been limited ecosystem impacts. The occurrence, distribution and abundance of introduced species are limited and have minimal impact on ecosystem function
🟧	Poor	Diseases or algal blooms occur regularly in some areas. Occurrences of pests require significant intervention or have significant effects on ecosystem function. The occurrence, distribution and abundance of introduced species trigger management responses, or have resulted in significant impacts on ecosystem functions
🟥	Very poor	Diseases or algal blooms occur regularly across the region. Occurrences of pests or introduced species are uncontrolled in some areas and are seriously affecting ecosystem functions

NIMPIS = National Introduced Marine Pest Information System

6.6 Assessment summary

State and trends of the national marine environment

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Habitats for species	Overall, the 22 types of habitats assessed are in very good condition. However, nationally, two seabed habitats of the outer continental shelf and slope are in poor condition, and the condition of the water column of the inner shelf and shoreline (<50 m depth) is declining. Habitats in the east and south-east are in the poorest condition				—	◒	◒
Species populations and species groups	Overall, the 32 species groups assessed are in good condition, but 13 groups are in poor or very poor condition, and only 5 groups are considered to be in very good condition. Nationally, 4 species groups are in decline, and 7 are recovering from extensive hunting and fishing of earlier times. The species of the east are in the poorest condition			—		◒	◒
Ecological processes	Overall, the 16 types of ecological processes are in very good condition. Nationally, predation is poor, reflecting the extensive impacts of historical and present-day fishing, and connectivity in the south-east continues to decline				—	◒	◒
Physical and chemical processes	Overall, the 27 physical and chemical processes assessed are in excellent condition, with most indicating no significant changes caused by humans that would affect ecosystem structure or functions. However, the worst places show substantial changes, with significant ecological impacts—the south-east region is the worst affected, with major changes to freshwater, sediment and nutrient input to estuaries and bays				—	◒	◒
Pests, introduced species, diseases and algal blooms	Overall, there are no regionally or nationally significant changes to ecosystems caused by these factors, although in the worst places there are effects that are significant. The east, south-east and south-west regions are the worst affected, and impacts are major in some areas				—	◒	◒

Recent trends	↗ Improving	— Stable	
	↙ Deteriorating	? Unclear	
Confidence	● Adequate high-quality evidence and high level of consensus		
	◒ Limited evidence or limited consensus		
	○ Evidence and consensus too low to make an assessment		
Grades	🟩 Very good	🟫 Good	🟧 Poor
	🟥 Very poor		

3

Pressures affecting the marine environment

Australia's oceans are highly dynamic—they vary daily, monthly and annually, driven by winds and tides, the seasons, the influence of the world's major ocean currents and the global climate. Near the shore, marine ecosystems are heavily influenced by land-based factors such as river run-off, non–point sources of pollution and the effects of human activities. Most of these impacts have historically been focused in the coastal lands (such as mangrove wetlands, shallow reefs and beaches) and the shallow inshore waters down to a depth of approximately 100 metres, which are usually found close to shore and are readily accessible by small boat.

However, technological advances have enabled our marine activities to become more intensive in nearshore waters and progressively expand into deeper waters. For example, in the past three decades, high-quality position-finding and underwater acoustic systems have become affordable and widely available. As a result, oil and gas exploration and fishing have now moved into waters more than 1 kilometre in depth. This has increased the potential for impacts in the oceans in remote places and at greater depths. The exploitation of places that were once beyond the reach of fishing, or could not be repeatedly targeted, has contributed to the problems of overexploitation in many fisheries—the refuges that once existed for many species in places remote from the coast, or where the seabed was formerly too rugged to be fished, have been reduced or removed. Equally, onshore development is reducing the size of coastal wetlands that are valued as breeding and nursery areas for marine species.

The primary broad drivers of environmental change in Australia's marine ecosystems are outlined in Chapter 2: Drivers. These drivers are expressed in various places and times as specific pressures on the marine environment, many of which cause obvious and measurable ecosystem impacts. However, not all the impacts are measurable, because of their type, extent or complexity; and many ecosystem changes result from the cumulative effect of two or more pressures. As a result, it is rarely possible to identify a single cause for changes that may be considered detrimental.

At a glance

The Australian marine environment is experiencing a broad range of pressures that affect the quality of habitats, species and environmental health. The main pressures are in coastal areas, particularly in sheltered enclosed bays, estuaries and lagoons, where removal of land-based sources of pollution and wastes by flushing is most limited. These pressures and their impacts primarily affect the east, south-east and south-west regions; many parts of the north and north-west regions remain in near-pristine condition, although development pressures are rapidly increasing. This pattern reflects both the existing distribution of Australia's population and the distribution of the industries and activities that rely on coastal resources.

Exploitation has overtaken waste disposal as the major source of impacts in Australia's oceans. Although the overall set of pressures is much more limited than in many other nations, the worst areas in Australia are equivalent to, and in some cases actually are, the world's worst. The juxtaposition of the persistent Macquarie Harbour anoxic (low or no oxygen) dead zones and the nearby pristine Tasmanian marine and forest wildernesses stands as a stark reminder of the issues. Such localised but severe cases serve as early warning that Australia is not immune to the pressures and impacts that are widespread in some other countries.

The present-day pressures are interacting with the effects of past activities (legacy impacts). In the case of fishing and coastal development, although today's management practices are much improved, a number of ecosystems, habitats and species were heavily impacted in previous centuries and will continue in their degraded condition under current management policies and practices. The resilience of the environment in the face of the emerging pressures of climate change, oil and gas production, aquaculture, energy generation and desalination is highly uncertain.

The pressures and their impacts primarily affect the east, south-east and south-west regions; many parts of the north and north-west regions remain in near-pristine condition, although development pressures there are rapidly increasing, particularly from mining. Pressures in parts of the temperate regions are very high; they include the impacts of climate change, urban areas, ports, catchment run-off, fishing, aquaculture, tourism and mining. This pattern reflects both the existing distribution of our population and the distribution of the industries and activities that rely on coastal resources.

Australia is also following the global pattern for coastal zone areas, which are under much greater pressure than the offshore areas. Despite our investments in management systems, many of the same impacts that occur overseas are apparent in areas of Australia's oceans and coasts. For example, the impacts of fishing—such as the large and broadscale reductions in biomass that persist even when fishing ceases—have been observed in many large species that are fished, across all the global oceans[39] and in Australian waters. It is possible for biodiversity to recover when pressures are reduced, as has been observed in the case of humpback whales in Australia's waters. However, the recovery is usually much slower than the rate of decline and often more uncertain.

This section summarises the known and likely extent of impacts from the drivers and pressures on the environment, considering the interactions between the highly complex and natural dynamics of the ocean ecosystems and the effects from human sources.

3.1 Pressures resulting from climate change

Australia's oceans and marine ecosystems are changing in response to changes in the global climate systems. A recent review of the Australian marine impacts of climate change found that significant changes were under way in 15 of the 17 environmental aspects considered, and that these changes could be linked to climate change factors with varying degrees of confidence.[40] The review concluded that:

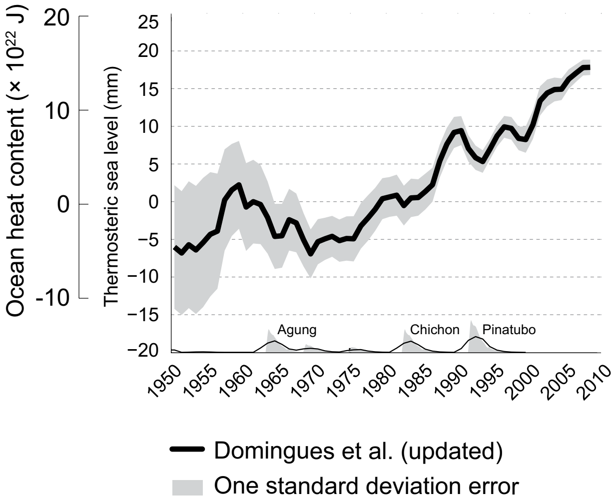
- Australian ocean temperatures have warmed, with south-western and south-eastern waters warming fastest
- the flow of the East Australian Current has strengthened, and is likely to strengthen by a further 20% by 2100
- marine biodiversity is changing in south-east Australia in response to increasing temperatures and a stronger East Australian Current
- observed declines of more than 10% in growth rates of massive corals on the Great Barrier Reef are likely to be due to ocean acidification and thermal stress.

The most important changes deriving from climate change that will affect marine ecosystems are gradually increasing water and air temperatures, sea level rises and acidification. Nearshore, the increased frequency of storms and associated run-off of fresh water, nutrients and suspended sediments will also be very important.

3.1.1 Temperature

Sea surface temperatures (SSTs) around Australia have significantly increased since the early 20th century (by 0.7 °C, comparing 1910–29 with 1989–2008). This rate of warming is similar to that for global average land and sea temperatures. All global and regional temperatures have accelerated their rate of warming since the middle of the 20th century (Figure 6.12)—for Australian SSTs, the rate of warming was 0.08 °C per decade from 1910 to 2008, and 0.11 °C per decade from 1950 to 2008. The warmest year for Australian average SSTs was 1998, and 6 of the 10 warmest years for SST have occurred in the last 10 years (based on data since 1910).[41] The rate of warming of the ocean, although interrupted by volcanic eruptions and hence variable, has been steady since 1950, and is observable at all depths in the ocean.[42] Although there are seasonal and spatial variations in the magnitude of SST increase around Australia, the greatest rates of warming have been observed off the south-west and south-east coasts.[41]

By the 2030s, SSTs are projected to be around 1 °C higher (relative to 1980–99) around Australia, with slightly less warming to the south of the continent. By the 2070s, SSTs are projected to be 1.5–3.0 °C higher, with slightly less warming to the south of the continent and the greatest warming to the east and north-east of Tasmania.[41]



J = joule; mm = millimetre

Source: Adapted from Church et al.[42]

Figure 6.12 Updated estimates of changes in upper ocean heat content relative to 1970

The timeseries updated by Domingues et al.[43] is shown by the black line, with one standard deviation uncertainty estimates shown by the grey shading. Uncertainties are smaller for recent years because of more numerous and accurate observations of ocean temperature. Volcanic eruptions are indicated along the horizontal axis.

This changing ocean temperature directly affects the distribution and abundance of many species and habitats, including seagrasses, macroalgae, phytoplankton, coral reefs, tropical and temperate fish, pelagic fish, marine reptiles and seabirds. The general trend is that species habitats and distributions are forced southward, consistent with the prevailing temperature regime. In the future, we are likely to see further declines in nearshore seagrass meadows and algal beds due to storms, turbidity and warmer water, and a loss of diversity in coral-dependent fish and other coral-dependent organisms.

For species that require shallow and cool coastal waters, such as for breeding or nursery grounds, this southward shift in temperatures will eventually result in major population reductions as the availability of habitat decreases and finally disappears south of the mainland and Tasmania. Temperature alone is likely to create the greatest set of ecological changes in shallow-water marine ecosystems in the coming decades.[41] Increasing ocean temperatures play an important role in coral bleaching, and probably pose the most severe threat to Australia's coral reef systems (see Box 6.2).

3.1.2 Ocean acidification

The natural physical and biological processes of the ocean's carbon cycle absorb carbon dioxide gas from the atmosphere. Human-derived carbon dioxide emissions have increased, mainly as a result of fossil-fuel combustion, land-use practices and concrete production during and since the industrial revolution. The end result is more carbon dioxide dissolved in the world's oceans.

The ocean is a weakly alkaline solution (with a pH of around 8.1), but the extra carbon dioxide changes the carbon chemistry of the surface waters of the ocean. The carbon dioxide forms a weak acid (carbonic acid) in water, making the ocean more acidic (lowering the ocean's pH). This process is referred to as 'ocean acidification'.

The process of ocean acidification is already under way and has lowered the pH of the global oceans by about 0.1 pH units from their pre-industrial state. The concentration of atmospheric carbon dioxide is now higher than at any time in at least the past 650 000 years, and probably the past 20 million years. By the end of this century, the ocean's pH is likely to drop to 0.2–0.3 units below pre-industrial levels.[44]

Carbon dioxide–driven acidification shifts the proportion of dissolved carbon dioxide away from carbonate ions and towards bicarbonate ions. Organisms that make their shells from calcium carbonate need carbonate ions for the biological calcification processes that create their shell. Ocean acidification poses a risk to marine food chains, potentially affecting fisheries and highly valued species by also affecting the primary production systems in the ocean. Observational data have now begun to detect changes in calcification in Southern Ocean zooplankton and Great Barrier Reef corals, indicating that acidification has already started to have detectable impacts on biological processes in our oceans.[44]

Box 6.2 Coral bleaching in Australia's waters

The world's tropical coral reefs are increasingly threatened by climate change and ocean acidification. Ocean warming leads to increased risk of mass coral bleaching events, coral disease outbreaks and the formation of stronger storms. The bleaching of corals occurs when the coral host expels its zooxanthellae (marine algae living in symbiosis with the coral) in response to increased water temperatures. This often results in the death of coral organisms, and the subsequent overgrowth of skeletal structures with algae, or erosion of the skeletal remains.

Ocean acidification reduces the availability of the carbonate ion that is needed to build aragonite (the chemical building block of corals), reducing the capacity of marine calcifying organisms, including corals, to build calcium carbonate skeletons and maintain reef structures.

Australia has some of the world's most spectacular coral reefs: the Great Barrier Reef in the east and Ningaloo Reef in the west (added to the list of Australia's World Heritage properties in 2011). Australia also has significant coral reefs at high latitudes, including Lord Howe Island in the south-east and the Houtman Abrolhos Islands in the south-west. Individually and collectively, these reef systems are an important part of Australia's and the world's natural heritage and add significant revenue to the national economy—the Great Barrier Reef alone contributes more than $5 billion per year.

Severe coral bleaching on Australian reefs has, in the past two decades, been confined mainly to the Great Barrier Reef and other reefs at low latitudes (e.g. Scott Reef in the north-west); however, the first extensive bleaching events have now also been recorded around Ningaloo Reef, and the high-latitude reefs of Lord Howe, Houtman Abrolhos and Rottnest islands.

The scientific evidence supporting a causal relationship between concentrations of greenhouse gases (mainly carbon dioxide) in the atmosphere and declining health of the world's coral reef ecosystems is growing stronger. Since 1998, when more than 16% of the world's coral reefs were devastated by coral bleaching, several extensive bleaching events of varying severity have occurred on Australia's coral reefs. An expanding body of experimental research indicates that interactions of thermal stress with other stressors, such as ocean acidification and declining water quality, are likely to increase the risk to reef ecosystems. For example, the risk of mortality from thermal bleaching is higher under more acidic conditions, and potentially under conditions of high nutrient concentrations. Further, the increased fragility of coral skeletons and accelerated rates of reef erosion under more acidic ocean conditions will increase the susceptibility of reefs to storm damage. The decreased calcification rate of corals in a low-pH ocean will also reduce the speed at which corals and coral reefs can recover from events such as tropical cyclones and mass bleaching, further reducing the resilience of the ecosystem.

The recent history of extensive bleaching episodes, in conjunction with projections for ocean acidification, raises important questions about whether Australia's high-latitude and low-latitude reefs could become refuges or high-risk sites in the world's changing oceans.

Information provided by Ken Anthony, Research Team Leader—Climate Change and Ocean Acidification, Australian Institute of Marine Science (AIMS); Peter Harrison, Director, Coral Reef Research Centre, Southern Cross University; Janice Lough, Senior Principal Research Scientist, AIMS; Richard Brinkman, Lead Physical Oceanographer, AIMS; Jamie Oliver, Science Leader, Western Australia, AIMS; and David Wachenfeld, Chief Scientist, Director—Science Co-ordination, Great Barrier Reef Marine Park Authority; July 2011

3.2 Fishing

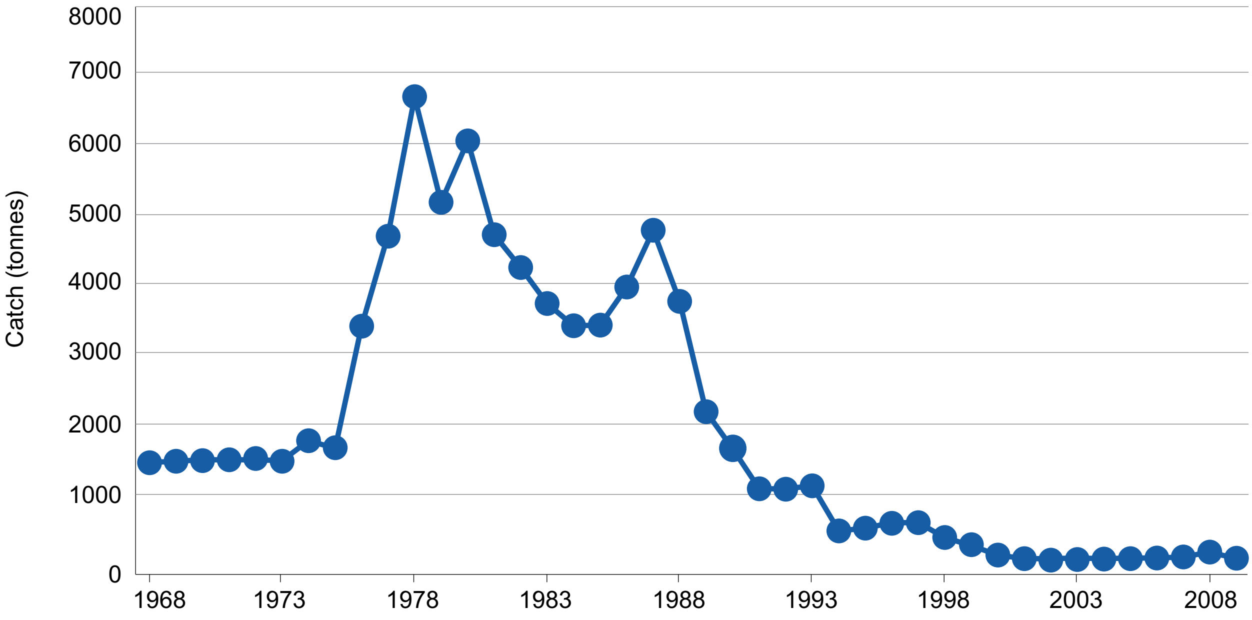
Fishing has provided an important commercial, recreational and subsistence resource for Australians for many decades. As fishing effort has expanded, so have the environmental impacts that inevitably accompany such exploitation. These impacts include the direct effects of fishing on the species being caught (related to the intensity and extent of fishing effort); the effects on other species that may depend on the targeted species as predators or prey; the direct effects of fishing gear on habitats; and the catch of unwanted species (bycatch). Fishing in all its forms is now recognised as a major factor affecting marine ecosystems through these various impacts. Jointly, exploitation and habitat loss are considered to be the primary threats to fish stocks, with major potential impacts on the ecology of ocean ecosystems.[35] Almost all the species that are large enough and abundant enough to be fished are targeted, and they comprise important ecological components of the ecosystems.[45]

Despite this, there is no nationally integrated analysis of the cumulative impacts of fishing or fisheries on ecosystem structure or function, and no national-level initiatives to assess and report on ecological sustainability of commercial or recreational fishing sectors. This major gap limits the extent to which the pressures on marine ecosystems can be assessed.

With increasing population and rapidly improving technology, virtually all of Australia's marine areas that are less than 1 kilometre in depth are, or have been, fished to some extent. In the sanctuary zones of marine protected areas and other small areas protected from fishing as nursery grounds (less than 5% of our marine environment), all forms of fishing are permanently banned to protect biodiversity, and there are some areas where fishing gear is too difficult to use. These highly protected areas and topographic refuges are mainly found offshore and in deep waters; the biodiversity of these deeper regions is poorly understood, with more than half of species in some surveys previously undescribed. Some regions have areas with high levels of permanent restrictions on fishing (for example, within more than a third of the Great Barrier Reef Marine Park). Numerous smaller fishery closures have been implemented in recent years to protect sensitive habitats and species.

The historical patterns of catches over the period of post-European exploitation of Australia's fish stocks reveal that there have been major changes in many of the stocks and probably also in their associated ocean ecosystems. In many cases, fishing has shifted from one species to another as a target species becomes difficult to catch. This is known as serial depletion—the systematic 'fishdown' of target species to levels that become uneconomic to exploit. In Australian waters, there are a number of examples of such depletion and, although it has not resulted in the extinction of any fished species, many stocks have been left at such low levels that they may take many years (and possibly centuries) to recover. Most stocks are managed to avoid such extremely low biomass, and a number have been restored by strong management actions after very low stock sizes were detected. Possibly the worst contemporary example of fishdown is the eastern gemfish population in south-eastern Australian waters, which has been intensively fished down over the past 50 years (Figure 6.13).

AFMA-managed fisheries are using the newly developed harvest strategy (see Section 1.5.2),[23] to move towards a more secure and sustainable level of production for the various species within the Commonwealth jurisdiction. The need for this strategy is illustrated by the history of the Western Deepwater Trawl Fishery (Box 6.3).



Source: Little & Rowling[46]

Figure 6.13 Total reported retained and bycatch landings of eastern gemfish, 1969–2009

Box 6.3 Western Deepwater Trawl Fishery

The Western Deepwater Trawl Fishery (WDTF), managed by the Australian Fisheries Management Authority, operates off Western Australia between the western boundary of the Great Australian Bight Trawl Sector in the south and the western boundary of the North West Slope Trawl Fishery in the north. The WDTF targets more than 50 species in waters exceeding 200 metres in depth, in habitats ranging from temperate–subtropical in the southern region to tropical in the north.[23]

The history of the WDTF follows the trajectory of many of Australia's offshore fisheries—a boom period of exploitation, followed by a long, sometimes slow, decline, and now either a continuing low level of productivity or, in extreme cases, closure of the fishery.

The WDTF was initially discovered in the early 1980s. Eight fishing licences were awarded, eventually increasing to more than 100 licences. By the mid-1990s, fishing permits had been reduced to 11, the dominant species in the initial exploratory catches (boarfish) were no longer caught, and the fishery had moved to other nearby areas and a different primary species (ruby snapper). Boarfish were assessed as 'underfished' in the 1992–95 stock status reports from the Bureau of Rural Sciences, but in 2009 reported catches of this fish were so low that it was effectively dropped from the reporting system. The fishery has also previously targeted three species of shark that are now considered too low in abundance to permit ongoing harvest.[23]

The species mix in the present-day catches is very different from that in the early days of the fishery. As well as a change in targeted species, this probably reflects a local reduction in populations and a consequent ecological impact of the fishery on the structure and function of the ecosystem. Recovery of the affected species is possible, although the timescale is uncertain and likely to be long.

Both offshore and coastal fisheries have suffered substantial declines over the past century. A recent study of the coastal fish of Tasmanian waters[47] suggests that both climate change and fishing have had severe impacts on approximately 20% of the island's coastal fish species, beginning with the arrival of Europeans and their fishing practices in the early 1800s, and made worse more recently by accelerating climate change. The reduction in a number of popular fishing species has been offset by the appearance of several alternative species that are expanding their range southwards from the mainland. These substantial changes in species composition demonstrate that the drivers of long-term shifts in coastal diversity may have a variety of sources, and their ecological impacts may extend beyond a reduction in fishing resources to include direct impacts on coastal ecosystems by affecting interactions within the food chain.[47]

In other states, the coastal fisheries are also suffering declines—many species are considered to be fully fished, while others are recognised to be depleted and suffering population declines.[18,48] In coastal waters and the continental shelf, the species that can be fished are mostly fished to their limits and, for some, overfishing has resulted in population collapse.[48] So, while modern-day fishing practices are generally much improved over practices used as recently as 30 years ago, the legacy effects from the intense fishdown phase of virgin stocks (such as in the South-east Tiger Flathead Fishery—see Box 6.4) are a dominant feature of the population structure of most fishable species. The relative risks from other impacts are now increasing, requiring intense vigilance from fishery managers to avoid catastrophic and long-term impacts on populations of these (mostly large) marine species that were once considered to be abundant and widespread in our oceans and estuaries.

There is a high risk that, after heavy fishdown or other forms of overfishing, depleted stocks may not be resilient or recover quickly (such as the eastern gemfish example in Figure 6.13). While they are in such poor condition, they may be subject to other environmental pressures, including climate change impacts. The flow-on effects on the ecological functions of the oceans are largely unknown. It is likely, however, that fishdowns of most of the fished species have left Australia's oceans much less resilient by reducing diversity, modularity and feedback within ecosystems (see Section 5 of this chapter). This probably has important consequences for the capacity of marine ecosystems to adapt to the combined effects of the present-day pressures of climate change, habitat loss and fishing pressure.[45]

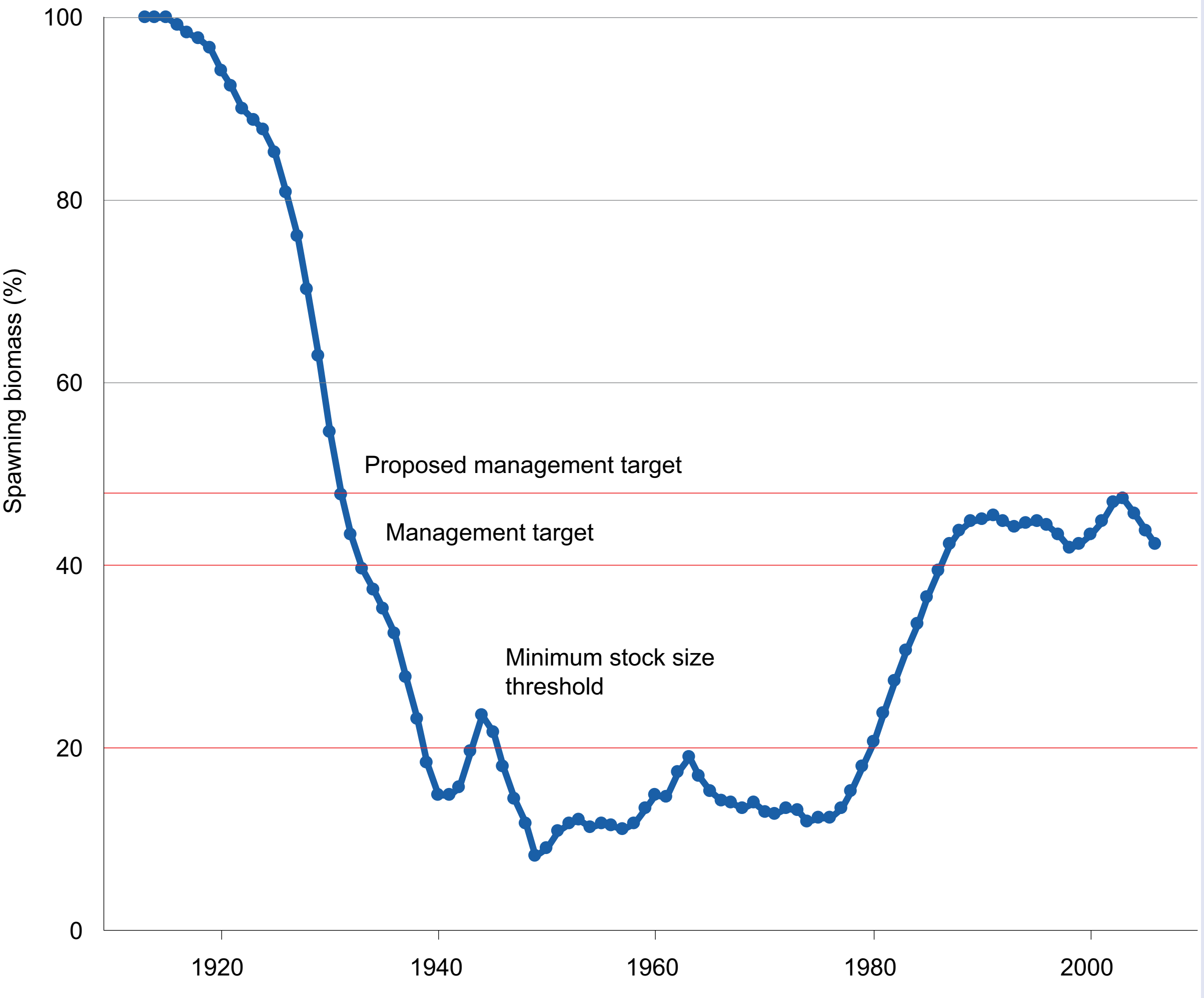
Declining stocks may lead fishers to fish harder to catch the remaining fish. In fish catch data, this pattern can be detected as a progressive reduction in the size of catches, reduction in the size of fish being caught, or a change in the type of fish being caught. It can also bring about a shift in the trophic level of the fish in the catch. Where this occurs, fish catches shift from

Box 6.4 South-east Tiger Flathead Fishery

According to Klaer,[51] tiger flathead have been commercially fished since the development of the steam trawl fishery in 1915. Steam trawlers were used until about 1960. Danish-seine gear, a fishing method that is still being used today, was developed in the 1930s. Diesel trawlers began landing tiger flathead in the 1970s, and currently diesel trawlers and Danish-seine methods take the total catch.[51] A total allowable catch was introduced in the fishery for this species in 1992.

With increasing catches, population biomass declined until about 1950. In the 1980s, the population began to increase again, until it stabilised at the present-day level of around 45% of pristine levels. The fishery is now managed to maintain the spawning stock biomass (an approximate index for the size of the total population biomass) at around the 40–50% level, which is considered to be near-optimal to maintain ongoing economic production from this fishery (Figure A).

Catches from the fishery have repeatedly spiked and declined over the years (Figure B), and catches in the past few years have been trending downwards.

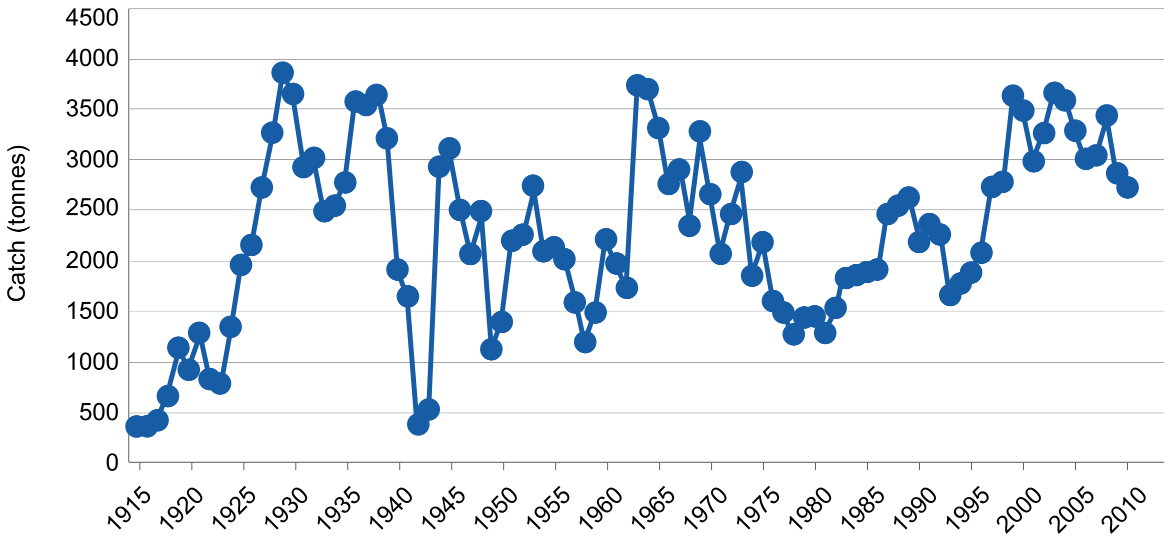


Source: Adapted from Australian Fisheries Management Authority, www.afma.gov.au/wp-content/uploads/2010/08/sessmac-2-shelf_rag_species_summary2007.pdf; © Australian Fisheries Management Authority

Figure A Spawning stock biomass levels in the South-east Tiger Flathead Fishery

This is the base-case analysis of the 2006 full assessment. The horizontal lines represent the 20%, 40% and 48% limit and target reference points.

Box 6.4 *continued*



Source: Klaer, CSIRO, pers. comm.; Klaer;[51] Melville-Smith[45]

Figure B Total retained catches of tiger flathead, 1915–2010 calendar years (catch is estimated for 2010)

species higher in the food chain (at a high trophic level), including large carnivores such as sharks, to successively lower trophic levels of smaller and less valuable fish. This is measured by the marine trophic index (MTI)—an international marine indicator.[49]

For most Australian stocks, there are insufficient data to calculate a shift in trophic structure of the fisheries, such as that estimated by the MTI.[50] However, there is evidence in places that fishing may have altered species composition. Although the MTI is a gross index, it is the only indicator that is widely used to detect and report on gross changes in the trophic structure of fished ecosystems over time. The MTI has not been adopted in Australia, and there is no requirement for fisheries to report on such matters. Most of the impacts of fisheries in Australia are now historical, and present-day management practices are (generally) much improved. However, most of today's fisheries have harvest strategies that manage the stock biomass at an agreed level that is significantly lower than pristine levels (typically 40%), with management arrangements to reduce pressure if stocks drop below this level. The pressure of present-day fishing (both commercial and recreational) acts to maintain low abundances and biomass (relative to pristine levels) and probably to reduce the resilience of the populations being fished and their ocean ecosystems.

However, not all fished stocks have failed to recover from overfishing, and there are a number of documented recoveries and management success stories, most notably the South-east Tiger Flathead Fishery (Box 6.4). After extensive management intervention, this species has been found to be remarkably resilient and has shown significant population recovery.

Recovery of fish stocks is a common objective of modern fisheries management, and Australia has a number of success stories. It has long been known that the key to success is to ensure that populations are fished at rates that are below the level at which optimum yield could be taken, allowing stocks to gradually rebuild while continuing to provide for sustainable fishing.[52] By extracting slightly less each year than the maximum sustainable yield, a fishery can gradually increase both the overall stock size and the annual yield, providing for substantial long-term gains at the cost of minor short-term losses (in terms of catch). Such approaches are now in wide use, together with the careful application of no-take marine protected areas and reserves (see Box 6.5), to begin the long process of rebuilding stocks and recovering degraded ecosystem functions. However, the effectiveness of these management interventions to achieve long-term stock rebuilding remains to be assessed in most Australian fisheries.

Box 6.5 Assessing the condition of fish populations using ecological criteria

More than 5000 species of fish are known from Australian marine waters,[10] but assessments of population condition have been conducted for only a few of these species. Available assessments have been mainly for fisheries management purposes, and do not take account of a range of environmental and ecological issues that are known to influence the vulnerability, status and resilience of fish populations.[53]

Three ecological indicators—inherent vulnerability to extinction, current population status and population resilience—and 10 associated criteria have been used to demonstrate how existing data and knowledge can be applied to assess the ecological condition of marine fish populations.[35] The populations of two fish species with contrasting ecology and life history (the redfin butterflyfish, *Chaetodon lunulatus*, and the leopard coral trout, *Plectropomus leopardus*) were assessed to demonstrate the usefulness of this approach. Population condition was graded on a scale of very good, good, poor or very poor.[35]

The inherent vulnerability to extinction for both species was considered low, given their reasonably large geographic ranges and ability to use a wide range of different reef habitats. The current population status of both species was considered good, with no evidence of long-term, reef-wide declines in abundance. However, both species are facing distinct threats, due to habitat degradation (especially coral loss for butterflyfish) and direct fisheries exploitation (for coral trout). Current fisheries for the coral trout on the Great Barrier Reef appear to be sustainable, and the populations exhibit considerable resilience. With the recent expansion of no-take marine reserves to cover more than 30% of the Great Barrier Reef Marine Park, the populations of coral trout on reefs closed to fishing have recovered very quickly from earlier intensive fishing, and population resilience is assessed as good. In contrast, the butterflyfish appears to have poor population resilience, with no recovery observed more than five years after severe coral bleaching in the central Great Barrier Reef.

The leopard coral trout, *Plectropomus leopardus* (photo by A Frisch, Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University)

The redfin butterflyfish, *Chaetodon lunulatus*, taking bites from a colony of *Acropora* (photo by M Pratchett, Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University)

Indicator	Criterion	Leopard coral trout condition	Redfin butterflyfish condition
Inherent vulnerability to extinction	Geographic range	Good	Very good
	Population size	Poor	Good
	Ecological versatility	Good	Poor
	Resource vulnerability	Good	Good
Current population status	Population trends	Good	Very good
	Extent of known threats	Poor	Poor
	Population structure	Good	Good
Population resilience	Observed recovery	Good	Poor
	Reproductive mode and recruitment	Good	Good
	Population connectivity	Good	Poor

Source: Pratchett[35]

3.3 Oil and gas exploration and production

Australia has large reserves of gas and significant reserves of oil, for which there is both a domestic and a global demand. The risks to, and impacts on, the marine environment from the oil and gas industry are assessed and managed by both state governments and the Australian Government, depending on the location of the specific activities being considered (Box 6.6). Issues associated with this industry include the direct impacts of seabed structures such as wellheads, anchors and pipelines; the large amounts of shipping traffic; and the risks from accidents and spills. There is also significant coastal impact from the associated infrastructure, such as industrial sites where ports and processing equipment are located, the residential base for the workforce, onsite engineering maintenance, transport and related industries. These land-based facilities usually require new ports and harbours, land reclamation and major channel dredging. In Western Australia alone, more than 200 million cubic metres—equivalent to nearly half the volume of water in Sydney Harbour—of dredge spoil (sediments and materials removed from the seabed during dredging) from new coastal developments, mainly for the oil and gas industry, has recently been approved for ocean and coastal disposal.

Exploration in the oil and gas industry involves geophysical surveys (using acoustic arrays and other specialist survey tools), exploratory drilling of seabed cores and test wells. Production involves a range of fixed and moveable facilities, such as fixed production platforms and floating platforms that are used as the base for drilling of wells and, with an appropriate array of seabed pipelines, as collection points for oil and gas. Every stage of development and production of these facilities involves substantial risks. The world's worst oil and gas industry impacts have arisen from all stages of the industry's activity: shipping, production and exploration. In Australia, the activities of the oil and gas industry are now concentrated in Bass Strait and in the north and north-west regions (Figure 6.5).

In Australia, as well as complying with national environment law, industry must comply with several national industry laws, including the *Offshore Petroleum and Greenhouse Gas Storage Act 2006*, which is administered by the Australian Government Department of Resources, Energy and Tourism. Under this legislation, companies must prepare legally binding environmental plans, including oil spill contingency plans (see Box 6.7).

Box 6.6 North West Shelf Flatback Turtle Conservation Program

In Western Australia, the Gorgon gas production project is the largest ever approved. It is building an industrial base on Barrow Island, approximately 30 kilometres off the coast west of Dampier. Barrow Island has been recognised as an outstanding island for nature conservation. A large proportion of Australia's flatback turtle population uses the beaches of Barrow Island for nesting, and the Gorgon project has been predicted to significantly affect the access and use of nesting beaches by these turtles. Although the Western Australian Environmental Protection Authority initially recommended against the island's use for this project, the decision was subsequently revised to permit the industry to build on the island, subject to a number of environmental management conditions and commitments to offset impacts by improving protection of turtles elsewhere in the region.

The Gorgon project is funding the North West Shelf Flatback Turtle Conservation Program, contributing around $1 million per year for 60 years to increase protection of flatback and other turtles. It is also funding the monitoring and auditing of marine activities during the project's dredging and marine construction phase.[a]

The environmental management and research activities developed and applied as conditions to the development project are not likely to substantively mitigate the impacts of the industry's activity on the nesting of flatback turtles at Barrow Island itself. The research projects aim to increase survival of flatbacks (and other turtles) at other locations, and to gather more detail about the impacts of the reduction of Barrow Island nesting beaches on the flatback population. The program is supervised and assessed by a Marine Turtle Expert Panel of company and government experts appointed by, and accountable to, the Western Australian Minister for the Environment. This, and similar mining environmental offset arrangements in Western Australia, has been heavily criticised for a lack of transparency and public accountability.[b]

[a] www.dsd.wa.gov.au/7599.aspx
[b] www.audit.wa.gov.au/reports/pdfreports/report2011_08.pdf

Box 6.7 Montara spill

On Friday 21 August 2009, the West Atlas wellhead platform drilling rig owned by PTT Exploration and Production Australasia suffered a wellhead accident at the Montara Well, resulting in the uncontrolled discharge of oil and gas about 125 kilometres from Cartier Island Marine Reserve and 175 kilometres from Ashmore Reef National Nature Reserve (a declared Ramsar Wetland of International Importance). Other sensitive habitats in the region include the Hibernia Reef and the Jabiru Shoals. For 74 days, oil and gas continued to flow unabated into the Timor Sea. Initial estimates provided by the operator were that 64 tonnes (400 barrels) of crude oil were being lost per day. However, this estimate could not be confirmed at any time during the incident. The initial release of oil could have been as high as 1000–1500 barrels per day.[54]

This incident is Australia's worst seabed exploration oil accident, and has exposed a number of governance, science and logistics inadequacies. While a number of sensitive animals were known to have been directly killed by the oil, the early response of authorities to spray the ongoing spill with dispersant means that most short-term and medium-term toxic effects are likely to have been greater than would have occurred if no dispersant had been used. These effects occurred below the sea surface in the water column and seabed. Indicative post-spill monitoring showed that the oil effects may have subsequently spread to reach shallow seabed areas within 70 kilometres of the wellhead, and that the oil and the dispersant–oil mix was concentrated below the ocean surface in biologically sensitive depths of the water column. These subsurface areas are highly biologically productive, and fish and all air-breathing fauna (such as cetaceans, turtles and sea snakes) would have been heavily exposed to this pollution. Nonetheless, the surface expression of biological impacts was limited, and it appears that oil did not reach the sensitive reef areas of Australia's offshore islands.[a,55] The decision to use dispersants was consistent with information available to the Australian Maritime Safety Authority at the time, and was taken to avoid oil impacting on Ashmore Reef and Cartier Island and the coastline of Western Australia.[54]

The Montara spill highlighted some of the challenges that industry and governments face in ensuring that the best technologies, processes and practices are in place to prevent these types of incidents, which affect Australia's oceans and shores, and the many people and industries that rely on them. Since the spill, the environmental assessment process has been revised. For example, every assessment of an offshore oil and gas project now considers a spill scenario of at least 11 weeks duration, although it is not yet clear how useful this will be, since modelling systems are not sufficiently advanced to make accurate predictions at such scales. The plans, technologies and processes that a company now has in place to respond to this type of spill are also the subject of greater scrutiny.

Overall, this accident redefined the risks posed by this industry, highlighting the vast spatial and temporal scales over which impacts may occur, and the need for far greater control and scrutiny of onsite operations by government regulators. The clear message from recent accidents in this industry is that the location of exploration and production activities relative to globally unique ecosystems and highly valued natural features is a critical planning consideration.[b] Improvements in oil spill monitoring, modelling, forecasting, emergency response and environmental risk assessment would increase confidence in offshore oil and gas development proposals and planning.

[a] www.environment.gov.au/coasts/oilspill.html#studies
[b] www.environment.gov.au/epbc/publications/oil-gas-industry.html

The oil and gas industry in north-western Australia is rapidly expanding. Although individual wells or a coastal processing plant may have limited and local impacts, the widespread development of the industry is bringing new challenges to regional planning systems. Among other issues, the cumulative effects of dispersed production water, drilling fluids and wastes, and the increasing risk of ship strike and acoustic impacts on cetaceans are becoming significant management issues for fisheries and wildlife management. At present, there are:

- no regional strategic environmental assessments to guide planning and impact management systems, and limited baseline studies of existing conditions
- no systematic or structured interfaces with regional conservation and environmental management; each development is considered on its own merits, with very little consideration of cumulative impacts across a region
- no regionally integrated transportation management systems that recognise the specific requirements of the sensitive species and habitats of the region; there is no upper limit on vessel size, shipping lane use, frequency of transits or seasonal constraints on oil-industry vessels transiting the north-west in the path of the 'whale highway'—a feature of north-western Australia (see Section 1.4).[56]

3.4 Shipping and associated infrastructure

The shipping industry, with its associated substantial infrastructure (ports, harbours, shipping lanes, coastal support), is the major transportation link between Australia and other nations, and provides important linkages between regional Australia and the cities. Ports and shipping are a key component of the economic activity of Australia, with 99% by weight and 74% by value of our international trade carried by sea. Seventy commercial ports around the Australian coast deal with international shipping, and there are hundreds more smaller facilities providing critical infrastructure for a range of activities. In 2008–09, approximately 800 million tonnes of cargo were moved through Australian wharves by 4200 vessels that made 26 700 port calls.[57] In 2002, more than 3000 foreign commercial ships made more than 18 000 separate calls at Australian ports.[4] In Dampier (Western Australia) alone, in 2006, there were more than 3000 vessel visits, mostly from overseas ports, and these vessels discharged 42 million tonnes of water.[58]

The continuing development of regional Australia is resulting in many new ports and expanding and upgrading of existing ports. To service these developments, there is always a backdrop of coastal infrastructure, some of which is new, creating further demand on coastal land and recreational facilities in marine systems. Many of these new and upgraded facilities are developing to support the growing mining industry in Queensland, the Northern Territory and Western Australia.

Shipping lanes traverse some of the most ecologically sensitive marine areas, and regular groundings and accidents at sea place additional pressure on the marine environment. Also of increasing concern is the frequency of ship strikes on marine mammals, many of which occur in open waters and pass unreported.

The increase in shipping traffic is also increasing the risk of introductions of foreign marine species, and there is a risk that some of these will turn into serious pests in our waters. Many hundreds of introduced marine plants and animals have already hitchhiked to Australian waters on vessels of all types, from yachts to commercial ships, carried on their hulls and in ballast waters (water carried in tanks to maintain stability when a ship is lightly loaded). Some of these species have taken over habitats from our native species, changing our coastal areas and damaging our fishing, aquaculture and tourism industries.

Once marine pests are established, eliminating them is virtually impossible. Where conditions suit, they may multiply quickly and force out native species. Some (such as toxic algae) can pose a threat to human health as well as ecological health. The Australian, state and territory governments, along with marine industries and marine scientists, are implementing a National System for the Prevention and Management of Marine Pest Incursions to identify and respond to marine pests. This system aims to prevent new pests arriving, respond if a new pest does arrive, and minimise the spread and impact of pests that are already established in Australia. The system accepts that, where they have become established, marine pests will not be able to be eradicated, so ongoing management and control of introduced marine pests will be required.[59]

3.5 Aquaculture facilities

Australia's sheltered coastal waters are increasingly being considered as providing important opportunities for aquaculture. The main species being farmed are Atlantic salmon, southern bluefin tuna, rock oysters, pearl oysters, mussels, prawns and abalone.
These species are farmed in land-based and sea-based facilities, both of which have a range of environmental risks. There are four main areas of environmental concern: the potential for spread of diseases and parasites, the impacts of the facilities and supporting infrastructure, the interaction with wildlife, and the source and sustainability of wild stocks (if required) and feed. Key issues of environmental concern are diseases that can be harboured in, and spread from, both types of facilities; treatment and impacts of wastes, particularly feed and faeces; intensification of infrastructure in sensitive habitats; and effects on species that may become dependent on the structures or waste discharges.

In Australian waters, evidence indicates that both land-based and sea-based aquaculture has been the source of a number of major outbreaks of diseases in wild populations. The resulting impacts have been ecologically significant and will leave a lasting imprint on some of the affected ecosystems. In addition to disease outbreaks, there have been issues associated with use of chemicals, and impacts on threatened species such as sharks and seals. This is consistent with overseas experience of aquaculture impacts.[60] However, given appropriate levels of management and verification, the impacts of aquaculture facilities can be constrained to a minimal and acceptable level, bringing

the aquaculture industry in Australia into line with other modern farming practices to produce wealth from the ocean with minimal environmental degradation.

3.5.1 Sydney rock oyster

Australia has a long history of aquaculture in the estuaries of the east coast. The Sydney rock oyster (shell) was harvested for use as lime in cement production in Sydney in the 1800s, but this quickly depleted the local oyster beds. The earliest marine farming operations of oysters were subsequently established by Thomas Holt in Gwawley Bay (Georges River) in 1872, in response to the depletion of wild oysters. The industry was heavily focused on the Hawkesbury River in its early years, but declining water conditions and high levels of diseases have now almost eliminated production from this estuary. Oyster farming in New South Wales has now diversified to include the Pacific and flat oyster, on selected sites held under some 3200 aquaculture leases, with a total current area of approximately 4300 hectares.[61] The main oyster-producing areas are located away from urban areas. Commercial production in New South Wales occurs in 41 estuaries between Eden in the south and the Tweed River in the north, although Wallis Lake (on the north coast) is now the main Sydney rock oyster–producing area.

In the first 75 years of the New South Wales oyster industry, production of the endemic Sydney rock oyster grew to about 60 million oysters per year. In the subsequent 25 years, production increased to about 175 million oysters per year, peaking in 1977, and then trended downwards to the current 70 million oysters per year—less than half the production of the industry at its peak. Disease and environmental issues remain significant problems for this industry.

The statewide reduction in production is related to the impact of land-based sources of pollution (from urbanised areas and agriculture), and to an extensive and diverse set of waterborne diseases in farmed oysters, including viral and bacterial infections, protozoa and flatworms.[62] These accelerating issues have resulted in a much greater emphasis on the development of land management in river catchments that recognises the need for high water quality in oyster-growing areas.

■ Plastic bags and other plastic materials float on the surface of the ocean

Photo by Gary Bell

Disease issues in the oyster industry are also concerns for wild oyster populations. They include the potential transmission of diseases between the estuaries, related to industry practices, and possible maintenance of diseases in the wild population that might otherwise naturally dissipate to background levels. Oysters (wild and farmed) have an important role in estuaries, filtering water and feeding on plankton and other fine debris to clarify the water. Although the role of the intensive aquaculture system in transporting and spreading disease among the wild population or to other molluscs is unclear, these are important ecological impact issues for these estuaries and coastal waters. Also of concern is the spread of the Pacific oyster—this species is endemic to Japan and farmed in several states, and has developed many naturalised populations along the east coast. The ecological impact of this introduced species is uncertain, but is likely to be significant. Where its populations have become established, it is likely to compete with native species (including the Sydney rock oyster) for space and food, and possibly has impacts on a range of other sedentary species that also inhabit the estuaries of New South Wales.

3.5.2 Abalone

Abalone aquaculture is a recent initiative, mainly undertaken in Tasmania, Victoria and South Australia, where the most substantial natural populations of abalone also occur. In 2008–09, around 640 tonnes of abalone were produced from the aquaculture facilities in these states.

Two species are farmed—greenlip abalone (*Haliotis laevigata*) and blacklip abalone (*H. rubra*)—as well as a hybrid of these species, in land-based and sea-based farming systems. The two systems have very different siting and infrastructure requirements, and a different range of associated environmental risks. For example, in land-based tank systems, the growing abalone are fed on an artificial diet, require large volumes of fresh sea water and produce a large volume of wastewater. In sea-based systems, the growing abalone are fed on natural macroalgae (which may be harvested locally by hand), require only modest current flows of high-quality sea water and produce little waste. However, in both cases, high densities of individuals can lead to the risk of outbreaks of diseases that can very quickly (within days) become difficult to treat and control (Box 6.8).

Box 6.8 Abalone viral ganglioneuritis

In 2010, wild abalone populations in Victoria suffered from an outbreak of the lethal abalone virus known as abalone viral ganglioneuritis (AVG). AVG is a herpes-like virus that causes inflammation of the nervous tissues in the abalone, interfering with its ability to properly adhere to surfaces or feed. An AVG outbreak has also recently been identified in Tasmanian farmed abalone, although it is suspected to be of a different origin from the strain in Victoria.[63-64]

AVG was first reported in Australia in December 2005, when several abalone aquaculture farms near Portland and Port Fairy in western Victoria experienced unusually high levels of abalone deaths. It is suspected that a discharge from one of these farms where AVG was first detected permitted the virus to escape and infect wild abalone nearby. Since then, the virus has caused substantial deaths in wild abalone populations and continues to spread eastwards along the coastal waters of Victoria to Cape Otway. The persistence of AVG in wild abalone populations now threatens the vigour of these populations in Victorian waters, and may also affect the fishery for wild abalone. The broader ecological impacts of this disease outbreak are as yet unknown, but are likely to be regionally significant, given the important role that abalone play in the benthic ecology of reef systems across the southern Australian shores, from New South Wales to Western Australia.

3.5.3 Cage fish culture

At-sea cages for salmon culture are the fastest growing Australian aquaculture industry. The salmon farming industry is now Australia's single most valuable seafood production sector, overtaking the wild-catch fishery for western rock lobster, which has been in decline for a number of years. Australia's total production of caged salmonids—around 30 000 tonnes of salmon and trout, mainly Atlantic salmon from Tasmanian waters—was valued at $323 million in 2008–09, while the Western Rock Lobster Fishery production was valued at less than $200 million. However, salmon farming is not without environmental impact, and there are many areas of major uncertainty, particularly surrounding the use of chemicals to treat disease outbreaks.[65] Disease outbreaks destroy the farmed stock, can easily escape into wild populations[66] and are the subject of intense management in marine fish-farming systems (see Box 6.9). Entrainment of wild species on cage facilities is also a major global issue, attracting fish to the locality of the cages for access to uneaten feed pellets and other waste materials from the cages.[67]

Despite these and other issues, the careful siting and management of caged fish facilities can result in acceptably low impacts and risks. For example, the Australian Conservation Foundation has accepted the barramundi sea cage farm at Cone Bay, Kimberley, for recommendation within its sustainable seafood program, after an independent ecological assessment found that the impacts of these key factors were acceptably low.[68]

Box 6.9 Pilchard kills

Perhaps the worst fish kill in a wild population recorded from human causes is the massive series of pilchard kills that repeatedly occurred across temperate Australian waters (New South Wales to Western Australia) in 1995 and 1998–99. After a single event in 1999, at three Western Australian locations, 28 000 tonnes of pilchards were estimated to have been killed.[66,69] The fish kill episodes were observed across more than 4000 kilometres of temperate Australian coastline. Although there has been no attempt to estimate the total mortality of pilchards, mass fish mortalities of this scale are of national and probably global importance. The most likely source of the virus thought to be responsible is the frozen, but otherwise unprocessed, food used for tuna aquaculture sea cages on the Eyre Peninsula in South Australia.[66] Food for aquaculture purposes is now more systematically managed to reduce the risk of such disease importations. However, the virus that affected the pilchards is probably now well established in Australian marine ecosystems and likely to have low-level but ongoing impacts on the pilchard population and species that depend on this fish, including seabirds such as terns and penguins.[70]

3.5.4 Longline culture

The main aquaculture system based on lines is Australia's tropical pearl farming industry. This is a lucrative business that harvests natural tropical pearl oysters, seeds them with 'nuclei' of carbonate material, and then grows the oysters attached to long lines or dropper lines in at-sea facilities. A similar system is used to culture mussels in various bays and gulfs of temperate Australia. Such line systems, provided they are well designed and managed, are thought to have only limited environmental impacts on surrounding waters and seabeds; however, their extensive spatial scale can have other impacts, depending on the location of the facilities. The leases for pearl culture, for example, can spread across large areas, restricting access for other marine users (such as recreational fishers and boaters, and Indigenous people wishing to access their sea country[71]); dolphins and their calves, which avoid transit through the facilities; and whales, which are at risk of entanglement.[72]

3.6 Catchment run-off and land-based sources of pollution

Coastal habitats are susceptible to many impacts that arise from the adjacent lands, and from rivers that discharge into the gulfs, coastal lakes and lagoons and directly to inshore waters. The species and habitats that occupy these marine areas are often well adapted to the dynamics of variable levels of salinity and contaminants such as suspended sediments and nutrients, although their capacity to withstand these pressures is limited. Extensive and frequent extreme weather events, or persistent low-level pollution from rivers, may exceed the capacity of many species to resist such pressures. If these impacts occur broadly across a region, or persist locally for a long time, they will lead to irreversible change in habitats and species distributions. Examples from New South Wales and Western Australia illustrate these problems.

More than half the estuaries in New South Wales are subject to double the natural levels of sediment and nutrient inputs, and around one-third of catchments are more than 50% cleared of natural vegetation.[18] These and other pressures are directly linked to the poor water quality found in a high proportion of New South Wales estuaries—only 11% of the estuaries were found to comply more than 90% of the time with guidance levels for chlorophyll-a—and to losses of coastal vegetation, including seagrasses, which are estimated to have been reduced by more than 30% from their natural (pre-European colonisation) extent.[18]

The Northern Rivers region of New South Wales has 46 estuaries (25% of the total in the state) that cover 350 square kilometres (20% of the total state estuarine area) and drain an estuary catchment area of 49 600 square kilometres (39% of the total in the state). The 46 estuaries comprise 20 barrier rivers and lakes that are generally open, 23 creeks and lagoons with intermittently open entrances, and 3 brackish water bodies. Measured against benchmarks in recent history and using comparisons with the existing conditions in other New South Wales estuaries (which may also be degraded), a number of indicators are rated as very poor, including seagrasses, saltmarsh and chlorophyll in the water column. Many of the estuaries are under pressure from excessive inputs of sediments and nutrients, and altered freshwater inputs and hydrological regimes.[18,73]

Tuggerah Lakes in New South Wales is a barrier estuary with a long history of urbanisation of the catchment, including reclamation of foreshore wetlands and structural realignment of water passages between the individual lakes and the opening to the ocean. About half of the wetlands (the upstream 'biological filter' system) are already lost, including 85% of the saltmarsh, and urban development is directing surges of stormwater into the lakes. These changes contribute to problems such as 'black ooze' (monosulfidic black ooze causes rapid oxygen depletion of lake and drainage waters when the ooze is mixed with oxygenated waters during disturbance) and serious degradation of water quality in the lakes.[74] The lakes system has been subjected to a long series of structural solutions (such as dredging of the lake bed) over many years, and is currently funded for major ongoing restoration and environmental management works under the Australian Government's Caring for our Country program.

As with most such estuaries, coastal lakes and lagoon systems, many issues and many authorities are involved in management attempts to reduce environmental impacts and restore more desirable natural conditions. The New South Wales Government 'owns' the Tuggerah Lakes, while Wyong Shire Council is the main manager of the catchment that flows into and affects the environmental health of the

Tuggerah Lakes estuary. A number of state and federal authorities have a role in management. Private and community sector organisations also have a direct interest in the management of the lakes, including community groups, the real estate industry, various recreational groups and commercial fishers.

The most recent assessment of Tuggerah Lakes indicates that, although turbidity is ranked as fair, important ecological aspects are in good or very good condition, including fish, seagrasses and saltmarshes, suggesting that restoration efforts have been at least partially successful.[73,75]

In Mandurah (Western Australia), major nutrient and algal bloom problems have a long history in the Peel–Harvey Estuary, caused principally by nutrient pollution from upstream agricultural lands.[76] The $57 million Dawesville Channel was opened in 1994 to create an artificial opening from the Peel–Harvey Estuary to the ocean, to increase flushing in the estuary and reduce the frequent and extensive algal blooms and nutrient pollution problems. Subsequently, local residents observed a temporary improvement in conditions, but deteriorating water quality and adverse biological conditions returned within five years of the channel opening. These included further major algal blooms and deterioration of some indicator species to levels equivalent to those documented before the channel.[77] Thus, despite a large investment of public funds, restoration efforts may not have been able to persistently improve environmental conditions in this estuary.

In addition to impacts in enclosed coastal waters, such as the examples above, land-based sources of pollution can have serious impacts in open coastal waters. On the Queensland coast adjacent to the Great Barrier Reef, there are 38 major river catchments, including some of Australia's largest rivers (such as the Burdekin and Fitzroy rivers), and these combined sources deliver substantial amounts of sediments and nutrients into the shallow coastal waters of the nearshore lagoon system. The catchments now deliver 2–10 times more nutrients and sediments to the lagoon waters than they did before European settlement.[31] They also deliver significant amounts of pesticides to the reef and lagoon waters, although the impact of these chemicals on habitats and species are as yet unclear.[32] Nonetheless, the combined impacts of the sediments, nutrients and agricultural chemicals reaching the coral reef systems of the Great Barrier Reef are considered to be highly significant. Models have estimated that minimising agricultural run-off could reduce macroalgal cover, which threatens the viability of corals on reefs across the Great Barrier Reef, by 39% on average, and increase the richness of hard corals and phototrophic octocorals on average by 16% and 33%, respectively.[78]

The evidence indicates that, although we can point to many small-scale successes, the problems of land-based pollutant sources, coastal development and catchment run-off are likely to be much more effectively resolved by systems that deliver prevention rather than cure. Both prevention and cure can be complex and expensive, and take a long time to implement and produce results. Whereas the pathway to effective prevention is moderately clear, achieving a successful cure for impacts of coastal development once they have occurred is not only difficult and costly, but also uncertain. Unfortunately, management systems around Australia appear to have difficulty learning from past failures, and this impedes the application of more effective planning for prevention rather than applying a cure.

3.7 Additional pressures

A large range of additional pressures not discussed here also operate across the regions. These include other pollutants, such as marine debris; and the activities of a range of industries and groups, such as tourism, mining, energy generation, desalination, defence, recreational boating and the traditional use of marine resources.

Generally, these apply less acute pressure, or data on their impacts are more difficult to acquire. For example, marine debris (particularly derelict fishing nets) is a well-known issue in Australian and global tropical waters. Available information indicates that at least 77 species of marine wildlife found in Australian waters, including turtles, cetaceans and seabirds, have been affected by entanglement in, or ingestion of, plastic debris during the past three and a half decades (1974–2008). Most records of impacts of plastic debris on wildlife relate to entanglement, rather than ingestion.[80] The extent of impact from marine debris on marine populations overall is unclear.

Box 6.10 River flood plumes from the dry tropics into the Great Barrier Reef lagoon

Source: Based on or contains data provided by the Commonwealth Scientific and Industrial Research Organisation, NASA (source data) and Geoscience Australia. These organisations give no warranty in relation to the data and accept no liability for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for direct marketing or be used in breach of the privacy laws. Also includes data from the Great Barrier Reef Marine Park Authority.

Satellite image of the Burdekin River flood plume on 22 February 2008

From 2000 to 2006, the Burdekin and Fitzroy river catchments received relatively small amounts of rainfall (around 670 millimetres annually), leading to only limited river plumes flowing into the Great Barrier Reef lagoon. From 2007 to the 2011 wet season, this changed significantly. Monsoonal or cyclonic rainfall sometimes reached the annual average for the catchment in a few weeks, causing small, medium and large river flood plumes along the entire east Queensland coast that extended well into the lagoon.

The flood plume shown by the true-colour satellite image above extended more than 40 kilometres into the Great Barrier Reef lagoon and was caused by significant rainfall from several low pressure systems.[79] This flood plume merged with the wide band of flood-affected waters following the coast in a south-to-north direction, originating mainly from the Fitzroy, Pioneer and Proserpine rivers. The clear, beige colour shows water masses that are strongly dominated by freshwater suspended sediment, such as clays, whereas the water with a darker brown colour is a mix of fresh and marine water, with more dissolved and particulate organic material. The mid-shelf broad green band south of the plume is likely to be a phytoplankton bloom that resulted from the increase in nutrient availability provided by the river flood plume waters. The satellite image shows that the coarse material of suspended sediments is deposited near the coast, while the finer particulate and dissolved fractions merge into a 30–40-kilometre-wide band that gradually disperses towards the Reef. In some cases, these floodwaters may disperse through the inner, mid and outer reef into the Coral Sea, and occasionally curve back towards the outer reefs tens to hundreds of kilometres north of their source rivers. There is evidence that an increase in frequency, intensity or duration of these flood plumes causes increased primary production during the wet season through phytoplankton growth, and this may contribute to decreased resilience of the coral systems of the Reef.

The long Great Barrier Reef coastline (2000 kilometres) and the short-term duration of floods make monitoring the flood plumes difficult. However, several institutes (Commonwealth Scientific and Industrial Research Organisation, James Cook University, Australian Institute of Marine Science, Great Barrier Reef Marine Park Authority) regularly combine their field sampling efforts and expertise to monitor such events and assess the impact of floods on the water quality of this world-renowned ecosystem.

Source: Blondeau-Patissier[38]

6.7 Assessment summary

Pressures affecting the marine environment

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Pressures resulting from climate change	Sea level rise, increasing ocean temperatures and acidity are beginning to have significant impacts in all regions, and these effects are expected to increase. The worst affected areas are in the south-east and south-west, and are irreversibly and very seriously impacted. Changes in ocean current dynamics driven by climate change are also affecting these two regions			↙		◒	◒
Coastal urban development	The worst affected areas are in the east, south-east and south-west, and are irreversibly and very seriously impacted			↙		●	●
Port facilities	Pressures are widespread and serious in all regions except the north		↙			●	◒
Oil and gas exploration and production	Most pressures are localised. The worst areas are in the south-east and north-west, but impacts remain minor overall. Pressures are expected to increase in the north-west				—	◒	◒
Fishing	Pressures are decreasing overall, although in the worst areas of the south-east, east and south-west, pressures are widespread and causing serious degradation, and the east continues to degrade			↗		●	◒
Shipping	Pressures are increasing in all regions, resulting in declining conditions			↙		●	◒
Aquaculture	Pressures continue to increase in the south-east, where the worst areas are already suffering serious degradation			—		●	●
Catchment run-off	Most areas in the south-east and east are suffering serious degradation			—		●	◒
Marine debris	There are widespread pressures in all regions		↙			◒	◒

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Tourism facilities	The worst areas, in the south-west, have suffered serious degradation			—		◒	◒
Mining and industry	The worst areas, in the south-east and south-west, have suffered serious degradation			—		◒	◒
Energy generation	These pressures are localised and stable				?	◒	○
Desalination	Only local impacts have been observed			—		◒	◒
Recreational boating	There are widespread pressures that are increasing			↙		●	●
Defence	These pressures are localised and stable			—		◒	●
Traditional use of marine resources	These pressures are localised and stable			—		◒	◒

Recent trends

- ↗ Improving
- ↙ Deteriorating
- — Stable
- ? Unclear

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◒ Limited evidence or limited consensus
- ○ Evidence and consensus too low to make an assessment

Grades

🟩	Very low	There are few or negligible impacts from this pressure, and accepted predictions indicate that future impacts on the environmental values of the region are likely to be negligible
🟫	Low	There are minor impacts in some areas, and accepted predictions indicate that future impacts from this pressure on the environmental values of the region are likely to occur but will be localised
🟧	High	The current and predicted environmental impacts of this pressure are significantly affecting the values of the region, and predictions indicate serious environmental degradation within 50 years
🟥	Very high	The current and predicted environmental impacts of this pressure are widespread, irreversibly affecting the values of the region, and predictions indicate widespread and serious environmental degradation across the region within 10 years

Effectiveness of marine management

Assessing management effectiveness addresses the question of how well the management responses that are applied to an environmental problem identify, avoid, react to or resolve the issue. Each government entity—national, state or territory, local—has a range of different policies, laws, regulations and established practices at their disposal to deal with environmental issues. These cover the full gamut of strategic planning, implementation of management activities, and compliance assessment and reporting. Increasingly, larger private-sector entities (such as major companies) have a range of similar tools available to them to plan for and manage environmental problems that may arise within their areas of control, usually to ensure compliance with government requirements. Indeed, in some jurisdictions, some specific government responsibilities are devolved to private-sector entities to implement under the broad strategic guidance of government. Common tools applied to environmental issues in the private sector include strategic planning systems (such as risk assessment), operational management systems (such as best-practice guidelines), and whole-of-operation reporting systems. These may be developed on an industry-wide basis or, more commonly, on a company-wide or operation-wide basis.

Assessing private-sector and public-sector management of any specific marine environmental issue in Australia requires a comprehensive analysis of the hierarchical relationships between the various entities with jurisdiction and responsibility, and the extent of achievement of the explicit and implicit intended environmental outcomes. The ultimate measure of effectiveness is the extent to which the environment is protected. This can best be demonstrated through performance reporting on habitats, species and ecological health against established standards (as summarised in Section 2 of this chapter). The situation and issues in some selected jurisdictions are discussed below.

4.1 Environment protection systems

All jurisdictions in Australia have core environmental management and conservation functions, expressed through their respective legislation, policies and programs. This section considers a small sample of relevant activities.

At a glance

Many improvements in management systems at both state and national levels have produced substantial and persistent outcomes for marine ecosystems and biodiversity. These arise from programs devoting considerable resources to environmental protection and improvement of estuarine and coastal ecosystems across all jurisdictions. Nonetheless, most of these efforts are poorly coordinated within jurisdictions and only weakly harmonised with a national approach, and there are no systematically derived regional objectives for marine biodiversity to guide strategic planning or management. There is limited federal leadership in the implementation of an effective national system for management of coastal marine ecosystems and biodiversity, and their protection from persistent and emerging threats. There is continued loss of biodiversity, duplication of effort, inefficiencies, an overall lack of effectiveness, and distrust among the sectors, the various jurisdictions and the community. This issue has been raised as a high priority by every national State of the Environment report, and by many authoritative reviews and commissions over decades. A vertically and horizontally integrated national system for marine conservation and management is widely seen as a critical gap in management.

4.1.1 Australian Government

The Australian Government's principal regulatory tool for managing marine environmental issues is the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Act provides a framework for the management of matters of national environmental significance in the entire Australian marine environment. The primary activities of the EPBC Act in marine matters relate to marine bioregional planning, protected and listed species, world heritage and, in the Commonwealth marine area, marine reserves and mitigation of marine impacts. The Act also provides for activities in relation to threatened ecological communities, but no marine communities have yet been approved for EPBC Act listing.

In Australia, Commonwealth-managed fisheries and all fisheries intending to export products (irrespective of jurisdictional control) are assessed within the terms of the EPBC Act, principally using the *Guidelines for the ecologically sustainable management of fisheries* (second edition) (GESMF), established under the Act. These guidelines explicitly endorse and aim to facilitate ecosystem-based fisheries management, in addition to the management of specific target and protected species. The GESMF provides a basis for evaluating the environmental performance of fisheries, including:

- the strategic assessment of fisheries (under Part 10 of the Act)
- assessments relating to impacts on protected marine species (under Part 13 of the Act)
- assessments for the purpose of export approval (under Part 13A of the Act).

The areas of the Act that relate to exploited marine species are dominated by matters involving fishing systems, particularly aspects of fishing that relate to two key issues:

- the condition of the species being exploited (through assessments using the GESMF)
- the impacts of fishing systems on protected and listed species, and more generally on marine ecosystems.

The primary tools used to assess the condition of exploited species are the GESMF and the strategic assessment of exploited species for export purposes. Both assessments are conducted by the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), based on information provided by individual proponents specifically for the assessment process, and public comment. The proponents are usually state fishing agencies, AFMA or individual fishing entities (such as fishing companies and industry associations); submissions often include scientific research and assessments commissioned by these entities. More than 120 fisheries around Australia have been assessed under the EPBC Act and the GESMF. Most of the assessment process is devoted to the condition of the exploited stocks, and the extent and nature of the direct impacts of fishing activities on listed and protected species under the Act (through assessing byproduct and bycatch). There is typically less information to support the consideration of broader marine conservation issues at the ecosystem level, including trophic and cumulative impacts.

Strategic assessment under the EPBC Act assesses fishing activity at the level of management plans or policy, rather than each individual action or permit. The benefit of this approach is that it enables the collective impacts of a fishery to be considered and provides certainty for the proponent about the activities that are permitted. When the assessment is complete, the Australian minister for the environment may then ‘accredit’ the management plan or policy and make a declaration under the Act that activities conducted under the accredited plan or policy do not require further impact assessment approval under the EPBC Act.

Although a number of marine species are listed under the provisions of the EPBC Act (mainly marine mammals, seabirds, reptiles and some fish species, including seahorses and their relatives), their conservation is assisted by few recovery plans or threat abatement plans. Threat abatement plans address key threatening processes rather than individual species, but only two threat abatement plans have been approved for action to protect marine species (relating to the impacts of marine debris and the bycatch of seabirds in longline fishing).[f] No listed marine species have yet recovered to population levels that have removed them from protected status under the Act. The recent independent review of the Act[81] recommended significant changes. In particular, the review noted that any change should improve, not downgrade, the standards of protection afforded to marine ecosystems in fishery assessment systems under the Act, and provide for much greater levels of integration in the vertical and horizontal directions (between national, state, industry and community organisations; and between the organisations themselves). This is a call for change that has been widely recognised in the marine science community for many years. The Resources Assessment Commission Coastal Zone Inquiry (1993),[82] the preparatory phase for Australia’s Oceans Policy (1998)[83-84] and many more reviews over recent decades have called for a systematic and nationally integrated approach to management of the oceans and coasts. The independent review of the EPBC Act reinforced the principle of subsidiarity (that decisions should be made by a central authority where they cannot be made effectively by a lower level of government), and that a coordinated and integrated national approach to environmental management is the most appropriate way to ensure credible and lasting national outcomes.

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[f] www.environment.gov.au/biodiversity/threatened/tap-approved.html

Important achievements of the EPBC Act have been the setting of approaches and standards for listed marine species—those considered to be rare, endangered, or vulnerable to excessive impacts or exploitation; to be related to matters of national environmental significance; or to have special international significance (such as migratory wading birds). In this matter, the Act has provided a system that propagates from Australian Government policy-level decisions down to state-level policy and operational management systems, and gives significant effect to the principle of subsidiarity. However, the Act is silent, or gives only weak guidance, on many other important aspects of the marine environment.

Although there have been important achievements under the EPBC Act, the lack of effective outcomes in marine environments is clear, and the independent review draws attention to the structural, process and content issues with the Act that need attention to enable an integrated approach to environmental protection and management. The review identifies the need to establish a new Act (notionally, the Australian Environment Act) with improved structure and objects, designed to give primacy to the protection of the Australian environment 'through the conservation of ecological integrity and nationally important biological diversity and heritage'.[81]

Beyond the EPBC Act, the Australian Government also has a range of responsibilities to provide broad policy guidance on many land-based environmental issues that affect marine ecosystems, and particularly coastal and estuarine systems. These include catchment management systems, various aspects of urban and agricultural land use, natural resource management, and specific issues in rainforests and coastal ecosystems.

To improve knowledge about the oceans, the Australian Government has funded a series of major new programs. These include ocean observing systems to build a better understanding of the current flows and their variability (such as the Integrated Marine Observing System[g]), and research to better understand how climate changes may affect the ocean systems (such as programs conducted by the Commonwealth Scientific and Industrial Research Organisation, the Bureau of Meteorology and the Australian Institute of Marine Science). The Australian Government (through DSEWPaC) has also recently established the National Environmental Research Program, which is providing public-good funding for marine (and terrestrial) biodiversity research.[h]

These and a number of other measurement and monitoring systems are greatly improving our knowledge of the physical aspects of the oceans, but a considerable amount of uncertainty remains on biological and ecological issues. There is also a major lack of capacity to translate our modern understanding of the science issues into information that is used in management and policy decision systems. These combined weaknesses significantly hinder, for example, our understanding of the interaction of climate change with the marine and coastal values and resources, and hence the extent of environmental impacts, and the level and extent of changes that may be required in management programs.

4.1.2 State and territory governments

State governments have initiated a number of state-level programs aimed at mitigating recognised issues in their waters. These include area-specific programs such as the Derwent Estuary Program in Tasmania, the Healthy Waterways Program in southern Queensland, and the Cockburn Sound Management Strategy in Western Australia. Many of these have achieved significant success. For example, the Reef Water Quality Protection Plan brings together people and projects to help improve the quality of water entering the Great Barrier Reef lagoon. Launched in 2003 as a joint initiative of the Australian and Queensland governments, the plan was revised and updated in 2009. The plan has two primary goals: to halt and reverse the decline in water quality entering the Great Barrier Reef by 2013, and to ensure that, by 2020, the quality of water entering the Reef from adjacent catchments has no detrimental impact on the reef's health and resilience. These are all important initiatives, incrementally contributing to reducing pressures on the ecosystems by addressing local factors that are considered to be important stresses on ecosystems.

The states and territories also have a highly complex set of Acts, regulations, policies and strategies affecting the marine environment. These jurisdictions have direct control over their internal waters and most aspects of their nearshore waters (the three-mile zone). They also have various levels of control over many of the Australian Government's renewable, and some nonrenewable, resources in the exclusive economic

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[g] www.imos.org.au

[h] www.environment.gov.au/about/programs/nerp/hubs.html

zone. Responsibility for these resources was provided to the respective states and territories under the Offshore Constitutional Settlement and formalised in the Coastal Waters Acts in 1980, which give the states and the Northern Territory powers over three nautical miles of the territorial sea. A number of major fisheries are managed under this arrangement—as a result, a fishery may be managed either by a state, by the Australian Government, by a joint authority, or by both a state government and the Australian Government. Similarly, the Australian Government delegates the assessment of various environmental impacts to state agencies under a system of joint arrangements. The states and territories also directly control the land-based activities that result in pressures and impacts in the highly valued nearshore waters of coastal marine ecosystems. Overall, it could be argued that the state jurisdictions may have greater influence on the status and values of Australia's marine biodiversity than does the Australian Government. An overarching framework for nationally integrated management would therefore make a major contribution to improving management of the marine environment.

State-level arrangements for managing issues in marine and coastal ecosystems are complex. For example, in Western Australia, a number of agencies and their respective Acts have responsibility for various marine and coastal issues, and there are only weak arrangements for horizontal integration to ensure that the full range of values of marine ecosystems are maintained within the state jurisdiction. The agencies with such responsibilities include:

- Department of Environment and Conservation (marine mammals, seabirds, reptiles, marine water pollution and quality, environmental impacts, terrestrial and marine parks and reserves)
- Department of Water (estuaries and rivers, water quality, environmental health, aquatic and fringing vegetation)
- Department of Fisheries (fisheries for exploited species, aquaculture)
- Department of Planning (regional and local coastal planning)
- Department of Transport (coastal beaches, dunes, commercial and recreational boating, marinas, jetties, shipping channels)
- Department of Mines and Petroleum (mining and exploration).

The state agencies have established coordination mechanisms that might best be described as 'systems to avoid treading on each others' toes', but there is no formal or informal system that has the responsibility of maintaining the environmental values of the marine and coastal ecosystems of Western Australia or providing for systematic reporting on their condition. The Marine Parks and Reserves Authority has established a systematic process for auditing and reporting on the environmental conditions in marine parks and reserves, and the Cockburn Sound Management Council has a system of auditing and reporting for Cockburn Sound. However, together these cover only a very limited area of Western Australia's marine environment, and issues remain about lack of capacity and resourcing for auditing and reporting.[85]

Like all Australian SoE reports at either state or national level, the compilation of the Western Australian SoE report has been hampered by a major lack of data and information about the condition of the Western Australian marine environment. A significant amount of marine monitoring data has been collected to inform and report on the success of management initiatives in Cockburn Sound, but marine management and reporting programs elsewhere are fragmented and only weakly coordinated.[48] Where monitoring data are available and recent investigations have been conducted, such as in the Peel–Harvey Estuary, further environmental degradation has been observed, contrary to model predictions made as recently as 20 years ago,[77] reinforcing the need for a comprehensive system of monitoring and reporting to ensure that public expenditure on environmental reforms achieves its intended outcomes.

All states and territories have equivalent agencies and responsibilities, although they vary greatly in the way they are structured and how they work together.

In New South Wales, the State Plan 2006 was established to stem decline in water quality conditions and biodiversity across the state's marine, coastal lake and estuarine ecosystems,[18] with an explicit commitment that, by 2015, there will be no decline in the condition of ecosystems. The plan identifies the need for a mix of natural resource management and conservation measures to meet the goal. The principal legislative instruments applied in New South Wales waters to protect and manage these ecosystems and associated biodiversity are the *Environmental Planning and Assessment Act 1979*, the *Coastal Protection Act 1979*,

the NSW Coastal Policy 1997, the *Fisheries Management Act 1994* and the *Marine Parks Act 1997*. These are supported by legislation to control point sources and shipping sources of pollution and the establishment of an IMOS (Integrated Marine Observing System) monitoring system near Sydney. This set of legislation is typical of the diverse and complex policies that apply at state and territory level to the protection of coastal and marine ecosystems across Australia.

Fisheries legislation in all jurisdictions is tasked with maintaining sustainable fisheries, but most (e.g. New South Wales, Victoria, South Australia, Western Australia) also have a requirement to manage ecosystem impacts and a commitment to ecosystem-based approaches to fisheries management. The latter is intended to provide broader and more precautionary levels of protection for targeted marine populations and their supporting ecological communities. Ecologically sustainable development in fisheries is interpreted and applied in Australia to ensure that the maximum sustainable economic yield can be extracted from target populations. Additional restrictions or closure of fisheries most often occur when the target stocks drop to a level where the economic and ecological viability of a fishery can no longer be assured. A recent international evaluation of ecosystem-based management in fisheries found that the Australian system rated as 'adequate' (behind six other countries), while the New South Wales system failed.[86]

Best-practice fishery management approaches applied to both nontarget and target species dictate that populations of nontarget species affected by fishing (either directly, such as through bycatch, or indirectly, such as through trophic dependencies) need to be considered. For instance, Sainsbury[87] suggested that, to ensure that natural trophic dependencies are maintained and natural ecosystem functions can continue, nontarget species in fisheries may need to be maintained at or above 75% of their natural population levels. However, there are few documented examples where such standards are applied (or achieved) in Australian fisheries, and most fisheries do not report on such matters. Most of the fisheries that do report in this manner are Commonwealth-managed fisheries, but they comprise only 14% of Australia's fisheries by value (30% by weight of catch). Using fishery legislation only to protect and manage marine environments gives primacy to use rather than conservation and, worldwide, this has resulted in significant problems in maintaining the biodiversity and trophic structures of marine ecosystems where intensive fishing is conducted.

■ Schooling green puller (*Chromis virdis*) and orange fairy basslets (*Pseudanthias squamipinnis*) above *Acropora* coral, Great Barrier Reef, Queensland

Photo by Gary Bell

4.2 Marine protected areas

All jurisdictions other than the Northern Territory have legislation dedicated to the design, declaration and management of marine protected areas (MPAs) in their waters. Australia has a national program to coordinate the jurisdictions in their approach to design, declaration and reporting of MPAs (the National Representative System of Marine Protected Areas—NRSMPA),[88] and all jurisdictions support the NRSMPA. However, although the program has been in operation for 20 years, it has been unable to achieve a significant level of standardisation in planning, design or reporting on MPAs in Australian waters.

In 2004, the NRSMPA covered just 7% of Australia's marine jurisdiction. It has now expanded to nearly 10% of Australia's marine waters, mainly as a result of the declaration of large areas of MPAs in the south-east region.[88] It is clear that Australia has been proactive in declaring MPAs to assist with biodiversity conservation, probably as a result of the highly valued marine biodiversity in our waters.

However, Australia's focus has been on declaring MPAs for high protection in the offshore deep waters and on the Great Barrier Reef, not the continental shelf and shoreline elsewhere, where biodiversity values are most under pressure.[89] Although there have been some attempts at interjurisdictional cooperation, the cross-shelf and interjurisdictional MPA planning to protect mutual biodiversity values and ecological processes has been lacking or heavily constrained. Although several states (such as South Australia) have active programs of MPAs that are well advanced, it is unclear what contributions these will make to the national system of MPAs. Many of the MPA designations have resulted from piecemeal or ad hoc decision-making and do not reflect the ecosystem-based or regionwide needs for conservation. In addition, a consistent approach among jurisdictions to the use of MPA designations is lacking—for example, a 'marine park' in Western Australia permits fishing, while in Victoria it does not.

Table 6.1 Area (square kilometres) of Australia's marine parks and reserves in high-protection categories (IUCN categories I and II)

	C'wlth	NSW	NT	Qld	SA	Tas	Vic	WA	Australia
IUCN I	240 039	665	0	412	771	737	0	2 974	
IUCN II	117 558	0	–[a]	16 197	865	477	535	–[a]	
Sum of IUCN I and II	357 597	665	0	16 609	1 636	1 215	535	2 974	381 230
Total waters	8 528 214	8 802	71 839	121 994	60 032	22 357	10 213	115 740	8 939 191
% in IUCN I and II	4.19	7.56	0.00	13.61	2.72	5.43	5.24	2.57	4.26

Australia = total for all jurisdictions; C'wlth = Commonwealth (managed by the Australian Government); IUCN = International Union for Conservation of Nature; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

[a] IUCN II data from Western Australia and the Northern Territory have been removed, because in these jurisdictions fishing is permitted, which is inconsistent with IUCN II zoning.

Source: 2008 Collaborative Australian Protected Area Database data (excludes the extended continental shelf and the Australian Antarctic Territory)

In Victorian waters, there are 24 MPAs of category I or II (highly protected) under the classification system of the International Union for Conservation of Nature (IUCN). However, a recent audit of performance found that only weak arrangements were in place to enable a clear definition of roles, responsibilities and accountabilities between stakeholders, and this prevented effective planning and management of the Victorian MPAs. The audit also found that there was little interaction between the various Victorian agencies that have marine interests or activities. This resulted in a lack of effective or efficient mechanisms for integrated management across all the environment issues in the state's marine waters.[90] In the face of the many environmental pressures, some of which are accelerating, this situation would generally be considered to pose an unacceptably high risk that significant biodiversity loss may be happening and passing unnoticed.

While the NRSMPA is intended to be underpinned by the 'CAR' principles of comprehensiveness, adequacy and representativeness,[i] interpretation and implementation of these principles vary across jurisdictions, and there is considerable concern about a lack of attention to CAR principles in the NRSMPA.[91] Clear and nationally consistent guidelines are lacking for applying CAR principles to inform the prioritisation and selection of areas; and complementary, ecosystem-based, cross-shelf planning is not widely conducted to coordinate national and state efforts. The lack of a cooperative and integrated approach to the planning and management of MPAs in Australian waters (particularly coastal shelf waters) has become a critical impediment to achieving an adequate level of conservation and effective management of representative elements of Australia's marine environment and biodiversity.

As of 2008, Australia had declared 4.3% of its waters as highly protected (IUCN categories I and II) MPAs, including MPAs in Australian waters and state and territory waters (Table 6.1).

In addition to the NRSMPA system, a wide range of jurisdictional measures provide other forms of area protection for marine ecosystems. Each of these contributes to some elements of marine biodiversity protection, although not in any planned or systematic manner, nor with specific objectives for nature conservation. They include subsidiary marine protected areas that may be designated as no-fishing zones for the management of fish stocks, recreational zones designed for non-extractive tourism ventures, and Indigenous protected areas (IPAs). These subsidiary protected areas typically allow various forms of resource extraction, provide limited protection for species, and do not afford comprehensive area protection.

In northern Australia, there is rapidly increasing momentum to establish marine IPAs (on waters adjacent to Indigenous lands), but this is on an ad hoc

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[i] www.environment.gov.au/coasts/mpa/nrsmpa/index.html

basis without any consistent regional approach, and without any national or state and territory policy frameworks. The lack of these latter arrangements inhibits integration with broader management frameworks to ensure that protected area planning contributes to biodiversity protection through systematic planning underpinned by CAR principles. Terrestrial IPAs (see, for example, the Dhimurru IPA plan of management[92]) currently make a significant contribution to the regional terrestrial CAR principles, and it seems likely that well-planned marine IPAs could ultimately make an important contribution to regional marine conservation objectives.

At present, these various types of subsidiary areas are not considered to make a formal contribution to marine biodiversity protection because they usually do not have secure tenure—their uses can be reversed or altered without recourse to open public scrutiny and transparency. Generally, when MPAs are declared under parks and reserves legislation, formal public parliamentary processes—including a public debate—are required before their use can be altered or rescinded. Collectively, the lesser forms of protection cover large areas of Australia's marine environment, but their contribution to the protection and conservation of marine biodiversity and environments cannot be easily assessed or compared with areas that are determined with a higher level of certainty, such as MPAs managed for high protection (IUCN categories I and II).

4.3 Managing for the externalities

Australia's formal environment protection system is broadly charged with the responsibility to deliver protection of the environment while providing for the ongoing development of the wealth and wellbeing of our human communities. This objective means that governments and their environmental protection and management systems need to provide a balanced view of the extent of environmental degradation that can be accepted in achieving acceptable environmental, social and economic outcomes. That is, the environment is protected to the extent that it can be while still providing for advancing economic and social development. This approach can result in, for example, a government authority rejecting an industry proposal on the grounds of unacceptable levels of environment impact, but the government of the day overturning this decision, seeking to provide the balance described above. In this way, setting policy objectives and processes to achieve balance can trade away environmental quality through the tyranny of many small decisions ('death by a thousand cuts').

The balance in the Australian environment has become heavily contingent on globalisation of the markets for Australia's raw resources, commodity goods and services. The price that can be achieved for an exportable resource or product governs the extent to which Australia can achieve increased economic and social development. This typically moves the balance and can allow economic drivers from overseas to increase local environmental impacts by greatly increasing the attractiveness and economic feasibility of (for example) an individual resource exploitation project.

'Creeping degradation' can be effectively prevented by the establishment of absolute standards for the environment. Important calls have been made for environmental benchmarks to be set for use in environmental accounts,[93] but a set of standards based on equivalent metrics is equally important. The lack of a set of standards for the Australian marine environment that are based on measurable and ecologically sound metrics means that acceptability on social and economic grounds can, and often does, result in greater pressures being applied to the Australian environment.

In marine systems, there are very few defendable metrics that can be used within management frameworks for this purpose. Probably the best developed standards are those within the Australian Government's fisheries management systems, although these are primarily directed at production systems, not environmental protection. Not only are there few marine standards, but there are no national monitoring systems that could be used to determine if a relevant standard is being achieved and maintained.

In the absence of a system of national marine standards for ecosystems and biodiversity, or an integrated framework of national marine management that could be used to apply such standards, the marine environment is destined to be continually rebalanced in a downward direction. Although there are many examples of improving local conditions, there are very few examples of improvements in ecosystems at the regional scale. For this report, 13 of the 31 major species or groups assessed (40%) were rated as being in poor or very poor condition, and only four of these were considered to be improving. These four groups were considered to be recovering because of the removal of excessive fishing pressure, reflecting the legacy of overfishing and the improvements in contemporary AFMA fisheries management practices. It is therefore clear that sector-by-sector changes can be (and have been) made to reduce impacts. However, such changes are slow and costly unless an integrated system of management is established that sets targets based on environmental standards.

4.4 Integrated management

Integrated marine management involves establishing objectives for managing all activities pertaining to assets and values of the environment. In this sense, the values and assets of the marine environment, and the processes that support them, become the endpoints for management. Maintaining these values and assets involves responsibilities across many spheres of government, the private sector and local communities. Each of these has to know what is expected of their activities in relation to the quality of the values and assets, so that each knows what types of activities will be acceptable and compatible with the marine values and assets. An integrated approach to management involves establishing and maintaining a set of standards that reflect the desired condition of the values and assets; controlling activities to ensure that the standards are met; and establishing appropriate information, consultation and transparency systems to ensure that the public knows that the standards are appropriate and maintained. This is particularly important for the marine environment, because many aspects of marine management, and marine values and assets, involve the expenditure of large amounts of public funds, for which accountability is required.

Many attempts have been made to develop and implement various forms of integrated marine management in Australian waters, but none have persisted. In 1998, the Australian Government released Australia's Oceans Policy, a far-reaching initiative that was intended to provide, for the first time, a nationally integrated approach to the management of Australia's maritime jurisdiction outside the three-mile zone. Unfortunately, the Oceans Policy has failed to achieve its primary objective—it has not embedded integrated approaches, but has merely become an additional tool for marine environmental protection.[2-4]

There are a number of small-scale integrated marine management initiatives (such as at Rottnest Island near Perth). The most successful example is the Great Barrier Reef Marine Park (GBRMP), which operates under its own Act of Parliament, the *Great Barrier Reef Marine Park Act 1975*. The Act provides a framework for the Great Barrier Reef Marine Park Authority to address pressures on the values of the GBRMP from activities within the GBRMP. Pressures on the values of the GBRMP that occur from activities outside the GBRMP are addressed through the EPBC Act. The Great Barrier Reef Marine Park Authority has recently completed a pioneering analysis of management systems and effectiveness in the GBRMP, culminating in an outlook report that identifies the full range of issues, anticipates the future and highlights the key pressures that will influence the future condition of the GBRMP.[31] The report identifies issues that span many sectors of activity, including activities that do not occur within the GBRMP but have an important bearing on the future condition of the park and its conservation status. It reflects an integrated approach to management, focused on achieving specific objectives for the natural ecosystems of the GBRMP (including resource exploitation).

4.5 Evaluation of management effectiveness

Evaluation of management effectiveness involves assessing each of the core elements of an effective and efficient management framework (understanding, planning, inputs, processes, outputs and outcomes—see Chapter 1: Approach).

No national evaluation of marine management effectiveness has been conducted. Applying the principle of subsidiarity (as proposed by the independent review of the EPBC Act[81]) implies that an analysis of the Australian Government's marine management system would be a suitable point to start an initial national evaluation. Although the independent review of the EPBC Act mainly considered future arrangements, with past performance inferred rather than reported, the depth and breadth of the recommended improvements in relation to all marine matters suggest a high level of inadequacy in existing arrangements.[81] Notwithstanding progressive improvements and many important recent achievements from both the states and the Australian Government management systems, the review's summary of an expected role for the Australian Government in such matters encapsulates the broad extent of the system's weaknesses and needs:

> The Commonwealth's role in a national system should be one of leadership, as a champion of the national interest, and a standard setter in environmental management.

In assessing the effectiveness of current management of the marine environment, it is valuable to examine the effectiveness of the management system—particularly the six elements of management listed above—in dealing with the main pressures on the environment (as identified in Section 3 of this chapter), to maintain the assets, values and resilience of the marine environment.

Smaller scale assessments of management effectiveness have been conducted in marine areas across Australia—for example, in the Great Barrier Reef and in Western Australia.

The GBRMP evaluation found that many of these elements were being achieved. Importantly, objectives relating to community understanding of issues and development of effective partnerships were found to be achieved. However, arguably the most substantive element (achievement of desired outcomes) was ranked as poor for GBRMP management effectiveness as a whole. Achievement of desired outcomes (values protected, threats reduced, long-term environmental and economic sustainability) was found to be very variable across issues. Overall, the greatest concern in relation to achieving desired outcomes related to the management of impacts of climate change. Poor outcomes were also found for management of coastal development, extractive use (fishing) and water quality.[94]

At a state level, in Western Australia, 18 actions were identified by the Western Australian Government for the 'Marine' theme in response to the 1998 Western Australian SoE report. By 2007, 14 of these actions remained incomplete, 2 were completed but not evaluated, and only 2 had been completed and evaluated. The large number of incomplete actions reflects the lack of attention to the marine environment and the sheer size of the state's marine environment, its remoteness from major settlements and the high costs of research and monitoring in such circumstances.[48]

Shark fishing for their fins alone is illegal in Australian waters

Photo © Australian Fisheries Management Authority

6.8 Assessment summary

Effectiveness of marine management

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Climate change impacts						
Understanding: Strong institutional partnerships are being formed to develop a comprehensive and agreed knowledge base about drivers—includes knowledge of physical processes; knowledge of biological process is lagging. Cross-discipline synthesis programs are developing, as yet embryonic			↗		◒	◒
Planning: Limited preparedness or anticipation in most affected assets and systems		—			◒	◒
Inputs: Few resources are devoted to identifying the issues, or to strategies for responses or mitigation of impacts		—			◒	◒
Processes: Very limited development of management tools or approaches to adapt in an integrated manner to climate impacts		—			◒	◒
Outputs: 'Business as usual' strategies prevail, except in coastal flood-prone lands; few strategic responses to provide for maintenance of biodiversity values	?				◒	○
Outcomes: Habitat and species declines are beginning to become evident, with limited preparedness to adapt	?				◒	○
Coastal urban development						
Understanding: Good understanding of types and sources of pollution, impacts of habitat alienation, and broad dependencies of coastal ecosystems and valued assets. Information base lagging on impacts of endocrine disruptors from sewage, stormwater, groundwater and agricultural systems on nearshore species and habitats			↗		●	◒
Planning: Strong regulatory measures are being developed and applied. Asset amenity and economics of coastal lands continue to preclude assessment of environmental issues that reflect ecological processes and biodiversity values			—		●	◒
Inputs: Major resources are devoted to planning and management at all levels of government			—		●	◒
Processes: No national synthesis of coastal impacts or development issues recognising the natural values of coastal systems. No integration of effective management approaches or frameworks. Incremental development prevails, focusing on technological advancement rather than avoidance of impacts		—			●	◒
Outputs: Impacts are decreasing, but no agreed management system for identifying capacity limits, or low-impact development solutions that maintain biodiversity and ecological aspects of shoreline ecosystems		↗			●	◒
Outcomes: Coastal lands continue to be developed, with pollution and impacts on habitats in adjacent waters, and extensive growth in all regions		—			◒	◒

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Port facilities						
Understanding: Management issues and impacts of port developments are well known				↗	●	◒
Planning: Planning and approval systems are advanced, and continue to provide high-quality assessment systems to minimise impacts			↗		●	◒
Inputs: Commitment of resources to avoiding impacts is limited by cost factors and operational requirements			—		◒	◒
Processes: Issues are managed on a local and individual issue scale; little management of cumulative impacts or impacts outside local precincts			—		◒	◒
Outputs: Ports are managed loosely as a system, often privatised and outside direct government control, typically implementing generic rule-based systems that do not always recognise impacts on local values		↗			◒	◒
Outcomes: Port developments continue to be driven by operational requirements at the expense of local species and habitats, with substantial ongoing levels of cumulative impact		↗			◒	◒
Oil and gas exploration and production						
Understanding: Impacts of the exploration, production and transport phases of the industry are well understood, although specific issues about dispersants and medium-term effects are yet to be resolved			↗		◒	◒
Planning: Major lack of a regional environmental planning and assessment framework with relevant constraints on development	—				◒	◒
Inputs: Substantial resources are applied to the impact issues			—		◒	◒
Processes: Individual sites are approved based on production and economic requirements rather than environmental constraints; there appears to be only limited cumulative impact assessment. Site-based processes are good, although human error continues to have major consequences and needs much better supervision of compliance		—			◒	◒
Outputs: Strong regulatory regime at the site level, although lacking in onsite compliance systems; few effective outputs at the region level			↗		◒	◒
Outcomes: Increasing rate of disturbance of marine mammals, and risk of accidents and oil spills due to large number of seabed and land-based structures; increasing exploration, construction activity and ship movements; and remoteness from regulatory control centres		—			◒	◒

Continued next page

Effectiveness of marine management *continued*

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Fishing						
Understanding: Limited context is applied, mainly focused on resource use; limited recognition of trophic or cumulative impacts		—			◒	◒
Planning: EPBC Act assessments cover more than 120 fisheries. Marine bioregional planning for Commonwealth waters is committed to considering pressures, including fishing. State-based fisheries legislation is generally committed to ecological outcomes, as well as economic ones. However, there is no comprehensive national assessment or reporting system for fisheries sustainability or environmental impacts; no national mechanism for assessing environmental outcomes; no national system for information capture across environmental aspects		—			◒	◒
Inputs: Limited mainly to resource management systems, not environmental impacts		↗			◒	◒
Processes: Strong systems are in place for management of commercial fishing impacts on habitat and EPBC Act–listed species, but limited management of trophic impacts. Limited management of recreational fishing. Many jurisdictions, including the Commonwealth, are moving to improve ecosystem-based fisheries management approaches		↗			◒	◒
Outputs: Good achievement of commercial fisheries programs; limited achievement in recreational fishing management; strong growth of resource certification systems in the private sector		↗			◒	◒
Outcomes: Fisheries management achieves limited environmental outcomes: all species that can be fished are held at population sizes significantly below pristine levels under current management systems. Trophic structures in the oceans are heavily impacted—ecosystem resilience to trophic impacts, cumulative impacts and potential time to recovery are uncertain		—			◒	◒
Shipping						
Understanding: Good understanding of impacts, other than acoustic impacts and behavioural disturbance			↗		●	◒
Planning: Good level of national and international coordination to manage shipping impacts			↗		●	◒
Inputs: Strong management systems are in place, although issues remain regarding monitoring and compliance			↗		●	◒
Processes: Shipping management systems are well developed and moderately effective. Groundings, shipping lanes and pest species are generally well managed nationally and internationally, but species introductions continue to occur at a high rate		↗			●	◒
Outputs: Further management is needed to ensure that best-practice procedures are maintained			—		●	◒
Outcomes: Intensification of shipping remains a significant risk for pests, groundings and marine mammals			—		◒	◒

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Aquaculture						
Understanding: Impacts and risks of land-based and sea-based aquaculture are reasonably well understood			↗		●	◒
Planning: Management systems are dominated by resource and commercial issues, not environmental impacts; limited regional planning systems have been developed		—			●	◒
Inputs: Very limited external inputs are deployed; management systems are mainly confidential and commercial property; inputs to management of diseases, chemical use and wildlife interaction are generally very limited	—				◒	◒
Processes: Limited management systems control and report on impacts of aquaculture. All industries are managed with some attention to major environmental issues, but with little public scrutiny or government accountability. Site-level management is held to best industry practice, but there is limited compliance monitoring		—			◒	◒
Outputs: Repeated episodes of serious disease outbreaks sourced from farms, both within farms and in wild species. Rapid growth of sea cages resulted in increasing fishing pressure on wild populations of small pelagic fish for feed. Wild-caught sardines for use as aquaculture food are now Australia's largest fishery by weight		↙			◒	◒
Outcomes: Widespread ecological impacts from multiple disease outbreaks; local impacts on ecosystems; increasing trophic impacts from small pelagic fishing; very limited control of cumulative impacts	—				◒	◒
Catchment run-off						
Understanding: Issues and context are reasonably well defined, including nutrients, sediments, agricultural pollutants, dams, soil management practices; linkages to marine impacts are not well known			↗		●	◒
Planning: A strong catchment management ethos and natural resource management system are developing to better manage catchments and land run-off			↗		●	◒
Inputs: Commercial pressures are high, and restoring catchments is expensive; dealing with catchment health as it impacts marine ecosystems has had a limited focus		—			●	◒
Processes: Catchment management systems and natural resource management organisations are becoming well developed; effectiveness across Australia is variable, particularly for the estuaries and nearshore marine ecosystems		—			●	◒

Continued next page

Effectiveness of marine management *continued*

Catchment run-off *continued*

Summary	Ineffective	Partially effective	Effective	Very effective	Confidence In grade	Confidence In trend
Outputs: Historical degradation of soils, deforestation and salinisation of lands. Estuaries remote from urban areas are affected, some severely, by nutrients and sediments from poor agricultural practices. More urban rivers are affected by poor sewage and stormwater practices		—			◒	◒
Outcomes: Legacy of heavily impacted estuaries and nearshore ecosystems, including wetland habitats reclaimed; rivers with highly altered flood regimes; and coastal rivers, lakes and lagoons with altered mouth dynamics	—				◒	◒

Tourism facilities

Summary	Ineffective	Partially effective	Effective	Very effective	Confidence In grade	Confidence In trend
Understanding: Good understanding of the issues and management requirements				↗	●	◒
Planning: Planning systems are comprehensive, and many respect the environmental assets that are also the attractions, although cumulative impacts remain a weak area of knowledge				↗	●	◒
Inputs: Considerable private and public input of resources and activities to manage and maintain environments; management of unstructured tourism and cumulative impacts is limited			↗		●	◒
Processes: Strong management of commercial tourism facilities. Effective measures ensure impacts are acceptably small. Unstructured tourism is largely unmanaged			↗		●	◒
Outputs: Industry best-practice systems are in place; some certification systems operate; structured tourism conducts self-assessment and monitoring			↗		●	◒
Outcomes: Structured tourism has few significant impacts. Unstructured tourism is reliant on site, asset and values management, which has limited effectiveness in marine ecosystems			↗		●	◒

Mining and industry

Summary	Ineffective	Partially effective	Effective	Very effective	Confidence In grade	Confidence In trend
Understanding: Impact issues are clear, although cumulative effects are poorly understood				↗	◒	◒
Planning: In relation to marine issues, this is mainly ad hoc, driven by commercial constraints; resource projects are not denied on environmental impact grounds; there is little consideration of regional cumulative impacts		↗			◒	◒
Inputs: Site-based inputs are substantial, and there is substantial monitoring of site impacts		—			◒	◒
Processes: Shoreline and marine-based structures are heavily regulated and subjected to site-based assessments to minimise local impacts			—		◒	◒

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Mining and industry *continued*						
Outputs: Increasing management programs for water, air and land pollution; limited management of cumulative impacts, alienation of coastal habitats for infrastructure requirements, or alterations to water and sediment regimes in adjacent areas		—			◒	◒
Outcomes: Modern industry and mining have limited local area impacts, except where the resource itself is mined, such as marine sands. However, cumulative impacts of infrastructure are significant, and risks (such as pollution) are increased by intensification, with demonstrated impacts on local habitats and species		—			◒	◒
Marine debris						
Understanding: Management systems are poorly informed about the extent and risks of debris, or the relationships to trade globalisation and container shipping systems		—			●	◒
Planning: Much of the issue is global, and global shipping systems (International Convention for the Prevention of Pollution from Ships [MARPOL]) are in place, but there are few practical arrangements in place to combat either gross or microparticle debris	↙				●	◒
Inputs: Domestic and global waste management programs have been developed	↙				◒	◒
Processes: Management of marine debris issues is weak; domestic and foreign-sourced materials management is limited to industry arrangements and codes of conduct on shipping traffic and fishing vessels; limited processes to reduce losses from container vessels or manage waste from accidents	↙				◒	◒
Outputs: Limited compliance monitoring of vessel-based waste management arrangements	↙				◒	◒
Outcomes: Debris heavily impacts tropical waters; whales, birds and turtles are impacted (entanglement and ingestion) and probably a range of invertebrates. Plastic microparticles are globally widespread and increasing in all ocean waters, with an increasing but unknown level of ecological impact	↙				◒	◒

Recent trends
↗ Improving
— Stable
↙ Deteriorating
? Unclear

Confidence
● Adequate high-quality evidence and high level of consensus
◒ Limited evidence or limited consensus
○ Evidence and consensus too low to make an assessment

Grades
🟩 Very effective
🟨 Effective
🟧 Partially effective
🟥 Ineffective

5

Resilience of the marine environment

The resilience of marine systems is a function of the structure of the ecosystems (such as the types and numbers of species they contain), the components and functions of the habitats that support those species, and the interaction of this ecological system with physical attributes such as the dynamics of the ocean currents.

Assessing the resilience of marine systems is based on the concept that resilient systems do not remain unchanged, but that change occurs within limits. Resilience of ecosystems can be assessed by asking:

- What has been the past resilience of the system? What evidence is there of past resilience?
- What are the known pressures that will have to be dealt with? Is the management system prepared to deal with, or respond to, these anticipated pressures?
- Are the attributes of the ecosystems in good shape to permit a favourable response to unpredicted pressures or changes that may arise? Are the factors that affect the capacity to deal with surprises intact?

Keeping ecosystems resilient is an important attribute of ecosystems and a common generic goal of management, but rarely can resilience itself be quantified or measured. There are no national-scale reporting systems or datastreams that can provide useful surrogates to measure or report on the resilience of marine ecosystems, habitats or species. This section considers some of the important attributes of resilient systems in relation to the management of marine issues.

5.1 Resilience of marine systems

Marine populations wax and wane over time. This natural variation is caused by the natural environmental drivers of change, such as differences in conditions between seasons and years. However, sudden environmental shocks (such as major storms or flood events) can create major changes in populations and ecosystems related to the size of the disturbance. Few ecosystems affected in such major ways will ‘bounce back’ to the same state they were in before the serious shock. However, humans tend to focus on rapid change and are slow to appreciate less obvious, but not necessarily less relevant, change.[95] This is sometimes caused by the phenomenon known as the ‘shifting baseline’, when managers base decisions on conditions they have personally experienced, with each successive manager relating to sequentially degraded conditions. With fishing, scientists, managers and even the general public are quick to identify and attempt to curb obvious overfishing or damage due to irresponsible fishing practices, but they have been slow to respond to less obvious signals, such as those due to climate change and fishing-induced genetic impacts.[45] Both the fast (major shock) and the slow (incremental temperature shifts or genetic restructure) drivers of impacts affect resilience, and they can be equally significant.

■ Harlequin shrimp (*Hymenocera picta*) on a sea star, Great Barrier Reef, Queensland
Photo by Gary Bell

At a glance

Diversity is common to all parts of the concept of resilience—diversity at the habitat and population level, diversity of stakeholder engagement and social institutions, and diversity of management approaches supported by a range of empirical observations to verify performance. Retaining biodiversity of all forms in ecosystems is important to retain resilience. This should include the structure of biodiversity at the ecosystem level (species types, distributions and abundance), and genetic diversity at the population level (gene diversity, subpopulation differences, distribution heterogeneity). Diverse structural biodiversity and genetic diversity help organisms to respond to environmental pressures when they occur.

Maintaining resilience also requires support for flexible institutions and social networks in multilevel governance systems, and multiple institutional linkages among user groups, communities, government agencies and nongovernmental organisations, from local to international levels.

Considering fishing as an example, species that are fished are ecologically important—they are often large, long lived and abundant, so are important in marine ecosystem functions. However, while fishing mortality plays a part in influencing resilience, other forces act on the population and its ecosystem that determine the population's ability to recover from fishing (and other) pressures. Events that accompany overfishing often include pollution, eutrophication (a large increase in nutrients in the water, often leading to algal blooms), physical destruction of habitats and introduction of pest species. These impacts are often further complicated by social and economic responses of governments and communities that try to maintain stability in ways that have outcomes that are counter to their objectives.[24] Systems that are compromised by the effects of overfishing are made more vulnerable to these additional disturbances, potentially opening the way to population collapse.[96]

Recovery of ecosystems can be hindered by complex and often indirect species interactions. One of the factors that helps to make ecosystems more resilient to change is high ecological redundancy (i.e. there are many species that perform similar functions), because this allows other species to potentially replace one or more key species in the ecosystem to maintain ecosystem services.[97] Species-rich systems are more likely to have greater functional redundancy and flexibility, and this can provide them with a degree of ecological insurance against uncertainty,[98] although this is not always the case.[35] Populations in highly diverse ecosystems may therefore be more likely to be resilient to change—in diverse ecosystems, compared with systems that are naturally low in species numbers, a smaller fraction of commercially fished species have collapsed, and there has been a higher rate of recovery of collapsed species.[97]

The natural dynamics of marine species are related to the recovery potential of healthy marine populations. Those that have high levels of spawning biomass, a natural range of ages in populations and are widely distributed across their habitat range can be considered to be naturally resilient.[35] When a diversity of secure areas protected from environmental and human pressures is available, populations can capitalise on good environmental conditions with strong reproductive outputs, often creating a strong year-class (all individuals spawned in a single year) that will survive and maintain the population's recovery potential through subsequent poor years until the next environmentally favourable year occurs. This feature can also provide fisheries with increased security of catch and a greater buffer against environmentally driven fluctuations that would otherwise reduce stability in the industry.

A recent international workshop that reviewed human impacts in the global oceans concluded that the extent and importance of the cumulative impacts of the various types of pressures (exploitation, climate change, pollution, habitat loss) have been significantly underestimated.[99] In particular, the extinction threat to species is rapidly accelerating, and there is an unparalleled global rate of regional extinction of marine habitat types. The review concluded that a number of high-priority actions are required, including the proper and universal application of the precautionary principle to reverse the burden of proof (new activities that may damage the oceans should only be approved when they can show minimal and acceptable levels of impact both singly and cumulatively with other stressors). The review has also proposed that a United Nations Global Ocean Compliance Commission be established to oversee the charter of ocean protection.[99]

5.2 Management for resilience

Management of marine systems to support and build resilience has been considered to require four key attributes:[98]

1. Embracing uncertainty and change: management systems need to accept that external change, such as climate effects, evolving market demands, or changes to economic subsidies and government policies, are inherently a part of resilient systems.
2. Building knowledge and understanding of resource and ecosystem dynamics: supporting resilience requires an understanding of ecosystem processes and functions; the scale of issues and the functional roles of biodiversity are crucial components of marine resilience.
3. Developing management practices that measure, interpret and respond to ecological feedback: successful management must continuously test, learn from and modify its activities and understanding for coping with change and uncertainty in complex systems. Knowledge of ecosystems should evolve with the institutional and organisational aspects of management.

4 Supporting flexible institutions and social networks in multilevel governance systems: an adaptive governance framework relies on the collaboration of a diverse set of stakeholders operating at different social and ecological scales. The sharing of management power and responsibility can involve multiple institutional linkages among user groups or communities, government agencies and nongovernmental organisations, from local to international levels.

Considering fishing, developing management systems that are consistent with multiscale ecological drivers to support resilience is a major challenge. Institutions that manage fisheries at a very broad scale are likely to ignore local heterogeneity (e.g. small-scale spawning aggregations that are readily fished to extinction) and thereby reduce population-level diversity and resilience. Conversely, institutions that are narrowly concerned with a particular locality or a particular species are susceptible to external processes (such as recruitment failure, climate change and market demands) that operate predominantly at larger scales.[98] Similarly, institutions that are concerned mainly with resource management are susceptible to ignoring the environmental changes brought about by resource extraction but expressed at scales that are inconsistent with the resource management system or the natural scales at which the ecological system operates.

Considering coral reef ecotourism, resilience has been linked to the type and level of stakeholder engagement. Higher lifestyle values in tourist operators (more experience, more active choice of tourism venture) are also associated with a higher level of support for reef conservation in tourists, a greater level of participation in reef conservation activities and a greater level of resilience of the tourism venture itself. It is perhaps unsurprising that coral condition relates to the resilience of tourism ventures (although the relationship is far from clear), but perhaps of greater relevance is the role that such tourists play in supporting reef conservation values, and hence indirectly promoting reef resilience. This support role played by tourists appears to depend on the type of operator—operators with higher lifestyle values are likely to promote greater resilience of the social–ecological enterprise that is ecotourism, including natural values. In this sense, maintaining a tourism industry that comprises both operators and tourists with higher lifestyle values should be an important objective of resource management, since there are indirect connections to the resilience of the resource.[100]

■ Aquaculture sea cages for fish farming, Jurien Bay, Western Australia

Photo by Trevor Ward, Greenward Consulting

6

Risks to the marine environment

This section summarises the main risks to the marine environment and ranks their potential for impact in 20-year and 50-year timeframes, presented in the form of a simplified risk assessment matrix. These risks have been assessed as remaining risks, taking into account current management arrangements that apply in the relevant jurisdictions. The risk assessment approach and grading statements are described in Chapter 1: Approach.

Sheng Neng 1 bulk ore carrier aground on the Great Barrier Reef, Queensland

Photo by Great Barrier Reef Marine Park Authority

At a glance

The main risks to the future of the marine environment are from the impacts of climate change—mainly increased temperature, ocean acidification and sea level changes. The interaction of these with the legacy effects of past poor management practices, and with the existing pressures of fishing, catchment-derived pollutants, and coastal urban, industry and port development, pose a major threat to the values of marine ecosystems as we currently know them.

The changes are likely to affect the natural diversity and ecology of inshore waters, bays, estuaries and intertidal zones, and the fishing, recreation and tourism industries, with unpredictable results. For example, as ocean temperatures rise, the survival of cold-water species that are fished may be gradually reduced, but these species might be temporarily replaced by warmer water species. In the east, the impacts of rising ocean temperatures will also affect coral species diversity, distribution and, ultimately, survival.

Each region has a specific set of pressures that will almost certainly increase in risk ranking over the coming 20–50 years, given current management arrangements. For example, in the north-west, while many habitats and species populations are in near-pristine condition, more impacts will occur with the escalation of the oil and gas industry. The lack of a regionally integrated framework for management of the marine environment is currently a major risk, and this will increase as the pressures and complexities grow, with unpredictable consequences for marine ecosystems.

Hardy Reef, Great Barrier Reef, Queensland

Photo by Darren Jew

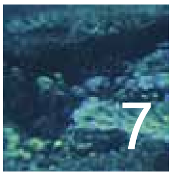
6.9 Assessment summary

Current and emerging risks to the marine environment

	Catastrophic	Major	Moderate	Minor	Insignificant
Almost certain	■ Ocean temperature increases, with impacts on corals, fish and plankton ■ Ocean acidification, with impacts on plankton and production, corals, and shell calcification processes	■ Port development or coastal urban development, leading to destruction or disturbance of the environment ■ Fishing (recreational and illegal), leading to change or loss of species or impacts on ecosystems ■ Marine debris, which may poison or entangle species ■ Sea level rise and impacts of coastal erosion and inundation ■ Extreme or severe event (storm, tidal, rainfall, flooding), which may increase run-off and sediment/nutrient levels ■ Increase in catchment-sourced nutrients, sediments and toxins ■ Algal blooms in estuaries, which can be toxic or may result in hypoxic water ■ Ocean current changes, leading to shifts in production	■ Fishing (commercial), leading to change or loss of species or impacts on ecosystems ■ Shipping, leading to the wider introduction of pests ■ Beach or shoreline modifications, leading to change or loss of habitat ■ Oil and gas extraction, leading to increased shipping and onshore development, and consequent impacts on ecosystems	■ Fishing (traditional), leading to change or loss of species ■ Vessel strikes on cetaceans ■ Ghost fishing—lost nets that may entangle species	

	Catastrophic	Major	Moderate	Minor	Insignificant
Likely	■ Aquaculture disease escapes, with impacts on native species	■ Oil and gas accidents, or oil spills, with impacts on species populations, ecosystems and habitat ■ Shipping accidents, with impacts on species populations and habitats ■ Mining of sand, shorelines and islands, leading to destruction or disturbance to species populations and habitats ■ Pest species introductions and outbreaks, leading to increased competition or other impacts for native species ■ Lack of integrated management, affecting the conservation of ecosystems	■ Aquaculture sea cages and related risks of waste disposal, dependence of wild species, impacts on feed stock ■ Desalination discharges, with impacts on water quality and habitats ■ River damming or flood mitigation that changes local habitats and freshwater flows into the ocean	■ Oil and gas exploration and related risks of seabed disturbance ■ Coastal and island tourism facilities, leading to disturbance or destruction of the environment	
Possible	■ Major volcanic/ tectonic event in Indonesian plate; leading to tsunami and atmospheric deposition		■ Introduced species outbreaks ■ Shipping noise, with impacts on marine mammals		
Unlikely					
Rare					

☐ Not considered



7

Outlook for the marine environment

Our ocean and coastal ecosystems are used by everybody but are the primary responsibility of nobody. They are consequently suffering from 'death by a thousand cuts'. The often-identified need for the integration of marine management is now critical and urgent. The most significant and urgent challenge for policy makers is to establish an effective set of national arrangements to connect national and international policies with state and local management activities, and to involve communities and the private sector. Marine ecosystems and the environment are naturally dynamic—change is their byline. We have linked our communities to many of the assets and resources offered by coastal waters and estuaries, and we have built our communities on their shores. Now that they are recognisably changing, and we can detect the early signs of accelerating change, we must prepare ourselves to adapt to these changes.

Nearshore development proceeds apace, replacing vegetated landscapes with hard surfaces and converting marine habitats into new land. Land-based sources of pollution and expanding pressure on coastal lands continue to be significant concerns, despite strong improvements in land-use planning and the management of many pollution point sources. Fishing has reduced most populations of sought-after species to low levels, mainly in previous decades, and these persistent low population levels probably have significant flow-on consequences for the resilience and persistence of marine biodiversity in the inshore waters. The major looming threat for our oceans and coastal waterways is the changing global climate, which is creating significant changes in ecosystems and biodiversity, shorelines and coastal lands, and our wealth generation from the oceans. Climate change is also threatening the existence of our coral reefs at their present-day scale and grandeur (particularly in the east region). A proliferation of oil and gas exploration and extraction, together with mining, wave energy and desalination systems, and other shoreline industries, will not only generate wealth but also bring a new set of major risks to our waters that will need intensive strategic and regional management.

At a glance

Australia's oceans and coastal marine ecosystems are overall in good condition and have experienced only gradual decline, although there are many coastal areas where conditions are already poor or very poor. Indeed, some of the world's worst examples of impacts from pollution can be found in Australian waters. Australia is leading the world in many areas of marine management, but we have basked in the luxury that resilience has been high because pressures have been low. Now there are strong signals that many systems and resources have reached their finite limit, and pressures are building to levels at which impacts can be easily seen in each of our ocean regions. We need our oceans and coastal ecosystems to continue to sustain and inspire Australia's future, as they have in our past. The lessons from overseas are stark—continuing business as usual will result in loss and decay.

This is particularly true for the north-west region, which is under intense development pressures from the resource extraction sectors (oil and gas, mining, fishing, shipping). The national demand for port capacity is forecast by the Australian Bureau of Agricultural and Resource Economics and Sciences to double each coming decade to service growth in cities and the mining sector. Only the marine values and assets of the north region remain relatively pristine; however, even there, mining and the damming of rivers are beginning to become more substantial regional pressures. The south-east region remains under the greatest stress, with a legacy of impacts from a wide variety of sources, and is suffering the greatest impacts from climate change—the East Australian Current is changing its pattern of extension into Tasmanian waters, with an intensification of gyres (circular currents), and is becoming warmer and saltier. There has been substantial coastal retreat (loss of coastal land due to higher sea levels) in areas such as Corner Inlet; urchin barrens (where unchecked urchin populations are so dense that they consume all vegetation) have expanded; and there have been major changes in cold-water algal beds caused by the changes in water temperature. The recent blooms of the zooplankton *Noctiluca*, extending its range from the east region, raises the spectre of regime shift (the rapid and complete reorganisation of an ecosystem from one relatively stable state to another)—this species has rapidly become the dominant grazer in Tasmanian marine waters in recent years, with uncertain ecological consequences.

The interaction of accelerating changes in atmospheric and ocean climate with existing land uses, fishing systems, shoreline industries and new risks has raised the management stakes to an unprecedented level. There is a plethora of responses to this situation, many of which are achieving good outcomes; some are even reducing pressures and holding aspects of the ecosystems and biodiversity in good condition. These are a necessary but insufficient response. The evidence is that the fractured, weakly coordinated and poorly integrated management systems that we have currently deployed will inevitably result in accelerating degradation of the unique values of our oceans and coastal ecosystems, spreading outwards from the current centres of local environment degradation where system complexity is highest. The early signals of such decline are now evident across a number of areas of our coastal waters. The experience of the Oceans Policy of 1998 demonstrates the major challenge of achieving a truly national approach to address the drivers of decline in Australia's marine ecosystems.

The overall outlook for Australia's marine environment is uncertain—most aspects are currently not in decline, and those that are declining have moderately well understood underlying pressures and drivers. Of those assets and values that are already in poor condition, very few are recovering. But perhaps most critical of all, there are several important uncertainties that are yet to be addressed, most notably our own ability to design and deliver good, effective and efficient multilevel governance (including information and reporting systems) to address the known threats and accelerating risks to our unique marine environment.

Surgeonfish beneath a breaking wave over coral reef, Great Barrier Reef, Queensland

Photo by Gary Bell

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