Australia
State of the Environment 2016

Biodiversity

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Acknowledgement of Country

The authors acknowledge the traditional owners of Country throughout Australia,
and their continuing connection to land, sea and community;
and pay respect to them and their cultures,
and to their Elders both past and present.

Australian Government
Department of the Environment and Energy

Publication information

Citation

Cresswell ID & Murphy HT (2017). *Australia state of the environment 2016: biodiversity*, independent report to the Australian Government Minister for the Environment and Energy, Australian Government Department of the Environment and Energy, Canberra.

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Cover photo: Golden-tailed gecko (*Strophurus taenicauda*) near Chincilla, Queensland, by Eric Vanderduys

Editing, design and production: Biotext, Canberra

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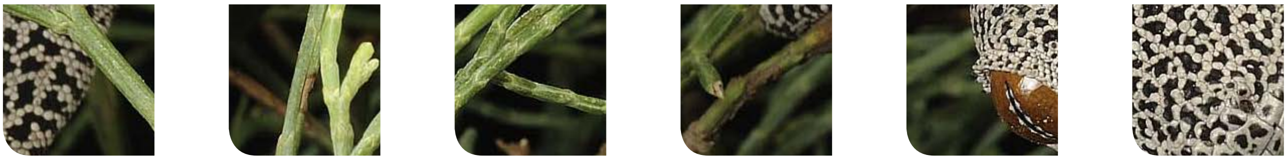


Executive summary

The value of Australia's biodiversity is difficult to measure, but biodiversity is a key part of Australia's national identity, and is integral to subsistence and cultural activity for Indigenous Australians. It is also fundamentally important to environmental services that support human health and wellbeing, and economically important to a wide range of industries (e.g. tourism, agriculture, pharmaceuticals).

This report demonstrates that Australia's biodiversity is under increased threat and has, overall, continued to decline. All levels of Australian government have enacted legislation to protect biodiversity, and Australia has made good progress in increasing the extent of the National Reserve System since 2011, driven by growth in Indigenous Protected Areas. We now have more than 17 per cent of our terrestrial land and 36 per cent of our marine area under some form of protection. Some individual measures to conserve biodiversity are having success, and many local and regional examples show successful recovery of threatened species, eradication or control of invasive species, or improvements in habitat quality or extent.

However, many species and communities suffer from the cumulative impacts of multiple pressures. Most jurisdictions consider the status of threatened species to be poor and the trend to be declining. Invasive species, particularly feral animals, are unequivocally increasing the pressure they exert on Australia's biodiversity, and habitat fragmentation and degradation continue in many areas. The impacts of climate change are increasing. Key reports on the state and trends of mammals in 2014 and birds in 2015, supported by citizen-science efforts, have vastly improved our understanding of these 2 taxa. However, even for these relatively well-known Australian animals, monitoring data are often inadequate to robustly assess state and trends. The lack of data is more pronounced for plants, amphibians and reptiles, and even more so for cryptic taxa such as freshwater fish, invertebrates and fungi, for which very little information is available to assess state and trends.

Australia is unable to measure the effectiveness of most of our investments in biodiversity management or management of pressures. The outcomes of management actions are rarely monitored and reported for long enough to clearly demonstrate effectiveness.

The outlook for Australian biodiversity is generally poor, given the current overall poor status, deteriorating trends and increasing pressures. Our current investments in biodiversity management are not keeping pace with the scale and magnitude of current pressures. Resources for managing biodiversity and for limiting the impact of key pressures mostly appear inadequate to arrest the declining status of many species. Biodiversity and broader conservation management will require major reinvestments across long timeframes to reverse deteriorating trends.

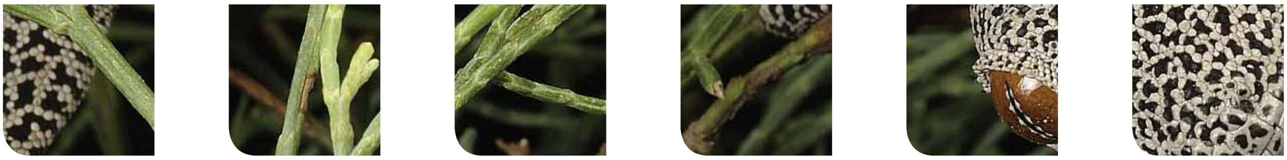
Key findings

Key finding	Explanatory text
There is no indication that the major pressures on biodiversity outlined in the state of the environment (SoE) 2011 report have decreased	The key pressures of habitat clearing and fragmentation, invasive species and climate change remain high on the list of pressures (identified by jurisdictions) that threaten listed species and ecological communities, and biodiversity in general.
The number of threatened species and threatened ecological communities has increased since 2011	Major contributors to the increase in the number of threatened species since 2011 have been an increased understanding of the status of threatened birds and mammals, and improvements in the efficiency of listing processes.
Vegetation clearing rates have stabilised across all jurisdictions since 2011, except Queensland, where clearing rates have increased	Weakening of vegetation clearing legislation in Queensland since 2011 has resulted in a tripling of clearing rates in that state in 2013–14 compared with 2009–10.
The cumulative impact of multiple pressures and the interactions between them amplify the threat faced by biodiversity	Interactions between pressures such as changed fire regimes, invasive species and changing land use have contributed to significant population declines in Australian mammals and birds, and, presumably, in other animal and plant groups.
Knowledge about the distribution and abundance of invasive species and their impacts on biodiversity remains incomplete and a high risk to the resilience of biodiversity	Impacts of invasive species have increased in importance as key threatening processes at both national and state/territory levels. The general consensus is that the impact of invasive species is not diminishing and, in combination with other stressors, may be increasing. Natural resource managers consistently identify a lack of resources for managing invasive species as a key impediment to successful management.

Key finding	Explanatory text
It is not possible to assess the overall long-term effectiveness of management actions taken to limit the impact of invasive species	Although there are excellent examples of successful local eradication efforts and management to reduce the impact of invasive species, assessing overall management effectiveness is difficult because monitoring is often missing, incomplete or only at a local scale. Reporting of management outcomes is often very limited.
Reducing the impact of feral predators is an essential action for the conservation of Australian fauna	Feral cats and foxes are key pressures that have contributed to the population decline of small mammals in northern Australia and lack of recovery of these mammals in southern Australia. The interaction between feral cat predation and fire regimes is now known to be particularly important in driving negative impacts.
Reducing the impact of feral herbivores is an essential action for management of Australian ecosystems	Damage from feral buffalo, camels, cattle, donkeys, goats, horses and pigs is a key pressure on native ecosystems. Introduced herbivores transform ecosystems, thus reducing the resilience of native systems, opening pathways for weed invasion and increasing fire risks.
The nature of impacts of climate change on biodiversity is becoming better understood	Broad understanding of potential impacts of climate change on some Australian species (e.g. birds) has increased. In the past 5 years, all jurisdictions have put in place climate change strategies or have significantly advanced planning for adaptation. However, the level of detail underpinning these strategies is often inadequate to allow land managers to translate strategy to on-ground actions that will effectively mitigate impacts on biodiversity.
Continuing population growth in urban and peri-urban areas impacts surrounding natural ecosystems directly and indirectly	Urban and peri-urban areas continue to directly encroach into surrounding natural ecosystems and may also cause indirect impacts by acting as a source of invasive species. Native wildlife in urban areas can be viewed as a benefit by residents, but can also be a source of conflict as humans and wildlife come into contact.
Evidence for the effectiveness of recovery planning for threatened species is variable. Little evidence exists to suggest improvement in the state or trend of most threatened species	The introduction of a national Threatened Species Strategy and the appointment of a Threatened Species Commissioner in 2015 signals a recognition of the importance of halting declines in threatened species. The strategy identified 20 high-priority mammal and bird species, and 30 plant species targeted for recovery by 2020, and a range of projects have been funded.

Key finding	Explanatory text
Ongoing improvement of our knowledge of the distribution, diversity and taxonomy of invertebrates (including subterranean fauna) and fungi is critical for management	The majority of Australia's invertebrates and fungi are yet to be described—many have small, restricted distributions and specific ecological requirements that make them sensitive to ecological change. Subterranean invertebrates are particularly threatened by mining activities. Better understanding of the number and variety of subterranean fauna species, and the ecosystems they reside in is an ongoing part of mining operations, as part of both environmental impact assessments and threat abatement actions.
The lack of data and information from long-term monitoring of biodiversity is universally acknowledged as a major impediment to biodiversity conservation	The lack of effective monitoring and reporting has been raised in every jurisdictional report, and multiple other reports and papers as a major impediment to understanding the state and trends of Australian biodiversity.
Translocation of threatened species to offset development is increasingly used as a tool of last resort in conservation management and recovery planning	Australia has been a world leader in the translocation of threatened species for conservation, which will continue to play a key role in management in the future. Translocation of threatened species is increasing, and its overall long-term costs and benefits need to be well understood, particularly given the growing need to use translocation to meet environmental conditions of approval of development applications. The past 5 years have seen an increase in effort to trial 'future proofing' of wild populations of threatened species in new areas.
Significant progress has been made in expanding Australia's National Reserve System since SoE 2011	Increases in the Australian terrestrial protected area network have been driven primarily by an increase in the number of Indigenous Protected Areas. Some progress still needs to be made in attaining comprehensiveness, representation and adequacy targets for protected areas.
The critical importance of Indigenous land management to the ongoing maintenance of biodiversity is increasing and becoming better understood	The increasing area of Australia under Indigenous management is enabling traditional practices to form the basis of new forms of contemporary, collaborative environmental and resource management. The rapid expansion of Indigenous ranger programs, combined with increased respect of Indigenous cultural rights, obligations, knowledge and resource management practices, provides new opportunities for better understanding and management of biodiversity.

Key finding	Explanatory text
Some government initiatives for biodiversity discovery and management have ceased, while new activities have begun, but they have not been able to halt overall decline	In 2011–16, overall funding for several major government initiatives changed, with funding for landcare significantly reduced, and new programs such as the Green Army and the Biodiversity Fund introduced. Funding for climate adaptation research has declined significantly since 2011.
Citizen scientists involved in biodiversity monitoring and discovery have contributed to our understanding of the state and trends of biodiversity and pressures	Citizen-science efforts are becoming increasingly important in contributing data that improve our understanding of the state and trends of biodiversity in Australia. The Atlas of Living Australia has improved access to knowledge about the distribution of biodiversity.
Rapid improvement in technology is likely to lead to significant improvements in our understanding of Australia's species and genetic diversity	Improved tools and technical advances are becoming more available, sophisticated and cost-effective for biodiversity assessment, monitoring and management. Advances in satellite telemetry; transponders; lightweight transmitters; remote cameras; remote audio devices; capability to store, analyse and present large datasets; and ability to cost-effectively generate large-scale genomic databases all add to our knowledge of organisms that have previously been difficult to identify and monitor.



Approach

This report identifies the key pressures affecting biodiversity, using a similar approach to the 'Biodiversity' chapter in the 2011 state of the environment (SoE 2011) report. Components of biodiversity identified for assessment were set in SoE 2011, and SoE 2016 was required to provide updates on these assessments. Current understanding of the state and recent trends of key components of biodiversity are presented, as well as discussions on biodiversity management effectiveness, resilience and risks to biodiversity.

The *Biodiversity* report now includes consideration of pressures on, and state and trends of, aquatic biodiversity in addition to the previous focus on terrestrial biodiversity. Aquatic biodiversity is also partly addressed in the *Inland water* and *Coasts* reports.

The *Biodiversity* report draws on many of the other reports in SoE 2016, particularly *Coasts*, *Inland water*, *Marine environment* and *Land*. Where relevant, we provide a short synthesis and note that particular sections are covered in detail in other reports.

The Effectiveness of biodiversity management section is structured slightly differently from that in SoE 2011. We have focused on management context, capacity and status. Assessment summaries are not based solely on the effectiveness of the management of pressures, but also on the effectiveness of the management of Australia's National Reserve System, and threatened species and communities.

This report is primarily concerned with known changes in biodiversity since SoE 2011. Our assessment summaries use the 2011 report as a baseline, and we reflect on changes since 2011 that have led to an improvement or deterioration in grade and trends. As with SoE 2011, the reference point from which the assessment of grade and trends is measured in the long term is the biodiversity understood to exist before European settlement (approximately 1750). This reference point has been accepted as the basis for planning the National Reserve System, measuring trends in distribution and abundance of organisms and ecosystems, documenting extinctions, and developing biodiversity conservation strategies.

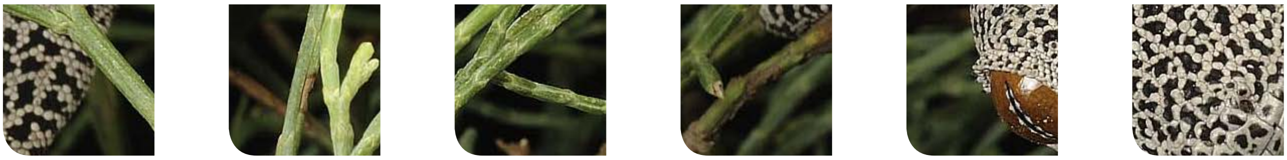
This report is designed as an overview of the state and trends of biodiversity based on the published literature, rather than a detailed scientific paper, and we have not referenced every statement. The authors have endeavoured to report only where there was some evidence base for claims of management achievement, or for claims of biodiversity decline or loss. However, given that no comprehensive information base was available on which to make informed quantitative analysis, we are aware that elements of this report are subjective opinions based on our best judgement of the available literature.

Assessing and interpreting changes in biodiversity

No simple set of measurements is taken nationally that allows a comprehensive assessment of change in biodiversity. This report draws on a variety of sources, including jurisdictional reports and updates—for informing trends in the nature and impacts of pressures (see Pressures affecting biodiversity), trends in vegetation conditions and extent (see Terrestrial ecosystems and communities), and trends in threatened species and ecological communities (see Terrestrial plant and animal species and Freshwater species and ecosystems). However, the jurisdictional reports differ greatly from each other in their coverage and presentation of these topics, the indicators used and reporting periods. Some jurisdictions do not produce an SoE report, and some have not produced a report since 2011 (Northern Territory, Queensland, Tasmania and Western Australia). These jurisdictions have provided a brief assessment against key pressures and key trends in vegetation, fauna, and threatened species and communities. For other jurisdictions, the latest SoE reports were used to provide broad assessments of change (Australian Capital Territory 2015, New South Wales 2015, South Australia 2013, Victoria 2013). For South Australia, the 2015 natural resource management report card was also used.

At the national level, it is only possible to provide a reasonable level of assessment detail for mammals and birds, because large amounts of data are available on their state and trends in *The action plan for Australian mammals 2012* (Woinarski et al. 2014), the *State of Australia's birds 2015* (BirdLife Australia 2015) and *The action plan for Australian birds 2010* (Garnett et al. 2011). The relevant sections describing the status and trends of these taxa draw heavily on these reports. For all other taxa, we rely on identifying changes through smaller-scale reports, scientific papers, case studies and expert opinion, or are unable to make any definitive comments.

Gecko (*Nephrurus* sp.)
Photo by Eric Vanderduys



Introduction

Biodiversity is defined as the variety of all living organisms on Earth at all levels of organisation. It includes organisms that occur on land, in the sea and in fresh water, and includes bacteria, viruses, fungi, plants, and invertebrate and vertebrate animals. The definition of biodiversity also encompasses the diversity of the genetic material within each species and the diversity of ecosystems they inhabit, as well as the diversity of ecological and evolutionary processes that are performed by genes and species, and the interactions among them.

Importance of biodiversity

Biodiversity is important to humans for many reasons. Biodiversity is also considered by many to have intrinsic value—that is, each species has a value and a right to exist, whether or not it is known to have value to humans. The biodiversity book by the Commonwealth Scientific and Industrial Research Organisation (CSIRO; Morton & Hill 2014) describes 5 core (and interacting) values that humans place on biodiversity:

- Economic—biodiversity provides humans with raw materials for consumption and production. Many livelihoods, such as those of farmers, fishers and timber workers, are dependent on biodiversity.
- Ecological life support—biodiversity provides functioning ecosystems that supply oxygen, clean air and water, pollination of plants, pest control, wastewater treatment and many ecosystem services.
- Recreation—many recreational pursuits rely on our unique biodiversity, such as birdwatching, hiking, camping and fishing. Our tourism industry also depends on biodiversity.
- Cultural—the Australian culture is closely connected to biodiversity through the expression of identity, through spirituality and through aesthetic appreciation. Indigenous Australians have strong connections and obligations to biodiversity arising from spiritual beliefs about animals and plants.
- Scientific—biodiversity represents a wealth of systematic ecological data that help us to understand the natural world and its origins.

Any loss or deterioration in the condition of biodiversity can compromise all the values outlined above and affect human wellbeing. The Millennium Ecosystem Assessment in 2005 was the first global effort to examine links between human wellbeing and biodiversity. The assessment found benefits to societies from biodiversity in material welfare, security of communities, resilience of local economies, relations among groups in communities, and human health. It also emphasised the term 'ecosystem services' under 4 broad categories (Morton & Hill 2014):

- provisioning services—the production of food, fibre and water
- regulating services—the control of climate and diseases
- supporting services—nutrient cycling and crop pollination
- cultural services—such as spiritual and recreational benefits.

Global importance

Australia is renowned for its globally distinct ecosystems, made up of diverse flora and fauna. Around 150,000 species have been formally described in Australia, but this is only about 25 per cent of the total number present. Many species, such as insects, remain largely undiscovered. Australia is considered one of the world's 17 megadiverse countries, which together account for 70 per cent of the world's biological diversity across less than 10 per cent of the world's surface. Scientifically, our biodiversity is highly regarded for its diversity, endemism and evolutionary adaptations, but it is also an inseparable part of our Indigenous culture and how we identify as Australians.

Australia has an evolutionarily distinct flora and fauna, including many palaeoendemics, which have ancient lineages associated with the Australian continent. Some of these are the few remaining species surviving from ancient times (e.g. gymnosperms such as the pencil pine—*Athrotaxis cupressoides* and the Wollemi pine—*Wollemia nobilis*).

When compared with other countries, Australia has very high levels of endemism (i.e. species found only in Australia): 46 per cent of our birds, 69 per cent of mammals (including marine mammals), 94 per cent of amphibians, 93 per cent of flowering plants and 93 per cent of reptiles. Other groups, such as the eucalypts, are mostly found in Australia or nearby.

In 2015, Australia had 20 sites on the World Heritage List (Figure BIO1). The United Nations Educational, Scientific and Cultural Organization considers World Heritage sites to have 'outstanding universal value', and to meet at least 1 of 10 cultural or natural criteria. Of the 19 Australian sites, 12 are listed for natural values, 3 for cultural values, and 4 for both natural and cultural values. The Great Barrier Reef, the Tasmanian Wilderness, the Wet Tropics of Queensland and Shark Bay meet all 4 World Heritage criteria for natural heritage; Kakadu National Park, Uluru–Kata Tjuta National Park, Willandra Lakes Region and the Tasmanian Wilderness are listed for both natural and cultural criteria. The Ningaloo Coast in Western Australia was inscribed on the World Heritage List for its natural beauty and biological diversity in 2011. The Ningaloo–Shark Bay National Landscape now boasts 2 World Heritage Areas at its northern and southern ends. The 1.3 million hectare Tasmanian Wilderness World Heritage Area was inscribed in 1982, and extended in 2010, 2012 and 2013. It meets 7 of the 10 criteria—more than anywhere else on Earth.

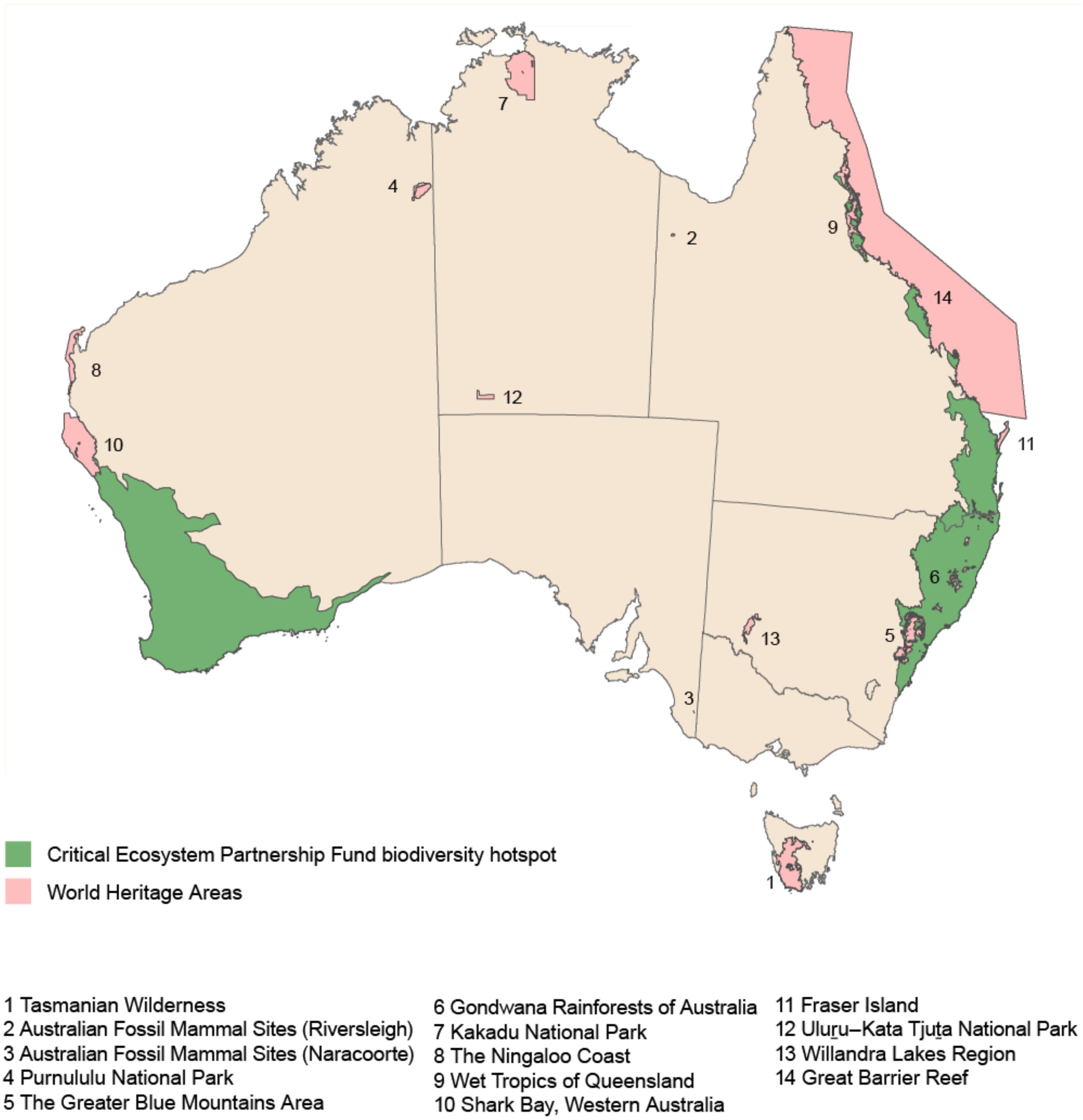
Wetlands of International Importance in Australia are designated under the Ramsar Convention; these wetlands are representative, rare or unique sites that are important for conserving biodiversity. In designating a wetland as a Ramsar site, countries agree to establish and oversee a management framework to conserve the wetland and ensure its wise use. Australia currently has 65 Wetlands of International Importance under the Ramsar Convention, covering more than 8.3 million hectares.

Conservation International identifies 'global biodiversity hotspots' to highlight where exceptional concentrations of endemic species exist and to promote actions to stem biodiversity loss. Biodiversity hotspots were first identified by the British ecologist Norman Myers in 1988 (Myers 1988). Conservation International adopted Myers's hotspots as its institutional blueprint in 1989 and, afterwards, worked with him in a first systematic update of the global hotspots. Myers, Conservation International and collaborators later revised estimates of remaining primary habitat, and defined the hotspots formally as biogeographic regions with more than 1500 endemic vascular plant species and less than 30 per cent of original primary habitat (Myers et al. 2000). A new hotspot in Australia was agreed to in 2011 (Williams et al. 2011): the 35th global biodiversity hotspot (Australia's second following the South-west Australia Ecoregion) is the 'Forests of East Australia', which includes the Eastern Australian Temperate Forests and Queensland Tropical Rainforests (Figure BIO1). This region, spanning 20 degrees of latitude and more than 250,000 square kilometres, contains more than 2100 endemic vascular plants, but more than 70 per cent of the area has been cleared or degraded. Conservation efforts in the past 30 years mean that around 18 per cent of the area is under formal protection (Williams et al. 2011).

National importance

Biodiversity plays a key role in providing numerous irreplaceable services to the Australian community. Yet these remain poorly measured and demonstrated, with many changes occurring subtly on timescales that are not immediately evident to the vast majority of Australians. What was once common in our grandparents' time is now absent in many places across Australia. Understanding the state and trend of biodiversity is crucial to what we leave behind for our grandchildren.

The importance of biodiversity for numerous industries across Australia has not been quantified, but recent issues exemplify our ongoing reliance on functioning ecosystems to maintain key processes that, in the past, may have been taken for granted. For instance, the role of native insects in pollination, which is critical for agriculture, has been highlighted in recent years. There are more than 1500 species of Australian native bee, and very few of these are well known to ecologists or agricultural scientists. Tourism is one of Australia's most important industries, which continues to grow, and has a well-established reliance on iconic natural assets and destinations. The latest Australian tourism campaign



Note: Lord Howe Island Group; Macquarie Island; and Heard Island and McDonald Islands are not shown.
Source: Critical Ecosystem Partnership Fund, used under CC BY 3.0; World Heritage List database, Australian Government Department of the Environment and Energy

Figure BIO1 Global biodiversity hotspots and natural value World Heritage Areas in Australia relies heavily on multiple iconic wild places throughout Australia to lure increased numbers of tourists to Australia at a time of a global downturn in the tourism market. Any major impact on our biodiversity, such as the massive coral bleaching event that occurred on the Great Barrier Reef and Ningaloo Reef in 2016, can adversely affect our vibrant and growing tourism sector.

The *Australian national outlook 2015* (CSIRO 2015) demonstrates several future scenarios for Australia in which policy settings that give market value to ecosystem services deliver substantial environmental benefits (including habitat restoration, improved biodiversity and carbon sequestration). These are at little or no cost to government, while boosting and diversifying landholder incomes, and creating new areas of national economic advantage. The analysis found that stronger support for ecosystem services would provide multiple benefits and, together with improvements in resource efficiency, could lead to new sources of economic opportunity and growth, enhancing economic performance while restoring and protecting natural assets that are essential to long-term wellbeing.

In this report

This report describes the current pressures on biodiversity, and the state and trends of terrestrial and aquatic ecosystems and organisms in 2016. We describe how biodiversity is managed in 2016, how the adequacy of data and knowledge affects our capacity to manage biodiversity, and our lack of ability to measure the effectiveness of our investments in management.

We look at the resilience of biodiversity to key pressures and factors affecting the potential capacity of biodiversity to adapt to future changes. In Risks to biodiversity, we describe how current pressures may escalate and what emerging risks may impact biodiversity in the future. We conclude with an outlook for Australian biodiversity.

Biodiversity: 2011–16 in context

Overall, this 2016 report raises many of the same issues that were raised in all the previous SoE reports dating back to 1996. In the past 20 years, each report has highlighted the value of biodiversity, the key pressures and the gaps hindering effective biodiversity management; and each report has noted the need for urgent action and investment to balance biodiversity, human population growth and economic development. Since 2011, we have improved our understanding of the data, tools and technologies required to achieve this balance, but investment and implementation are not keeping pace with the increase in pressures exerted by the key drivers of environmental change. As a result, pressures on biodiversity have mostly increased since 2011, and the status of biodiversity has mostly decreased. During the past 5 years, experts confirmed the extinction of the Bramble Cay melomys (*Melomys rubicola*) from Australia, continuing our very poor record in contemporary mammal extinctions. In addition, the extinction of the Christmas Island forest skink (*Emoia nativitatis*) occurred on 31 May 2014, when the last of 3 captive individuals died.

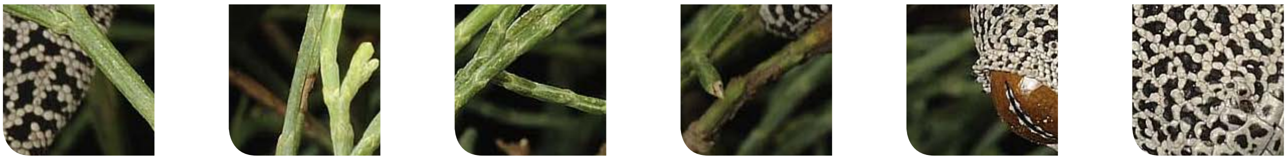
It has been difficult to assess what progress has been achieved in implementing Australia's Biodiversity Conservation Strategy 2010–2030 during the past 5 years. Most targets established under the strategy cannot currently be measured with national-scale data, and some have simply not been achieved. An exception is the increase in the area of land managed for biodiversity conservation in Australia; good progress has been made against this target through an expansion of the National Reserve System.

Some key reports and research since 2011 have contributed significantly to our understanding of the state and trends of biodiversity, and of the impact of pressures. Citizen-science initiatives are also increasingly contributing to this knowledge base. However, consistent with every SoE report since 1996, this report highlights that we are still unable to assess state and trends of the vast majority of Australia's species and ecosystems, including those that are listed as threatened in Australian, or state or territory legislation. In addition, we are still unable to robustly assess the effectiveness of our investments in biodiversity management and the management of pressures.

The risks faced by biodiversity in Australia today are much the same as in 2011. SoE 2011 noted that many risks facing biodiversity in the short and medium term relate to potential failure to take advantage of current opportunities for better management. If anything, these risks have increased in 2016 because, although the impact of pressures overall has increased, the resources available for managing biodiversity, and undertaking research and monitoring have not.

Mobo Creek—still and covered in pollen in the late dry season—Wet Tropics World Heritage Area, far north Queensland

Photo by David Westcott



Pressures
affecting biodiversity

At a glance

The pressures affecting biodiversity remain largely consistent with those identified in the 1996, 2001, 2006 and 2011 state of the environment reports.

The most significant current pressures are clearing, fragmentation and declining quality of habitat; invasive species; climate change; changed fire regimes; grazing; and changed hydrology. Most of these exert a high to very high pressure on biodiversity, and are worsening. The cumulative and interacting effects of many of these pressures amplify the threat to biodiversity in Australia. Jurisdictional reports all note that their understanding of the full impact of these key pressures on biodiversity is low because of the inadequacy of long-term data and monitoring.

Clearing has stabilised across most states since 2011, except in Queensland. However, the legacy of past clearing means that its effects on biodiversity are not decreasing. High rates of population growth in urban and peri-urban areas result in continued conversion and degradation of the surrounding natural ecosystems.

The pressure from invasive species and pathogens continues a very high and worsening trend. Invasive plants and animals are the most frequently cited threats to species listed in the *Environment Protection and Biodiversity Conservation Act 1999*, and account for 12 of the 21 identified key threatening processes. Almost all states and territories note that data on the distribution and abundance of pest plants and animals, and management effectiveness for these pests are poor.

The impacts of a changing climate are increasingly clear, and include changes to ecosystem structure and composition, phenology (timing of lifecycle events), fire regimes and hydrology. Climate variability and climate change are also considered to have a high or very high impact, with a worsening trend in coastal, marine and inland water environments, and a range of impacts on aquatic biodiversity.

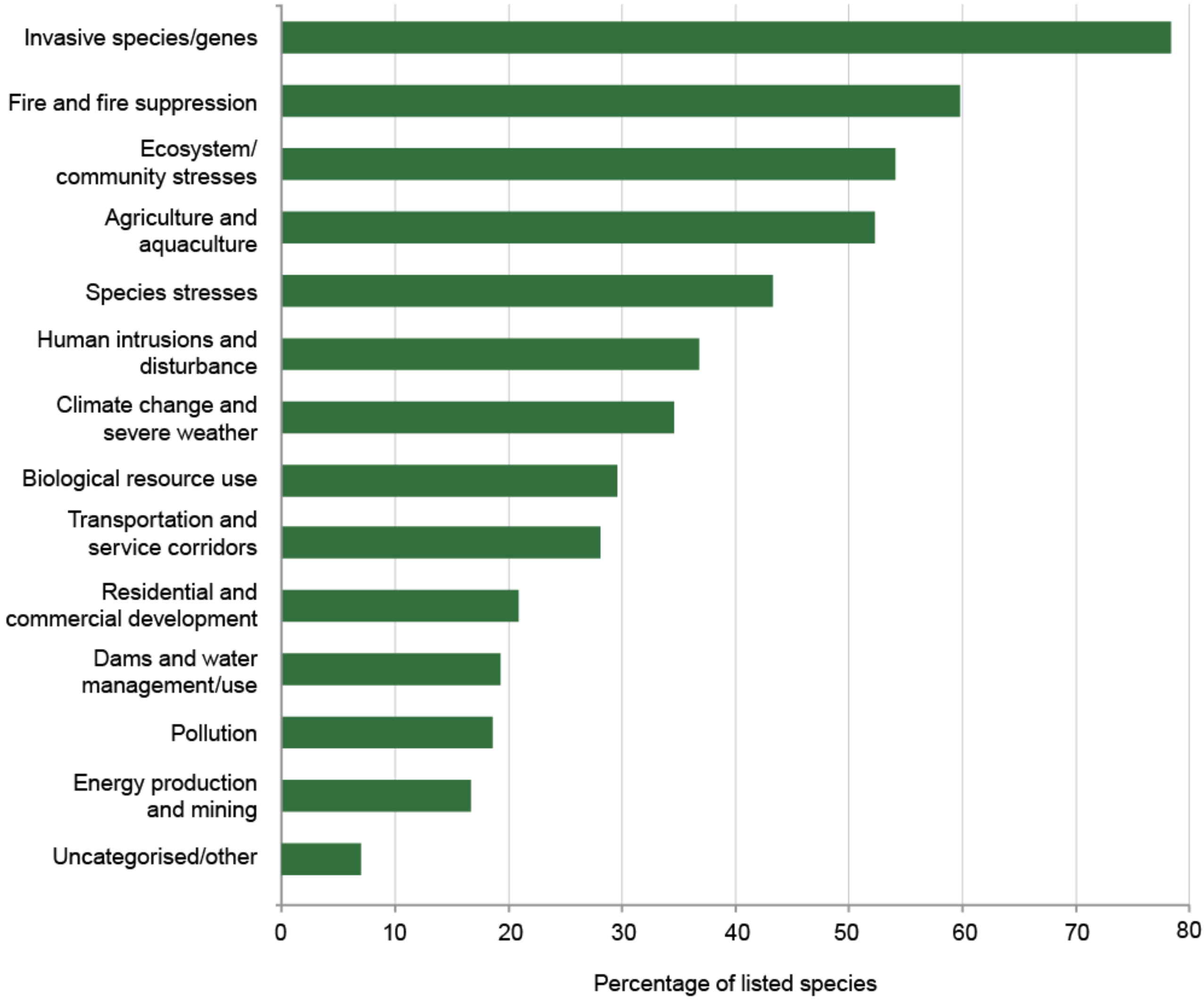
Livestock production is considered a major contributing factor to the decline of threatened mammals in northern Australia and, in conjunction with other pressures, contributes to changes in bird populations. However, the complete impact of grazing on biodiversity and ecosystem functioning is largely unknown.

No comprehensive national update on pressures affecting biodiversity has been published since the 2008 *Assessment of Australia's terrestrial biodiversity* report (DEWHA 2009), which identified the following key pressures:

- fragmentation of habitat
- climate change
- land-use change
- invasive species and pathogens
- grazing pressure
- altered fire regimes
- changed hydrology.

However, as highlighted in all previous SoE reports (1996, 2001, 2006 and 2011), the major pressures on biodiversity are clear; these same pressures remain in 2016.

Information about pressures facing biodiversity is provided from the threatened species listing process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Invasive species are the most frequently cited pressure affecting species listed under the EPBC Act, with approximately 80 per cent of species considered to be at potential risk from the impact of invasive species (Figure BIO2). Changing fire regimes are considered a threat to 60 per cent of listed species.



Note: Includes 1689 of the 1808 species currently listed under the *Environment Protection and Biodiversity Conservation Act 1999*.
Source: Species Profile and Threats Database, Australian Government Department of the Environment and Energy, 2016

Figure BIO2 Pressures affecting species listed as nationally threatened under the *Environment Protection and Biodiversity Conservation Act 1999*

Wolf spider
Photo by Eric Vanderduys

Currently, 21 key threatening processes are listed under the EPBC Act. In the past 5 years, 2 key threatening processes have been added: 'Aggressive exclusion of birds from potential woodland and forest habitat by overabundant noisy miners (*Manorina melanocephala*)' in May 2014, and 'Novel biota and their impact on biodiversity' in February 2013 (more detail is provided in Pest species and pathogens).

Availability of information

No consistent national-level data are available on the impact of pressures on all aspects of biodiversity in the past 5 years. The Australian Government released a Threatened Species Strategy in 2015 (DoE 2015a), which provides insight into threats to a limited number of high-priority taxa or species. For example, the impact of feral cats on small mammals has been well documented. However, information on which to base a comprehensive assessment of trends in pressures and the relative impact of different pressures broadly across ecosystems is very limited (see Box BIO1). Information about the entire range of species that make up the bulk of our biodiversity or on ecological processes that maintain biodiversity is also very limited.

Box BIO1 Current and future pressures on biodiversity—a survey of the ecological community

In December 2015, Ecological Society of Australia (ESA) members were surveyed to solicit opinions on the current and emerging pressures on biodiversity, and impediments to effective management (hereafter referred to as the 2015 ESA survey); 155 members responded. A summary of the responses to these questions is given below.

What are the 5 most significant threats facing biodiversity in 2015?

Clearing and land-use change was the most common response, and rated as the most important significant threat (i.e. ranked first in 56 per cent of responses).

Furthermore, clearing and land-use change was given as one of the top 5 significant threats by 94 per cent of respondents. Climate change was most commonly given as the next most important threat, with 76 per cent of respondents rating climate change as one of the top 5 significant threats. Invasive species and pathogens were next; 69 per cent of respondents rated invasive species and pathogens as one of the top 5 significant threats. Respondents also identified a range of governance and social issues as a threat to biodiversity, including issues relating to low resourcing of land management actions, agencies and research; poor public education; and lack of empathy for biodiversity (Table BIO1).

Table BIO1 Most significant threats facing biodiversity

Threat	Rank 1 (%)	Rank 2 (%)	Rank 3 (%)	Rank 4 (%)	Rank 5 (%)	Total (%)
Clearing and land-use change	56	43	32	27	21	94
Climate change	20	15	16	16	17	76
Invasive species and pathogens	14	21	25	22	14	69
Governance issues	7	9	9	16	18	38
Changed fire regimes	1	10	8	6	12	35
Pollution	1	1	4	8	9	18
Social issues	1	1	4	4	6	13
Species-level changes	1	1	2	1	3	6

Note: Rank is the order in which respondents ranked the threat (Rank 1 = most significant threat). Total (%) is the proportion of respondents who listed the threat as one of the top 5 most significant.
Source: Survey of Ecological Society of Australia members, 2015

Box BIO1 (continued)

What are the top 5 emerging issues with the potential to have serious outcomes for biodiversity in the next 10 years?

Climate change was ranked as the most important emerging threat in 44 per cent of responses, and 73 per cent of respondents noted climate change as one of the top 5 emerging issues. Clearing and habitat modification, and governance issues were the next 2 most important emerging issues; 53 per cent noted clearing and habitat modification, and 49 per cent noted biosecurity in the top 5 emerging issues. Most of the responses in the governance issues category referred to a range of poor or inadequate government policy and effective legislation, and a lack of adequate protection and management in reserves—this was often related to a lack of resourcing for areas in the conservation estate and for natural resource management managers.

Mining and development as an emerging risk was noted by 34 per cent of respondents. Many referred to the expansion of mining and development generally; some specifically referred to development in northern Australia or to coal-seam gas. Overall, most of the responses related to escalation of existing pressures, rather than emerging pressures (Table BIO2).

Table BIO2 Top 5 emerging issues for biodiversity

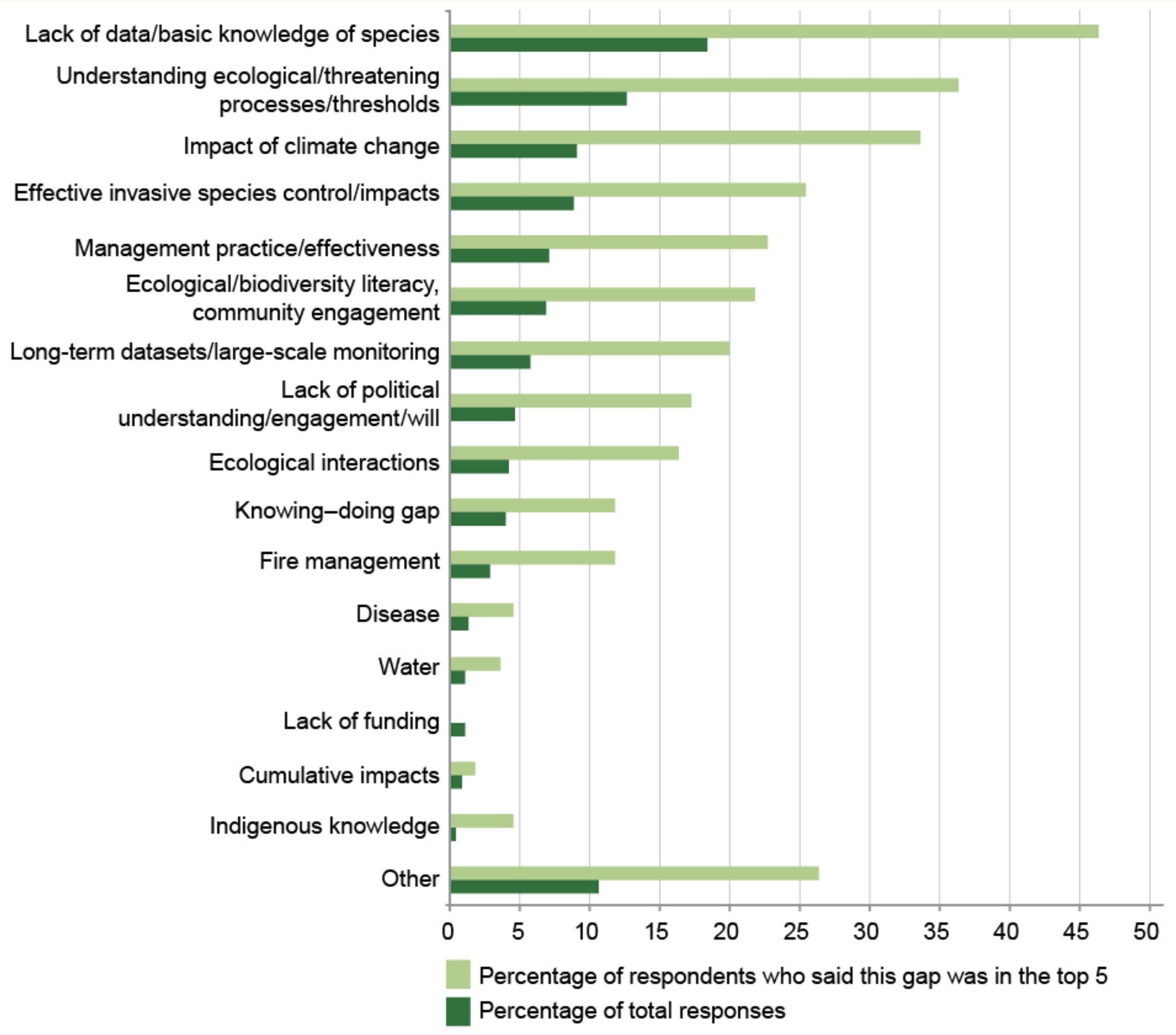
Emerging issue	Rank 1 (%)	Rank 2 (%)	Rank 3 (%)	Rank 4 (%)	Rank 5 (%)	Total (%)
Climate change	44	12	11	9	5	73
Clearing and habitat modification	11	16	23	14	18	53
Biosecurity	9	12	20	18	16	49
Governance issues	10	10	4	12	15	38
Mining and development	9	13	10	8	12	34
Population growth and urbanisation	8	14	7	7	4	26
Fire regime change	2	7	2	7	6	22
Species-level changes	3	4	7	5	8	19
Social issues	1	6	4	7	7	18
Pollution	1	5	3	4	5	13
Knowledge, evidence, research	2	2	7	6	3	12
Other	0	0	2	3	1	4

Note: Rank is the order in which respondents ranked the threat (Rank 1 = most important emerging issue). Total (%) is the proportion of people who included the response in one of the 5 ranks.
Source: Survey of Ecological Society of Australia members, 2015

Box BIO1 (continued)

What are the 5 most important knowledge gaps hindering effective management of biodiversity?

The highest-ranked response (18 per cent) was a lack of basic knowledge about species distributions and abundances, and particularly of threatened species (46 per cent of respondents included this category in the top 5). Other responses identified a lack of understanding of ecological processes, threatening processes, and potential ecological thresholds or tipping points. The survey identified a lack of effective control of invasive species and a lack of knowledge about the impacts of climate change as the most important targets that need to be addressed to manage biodiversity cost-effectively. The survey further identified that management was hampered by a lack of understanding about the effectiveness of management and about best-practice management (Figure BIO3).



Source: Survey of Ecological Society of Australia members, 2015

Figure BIO3 Most important knowledge gaps hindering effective management of biodiversity

Jurisdictional reporting on pressures

Each state and territory in Australia has highlighted a range of key pressures in their jurisdictional reporting. Many of these pressures are common across all jurisdictions—for example, land clearing and vegetation fragmentation, pest animals, weeds, disease and pressures resulting from climate change—with varying impacts in each jurisdiction. Understanding of the full impact of these key pressures on biodiversity is generally considered to be low because of the inadequacy of long-term data and monitoring.

Australian Capital Territory

- Key pressures:
  - Major threats are habitat loss and modification, pest plants and animals, and altered fire regimes.
  - Connectivity is being lost through developments such as the Majura Parkway and urban development, but key links are being protected, and revegetation is undertaken in other key areas for connectivity.
- Assessment grade and adequacy of information:
  - Distribution and abundance of non-native species: status—high; trend—stable; confidence—low. Little specific assessment has been done on the effects of pests and weeds on biodiversity, or the abundance and distribution of weed species.
  - Fire: status—low; trend—stable; confidence—limited. The uncertainty comes from the limited data on effects of fire on biodiversity in the Australian Capital Territory.

New South Wales

- Key pressures:
  - The pressure affecting the largest number of terrestrial threatened species in New South Wales (87 per cent) is clearing and disturbance of native vegetation, followed by invasive pest and weed species.
  - Currently, 46 key threatening processes are listed in state legislation; 1 key threatening process has been listed since 2012 (noisy miner).
  - Introduced pests, especially foxes and cats, have the greatest impact on native fauna.
  - Two new invasive species incursions have been reported since 2012 (red imported fire ants, tilapia).
  - Cane toads are considered an emerging species of concern, with several populations established. The invasion and establishment of the cane toad were listed under the *Threatened Species Conservation Act 1995* (NSW) as a key threatening process in 2006.
  - Several emerging weed risks have recently been identified (orange hawkweed, mouse-ear hawkweed, sea spurge).
  - Pathogens and diseases are an emerging threat.
- Assessment grade and adequacy of information:
  - Number of new invasive species detected: status—moderate; trend—stable; information availability—limited.
  - Spread of emerging invasive species: status—moderate; trend—increasing impact; information availability—limited.
  - Impact of widespread invasive species: status—poor; trend—stable; information availability—reasonable.

Queensland

- Key pressures:
  - Sixty-eight major threats have been identified that affect Queensland threatened fauna. The threats affecting the most species are clearing of vegetation, inappropriate fire regimes and inappropriate grazing regimes.
  - Land clearing for pasture is the greatest pressure on threatened flora and fauna, and affects the eastern coastal bioregions at a higher rate; clearing has almost doubled since 2011–12.
  - Fragmentation is another key pressure; eastern bioregions—in particular, south-east Queensland—are the most heavily fragmented and prone to further degradation because they are close to cleared land.
  - Introduced pest animals place considerable pressure on Queensland's native biodiversity. Negative environmental impacts include
    - predation on native fauna—foxes and feral cats have been implicated in the decline or extinction of native species

- › destruction of habitats and natural resources, including reduced water quality, increased soil erosion and land degradation, and destruction of native plants that provide food and shelter to native species
  - › competition with native animals for food and shelter
  - › disease, poisoning or injury to native animals—a decline of native predators has been attributed to poisoning from cane toads.
- Invasive non-native plants (weeds) are widespread across Queensland, and have the potential to degrade natural vegetation and affect biodiversity.

- Assessment grade and adequacy of information:
  - Knowledge of threats facing fauna—good; knowledge of invasive flora—moderate; knowledge of fragmentation—moderate.

Victoria

- Key pressures:
  - For threatened species, key threatening processes are
    - › habitat loss (affecting 109 species)
    - › weed invasion (108 species)
    - › grazing (99 species)
    - › inappropriate fire regimes (63 species).
  - Key pressures for fauna species include
    - › population fragmentation, leading to poor population viability, in part caused by habitat loss and fragmentation
    - › predation by introduced species (e.g. foxes, feral cats, wild dogs)
    - › competition for resources with introduced species.
  - Salvage logging of fire-affected dead trees has increased in the past 5 years in response to large fires; this can be detrimental to fauna by removing important habitat.
- Assessment grade and adequacy of information:
  - No assessment provided.

South Australia

- Key pressures:
  - Illegal land clearing is increasing.
  - The number, distribution and abundance of most pest plants, pest animals and diseases are increasing; the numbers of weeds, marine pests, aquatic pests and native plant diseases are increasing; the number of terrestrial vertebrate pests is steady; and the number of wildlife diseases is unknown.
  - Several weeds (gorse, blackberry) and 1 pest (feral camels) have decreased in distribution and abundance.
  - Some aquatic pests are increasing and some are decreasing, although the distribution and abundance of most aquatic pests are unknown.
  - Climate change has altered fire regimes.
  - Diseases are increasing (chytridiomycosis in amphibians, sarcoptic mange and alkaloid toxicity in wombats, psittacine beak and feather disease in parrots, blindness in kangaroos, chlamydia in koalas).
  - Phytophthora (causing rootrot and dieback in plants) is becoming more widespread.
- Assessment grade and adequacy of information:
  - Introduced species: status—very poor; trend—deteriorating; confidence—low. Confidence in the assessment of trends of introduced species is limited because of a lack of evidence or consensus.
  - Insufficient data exist about the abundance and trends of aquatic pests.
  - The extent of disease in native fauna is largely unknown.

Western Australia

- Key pressures:
  - Habitat loss or modification is resulting from introduced plants (weeds) or plant diseases, vegetation clearing, fragmentation and edge effects, altered fire regimes, or altered hydrological regimes, including salinity and acidification.
  - Introduced or feral animals cause a range of pressures on biodiversity, including
    - predation (e.g. foxes, rats, feral cats)
    - competition for food and/or habitats (e.g. camels, donkeys, goats, rabbits, feral cattle)
    - ingestion (e.g. cane toads).
  - Emerging plant diseases include
    - phytophthora dieback
    - canker
    - myrtle rust.
  - The changing climate is also bringing a range of pressures—in particular, the drying climate, such as in the south-west, is affecting a range of species.
- Assessment grade and adequacy of information
  - No assessment provided.

Tasmania

- Key pressures:
  - Vegetation clearance has predominantly been for dairy farming and cropping, with plantation clearing markedly reduced since 2010. Other pressures are fire and diseases (e.g. myrtle rust, phytophthora dieback).
  - Clearance and degradation of habitat (vegetation, soil, hydrology) have been because of
    - residential development
    - agricultural and forestry activities (clearance, dams)
    - hydro-electrical requirements
    - expansion of irrigation schemes
    - inappropriate fire regimes (frequency, intensity), which are expected to worsen with climate change.
  - Introduced species and weed invasion affect native species.
  - Drought has directly affected biodiversity and has also increased the browsing pressure from native animals.
  - A range of unpredictable threats to rare species exist.
  - Climate-induced change in the marine environment is affecting
    - ocean chemistry
    - food availability
    - foraging areas (changing temperatures and currents).
- Assessment grade and adequacy of information:
  - No assessment provided.

Northern Territory

- Key pressures:
  - In most terrestrial environments, the key pressures are
    - altered fire regimes, particularly more frequent, intense and/or extensive fires
    - habitat degradation by large feral herbivores and pigs
    - predation by predators (feral cats and foxes)
    - habitat modification by major environmental weeds
    - cane toads.
  - The relative importance of these pressures varies regionally and for different biota; significant interactions between pressures are increasingly being recognised, with important implications for management.
  - The extent of clearing and fragmentation of native vegetation is relatively small, but is a significant pressure in the Greater Darwin region and Daly River catchment.
  - A significant and well-quantified increase in the extent and/or severity of some threats has been seen in the past decade, including gamba grass in the north-western Northern Territory and feral buffalo in Arnhem Land.
  - The density of feral camels in the territory has been greatly reduced as a result of the Australian Feral Camel Management Project between 2009 and 2014.

- Management or containment of some weed and pest ant species has been effective at local or catchment scales.
- Landscape-scale fire management for greenhouse gas abatement ('savanna burning'), primarily on Indigenous-managed lands in the north of the Northern Territory, has ameliorated damaging fire regimes in some areas (notably western Arnhem Land).
- Some new pathogens have recently emerged (e.g. myrtle rust), with uncertain impacts on native biota.
- Sea level rise, saltwater intrusion and severe weather events (ultimately caused by climate change) are increasingly severe pressures on coastal environments, particularly floodplains. Recent extensive dieback of mangroves is likely linked to climate change. Climate change impacts on marine environments and biota are very poorly known.

- Assessment grade and adequacy of information:
  - No systematic remote monitoring of vegetation clearing currently exists.
  - Recent quantitative data are available about the extent and density of some feral animal species, either for the entire territory (camels) or for some regions (feral buffalo, feral horses).
  - Very poor data exist for the density distribution of feral cats, although techniques are currently being developed to monitor cat occupancy and abundance.
  - Generally good data are available about the spatial extent of major weed species.
  - Good spatial data are available about the annual extent of fire throughout the territory.

Spatial distribution of pressures

There has been no updated overall synthesis of the spatial distribution of pressures affecting biodiversity in the past 5 years. A 2015 publication (Lee et al. 2015) assessed the spatial distribution of climate vulnerability for listed species across Australia, and the spatial distribution of threats has been considered in more detail for mammals in *The action plan for Australian mammals 2012* (Woinarski et al. 2014) (see Terrestrial plant and animal species).

Global climate change and climate variability

All recent state and territory SoE reports note the adverse effects of global climate change on biodiversity. These increasingly include extreme weather, as well as bushfire, drought, cyclones and flood. Climate change is predicted to generally exacerbate existing pressures; the general consensus is that the capacity of biodiversity to adapt to climate change will therefore be improved if other existing threats are addressed or ameliorated to some extent. Some state and territory reports also acknowledge that climate change could surpass habitat modification as the greatest threat to biodiversity in the next few decades. In an assessment of the pressures on New South Wales vegetation classes, climate change was the only pressure to affect all classes. It was described as the most pervasive pressure and described as 'intensifying' (NSW EPA 2012). Data about the impact of adverse climate as a pressure on animal distributions are generally not available, but individual species information suggests that this pressure is increasing, sometimes with devastating results. A Queensland Government report released in May 2016 reported the probable extinction of the Bramble Cay melomys (*Melomys rubicola*) from its only known island home in Torres Strait because of climate change (Gynther et al. 2016). The last known individual was sighted in 2009, and extensive surveys in 2014 failed to locate any animals. The key factor responsible for the extinction was the increased frequency and intensity of weather events, which produced extreme high water levels and damaging storm surges, and caused dramatic habitat loss and possibly direct mortality.

The broad impacts of climate change on biodiversity are increasingly well understood and are expected to vary, depending on the Australian region under consideration. In arid Australia, temperatures are predicted to increase, as are the frequency and intensity of extreme rainfall events, which are likely to increase threats to biodiversity directly and indirectly. In alpine Australia, changes in climate are already having significant impacts on biodiversity. In both Tasmania and Victoria, dynamic shifts in fire regimes are potentially leading to significant changes in ecosystems. In Tasmania, the 2015–16 summer was one of the driest on record. Lightning strikes ignited drying peat soils, causing

Pencil pine (*Athrotaxis cupressoides*) ecosystems burned in a wildfire at Lake Mackenzie (Tasmanian Wilderness World Heritage Area) in January 2016
Photo by Chris Emms, Tasmanian Parks and Wildlife Service

large fires in remote areas. Some 124,742 hectares of country were affected by fires, including the globally unique fire-sensitive pencil pine ecosystems, with 20,125 hectares or 1.27 per cent of the Tasmanian Wilderness World Heritage Area burned. This was followed by the wettest 3-month period on record.

Extreme heat events across Australia are the cause of high mortality for some fauna. For example, record temperatures in southern Queensland in January 2014 resulted in the deaths of more than 45,000 flying foxes in 1 day (Welbergen et al. 2014).

The *Climate change adaptation plan for Australian birds* (Garnett & Franklin 2014) assessed the vulnerability to climate change of all Australian bird species and subspecies that are resident on the continent or that visit on migration (1237 taxa in all) under a 2085 Representative Concentration Pathway (RCP) 8.5 scenario.[1] The plan provided adaptation strategies for a 50-year timeframe for those taxa deemed most at risk. The risk model used was that vulnerability arises from a combination of sensitivity and exposure. A total of 177 birds were assessed as highly exposed, 151 as highly sensitive and 69 as both (referred to as highly vulnerable). Of the highly vulnerable species, 16 occupy the marine environment, and the remainder are terrestrial. A series of 12 management actions was developed and costed for each highly vulnerable species (or subspecies), giving an annual cost of adaptation of $5.08 million for just these birds.

Assessment of the extent to which species are vulnerable to climate change relative to other threats is necessary for effective recovery planning and conservation management. Lee et al. (2015) assessed the vulnerability to climate change of a sample of EPBC Act–listed species, including birds (44 species), mammals (43 species), amphibians (19 species) and reptiles (14 species) for which there were known population trends (recorded in 2002). Nearly half of these species were assessed to be vulnerable to climate change, with amphibians being the most vulnerable taxa. Species with smaller geographic ranges are more vulnerable than more widespread species.

Evidence is building that changes in phenology of Australian organisms are attributable to climate change. Phenology describes the timing of lifecycle events such as flowering and fruiting in plants, the onset of breeding in animals, the timing of migration, and the emergence date for arthropods. Shifts in phenology can affect ecosystems through changes in ecological interactions, such as plant–pollinator and predator–prey dynamics. These shifts have important consequences for agricultural production, human health, societies and economies. Shifts in phenology in Australian organisms have been documented in many long-term datasets, which show an average earlier phenology for plants of 9.7 days per decade (mostly based on data on grapevines from the viticulture industry) and for birds of 2.6 days per decade (Chambers et al. 2013). Examples of documented shifts in phenology include populations of dollarbirds (*Eurystomus orientalis*) and common koels (*Eudynamys scolopacea*) arriving significantly earlier at their south-eastern Australian breeding grounds (although not in more northerly regions).

Another pressure to coastal systems from global climate change is sea level rise, particularly for low-lying systems, such as coastal saltmarshes and terminal floodplain systems. Sea level rise may also carry a risk of irreversible damage to sacred and cultural sites, which can be (but is not always) significant for biodiversity. The pressure from sea level rise is described in more detail in the *Coasts* report.

Pollution

Pollution issues affecting biodiversity in Australia can generally be categorised as relatively local in nature (e.g. specific waste streams from poorly managed activities or legacy sources in groundwater, such as plumes under industrial sites) or relating to broad landscape processes (e.g. nutrient enrichment in the Great Barrier Reef from farming or inappropriate pesticide use). The *Coasts* report describes impacts from pollution on coastal ecosystems in Australia. Common contaminants found in coastal rivers and estuaries around Australia include metals, pesticides, herbicides, terrigenous sediments and debris (predominantly plastics). The current state of coastal river and estuary pollution is poor, and has been deteriorating since 2011. Nationally, pollution pressure on many coastal waters is moderate to strong, but varies greatly among waterways. In the eastern states, pollution is most intense in more developed estuaries, although overall pressures appear to be moderate.

Perhaps the largest pollution issue of concern for biodiversity in Australia that has risen in prominence during the past 5 years is marine debris and ingestion of plastics by marine animals. The *Coasts* and *Marine environment* reports both describe the impact of marine debris on coastal and marine fauna. Debris may directly entangle fauna, such as in the Gulf of Carpentaria where an estimated 5000–15,000 turtles become ensnared in discarded fishing nets each year. Shorebirds, turtles and invertebrates may ingest and accumulate plastics. The ecological effects of microplastics are largely unknown,

1 Representative Concentration Pathways (RCPs) are 4 greenhouse gas concentration trajectories—which describe the radiative forcing values in the year 2100 relative to pre-industrial values—adopted by the Intergovernmental Panel on Climate Change for its Fifth Assessment Report in 2014: RCP2.6, RCP4.5, RCP6 and RCP8.5.

but include bioaccumulation of toxins, which potentially transfer up the food chain and enter human diets. Four states and territories have banned single-use plastic bags in the past 7 years (South Australia—2009, the Australian Capital Territory—2011, the Northern Territory—2011 and Tasmania—2013) as a direct measure to decrease impacts on marine life.

Although global concern regarding micropollutants has increased during the past 5 years, micropollutants have not yet been formally recognised as a threat to Australian marine fauna. Pesticides used to spray insect pests, such as fenitrothion for locust plagues, has an impact on some species. Of serious concern is the cumulative impact of many threats, including the impact of pesticides on the plains-wanderer (*Pedionomus torquatus*) in southern Australia. The *National recovery plan for the plains-wanderer* (DoE & DEWNR 2016) reports that the actual impact of pesticides is unknown, but that the concentration of fenitrothion that is used for spraying can kill birds that come in contact with the chemical.

Several Queensland rivers and estuaries have recorded moderate to strong environmental impacts of sediments and pesticides. A report card system is in place for south-east Queensland, Gladstone Harbour, the Great Barrier Reef and Mackay. However, monitoring has shown little improvement in water quality in the past 5 years, which can be explained by the scale of the problem, and the necessary transition and cost of agricultural reform.

Consumption and extraction of natural resources

Harvesting of species

The impact of harvesting is considered a potential threat to 30 per cent of listed threatened species across a wide range of taxa. The collecting of terrestrial plant species is considered a threat to 14 listed cycad species, 13 fern species and 176 other plant species, including 29 critically endangered orchids. In Tasmania, harvesting of terrestrial plant species or products, such as seeds, wildflowers and tree ferns, is regulated under state-based management plans; export is approved under the EPBC Act. The Department of Parks and Wildlife in Western Australia manages wildflower and seed harvesting in accordance with a management plan that is approved under the EPBC Act. Seed collection of forest species is also important in other states and territories, for use in native forest regeneration, plantation establishment, propagation of nursery stock and landcare plantings. Collection is regulated and reported by relevant public authorities. Illegal harvesting of some species of terrestrial plants is a concern—for example, for tree ferns and orchids.

Indirect harvesting (including activities such as timber logging) is identified as a significant pressure for many Australian species, including listed threatened species. For example, 4 threatened mammals and 3 near threatened mammals have timber harvesting identified as a pressure in *The action plan for Australian mammals 2012* (Woinarski et al. 2014). Similarly, current commercial logging practices in Victoria's wet forests are considered one of the major pressures on the critically endangered Leadbeater's possum (*Gymnobelideus leadbeateri*), leading to concerns about its population viability in the wild (Lindenmayer et al. 2015). Timber harvesting is also identified as a significant pressure for a small number of hollow-nesting species, particularly those that require large hollows in which to breed, such as the masked owl in Tasmania (*Tyto novaehollandiae*) and the barking owl in southern Australia (*Ninox connivens*).

Harvesting of native birds continues under both traditional and nontraditional activities in northern Australia. Harvesting of emu (*Dromaius novaehollandiae*), Australian bustard (*Ardeotis australis*) and magpie goose (*Anseranas semipalmata*), among others, occurs in northern Australia. One of the largest harvests of native birds occurs in Tasmania where short-tailed shearwaters (*Ardenna tenuirostris*) are taken as part of traditional Tasmanian Aboriginal cultural practice, as well as by commercial and recreational harvesters. The harvest is managed by the Tasmanian Department of Primary Industries, Parks, Water and Environment.

Duck and quail hunting is an ongoing activity in Victoria, South Australia and Tasmania, with hunting seasons in each of these states typically running from late autumn to winter. Only common species are declared as 'game' and can be hunted. There are strict bag limits and restrictions on locations where hunting is permissible, aimed at ensuring sustainability of the harvest. Although it appears that hunting is having no adverse impact on game bird populations, there is ongoing concern that hunting may adversely affect other species, including threatened species, during times of stress. For example, in Victoria, the total wetland area index was the lowest on record in 2015, with water storages at low levels. The ongoing decline and fragmentation of wetlands, combined with multiple pressures including hunting activities, place some species at an increased risk—for example, one of Australia's rarest waterbirds, the freckled duck (*Stictonetta naevosa*).

Although the hunting and harvesting of native animals is subject to laws in all jurisdictions, monitoring of compliance with regulations for harvesting of species is variable across Australia. For instance, the growth in the Indigenous estate (often in remote and hard-to-access parts of Australia) has not been matched by an increase in management resources.

Harvesting for meat and skin products is largely restricted to species that are considered common (kangaroos and wallabies), and, in most cases, requires a permit. Commercial export of product is undertaken under state and territory management plans approved under the EPBC Act. An approved wildlife trade operation under the EPBC Act allows the export of fur products sourced from wallabies that are harvested for meat in the domestic market.

The depletion of some fish stocks and the question of ecological sustainability of some of Australia's fisheries present an ongoing need for increased management to conserve biodiversity. By way of management, the EPBC Act requires an independent assessment of the environmental performance of all Commonwealth fisheries, and all fisheries from which product is exported. Further information on impacts of recreational fishing, and take for the aquarium trade and commercial fisheries is presented in the *Marine environment* report.

Pressures related to population size and lifestyles

One of the main drivers of environmental change identified in the *Drivers* report is human population growth. Australia's population continues to increase, with a distinct regional pattern: population growth is concentrated in capital cities and in coastal areas. Although our population is relatively small compared with our land mass, Australia's ecological footprint is the 13th highest globally, behind countries such as Qatar, Kuwait, the United Arab Emirates, Denmark, the United States and Belgium (McLellan et al. 2014). The ecological footprint is a measure of the impact humans have on the environment. Our high ecological footprint indicates that we are consuming resources at a much faster rate than the planet can regenerate.

The impact of population growth in terms of urban expansion is discussed in detail in the *Built environment* report.

Consumption of water

Water volumes extracted from the environment to support households and industry have grown in the past few years, from 75,000 gigalitres (GL) in 2011–12 to 92,300 GL in 2013–14. Urban water demand increased from 2011 to 2014. Melbourne, Sydney, Brisbane and Perth generally saw upswings in water abstraction, urban claim and household water supply during this period. In Australia, agriculture is the single largest water-consuming industry.

Governments in Australia purchase water entitlements for purposes that include protecting and restoring environmental assets. For example, the Victorian Government, through the Victorian Environmental Water Holder, holds more than 25 entitlements and delivered around 440,300 megalitres of environmental water to priority rivers, wetlands and floodplain systems from July 2015 to April 2016. The Commonwealth Environmental Water Holder increased entitlements for the Murray–Darling Basin in 2012–15, from 1368 GL to 2396 GL. Year-to-year variability in water use is influenced by weather and available water. Detailed information on Australia's water use is available in the *Inland water* report.

Extractive industries

Mineral prospecting and exploration are allowed throughout most of Australia, and mining potentially affects biodiversity. Australia is a globally significant supplier of minerals and energy, holding a substantial proportion of the world's known reserves of many important minerals. Mining exports have increased rapidly during recent decades on the back of unprecedented demand from China and other developing economies, with annual production of black coal and iron ore increasing exponentially (Andersen et al. 2014). However, individual mines are typically small—except for open-cut coal, iron-ore and bauxite mines—and collectively account for less than 0.26 per cent of the land mass of Australia (with only 0.64 per cent under granted mining leases).

The localised effects of mining can, however, have major detrimental effects, particularly on short-range endemic species, and there are many examples of serious environmental impacts from old mines that operated under lax environmental regulation. However, the greatest potential for negative impacts on biodiversity is not usually from individual mines, but from the cumulative impacts of extensive development in highly prospective regions (e.g. iron-ore mining in Western Australia's Pilbara and coalmining in the Galilee Basin in central Queensland), or where diffuse exploration and development take place across large regions (e.g. coal-seam gas development in eastern Australia—see Box BIO2; and exploration for gas, oil and minerals across outback Australia). In these situations, mining can dominate regional development and potentially affect biodiversity through a combination of the scale of exploration activity, the mine sites themselves and, importantly, the roads, towns, pipelines, water supplies and ports required to service them (Andersen et al. 2014).

Clearing and fragmentation of native ecosystems

Land clearing and fragmentation are noted as key threats in every jurisdictional SoE report. Half of all EPBC Act–listed species are considered to be at risk from habitat fragmentation. The *Land* report contains details of historical clearing in Australia, as well as current rates of clearing. In summary, rates of land clearing are broadly stable or decreasing in most states except Queensland. A relaxation of tree-clearing legislation was responsible for a significant increase in clearing rates of both remnant and nonremnant vegetation in Queensland in 2012–13. In particular, in Queensland's reef catchments, clearing rates rose by 229 per cent between 2008–09 and 2013–14.

Across Australia, most clearing (more than 70 per cent) now occurs in areas that have previously been cleared (Figure BIO4). However, of land being cleared for the first time in 2015, more than 50 per cent was in Queensland.

Box BIO2 Coal-seam gas

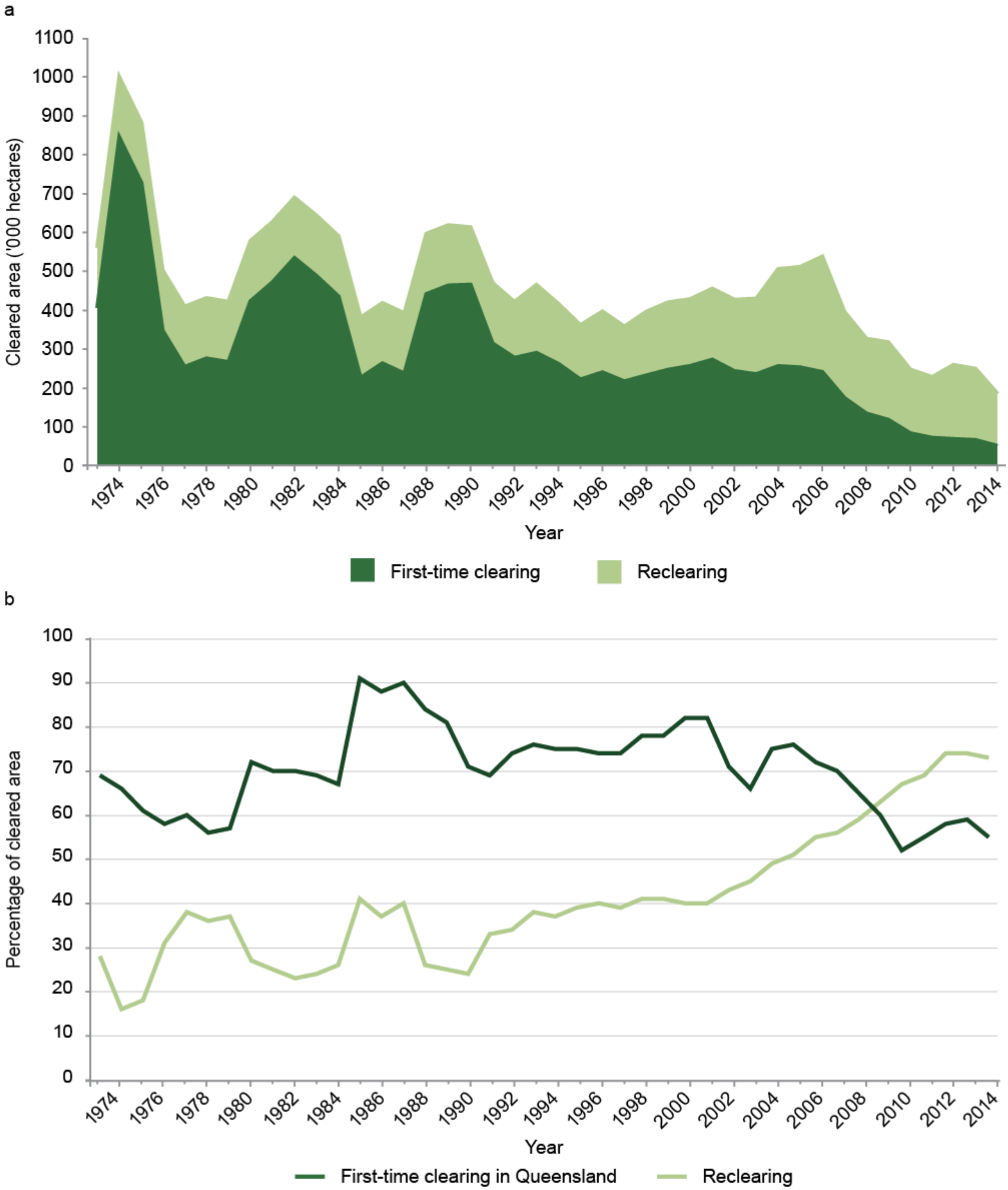
In eastern Australia, significant resources of coal-seam gas are known in the Bowen and Surat basins in Queensland. In New South Wales, reserves have been proven in the Sydney, Gunnedah, Clarence–Moreton and Gloucester basins. Coal-seam gas exploration, extraction, processing, storage and transport require the construction, maintenance and operation of various above-ground infrastructure. The grid of production wells and associated access tracks, as well as transmission pipelines to sea ports, can contribute to the perforation and fragmentation of remnant native vegetation.

Expansion of the coal-seam gas industry in eastern Australia could have further significant impacts on the remaining terrestrial biodiversity in areas that have already been extensively affected by other human activities, such as agriculture, mining and infrastructure development (Williams E et al. 2014).

The Gas Industry Social and Environmental Research Alliance conducted a priority threat management project on biodiversity across the coal-seam gas development region in Queensland (Ponce Reyes et al. 2016), and field research on the impacts of fire management in the grasslands near the coal-seam gas fields. The priority threat work showed that the cumulative impact of vegetation loss, land degradation, development (including the expansion of the coal-seam gas industry), invasive species and climate change in the Queensland Brigalow Belt is causing a significant negative outlook for species in the bioregion. Managing fire regimes and invasive plants was deemed to be the most cost-effective management strategy to ensure the future persistence of biodiversity.

However, in such a contested area, it noted that building and implementing a common vision among stakeholders is crucial for balancing biodiversity goals with social, economic and cultural objectives (Ponce Reyes et al. 2015).

The research into the impacts of fire management in the grasslands near the coal-seam gas fields found that any modest change in regional fire regimes was unlikely to have a significant impact on biodiversity in eucalypt-dominated grassy woodlands, and recommended that an ongoing fire-monitoring program be established.



Source: Adapted from Taylor et al. (2014a), using data in the 'Land use, land use change and forestry activity table 1990–2014' (August 2016) from the Australian Greenhouse Emissions Information System

Figure BIO4 Forest conversion in Australia, 1973–2014: (a) overall trends in first-time forest conversion and reclearing; (b) percentage of forest conversion (Australia-wide) that was reclearing, and percentage of first-time forest conversion that occurred in Queensland

Julianne's peacock spider (*Maratus julianneae*)
Photo by Robert Whyte

Urban development

A growing population puts increasing pressure on biodiversity when residential areas encroach on natural systems. The *Built environment* report describes Australia's urban footprint, and the implications for air quality, water quality and the natural environment.

As Australia's population grows, additional urban land is required, or existing land is used more intensely. In Australia, population growth tends to be most concentrated in outer suburbs, in inner cities, in urban infill areas and along the coast. Our big cities continue to expand into natural areas on the city fringes, despite the well-recognised problems associated with higher infrastructure costs, lack of amenity, car dependency, poor job access, and diminished agriculture and open space (Newton 2012). In Melbourne, 50 per cent of the approximately 40,000 new dwellings built each year are in new greenfield sites (Buxton 2014). Targets for infill housing established in recent metropolitan strategic plans are not being achieved (Newton 2012).

The threatened Grassy Eucalypt Woodland of the Victorian Volcanic Plain is encroached on by Melbourne's peri-urban zone, with woodland remnants cleared to allow increasing urban development. Additional growth centres are planned. In response, the Victorian Government is establishing conservation areas in and outside the growth corridors to protect threatened species and ecological communities of national and state significance, and to manage the impacts of urban development in urban growth corridors. Similarly, encroachment of urban development on the Cumberland Plain Woodland in the Sydney Basin has reduced the community to small fragments scattered across the western suburbs of Sydney, and it is now listed as critically endangered.

Urban development is a major driver of environmental change. Urban areas contain threats to, and opportunities for, biodiversity. The conversion or degradation of natural ecosystems in urban areas has the most obvious and immediate impacts on biodiversity. In addition, human settlements and development are often the entry point for introduced species, which are a major pressure on biodiversity. For example, non-native invasive garden plants, introduced to Australia by and for the urban population, make up an estimated 72 per cent of environmental weeds that affect biodiversity (Groves et al. 2005).

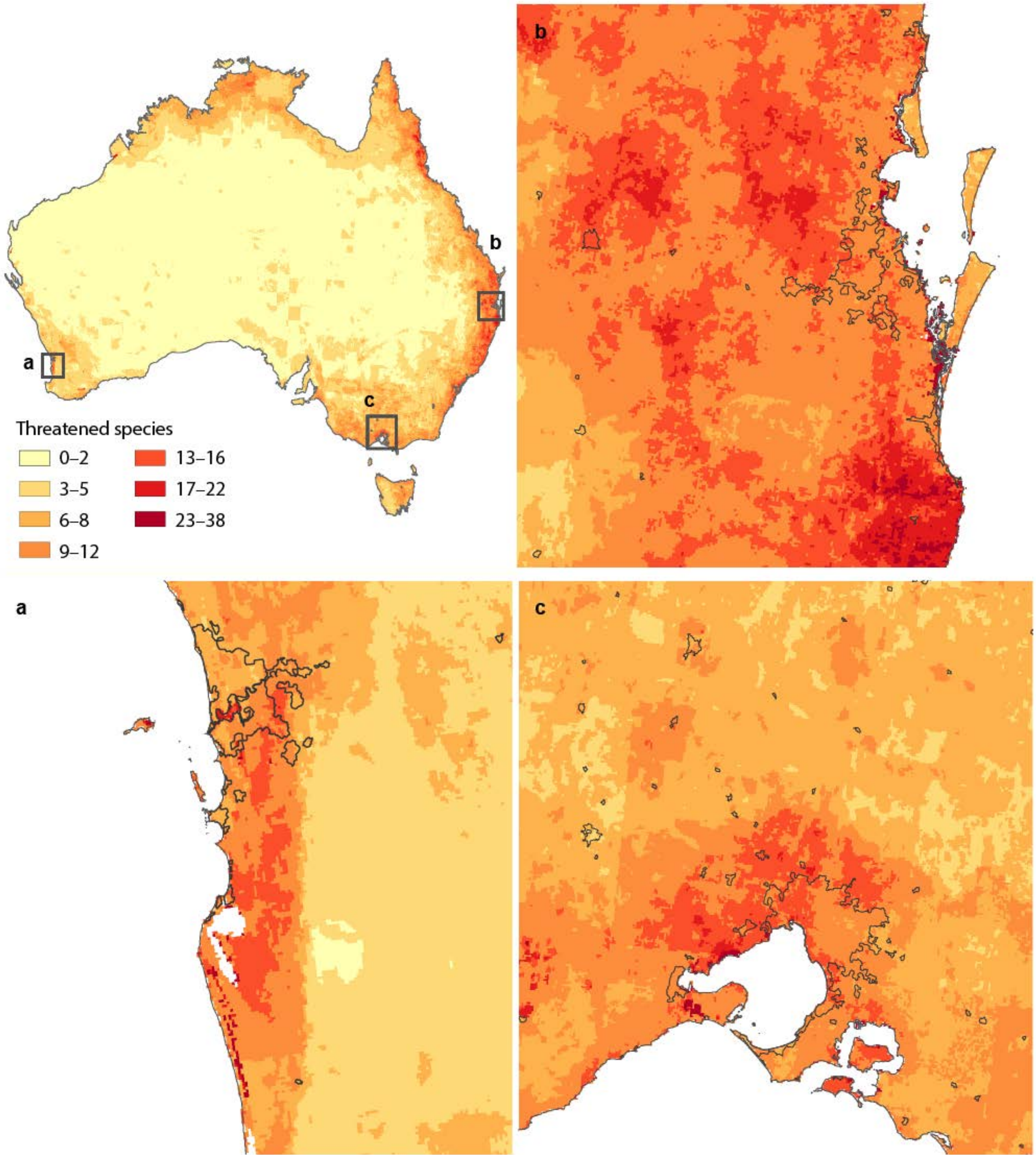
In contrast, the urban environment can prove an attractive habitat for a wide range of taxa because of abundant food and shelter. Urban areas may also provide more stable resources for some native species as a result of planting selection and supplemental watering. Some urban habitats, such as railway lines, abandoned industrial lands and urban wetlands, can be rich in native species and can play an important role in maintaining the biodiversity of a city.

Although the presence of wildlife in urban areas can enhance human quality of life (see Box BIO3), some urban animal populations can prove problematic because of their impacts on amenity or their role as vectors of disease. For example, roosting by flying foxes in urban and peri-urban areas can result in contact and conflict with humans. Human concerns include noise, odour and faeces from flying fox camps, particularly when they occur near residences. Transmission of disease, particularly Hendra virus and Australian bat lyssavirus, is also a key concern and has received much attention during the past few years. Although smaller camps are often tolerated, larger camps become a focus of community disquiet. The spectacled flying fox (*Pteropus conspicillatus*) and grey-headed flying fox (*P. poliocephalus*) are both listed as vulnerable under the EPBC Act. They have both shown marked changes in the distribution of their abundance during the past 15 years, in the form of increases in the number of urban camps and in the proportion of their populations found in urban contexts (Tait et al. 2014, Westcott et al. 2015). It is unclear whether these changes represent responses to the development of appropriate conditions in urban areas, the deterioration of conditions elsewhere or the cessation of exclusion from urban areas. Regardless, the shift represents a major management dilemma, given the conflict it produces and the conservation status of the 2 species.

Cities are often located in areas with high biodiversity, and the process of urbanisation itself is likely to have led to many species that formerly occurred in these places now being threatened. In 2015, Ives et al. (2016) analysed the extent to which the distribution of 1643 species of national environmental significance under the EPBC Act overlapped with 99 Australian cities of more than 10,000 residents (Figure BIO5). They found that 25 per cent of listed plants and 46 per cent of listed animals had distributions that intersected with cities. The distributions of 8 threatened species (all plants) entirely overlapped with cities, whereas 51 (10 per cent) of the 503 threatened species found in cities had more than 30 per cent of their distribution in urban areas. The research showed that cities contain substantially more threatened species per unit area than non-urban areas.

Urban growth has been shown to cause overall reductions in the distributions of birds in Brisbane; however, spatially constrained, compact development substantially slows these reductions, resulting in fewer local extinctions. Averted local extinctions under compact development are most pronounced for urban-sensitive species that are dependent on large intact remnants of natural habitat or open space within a city (Sushinsky et al. 2013). Other research has shown that large native trees in urban areas provide crucial habitat for wildlife. In Canberra, the presence of large native trees in urban parks increases bird diversity and abundance (Stagoll et al. 2012).

Citizen-science initiatives focused on urban areas, such as BirdLife Australia's Birds in Backyards and School of Ants Australia, are helping to improve knowledge about urban biodiversity and management.



Note: Urban areas are outlined in black. Cities shown in greater detail in boxes are (a) Perth, (b) Brisbane and (c) Melbourne.
Source: Dr Pia Lentini, University of Melbourne, used under CC BY NC using data supplied by the Australian Government Department of the Environment and Energy

Figure BIO5 Threatened species richness across Australia

Box BIO3 The critical role of 'everyday nature' for the future of cities

Nature in cities delivers a remarkable range of benefits to human health and wellbeing. Individuals are more likely to live longer (Donovan et al. 2013), and have better general health and wellbeing (Dallimer et al. 2012) in a city with more trees.

Urban greening can substantially improve the resilience of cities to climate change, potentially cooling cities by up to 8 °C in summer, alleviating the impacts of flooding and providing shelter from extreme weather events. Vegetation in cities can also play a significant role in mitigating climate change impacts by sequestering greenhouse gases, and reducing energy consumption for cooling and heating.

Cities host numerous threatened plant and animal species. In Australian cities, more than 3 times as many threatened species are found per unit area than in rural areas (Ives et al. 2016). Some species are found only in cities, whereas others rely on cities for key food and habitat resources. The future of many threatened species will depend on actions to accommodate their needs within city boundaries.

Creating opportunities in cities for everyday interactions with nature provides an unparalleled opportunity to reconnect people with biodiversity, and expose urban residents to the myriad health and wellbeing benefits provided by nature. Furthermore, urban renaturing has the potential to connect urban residents with Indigenous history and culture, and create an avenue for preserving traditional knowledge and engaging urban Indigenous people in city planning processes.

The reasons for embracing nature in cities are compelling, but the pathways to achieve this vision are not always straightforward. An important first step is to reframe the way nature is considered in the planning process. Rather than considering nature as a constraint—a 'problem' to be dealt with—nature can be seen as an opportunity and a valued resource to be preserved and maximised at all stages of planning and design. It also requires a different conceptualisation of nature, where novelty is the norm and apparently scrappy bits of urban nature can have as much value as pristine nature reserves. The future of our cities may well depend on a new conceptualisation of urban landscapes, where nature can thrive and people can enjoy—every day—the remarkable range of benefits that nature can deliver (Figure BIO6).

Figure BIO6 Livable cities

Pressures from livestock production

Livestock production is the dominant land use in the extensive land-use zone of Australia (see the *Land* report for further information). It is considered a major contributing factor to the decline of 8 threatened mammal species and a significant pressure on a further 8 near threatened species under *The action plan for Australian mammals 2012* (Woinarski et al. 2014). Small mammal populations in northern Australia have been shown to increase rapidly in diversity and abundance following destocking of grazing animals (Legge et al. 2011).

Conclusive evidence for the impact of grazing on bird assemblages has proven difficult to attain (Kutt et al. 2012). However, the local extinction of several bird species has been co-attributed to the impact of grazing livestock and associated management changes, in conjunction with other threats.

Changes to ecological processes arising from damage to biological soil crusts are likely to be particularly significant. Biological soil crusts occur as extensive carpets of lichens, bryophytes and cyanobacteria, which play a major function as the dominant primary producers on which other organisms depend as a food source at multiple levels in the food chain in arid and semi-arid Australia. In north-western Victoria, only 5 per cent of native vegetation remains. In remnant grassy woodlands of the region, biological soil crusts are abundant in areas with low tree and litter cover, and where disturbance is minimal (Read et al. 2008, 2011). But this important element of the ecosystem is often reduced or absent in the many remnants used for livestock shelter, and there is a strong negative correlation between remnant size and livestock disturbance (Duncan et al. 2008, Duncan & Dorrough 2009), with negligible crust cover in highly disturbed, small sites.

Pest species and pathogens

Pest plants, pest animals and pathogens have been identified by every state and territory as a key threat to biodiversity generally, and to threatened species specifically. Almost all states and territories also note that data on the distribution and abundance of pest plants and animals, and management effectiveness for these pests are poor. For states that provide assessment grades similar to those used by the Australian Government, the state for pest plants and animals is considered poor to very poor, and the trend is deteriorating (South Australian natural resource management [NRM] report card, Victorian SoE, Australian Capital Territory SoE). Similar concerns have been raised regarding lack of data on pest plants and animals on much of the Indigenous estate. In general, landowners or land managers are legally responsible for the control of pest plants and animals, which can create an onerous demand on resources. In particular, many Indigenous land managers, with the notable exception of Land and Sea Rangers, have inadequate capacity to meet that obligation.

The impact of invasive species is the most frequently cited threat to EPBC Act–listed species. Of the 21 key threatening processes listed under the EPBC Act, 12 describe declines in native species and/or ecological communities caused by 1 or more invasive taxa, including cats, rabbits, goats, rats, cane toads, foxes, feral pigs, gamba grass, escaped garden plants, red imported fire ants and yellow crazy ants. A further 3 are concerned with threats arising from pathogens—the rootrot fungus *Phytophthora cinnamomi*; psittacine circoviral (beak and feather) disease, affecting endangered parrots; and chitrid fungus disease, affecting amphibians.

In February 2013, novel biota were listed as a key threatening process under the EPBC Act. The key threatening process listing covers 6 major groups of novel biota and associated processes that are affecting biodiversity:

- competition, predation, or herbivory and habitat degradation by vertebrate pests
- competition, predation, or herbivory and habitat degradation by invertebrate pests
- competition, habitat loss and degradation caused by terrestrial weeds
- competition, habitat loss and degradation caused by aquatic weeds and algae
- competition, predation, or herbivory and habitat degradation by marine pests
- mortality, habitat loss and degradation caused by pathogens.

Novel biota encompass those invasive taxa that are separately listed as key threatening processes, as well as other novel biota that are already established in Australia and species with the potential to become invasive in the future.

In April 2014, 'Aggressive exclusion of birds from potential woodland and forest habitat by overabundant noisy miners (*Manorina melanocephala*)' was listed as a key threatening process. The native noisy miner has benefited from extensive fragmentation of woodland habitat with high edge:interior ratios and is considered a pest species. Noisy miners live in large colonies and, in areas where they are abundant, aggressively defend their territory by physically attacking other birds. The abundance of other native woodland birds is demonstrably lower in areas where noisy miners are present, and the effects of the noisy miner are substantially greater than the effects of other recognised threats such as grazing or habitat removal.

Weeds

Since European colonisation, more than 41,000 plant species have been introduced to Australia, and 3175 of these have become naturalised (see the *Land* report). The vast majority (around 70 per cent) of exotic plant species that have gone on to become serious invaders have been introduced for the horticulture trade or as aquatic ornamental species (Gallagher & Leishman 2014). It is widely understood that the abundance and diversity of native plant species decline in areas where weeds have become dominant. However, there remains a lack of detailed knowledge about the broader impacts of weeds on many ecosystems. Although there is a growing understanding of the economic impact of agricultural weeds, possible social and economic impacts of environmental weeds are generally poorly understood.

Northern Australia floodplain systems, including areas of high conservation significance such as the Kakadu region, are under threat from weeds, especially exotic pasture grasses such as olive hymenachne (*Hymenachne amplexicaulis*) and para grass (*Urochloa mutica*), and woody weeds such as giant sensitive plant (*Mimosa pigra*) and rubber vine (*Cryptostegia grandiflora*) (DNP 2016). Australian riparian ecosystems suffer from weed invasions where there has been extensive habitat modification to the surrounding areas, or where there is an effective vector for spread of weeds (e.g. the introduction of pasture grasses, such as gamba grass—*Andropogon gayanus*—in northern Australia). Aquatic weeds such as cabomba (*Cabomba caroliniana*) and giant salvinia (*Salvinia molesta*) are not as large a threat, but may be problematic in local regions (e.g. Darwin region).

Woody trees and shrubs are increasingly recognised as serious invaders in Australia. A global survey in 2011 identified Australia as the biogeographic region with the highest number of woody invaders (183 species) (Richardson & Rejmánek 2011).

Novel biota key threatening process

The 2013 recognition of the key threatening process 'novel biota' under the EPBC Act specifically highlights the dangers of new genetic material[2] of invasive species already present in Australia being introduced. This could increase their potential to become even more invasive, or could change what are now relatively benign exotic species into much more serious invaders of native ecosystems. An example is the introduced perennial pasture species buffel grass (*Cenchrus ciliaris*), which occurs across much of arid and semi-arid Australia. Buffel grass continues to spread with the aid of new cultivars imported from its native range that have different tolerances to drought and temperature, and different palatability and growth forms. As with other high-biomass invasive grasses (e.g. gamba grass, and perennial mission grass—*Cenchrus polystachios* syn. *Pennisetum polystachion*), buffel grass affects biodiversity directly and indirectly through competition, and by increasing the frequency and intensity of fires. These hotter fires can affect groundcover vegetation (including bushfoods that are important to Indigenous communities) and carry into the canopy of keystone arid-zone trees such as river red gums (*Eucalyptus camaldulensis*), corkwoods (*Hakea* species) and beefwoods (*Grevillea striata*), with flow-on effects to other plants and animals. A threat abatement advice for buffel grass was completed in 2015. A threat abatement plan (2012) was developed to reduce the impacts on northern Australian biodiversity of 5 listed introduced grasses: gamba grass, olive hymenachne, para grass, perennial mission grass and annual mission grass (*Cenchrus pedicellatus* syn. *Pennisetum pedicellatum*).

2 New genetic material includes new strains or varieties of plants or animals brought into Australia, which may then increase the species' ability to survive and spread beyond their current range.

The novel biota key threatening process also includes threats from the introduction, or further cultivation, of potentially weedy species for the biofuel industry. Many good candidates for large-scale biofuel production in Australia have 'weedy' qualities (e.g. climatic hardiness, high biomass, early reproduction, resistance to pathogens), and many are already damaging invaders of natural systems elsewhere in the world.

Escaped garden plants

In 2014, the Australian Government Minister for the Environment reviewed the EPBC Act–listed key threatening process of 'loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants' (listed in January 2010), and concluded that a threat abatement plan was not a feasible, effective or efficient way to abate the process at this time. The minister accepted that the measures in place at national, and state and territory levels provide a framework for a broad range of actions for border protection, and weed management and control. These measures include national biosecurity controls undertaken by the Australian Government Department of Agriculture and Water Resources, such as the weed risk assessment system (to prevent the importation of new plants, including ornamental plants used in the nursery trade, that have a high potential to become weeds), as well as state and territory legislation, policy and programs to address established and emerging weed issues.

Pathogens

In SoE 2011, 3 pathogens of concern were highlighted: chitrid fungus disease (*Batrachochytrium dendrobatidis*—Bd), myrtle rust (*Puccinia psidii*) and *Phytophthora cinnamomi*.

Chitrid fungal disease

The amphibian pathogen Bd has been identified as a leading agent of amphibian declines globally. SoE 2011 highlighted that increased temperatures had been correlated with Bd-driven declines of frogs in Costa Rica. Work in other jurisdictions has been somewhat equivocal on interactions between Bd and temperature. In Australia, work on the interactions between temperature, Bd and other environmental factors is ongoing, and results suggest that complex environmental and ecological interactions influence the likelihood of Bd causing significant ongoing declines (Daskin et al. 2014, Roznik et al. 2015). In 2014, 7 frog species were identified as being at high extinction risk from Bd infection in Australia, and 22 species were assessed as being at moderate to lower risk of extinction. The 7 high-risk species all occur in low absolute numbers in the wild (probably less than 2000 individuals) and, except for the Tasmanian tree frog (*Litoria burrowsae*), are listed as endangered or critically endangered in state and Australian legislation. Most of the Tasmanian tree frog's range (predominantly south-west Tasmania) is currently free from Bd. However, Bd is present in Tasmania, including on the fringes of the tree frog's range, and is predicted to cause major declines in Tasmanian tree frogs, with its spread mediated by other Tasmanian frogs (Voyles et al. 2014). Importantly, of the 7 high-risk species, only 2 occur in Queensland, where most of the Bd-driven extinction and decline has been identified. Of the species at moderate to lower extinction risk from Bd, many are in south-eastern Australia. A national threat abatement plan was published in 2006 and reviewed in 2013, and a new plan was released in 2016.

Myrtle rust

The invasive myrtle rust was detected in Australia in New South Wales in 2010. The rust spread rapidly, becoming established in natural ecosystems throughout coastal New South Wales and south-east Queensland by mid-2011, and in far north Queensland by mid-2012. By 2015, it was established, with more limited distribution, in Victoria, Tasmania and the Northern Territory (Carnegie et al. 2015). There are now 232 species known as hosts because of natural infection in Australia (all but 18 are native to Australia) and another 115 hosts recorded from artificial inoculation only (Carnegie et al. 2015). Australia is floristically dominated by the family Myrtaceae, which is a core component of our vegetation and a key driver of ecological processes. As well, many industries rely on Myrtaceae species, such as the forestry, nursery, essential oils and cut flowers industries. *P. psidii* has been listed as a key threatening process to the natural environment in New South Wales. In 2014–15, the Threatened Species Scientific Committee considered a public nomination to list 'exotic rust fungi of the order Pucciniales that are pathogenic on plants of the family Myrtaceae' as a key threatening process under the EPBC Act. The committee decided that such pathogens are encompassed within the existing 'novel biota and their impact on biodiversity' key threatening process.

Southern cassowary (*Casuarius casuarius*) at Meunga Creek, far north Queensland

Photo by David Westcott

Phytophthora

A national threat abatement plan for disease in natural ecosystems caused by *P. cinnamomi* came into force on 31 January 2014. The area of native vegetation affected by *P. cinnamomi* exceeds 1 million hectares in Western Australia, many hundreds of thousands of hectares in Victoria and Tasmania, and tens of thousands of hectares in South Australia (DoE 2014b). South Australia reports that *P. cinnamomi* is becoming more widespread in that state.

Other pathogens

Another pathogen highlighted in jurisdictional reports is psittacine circoviral (beak and feather) disease, which affects native parrots, including some threatened species (NSW EPA 2012). This disease is listed as a key threatening process under the *Threatened Species Conservation Act 1995* (NSW) and was listed under the EPBC Act as a key threatening process in 2001. A national threat abatement plan was published in 2005 and automatically repealed on 1 October 2015. Nonstatutory threat abatement advice is currently being developed.

A pathogen affecting one of Australia's iconic species, the Tasmanian devil, is highlighted in Box BIO4.

Box BIO4 The fight against Tasmanian devil facial tumour disease

Tasmanian devils (*Sarcophilus harrisii*) are iconic marsupial carnivores that are endemic to Tasmania. Devil facial tumour disease (DFTD) is a relatively new disease that is having a devastating effect on Tasmanian devils. DFTD is a very rare transmissible cancer, and can be passed between individuals through biting and close contact. The cancer is characterised by facial tumours around the head and neck, and animals usually die within a few months of showing symptoms. The Tasmanian devil is listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999*. Since the mid-1990s when the first signs of DFTD were observed, the disease has spread through most of Tasmania and triggered a population decline of about 85 per cent (Hogg et al. 2015, Pye et al. 2016). In 2014 and 2015, a second transmissible cancer was detected in devil populations in southern Tasmania, adding further to concerns about the species' prospects.

In 2005, the Save the Tasmanian Devil Program began to establish an 'insurance population' of captive-bred individuals to ensure the survival of the species and to re-establish healthy wild populations in Tasmania. Successful captive breeding has increased the captive-bred population to 600 individuals (Hogg et al. 2015). A range of other activities and management, including establishment of free-range enclosures and translocations, are also being implemented to isolate and protect populations of healthy devils.

Pest animals

The most frequently cited invasive vertebrates in state and territory reports are cats, foxes, wild dogs, camels, deer, goats, rabbits, pigs and cane toads. Threat abatement plans under the EPBC Act are in place for feral cats, the European red fox, unmanaged goats, feral rabbits, feral pigs, cane toads, and exotic rodents on offshore islands. A *National feral camel action plan* (DSEWPaC 2010) and a *National wild dog action plan* (WoolProducers Australia 2014) are in place for these established pests of national significance in accordance with the Australian Pest Animal Strategy.

Many states note that there are insufficient data to assess the abundance and trends of most invasive animals. However, many invasive animals do appear to be increasing in their distribution and abundance—for example, South Australia reports increases in the distribution of cats, rabbits and foxes, although camels are decreasing because of significant control efforts. The Northern Territory also reports significant declines in camels as a result of the Australian Feral Camel Management Project between 2009 and 2014. In New South Wales, foxes, cats, goats, rabbits and pigs occur so extensively throughout the state that there is limited potential for further expansion. These species are listed as key threatening processes under the New South Wales *Threatened Species Conservation Act 1995*.

The pressure that has contributed the most to mammal extinction in Australia and is contributing to the decline of the highest number of threatened mammals is predation by feral cats and red foxes (Woinarski et al. 2014; Table BIO2). It is also a threat affecting most of the species of near threatened mammals identified in *The action plan for Australian mammals 2012*. The feral cat occurs throughout Australia and on many of its territorial islands; it inhabits deserts, savanna grasslands, urban and agricultural lands, and temperate and tropical woodlands. Cats are listed as a key threatening process under the EPBC Act. A recent continental-scale analysis of the diet of feral cats recorded 400 vertebrate species that feral cats feed on or kill in Australia (Doherty et al. 2015). These include 123 birds, 15 reptiles, 58 marsupials, 27 rodents, 5 bats, 21 frogs and 9 medium-sized and large exotic mammals. Cats also consume a wide range of insects, spiders, scorpions, centipedes and crustaceans. Cats were recorded to consume or kill 28 species on the Red List of the International Union for Conservation of Nature (IUCN); 17 of the consumed species identified are also listed under the EPBC Act. Reducing the impact from cats is considered an essential action for the conservation of Australian birds and mammals (Woinarski et al. 2011, 2014; Garnett et al. 2011).

Poisoning by the invasive cane toad (*Rhinella marina*) is a major threat to 4 species of threatened mammal. The cane toad has had a significant impact on populations of the northern quoll (*Dasyurus hallucatus*) in northern Australia (Woinarski et al. 2014). Scientists have also recorded marked declines during the past 5 years in many iconic, and culturally and ecologically significant reptile species across northern Australia because of poisoning by cane toads (Shine & Wiens 2010, Fukada et al. 2016). For example, 35 years of surveys of the Australian freshwater crocodile in the Daly River in the Northern Territory reveals that the density of crocodiles decreased by nearly 70 per cent between 1997 and 2013 following invasion by the cane toad between 1999 and 2003 (Fukada et al. 2016).

The introduced black rat has contributed to the extinction of several mammal species through predation, competition or disease transmission: the Lord Howe long-eared bat (*Nyctophilus howensis*); 2 Christmas Island rats (Maclear's rat—*Rattus macleari*, and the bulldog rat—*Rattus nativitatis*); and some island subpopulations (e.g. spectacled hare wallaby—*Lagorchestes conspicillatus*, and golden bandicoot—*Isoodon auratus* in the Montebello Islands). It is considered a major threat for a number of other threatened species identified in *The action plan for Australian mammals 2012*. Predation by the black rat has also contributed to the historical extinction of several island bird species, including the robust white-eye (*Zosterops strenuus*) on Lord Howe Island. It continues to be a pressure on island populations of birds, including the scarlet robin (*Petroica boodang*) on Norfolk Island and island thrush (*Turdus poliocephalus erythropleurus*) on Christmas Island.

The control of dingoes (*Canis lupus dingo*) and their impact on biodiversity continue to create debate in both the scientific literature and the mainstream public discourse. Dingoes are cast as having positive and negative effects on biodiversity in Australian ecosystems. It is generally recognised that dingoes play an important role as an apex predator, and may have some role in changing pest–predator impacts in the ecosystem by preying on other predators or by competing with them for resources. One review of 31,000 dingo diet records in the literature found that less than 1 per cent contained any evidence of cat consumption; however, it is important to note that this is not a measure of the overall effects of competition for resources, or other indirect impacts, such as changes in the behaviour of pests and predators to avoid being active when dingoes are active (Glen 2014).

Dingoes are also important in the spiritual and cultural practices of some Indigenous peoples. Furthermore, they are gaining importance as an element of wildlife that attracts tourists, with potential flow-on economic benefits.

Invasive species affecting inland aquatic environments

The *Inland water* report describes the observed extent of some invasive species affecting aquatic environments, including the freshwater fish common carp (*Cyprinus carpio*) and eastern gambusia (*Gambusia holbrooki*), and 2 new (2012) aquatic Weeds of National Significance—sagittaria/arrowhead (*Sagittaria platyphylla*) and water hyacinth (*Eichhornia crassipes*).

In Australia, the introduction, stocking and translocation of fishes may threaten biodiversity. Since the mid-1800s, introductions of species for recreation and food, escapes from captivity of ornamental species, and releases of fish for pest control have all increased the number of exotic species established in the wild. Currently, around 43 freshwater fish species have established wild populations, 34 of which continue to spread (Harris 2013). However, uncertainty surrounds this number—survey data are scarce, and not all aquatic ecosystems have been surveyed.

In the Murray–Darling Basin, the condition of fish communities, including the proportions of non-native species in terms of abundance and biomass, was a foundation for river health assessments in the Sustainable Rivers Audit (Davies et al. 2010). Sampling yielded 38 species, 10 of which were introduced, and constituted 43 per cent of individual abundance and 68 per cent of total biomass. Non-native species rivalled or outnumbered natives in 9 of the 23 Basin valleys, with common carp, eastern gambusia and goldfish (*Carassius auratus*) present throughout. Carp were overwhelmingly dominant, representing 87 per cent of non-native fish biomass and 58 per cent of total fish biomass. Non-native fish species also outnumber native species in some other, mostly densely populated, catchments (e.g. in the south-west of Western Australia).

Some frog species, such as the bell frogs and grass frogs (*Litoria aurea*, *L. castanea* and *L. raniformis*), are potentially threatened by eastern gambusia. Eastern gambusia is also the primary threat to the endangered (critically endangered in the IUCN Red List) red-finned blue-eye (*Scaturiginichthys vermeilipinnis*) and probably a significant threat to the Edgbaston goby (*Chlamydogobius squamigenus*—endangered in Queensland, vulnerable in Australia). These 2 fish species are also threatened by feral pigs damaging the small, shallow, spring-fed waterholes in which they live, and by invasive para grass.

Marine invasive species

The *Marine environment* report includes a description of invasive species affecting marine environments. The report highlights that the number of introduced pests is increasing in marine environments, but that their impacts and trend are highly uncertain. Widespread marine invasive species include the New Zealand screw shell (*Maoricolpus roseus*) and the northern Pacific starfish (*Asterias amurensis*). Despite concentrated efforts to develop monitoring systems, ongoing monitoring of marine pests is limited, so any failure of Australia's national and local prevention arrangements is likely to be detected first as a new established invasion.

Altered fire regimes

The *Land* report describes how fire frequencies have increased in Australia during the past decade. Alteration in fire regimes is considered a major threat that has contributed to the extinction of 6 mammal species, and is a significant pressure on 35 threatened and 22 near threatened mammal species identified in *The action plan for Australian mammals 2012* (Woinarski et al. 2014). Changed fire regimes are increasing in importance as a threat for mammals through much of Australia. In particular, fire regimes in northern Australia have changed significantly since European arrival; they are now dominated by very large fires occurring at shorter fire return intervals. These changed regimes (frequency and extent) have been implicated in the decline of small mammals in northern Australia during recent decades (Griffiths et al. 2015, Lawes et al. 2015). Recurrent wildfire also threatens forest-dwelling mammals in much of southern and eastern Australia (Lindenmayer 2015).

Alteration in fire regimes is also considered a significant pressure on many threatened bird species, especially in northern Australia. The increase in the intensity, area and timing of fire (late dry-season versus early dry-season fires) has affected birds in northern Australia and is an ongoing issue (Garnett et al. 2011). A recent review concluded that the current fire regime in northern Australia is suboptimal for many bird species, especially grain-eating and fruit-eating birds, and hollow-dependent and ground-nesting species. The review recommended that, in northern Australia, at least 25 per cent of the savanna landscape should be unburned for at least 3 years and at least 5 per cent should be unburned for at least 10 years (Woinarski & Legge 2013).

Changed fire regimes may be increasing in importance as a threat for birds in southern Australia. An example is the endangered eastern bristlebird (*Dasyornis brachypterus*) of eastern Australia, for which extensive wildfire is considered the main threat. Research in semi-arid shrubland of the Murray Mallee region of Victoria showed that 16 of 30 bird species for which there were enough data to model responses showed significant variation in probability of occurrence with time since fire. Of these 16 species, all but 1 occurred more frequently in vegetation where there had been more than 20 years since the last fire. The study concluded that birds displayed a limited response to time since fire; therefore, greater time between fires should allow the provision of suitable vegetation for most species (Watson et al. 2014).

Increased fire frequency can affect the viability of some plant species by damaging or destroying individuals before they reproduce. The 'minimum tolerable fire interval' is the minimum period between fires required to allow species within the area to reach reproductive maturity. This is set by the key fire-response species, which take the longest time to reach maturity. These species are adversely affected when fires are too frequent. In Victoria in 2012, 40 per cent of native vegetation was estimated to be below minimum tolerable fire intervals, with 3 per cent above the maximum interval. Only 18 per cent of native vegetation assessed was found to be within the required interval to maintain vegetation communities. The tolerable fire interval could not be calculated for 39 per cent of native vegetation because of a lack of fire history.

Changed hydrology

Surface-water and groundwater conditions have varied considerably since 2011, largely in response to climate. Changes to flows and water levels are described in detail in the *Inland water* report. The *Inland water* report describes how short-term and long-term changes to flows and water levels affect ecological systems in a range of ways. Increased low-flow and zero-flow days during droughts decrease environmentally important hydrological connectivity and increase pressure on refuge areas such as pools. Long periods of regulated flows and contraseasonal flows (e.g. high flows in dry periods to meet irrigation needs) disrupt the timing and nature of ecological events, such as plant growth, and fish or bird breeding. Other significant impacts on native fish arising from altered flows include barriers to migration and altered water quality (e.g. temperature, turbidity, dissolved oxygen).

River regulation and water resource development have a negative impact on some waterbird populations. This pressure is particularly prevalent in the Murray–Darling Basin of south-eastern Australia. The impact of this pressure varies across functional groups, but has recently been shown to be a significant issue for colonial nesting waterbirds (egrets, herons, ibis and spoonbills) in the Basin (Reid et al. 2013).

Overallocation of water resources is not confined to the south-east. Issues have been identified in northern Australia associated with the Tindall Limestone Aquifer underlying the Katherine–Daly Basin, and with the aquifer that sustains Howard Springs and other peri-urban water bodies in the broader Darwin area. Rivers across the south-west of Western Australia are under considerable pressure from climate change, as well as pressures associated with a growing population, including increased demand for water. Rainfall is now around 16 per cent below the long-term average in this part of Western Australia, and reduction of run-off into rivers and streams of up to 50 per cent has been recorded. The reduced run-off has resulted in a general decline in flows, causing reductions in the duration of continuous flow and increases in the period of disconnection (many systems are naturally seasonal). Drying of river pools has also been recorded in some areas.

Changed hydrology can also have beneficial effects in areas that have previously been significantly altered for agriculture. For instance, much of the bird diversity in agricultural landscapes is dependent on dams and waterways remaining hydrated. Creating and protecting habitat around waterways also creates habitat for a range of mammals and frogs. The Australian Association of Bush Regenerators (AABR) is a private organisation promoting the effective management of natural areas based on sound ecological principles. AABR reported (Barrett & Davidson 1999, Barrett 2000):

- a 3 per cent increase in diversity of woodland-dependent birds for each additional farm dam present where adequate tree and shrub cover provided habitat
- a 14 per cent increase in waterbird diversity if dense, shrubby vegetation; shallow areas; islands or dead trees for roosting; or stock-excluding fences were added.

Pressures facing aquatic ecosystems

In this report, we describe pressures facing biodiversity in general. However, pressures facing aquatic ecosystems are described in detail in the *Coasts* (coastal and estuarine ecosystems), *Inland water* (freshwater ecosystems) and *Marine environment* reports. A summary of the pressures outlined in those reports is given below.

Coastal ecosystems

The *Coasts* report describes how pressures on the coastal zone are strongly related to catchment land use and development. Pressures on coasts outside urban areas include those associated with resource extraction and agriculture. The pressures described in the *Coasts* report include the following (pressures with high impacts and worsening trends are noted in brackets):

- tourism and recreation
- oil, gas and mining
- climate and weather (high, worsening)

- sea level change
- erosion and inundation (high, worsening)
- sediment transport (high, worsening)
- desalination
- coastal river and estuary pollution (high, worsening)
- nutrient pollution (high, worsening)
- toxins, pesticides and herbicides (high, worsening)
- water turbidity, transparency and colour (high, worsening)
- marine debris (high, worsening)
- flow regimes
- water abstraction (high, worsening)
- seawater intrusion (high, worsening)
- dredging (high, worsening)
- fishing (high, worsening)
- artificial reefs (high, worsening)
- aquaculture
- vessel activity and infrastructure (high, worsening)
- invasive species (high, worsening)
- disease, infestation and fish kills (high, worsening)
- algal blooms
- jellyfish blooms
- low-oxygen dead zones.

Freshwater ecosystems

The *Inland water* report describes the pressures on freshwater ecosystems that arise from:

- climate variability and change
- water resource development
- land use and management
- pests and invasive species.

All 4 of the above pressures are assessed as high impact. Pressures resulting from climate variability and climate change, and pests and invasive species had a worsening trend; the trend for water resource development, and land use and management was stable.

Marine ecosystems

Pressures described in detail in the *Marine environment* report include:

- climate system variability and climate change
- commercial and recreational fishing
- traditional use of marine resources
- marine oil and gas exploration, and marine mining and industry
- marine renewable energy
- shipping
- noise
- marine debris
- toxins, pesticides and herbicides
- dumped waste.

Among these pressures, ocean acidification associated with climate change received the highest impact grade (very high). Several other climate-related pressures received a 'high' impact grade, as did recreational fishing and marine debris.

Interactions among pressures

Few of the pressures documented in this section occur in isolation. Rather, pressures interact in complex ways, often compounding the threat to biodiversity. For example, land clearing removes natural habitat and typically replaces it with agricultural, urban or industrial development, which may bring additional pressures such as grazing or pollution. In addition, remnant vegetation after land clearing is often fragmented and isolated. Fragmented woodland landscapes have been shown to have more vertebrate pests than intact woodlands (Graham et al. 2012).

Interactions between multiple pressures amplify the threat faced by native mammals across Australian ecosystems. For example, during the past 5 years, evidence has emerged that the greatest impact on mammals in northern Australia comes from a combination of predation by feral cats in recently burned environments. These impacts are synergistic. Specifically, in the absence of cats, native mammals are able to survive fire and continue to find food. In addition, cats forage less effectively in unburned environments (Ziembicki et al. 2014).

Recent experimental evidence supports an association between grazing by introduced herbivores (cattle, horses, donkeys and buffalo) and the magnitude of small mammal decline. Both fire and grazing regimes in northern Australia have intensified substantially over recent decades in ways that could contribute to the contemporary decline in native mammals. These changes to fire and grazing regimes have generally made grass communities less complex and more open. They also create conditions that favour feral cats, probably because their hunting success is improved (McGregor et al. 2014).

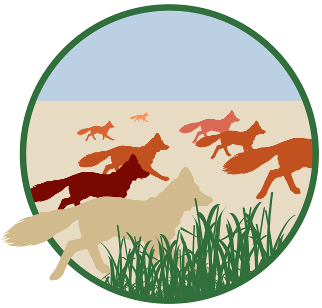
Other interactions among pressures include those between invasive plants, particularly high-biomass pasture grasses, and fire. High-biomass grasses fuel intense fires that kill trees, which in turn facilitates the further invasion of grasses, creating a positive feedback loop.

The growing Indigenous estate faces challenges in dealing with the interaction among pressures because of its large size, diversity of management and overall low capacity. One example of proactive distribution of relevant Indigenous ecological knowledge that can be incorporated into management is through the production of seasonal calendars, which highlight the high level of Indigenous understanding of biodiversity interaction linked to human activity.

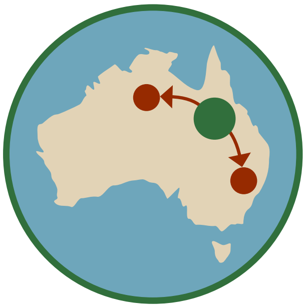
Interactions of multiple pressures with climate extremes is an area of intense debate. In the past 5 years, Australia has seen record-breaking summer temperatures in some places, particularly in 2012–13. Monitoring of the occurrence and severity of daily fire weather increased, with statistically significant increases at 16 of 38 climate reference sites in Australia from 1973 to 2010, and nonstatistically significant increases at the other sites. As well, extreme fire-weather days became more extreme at 24 of the 38 locations since the 1970s (BoM & CSIRO 2014). The most significant increases occurred in the south-east, and the largest increases occurred inland. Quantifying the cumulative impact of climate extremes interacting with the multiple other pressures affecting biodiversity (invasive species, habitat fragmentation and clearing) is extremely difficult, but this cumulative impact is widely considered to be a key threat across terrestrial, aquatic and marine habitats. The *Overview* report notes that climate pressure has only recently started to become a significant detectable impact.

The impact of invasive species is immense

Invasives are everywhere and expanding.



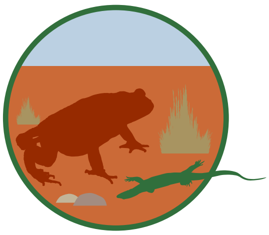
Increasing in numbers



Expanding distribution

Often overlapping and creating multiple stressors

Invasives are a universal pressure on threatened species and ecosystems. They impact directly by:



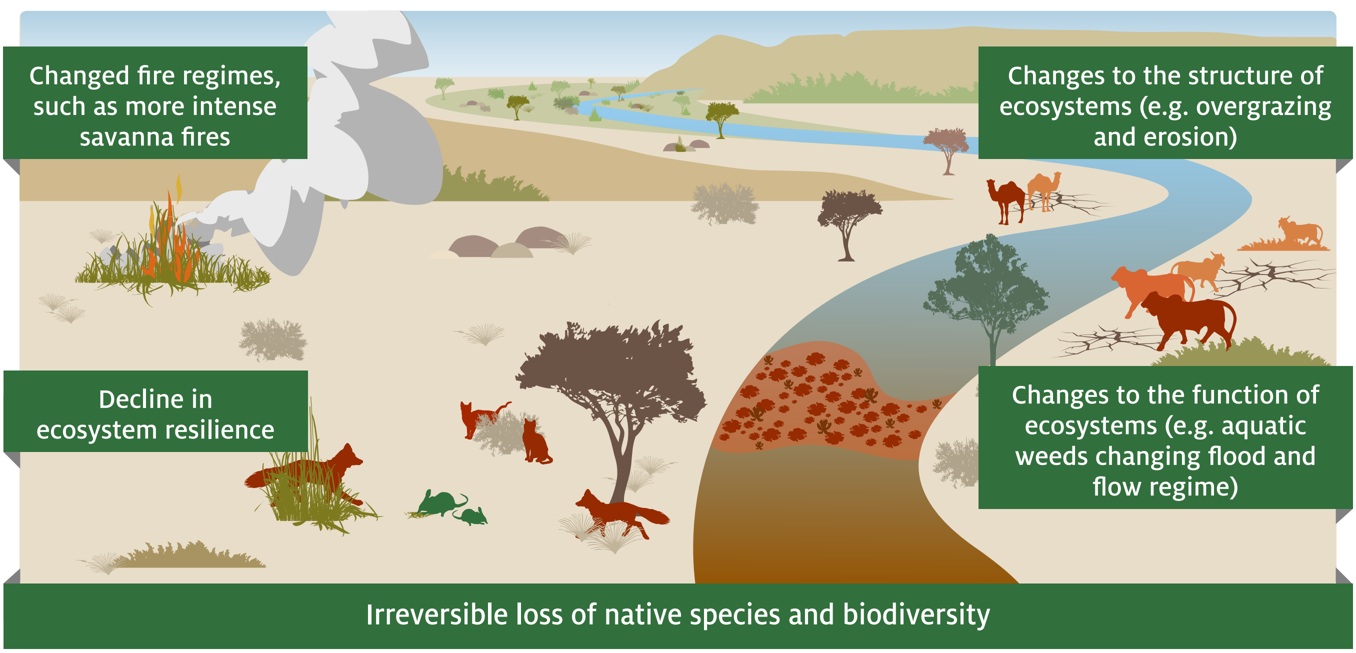
Causing mortality

Preying on native species

Competing for resources and space

Causing habitat degradation/loss

They are causing a massive impact on natural ecosystems:



Assessment summary 1
Pressures affecting biodiversity

Component	Summary	Assessment grade (Very high impact / High impact / Low impact / Very low impact)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Global climate change—terrestrial systems	Jurisdictional reports note extreme weather—including fire, drought, cyclones and flood—as having increasingly pervasive impacts on biodiversity				
Global climate change—aquatic system	Among threatened taxa, amphibians are particularly vulnerable to climate change				X
Pollution—point-source pollution (e.g. from factories)	Point-source pollution is mostly mitigated by regulations, and no new evidence is available to suggest that it is a high or increasing pressure				
Pollution—diffuse and broadscale pollution	Pollution pressure from diffuse sources remains high, and impacts on terrestrial and aquatic systems persist. Marine debris and micropollutants are of increasing concern				
Consumption/ extraction of biodiversity and/or other natural resources—terrestrial systems	Harvesting impacts a significant portion of threatened terrestrial plant species. Harvesting of terrestrial mammals is regulated, and impacts are generally limited to a few terrestrial species				X
Consumption/ extraction of biodiversity and/or other natural resources—aquatic systems	Impacts of hunting and harvesting have been documented for a few marine fish and mammal species, and for wetland birds				X

Assessment summary 1 (continued)

Component	Summary	Assessment grade (Very high impact / High impact / Low impact / Very low impact)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Clearing and fragmentation of native ecosystems—terrestrial vegetation, Queensland	Clearing rates have increased in Queensland since 2011, including significant increases in remnant vegetation clearing				X
Clearing and fragmentation of native ecosystems—terrestrial vegetation, other states and territories	Clearing rates have stabilised; however, all jurisdictions note clearing and fragmentation as key ongoing threats. Half of all EPBC Act–listed species are considered to be at risk from habitat fragmentation				
Pressures from livestock production	Grazing in the extensive land-use zone of Australia is considered a major threat to biodiversity. Along with other management changes, it is considered a key pressure on northern Australian mammal populations				
Invasive species and pathogens—terrestrial systems	Pest plants, animals and pathogens have been identified by every jurisdiction as a key threat to biodiversity generally, and to threatened species specifically				
Invasive species and pathogens—aquatic systems	Invasive aquatic species are having major impacts on aquatic biodiversity; in particular, invasive fish influence, and are indicators of, aquatic system health				X
Altered fire regimes	Altered fire regimes are considered a major threat to mammal and bird species, and a significant pressure on EPBC Act–listed species				

Assessment summary 1 (continued)

Component	Summary	Assessment grade (Very high impact / High impact / Low impact / Very low impact)	Confidence (In grade / In trend)	Comparability (To 2011 assessment)
Changed hydrology	River regulation and water resource development have a negative impact on some waterbird populations. This pressure is particularly prevalent in the Murray–Darling Basin in south-eastern Australia			

EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*

Recent trends

Improving

Deteriorating

Stable

Unclear

Grades

Very low impact: Few, if any, species and/or ecosystems are suffering substantial adverse effects from this pressure

Low impact: A small proportion of species and/or ecosystems are suffering substantial adverse effects from this pressure

High impact: A significant proportion of species and/or ecosystems are suffering substantial adverse effects from this pressure

Very high impact: A large proportion of species and/or ecosystems are suffering substantial adverse effects from this pressure

Confidence

Adequate: Adequate high-quality evidence **and** high level of consensus

Somewhat adequate: Adequate high-quality evidence **or** high level of consensus

Limited: Limited evidence **or** limited consensus

Very limited: Limited evidence **and** limited consensus

Low: Evidence and consensus too low to make an assessment

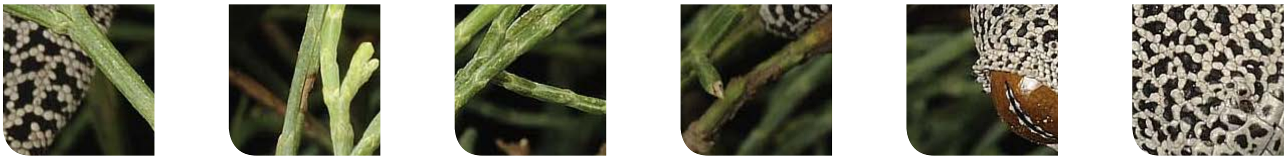
Comparability

Comparable: Grade and trend are comparable to the previous assessment

Somewhat comparable: Grade and trend are somewhat comparable to the previous assessment

Not comparable: Grade and trend are not comparable to the previous assessment

X **Not previously assessed**



State and trends
of biodiversity

At a glance

Understanding of the state and trends of the vast majority of individual species in Australia is limited. The lack of effective monitoring data for understanding state and trends, even for threatened species, is highlighted by every jurisdiction and all previous state of the environment reports. Information about the extent of vegetation communities is good; however, most jurisdictions note that knowledge about vegetation condition is limited. Significant reports on the state of mammals (*The action plan for Australian mammals*) and birds (*State of Australian birds*) have improved understanding of these animal groups since 2011.

At the end of 2015, 74 ecological communities were listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act); 31 are critically endangered. There have been 30 new listings since 2011. Threatened ecological communities are concentrated in south-eastern Australia. The overall number of threatened species listed under the EPBC Act has increased by 44, to 1808 species.

Based on the information available about vegetation extent and condition, and the small number of species for which there is some understanding of trends in distribution and abundance, the status of biodiversity in Australia is generally considered poor and worsening.

Mammal declines in northern Australia have continued. In southern and eastern Australia, the number of species of conservation concern has increased. Bird groups show variable trends, but some groups, such as woodland-dependent species in the mallee and carnivore species in the arid zone, are in significant decline. Trend analyses for abundance of eastern Australian inland waterbirds and for some migratory shorebirds indicate that populations are currently well below long-term averages.

Very limited information is available to assess the state and trends of reptiles, amphibians and invertebrates, except for a few high-profile species.

The jurisdictions generally report the condition of aquatic ecosystems and species as poor to moderate, although the availability of information is also often described as poor or limited.

Availability of information

Understanding of the state and trend of biodiversity in Australia is limited. Few long-term national-scale monitoring programs are available; there are some disparate datasets on a smattering of species and ecosystems at regional to local levels. Although long-term monitoring has been recognised as a fundamental gap in designing effective management by the scientific community, Australia does not have an agreed plan for how to address this gap. This lack of information is also widely acknowledged by policy-makers and resource managers as a major impediment to biodiversity conservation. The lack of effective monitoring and reporting has been raised consistently in every SoE report since 1996, in every jurisdictional report, in the original *National strategy for the conservation of Australia's biological diversity* (1996) and in the updated Biodiversity Conservation Strategy 2010–2030 (NRMMC 2010) as a major impediment to understanding the state and trends of Australian biodiversity. In 2016, the situation remains the same.

Although a key objective of Australia's Biodiversity Conservation Strategy 2010–2030 is to 'by 2015, establish a national long-term biodiversity monitoring and reporting system', this has not been completed. The Australian Government has made some progress in the past 5 years in seeking to establish formal monitoring programs as a fundamental component of several of its large-scale, long-term environmental initiatives, but these are a collection of discrete activities and, when compiled, fall well short of a comprehensive national system.

The Terrestrial Ecosystem Research Network, funded through the Australian Government Department of Innovation, Science and Research, commenced funding in 2011 to maintain existing long-term plot networks and environmental gradient transects in several parts of Australia. This resulted in about 500 plots of varying sizes across a wide (but not comprehensive) range of ecosystem types.

Specific monitoring programs do exist for some individual threatened species, and for area-based management of mammal species and broadscale predator control programs (e.g. Western Shield in Western Australia and Gippsland Ark in south-east Australia). Western Shield is one of the biggest wildlife conservation programs ever undertaken in Australia and re-establishes native animals in selected areas of Western Australia to levels comparable to pre-European settlement. These types of programs are characterised by excellent monitoring (e.g. Wayne et al. 2015).

Monitoring programs run by nongovernment organisations are increasing as independent land conservation bodies continue to acquire and protect land for biodiversity conservation. Major programs run by the Australian Wildlife Conservancy, Bush Heritage Australia, The Nature Conservancy, the Tasmanian Land Conservancy, and Trust for Nature contribute new information about the state and trend of threatened species, in particular.

The National Environmental Research Program (NERP) Marine Biodiversity Hub developed an outline for monitoring marine biodiversity based on identifying the informative links between values and pressures (see the *Marine environment* report, Box MAR11). Such an approach could improve monitoring and assessment of the environment, including beginning to deal with the cumulative impact from multiple sectors. At a regional level, the Great Barrier Reef Marine Park Authority has compiled the *Science strategy and information needs for the Great Barrier Reef Marine Park* to identify priority information needs. The aim is to ensure that monitoring activities are relevant and targeted to address management issues, and that the outcomes for the Great Barrier Reef Marine Park are easily identifiable and accessible (GBRMPA 2014).

The NERP Northern Hub developed monitoring and reporting tools in collaboration with Indigenous land and sea managers to monitor seagrass feeding grounds, turtles, dugongs and freshwater wetlands. The NERP Tropical Ecosystems Hub also developed baseline monitoring data on 2 key threatened species: the southern cassowary (*Casuarius casuarius*) in the Wet Tropics region part of its range and the spectacled flying fox (*Pteropus conspicillatus*). Further to this, the Australian, and state and territory governments are working together to implement a multiyear monitoring program known as the National Flying-fox Monitoring Programme, which is primarily focused on monitoring national grey-headed (*Pteropus poliocephalus*) and spectacled flying fox populations.

Genetic and species diversity

Despite recognition that the pressures described in Pressures affecting biodiversity have a key role in shaping biodiversity at the species and community levels, the role of these pressures in shaping patterns and distribution of genetic diversity is poorly understood. This is a major knowledge gap, because genetic diversity has important consequences for all levels of biodiversity, by influencing the (Banks et al. 2013):

- fitness of individuals
- viability of populations
- adaptability of species to environmental change
- evolution of new species
- structure of communities
- function of ecosystems.

New genomic techniques are providing opportunities to fill this knowledge gap (see New technologies, solutions and innovations), but data and synthesis from them remain limited.

In SoE 2011, the distributions of weighted endemism (i.e. the extent to which species are found nowhere else) and species richness were shown for plants, mammals, birds, reptiles and amphibians. The different taxa show variation in the distribution of endemism in Australia, but some areas have high endemism for many species.

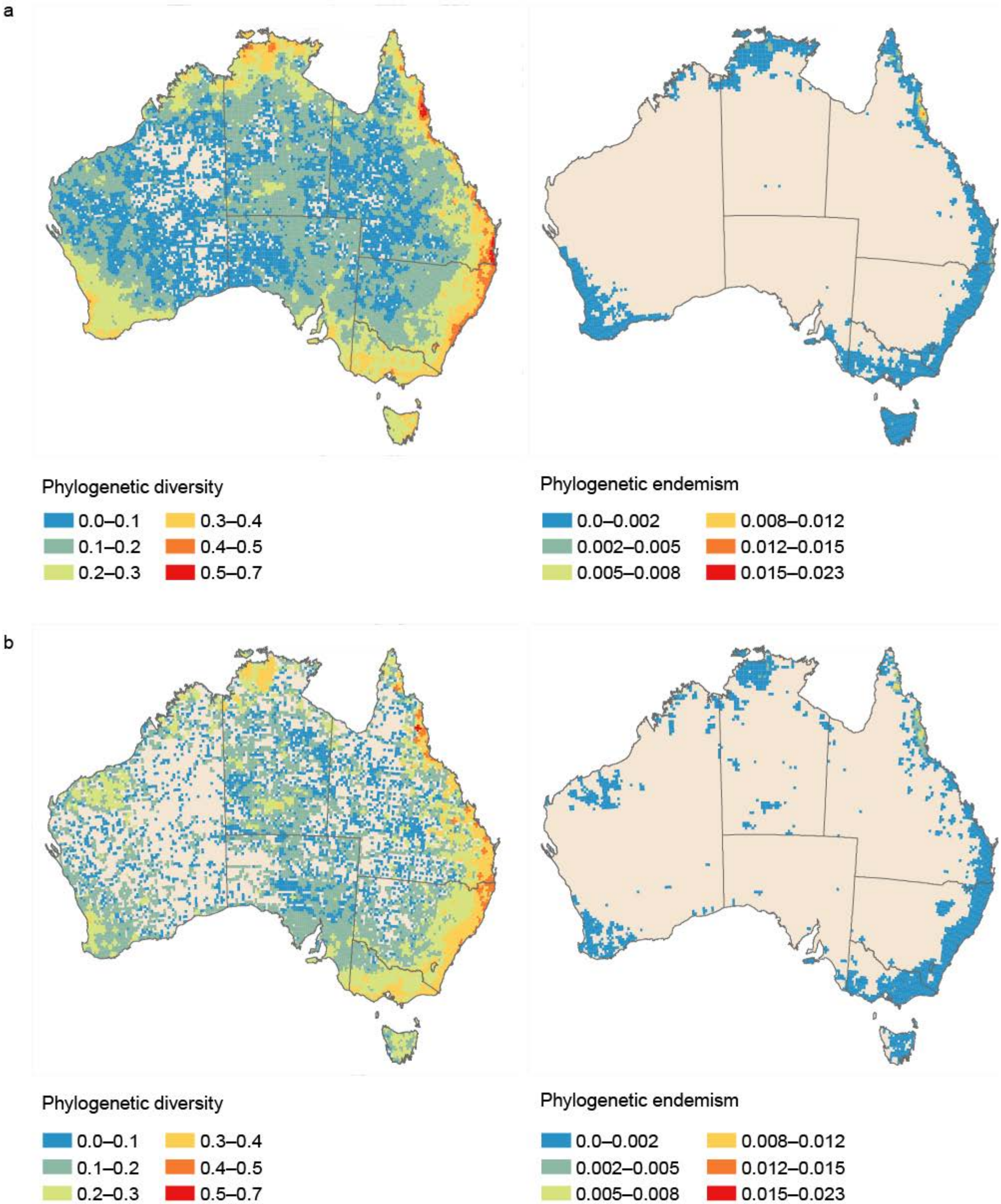
Hibiscus harlequin bug (*Tectocoris diophthalmus*) nymph feeding on a beach almond (*Terminalia catappa*) fruit, Hope Island near Cooktown, far north Queensland

Photo by David Westcott

The south-west of Western Australia, the Wet Tropics and the New South Wales – Queensland border ranges are areas of high endemism and recognised as such in their listings as global biodiversity hotspots (see Global importance).

Since 2011, significant progress has been made in measuring aspects of biodiversity that reflect the evolutionary history of taxa in Australia. Phylogenetic diversity is a measure of the representation of evolutionary history and extends to a family of 'phylodiversity' measures (Laity et al. 2015). Different species differ greatly in the amounts of evolutionary history they represent, and this has important implications for conservation. For example, the extinction of a species that does not have any close living relatives, such as the Wollemi pine—the sole living descendent of a 150 million-year-old lineage—would result in a greater loss of phylogenetic diversity than the extinction of a young species with many close relatives. In addition, maintenance of phylogenetic diversity is crucial for maximising the capacity of species to adapt to environmental change. Phylogenetic endemism is a measure of the geographic rarity of phylogenetic lineages.

Figure BIO7 shows the distributions of phylogenetic diversity and phylogenetic endemism for plants, mammals, passerine birds, snakes and lizards, and myobatrachid and hylid frogs across Australia. The distributions vary across taxa, but some patterns are evident. The east coast of Australia has higher levels of phylogenetic diversity for all taxa, particularly in the Wet Tropics. The south-west of Australia is important for plants and birds, whereas the region around Darwin is also important for most taxa. Phylogenetic endemism is concentrated in the Wet Tropics for all taxa; for frogs, the higher elevation areas along the east coast are centres of high phylogenetic endemism. The areas highlighted by the phylogenetic endemism measure are important because they represent the current restricted ranges of long-diverged lineages whose ability to persist and evolve in the future depends on what occurs within their current habitats (Rosauer et al. 2009).



Source: Australian Natural Heritage Assessment Tool, 2016, Australian Government Department of the Environment and Energy

Figure BIO7 Phylogenetic diversity and phylogenetic endemism for (a) vascular plants and (b) mammals

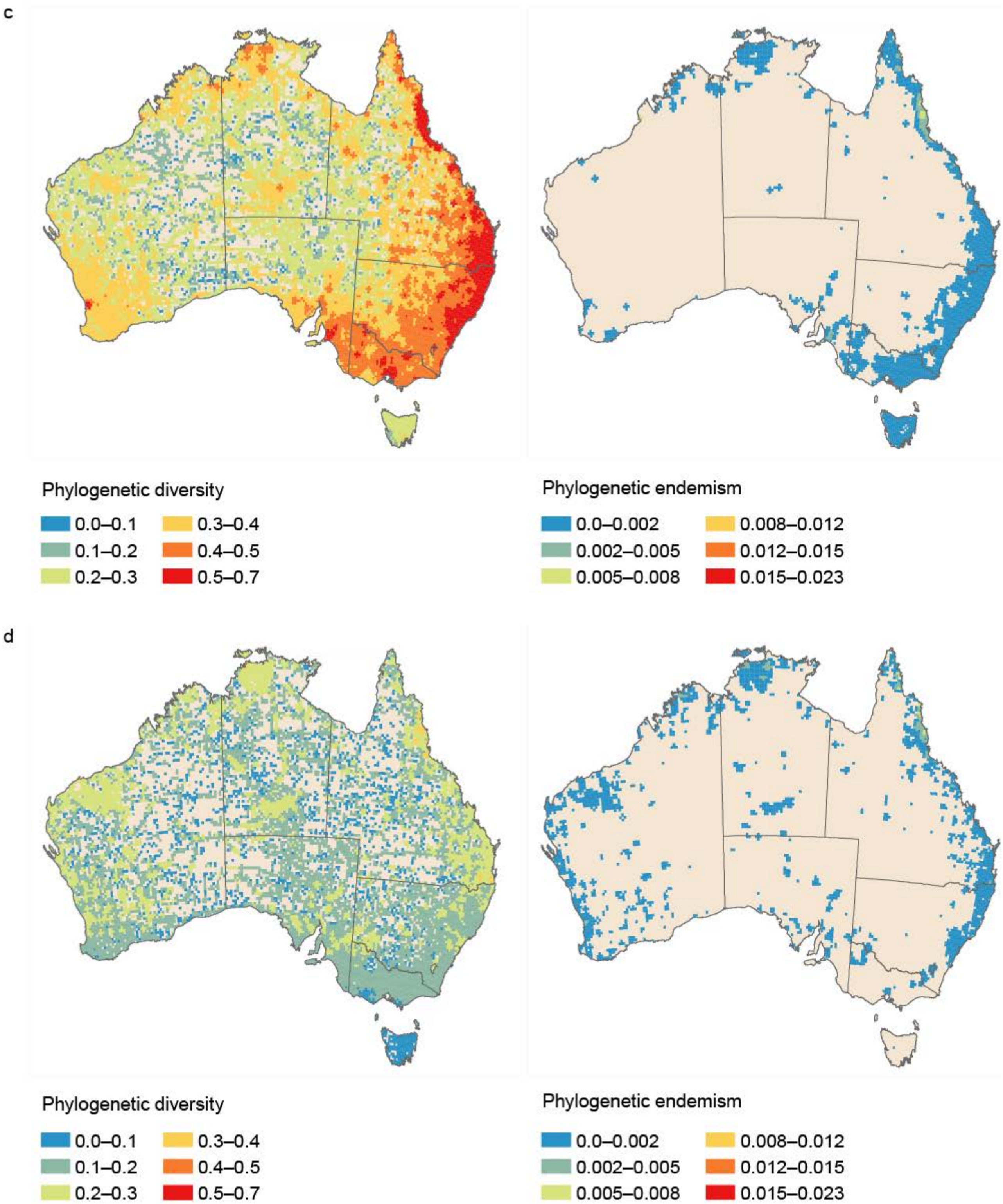


Figure BIO7 (continued) Phylogenetic diversity and phylogenetic endemism for (c) passerine birds and (d) snakes and lizards

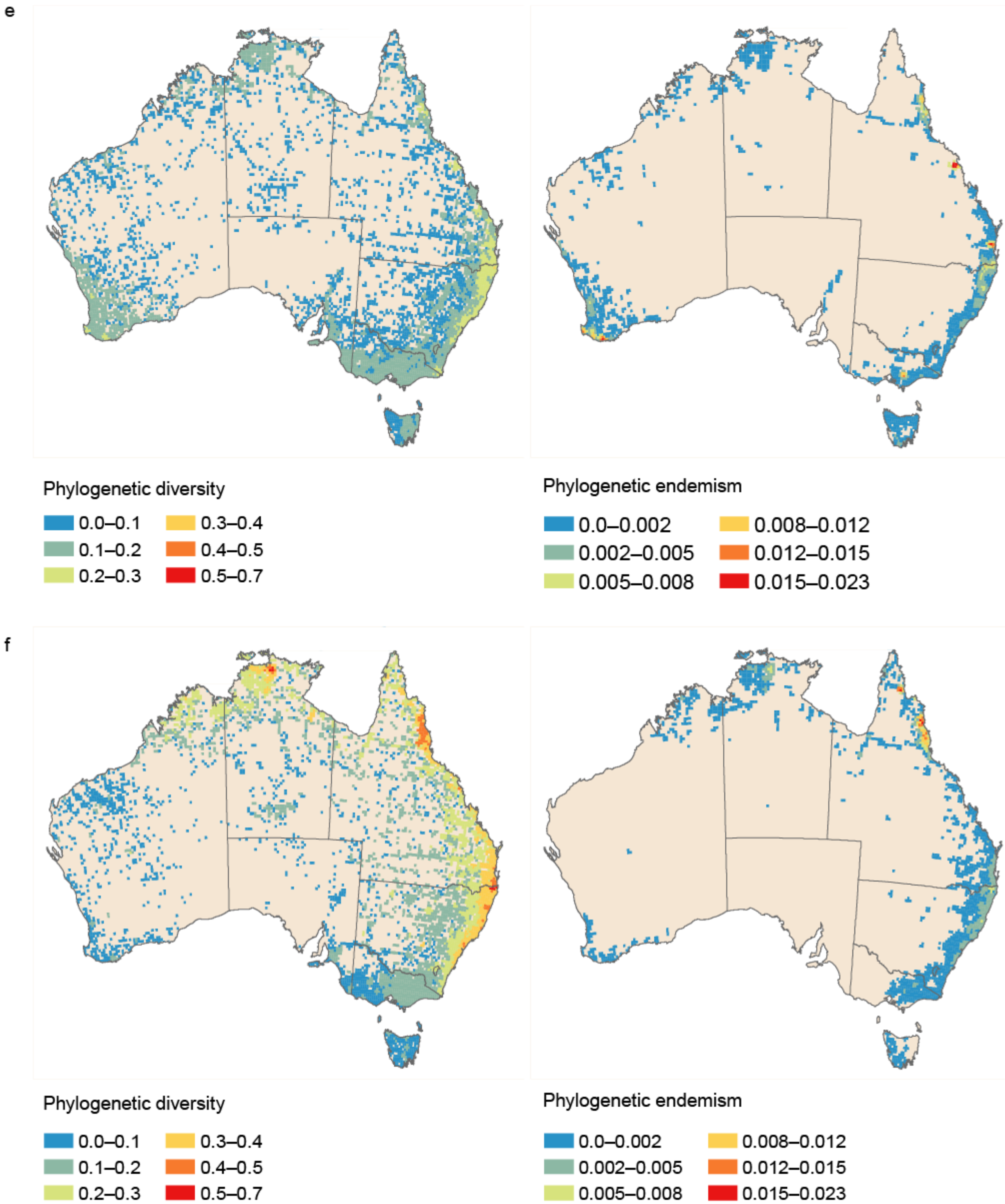


Figure BIO7 (continued) Phylogenetic diversity and phylogenetic endemism for (e) myobatrachid frogs and (f) hylid frogs

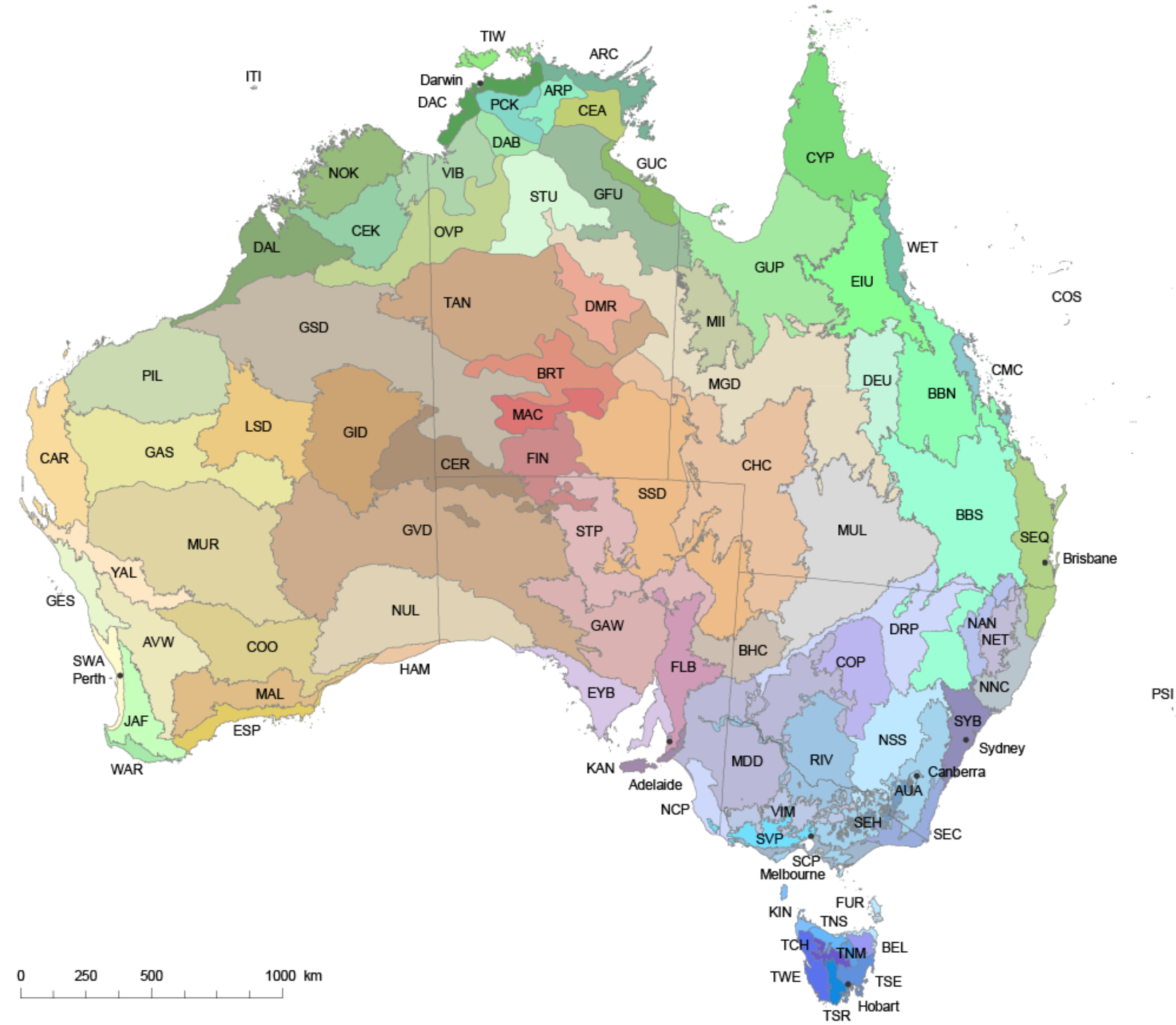
Terrestrial ecosystems and communities

The Interim Biogeographic Regionalisation for Australia (IBRA; Figure BIO8) classifies Australia's landscapes into 89 large, geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information. The 89 bioregions are further refined to 419 subregions, which are more localised geomorphological units within each bioregion. The IBRA classification is used as a key planning tool for identifying land for conservation under the National Reserve System (Thackway & Cresswell 1995). It is used throughout this report to document the distribution of threatened species and communities and, in Effectiveness of biodiversity management, for understanding comprehensiveness, adequacy and representation of the National Reserve System.

In December 2015, 74 ecological communities were listed as threatened under the EPBC Act: 31 as critically endangered, 41 as endangered and 2 as vulnerable (see Box BIO5). Thirty of these are new listings since 2011. EPBC Act–listed ecological communities are concentrated in south-eastern Australia (Figure BIO9). In particular, the Brigalow Belt IBRA region in Queensland, the Sydney Basin and Riverina IBRA regions in New South Wales, the Southern Volcanic Plain IBRA region in Victoria and the Murray–Darling Depression IBRA region all have high numbers of threatened ecological communities.

Noisy pitta (*Pitta versicolor*) at Meunga Creek, Wet Tropics World Heritage Area, far north Queensland

Photo by David Westcott

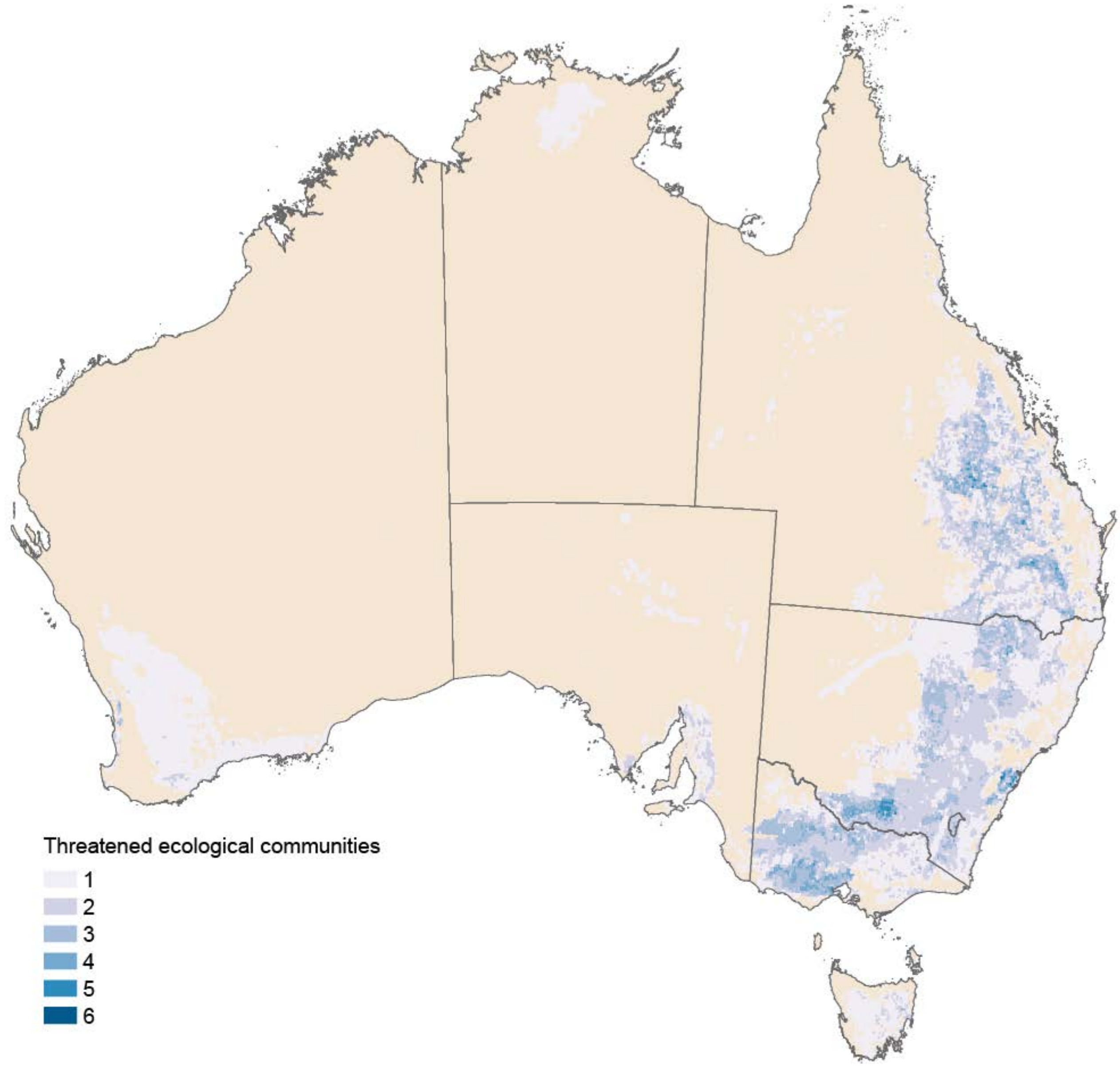


ARC	Arnhem Coast	DMR	Davenport Murchison Ranges	MAC	MacDonnell Ranges	SEQ	South Eastern Queensland
ARP	Arnhem Plateau	DRP	Darling Riverine Plains	MAL	Mallee	SSD	Simpson Strzelecki Dunefields
AUA	Australian Alps	EIU	Einasleigh Uplands	MDD	Murray Darling Depression	STP	Stony Plains
AVW	Avon Wheatbelt	ESP	Esperance Plains	MGD	Mitchell Grass Downs	STU	Sturt Plateau
BBN	Brigalow Belt North	EYB	Eyre Yorke Block	MII	Mount Isa Inlier	SVP	Southern Volcanic Plain
BBS	Brigalow Belt South	FIN	Finke	MUL	Mulga Lands	SWA	Swan Coastal Plain
BEL	Ben Lomond	FLB	Flinders Lofty Block	MUR	Murchison	SYB	Sydney Basin
BHC	Broken Hill Complex	FUR	Furneaux	NAN	Nandewar	TAN	Tanami
BRT	Burt Plain	GAS	Gascoyne	NCP	Naracoorte Coastal Plain	TCH	Tasmanian Central Highlands
CAR	Carnarvon	GAW	Gawler	NET	New England Tablelands	TIW	Tiwi Cobourg
CEA	Central Arnhem	GES	Geraldton Sandplains	NNC	NSW North Coast	TNM	Tasmanian Northern Midlands
CEK	Central Kimberley	GFU	Gulf Fall and Uplands	NOK	Northern Kimberley	TNS	Tasmanian Northern Slopes
CER	Central Ranges	GID	Gibson Desert	NSS	NSW South Western Slopes	TSE	Tasmanian South East
CHC	Channel Country	GSD	Great Sandy Desert	NUL	Nullarbor	TSR	Tasmanian Southern Ranges
CMC	Central Mackay Coast	GUC	Gulf Coastal	OVP	Ord Victoria Plain	TWE	Tasmanian West
COO	Coolgardie	GUP	Gulf Plains	PCK	Pine Creek	VIB	Victoria Bonaparte
COP	Cobar Peneplain	GVD	Great Victoria Desert	PIL	Pilbara	VIM	Victorian Midlands
COS	Coral Sea	HAM	Hampton	PSI	Pacific Subtropical Islands	WAR	Warren
CYP	Cape York Peninsula	ITI	Indian Tropical Islands	RIV	Riverina	WET	Wet Tropics
DAB	Daly Basin	JAF	Jarrah Forest	SAI	Subantarctic Islands	YAL	Yalgoo
DAC	Darwin Coastal	KAN	Kanmantoo	SCP	South East Coastal Plain		
DAL	Dampierland	KIN	King	SEC	South East Corner		
DEU	Desert Uplands	LSD	Little Sandy Desert	SEH	South Eastern Highlands		

Note: IBRA maps in the *Biodiversity* report do not include the Indian Tropical Islands, including Christmas Island, Cocos (Keeling) Islands and the Timor Sea Islands; Pacific Subtropical Islands, including Norfolk and Lord Howe Islands; the Subantarctic Islands including Macquarie, Heard Island and MacDonald Islands; and Coral Sea Islands.

Source: IBRA 7; compiled by the Environmental Resources Information Network, Australian Government Department of the Environment and Energy

Figure BIO8 Interim Biogeographic Regionalisation for Australia regions



Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2015

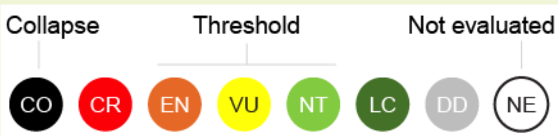
Figure BIO9 Distribution of ecological communities in Australia listed under the *Environment Protection and Biodiversity Conservation Act 1999*

Box BIO5 Global and national lists of threatened ecosystems

Australia has maintained lists of nationally threatened species and ecological communities since 1992 (initially under the *Endangered Species Protection Act 1992* and subsequently under the *Environment Protection and Biodiversity Conservation Act 1999*). Independently, the International Union for Conservation of Nature (IUCN) has maintained the IUCN Red List of Threatened Species since 1964 and, in 2008, initiated the global Red List of Ecosystems (Keith et al. 2013).

For the IUCN Red List of Ecosystems, there are 7 categories of risk that mirror those used for species (Figure BIO10). An additional category (collapse—CO) is assigned to ecosystems that have collapsed throughout their distribution, the analogue of the extinct (EX) category for species.

As at October 2016, assessment for 17 Australian ecosystems had been completed using the IUCN criteria; 3 were undertaken or led by the IUCN, and a further 14 were undertaken regionally in Australia.



CO = collapse; CR = critically endangered; DD = data deficient; EN = endangered; LC = least concern; NE = not evaluated; NT = not threatened; VU = vulnerable
Source: © International Union for Conservation of Nature, all rights reserved

Figure BIO10 International Union for Conservation of Nature categories of risk

Jurisdictional reporting on vegetation condition and extent

Jurisdictions report on key trends in vegetation condition and extent. The assessment grade and adequacy of information, if given, are also noted. Trends in vegetation condition and extent are variable across jurisdictions. Queensland and Victoria note declines in extent, whereas the Australian Capital Territory notes improvements in condition because of recovery from drought and land management activities.

Australian Capital Territory

- Key trends in vegetation:
  - Grassland condition is relatively stable, although exotic species cover and richness increased towards the end of 2013–14.
  - General improvement in woodland condition is noted from 2004 to 2012–13, possibly as a result of recovery from drought, as well as land management activities.
  - Riparian condition along the Murrumbidgee River varies widely. In the areas covered by the National Reserve System, it is generally good; outside protected areas, condition is affected by rural land uses.
  - Exotic weeds are a pervasive feature.
- Assessment grade and adequacy of information:
  - Connectivity of terrestrial native vegetation: status—good; trend—stable. Fine-scale modelling of existing fauna habitat and connectivity across the territory means that these values are now well understood.

New South Wales

- Key trends in vegetation:
  - Clearing rates have been generally stable during the past 10 years.
  - Nine per cent of vegetation is close to natural condition.
  - Condition has generally deteriorated because of changed land use and land management.
- Assessment grade and adequacy of information:
  - Clearing rate for woody native vegetation: status—moderate; trend—stable; information availability—good.
  - Extent of native vegetation: status—moderate; trend—stable; information availability—reasonable.
  - Condition of native vegetation: status—moderate; trend—increasing impact; information availability—limited.
  - Levels of pressure on native vegetation condition: status—moderate; trend—stable; information availability—limited.

Queensland

- Key trends in vegetation:
  - Vegetation clearing rates in Queensland have been monitored since 1997 and reached a peak during 1999–2000, when about 0.4 per cent of the state's remnant vegetation was cleared in 1 year.
  - Clearing rates have since decreased to reach 0.014 per cent per year of the state's remnant vegetation in 2009–11, and then increased to 0.02 per cent per year in 2011–13.
  - In 2013–14, 296,324 hectares per year of woody vegetation were cleared statewide; this represented a 93 per cent increase from 2011 to 2012 and the highest woody vegetation clearing rate since 2006.
  - Pasture was the dominant replacement land-cover class, contributing to 92 per cent of the total statewide clearing.
  - Of the 16 broad vegetation groups statewide, 2 (mainly comprising acacia and eucalypt forests) have less than 60 per cent remnant native vegetation as at 2013.
- Assessment grade and adequacy of information:
  - Knowledge of vegetation clearing rates—good.

Victoria

- Key trends in vegetation:
  - The extent and condition of native vegetation in Victoria continue to decline, particularly through chronic degradation of habitat condition, mainly in fragmented landscapes.
  - Vegetation quality is generally stable on public land and in largely intact landscapes.
- Assessment grade and adequacy of information:
  - Extent and condition of Victoria's native vegetation: status—poor; trend—deteriorating.
  - Confidence in the assessment grade is given as fair, indicating limited evidence or consensus.

South Australia

- Key trends in vegetation:
  - The area under some form of protected status has increased by about 10 per cent since 2008.
  - The area of revegetation has decreased since 2008.
  - At the end of 2013, 31 per cent of the 382 ecosystems in South Australia were classified as adequately protected (NRM report card).
- Assessment grade and adequacy of information:
  - Native vegetation: status—poor; trend—deteriorating.
  - Vegetation clearing: trend 1999–2014—stable; reliability of information on vegetation extent and connectivity—very good (NRM report card).
  - Native vegetation protection: trend—improving; reliability of information on protection of native vegetation—very good (NRM report card).

Western Australia

- Key trends in vegetation:
  - The number of plant species discovered and described increased by an average of more than 50 per year, but there are still many to find.
  - Between 100 per cent and 0.55 per cent (average 78 per cent) of vegetation ecosystems in the south-west land division remain, compared with the pre-European extent.
- Assessment grade and adequacy of information:
  - No assessment provided.

Tasmania

- Key trends in vegetation:
  - From 2005 to 2015, the area of native vegetation in Tasmania decreased by 1.1 per cent. The total area of native forest decreased by approximately 42,000 hectares, and the total area of native nonforest vegetation decreased by approximately 15,000 hectares during this period.
  - Since 2009, a further 4 per cent of Tasmania's native vegetation has been added to the National Reserve System in Tasmania, culminating in 54.5 per cent of native vegetation being reserved in 2015.
- Assessment grade and adequacy of information:
  - These vegetation extent figures are based on existing datasets rather than a systematic change detection program. Comprehensive data will be available towards the end of 2016. The level of confidence in the extent and change of native nonforest vegetation is lower than for forest vegetation. This is primarily because of fewer requirements for recording clearing activity and greater difficulty in detecting change in nonforest vegetation using current methods.

Northern Territory

- Key trends in vegetation:
  - The extent of clearing of native vegetation in the territory was estimated as 937,687 hectares (0.66 per cent of the land area) in 2004. Native vegetation extent has not been systematically monitored since then.
  - Between 2003 and 2015, an annual average of 5005 hectares of clearing of native vegetation was approved on pastoral land, and the rate of clearing on this tenure remained approximately constant during this period.
  - Land clearing has primarily occurred in the Daly Basin and Darwin Coastal bioregions, and on Melville Island.
  - Long-term systematic monitoring of vegetation structure and floristic composition in some conservation reserves has shown a decline in vegetation condition in some ecosystems, mostly associated with damaging fire regimes.
- Assessment grade and adequacy of information:
  - There is currently no systematic remote monitoring of land-cover change in the Northern Territory.
  - Data are available for permits granted to clear native vegetation, but not all permit areas are ultimately cleared.
  - There is no standard methodology for assessing vegetation condition in the Northern Territory, and very limited systematic assessment and monitoring of vegetation condition.
  - The Pastoral Land Board reports on the condition of pastoral land in the Northern Territory, which is predominantly native vegetation. Pastoral land condition is currently monitored at 256 sites on 45 properties in 9 of the 11 pastoral districts. In 2014–15, 55 per cent of monitoring sites were assessed as in good condition, 25 per cent were fair and 20 per cent were poor.

Extent of vegetation communities

The *Land* report details the current extent of vegetation communities across Australia. A summary is provided here.

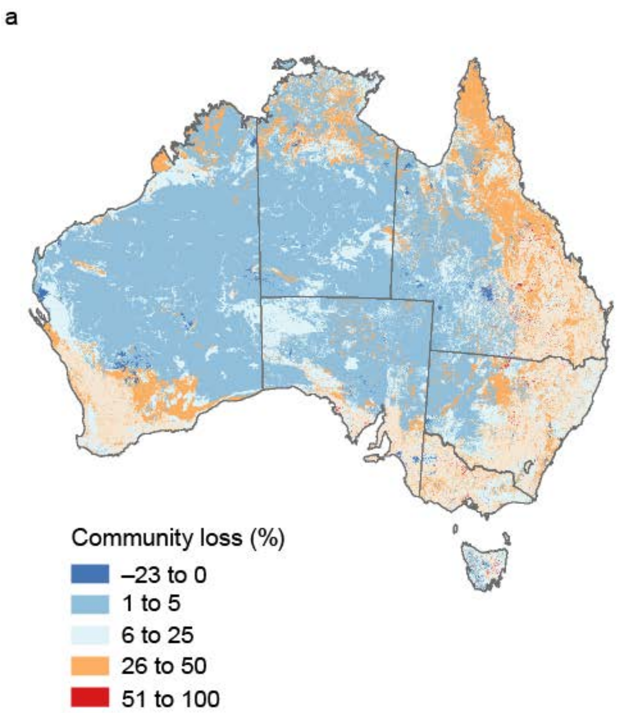
A 2015 publication (Tulloch et al. 2015) assessed the relative change in vegetation extent and patch size in 75 Australian vegetation communities (as defined by the National Vegetation Information System 4.1). In Australia, 24 broad vegetation communities (32 per cent of the 75 evaluated) have lost at least 20 per cent of their original extent, and 7 communities (9 per cent) have lost more than 40 per cent of their original extent. Many of those most heavily cleared occur in the agriculturally productive coastal regions of Australia (Tulloch et al. 2015; Figure BIO11).

A net loss of about 1.4 million hectares of forest was recorded between 2005 and 2010 (Figure BIO12). This was primarily a result of land-use change for urban development and agriculture, as well as short-term factors such as fire and drought (MIG & NFISC 2013).

Quality of habitat

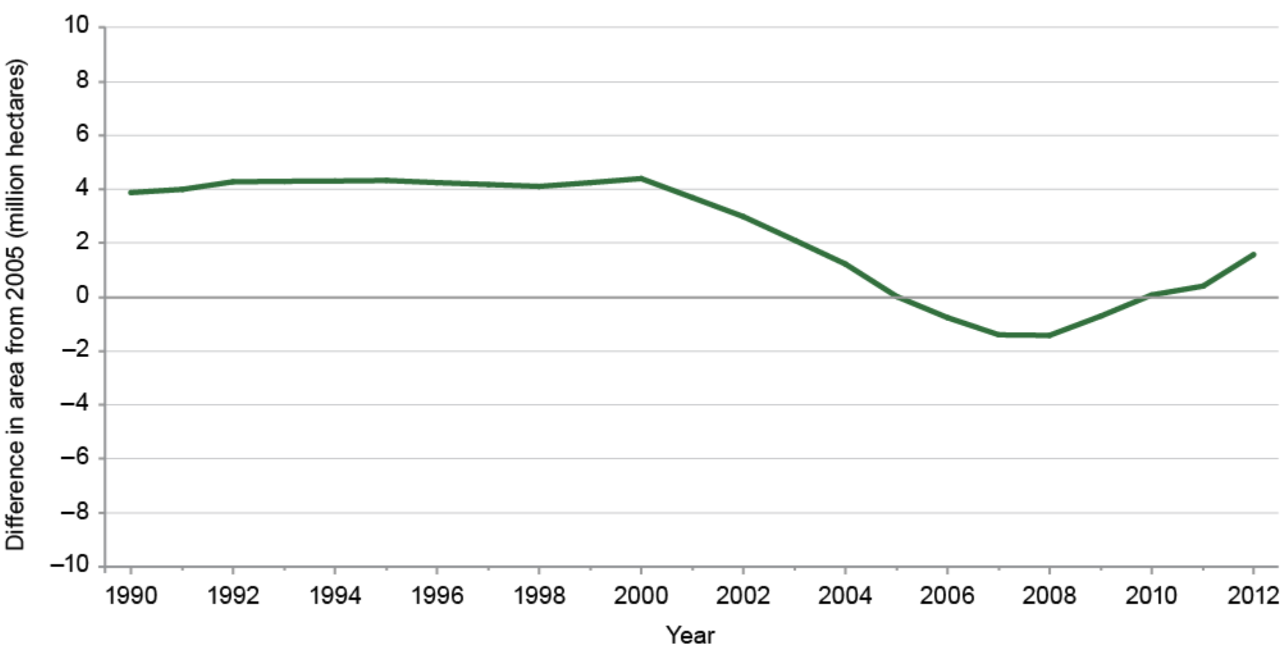
Most jurisdictions note that the condition of habitat is mostly in decline, although knowledge about vegetation condition is generally described as limited. The Australian Capital Territory notes some improvements in woodland condition between 2004 and 2012–13, possibly as a result of recovery from drought and land management activities.

An important implication of the loss of extent of vegetation is that ecological communities today have fewer larger patches of contiguous vegetation (Tulloch et al. 2015). For example, Brigalow Belt formerly extended across 96,492 square kilometres, distributed among 10,136 patches of vegetation. Today, this has been reduced by 87 per cent to 12,665 square kilometres distributed among 48,618 patches: a 4-fold increase in the original number of patches, despite the enormous overall decline in extent. At least 22 per cent of major vegetation communities in Australia have more than 50 per cent of their remaining extent in patches of less than 1000 hectares. Four ecological communities have at least 25 per cent of their remaining distribution in patches smaller than 10 hectares (open mallee woodlands, leptospermum forests and woodlands, eucalyptus tall open forest with fine-leaved shrubby understorey, and boulders or alpine fjaeldmarks). Despite 3 of these being naturally patchy (eucalyptus forest, leptospermum forests and boulders), this proportion has increased for all communities. Smaller patches of vegetation are subject to increased edge effects—that is, disturbance from surrounding land uses affects relatively more of the area of small patches. Small patches are more likely to be cleared, and small patches often have lower species diversity then larger contiguous patches.



Source: Adapted from Tulloch et al. (2015), used under CC BY NC ND 4.0

Figure BIO11 (a) Total loss of extent of vegetation communities in Australia from pre-1750 extents; (b) a fragmentation measure reflecting the change in proportion of vegetation patches made up of less than 5000 hectares



Note: Plotted values are differences from the 2005 forest area (108.1 million hectares), which is zero.
Source: Calculated by the Australian Bureau of Agricultural and Resources Economics and Sciences from data in the National Inventory Report (DoE 2012)

Figure BIO12 Australia's forest area (1990–2012) compared with 2005 forest area

Recent research has shown significant reductions in the abundance of large trees across a range of ecosystems globally, including in Australia. Large trees with cavities play a critical role in forest, agricultural and urban ecosystems, and their demise is an indicator of declining habitat quality, with impacts across many dependent fauna species. For example, long-term monitoring of large trees in mountain ash forests of south-eastern Australia has shown high rates of tree death primarily because of fire, and no recruitment of any new large trees. Large living and dead trees with cavities are a critical nesting and denning resource for more than 40 species of native vertebrates in mountain ash forests, including the endangered Leadbeater's possum (Lindenmayer et al. 2012).

Ecosystem services

One major area of endeavour that has increased in importance and maturity has been the quantification of ecosystem services for NRM. Although the ecosystem services concept has been around for several decades in the scientific literature, legal frameworks and policy documents, efforts to apply the concept to quantify benefits from well-functioning ecological systems have improved substantially during the past 5 years or so (Pittock et al. 2012, Wentworth Group 2014). Furthermore, we have started to see the idea of ecosystem services taken up more and more into natural resource planning and management, and the establishment of targets for monitoring, reporting and evaluation of natural resources programs (e.g. National Action Plan for Salinity and Water Quality, Natural Heritage Trust, Caring for our Country).

During the past 5 years, multiple reports have proposed that ecosystem services become more commonly used, including within a 'set of national accounts'. However, no system of assessment and reporting has seen major adoption (Cork 2011, Plant et al. 2012, BoM 2013, ABARES 2013, Wentworth Group 2014, ABS 2015). One regional example is that produced by the Australian Bureau of Statistics (ABS) for the Great Barrier Reef Region. The large body of scientific work undertaken in the region was connected with environmental and macro-economic indicators compiled by the ABS, to produce 'experimental' ecosystem accounts for agriculture, tourism, fishing and aquaculture (ABS 2015).

The *Drivers* report details efforts at the national and international level to improve environmental accounting.

Terrestrial plant and animal species

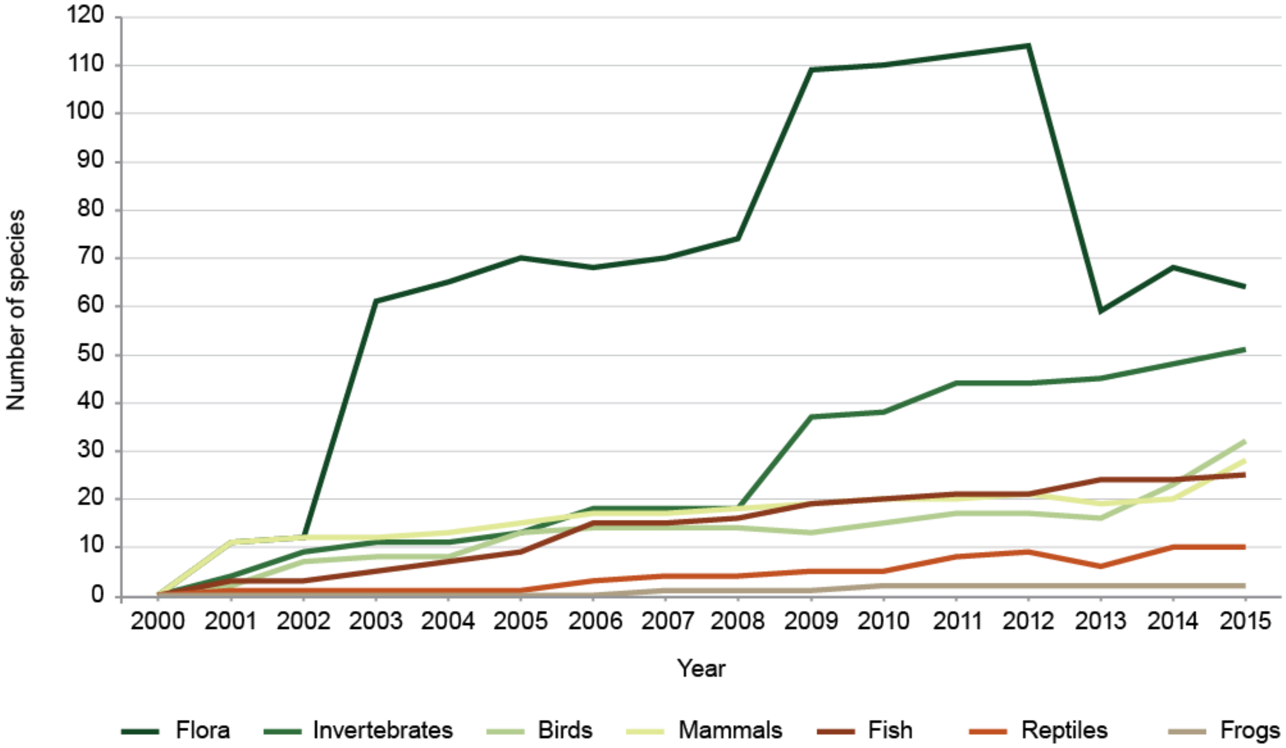
Threatened species lists

As at December 2015, a total of 480 fauna species (terrestrial and aquatic) were listed under the EPBC Act, including 55 that are listed as extinct or extinct in the wild. This reflects an overall increase of 44 species since 2011 (Figure BIO13). The number of nationally listed threatened species has increased for all animal taxa except amphibians. The overall number of plant species listed has increased only slightly during the past 5 years. A large number of delistings, primarily because of changes in taxonomic understanding, occurred in 2013.

The overall number of mammal species listed increased by 8 during the past 5 years (Figure BIO14). Christmas Island flying fox (*Pteropus melanotus natalis*) was added to the critically endangered category, and Leadbeater's possum was uplisted from endangered to critically endangered since 2011. Seven new species were added to the endangered species category, and 4 new species were assessed as vulnerable (see Box BIO6). Two species were delisted (northern and southern marsupial moles—*Notoryctes caurinus* and *N. typhlops*). These changes can be attributed to the publication of *The action plan for Australian mammals 2012*, which enabled more efficient assessment of mammal listings.

The number of threatened bird species has increased by 15 species; the number of critically endangered bird species increased by 7. Four species were uplisted to critically endangered since 2011: regent honeyeater (*Anthochaera phrygia*), helmeted honeyeater (*Lichenostomus melanops cassidix*) and western ground parrot (*Pezoporus flaviventris*) were uplisted from endangered to critically endangered, and plains-wanderer (*Pedionomus torquatus*) was uplisted from vulnerable to critically endangered.

Although the number of listed amphibian species remained the same, 2 species (northern corroboree frog—*Pseudophryne pengilleyi* and Kroombit tinker frog—*Taudactylus pleione*) were uplisted from vulnerable to critically endangered based on new information about their vulnerability to extinction. In addition, southern corroboree frog (*Pseudophryne corroboree*) was uplisted from endangered to critically endangered.

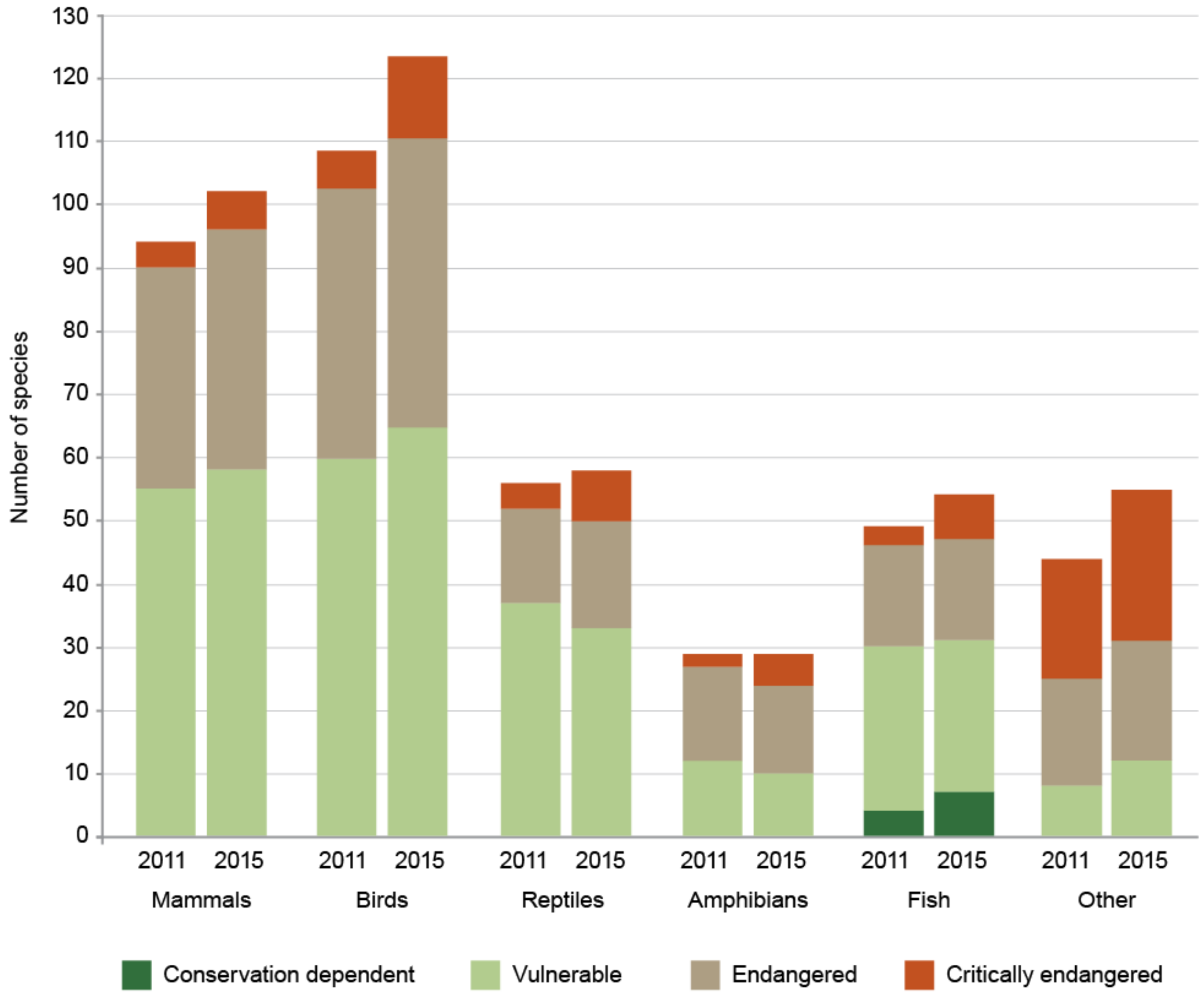


Notes:

1. Trend data include delistings.
2. Plotted values are differences from the numbers of species listed in 2000 (flora: 1230, invertebrates: 4, birds: 117, mammals: 101, fish: 30, reptiles: 49, frogs: 31), which are set at 0.

Source: Species Profile and Threats Database, Australian Government Department of the Environment and Energy, 2016

Figure BIO13 Net changes in the number of species listed under the *Environment Protection and Biodiversity Conservation Act 1999* since 2000

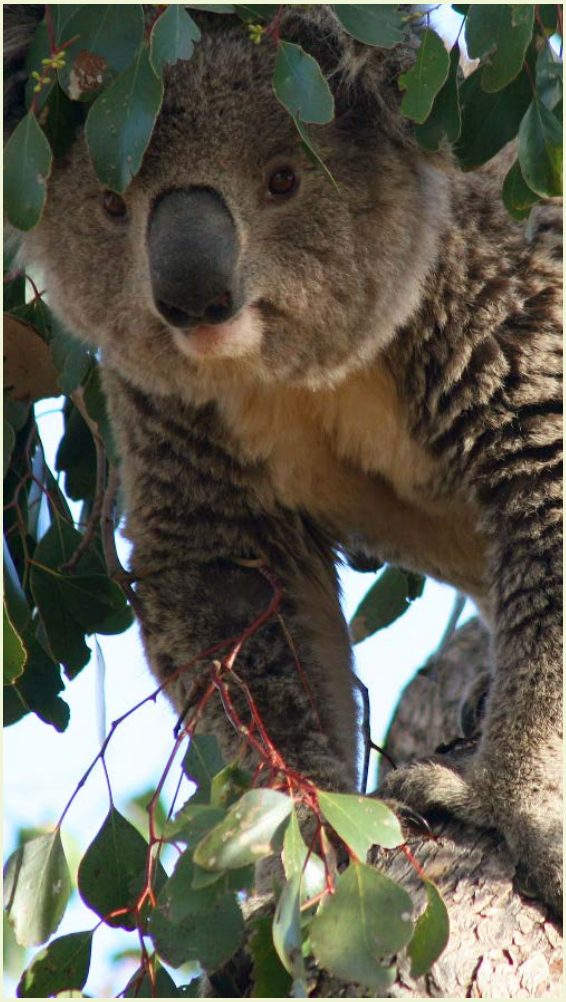


Source: Species Profile and Threats Database, Australian Government Department of the Environment and Energy

Figure BIO14 Number of fauna species listed under the *Environment Protection and Biodiversity Conservation Act 1999*, 2011 and 2015

Box BIO6 Koalas—a matter of national environmental significance

Koalas (*Phascolarctos cinereus*) in some parts of Australia face direct threats from urban expansion, disease, habitat loss, vehicle strike and predation by dogs, as well as indirect threats from drought and climate change. Our most at-risk koala populations—in Queensland, New South Wales and the Australian Capital Territory—were listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* in April 2012, strengthening the existing state and territory protections, and making them a matter of national environmental significance.

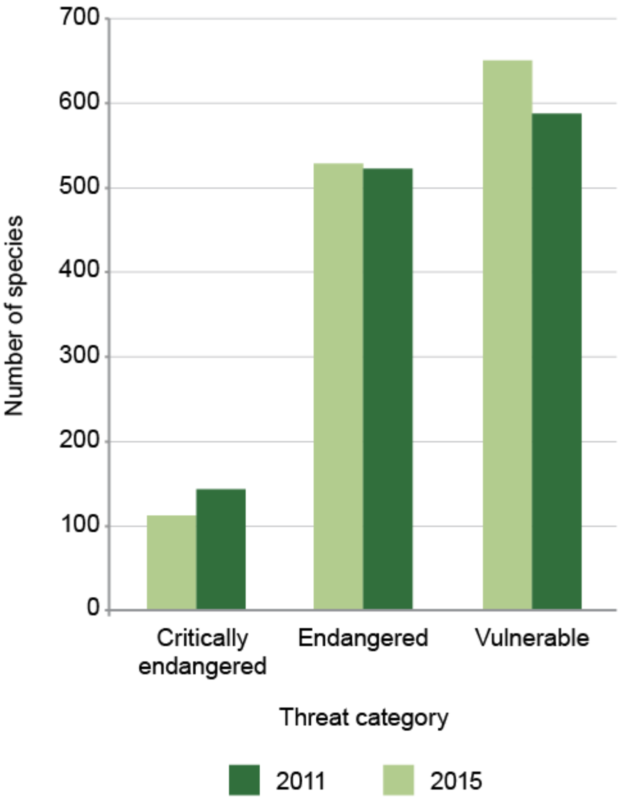


Koala

Photo by Dan Lunney

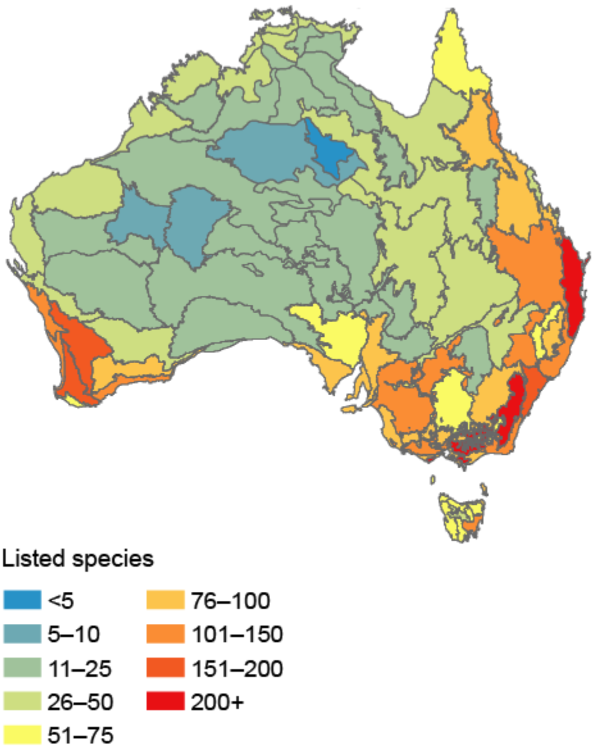
As at December 2015, 1294 plant species were listed, including 37 species that are listed as extinct in the wild. In 2011, 1289 species were listed (Figure BIO15). The number of species listed in the critically endangered category has increased by 31. The numbers of species in the endangered and vulnerable categories have decreased because of delistings, and uplistings to critically endangered.

The highest numbers of listed plant and animal species are found in the south-west of Western Australia and in south-eastern Australia (Figure BIO16). The current and historical intensity of pressures in these areas is relatively high. Relatively high numbers of critically endangered species also occur in Cape York Peninsula. The distribution of different taxa that are listed and critically endangered taxa shows some variation; this is explored further in the following taxa-specific sections.



Source: Species Profile and Threats Database, Australian Government Department of the Environment and Energy

Figure BIO15 **Number of plant species listed under the *Environment Protection and Biodiversity Conservation Act 1999*, 2011 and 2015**



Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2016

Figure BIO16 **Numbers of species and critically endangered species listed under the *Environment Protection and Biodiversity Conservation Act 1999* in each Interim Biogeographic Regionalisation for Australia region**

Jurisdictional reporting on threatened species and communities

Jurisdictions report on key trends in threatened species and communities. Most jurisdictions report ongoing declines in the distribution and abundance of threatened flora and fauna. Confidence in threatened species trends is limited; monitoring generally focuses on a small number of species in specific locations.

Australian Capital Territory

- Key trends in threatened species and communities:
  - Most threatened flora and fauna are declining, including the vulnerable brown treecreeper, glossy black cockatoo and scarlet robin, and the endangered regent honeyeater, grassland earless dragon and northern corroboree frog.
  - There have been increases in recordings of the vulnerable hooded robin, superb parrot and white-winged triller, and the endangered Brindabella midge orchid, Canberra spider orchid and Tarengo leek orchid.
  - Management has improved the extent and condition of many threatened ecological communities.
  - More than half (55 per cent) of the territory's entire land area is protected in the National Reserve System.
- Assessment grade and adequacy of information:
  - Extent and condition of threatened flora and fauna: status—poor to very poor; trend—deteriorating.
  - Extent and condition of threatened ecological communities: status—poor; trend—improving.

New South Wales

- Key trends in threatened species and communities:
  - The number of species considered at risk of extinction continues to rise.
  - Twenty-one additional species and 1 additional ecological community have been listed as threatened since 2012.
  - Eight species and 7 ecological communities have been upgraded to a higher threat status, because of increased extinction risk or an ongoing review of the schedules since the critically endangered category was legislated in 2005.
  - One species, black-throated finch, has been declared extinct in New South Wales, not having been sighted since 1994.
- Assessment grade and adequacy of information:
  - Number of threatened species, communities and populations: status—poor; trend—increasing impact; information availability for assessing the state and trend of this indicator—reasonable.
  - There have been no updates on the decline in terrestrial vertebrate species since 2010, and limited information is currently available to understand the overall status.
  - Limited information is readily available to understand the overall status and trends for threatened species.
  - Specific monitoring of the site-based response of threatened species to conservation actions will occur under the New South Wales Government's Saving our Species program.

Queensland

- Key trends in threatened species and communities:
  - The number of fauna species listed as threatened (vulnerable, endangered or extinct in the wild) increased by 61 between 2007 and 2015.
  - Three frog species have been listed as extinct in the wild.
  - Most western Queensland bioregions remained as remnant vegetation in 2013; however, significant areas of fauna habitat have been cleared in the fragmented eastern bioregions.
- Assessment grade and adequacy of information:
  - Number of threatened species, communities and populations: status—fair; trend—increasing impact; information availability for assessing the status and trend of this indicator—reasonable.
  - There is no broad strategy or framework to monitor the conservation status of species; limited information is readily available to understand the overall status and trend for threatened species.

Victoria

- Key trends in threatened species and communities:
  - The conservation status of many threatened vertebrate species continues to decline.
  - The conservation status of 33 vertebrate species worsened between 2007 and 2013, 8 improved and 3 were taken off the list; 13 species were added to the Advisory List of Rare and Threatened Vertebrate Fauna.
  - The eastern barred bandicoot became extinct in the wild in Victoria.
  - As at 2009, 1 invertebrate species and another 5 vertebrate species had become extinct in Victoria.
  - Expert opinion indicates a decline in the status of plant species.
- Assessment grade and adequacy of information:
  - Threatened species in Victoria: status—poor; trend—deteriorating; confidence in the assessment grade—fair.
  - There remain many species whose population trend is inconclusive or unclear.
  - Conservation of Victorian ecosystems and species: status—fair; trend—improving.
  - Because of information gaps, the current number of threatened species is likely to be vastly under-reported for invertebrates.

South Australia

- Key trends in threatened species and communities:
  - There has been a net increase in the number of endangered and vulnerable species and ecological communities since 2008.

- Twenty-three plant and animal species have been nationally listed as threatened with extinction in the past 5 years.
- Five ecological communities have been listed as threatened in the past 5 years.
- There has been an increase in recovery plans and actions.

- Assessment grade and adequacy of information:
  - Threatened species and ecological communities: status—poor; trend—deteriorating. Changes in the extent of threatened ecological communities have not been recorded since they were listed.
  - Regional trends in the number of plants and animals listed as threatened: trend—deteriorating (NRM report card).
  - Natural resource managers monitor the distribution and abundance of around 29 per cent of threatened plants and 38 per cent of threatened animals; for these plants and animals, monitoring programs are in place in all NRM regions where they have been recorded.

Western Australia

- Key trends in threatened species and communities:
  - There has been a net increase in the number of threatened species (critically endangered, endangered and vulnerable) since 2007, and a decrease in the total number of threatened fauna species by 2 in 2015. Ten species were removed from the list of threatened fauna in 2015. There was an increase of 3 threatened flora species in 2015.
  - No legislative mechanism is in place to protect threatened ecological communities, so they are currently listed under policy (new legislation was introduced to the Western Australian Parliament in late 2015 to remedy this).
  - There is ongoing listing of broadscale threatened ecological communities under the EPBC Act, covering significant areas of remnant vegetation in the south-west.
  - The number of species and ecological communities with recovery plans has increased.
- Assessment grade and adequacy of information:
  - There is generally good information on status for most threatened species and communities.
  - Information on trends is variable, depending on the species or community.
  - The ability to monitor fauna decreases if numbers drop to low levels.
  - Western Australia is refining location and condition data for threatened ecological communities that were recently listed under the EPBC Act.
  - Although significant funding for monitoring and research is provided through development project offsets, much is directed to specific species in specific locations for set time periods.

Tasmania

- Key trends in threatened species and communities:
  - Extinction risks for most threatened species in Tasmania may be increasing because of ongoing threats, increasing pressures from climate change and the need for targeted recovery work.
  - Tasmania lists 39 ecological vegetation communities as threatened. No change in status has been recorded for the reporting period.
  - Since 2009, 5 additional flora species have been listed under the EPBC Act, 4 have been delisted, 3 have been uplisted and 3 have been downlisted; 38 additional fauna species have been listed and 4 have been uplisted.
  - Four of the 5 new flora listings under the EPBC Act were for species on Macquarie Island; the introduced rabbit—one of the key threats to the vegetation on the island—has been eradicated in the interim. The trajectory of these 4 species is as yet unknown.
  - Four new ecological communities of relevance to Tasmania have been listed under the EPBC Act since 2009: Alpine Sphagnum Bogs and Associated Fens, Lowland Native Grasslands of Tasmania, Giant Kelp Marine Forests of South East Australia, and Subtropical and Temperate Coastal Saltmarsh.

- Since 2009, 14 additional flora species have been listed under the *Threatened Species Protection Act 1995*, 12 have been delisted, 6 have been uplisted, and 8 have been downlisted; 1 fauna species has been downlisted and 2 have been uplisted.
- Some species are awaiting gazettal: flora—13 new listings, 15 delistings, 2 downlistings and 4 uplistings; fauna—2 new listings and 1 uplisting.
- Since 2009, a further 4 per cent of Tasmania's native vegetation has been added to the National Reserve System in Tasmania, culminating in 54.5 per cent of native vegetation being reserved in 2015.

- Assessment grade and adequacy of information:
  - Tasmania manages a large World Heritage Area, as well as threatened vegetation communities and a large list of threatened species. Monitoring during the period has focused on the values within the World Heritage Area, as well as priority threatened species (particularly the orange-bellied parrot and the Tasmanian devil). The most comprehensive assessment of the maugean skate has also been undertaken during the past 5 years. For many other species, however, there has been limited monitoring work, and our current understanding of populations is limited.
  - A systematic review of the status of species listed under the EPBC Act and the Tasmanian *Threatened Species Protection Act 1995* has not been undertaken since 2009.
  - The majority of flora delistings and downlistings since 2009 have arisen because of an improvement in information, coupled, in some instances, with an improvement in reservation status. Four flora species listed as presumed extinct under the Threatened Species Protection Act have been rediscovered since 2009.

Northern Territory

- Key trends in threatened species and communities:
  - In 2007, 188 Northern Territory species were listed as threatened under territory or Australian legislation (and an additional 15 species were considered extinct in the Northern Territory). In 2015, 219 territory species were listed as threatened under either piece of legislation.
  - Changes to the threat status of species in the Northern Territory have been greater than indicated by this increase in listings. In a review of species listed as threatened under the *Territory Parks and Wildlife Conservation Act* in 2011–12, 44 species were added to the list, 13 species were removed from the list, 12 species on the list had increasing conservation concern and 4 species on the list had decreasing conservation concern.
  - Most of these changes result from taxonomic revisions and improved data on distribution and abundance, which have clarified species' conservation status. Approximately 20 per cent of changes reflect documented negative trends in species' extent and/or abundance, and a much smaller proportion reflect observed recovery.
  - The most notable negative trend is in the conservation status of many small mammal species in the north of the Northern Territory, where multiple lines of evidence indicate significant recent declines, including a reduction of 75 per cent in mammal site richness in 1 systematic monitoring program. Consequently, 7 mammal species occurring in the north of the territory have been added to the EPBC Act threatened species list since 2005.
  - Only 1 threatened ecological community is listed under the EPBC Act in the Northern Territory.
- Assessment grade and adequacy of information:
  - The conservation status of all territory species under the *Territory Parks and Wildlife Conservation Act* is being reviewed in 2016. This review will include implementation of a common assessment method to improve consistency in threatened species listing across all Australian jurisdictions.
  - Although systematic regional or community-level monitoring programs have been important in revealing the extent of small mammal decline, there are detailed quantitative data for trends in abundance for only a small proportion of threatened species in the Northern Territory.
  - The conservation status of most invertebrate groups is very poorly known.

The eastern barred bandicoot (*Perameles gunnii*) is a small nocturnal marsupial that was once common in south-eastern Australia, but has been severely impacted by clearing and introduced predators. It is listed as endangered nationally, and the mainland subspecies is now extinct in the wild. It has been listed as one of 20 priority mammals identified for action under the Australian Government's Threatened Species Strategy

Photo by Gerry Gibson Photography

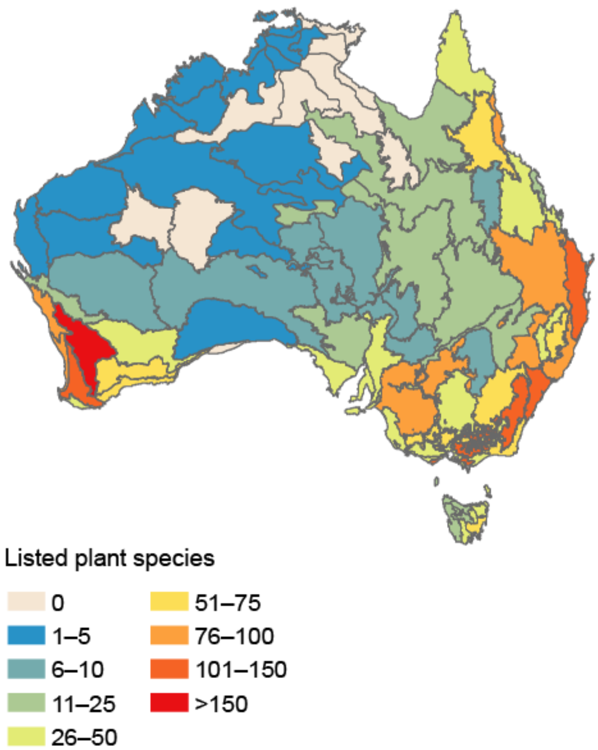
Plant species

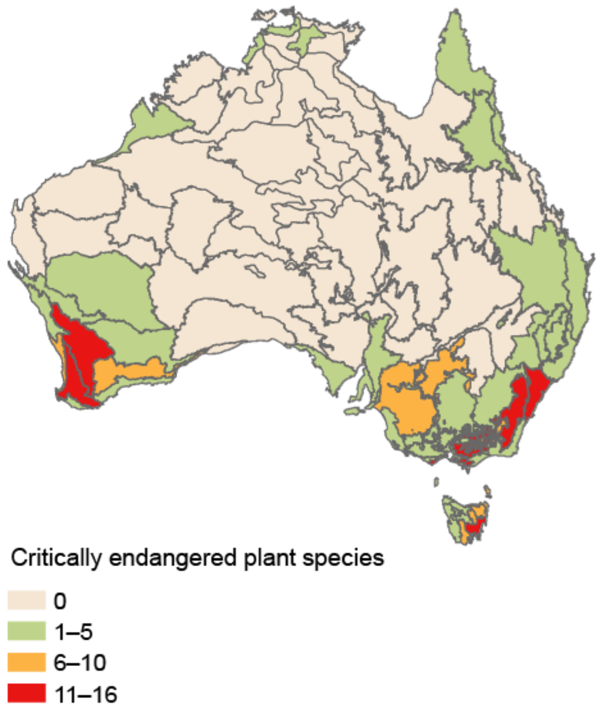
The pattern in distribution of listed plant species has not changed significantly since 2011. The general trend is for higher proportions of plants to be threatened along the east coast and in the south-west of Australia (Figure BIO17).

The highest number of listed threatened plant species occurs in the Wheatbelt region of Western Australia, with 157 listed species, 15 of them critically endangered. The South Eastern Queensland and Sydney Basin IBRA regions also have high numbers of listed species. The South Eastern Highlands region of Victoria and New South Wales has 124 listed species, 12 of which are critically endangered.

Fungi

Fungi are the hidden connectors between many of the visible plants and animals in ecosystems. Fungi provide significant ecosystem services through decomposition (recycling), because they can break down the complex cellulose and lignin molecules in wood. Fungi sporophores are also food for animals, enmeshing fungi in food webs. Numerous invertebrates gain food and shelter from fungi. Truffle-like fungi are especially numerous in Australia, and make up a significant component of the diet of many native mammals, especially potoroos and bettongs (many of which are threatened). Mycorrhizal (fungus–root) fungi form mutually beneficial relationships with most green plants. Such relationships are important in Australia's nutrient-poor soils, where fungi can efficiently extract





Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2016

Figure BIO17 Numbers of plant species and critically endangered plant species listed under the *Environment Protection and Biodiversity Conservation Act 1999* in each Interim Biogeographic Regionalisation for Australia region nutrients vital to plant growth, while plants provide fungi with sugar from photosynthesis. Fungi growing in soil compete for nutrients with myriad other microorganisms. Thus, many fungi produce secondary metabolites that have significant biological activity, such as antibiotics (e.g. penicillin was derived from a fungus).

In Australia, perhaps 50 per cent of the macrofungi are formally described, but most microfungi are yet to be collected and formally described. Estimates of the diversity of fungi have used multipliers of plant diversity, because of many fungi being specific to plants at the species, genus or family level. Estimates for Australian fungi range from 50,000 (× 2) to 250,000 (× 10) species. Recent analysis of DNA in soil, including samples from Australia, has revealed tens of thousands of species-level 'molecular taxa' of fungi among relatively small sample sets (fewer than 1000 separate samples), confirming the order of magnitude of the previous estimates of the diversity of the Kingdom Fungi. Most of these molecular taxa do not match known species.

As noted in SoE 2011, few references to fungi and other non-plant, non-animal species are included in jurisdictional reporting. No fungi are listed as threatened nationally under the EPBC Act. However, several states include fungi in threatened species legislation:

- New South Wales—9 species and 1 ecological community of fungi are listed under the *Threatened Species Conservation Act 1995*.
- Victoria—3 fungi are listed under the *Flora and Fauna Guarantee Act 1988*; 9 fungi are included in the 2014 Advisory List of Rare or Threatened Plants.
- Western Australia—39 fungi (including 24 lichens) are listed as Priority Species 1, 2 or 3 in the Threatened and Priority Flora List under the *Wildlife Conservation Act 1950*.
- Tasmania—23 fungi (all lichens) are listed under the *Threatened Species Protection Act 1995*.

No fungi are listed under state or territory threatened species legislation in the Australian Capital Territory, the Northern Territory, Queensland or South Australia.

One fungus that occurs in Australia (bunyip egg—*Claustula fischeri*) is listed on the IUCN Global Red List.

The low number of species currently formally listed under state and territory legislation reflects ad hoc nominations, mostly by community groups, and is not necessarily a true reflection of the proportion of species that are threatened. Community profiling (using metagenomic approaches—see New technologies, solutions and innovations) of fungi has the potential to establish how fungal communities vary across hosts and across plant communities. It is necessary to understand these relationships to increase confidence that current approaches to conservation of plant communities are effectively 'carrying along' the vast array of fungi that occur in Australia, in the absence of knowledge of each individual species of fungus.

Only Queensland, South Australia and Western Australia include coverage of fungi in their statewide checklists or census records. Fungi are also not represented in most biodiversity monitoring programs, except for FORESTCHECK in Western Australia, which has been sampling macrofungi. There is generally a lack of mycological expertise in Australia among taxonomists and ecologists, as well as within land management agencies, and most work is undertaken by nongovernment organisations and community groups (e.g. Fungimap and the Sydney Fungal Studies Group; also see Box BIO7).

Mammals

The state and trend of mammals varies considerably. In 2014, *The action plan for Australian mammals 2012* (Woinarski et al. 2014) was released. It reviews the status of all known Australian mammals, and provides a benchmark from which changes in both the population and status of all Australian mammal taxa can be assessed in the future.

In June 2016, experts confirmed the extinction of the Bramble Cay melomys (*Melomys rubicola*) from Australia. This small rodent was considered ecologically unique in being the Great Barrier Reef's only endemic mammal species (Gynther et al. 2016). The species was listed as endangered under Queensland and Australian legislation, and a recovery plan was developed in 2008. The melomys occurred only on Bramble Cay, a small (less than 5 hectare) island in Torres Strait. Intensive monitoring in 2014 failed to find any evidence of the species; a report by the Queensland Government determined the probable cause of the extinction to be sea level rise, and an increase in the frequency and severity of storm surge (Gynther et al. 2016).

Box BIO7 Mobilising fungi distribution data

Fungi refers to the Kingdom Fungi, comprising organisms such as mushrooms, puffballs, coral fungi, bracket fungi, moulds, mildews and rust fungi. There are also fungal-like organisms in the Protoctisa (slime moulds) and Chromista (water moulds). Fungi usually grow as threads called hyphae and reproduce by spores. Fungi are heterotrophic, gaining carbon nutrition through a range of nutritional strategies, including parasitism (of plants, animals and other fungi), saprotrophism (breaking down dead organic material such as wood) and mutualism (such as lichens or mycorrhizas).

Macrofungi are those with easily visible sporophores (fruiting bodies; such as mushrooms), whereas, for microfungi (such as many moulds), the whole organism is not readily visible. Sporophores are often short-lived, but the growing body of the fungus persists as microscopic hyphae within substrates such as soil, plant leaves or the gut of invertebrates. Lichens are fungi that grow in stable association with photosynthetic algae or cyanobacteria. Complex relationships have recently been revealed, with some lichens comprising multiorganism partnerships between algae, several species of fungi and bacteria.

Fungimap was founded in 1995 as a mapping scheme for readily recognisable species of Australian macrofungi, such as blue pixie's parasol (*Mycena interrupta*; Figure BIO18) and curry punk (*Piptoporus australiensis*). Since then, more than 100,000 observations have been submitted to Fungimap by a network of hundreds of recorders around Australia.

More than 350,000 records of fungi are now accessible through the Atlas of Living Australia (ALA). The ALA brings together observations and distribution data from specimens of fungi in reference collections, such as culture collections and fungaria. The ALA provides maps of each species, and a spatial portal that enables exploration of distribution against climate, soil and other environmental variables.

Regional fungal studies groups around Australia are also contributing data to Fungimap or directly to the ALA. The recent creation of online nature observation portals such as BowerBird and NatureShare is providing a forum for discussion about identification, and stimulating interest in recording groups such as fungi and invertebrates, while providing further data to the ALA.

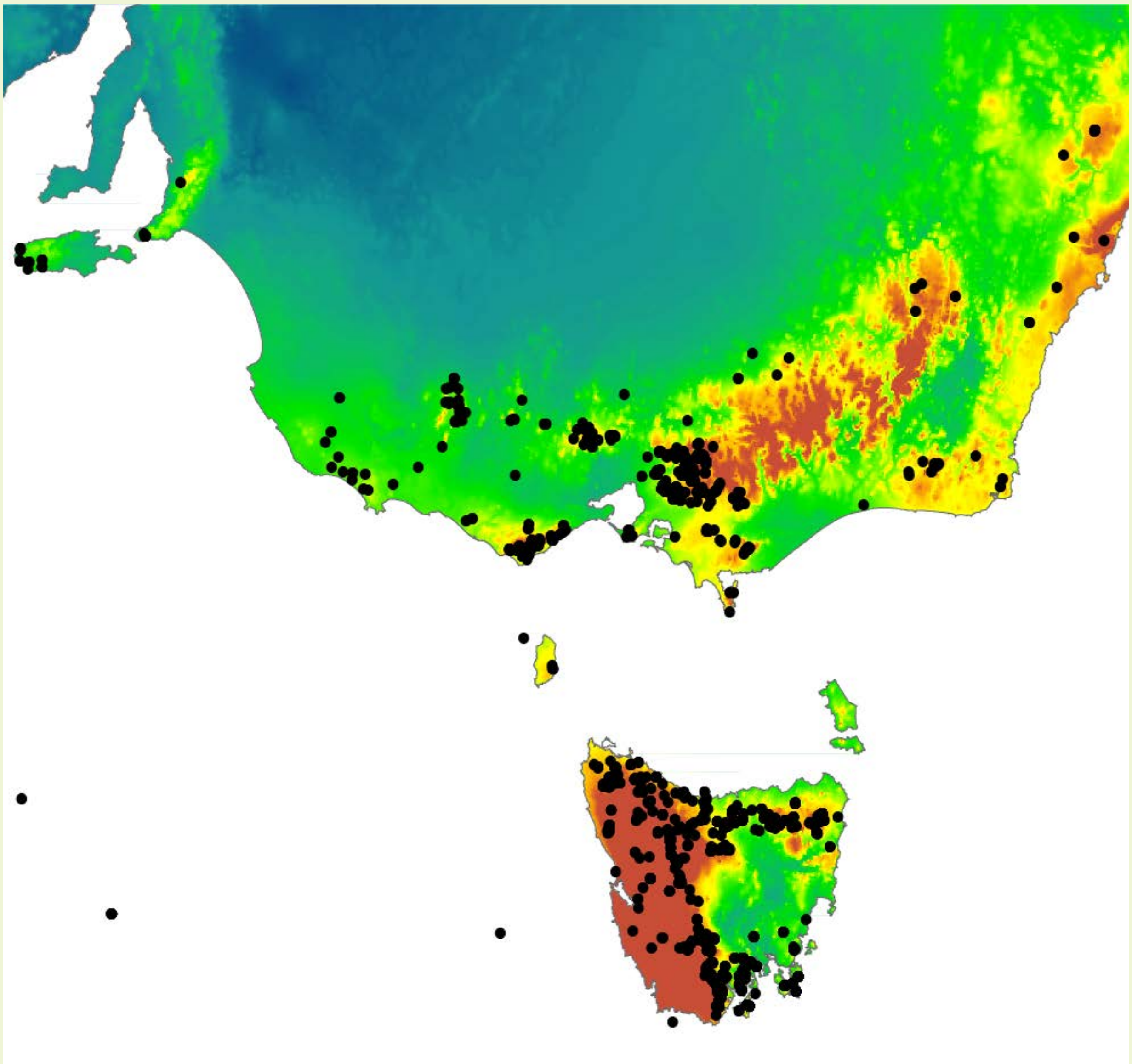
This unprecedented generation of, and access to, fungi data reveals widespread distribution patterns for many fungi, including detail of outliers and fragmentation. In addition, the ALA data confirm the rarity of some rare and threatened species of fungi. Fungimap has recently implemented a rare species database to allow more detailed tracking of location, population size and microdistribution of individuals for rare and threatened species such as tea-tree fingers (*Hypocreopsis amplectens*).

Ready access to fungi data through the ALA by a wide community (including land managers, researchers, naturalists and students) is in turn stimulating recording and collecting of fungi. The next step is to increase understanding of the requirements of each fungus in terms of host, substrate and habitat, to facilitate effective management. In addition, fungi distribution data accessible through the ALA will underpin comprehensive threat assessments for Australian fungi.

Blue pixie's parasol (*Mycena interrupta*) is one of the target species of Fungimap; it favours high-rainfall areas of south-eastern Australia, extending to southern Queensland

Photo by Steve Axford

Box BIO7 (continued)



Note the outlying populations on Kangaroo Island and Fleurieu Peninsula, South Australia.
Source: Atlas of Living Australia, used under CC BY 3.0

Figure BIO18 Distribution of blue pixie's parasol (*Mycena interrupta*) visualised in the spatial portal of the Atlas of Living Australia, based on 2838 records

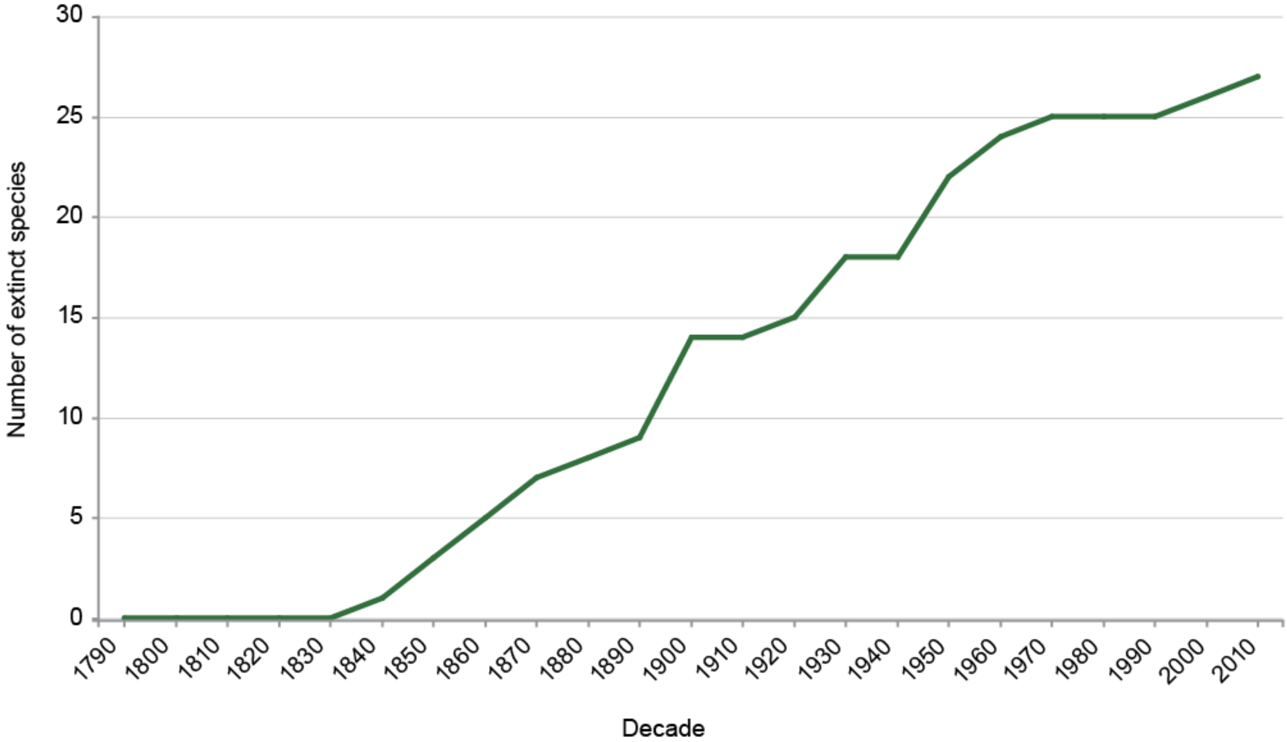
Source: Tom May, Royal Botanic Gardens Victoria, and the Fungimap Conservation and Biodiversity Subcommittee

The extinction of the Bramble Cay melomys followed that of the Christmas Island pipistrelle (*Pipistrellus murrayi*), a tiny insect-eating bat, in 2009. Although its decline had been monitored for 15 years, the decision to start a captive breeding program was delayed for 3 years after the program was first recommended, and no individuals could be captured (Martin et al. 2012). The last echolocation call of the species was detected in August 2009.

In northern Australia, evidence of ongoing mammal declines (major extinction of mammals occurred following European settlement of Australia; Figure BIO19) has continued to be evident in the Top End of the Northern Territory and the Kimberley region of Western Australia. Although not definitive, Cape York Peninsula has remained relatively stable, with the composition of mammal fauna in surveys from 2009 to 2012 similar to that from early descriptions (1948–80) and from surveys in 1985 (Perry et al. 2015).

In encouraging signs in arid Australia, improved data and targeted surveys have led to a better understanding of the distribution and abundance of critically endangered species (see Box BIO8), and the recommended downlisting of the conservation status of other species, such as marsupial moles (Woinarski et al. 2014).

In southern and eastern Australia, the number of species of conservation concern has increased, including what were previously common mammals. For instance, the arboreal greater glider (*Petauroides volans*) was once a common species but is now in steep decline (Lindenmayer et al. 2015) and has been listed as vulnerable under the EPBC Act. Some species face imminent extinction. The Leadbeater's possum has been listed as a species needing emergency intervention under the Australian Government's Threatened Species Strategy of 2015.



Note: The extinction of 3 species—*Bettongia pusilla*, *Conilurus capricornensis* and *Pseudomys glaucus*—cannot be readily and reliably dated, and these are not included in the timeline graph.
Source: Reproduced with permission from Woinarksi et al. (2014), © CSIRO Publishing, all rights reserved

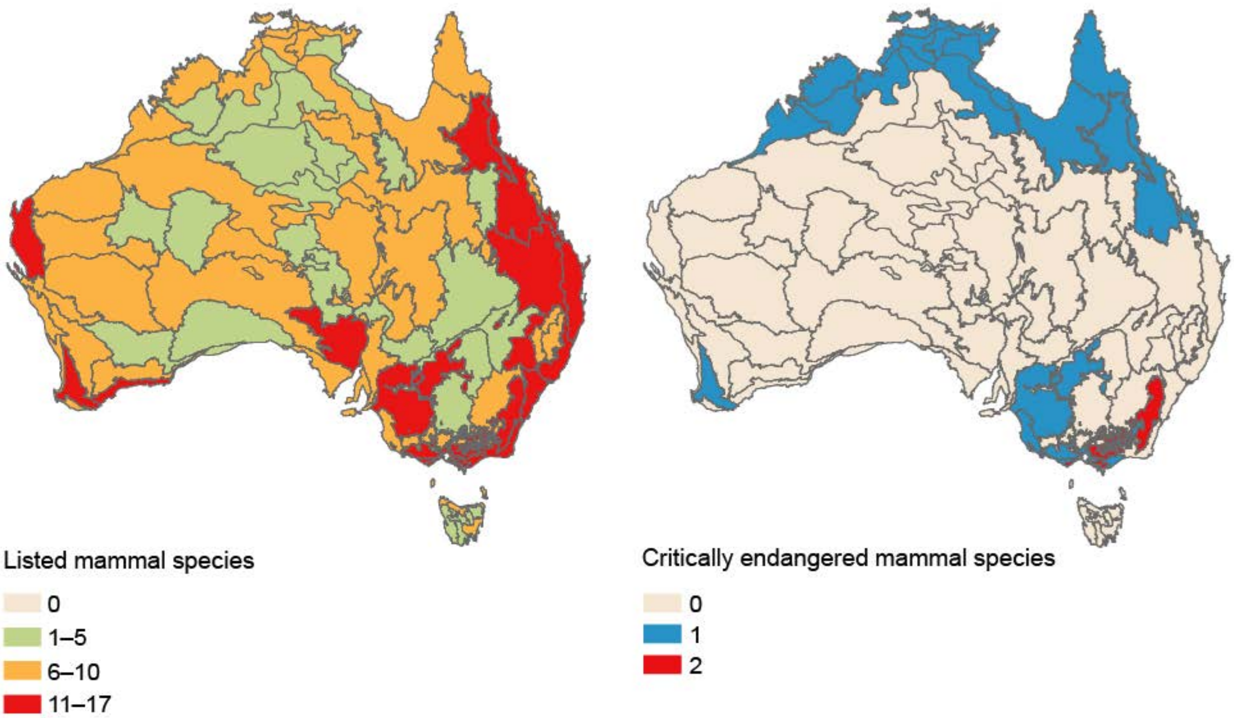
Figure BIO19 Cumulative historical extinctions of Australian mammal species

The action plan for Australian mammals 2012 (Woinarski et al. 2014) recommended major changes to the current list of mammals under the EPBC Act, leading to many species being listed for the first time or delisted, or having their status upgraded or downgraded. Many other species have been prioritised for assessment because of the action plan. The overall picture shows more decline than improvement. The plan recommended that:

- 39 EPBC Act–listed species (or at least 1 subspecies if the species is not listed) be elevated to one of the threatened categories or have the category that they are in elevated to a higher threat level (e.g. from vulnerable to endangered)
- 21 EPBC Act–listed species be delisted from one of the threatened categories or have the category that they are in downgraded to a lower threat level (e.g. from endangered to vulnerable)
- 8 EPBC Act–listed subspecies (where the species is not listed as threatened) be delisted from one of the threatened categories or have the category that they are in downgraded to a lower threatened level.

The action plan for Australian mammals 2012 also recommended retrospectively adding 8 extinct species that were previously not described or recognised as species under the EPBC Act: western long-beaked echidna (*Zaglossus bruijni*), desert bettong (*Bettongia ogilbyi*), Nullarbor dwarf bettong (*Bettongia pusilla*), Capricorn rabbit-rat (*Conilurus capricornensis*), broad-cheeked hopping mouse (*Notomys robustus*), long-eared mouse (*Notomys macrotis*), blue-grey mouse (*Pseudomys glaucus*) and Percy Island flying fox (*Pteropus brunneus*). These species add to the severity of the modern extinction event of mammals in Australia (Figure BIO19); the 30 mammal extinctions in Australia since European settlement is vastly greater than that recorded for any other country (Woinarski et al. 2015).

The highest numbers of EPBC Act–listed mammal species occur along the east and south coasts of Australia, and in the Murray–Darling (Victoria, New South Wales), Gawler (South Australia) and Carnavon (Western Australia) IBRA regions (Figure BIO20).



Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2016

Figure BIO20 Numbers of mammal species and critically endangered mammal species listed under the *Environment Protection and Biodiversity Conservation Act 1999* in each Interim Biogeographic Regionalisation for Australia region

Box BIO8 The central rock-rat

The central rock-rat (*Zyzomys pedunculatus*) is a medium-sized (body mass 70–150 grams) native rodent (family Muridae) that is endemic to the mountain ranges and adjacent foothills of arid central Australia. *The action plan for Australian mammals 2012* recommends an upgrade to its conservation status. Currently listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999*, it is recommended for an upgrade to critically endangered, given the apparent ongoing decline in population size, and its small area of occupancy and area of occurrence (Woinarski et al. 2014). It is already globally listed as critically endangered by the International Union for Conservation of Nature.

The central rock-rat has 'appeared' and 'disappeared' multiple times during the past 100 years. From its discovery in the 1890s until 1960, the species was recorded from several mountain range systems in central Australia. However, it then disappeared and—despite focused search effort—was not found again until 1996, when it was rediscovered in the MacDonnell Ranges. During the next 7 years, the central rock-rat was recorded at 13 sites across 600 square kilometres in and around West MacDonnell National Park. In 2002, when drought conditions prevailed and wildfires burned a large proportion of the region, the central rock-rat disappeared again. It was not until targeted surveys were held in 2009–10 that a population was located near the summit of Mount Sonder (at 1380 metres above sea level). Since then, the species has been recorded from a series of locations on high-elevation (more than 1100 metres) quartzite ridges and mountain peaks, despite substantial survey effort at lower elevations and on other geologies. Vegetation at occupied sites is characterised by a ground layer dominated by either hummock grasses or a mixture of forbs and subshrubs, with the upper strata comprising scattered shrubs or mallee-form eucalypts. The species is considered to be holding on in refuges (Pavey et al. 2015), and management of these core refuge areas, particularly by reducing threats from predators such as cats, is the focus of intensive management effort.

The Australian Government's Threatened Species Strategy 2015 recognises the central rock-rat as a species on the brink of extinction and highlights it as a species for emergency intervention.

Central rock-rat

Photo by Peter McDonald, Flora and Fauna Division, Northern Territory Government

Source: Chris Pavey, CSIRO

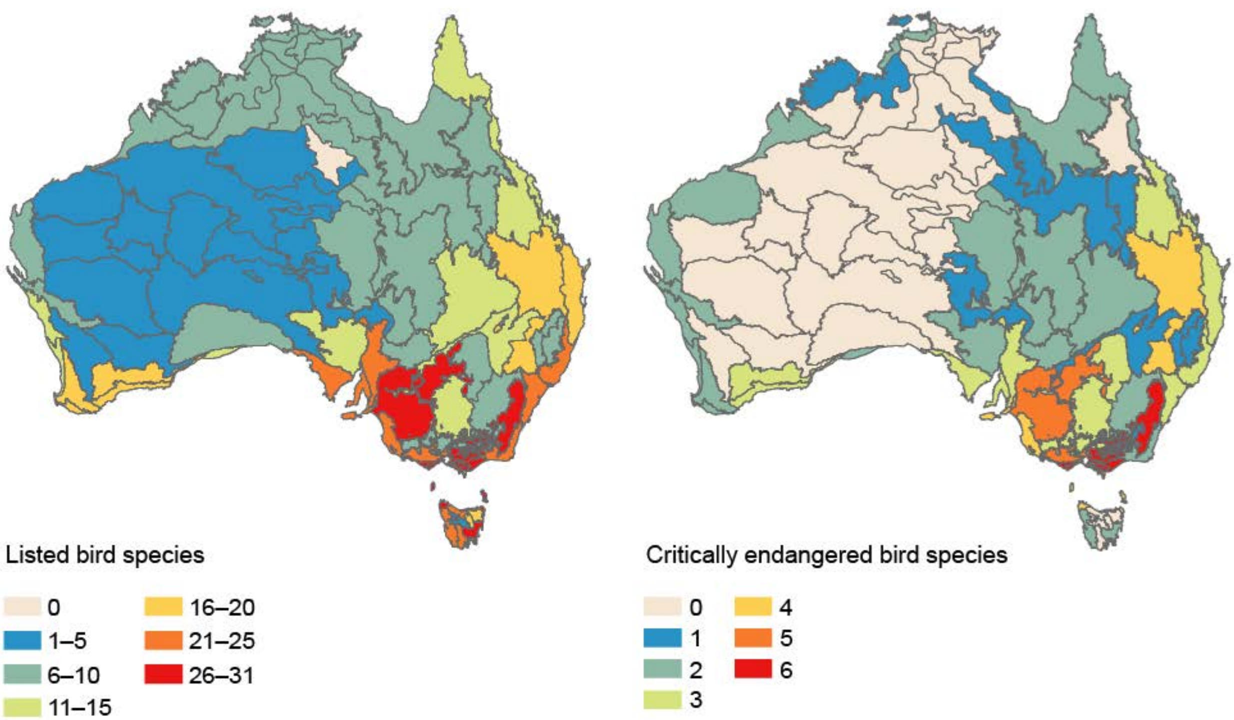
Pale-yellow robin (*Tregallasia capito*), Wet Tropics World Heritage Area, Queensland
Photo by David Westcott

Birds

BirdLife Australia undertakes Australia's largest citizen-science effort in producing regular national assessments of the state of Australia's birds, known as the Australian Bird Indices. BirdLife Australia also publishes an assessment of trends in bird numbers and distribution on a regional level every 5 years in the State of Australia's Birds (BirdLife Australia 2015). The Action Plan for Australian Birds provides 10-yearly updates on the status of Australia's bird taxa. *The action plan for Australian birds 2010* (Garnett et al. 2011) assesses 27 taxa as extinct, 20 as critically endangered, 60 as endangered, 68 as vulnerable and 63 as near threatened (as at 31 December 2010). *The state of Australia's birds 2015* shows variable trends in the IUCN status of Australian bird taxa from 2010 to 2015. The number of critically endangered (possibly extinct) and near threatened species has remained stable, the number of critically endangered and vulnerable taxa has increased, and the number of endangered taxa has decreased. Overall, in the threatened categories, the number of listed taxa has risen by 1 from 147 taxa (2010) to 148 taxa (2015).

The state of Australia's birds 2015 assesses trends on a regional level and across functional groupings of birds (including aerial insectivores, carnivores, common species, ground nesters, hollow nesters and mallee woodland–dependent species). Based on data up to 2013, major trends identified include the following (Figure BIO21):

- In the eastern mallee region, index values for common species, hollow nesters and mallee woodland–dependent species remained significantly below baseline levels (mallee woodland–dependent species being well below the baseline level).
- In the arid zone, the index values of 4 of the 6 functional groups were in significant decline by 2013. The most dramatic decline was in the carnivore group, where 12 of 20 species showed significant declines (see Box BIO9).
- In the east coast region, the index values do not show a consistent pattern. Some groups, such as rainforest-dependent species, appear to be increasing.
- In the south-eastern mainland, by 2013, index values for 4 groups were marginally above and indices for 2 groups were marginally below baseline levels.
- Mixed results (both decreases and increases) produce no consistent trend in the tropical savanna, Brigalow Belt and Tasmanian regions.
- The overall results can be judged as an overall decline in the state of birds.



Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2016

Figure BIO21 Numbers of bird species and critically endangered bird species listed under the *Environment Protection and Biodiversity Conservation Act 1999* in each Interim Biogeographic Regionalisation for Australia region

Box BIO9 The letter-winged kite

Australia is a country of boom and bust, and the previous state of the environment report in 2011 predicted that the extensive rainfall and floods in Australia in 2010–11 would lead to positive animal responses. However, the 2010–11 big wet in arid Australia did not see some species that had previously boomed following wet years return in large numbers.

The letter-winged kite (*Elanus scriptus*) is perhaps the best example of this trend. This kite lives in arid Australia, with most records from the Channel Country of western Queensland. It forages at night for small mammals, especially rodents. The letter-winged kite is the only species from the 2 orders of diurnal bird of prey (or raptors) that is capable of nocturnal activity, and is behaviourally unique on a global scale. It is sometimes referred to romantically as the 'moon kite of the Diamantina'.

The species occupies a region that has among the most unpredictable rainfalls on Earth. These unpredictable high-rainfall events trigger great flushes of vegetation and corresponding irruptions of the rodent prey of the letter-winged kite. In the years following such high-rainfall events, the numbers of rodents increase dramatically, and, in the past, kites responded by breeding rapidly and dispersing widely. These booms have occurred approximately every 10–15 years; however, for the vast majority of time, letter-winged kite populations are small and appear to persist in refuge areas that make up a small proportion of the area occupied during population irruptions.

Following the big wet of 2010–11, few records of the letter-winged kite have been made. For example, a site on Andado Station in the south-eastern Northern Territory that had up to 126 birds during the wet period of 2000–01 had only 9 birds in 2011, and this trend is nationwide. There are now grave concerns for its continued persistence. The causes of the decline are complex and not fully understood; however, introduced predators (feral cat and European red fox) are implicated in taking large numbers of rodents. This predation has restricted the ability of some rodent species to irrupt, and it seems that this has, in turn, affected the native predators of rodents such as the letter-winged kite. In addition, cats prey directly on kites at the nest, including vulnerable populations occupying drought refuges.

The kite is indicative of the decline in arid-zone carnivores noted in *The state of Australia's birds 2015* reporting.

Letter-winged kite

Photo by Peter Nunn, Ninox Photography

Sources: Chris Pavey, CSIRO; Pavey & Nano (2013); Dooley (2015)

Reptiles and amphibians

As was the case in SoE 2011, there has been little improvement in the status of listed reptile and amphibian taxa at the national level. However, some species are known to be performing better than previously thought—this is because increased survey effort has revealed greater ranges or additional, previously unknown populations. Examples are Allan's lerista (*Lerista allanae*), pygmy bluetongue lizard (*Tiliqua adelaidensis*), Eungella torrent frog (*Taudactylus eungellensis*) and waterfall frog (*Litoria nannotis*). Numerous species have been delisted or downlisted in state and territory legislation, whereas others have been uplisted. For example, in Queensland, 30 amphibians and reptiles were downlisted in December 2014, and 21 species were uplisted in August 2015. The uplistings include 3 from endangered to extinct, although these species were long recognised by the scientific community as being extinct.

The Christmas Island forest skink (*Emoia nativitatis*) has become extinct since 2011, with the last remaining captive individual dying on 31 May 2014 (Woinarski et al. 2017). Limited monitoring indicates that the species declined rapidly (along with other native reptiles on Christmas Island) after the late 1980s. The forest skink was listed as critically endangered in January 2014, only 4 months before its extinction. Two other Christmas Island reptiles are now considered extinct in the wild (see Box BIO10).

In contrast to the situation for mammals and birds, no new national action plans have been developed for amphibians and reptiles since SoE 2011. Both *The action plan for Australian frogs* (Tyler 1997) and *The action plan for Australian reptiles* (Cogger et al. 1993) are out of date. *The action plan for Australian frogs*, for example, was published before chytridiomycosis was identified as the likely cause of many frog declines and extinctions (Figure BIO22), and before the description of the pathogenic species *Batrachochytrium dendrobatidis* (see Pathogens).

The nationally endangered waterfall frog (*Litoria nannotis*) is endemic to the Wet Tropics of Queensland
Photo by Eric Vanderduys

Box BIO10 Ongoing declines of Christmas Island reptiles

Christmas Island covers an area of about 135 square kilometres, consisting of a large central plateau surrounded by a series of steep cliffs, terraces and slopes.

Five native terrestrial reptile species occur on the island, 4 of which are endemic. A sixth species that was endemic became extinct in 2014—Christmas Island forest skink (*Emoia nativitatis*). Five terrestrial reptile species have been introduced to Christmas Island (Smith M et al. 2012).

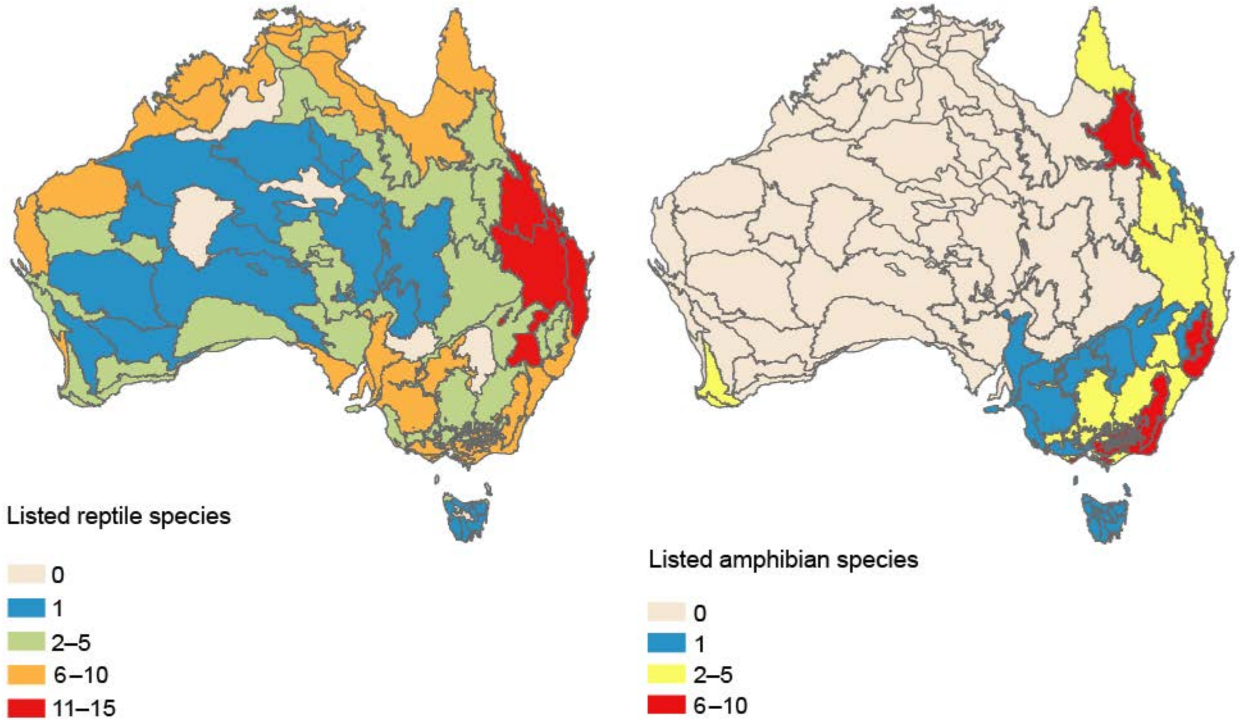
In the past 20–30 years, 4 of the remaining 5 species have declined significantly; 2 are listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act; Christmas Island blue-tailed skink—*Cryptoblepharus egeriae,* and Lister's gecko—*Lepidodactylus listeri*), and 1 is listed as endangered (Christmas Island giant gecko—*Cyrtodactylus sadleiri*). The coastal skink (*Emoia atrocostata*) has not been recorded in the wild since 2004 (it is not currently listed under the EPBC Act), the blue-tailed skink was last recorded in the wild in 2010, and Lister's gecko has not been recorded since 2012 (Webb et al. 2014). All were recorded as abundant in 1979 (Cogger et al. 1983). A fourth species, Christmas Island blind snake (*Ramphotyphlops exocoeti*), has been recorded so infrequently that the data are insufficient to assume a decline; it is listed as vulnerable under the EPBC Act.

Captive breeding programs have been successful for blue-tailed skink and Lister's gecko; by late 2016, more than 890 blue-tailed skinks and more than 700 geckos were in captivity on Christmas Island and in Taronga Zoo. However, the future of these species remains uncertain, since the processes threatening their persistence in the wild are not well understood (Webb et al. 2014). The success of the breeding program has provided the opportunity for the trial release of blue-tailed skinks into predator-proof compounds on the island to help assess effectiveness of predator control.

Predation by introduced predators is thought to be the key factor in the decline of native reptiles on Christmas Island. Many known reptile predators have now been introduced to the island, including the domestic/feral cat (*Felis catus*), house mouse (*Mus musculus*), giant centipede (*Scolopendra subspinipes*), red jungle fowl (*Gallus domesticus*), yellow crazy ant (*Anoplolepis gracilipes*), Asian wolf snake (*Lycodon capucinus*), black rat (*Rattus rattus*), and barking or house gecko (*Hemidactylus frenatus*) (Smith M et al. 2012).

'Gump', the last remaining captive forest skink (*Emoia nativitatis*), died in May 2014

Photo by Parks Australia



Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2016

Figure BIO22 **Numbers of reptile and amphibian species listed under the *Environment Protection and Biodiversity Conservation Act 1999* in each Interim Biogeographic Regionalisation for Australia region**

Invertebrates

Most of Australia's estimated 500,000 species are invertebrates, and half are insects. Invertebrates are the ecological glue that holds ecosystems together; they are a food source for many vertebrates, and provide ecological services such as nutrient recycling, pest control and pollination. Despite these critically important functions, invertebrates are rarely the iconic or charismatic animals that garner human attention, although some play an important role in Indigenous beliefs (see Box BIO11). In addition, several species transmit diseases to humans and animals.

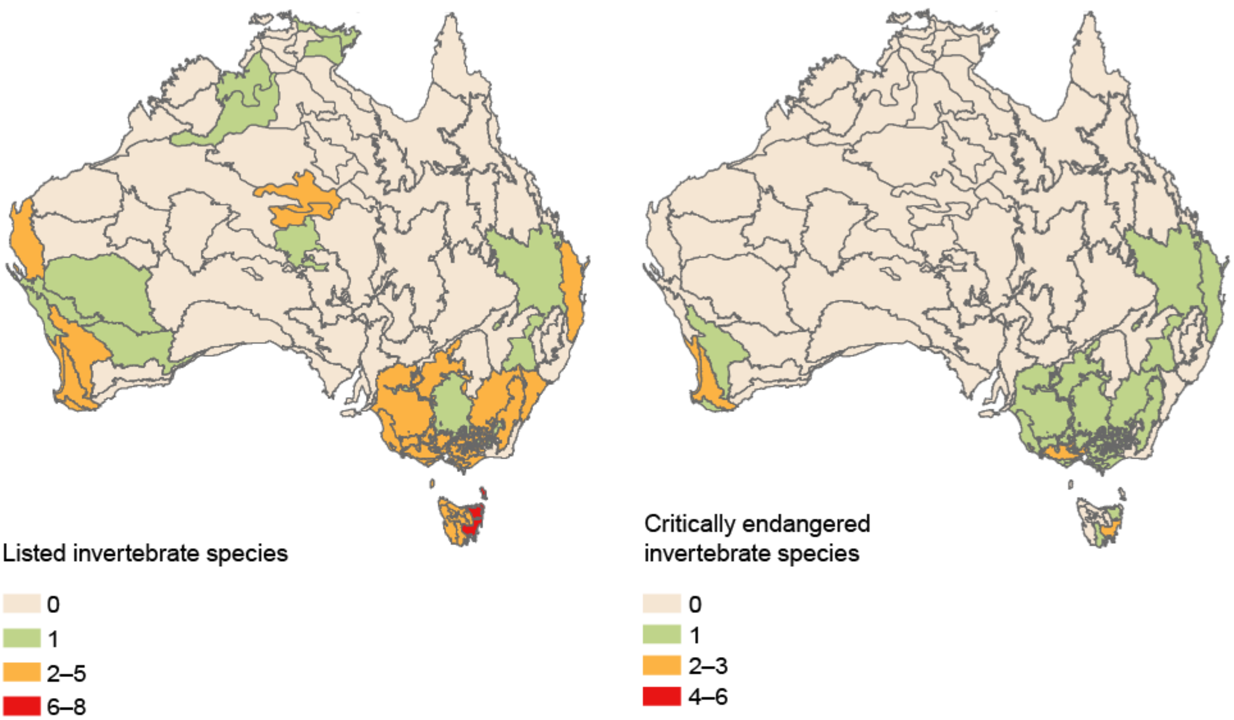
Unlike plants and mammals that are relatively well known, only about 25–30 per cent of Australia's insects have been formally catalogued and named by scientists. Many invertebrate species are small, have restricted distributions, have precise ecological requirements, and are difficult to identify without specialist knowledge and techniques. However, because of these attributes, many species are sensitive to very subtle environmental changes.

The main pressures on Australia's invertebrate biodiversity—habitat reduction and fragmentation, altered fire regimes, invasive species, and climate change—are increasing. There have been few direct measures of the status of Australia's invertebrate biodiversity. Indirect evidence from estimates of forest cover, and the distributions of rare and threatened vertebrates and plants suggests that invertebrate populations continue to be at increased extinction risk, especially along the east coast of Australia and in the south-west of Western Australia.

The IBRA regions containing the highest number of EPBC Act–listed invertebrates are in eastern Tasmania (Figure BIO23) and on Australian islands that cannot be seen in this figure. The Pacific Subtropical Islands IBRA region, including Lord Howe Island and Norfolk Island, contains 8 listed invertebrates, including 6 that are critically endangered. Flinders Island to the north-east of Tasmania also contains 8 listed species, including 5 that are endangered.

Seven of the 8 listed fauna on Norfolk Island (1 species) and Lord Howe Island (6 species) are land snails; the remaining species is Lord Howe Island phasmid (*Dryococelus australis*). Lord Howe Island fauna have suffered significantly from the introduction of exotic animals and human disturbance.

Listed species from eastern Tasmania and Flinders Island include insects (e.g. Tasmanian chaostola skipper—*Antipodia chaostola leucophaea*; endangered), crayfish (e.g. Furneax burrowing crayfish—*Engaeus martigener*; endangered), beetles (e.g. broad-toothed stag beetle—*Lissotes latidens*; endangered) and other invertebrates (e.g. blind velvet worm—*Tasmanipatus anophthalmus*; endangered).



Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2016

Figure BIO23 Numbers of invertebrate species and critically endangered invertebrate species listed under the *Environment Protection and Biodiversity Conservation Act 1999* in each Interim Biogeographic Regionalisation for Australia region

Box BIO11 Caterpillars as big as a mountain: the role of spiritual beliefs about animals and plants

Certain caterpillars have cultural relationships with Indigenous Australians that highlight complex links between ecology and human ecology. These caterpillars are imbued with meanings, values and uses for Aboriginal people that are very different from how western science views these species. Collaboration between Aboriginal knowledge holders and western scientists can provide land management information and the motivation needed to improve habitats that support valuable species.

Alice Springs, known as *Mparntwe* to Aboriginal and local people, has many sacred sites. Arrernte people believe these sites to be associated with ancestral beings who metamorphose as animals and plants, which can also be totems for individual people. Ancestral beings, including 4 different types of caterpillars and 1 beetle, created parts of the MacDonnell Ranges, and certain gaps, rock piles, trees and woodlands in the Alice Springs region. The caterpillar ancestors travelled from various directions through the region.

For Arrernte people, the imposing ridgeline of the eastern MacDonnell Ranges is also the *ayepe-arenye* caterpillar, and the *ntyalke* formed parts of the western MacDonnell Ranges. One dramatic gap (*ntaripe*/Heavitree), through which rivers periodically flow and people travel, is believed by Arrernte people to be formed where the *ilperenye* beetle savaged the *ayepe-arenye* and chewed off their heads.

These caterpillar characters correspond to 4 scientific taxa of hawk moth: *ayepe-arenye* is the white-lined hawk moth (*Hyles livornicoides*); *ntyalke* is the vine hawk moth (*Hippotion celerio*); *utnerrengatye* is the moth *Coenotes eremophilae*; and the fourth *irkngeltye* is possibly the convolvulus hawk moth (*Agrius convolvuli*).

Arrernte names and knowledge associate each caterpillar with a particular plant taxon: tarvine (*Boerhavia diffusa* and *B. schomburgkiana*), emu bush (*Eremophila longifolia*) and pink rockwort (*Sedopsis filsonii*). The plants provide forage and habitat for each caterpillar. The Arrente significance and complex linkages are exemplified in the word *ayepe*, which is synonymous with the plant *B. diffusa*, the umbilical cord of a newborn baby, and a practice that cares for the baby's wellbeing. The *ayepe* (tarvine) plant is habitat to *ayepe-arenye*, the caterpillar.

The caterpillars were also once an exceptional food source:

> *In olden times, people used to get all the yeperenyes and prepare them [to eat] in a ceremonial way … they have a certain way of cooking it up, gathering them and putting them in a coolamon [and] share it out with their families … they were tasty and fatty, more like prawns.* (Rosie Furber, Northern Territory Government, n.d.)

Nowadays, they are not eaten, perhaps partly because of their sacredness and increasing scarcity.

Arrernte expert Veronica Perrurle Dobson says:

> *There were once a lot of ayepe (tarvine) growing here. The tar vines relates to the ayepe-arenye caterpillar. Ayepe-arenye caterpillar lives on the ayepe plant and eats it bare then lays its eggs and goes underground to cocoon. It's a cycle that these plants and grubs go through.* (VP Dobson, pers. comm., 3 Dec 2015)

Custodians worry about declines in these iconic species. For example, *irkngeltye* is rarely seen, and *ayepe-arenye*, once common, persists in pockets. These declines can be slowed with the reintroduction of Arrernte landcare practices, weed removal and sacred site protection. Arrernte beliefs and knowledge provide insight into the ecological processes that can be observed, and link culture to land management for future generations of Aboriginal people and other Australians.

a) Caterpillar on tarvine

Box BIO11 (continued)

b) 4 caterpillars of 2 species

e) Caterpillar on tarvine with ochre sand background

c) Buffel grass with caterpillar range behind

f) Google Earth image screenshot

Images 1 to 5 provided by Fiona Walsh, Alice Springs, used under CC BY NC ND. Image f sourced from Google Earth v 6.2.2 (5 February 2009). Alice Springs, Australia, 23°17.67″S, 133°51′48.89″E, eye alt 7.74 km. 2016 Aerometrics. Google Earth, accessed 19 January 2016

d) Caterpillar on tarvine

Source: Fiona Walsh, CSIRO. Study sources included bush-based observations; senior Arrente knowledge holders Rosie Furber (dec.), Wenton Rubuntja (dec.), Veronica Perrurle Dobson and Doris Stuart; and Alice Springs ecologists Mike Gillam and David Albrecht. Martu people also provided information about species used as food. Max Moulds provided photo-based identification for the caterpillar species.

Freshwater species and ecosystems

The *Inland water* report assesses the state and trends of freshwater-related ecological processes and key species populations, with grades ranging from very poor with worsening trends across the Murray–Darling Basin, through poor to good condition with stable trends for south-eastern and south-western regions, to good grades for much of the rest of the country.

Despite being one of the world's most arid countries, Australia's aquatic environment supports a rich diversity and endemicity. Inland waters are characterised by high variability, which has shaped aquatic ecosystems. A significant number of plants and animals are dependent on these ecosystems during at least part of their lifecycle. Changes in land use and land management practices—such as changes in flow, water quality and the availability of habitat—can place significant pressures on aquatic environments. Freshwater and riparian ecosystems are also likely to be highly vulnerable to the effects of the current phase of rapid anthropogenic climate change because of their high levels of exposure and sensitivity to changes in climatic stimuli.

Jurisdictional reporting on freshwater species and ecosystems

Jurisdictions generally report the condition of aquatic ecosystems as poor to moderate, although availability of information is often described as poor or limited.

Australian Capital Territory

- Key trends:
  - Ecological condition of waterways in the Australian Capital Territory is generally poor, partly because sampling mostly occurs in areas that are heavily affected by urban or rural land use.
  - Since 2011, the number of sites monitored for ecological condition rated as severely or significantly impaired has declined, and the percentage of sites rated as similar to minimally disturbed reference areas has increased from 24 per cent to 34 per cent.
- Assessment grade and adequacy of information:
  - Ecological condition: grade—poor; trend—improving; confidence in grade and trend—good.

New South Wales

- Key trends:
  - The overall condition of rivers across New South Wales is moderate. Riverine aquatic ecosystems in the major rivers of the Murray–Darling Basin are generally in poorer condition than those in coastal rivers.
  - Fish communities are generally in poor condition across the state and continue to decline within the Murray–Darling Basin. The widespread distribution of introduced carp in the Murray–Darling Basin has had a significant impact on the health of fish communities.
  - Nine of the 28 native freshwater fish species found in the New South Wales portion of the Murray–Darling Basin are listed as threatened with extinction under the *Fisheries Management Act 1994*, and an additional 4 fish species have populations listed as endangered. Seven freshwater invertebrates are also listed as threatened species under the Act.
  - Freshwater fish surveys during the past 3 years found that
    - 8 per cent of all sites sampled were free from introduced fish, mainly in coastal rivers
    - 12.7 per cent of sites contained only introduced fish
    - introduced taxa accounted for 50 per cent of the fish species collected at each site, 52 per cent of total fish abundance and 72 per cent of total fish biomass, averaged across all sites

    These numbers are higher than those reported in NSW SoE 2012.
  - Increased rain and flooding from 2010 to 2012 inundated many wetlands, increasing waterbird abundance and breeding activity. In 2013–14, the return to a drying climatic phase has seen a reduction in the extent of wetland inundated, and a decrease in waterbird abundance and breeding activities.
  - Inland wetland vegetation communities that have received environmental watering have improved in condition since 2012. On-ground surveys at sites that received environmental water revealed that vegetation condition and waterbird diversity were maintained, with many of these wetlands acting as refuges for dependent species during the drying period.

- Assessment grade and adequacy of information:
    - Ecosystem health for the Murray–Darling Basin rivers: grade—poor; trend—stable; information availability—limited.
    - River condition for New South Wales rivers: grade—moderate; trend—unknown; information availability—limited.
    - Health of fish assemblages: grade—poor; trend—increasing impact; information availability—reasonable.
    - Nitrogen and phosphorus levels: grade—moderate; trend—decreasing impact; information availability—reasonable.
    - Wetland extent: grade—moderate; trend—stable; information availability—limited.
    - Wetland condition: grade—moderate; trend—stable; information availability—limited.
    - Waterbird abundance and diversity: grade—poor; trend—increasing impact; information availability—good.
    - Extent and condition of groundwater-dependent ecosystems: grade—unknown; trend—uncertain; information availability—limited.

Queensland

- Key trends:
    - Sediment, nutrients and chemicals, and the loss of riparian forests are the major catchment pressures that broadly affect Queensland's freshwater rivers, but vary in their relative importance between regions.
    - More than 94 per cent of the pre-European settlement extent of freshwater wetlands in Queensland remained in 2013. Changes in the extent of freshwater wetlands have been monitored in Queensland since 2001. Wetland loss peaked at a rate of 0.12 per cent during 2001–05. The rate of freshwater wetland loss decreased to 0.04 per cent during 2005–09 and 0.03 per cent in 2009–13.
    - Of the 3 freshwater wetland systems—lacustrine, palustrine and riverine—the greatest ongoing losses have occurred in palustrine and riverine systems in the Murray–Darling and North East Coast drainage divisions.
    - Eight per cent per cent of freshwater wetlands in Queensland are within protected areas. The majority are palustrine systems and are within national parks.
    - Invasive non-native fauna species, particularly pest fish, are relatively widespread in some sections of Queensland's freshwater ecosystems, and have the potential to degrade and modify aquatic environments, and displace native species.
    - Invasive non-native flora species can have significant impacts on freshwater ecosystems, including smothering native vegetation, blocking creeks, reducing water quality by preventing light penetration, reducing oxygenation of water, and choking out fish and other aquatic wildlife.
- Assessment grade and adequacy of information:
    - Queensland is well covered by water quality monitoring at different timescales, from annual report cards in coastal areas to less frequent monitoring in more remote regions. Areas such as the Gulf of Carpentaria and parts of the Murray–Darling Basin have not yet been covered, but will be addressed in future programs.
    - Assessment grades vary from one report card to another, and across time periods.

Victoria

- Key trends:
    - Results from the 2010 Index of Stream Condition report show that 23 per cent of major rivers and tributaries in Victoria were in good or excellent condition, 43 per cent were in moderate condition, and 32 per cent were in poor to very poor condition.
    - Almost half the basins in Victoria have less than 10 per cent of major rivers and tributaries in good or excellent condition. These are mainly in the mid-west of Victoria and have been extensively cleared for agriculture.
    - Results for riparian vegetation show that 21 of 29 river basins had less than 50 per cent of their assessed river length with riparian vegetation in good condition. Basins in the east of the state were generally in better condition than those in the west because of extensive clearing for agriculture.
    - Only 56 per cent of Victoria's high-value wetlands were assessed as being in good or excellent condition, and 14 per cent were in poor or very poor condition. For wetlands that are not of high value, 51 per cent were assessed as being in good or excellent condition, and 26 per cent in poor or very poor condition.

- The condition of wetlands on private land was poorer.
- Fish and amphibian species make up most critically endangered and endangered aquatic species; 43 per cent of amphibians and 55 per cent of freshwater fish are threatened in Victoria.
- Between 2007 and 2013, 9 inland aquatic vertebrate species declined in status, and 4 species were added to the Advisory List because of decreasing populations. Only 5 species improved their threatened status.
- In 20 of Victoria's river basins, non-native fish accounted for 60 per cent of the total fish biomass, and for more than 90 per cent of the total biomass in 7 river basins.

- Assessment grade and adequacy of information:
  - Condition of freshwater aquatic ecosystems: grade—poor; trend—stable; data quality—good.
  - Freshwater biodiversity: grade—poor; trend—deteriorating; data quality—good.
  - Statewide information on the number and distribution of introduced aquatic species remains poor and has not been updated since the 2008 Victorian SoE report.

South Australia

- Key trends:
  - Rivers, streams and drains that are in poor condition typically have elevated levels of nutrients, salt and fine sediment, as well as sparse vegetation and abundant weeds along their banks.
  - Some aquatic pests are increasing (European fan worm—*Sabella spallanzanii*, and oriental weatherloach—*Misgurnus anguillicaudatus*).
  - The distribution of European carp is stable, and species such as the alga *Caulerpa taxifolia* and speckled livebearer (*Phalloceros caudimaculatus*) are decreasing.
  - The distribution and abundance of aquatic and marine pests are largely unknown.
- Assessment grade and adequacy of information:
  - On average, rivers, streams and drains were assessed as fair. Reliability of information is very good.
  - The assessment grade for aquatic pests is given as unknown, and the reliability of information is poor.
  - The assessment grade for diseases affecting aquatic species is good (South Australia is relatively free from aquatic diseases), and the reliability of information is good.

Western Australia

- Key trends:
  - Fourteen freshwater (nonsubterranean) aquatic fauna species are listed as threatened, and 1 is listed as 'other specially protected'. A subterranean fauna biodiversity hotspot is recognised in the north-west of Western Australia, where 3 threatened vertebrate stygofauna are known from karst systems.
  - Aquatic threatened ecological communities are in varying condition, with a drying climate and altered hydrology (salinity, acidity, waterlogging, abstraction, reinjection) impacting on water quality and levels. As a result, vegetation, invertebrates and microbialite (thrombolite/stromatolite-like) assemblages of these communities are generally declining.
  - Hydrological mediation works are improving lake and assemblage condition in some areas.
  - Karst systems, including a threatened ecological community of stygofauna, are affected by physical removal, altered hydrology and altered water quality because of extraction of basic raw materials and minerals. Some springs are also impacted by groundwater drawdown associated with mining below the watertable. In some cases, spring flows and groundwater-dependent vegetation are maintained by artificial supplementation.
  - Approximately 20 per cent of wetlands on the Swan Coastal Plain are considered to retain high values. An analysis of Landsat satellite imagery from 1992 to 2012 indicates that approximately 4 hectares of perennial vegetation within wetlands are lost per day on the Swan Coastal Plain.

- Water storage in perennial and ephemeral lakes and wetlands has decreased in inland south-western Western Australia, increasing water and soil concentrations of salt, nutrients and sometimes acids. Eutrophication is occurring in some ephemeral wetlands from pastoral livestock. Riparian vegetation is generally declining in areal extent and density, because of declining groundwater levels from declining rainfall and land-use changes. Wetland depth has steadily declined across the south-west, at a rate disproportionately higher than the decline in rainfall that is the primary driver of the change. Soil carbon is decreasing in some organic wetlands, including in the Muir–Byenup Ramsar site.
- Groundwater-fed springs in the Mandora Marsh Ramsar site (north-western Western Australia) appear stable in extent, but show variable structure and condition. Poor condition is characterised by lower soil carbon, and higher weed and nutrient levels, associated with disturbance by cattle and camels.
- The invasive redclaw crayfish (*Cherax quadricarinatus*) has recently been found in natural waters of the Pilbara for the first time. Surveys are being undertaken to determine its extent and inform a management response.

- Assessment grade and adequacy of information:
  - Condition of lakes in threatened ecological communities—fair to good; condition of tumulus springs—excellent; condition of vegetation in threatened ecological communities—fair to good; condition of microbialite threatened ecological community—poor; trend—declining; reliability of information—excellent to fair.
  - Trends in extent and condition of wetlands on the Swan Coastal Plain—declining; reliability of information—good.
  - Wetland condition in inland south-western Western Australia—poor to moderate; reliability of information—good.
  - Extent and condition of groundwater-dependent ecosystems in north-western Western Australia is mostly unknown; trend is uncertain because of limited available information, but some groundwater-dependent ecosystems are artificially supplemented.

Tasmania

- Key trends:
  - Tasmania experienced exceptionally dry climatic conditions during winter–spring 2015 and summer 2015–16.
  - Results from Australian River Assessment System (AUSRIVAS) sampling at 98 sites (60 long-term sites and 38 additional sites) in spring 2015 across Tasmania showed that 52 per cent of the sites were rated as equivalent to reference condition, 32 per cent were significantly impaired, and 16 per cent were severely impaired.
  - Based on the spring 2015 results, the sites can be grouped into those that are
    - in good condition (typically with forested catchments)
    - quite affected (typically in agricultural catchments) and had ratings in spring 2015 that were in line with recent scores
    - very affected (typically in catchments with intense agriculture and/or in rivers that experienced very low flows in winter–spring 2015) and had the lowest ratings they have historically recorded in spring 2015.
  - These results reflect prolonged periods of very low flows in many rivers around Tasmania in winter–spring 2015 and the poor conditions they provide for aquatic fauna. Since May 2016, wetter than average climatic conditions have caused elevated baseflows and flooding in many rivers across Tasmania, which is likely to have improved the condition of some rivers.
- Assessment grade and adequacy of information:
  - Tasmania has a long-term (since 1998) river health monitoring program that employs AUSRIVAS protocols. This monitoring is based on sampling aquatic macroinvertebrates and using their community structure (and predictive models) to rate river condition.
  - Condition of Tasmanian rivers: grade—poor to good; trend—stable to declining; information availability—good.

Water rat
Photo by Eric Vanderduys

  - Assessment of data from several organisations external to the Department of Primary Industries, Parks, Water and Environment—including Forestry Tasmania, Hydro Tasmania and NRM regional groups, as part of determining state-specific guideline values for protecting aquatic ecosystems—indicates water quality supporting a range of ecological conditions, from high ecological value, to slightly to moderately disturbed ecosystem value. However, some inland water bodies are considered to have highly disturbed ecosystem value.

Northern Territory

- Key trends:
  - Large feral herbivores are the main immediate threat to many water bodies in the southern arid territory, affecting water quality, water volume and aquatic macroinvertebrates, and the surrounding ground vegetation. This pressure has been partly ameliorated by a large reduction in camel density under the Australian Feral Camel Management Project between 2009 and 2014, and ongoing reduction in feral horse densities in some Aboriginal Lands Trusts.
- Assessment grade and adequacy of information:
  - Freshwater ecosystems in the Northern Territory are generally in good condition, although quantitative data for trends are sparse and patchy.

Aquatic ecosystems

Two aquatic ecosystems were listed as threatened ecological communities under the EPBC Act since 2011: Coastal Upland Swamps in the Sydney Basin bioregion (listed 2014) were listed as endangered, and Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains (listed 2012) were listed as critically endangered. Clearing, altered hydrological processes and invasive species are indicated as ongoing threats to both ecosystems, as well as changed fire regimes and climate change.

Groundwater-dependent ecosystems

Groundwater-dependent ecosystems are geographically small, yet they are an important part of Australian biodiversity. Groundwater-dependent ecosystems are frequently connected to surface waters. In perennial rivers, such as the Daly and Roper rivers of the Northern Territory, permanent base flows are maintained by groundwater inputs during the dry season. Base flows allow fishes to persist through the dry season, and are important areas of production for aquatic invertebrate animals (Pollino & Couch 2014). Few jurisdictions report on the condition of groundwater-dependent ecosystems (however, see New South Wales and Western Australia in Jurisdictional reporting on freshwater species and ecosystems). The New South Wales Government has been actively engaged in identifying groundwater-dependent ecosystems across the state; however, the condition and trend of these ecosystems are largely unknown.

Murray–Darling Basin

The Murray–Darling Basin is a highly modified, regulated river system that covers 14 per cent of the Australian continent and generates approximately 45 per cent of Australia's irrigated agriculture. It is generally accepted that most flow-dependent ecosystems of the Basin are in poor ecological condition, particularly in the southern Basin, where river regulation and water diversions have resulted in the greatest alterations to flow regimes (Davies et al. 2010, 2012). In response to mounting ecological concerns, the Australian Government initiated major water reforms, culminating in the *Water Act 2007* and the Murray–Darling Basin Plan 2012 to address overallocation of irrigation water and restore flows to rivers. The Inland water report graded the state of ecological processes and key species populations in the Murray–Darling as very poor with a deteriorating trend, noting widespread loss of ecosystem function and species population decline.

The South Australian NRM report cards assessed the ecological condition of the Murray River in South Australia as poor, but noted that populations of some communities of aquatic plants, birds and aquatic animals improved between 2010 and 2013 in the Coorong, Lower Lakes and Murray Mouth. Since the millennium drought (which lasted from 2000 to 2010, although in some areas it began as early as 1997 and ended as late as 2012), the condition of river red gums on the floodplains has improved, but the 2013 (partial) Sustainable Rivers Audit found that fish populations in the Murray River channel declined from poor to very poor, and other aquatic animals remained in a moderate condition.

Rivers and riparian habitats

The ecological condition of waterways across Australia is variable; most states and territories (Australian Capital Territory, New South Wales, South Australia, Tasmania, Victoria and Western Australia) report poor to moderate condition of rivers and/or freshwater aquatic ecosystems (see Jurisdictional reporting on freshwater species and ecosystems). Twenty-three per cent of major rivers and tributaries in Victoria were in good or excellent condition.

In northern Australia, aquatic ecosystems (including estuaries, floodplain and riverine) are generally considered to be in overall good ecological condition, notwithstanding areas of localised poor condition (e.g. high riverine disturbance index values for the Fitzroy, Ord, Leichhardt and upper Mitchell rivers). In the arid zone, aquatic systems are considered to be in poorer condition overall because of the impacts of cattle and large feral mammals, as well as losses of some endemic fish and invertebrate fauna in some small spring systems because of introduced fish species. Connectivity of river systems in the arid zone is rated high for most rivers, because the number of impoundments and large dams is low compared with elsewhere in Australia (27 versus 467 dams of more than 0.2 GL).

Data from the Great Barrier Reef Marine Monitoring Program show that overall forest loss in riparian areas continued between 2009 and 2013 (31,000 hectares, or 0.4 per cent) in Great Barrier Reef catchments, with an increased rate of loss compared with previous periods.

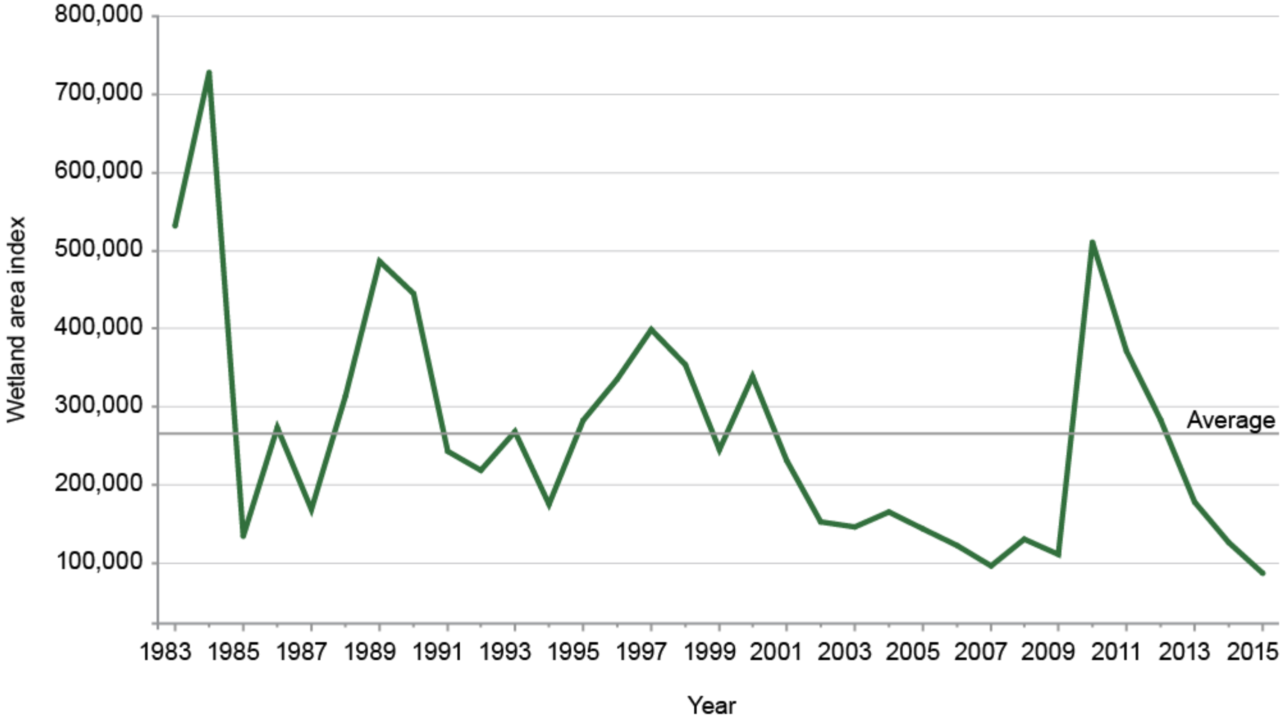
Wetlands

Australia has 65 wetlands listed under the Ramsar Convention, with a surface area of more than 8 million hectares. These wetlands are recognised as a matter of environmental significance under the EPBC Act. Australia's latest report to the Ramsar Convention (DoE 2015b) noted that there is currently no comprehensive national inventory of Ramsar wetlands in place, and it is not possible to definitively state whether the condition of wetlands overall in Australia has improved, deteriorated or stayed the same.

Wetland condition is generally reported by the jurisdictions to be overall poor to moderate (see Jurisdictional reporting on freshwater species and ecosystems); Victoria reports 56 per cent of high-value wetlands in good or excellent condition. Wetland extent is reported as declining in the Swan Coastal Plain and in Queensland. The greatest ongoing losses in Queensland occur in the Murray–Darling and north-east coast areas. Data from the Great Barrier Reef Marine Monitoring Program show that overall loss of wetlands in adjacent catchments continued between 2009 and 2013 (330 hectares, less than 0.1 per cent), although the rate of loss was lower than in previous periods. Wetland extent is reported as stable in New South Wales.

Waterbird communities have been found to be a useful indicator for identifying long-term trends in, and effects of water management on, biodiversity at a range of scales from the entire Murray–Darling Basin, to the Murray River catchment or individual wetlands (Kingsford et al. 2013). The Eastern Australian Waterbird Survey provides baseline information with which to assess changes in, and impacts on, eastern Australian wetlands and rivers. The survey includes estuaries, coastal lakes, rivers, swamps, floodplains and saline lakes, as well as dams, reservoirs and impoundments.

The survey results show that the wetland area across eastern Australia declined in 2015 to below the long-term average (1983–2015; Figure BIO24) (Porter et al. 2014). The 2015 aerial surveys showed that the Macquarie Marshes and Lowbidgee wetlands were partially filled by environmental flows, but these were relatively small areas compared with large flooding years. Most rivers in the Murray–Darling Basin had reduced flows, with mostly dry wetland habitat on their floodplains, including the large lakes of the Menindee Lakes (Porter et al. 2015). Lake Eyre and Cooper Creek wetlands were mostly dry except for a small group of rain-filled wetlands east of Lake Eyre. Other important wetlands were dry, including the Diamantina and Georgina rivers, and lakes Yamma Yamma, Torquinie and Mumbleberry in Queensland. Figure BIO24 illustrates a broad analysis of variation in wetland area during the past 30 years, with a strong correlation with the number of waterbirds in the system (see Terrestrial ecosystems and communities). The Murray–Darling Basin Plan (which came into effect in 2012) has established a coordinated Basin-wide environmental watering strategy across the Basin, agreed to by the Australian Government, and the South Australian, Victorian, New South Wales, Queensland and Australian Capital Territory governments.



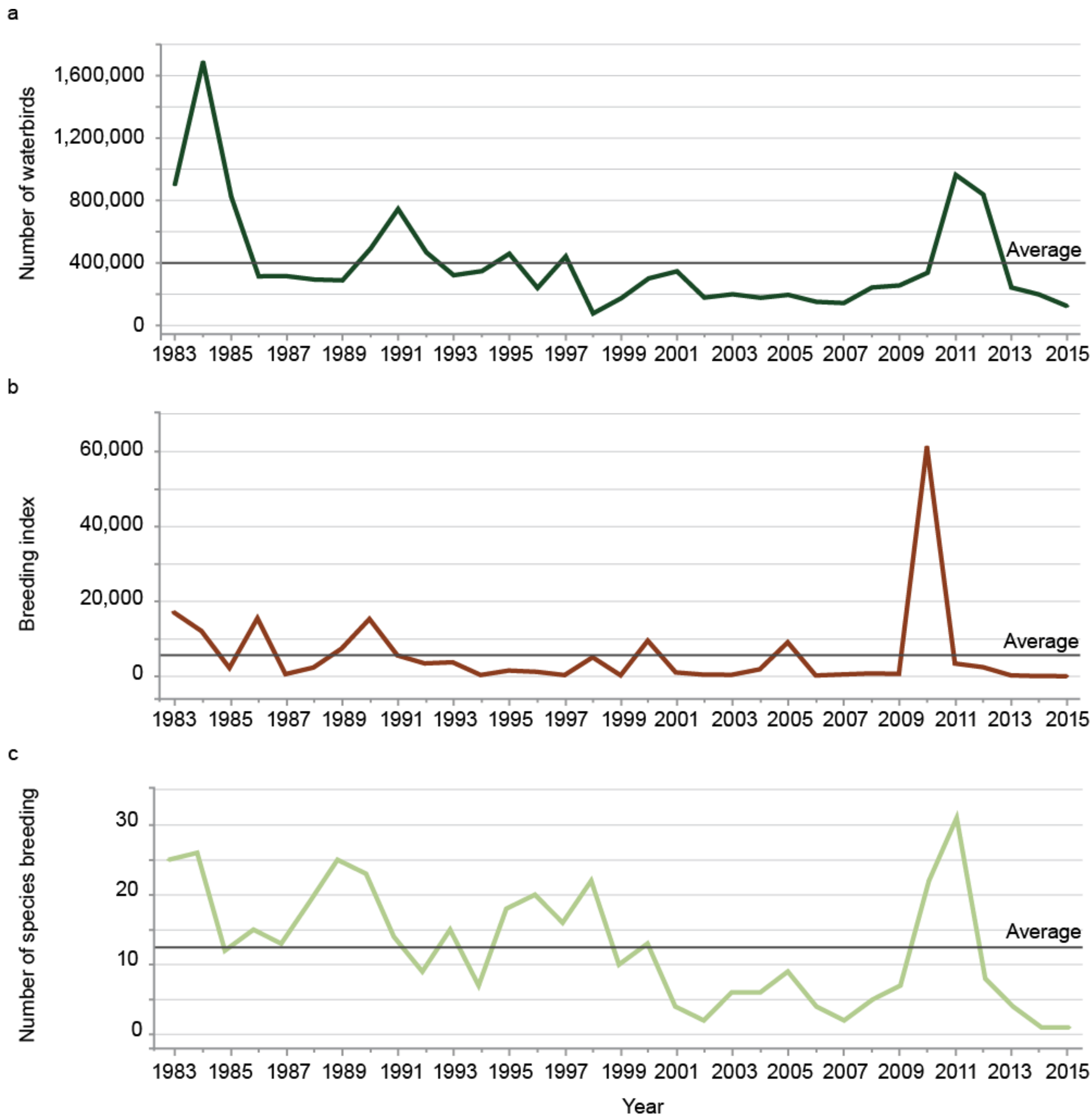
Source: Centre for Ecosystem Science, University of New South Wales

Figure BIO24 Total wetland area, 1983–2015

Birds

The annual Eastern Australian Waterbird Survey is one of the largest wildlife surveys in Australia. It surveys major wetland sites in the Murray–Darling Basin, and provides invaluable information on the ecosystem health of wetlands and rivers. These surveys have proved particularly relevant in understanding the dynamics of environmental water needs for biodiversity purposes, especially as they relate to waterbirds and wetlands. Changes in waterbird numbers provide a tangible and measurable indication of changes in the ecological health of river and wetland systems.

Trend analyses indicate continued long-term (33 years) declines in total waterbird abundance, breeding species richness and breeding abundance (Figure BIO25) (Porter et al. 2015). These major indices were well below long-term averages. Waterbirds were concentrated in relatively few important sites. Only 4 wetland systems held more than 5000 birds: Lake Killalpaninna, Lake Allallina, Paroo overflow lakes and Coolmunda Dam. These 4 wetlands held a relatively high proportion (20 per cent) of the survey total of waterbirds. In 2015, the total breeding index (all species combined) was the lowest on record and well below the long-term average. Breeding was recorded only in a single location. Breeding species richness was also the lowest on record, comprising 1 nongame species.

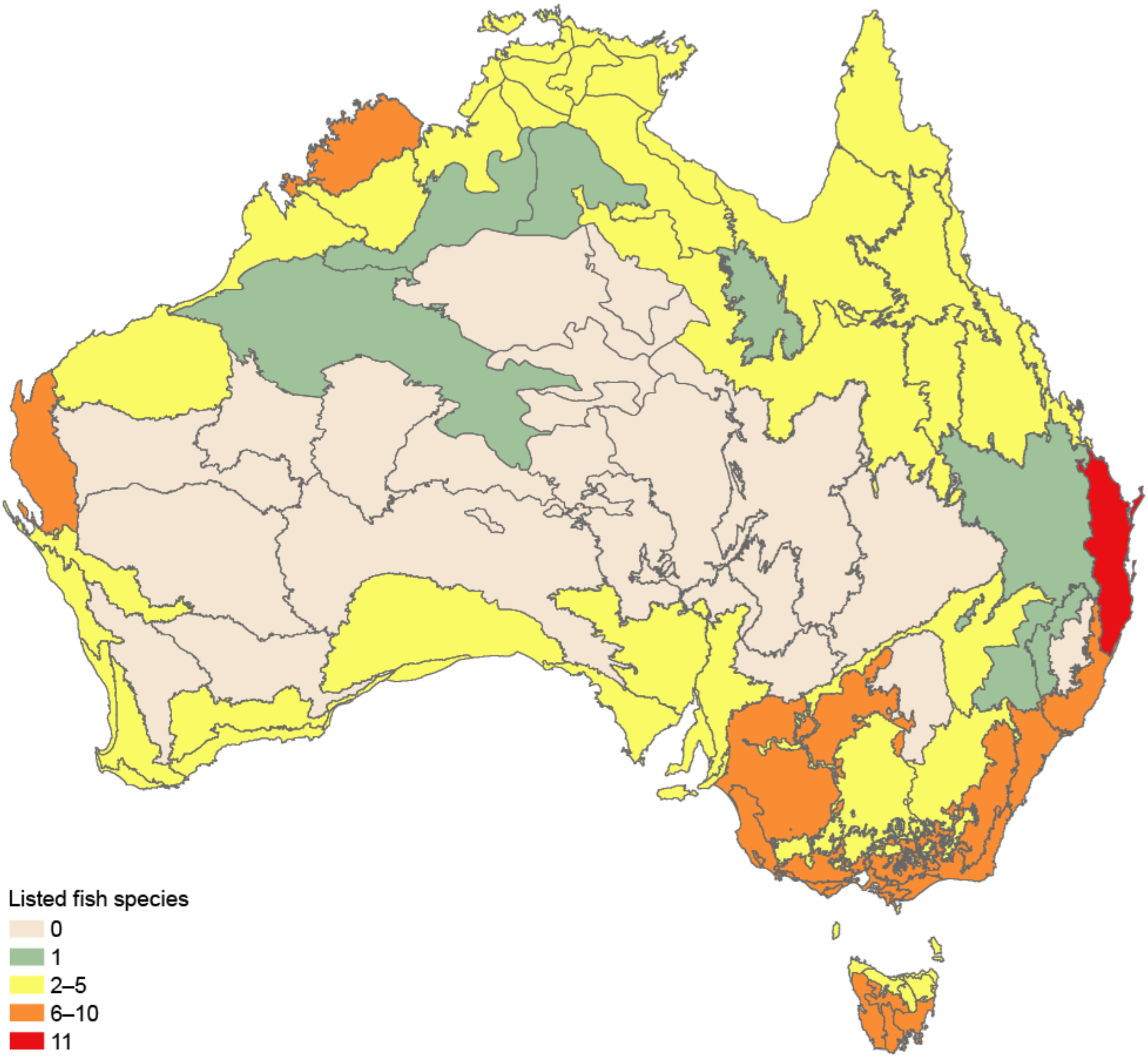


Source: Centre for Ecosystem Science, University of New South Wales

Figure BIO25 Eastern Australian Waterbird Survey results, 1983–2015: (a) number of waterbirds; (b) waterbird breeding abundance (i.e. count of breeding birds); (c) breeding species richness

Freshwater fish

In Australia, 36 freshwater fishes are listed as nationally threatened under the EPBC Act (Figure BIO26). A further 13 species are nationally listed by the Australian Society for Fish Biology, and another 25 species are listed under state or territory legislation (Lintermans 2013a). In northern Australia, the few freshwater fishes listed as threatened include elasmobranchs of high conservation significance, such as freshwater sawfish (*Pristis* spp.) and river sharks (*Glyphis* spp.). Of the more than 100 species of freshwater fish in northern Australia, only 6 species are listed in the lower risk, near threatened or data-deficient categories by the IUCN. Of these, it is now considered that 2 species (freckled hardyhead—*Craterocephalus lentiginosus*, and elongate glassfish—*Ambassis elongatus*) should be removed, based on recent better understanding of distributions. Another of these 6 (purple-spotted gudgeon—*Mogurnda adspersa*) is listed based on threats it faces in south-eastern Australia.



Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2016

Figure BIO26 Number of fish species listed under the *Environment Protection and Biodiversity Conservation Act 1999* in each Interim Biogeographic Regionalisation for Australia region

Currently, about 300 species of Australian freshwater fish are recognised from 59 families (Faulks et al. 2015). However, this knowledge is incomplete, because more species are being described with the aid of molecular and taxonomic surveys, so true species richness may exceed this estimate. Although this is a relatively small number compared with other continents, approximately 70 per cent of Australian inland fish species are endemic; further, they show unusual adaptations to highly varying environmental conditions. The highest endemism is found among the central, southern and western basins that are characterised by aridity and long-term isolation (Pollino & Couch 2014).

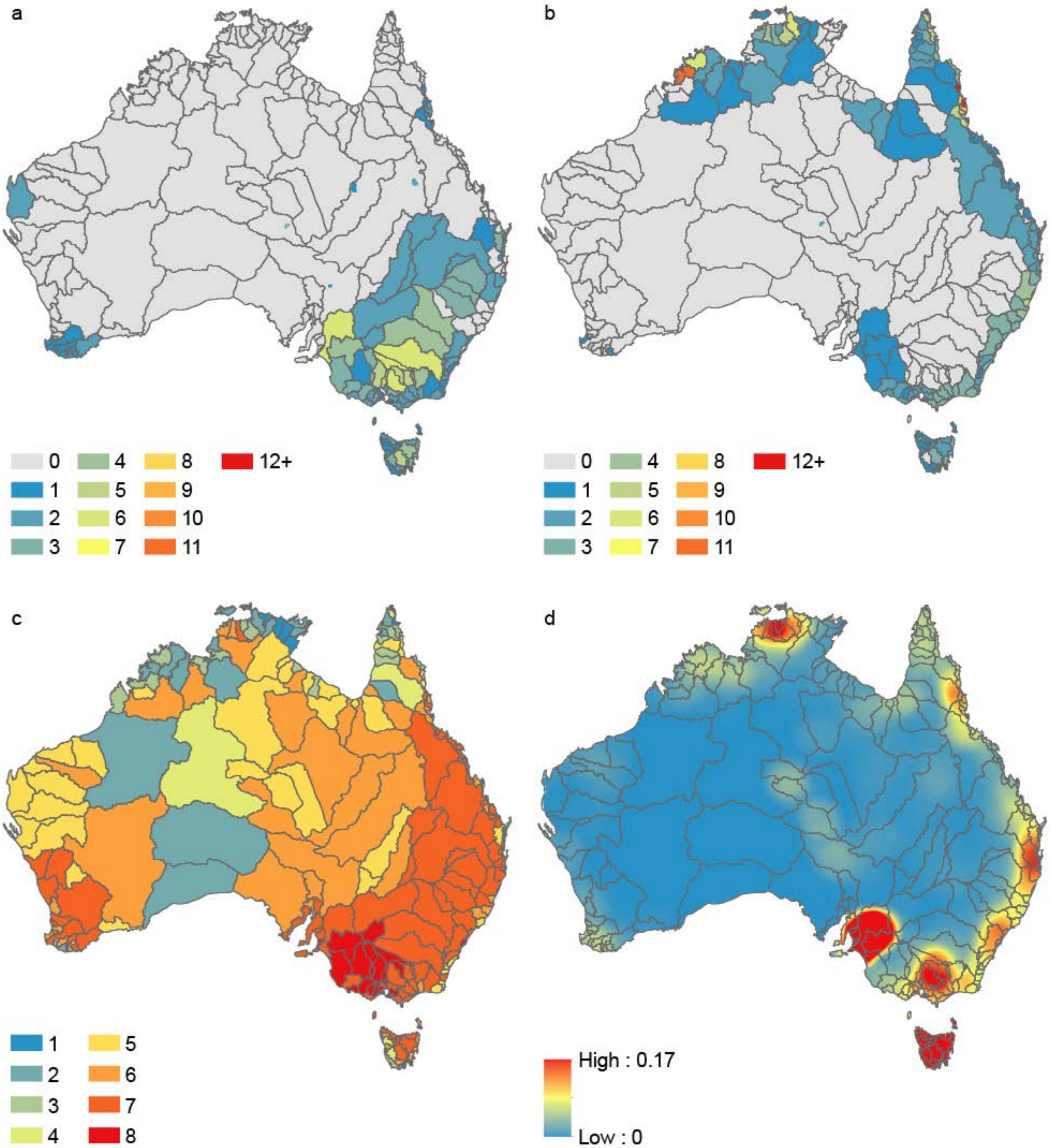
The distribution of northern Australian fishes is better understood than in SoE 2011 because of recent survey work, and compilation of historical and museum records. However, recent phylogeographic research highlights the potential presence of many undescribed cryptic species. Furthermore, in northern Australia, invasive non-native fish species are limited in number (5); instances of occurrence are largely limited to peri-urban areas, and most involve ornamental species.

In southern Australia in 2014, the New South Wales Department of Primary Industries confirmed that a population of the introduced tilapia species, Mozambique tilapia (*Oreochromis mossambicus*), had become established on the New South Wales far north coast; this was the first confirmed population of tilapia in the state. Three species of tilapia (Mozambique tilapia, spotted tilapia—*Tilapia mariae*, and redbelly tilapia—*T. zillii*) have established successful breeding populations at several sites in Queensland, Victoria and Western Australia. Populations of Mozambique tilapia in southern Queensland are as little as 3 kilometres from the Condamine–Balonne rivers catchment of the Murray–Darling Basin, posing a significant threat to the native fish of the Basin.

The distribution of currently listed threatened freshwater fish species is concentrated in south-eastern and south-western Australia and Tasmania. Although no Australian freshwater fish is known to have become extinct since European settlement, there is evidence of regional extinctions, particularly in south-eastern Australia (Lintermans 2013b). Recovery actions have saved several species (Pedder galaxias—*Galaxias pedderensis*, and barred galaxias—*G. fuscus*) from extinction and the Mary River cod (*Maccullochella mariensis*) from near extinction (Lintermans 2013a). Pedder galaxias persists only as 2 translocated wild populations outside its natural range.

Some 13 per cent of Australian freshwater fishes are recognised as nationally threatened (listed as conservation dependent, vulnerable, endangered, critically endangered or extinct under the EPBC Act). None has ever been downlisted or delisted, suggesting that ongoing management is critical (Figure BIO27). A study published in 2016 (Le Feuvre et al. 2016) identified a further 55 species that are potentially vulnerable, and highlighted the vulnerability of northern Australia's freshwater fishes to extinction. Three hotspots of potential extinction risk were identified: the Kimberley region, the Wet Tropics and, to a lesser extent, Arnhem Land. All 16 species identified as potentially vulnerable in the Kimberley region are endemic to that region, whereas the Wet Tropics and Arnhem Land had higher proportions of broader-range species.

A national survey of on-ground recovery actions for listed freshwater fish (Lintermans 2013b) reported 428 on-ground recovery actions in Australia, with the majority in the Murray–Darling Basin and south-eastern Australia. However, few or no recovery actions were reported for many species, with no coordinated plan to deal with their state, and few actions occurred in northern or western parts of the country.



Note: The scale represents the number of species of each category found in each catchment (a and b). The condition of Australian rivers (c) is adapted from Stein et al. (2002), with 1 being the most pristine and 8 the most disturbed catchments. Higher values indicate greater research effort (d). Differences in research effort between areas are not presented on a linear scale. Figure BIO27a differs slightly from Figure BIO26 in the following ways. For Figure BIO27a, species listed under the *Environment Protection and Biodiversity Conservation Act 1999* and the International Union for Conservation of Nature are included. Le Feuvre et al. (2016) also used known records from field guides, surveys and the Atlas of Living Australia to generate distributions, rather than the Environmental Resources Information Network distribution mapping of EPBC Act–listed species, which includes 'known to occur' and 'likely to occur' distribution data.
Source: Le Feuvre et al. (2016)

Figure BIO27 Distribution of (a) currently listed freshwater fish, (b) species identified as potentially vulnerable, (c) river condition and (d) freshwater fish research effort across Australia

Invertebrates

The Murray River Macroinvertebrate Monitoring Program systematically samples and records aquatic macroinvertebrate populations along the Murray River and its major tributaries. The program has been operating since 1980 and is a rare example of a long-term monitoring program, especially for aquatic fauna. The surveys revealed a substantial decline in biological health throughout the Murray River between 1996 and 2010 (also referred to as the millennium drought). During this period, species that are associated with poor water quality, habitat and flow conditions increased in diversity and abundance, whereas sensitive species declined. Data analysis from the 2 years after the 2010 flood event shows some evidence that communities are returning to a before-drought state; however, monitoring during the next few years will be needed to confirm the extent to which this occurs (Paul et al. 2013).

Tasmania is home to some very unusual freshwater crayfish. Fifteen species of *Engaeus* occur in Tasmania, 13 of which are endemic, with highly restricted distributions. Because of a range of factors, such as habitat loss, changed hydrology and the degradation of water catchments, some are listed as threatened species. Five species have been listed as threatened at both the state and national level, and are the focus of a recovery plan.

Australian subterranean fauna are increasingly being recognised and investigated, as highlighted in Box BIO12.

Box BIO12 Getting to know a whole new world of animals living underground

During the past 2 decades, it has become apparent that there are many animal species living within rock spaces deep underground, as well as in shallow unconfined aquifers associated with rivers. Subterranean fauna have persisted and diversified in their relatively buffered underground habitats for millions of years. They include aquatic animals living in the groundwater (stygofauna) and species living in subterranean airspaces in rock above the watertable (troglofauna).

Although subterranean fauna are found in many areas of Australia, no systematic national surveys have been done to fully understand their distribution. As with many invertebrate groups, our knowledge of the subterranean fauna is limited, in part because of the difficulty in accessing, sampling and studying subterranean environments, which can be hundreds of metres underground. Currently, only a small proportion of species have been formally described, and many new species are still being discovered (Smith G et al. 2012). Another challenge in understanding subterranean faunal diversity is that many species are hard to differentiate from each other and are only distinguishable through genetic analyses (Harrison et al. 2014).

However, greater levels of information have become available in association with mining operations in Western Australia and Queensland. A large number of surveys have been undertaken in many of the mining water monitoring bores across the Pilbara in Western Australia, and in Queensland, as part of the mandatory consideration of subterranean fauna in environmental impact assessments for mining developments.

Troglofauna and stygofauna are particularly diverse in the Pilbara region of Western Australia (Eberhard et al. 2005, Guzik et al. 2011), where more than 1000 species are estimated to occur (Halse & Pearson 2014, Halse et al. 2014). Almost all of the subterranean fauna residing in the Pilbara are invertebrates, many of which are short-range endemics whose entire distribution is restricted to a small area (less than 10 square kilometres for many species) (Halse & Pearson 2014).

The primary threats to subterranean fauna are activities associated with mining developments, including removal or disturbance of geological strata supporting faunal communities, and drawdown of the watertable following mine de-watering. Although these impacts are highly localised, they can deplete populations with very small ranges. In response, the configurations of some mining impact areas in the Pilbara have been altered to reduce the threat to short-range endemic subterranean fauna (EPA WA 2012).

Ongoing improvement of our knowledge of the distribution, diversity and taxonomy of subterranean fauna is critical for management. New analytical approaches to data, as well as taxonomic and genetic analyses, are required to better understand the number and variety of subterranean fauna species. Considerable effort is now being made to ensure that survey data are captured in publicly accessible databases to facilitate more widespread understanding and interpretation. Research into subterranean fauna and the ecosystems they reside in is an ongoing part of mining operations that informs threat abatement actions.

Box BIO12 (continued)

Examples of subterranean fauna from the Pilbara: (a) the stygofauna crustacean *Mangkurtu kutjarra*; (b) a troglofauna pseudoscorpion *Lagynochthonius* sp.

Photos: Stuart Halse, Bennelongia Environmental Consultants

Source: Karel Mokany, CSIRO

Coastal and marine species and ecosystems

The condition of Australian estuaries and bays, and coastal freshwater lakes and lagoons is covered in detail in the *Coasts* report. The *Marine environment* report provides a detailed assessment of the state and trends of marine organisms. We provide a high-level summary here.

Three coastal or marine ecosystems were listed as threatened ecological communities under the EPBC Act during the past 5 years:

- the Giant Kelp Marine Forests of South East Australia (2012) and *Posidonia australis* seagrass meadows of the Manning–Hawkesbury ecoregion (2015) were listed as endangered
- Subtropical and Temperate Coastal Saltmarsh (2013) was listed as vulnerable.

The primary threats affecting the Giant Kelp Marine Forests are the increase in sea surface temperatures associated with the southwards penetration of the East Australian Current, and the corresponding range expansion of kelp-grazing sea urchins. The cumulative consequences of coastal development (e.g. clearing and human-induced habitat modification), and invasive species, are considered key threats to the *P. australis* seagrass meadows and the Subtropical and Temperate Coastal Saltmarsh communities.

A range of habitats and communities—from the nearshore to the abyss, and from the seabed to the water column—were assessed for their current state and recent trends in the *Marine environment* report. Most were in good condition, and trends ranged from stable to improving, where they could be assessed. However, the condition of canyons, seamounts and coral reefs ranged from good to poor, depending on the specific geographic region. For example, severe storms, bleaching and crown-of-thorns starfish have affected eastern reefs, whereas many regions in the north-west have been affected by bleaching. Habitats and communities in the Great Barrier Reef to the end of 2015 are considered to range from poor and worsening condition (corals) to good and stable condition (macroalgae, offshore banks and shoals) (GBRMPA 2014). The ecosystem encompassing 'Fringing reefs—temperate rocky reefs' was classed as poor and worsening; warm-water events and overgrazing by sea urchins are negatively affecting some temperate reef habitats. Trends were generally noted to be associated with limited confidence for many habitats.

Most species groups assessed are regarded as being in good condition overall, although information is lacking to assess the condition or trend of some invertebrate groups. Trends are stable or improving for most fish species, except inner shelf reef species, which are in poor condition and worsening, similar to temperate rocky reef and coral reef habitats.

In addition, some species:

- have improved from past declines (e.g. long-nosed fur seals—*Arctocephalus forsteri*, southern Great Barrier Reef green turtles—*Chelonia mydas*, humpback whales—*Megaptera novaeangliae*, orange roughy—*Hoplostethus atlanticus*)
- are stable (e.g. mesopelagic and epipelagic fish species, shy albatross—*Thalassarche cauta*)
- have declined as a result of cumulative impacts associated with high fishing mortality, bycatch within fisheries and climate change (e.g. flesh-footed shearwater—*Puffinus carneipes*, Australian sea lion—*Neophoca cinerea*, north Queensland hawksbill turtle—*Eretmochelys imbricata*, demersal shark species).

Dugong populations in the southern Great Barrier Reef declined to very low levels during the past 50 years, with the aerial survey in 2011 showing the lowest numbers since the surveys began in 1986 (Sobtzick et al. 2012, 2015). In 2015, the Australian Government committed $5.3 million across 3 years for delivery of a Dugong and Turtle Protection Plan, including a Specialised Indigenous Ranger Program for strengthened enforcement and compliance, and an Australian Crime Commission investigation into the illegal poaching, transportation and trade of turtle and dugong meat in the Great Barrier Reef and Torres Strait. Other measures undertaken by local Indigenous people along the length of the Reef include a variety of sea Country management arrangements, including Traditional Use of Marine Resources Agreements and Marine Park Indigenous Land Use Agreements.

Large numbers of species and species groups are not regularly monitored or monitored at all, and, as a result, their status is unknown and recent trends are unclear. Trends were unclear for sharks and rays, most seabirds, sea snakes, some marine turtles and most marine mammals.

There is broad agreement on the current very poor state and deteriorating trend of shorebirds in the past 5 years (see Box BIO13), with consensus and evidence pointing to the causes as habitat loss, habitat degradation and harvest of prey, particularly in east Asia. Current trends in shorebird populations are described in detail in the *Coasts* report.

Box BIO13 Continental-scale decreases in migratory shorebirds

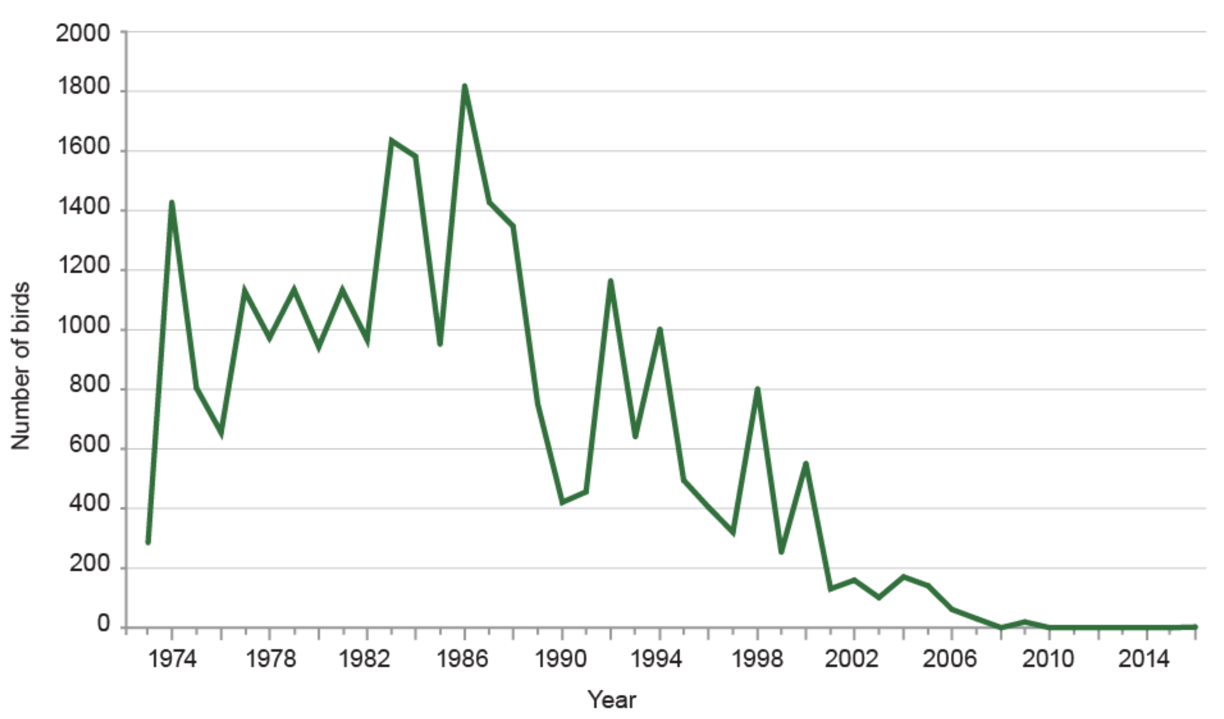
Australia is connected to Siberia and northern Alaska by a migration corridor used by more than 5 million shorebirds of 50 or so species. After breeding in the Northern Hemisphere, the shorebirds migrate to Australia along the East Asian–Australasian Flyway (EAAF).

A recent analysis of decadal timeseries of surveys of these species around Australia has shown that numerous species are decreasing, some at alarming rates (Clemens et al. 2016). The analyses examined population trends at inland and coastal sites around Australia for 19 species from 1973 to 2014. Continental-scale population decreases were identified in 12 of the 19 species, and regional decreases (southern Australia) were identified in 17 of the 19 species since 2000.

Tasmania is the southernmost destination in the EAAF, and is considered to be a bellwether for the flyway, with observed long-term decreases exceeding those observed on the Australian mainland. Decreases in migratory species' populations in Tasmania have been identified as precursors to decreases further north; as populations decrease in abundance, so can their range.

The Australian population of curlew sandpiper (*Calidris ferruginea*) is currently decreasing at more than 9 per cent per year (Clemens et al. 2016), but the species has virtually disappeared from south-eastern Tasmania, where fewer than 50 birds have been reported in the past decade, compared with annual counts approaching 2000 in the 1980s (Figure BIO28).

Other species are showing elevated rates of decrease in Tasmania compared with the mainland. One of the key drivers identified in the decreases in migratory shorebirds in Australia is the rapid and extensive loss of the intertidal mudflats in the Yellow Sea that are used as a feeding area en route (Iwamura et al. 2013; Murray et al. 2014, 2015). Conservation measures in Australia to protect Australia's migratory bird biodiversity will be constrained by the continuing loss of critical habitat elsewhere in the EAAF. Coordinated international efforts are critical to conserve trans-hemispheric migratory species.



Source: BirdLife Tasmania (formerly Bird Observer's Association of Tasmania and Birds Tasmania)

Figure BIO28 Number of curlew sandpipers in south-eastern Tasmania, 1973–2016

Box BIO13 (continued)

Curlew sandpipers
Photo by Alan Fletcher

Source: Eric J Woehler, BirdLife Tasmania, and the University of Tasmania

Jurisdictional reporting on marine species and ecosystems

The state of marine ecosystems is highly variable, but the jurisdictions report that many systems are in good condition. Trend is generally not known, and the reliability of information for many systems is also limited.

New South Wales

- Key trends:
  - Forty-one marine species and 1 marine population are currently listed as threatened, including some presumed extinct. Information on the status of marine species is generally not as good as that for terrestrial species.
  - Significant losses of aquatic vegetation have occurred since European settlement; however, information is too limited to assess recent changes. Ongoing losses of seagrass communities tend to be small, and many relate to localised climatic events.
- Assessment grade and adequacy of information:
  - Distribution of rocky reef covering biota: grade—good; trend—unknown; information availability—limited.
  - Distribution of estuarine macrophytes: grade—moderate; trend—unknown; information availability—limited.
  - Levels of estuarine catchment disturbance: grade—moderate; trend—increasing impact; information availability—limited.

Queensland

- Key trends:
  - Sediment, nutrients and chemicals, and litter are the major catchment pressures that affect Queensland estuaries and marine environments, but these vary in their relative importance between regions.
  - Changes to coastal habitat and reductions in connectivity are having an increasing effect on the region's ecosystems.
  - More than 96 per cent of the pre-European settlement extent of estuarine wetlands in Queensland remained in 2013. Changes in the extent of estuarine wetlands in Queensland have been monitored since 2001. The highest rate of estuarine wetland loss was recorded during 2009–13 (0.03 per cent), mostly in the North East Coast drainage division.
  - Of the 2 broad estuarine wetland types—mangrove and saltmarsh/salt flat—the greatest ongoing losses have occurred in saltmarsh and salt flats in the North East Coast drainage division, yet more than 95 per cent remain intact.
  - Thirty-six per cent of estuarine wetlands across Queensland are within areas of managed protection, which often overlap; of these, 26 per cent are in declared fish habitat area, 12 per cent are in highly protected marine park zones, and only 5 per cent are in protected areas.
  - About 17 per cent—or 1.8 million hectares—of Queensland's total marine wetlands are in highly protected marine park zones or a declared fish habitat area.
  - Queensland remains largely free from invasive non-native marine flora and fauna species (marine pests), despite a high possibility of introduction through international shipping activity.
  - The volume and load of nitrogen and phosphorus released from coastal sewage treatment plants into waterways in Queensland have remained relatively constant since 2010, except for a significant reduction in both volume and nitrogen loads released in 2014. Phosphorus loads increased in south-east Queensland in 2014, most likely because of reduced water recycling from advanced water treatment plants.
  - For the Great Barrier Reef
    - climate-related variables are already having an effect, and are predicted to continue to have far-reaching consequences for the Reef ecosystem
    - direct use of the region is a significant economic contributor, and its impact on the region's ecosystem is projected to increase with population growth

    - › declining marine water quality is one of the most significant threats to the Reef; however, agricultural practices are improving, resulting in reductions in land-based run-off entering the region
    - › evidence suggests that increased nutrient loads contribute to more frequent outbreaks of crown-of-thorns starfish—a major predator of coral—resulting in coral cover decline.
- Assessment grade and adequacy of information:
  - Assessment grades vary from one report card to another, and across time periods.
  - Most of Queensland's key fish stocks are considered sustainable.
  - At a Reef-wide scale, most ecological processes are considered to be in good condition; however, the inshore southern two-thirds of the region are in decline.
  - Queensland is well covered by water quality monitoring at different timescales, from annual report cards in coastal areas to less frequent monitoring in more remote regions. Areas such as the Gulf of Carpentaria and parts of the Murray–Darling Basin have not yet been covered, but will be addressed in future programs.

Victoria

- Key trends:
  - Monitoring has shown some positive changes in marine and coastal communities as a result of the establishment of marine parks and sanctuaries. However, changes in ecological community structure have also been observed, such as a decrease in the key habitat-forming seaweed in Port Phillip Heads Marine National Park, increased presence of pests such as the long-spined sea urchin (*Centrostephanus rodgersii*), decline of the southern rock lobster population, and a decline in broad-leaf seagrass (*Posidonia australis*).
  - Between 2007 and 2013, 6 marine and coastal bird species declined in status, and 2 bird species were added to the Advisory List because of decreasing populations. Only 1 species improved its threatened status during the past 5 years.
  - Assessment of threatened communities and species in marine environments is limited compared with terrestrial environments, particularly for marine flora, invertebrates and fish.
  - Marine and coastal ecosystems are under increased threat from invasive species.
- Assessment grade and adequacy of information:
  - Data on the condition of marine and coastal ecosystems are not gathered in a comprehensive manner. A lack of knowledge and understanding of marine systems is a major hindrance to the protection of marine biodiversity and the ability to report on its current condition.
  - Monitoring of invasive species remains poor, and is limited to Victoria's commercial ports and harbours.
  - Few data are available on the ecological condition of estuaries, although it is evident that most of Victoria's estuaries have degraded.
  - Marine and coastal health: grade—unknown; trend—unknown; data quality—poor.
  - Conservation of marine and coastal areas: grade—poor; trend—stable; data quality—good.
  - Marine and coastal biodiversity: grade—poor; trend—unknown; data quality—poor.

South Australia

- Key trends:
  - South Australian marine parks were established in November 2012, and restrictions on activities other than fishing began in March 2013. Fishing restrictions within marine parks took effect in October 2014.
  - In 2007, more than 90 per cent of mangroves were in good condition. Field surveys across the Eyre Peninsula NRM region in 2012 assessed the mangroves as being in good condition, with a score of 71 out of 100 (where 100 represents pristine, undisturbed condition). Trends in condition are unknown.
  - In 2007, more than 90 per cent of saltmarshes were in good condition. Trends in condition are unknown.

- Assessment grade and adequacy of information:
  - A monitoring, evaluation and reporting program has commenced, which will assess trends in the condition of the key ecological, environmental, cultural and socio-economic resources in each marine park.
  - The condition and trend of coastal dunes throughout the state are largely unknown. Studies of dune condition have not been undertaken in any NRM region.
  - Effectiveness of marine parks in protecting marine habitats and species: grade—good; trend—unknown; reliability of information—excellent.
  - The condition of coastal vegetation, estuaries and subtidal reefs has generally not been assessed in the reporting period. The most recent assessments given in the South Australian NRM report cards are
    - extent and condition of coastal dunes (2007): grade—unknown; trend—unknown; reliability of information—fair
    - extent and condition of mangroves (2007): grade—good; trend—unknown; reliability of information—good
    - extent and condition of saltmarshes (2007): grade—good; trend—unknown; reliability of information—good
    - extent and condition of seagrasses (2011): grade—unknown; trend—stable; reliability of information—good
    - condition of estuaries (2001): grade—poor; trend—unknown; reliability of information—fair
    - condition of subtidal reefs (2010): grade—unknown; trend—unknown; reliability of information—good.

Western Australia

- Key trends:
  - Western Australia has a network of marine parks and reserves across 13 of the state's 19 marine bioregions.
  - The subtropical and temperate saltmarsh threatened ecological community has declined in extent through land clearing or reclamation, altered hydrology, eutrophication and/or grazing.
  - Most south-western estuaries are affected to some extent by eutrophication, with several areas showing signs of severe impact.
  - Coral condition in marine parks and reserves is generally good, although abnormally warm water during the 2011 La Niña event caused coral bleaching, and coral cover declined on some mid-latitude to high-latitude reefs. The strong El Niño event in 2016 increased water temperature, and caused coral bleaching on reefs along the Kimberley coast and at some offshore atolls.
  - The 2011 La Niña warm-water event and flooding from storms were associated with a decline in cover of some seagrass species in Shark Bay Marine Park. Seagrass in the Swan–Canning estuary is generally in good condition. Warm water from the 2011 La Niña and strong La Niña events in the following 2 years have also contributed to reduced coverage of kelp on mid-latitude reefs, although kelp communities are still in good condition in southern waters.
  - The condition of marine turtles is generally good, although many more years of data are required to understand the potential long-term impacts of pressures associated with major industrial developments in the Pilbara region. Long-term data at Ningaloo indicate that green, hawksbill and loggerhead turtles have stable nesting abundances, and fox predation on eggs has been reduced to less than 1 per cent.
  - Humpback whale numbers in the west coast breeding stock have increased significantly to around 30,000 animals, and this species was moved from the threatened species list to the specially protected/conservation dependent category in 2015.
  - Salinity is increasing in the Swan–Canning estuary system (1995–2011), consistent with increased tidal influence and reduced river flow (with drying climate). Associated stratification has resulted in an improved oxygen trend in downstream reaches, but a decreasing trend in upper reaches. Nutrient levels are stable in upper reaches, but chlorophyll-a has increased (2005–11), possibly because of increased light penetration. Fish communities in the estuary system are stable.

- Assessment grade and adequacy of information:
  - The Department of Parks and Wildlife monitors the condition of key ecological assets relative to anthropogenic pressures and the condition of some threatened marine species.
  - Condition of saltmarsh ecological community: grade—good to fair; trend—declining; reliability of information—moderate to fair.
  - Condition of corals: grade—good; trend—generally stable, although declining at some reefs; reliability of information—good.
  - Condition of seagrass and macroalgal communities: grade—good; trend—stable, although some are declining at some locations; reliability of information—good.
  - Condition of mangroves: grade—good; trend—stable; reliability of information—good.
  - Condition of intertidal reefs: grade—good; trend—unknown, because timeseries data are insufficient; reliability of information—good.
  - Condition of marine turtles: grade—good; trend—unknown, because long-lived species require long timeseries of data; reliability of information—fair.

Tasmania

- Key trends:
  - State coastal (and marine) areas have been divided into mesoscale bioregions, based on biogeographical spatial distribution of biological and physical characteristics. The coastline has been divided further into 20-kilometre segments, based on naturalness values (evaluated on aquatic species and marine water–dependent terrestrial species present). Most regions have ecological conditions classified as slightly to moderately disturbed, with some of these regions classified as having high ecological value (mostly adjacent to the south-west Tasmania World Heritage Area). A few isolated areas that have been affected by significant land-based activities are classified as highly disturbed.
  - Port Davey and associated Bathurst Harbour in south-west Tasmania represent one of the world's most anomalous estuarine systems. The estuary contains several fragile deepwater invertebrate species growing at accessibly shallow depths; the reef habitats are susceptible to impacts and are of scientific importance. In 2011, the 2003 baseline survey of introduced marine pests was repeated at Port Davey. No target introduced marine pests were detected during the survey, which included collections made using benthic cores, diver video transects, diver searches, baited trapping, beach wrack searches, benthic phytoplankton cores and plankton net tows.
- Assessment grade and adequacy of information:
  - Limited coastal and marine ecosystem monitoring occurs outside sites used to assess impacts of activities, areas included in the Tamar and Derwent estuaries' strategic monitoring programs, and areas monitored as part of baseline ecological monitoring for managing marine farms. However, all CSIRO data processed as part of determining site-specific guideline values for protecting aquatic ecosystems indicate water quality sufficient to support slightly to moderately affected ecological condition.
  - Marine and coastal health: grade—fair to good; trend—stable to declining, but generally unknown outside locations being assessed; data quality—good, but nearshore data are generally limited.
  - Conservation of marine and coastal areas: grade—fair to good; trend—stable to declining, but generally unknown outside locations being assessed; data quality—fair to good, but limited.
  - Effectiveness of marine parks in protecting marine habitats and species: grade—good; trend—unknown; reliability of information—good.
  - Marine and coastal biodiversity: grade—fair to good (outside affected zones); trend—stable to declining, but generally unknown outside locations being assessed; data quality—fair to good, but limited.
  - Estuarine health: grade—poor to good; trend—stable to declining, but generally unknown outside locations being assessed; data quality—good, but generally limited to Institute for Marine and Antarctic Studies data and site-specific assessment of regulated activities.

Northern Territory

- Key trends and adequacy of information:
  - Systematic assessment of dugong populations in the territory show that the major population in the Gulf of Carpentaria has remained stable since 1994.
  - Systematic monitoring of saltwater crocodiles in the territory shows a continuing recovery since protection from hunting in 1970, with populations in the major river systems either continuing to increase slowly or stabilising, and a gradual shift towards larger individuals.
  - Extensive dieback of mangroves occurred in the Gulf of Carpentaria during 2015–16, with around 7000 hectares affected. This is likely linked to poor wet-season rainfall combined with very high temperatures.
  - There is also some anecdotal evidence of coral bleaching in coastal territory waters during 2015–16.
- Assessment grade:
  - The environmental condition of Darwin Harbour is assessed and reported annually against 4 key water quality indicators. In 2015, all sites were assessed as having very good or excellent water quality, except for Buffalo Creek (very poor), which receives discharge from a sewage treatment plant.
  - Marine and estuarine ecosystems in the Northern Territory are generally in good ecological condition, although quantitative data for trends are sparse.

Leaf-tailed gecko (*Phyllurus* sp.)
Photo by Eric Vanderduys

Assessment summary 2
State and trends of biodiversity

Component	Summary	Assessment grade (Very poor / Poor / Good / Very good) — Confidence (In grade / In trend) — Comparability (To 2011 assessment)
Terrestrial ecosystem (native vegetation) extent—northern and central Australia	Although native vegetation is largely intact across northern and central Australia, clearing rates have increased in Queensland, including in Cape York Peninsula	
Terrestrial ecosystem (native vegetation) extent—southern, eastern and south-western Australia	Rates of land clearing are relatively stable, but land-use changes, including increasing urban development, put significant pressure on the extent of native vegetation	
Terrestrial ecosystem (native vegetation) quality—remote areas and areas where agricultural and urban development have been minimal	Native vegetation across much of this area is in relatively good condition. However, increases in some pressures, such as altered fire regimes and invasive species, result in declining habitat quality	
Terrestrial ecosystem (native vegetation) quality—agricultural regions and around urban development	All jurisdictions note that habitat disturbance and modification are key threats to biodiversity	

Assessment summary 2 (continued)

Component	Summary	Assessment grade (Very poor / Poor / Good / Very good)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Terrestrial plant species—high-altitude, remote and/or very dry parts of Australia	Plant species appear to be in a relatively good state. However, information on plants in these areas is very limited. High-altitude areas contain relatively high numbers of threatened taxa and threatened ecological communities				
Terrestrial plant species—areas most suitable for urban development and/or agriculture	High numbers of threatened plant species are in areas with high population densities and in the intensive agriculture zone. Most jurisdictions report that the state of threatened plant species is poor and worsening, although there are a large number of threatened species whose state and trends are largely unknown				
Species other than plants and animals (e.g. fungi, algae, some microorganisms)—areas where vegetation remains largely intact	Very little information is available. It is likely that fungi are in relatively good condition in systems where vegetation remains largely intact	?			
Species other than plants and animals (e.g. fungi, algae, some microorganisms)—agricultural lands	Information is very limited. Loss of mutualism is likely in areas where vegetation extent and condition are poor. Many fungi associate with other organisms, such as through mycorrhizas and endophytes	?			
Terrestrial animals—mammals	State and trends of mammals vary across the country. Evidence of ongoing declines is seen for mammals across northern Australia. In southern and eastern Australia, increases in the number of species of conservation concern are seen. All jurisdictions report declines in the status and trends of mammals				

Assessment summary 2 (continued)

Component	Summary	Assessment grade (Very poor / Poor / Good / Very good)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Terrestrial animals—birds	Overall, populations of bird species across much of Australia are in decline. Some areas experience inconsistent trends, with some species increasing and some decreasing in the tropical savanna, Brigalow Belt and Tasmania regions. Rainforest-dependent species appear to be increasing				
Terrestrial animals—reptiles	Very limited information and jurisdictional reporting exist for the state and trends of reptiles. Overall, improvement in the status of listed taxa has been limited. The first known extinction of an Australian reptile occurred during the past 5 years				
Terrestrial animals—amphibians	Except for a few high-profile species, very limited information and jurisdictional reporting exist for the state and trends of amphibians. However, greater survey effort has revealed that the state of some populations is better than previously thought				
Terrestrial animals—invertebrates	Very limited information exists for the state and trends of invertebrates. However, the key pressures on Australia's invertebrates are increasing				
Aquatic species and ecosystems (see also the *Inland water* report)—northern and central Australia	In northern Australia, aquatic ecosystems are considered to be in overall good ecological condition, notwithstanding areas of localised poor condition. However, arid and northern aquatic ecosystems are impacted by cattle and feral animals, and invasive aquatic species are present				

Assessment summary 2 (continued)

Component	Summary	Assessment grade (Very poor / Poor / Good / Very good)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Aquatic species and ecosystems (see also the *Inland water* report)—southern, eastern and south-western Australia	The state of wetlands is generally poor, and rivers in high-intensity land-use areas are also in poor condition. Aquatic ecosystems across much of the Murray–Darling Basin region are in poor ecological condition				
Marine species and ecosystems (see also the *Marine environment* report)—overall	Overall condition of the marine environment is good. A number of pressures on marine species and ecosystems are increasing				
Marine species and ecosystems (see also the *Marine environment* report)—in a few areas	Some individual species and habitats are in poor condition, including coral reefs, fringing temperate rocky reefs and associated species				

Recent trends

- Improving
- Deteriorating
- Stable
- Unclear

Grades

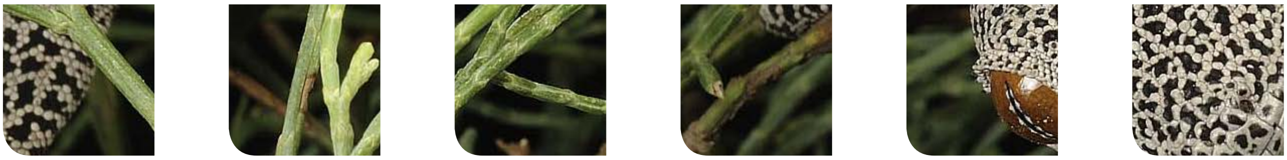
- **Very good:** The vast majority of taxa appear to have good prospects for long-term survival. Any declines are limited in spatial extent and severity, and are unlikely to threaten future viability of taxa
- **Good:** Most taxa appear to have good prospects for long-term survival, although a small proportion have suffered declines that might threaten long-term survival
- **Poor:** A significant proportion of taxa have suffered declines across most or all of Australia that potentially threaten their long-term survival
- **Very poor:** A large proportion of taxa have suffered declines across most or all of Australia

Confidence

- **Adequate:** Adequate high-quality evidence **and** high level of consensus
- **Somewhat adequate:** Adequate high-quality evidence **or** high level of consensus
- **Limited:** Limited evidence **or** limited consensus
- **Very limited:** Limited evidence **and** limited consensus
- **Low:** Evidence and consensus too low to make an assessment

Comparability

- **Comparable:** Grade and trend are comparable to the previous assessment
- **Somewhat comparable:** Grade and trend are somewhat comparable to the previous assessment
- **Not comparable:** Grade and trend are not comparable to the previous assessment
- X **Not previously assessed**



Effectiveness
of biodiversity management

At a glance

This report has documented the widespread lack of consistent long-term data for assessing the effectiveness of investments in biodiversity management in Australia. Although it is reasonable to assume that there are many program-related examples that link investment to positive outcomes for biodiversity, the limited published evidence, and broader accessibility and sparse communication of success remain issues. Conversely, it is much easier to document evidence of biodiversity declines and, therefore, insufficient or inefficient investment in the face of species extinctions, unfulfilled management targets and increasing pressures.

Australia's Biodiversity Conservation Strategy 2010–2030 is the primary instrument for Australia to implement its obligations under the United Nations Convention on Biological Diversity, and it outlines a range of biodiversity conservation targets. Most of the targets remain unmeasured, and it is therefore difficult to assess progress, although it is clear that some targets have not been achieved.

One of the targets that has been achieved is an increase in the area of habitat managed primarily for nature conservation. This has been achieved through increases in the National Reserve System—17 per cent of Australia's land and 36 per cent of marine waters are now contained within protected areas. Much of the increase in the terrestrial reserve system has been in land managed under Indigenous or joint management (now around 47 per cent of all protected areas). There has also been growth in conservation covenants on private lands in Australia, which contribute to the National Reserve System.

Progress is still required to meet representativeness, comprehensiveness and adequacy targets. Many of our species and communities listed under the *Environment Protection and Biodiversity Conservation Act 1999* are not well represented in the National Reserve System.

The effectiveness of recovery planning for threatened species and communities is very difficult to assess because of a lack of long-term monitoring data.

A key policy initiative for threatened species management since 2011 has been the development of a Threatened Species Strategy and the appointment of a Threatened Species Commissioner. The action plan associated with the strategy lists 20 mammals, 20 birds and 30 plants for priority action, along with a suite of feral cat control initiatives.

Many local-scale and regional-scale projects have been successful in managing pressures, and protecting threatened species and communities. However, at a national scale, the effectiveness of the management of pressures on biodiversity shows little improvement. The fact that the impact of most pressures is high and increasing, and the status of biodiversity overall is in decline suggests that management actions are insufficient to address the scale and magnitude of current pressures.

Overall, the level of investment in biodiversity and conservation management is in decline. However, concerted citizen-science efforts are contributing to our understanding of biodiversity and to management of biodiversity in Australia.

Management context

Biodiversity management is undertaken at all levels of government, by private enterprise, and by thousands of landholders and volunteers across Australia. At the broadest level, a national framework is provided by Australia's Biodiversity Conservation Strategy 2010–2030. The strategy, agreed to by the Australian Government and all states and territories in 2010, functions as a policy 'umbrella' over other more specific national frameworks, and is intended to provide a guiding policy for the diverse mix of Australian, state, territory and local government, and private-sector approaches to biodiversity conservation. It aims to coordinate efforts at a national level across all sectors to sustainably manage biological resources, and ensure their long-term resilience, health and viability.

It also functions as Australia's National Biodiversity Strategy and Action Plan under the United Nations Convention on Biological Diversity, providing the main instrument for Australia to implement its obligations under the convention at the national level. The strategy contained 10 interim national targets for implementation by 2015. In 2014, the Australian Government reported to the United Nations Convention on Biological Diversity that, in the 3 years since the strategy was agreed to by all Australian governments, good progress had been made towards some, but not all, of the 10 targets.

In 2015, a review of the strategy found that it was not possible to report achievement against each of the 10 targets because there were insufficient national-scale data to comprehensively report national progress. Also, some targets were inadequately specified to assess progress. Most of the targets remain unmeasured and therefore difficult to assess progress on, although it is clear that some have definitely not been achieved. The targets, and our assessment of their progress, are:

- achieve a 25 per cent increase in the number of Australians, and public and private organisations who participate in biodiversity conservation activities (not measured)
- achieve a 25 per cent increase in employment and participation of Indigenous people in biodiversity conservation (not measured, but some increases achieved through Indigenous ranger programs)
- achieve a doubling of the value of complementary markets for ecosystem services (not measured, and no known markets established)
- achieve a national increase of 600,000 square kilometres of native habitat managed primarily for biodiversity conservation across terrestrial, aquatic and marine environments (achieved through the National Reserve System)
- restore 1000 square kilometres of fragmented landscapes and aquatic systems to improve ecological connectivity (possibly achieved, but not measured)
- establish and manage 4 collaborative continental-scale linkages to improve ecological connectivity (some progress, but not fully achieved)
- reduce by at least 10 per cent the impacts of invasive species on threatened species and ecological communities in terrestrial, aquatic and marine environments (not measured)
- use nationally agreed science and knowledge priorities for biodiversity conservation to guide research activities (not achieved)
- review relevant legislation, policies and programs (by all jurisdictions) to maximise alignment with Australia's Biodiversity Conservation Strategy (some progress, but not fully achieved)
- establish a national long-term biodiversity monitoring and reporting system (not achieved).

No coordinated policy or programmatic response to the strategy was implemented to achieve the national targets, and the targets were not explicitly used to guide on-ground actions and thereby measure success. The process for implementing the strategy rested with a joint ministerial council that was disbanded in 2013, and no processes were put in place to provide a detailed framework for delivery. The 2015 review found that the strategy has not effectively influenced biodiversity conservation activities, and, going forward, increased coordination of effort on shared priorities for biodiversity management will be needed. This highlights the need for ongoing and increased investment in effective monitoring to be able to assess biodiversity condition and trends, and therefore make an assessment of the outcomes of the strategy.

United Nations Convention on Biological Diversity and Aichi targets

Australia has been a contracting party to the United Nations Convention on Biological Diversity since 1993. In 2010, a revised and updated Strategic Plan for Biodiversity 2011–2020 was adopted, including what are known as the Aichi Biodiversity Targets. Australia provides a 5-yearly report on measures taken to implement the convention, as well as progress against the Aichi targets. The Fifth National Report, which covers 2009–13, is the most recent report, and focuses on implementation of the 2011–20 strategic plan and progress achieved against the Aichi targets. There are 20 Aichi targets contained under 5 strategic goals:

- Strategic goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society.
- Strategic goal B: Reduce the direct pressures on biodiversity and promote sustainable use.
- Strategic goal C: Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity.
- Strategic goal D: Enhance the benefits to all from biodiversity and ecosystem services.
- Strategic goal E: Enhance implementation through participatory planning, knowledge management and capacity building.

Australia has a range of targets that support the Aichi Biodiversity Targets and the Strategic Plan for Biodiversity. Many of these are contained in 4 national strategies:

- Australia's Biodiversity Conservation Strategy 2010–2030
- Australia's Native Vegetation Framework 2012
- Australia's Strategy for the National Reserve System 2009–30
- Threatened Species Strategy.

In 2014, Australia reported to the United Nations Convention on Biological Diversity on our progress in achieving the Aichi Biodiversity Targets, noting progress on all targets, and significant progress in:

- Aichi Target 11 on protected areas
- Aichi Target 13 on the genetic diversity of cultivated plants, farmed and domesticated animals, and wild relatives
- Aichi Target 17 on an updated national biodiversity strategy and action plan
- Aichi Target 19 on improving the knowledge, science base and technologies relating to biodiversity.

Other relevant international conventions

Biodiversity management is also achieved under a range of other multilateral agreements that cover issues such as pollution, wetlands, heritage, trade in endangered species, migratory shorebirds, dugong and turtles. The Australian Government diligently reports to a large number of international bodies, including the:

- Antarctic Treaty
- Convention on the Conservation of Antarctic Marine Living Resources
- International Whaling Commission
- Convention on International Trade in Endangered Species of Wild Fauna and Flora
- United Nations Convention on the Conservation of Migratory Species of Wild Animals
- United Nations Convention Concerning the Protection of the World Cultural and Natural Heritage
- Ramsar Convention on Wetlands of International Importance.

These agreements, and many more, provide some insight into management. However, rather than providing some interlocking matrix that covers all aspects of biodiversity management, there is little connection and no overarching framework.

The *Heritage* report contains a detailed assessment of the current state and trends of Australia's World Heritage sites. In the most recent IUCN Heritage Outlook Report (2014), 3 Australian World Heritage sites are listed as of 'significant concern': the Great Barrier Reef, the Wet Tropics of Queensland and Kakadu National Park. A further 5 are of some concern (see the *Heritage* report for further details).

Management capacity

Jurisdictional reporting on management effectiveness

It is has been widely acknowledged that management agencies are required to manage biodiversity despite an incomplete understanding and limited resources. However, what is less well understood is the inability of management agencies to assess the effectiveness of conservation management investments. All jurisdictions face limitations in their ability to adequately assess the effectiveness of their management actions. Notwithstanding this, many on-ground managers use adaptive management techniques to continuously learn and improve from each management action taken.

Australian Capital Territory

- Long-term research, monitoring and evaluation remain limited, with previous SoE recommendations to improve these areas only partially implemented.
- Strategic monitoring and data consolidation across the territory are limited.
- Public reporting about biodiversity matters should clearly identify and assess the outcomes of decisions and activities that are related to individual species, populations and ecological communities in the Australian Capital Territory.

Victoria

- Audits into the effectiveness of state environmental management agencies indicate that, even when robust management frameworks exist, they have been undermined by inadequate data collection. Assessing the success or otherwise of management interventions becomes very difficult, resulting in a lack of accountability.
- The main reasons for gaps in monitoring are that:
    - the indicator has never been monitored
    - monitoring was undertaken but has ceased
    - monitoring is conducted across a limited spatial and temporal scale, and the accessibility of available data is significantly reduced by the disparate nature of biodiversity datasets.
- Biodiversity trends over time are difficult to determine because of methodology changes. Although changes can improve data quality, it is often not clear whether trends are because of actual changes, increased accuracy or methodology changes.
- In response, the Department of Environment, Land, Water and Planning (DELWP) is progressively implementing an approach to improving the effectiveness of management. The approach combines the collection and collation of spatial information on management activity with robust monitoring and evaluation studies, and focuses on clarifying the most important assumptions underpinning the relationship between management actions and biodiversity outcomes. DELWP is also rolling out a set of information products identifying the best management options to conserve biodiversity in certain areas. These 'strategic management prospects' are based on models of response to management action by a wide range of species. These underlying models will be progressively refined as improved understanding emerges from the studies.

South Australia

- The South Australian Government has developed a regionally based NRM reporting framework that allows state and regional natural resource managers to use the same information to understand the trend and condition of their natural assets, and to make informed planning decisions. The first complete set of report cards was released in 2014 and 2015. These are publicly available; they depict trend and condition of assets, and identify key data gaps.
- Decisions about where and how to invest will be improved by assessing the effectiveness of current and future investments against ecological, social and economic targets, and measures of the condition of natural resources.

New South Wales, Queensland, Western Australia, Tasmania, Northern Territory

- All other jurisdictions noted inadequate monitoring as a limitation in assessing species trends and the effects of pressures (see Jurisdictional reporting on pressures).

Adequacy of understanding and resources—terrestrial and aquatic

Monitoring data available for the most (relatively) well-known and visible taxa are often inadequate for assessing state and trends, and the effectiveness of management actions. *The action plan for Australian mammals 2012* (Woinarski et al. 2014) assessed the extent and adequacy of monitoring programs for all threatened, near threatened and data-deficient terrestrial mammals in Australia. Although there is some monitoring for most (76 per cent) terrestrial threatened (and near threatened and data-deficient) mammal taxa, no monitoring exists for the other 24 per cent of these terrestrial mammal taxa. The action plan notes that there are too few monitoring programs for threatened (and data-deficient) marine mammal taxa to allow a comparable analysis. In addition, a much higher proportion of marine (61 per cent) than terrestrial (1 per cent) mammal taxa is rated in the action plan as data deficient. This category reflects a lack of knowledge of key conservation parameters for many marine taxa.

Many of the monitoring programs for terrestrial mammals are very limited in their extent, periodicity, integration, design, duration, reporting, and direct link to management response (Table BIO3) (Woinarski et al. 2014). Given this dearth of information for the best understood taxon group in Australia—our mammals—it is very difficult to assign them an appropriate conservation status. For a few terrestrial mammals that are high-profile species, monitoring provides good understanding, such as with relatively well-resourced management investments for the Tasmanian devil, and taxa that are extremely restricted and with very small population sizes, for which monitoring may be reasonably simple and inexpensive (e.g. the northern hairy-nosed wombat—*Lasiorhinus krefftii*, Gilbert's potoroo—*Potorous gilbertii*).

Reporting on the monitoring of river health has decreased in Australia during the past decade after the National River Health Initiative program was completed, which produced the Australian River Assessment System (AUSRIVAS) macroinvertebrate models. At the time, the AUSRIVAS program was more concentrated in southern Australia.

Generally, in northern Australia, there is a poor understanding of state and trends of river health, except in Queensland, which still maintains a schedule of monitoring. For northern Australia, the Australian Government–funded TRaCK and the National Environmental Research Program increased knowledge of the importance of connections and cultural significance, and provided a better appreciation of the distribution of organisms, and the structure and basis of food webs. Through this work, the conservation importance of northern Australian aquatic systems has been better quantified and placed into a high-resolution spatial context. In general, however, analysis of the protected area system shows that aquatic systems are poorly protected by the existing conservation network.

In South Australia, consolidated reporting of ecological and abiotic monitoring of river systems has been undertaken for the Coorong, Lower Lakes and Murray Mouth; these areas were reported on each year (up until 2014). However, these reports have now been replaced by online Environment Protection Authority reports for aquatic ecosystem condition, covering the entire state.

Retro slider (*Lerista allanae*)
Photo by Eric Vanderduys

Table BIO3 Extent of monitoring, adequacy of monitoring design and links to management effectiveness for threatened (excluding extinct), near threatened and data-deficient terrestrial mammal species

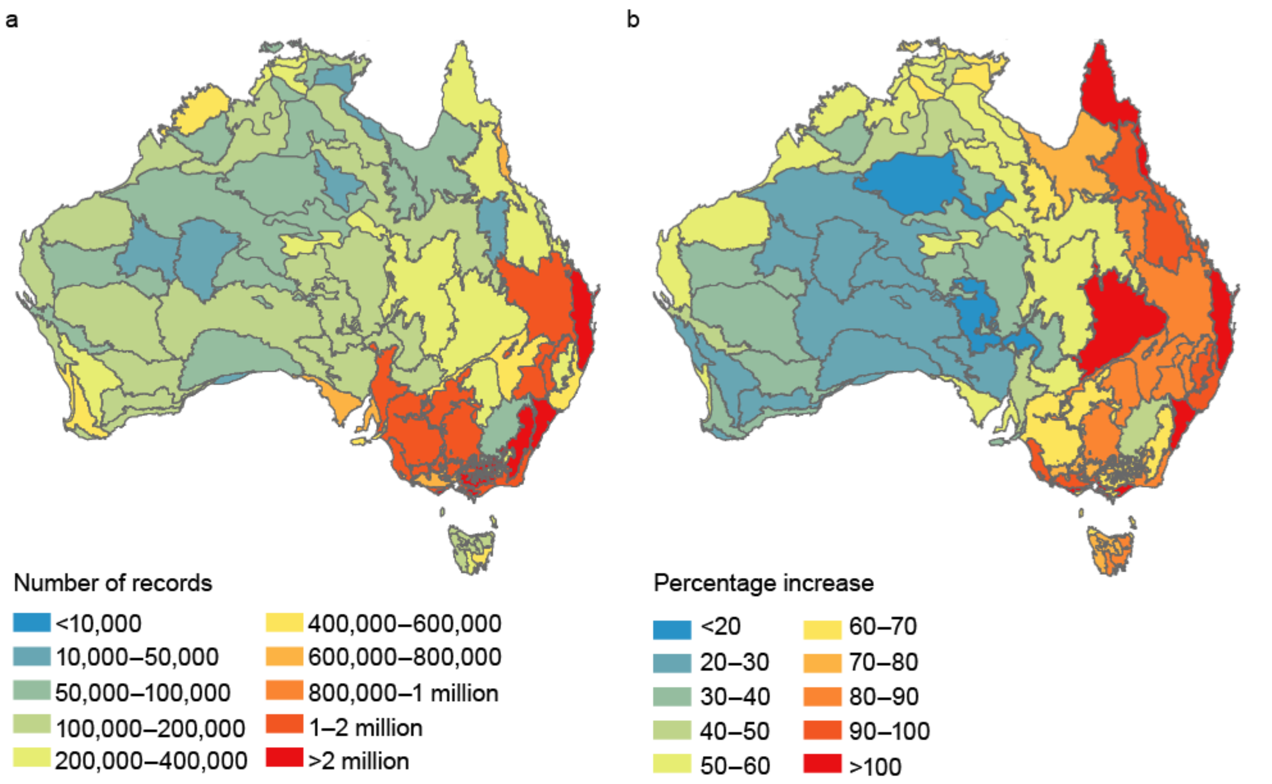
Monitoring program		Number of taxa
Monitoring programs rated according to extent of monitoring sites	Monitoring undertaken comprehensively across range	16
	Monitoring undertaken representatively at many sites across range	14
	Monitoring undertaken at several sites across range, but significant components not monitored	38
	Monitoring at a few sites, not necessarily representative	35
	Monitoring at 1 site only (except where this is the only site of occurrence)	23
	No monitoring	39
Monitoring programs rated according to adequacy of monitoring design	Monitoring with high statistical power to detect small (e.g. 5%) change in population size; power analysis may have been undertaken	2
	Monitoring with sufficient statistical power to reliably detect moderate (e.g. 30%) change in population size	31
	Monitoring with reasonable design, but low statistical power (e.g. unlikely to reliably detect 50% change in population size)	38
	Monitoring with only rudimentary design, but resulting in sufficient records to suggest broad changes in abundance	33
	Monitoring typically ad hoc with few records	22
	No monitoring	39
Monitoring programs rated according to extent to which monitoring is linked to assessment of management effectiveness	Monitoring closely linked to adaptive management, and explicit measurement of management performance	4
	Monitoring design explicitly tests different management impacts	22
	Monitoring programs provide some consideration of effects of different management regimes	35
	Monitoring program may provide weak inference about management, but no clear links to adaptive management	34
	Monitoring program not capable of assessing management effectiveness	31
	No monitoring	39

Source: Woinarski et al. (2014)

Information gaps and gap-filling initiatives—terrestrial and aquatic

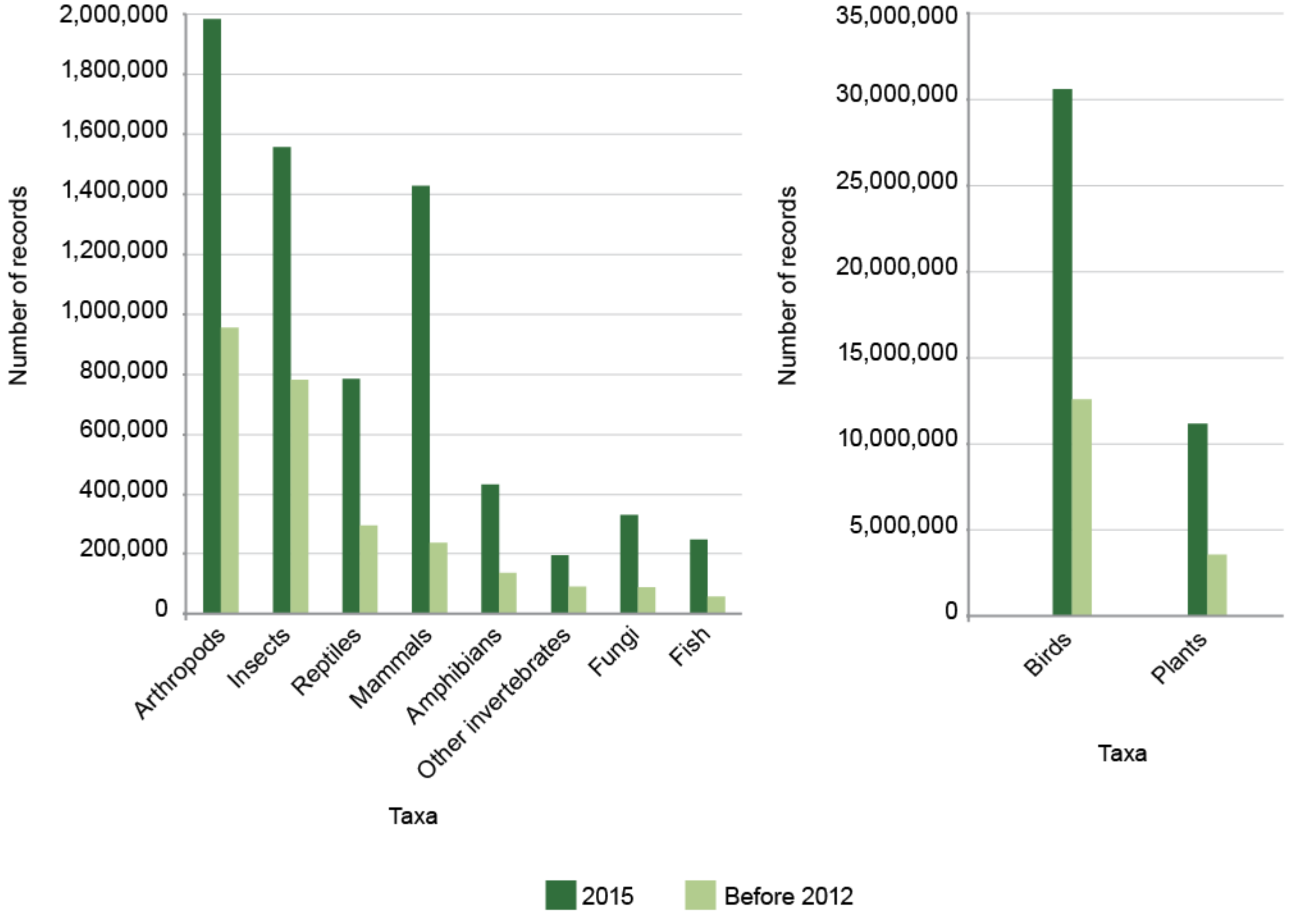
A major government-funded initiative contributing to advancing access to biodiversity information is the Atlas of Living Australia (ALA). The ALA is a national research infrastructure under the National Collaborative Research Infrastructure Strategy hosted by CSIRO. It is a supported collaborative partnership of organisations that have stewardship of biological data and expertise in biodiversity informatics, including museums, biological collections, community groups, research organisations, government (state and territory, and Australian) and natural resource managers. The ALA currently holds more than 57 million records of more than 110,000 different species from across Australia. Its adoption and use are illustrated by the more than 6 billion records that have been downloaded for use to date—an average of 3500 users per day.

Since 2012, the number of data records stored in the ALA has at least doubled for all taxa; tripled for amphibians, fungi and plants; and increased by more than 4 times for fish and mammals (Figure BIO29). Increases in the numbers of records collected (Figure BIO30) have been highest along the east coast, particularly in the Wet Tropics, Cape York Peninsula, South Eastern Queensland and Sydney Basin IBRA regions. The Mulga Lands IBRA region in south-west Queensland has also seen a significant increase in the number of records stored by the ALA.



Source: Environmental Resources Information Network, Australian Government Department of the Environment and Energy, 2016, using data from the Atlas of Living Australia (licensed under CC BY 3.0)

Figure BIO29 Records in the Atlas of Living Australia, by Interim Biogeographic Regionalisation for Australia region, 2012: (a) number; (b) percentage increase in number between 2012 and 2015



Note: Records are restricted to the border of terrestrial Australia. Note the vertical axis change for birds and plants.
Source: Atlas of Living Australia

Figure BIO30 Number of records in the Atlas of Living Australia for taxa, before 2012 and in 2015

Another major initiative that is contributing vital knowledge about Australia's biodiversity is Bush Blitz, which began in 2010. Bush Blitz is a unique partnership (comprising the Australian Government through Parks Australia and the Australian Biological Resources Study, BHP Billiton Sustainable Communities and Earthwatch Australia) whose goal is to document plants and animals across Australia. Since commencing, Bush Blitz has discovered (as at October 2016) more than 1196 putative new species, including 1139 new animals (mostly terrestrial invertebrates, including bugs, spiders, moths, beetles and bees), 27 new vascular plant species, 26 new lichen species and 4 new fungi species (see also Biodiversity funding).

University of Adelaide PhD student holding a new species of trapdoor spider at Judbarra (or Gregory) National Park, Northern Territory
Photo by Jo Harding, © Bush Blitz

Community engagement

In 2011–12, a survey of 'community engagement with nature conservation' was undertaken across Australia, aiming to measure Australians' engagement with the natural environment and participation in nature conservation activities. The survey produced some key findings:

- An estimated 8.1 million Australian adults (47 per cent) had participated in nature conservation activities at home or on the farm in the past 12 months: 43 per cent had planted or cared for Australian native trees or plants, and almost 1 in 5 (19 per cent) had cared for Australian native wildlife. People living outside capital cities were more likely to have undertaken these activities than those living in capital cities (54 per cent and 43 per cent, respectively).
- Of the people who had participated in nature conservation activities at home or on the farm, the most common reasons for planting or caring for Australian native trees or plants, or caring for Australian native wildlife, were 'non-environmental' reasons relating to making the garden more attractive and tidy (69 per cent), and enjoyment (68 per cent).
- Advocacy for nature conservation can include actions such as donating money to a relevant cause or organisation, signing a petition, participating in rallies and contacting a member of parliament. In 2011–12, nearly one-quarter of Australian adults (23 per cent) engaged in one of these activities: 17 per cent of Australian adults donated money, and 11 per cent signed a petition related to nature conservation. People living in Tasmania were more likely to sign a petition (15 per cent) than any other state or territory.
- In 2011–12, almost 2 in 5 Australian adults (39 per cent) indicated that they consider the negative environmental impact when purchasing particular products. Women (45 per cent) were more likely to do this than men (33 per cent).
- Australian adults were asked to indicate whether they could be encouraged to become involved or more involved in nature conservation activities. Nearly three-quarters of Australian adults (74 per cent) indicated that they could not be encouraged to become more involved in nature conservation activities.
- An estimated 4.5 million Australian adults (26 per cent) could be encouraged to become more involved in nature conservation activities. Of these, an estimated 2.5 million indicated that having more free time could encourage them to become more involved. Other motivators included more information or advertising on environmental issues (10 per cent), more environmental events in their local area (9 per cent), seeing the direct benefits of personal efforts (7 per cent), an increase in government rebates and incentives (6 per cent), and having more money to contribute (6 per cent).

In New South Wales, every 3 years the Office of Environment and Heritage surveys the New South Wales community and discussion groups to track trends in the public's environmental views, priorities, knowledge and actions. The 2012 research showed an increasingly positive view of the environment and its current condition than in previous surveys. Overall, environmental concerns had lessened compared with previous years, reflected in the lack of a single dominant environmental issue about which people expressed concern, an overall drop in concern about environmental problems, and a decline in environmental issues as a priority for government compared with other issues such as health, education and transport. There was also a more positive assessment of several environmental indicators compared with 2009 or 2006.

Indigenous engagement

The *Land* report contains information on Indigenous engagement in land and biodiversity management across Australia. The *Heritage* report contains information on Indigenous heritage across Australia. Both reports describe the increase of around 20 per cent from 2010 in Indigenous Protected Areas (IPAs), such that they now make up more than 44 per cent (72 IPAs as of January 2016) of the National Reserve System, and protect biodiversity and cultural heritage for Indigenous groups and Australian society. Considering jointly managed national parks and IPAs together, Indigenous groups are involved in the management of around 47 per cent of the National Reserve System. There has also been an increase in Indigenous management of sea Country in Australia, with IPAs declared that contain large marine components that are managed through Indigenous-led collaborative governance arrangements with government agencies, commercial fishers and other interested parties. Formal Indigenous land and sea management plans enable traditional practices to form the basis of contemporary, collaborative environmental and resource management governance. The rapid expansion of Indigenous ranger programs during the past 15 years has also increased Indigenous management capacity and governance of natural resources.

During the past decade, along with the increase in Indigenous-managed lands, there has been an increase in recognition and incorporation of Indigenous values and knowledge into land management more broadly. The application of traditional ecological knowledge to biodiversity monitoring occurs both on and off lands formally managed (or co-managed) by Indigenous people. The increase in IPAs has seen more formal recognition and adoption of Indigenous management practices, including a recognition that the high levels of biological diversity that exist are a direct result of traditional land management practices. Use of Indigenous ecological knowledge for management is not confined to IPAs. For instance, information about terrestrial native mammal fauna across northern Australia was compiled from a large series of interviews conducted across Indigenous communities to improve monitoring for management (Ziembicki et al. 2013). Similarly, collaborative research between the Aboriginal rangers from Warddeken Land Management Limited and western scientists has been used to quantify the ground-level impacts of buffalo on perennial freshwater springs of the Arnhem Plateau (Ens et al. 2010). The increase in uptake of Indigenous ecological knowledge into management is widely recognised as a major step forward in improving management effectiveness.

Target 2 of Australia's Biodiversity Conservation Strategy is 'by 2015, achieve a 25 per cent increase in employment and participation of Indigenous peoples in biodiversity conservation' (NRMMC 2010). The growth of Indigenous ranger programs may be the most significant nationwide development; the Closing the Gap report (2016) notes that 775 Indigenous people have been employed through Working on Country and IPAs. Mid-term evaluation of the Working on Country program's investment in rangers of $564 million from 2009 to 2018 identified strong mutual benefits in both supporting the interests of Indigenous people in caring for Country, including critical spiritual and cultural dimensions, and assisting the Australian Government to meet its responsibility to protect and conserve the environment (Ryan et al. 2012). The initiatives have steadily developed capacity among rangers, especially through exchanges between traditional and scientific knowledge, and by delivering environmental, employment, economic and cultural benefits. Many ranger groups have taken up scientific tools such as CyberTracker and other handheld data recorders for monitoring long-term change (Walsh et al. 2014). Carbon-related activities, such as burning or sequestration, may offer strong socio-economic and environmental outcomes throughout the Indigenous estate.

The National Environmental Science Programme's Northern Australia Environmental Resources Hub has identified that increasing Indigenous capacity and participation in management of land and sea Country is core to improving environmental management outcomes. Strengthening local Indigenous organisations will be critical for improved planning that incorporates Indigenous knowledge systems, increases rangers' services and on-ground work, and builds a peer-to-peer exchange for learning and management impact.

Management initiatives and investments

Biodiversity funding

NRM funding provides key measures that include many practical elements of protecting and sustainably managing biodiversity. For the past 30 years, the Australian Government—through the National Landcare Programme (established in 1992, revised in 2014), the Natural Heritage Trust (established in 1997) and Caring for our Country (established in 2008)—has provided community-based funding for improving land management practices and delivering environmental outcomes (Figure BIO31).

Phase 1 of the Caring for our Country initiative concluded in 2013, following an investment of $2.15 billion from 2008 to 2012. Another $316.7 million was paid in 2013–14 as part of the first year of phase 2 of Caring for our Country.

In 2014, the Australian Government announced the establishment of the (new) National Landcare Programme, merging the Caring for our Country and Landcare programs, with a budget of $1 billion across 4 years, which was a reduction of $471.6 million across 4 years from 2014–15 from the previous forward estimates. The savings were directed to fund other government priorities, including the Reef 2050 Long-term Sustainability Plan.

The 2015 Senate Standing Committee report on the National Landcare Programme (SECRC 2015) considered that there was ample evidence to conclude that the reduction in funding for Landcare will have a detrimental impact on NRM in Australia. The gains during the past 3 decades through the concerted efforts of government, NRM bodies, communities and landholders were considered to be under threat.

The National Landcare Programme supports regional NRM organisations across the country. In 2015–16, these organisations received funding totalling $108 million per year, representing a reduction in previous years' funding. However, the overall objectives of this component of the program remained largely consistent with previous programs (Caring for our Country). Although investment in the regional stream has decreased, investment in NRM has been supplemented by other government programs, including new investments in biosecurity.

The Biodiversity Fund program was established in 2011 to maintain ecosystem function and increase ecosystem resilience to climate change, and increase and improve the management of biodiverse carbon stores across the country. Significant investment was directed through the Biodiversity Fund from 2011–12 to 2017–18, providing approximately $350 million to increase the condition, extent, connectivity and resilience of native vegetation in project areas. The fund operated through a competitive, merit-based grants program, with an initial budget of $946.2 million across 6 years from 2011–12 to 2016–17. The program was broad in scope, with funding recipients including individual landholders through to large state government departments, and grants ranging from just over $7000 to $6 million. The program was closed in October 2013. At that time, almost $350 million was contracted to projects. Projects that received funding were to continue until 2017–18.

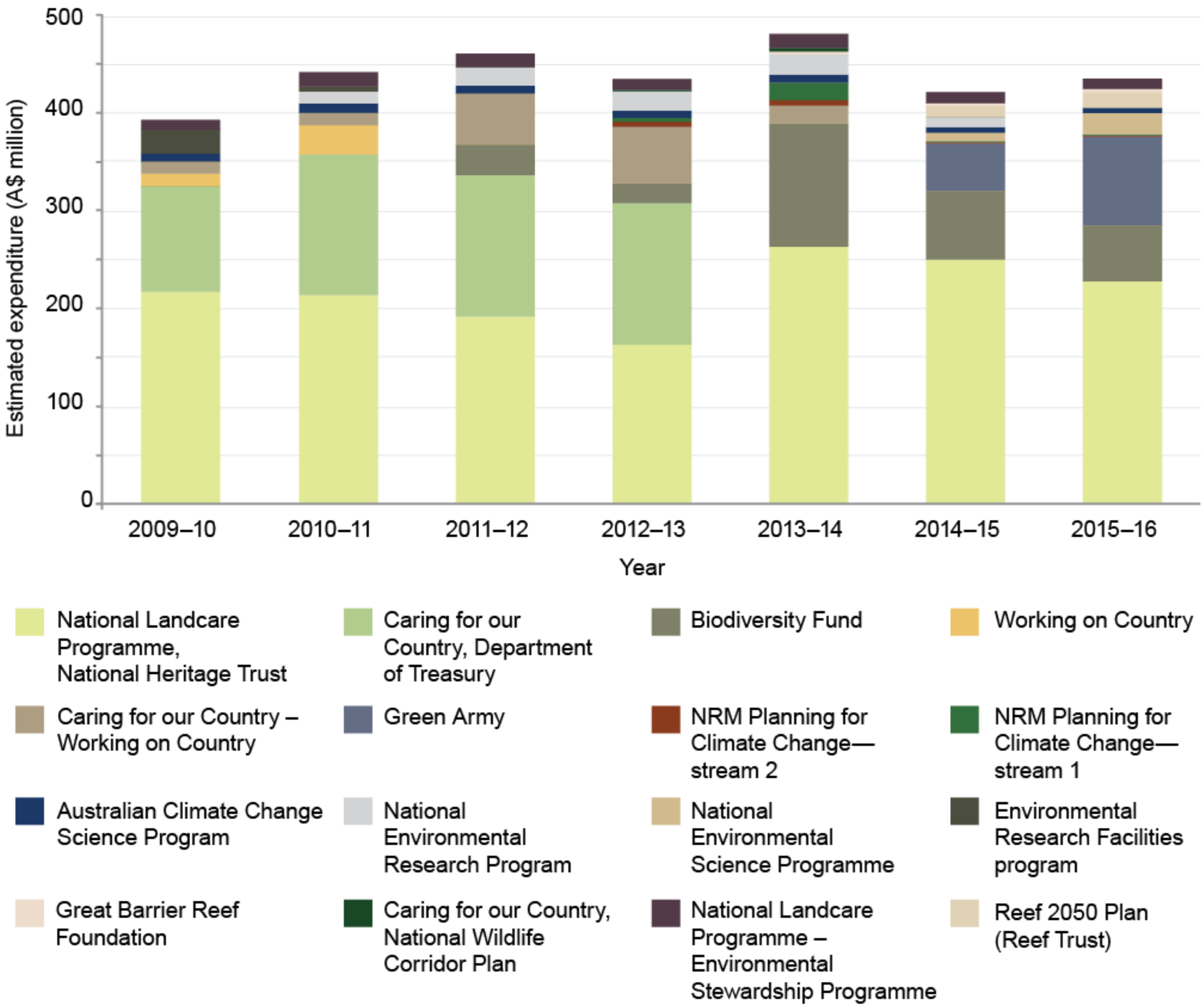
The Green Army, which was launched in 2014, is a hands-on practical environmental action program that supports local environment and heritage conservation projects across Australia. The program delivers environmental outcomes by working with communities, and building partnerships at the local and regional level. The Australian Government has provided more than $410 million for the program over 5 years from 1 July 2014 to support 1250 projects. Other sources of funding that contributed to the government's investment in NRM from 2014–15 include the Working on Country Indigenous rangers ($238 million over 4 years from 2014–15) and Reef Trust (currently $210 million over 8 years from 2014–15).

Since 1995–96, successive Australian governments have contributed close to $200 million towards the National Reserve System, and partners (state and territory governments, nongovernment organisations and private landowners) have also contributed funding and in-kind contributions. In 2014, the Australian Government ceased its dedicated acquisitions program, although funding is still available under the National Landcare Programme, including the 20 Million Trees Programme and Green Army, to support management activities on National Reserve System properties. Funding also continues to support consultation on, and declaration of, IPAs, which are an important component of the National Reserve System (72 properties, and more than 44 per cent of the National Reserve System).

Unfortunately, although massive effort has been mobilised over the years to undertake environmental works that should have major benefits for biodiversity (e.g. revegetation, weed control, fencing of waterways, improved stock management), documentation of the impacts of these actions has been poor, with no standardised way of reporting. Introduction of the Department of the Environment and Energy's online reporting tool, MERIT, in 2013 has gone some way to improving our understanding of the outcomes of Australian Government investments in NRM. The 2013 review of Caring for our Country noted achievements, among others, of expansion of the National Reserve System by more than 27 million hectares, including the declaration of 34 new IPAs, and off-reserve management of more than 10.8 million hectares of native habitat and vegetation projects to conserve native species, and enhance the condition and connectivity of landscapes.

Each state and territory also undertakes significant biodiversity conservation efforts,[3] as do local governments, nongovernment organisations and industry, through investment. For instance, in Victoria, there have been significant investment programs targeting biodiversity, such as the Victorian Environmental Partnerships Program (2013–15) and the Threatened Species Protection Initiative (2015–16).

3 It is not possible in this national report to outline all activities at a subnational scale.



Source: Based on data from the Australian Government Department of the Environment and Energy

Figure BIO31 Overall expenditure on biodiversity by the Australian Government, 2009–10 to 2015–16

Biodiversity discovery and research funding

Expenditure on biodiversity discovery and documentation has traditionally been undertaken by government through collections agencies (herbaria, museums) and university research, supported by the long-running National Taxonomy Research Grant Programme of the Australian Biological Resources Study (ABRS), managed by the Department of the Environment and Energy. During the past few decades, there has been a massive increase in investment from industry as part of development approvals. However, much of the information collected is not available more broadly for decision-making (and no information is available on the size of that investment). The ABRS Bush Blitz program is a partnership between the Australian Government, BHP Billiton Sustainable Communities and Earthwatch Australia. For the past 7 years, Bush Blitz has combined Department of the Environment and Energy funding with BHP Billiton investment, to discover, document and describe Australia's unique biodiversity (see Information gaps and gap-filling initiatives—terrestrial and aquatic). Figure BIO32 shows expenditure in the past 7 years for the ABRS and Bush Blitz.

Funding of the research infrastructure that supports biodiversity research is also an important component of government funding for biodiversity. The long-running programs of the Terrestrial Ecosystem Research Network (TERN), the ALA and the Integrated Marine Observing System (IMOS) all play key roles in the generation and distribution of biodiversity data and information that ultimately supports biodiversity management. Figure BIO33 shows biodiversity-related expenditure for the past 7 years for TERN, the ALA and IMOS. (The IMOS numbers are a conservative estimate based on 50 per cent of total IMOS spending being attributed to data that underpin biodiversity management.)

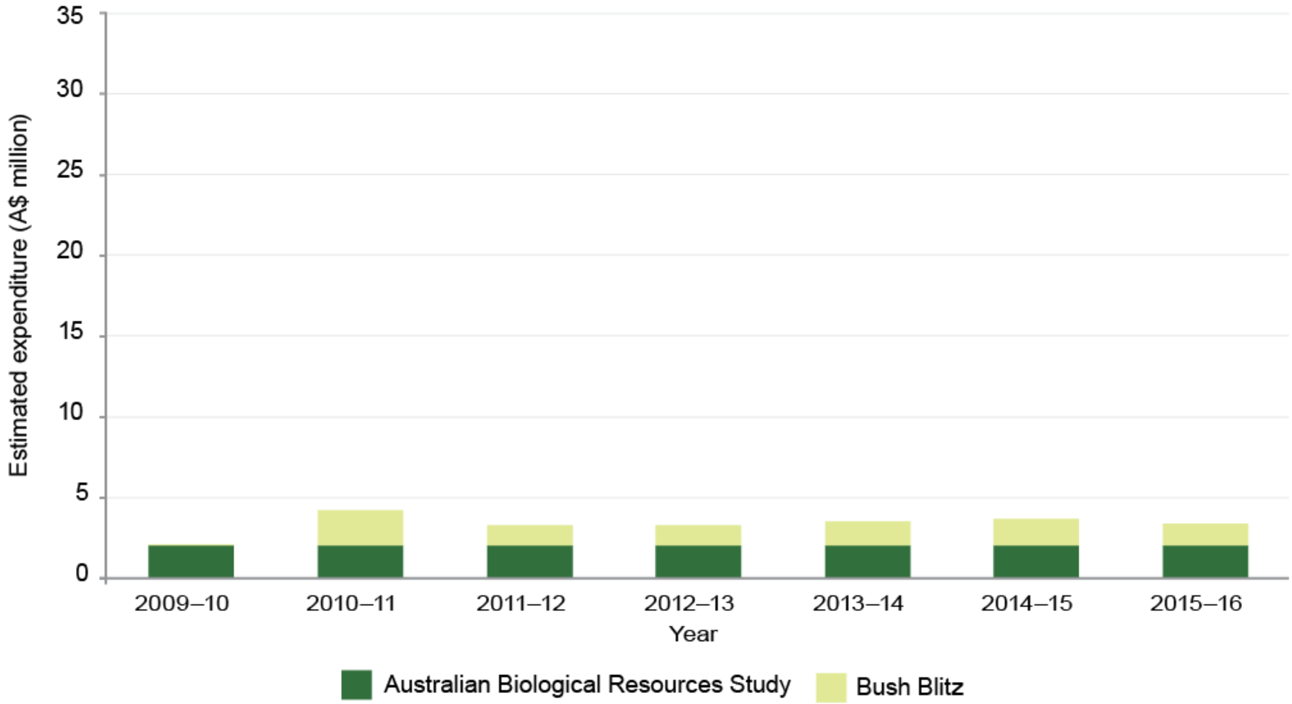
Climate science and adaptation funding

In response to the predicted effects of climate change, successive Australian governments have committed to a target of reducing, by 2020, Australia's carbon emissions to a level that is at least 5 per cent below the year 2000 emission levels. In July 2011, the Australian Government announced the Clean Energy Future initiative, which outlined planned measures to reduce Australia's carbon emissions to meet the 2020 target. The 4 key elements of the initiative were:

- the introduction of a carbon price
- a package of renewable energy programs
- a package of energy efficiency programs
- the Land Sector Package, which included the Biodiversity Fund program.

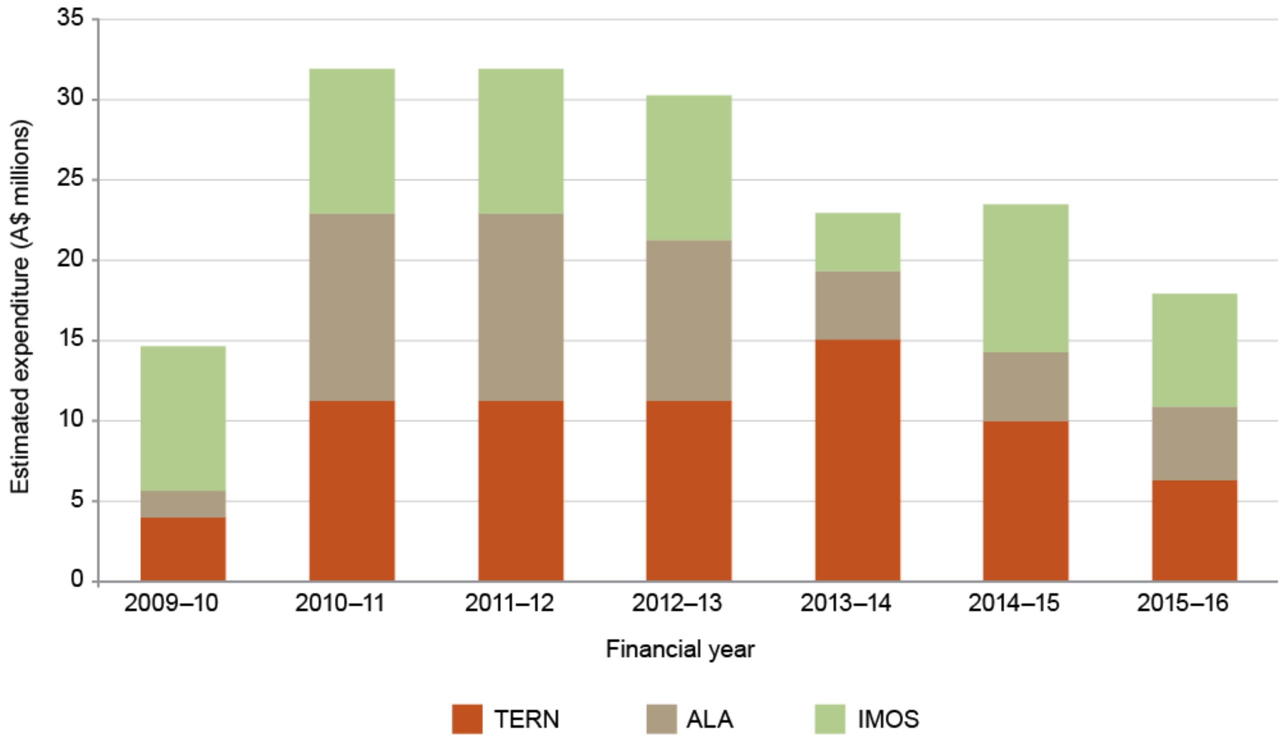
Overall funding to support climate research—such as data collection and measurements, and climate modelling—has fallen during the past 5 years. Figure BIO34 shows that climate science research funded directly by the Department of the Environment and Energy (not including contributions by other program partners or investment in climate research through other government departments, such as through Cooperative Research Centres or Centres of Excellence) was around $11 million in 2013 and has dropped to less than $6.5 million in 2015–16. Similarly, funding for climate change adaptation research from the department has dropped from around $18 million in 2013 to around $4 million in 2016.

Although not all research in these programs is directly related to biodiversity, the information gained provides the context for management to frame its response to the addition of climate impacts to a multitude of threatening processes. The loss or reduction of key climate programs that provided understanding of climate change and support for climate adaptation at a time of increasing climate pressures (see the *Atmosphere* report) has reduced activities that support the ongoing adaptive management of ecosystems.



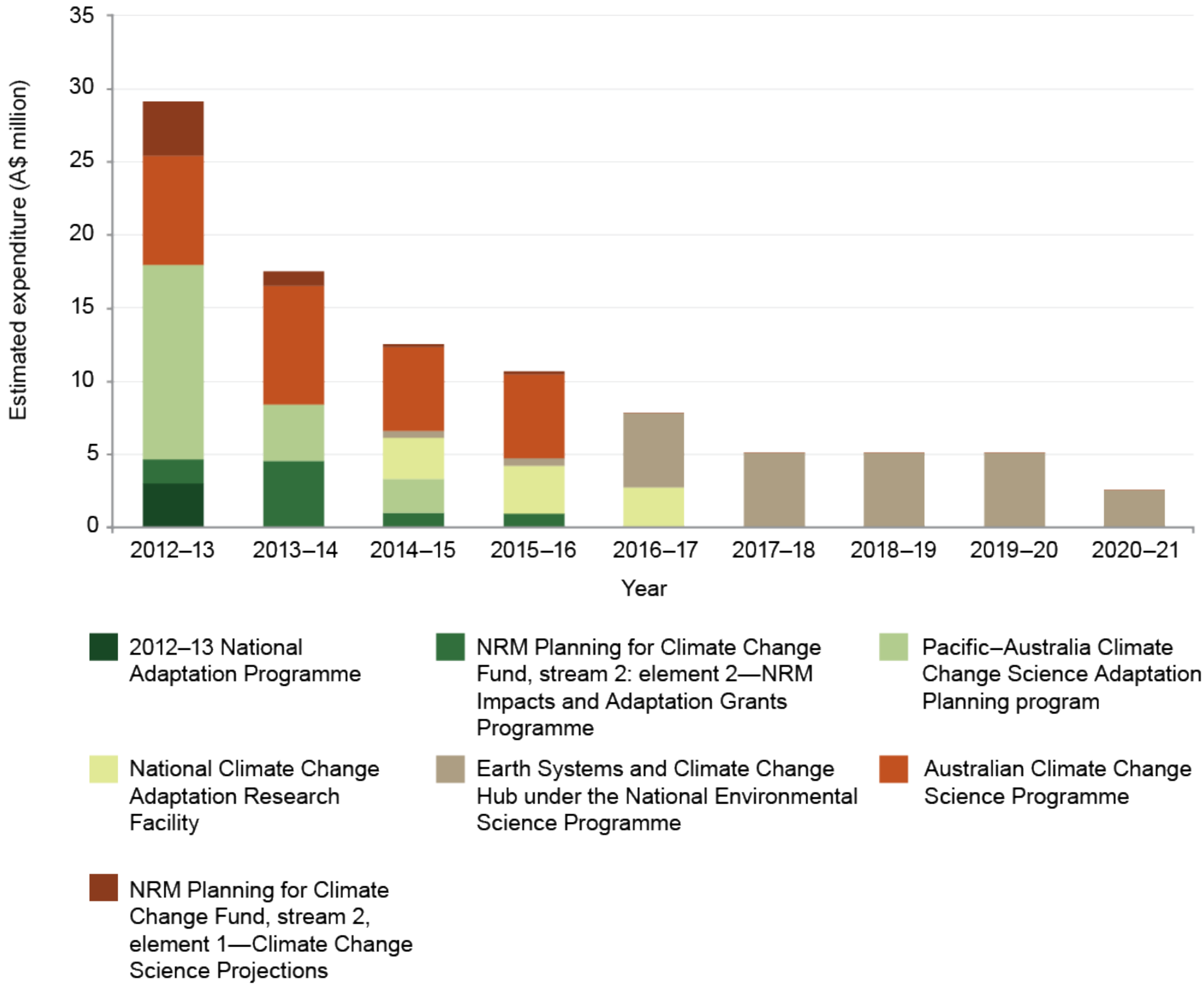
Source: Based on data from the Australian Government Department of the Environment and Energy

Figure BIO32 Funding for the Australian Biological Resources Study and Bush Blitz, 2009–10 to 2015–16



ALA = Atlas of Living Australia; IMOS = Integrated Marine Observing System; TERN = Terrestrial Ecosystem Research Network
Source: Based on data from the Australian Government Department of the Environment and Energy

Figure BIO33 Funding for TERN, the ALA and IMOS, 2009–10 to 2015–16



NRM = natural resource management
Source: Based on data from the Australian Government Department of the Environment and Energy

Figure BIO34 Expenditure by the Australian Government Department of the Environment and Energy on climate change research programs, 2012–13 to 2015–16, plus forward estimates

Biosecurity measures

Australia's biosecurity system is designed to manage the risk of pests and diseases entering, emerging, establishing or spreading in Australia, and causing harm to human, animal or plant health; the economy; the environment; and/or the community. Preventing pests and diseases from entering or emerging in Australia is more cost-effective than eradication, containment and ongoing management, and therefore biosecurity efforts are focused on keeping pests and diseases out of Australia.

Onshore and offshore, the Australian Government uses a range of sophisticated technologies and approaches—including research, shared international resources and intelligence—to prevent the introduction and spread of disease, and to manage and contain established pests and diseases. Biosecurity is a shared responsibility between the Australian Government, state and territory governments, farmers, industry, land managers and the wider community. In 2012, a range of measures—including the National Environmental Biosecurity Response Agreement, the Emergency Plant Pest Response Deed and the Emergency Animal Disease Response Agreement—were agreed to by all governments to provide national emergency response arrangements for biosecurity incidents that primarily affect the environment and/or social amenity, and involve plant pests and/or animal diseases.

Despite efforts to prevent pests and diseases from entering Australia, some pests and diseases do enter. They may be detected at ports and landing places; on farms; or in forests, urban areas and other environments. In 2012, Australia strengthened its ability to respond to outbreaks or incursions through the development of the nationally agreed Biosecurity Incident Management System. This system provides guidance on contemporary practices for the management of biosecurity incident response and initial recovery operations in Australia, such as eradication, re-establishing area freedoms (freedom from a pest or disease in an area), and helping industries and communities to rebuild.

Management status

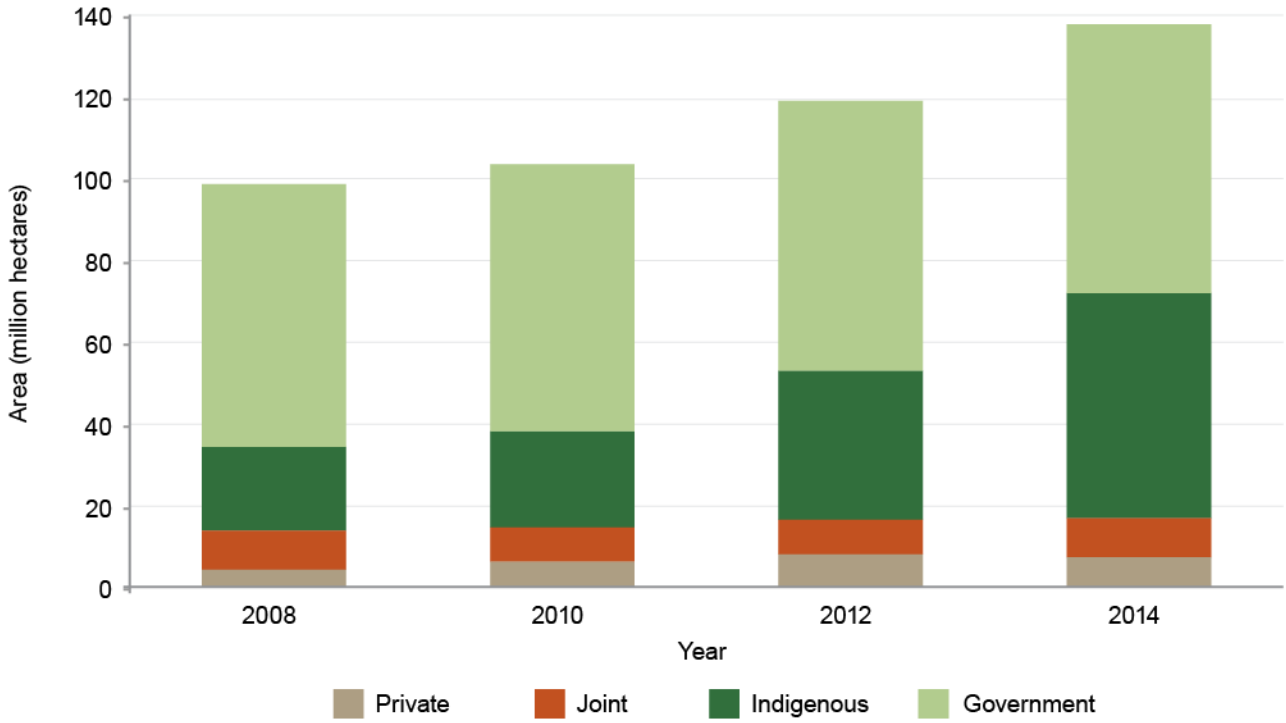
National Reserve System and National Representative System of Marine Protected Areas

Australia has an agreed intergovermental strategy for developing a comprehensive, adequate and representative National Reserve System: Australia's Strategy for the National Reserve System 2009–2030. Australia also has a Strategic Plan of Action for the National Representative System of Marine Protected Areas (ANZECC TFMPA 1999).

Australia's National Reserve System is a multijurisdictional, multitenure mosaic of protected terrestrial and marine areas under government, Indigenous or private management. IUCN categories I–VI protected areas contribute to national targets to meet international commitments, such as under the Convention on Biological Diversity. As of 2014, according to Collaborative Australian Protected Area Database (CAPAD) data, 47 per cent of the National Reserve System fell under Indigenous or joint management, 5.27 per cent was privately managed, and 47 per cent was managed by government (Figure BIO35).

Aichi Target 11 calls for 'by 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes'.

Since 2011, the National Reserve System has grown to cover 17.9 per cent of Australia's land area (CAPAD 2014), compared with 13.4 per cent in 2011 (CAPAD 2010). Highly protected areas such as national parks (IUCN categories I and II) account for nearly 45 per cent of the National Reserve System. The National Representative System of Marine Protected Areas (NRSMPA) extends across more than one-third of Australian waters, with 37 per cent of that area contained in highly protected areas (see the *Marine environment* report). Thus, Australia has met the area-based target of Aichi Target 11. However, additional efforts are



Source: Collaborative Australian Protected Area Database and Indigenous Protected Area database, Australian Government Department of the Environment and Energy, 2015

Figure BIO35 **Area of Indigenous, government, jointly held and private protected areas in the National Reserve System**

required to achieve an effectively managed, well-connected and ecologically representative National Reserve System. The current effort to achieve a representative terrestrial system is expanded on in the following section.

The extent of the terrestrial National Reserve System and the NRSMPA has increased substantially during the past 5 years; however, only limited evidence is available about the overall effectiveness of the reserve systems. There is a lack of consistent monitoring that could support evaluation of the effectiveness of the reserves and their management. Although threatening processes are actively managed within many reserves, biodiversity decline has been reported within some terrestrial conservation reserves (Woinarski et al. 2010, Lindenmayer et al. 2011, Smith M et al. 2012).

Further work is required to better define the full range of benefits we derive from the existence and management of conservation reserves, but there is no doubt that they play a critical role in maintaining biodiversity in Australia. Woinarski et al. (2013) found that the importance of different land tenures (including conservation reserves) varied between major taxonomic groups, but, in general, values were highest for conservation reserves, and this was particularly the case for threatened species. This 'biodiversity benefit' associated with conservation reserves is considered to be because of the positive effects of management.

However, recent changes to policy, legislative and management arrangements in some jurisdictions that allow an expansion of multiple uses of national parks, including activities that are generally considered detrimental to biodiversity, have raised new concerns about the viability of our national parks to maintain their biodiversity values (Ritchie et al. 2013). Continued improvements in management of our protected area system are critical for the protection of species and habitats, because they play a lead role in protecting the natural capital of Australia (Ziembicki et al. 2014, Taylor 2015a, Watson 2015, Barr et al. 2016).

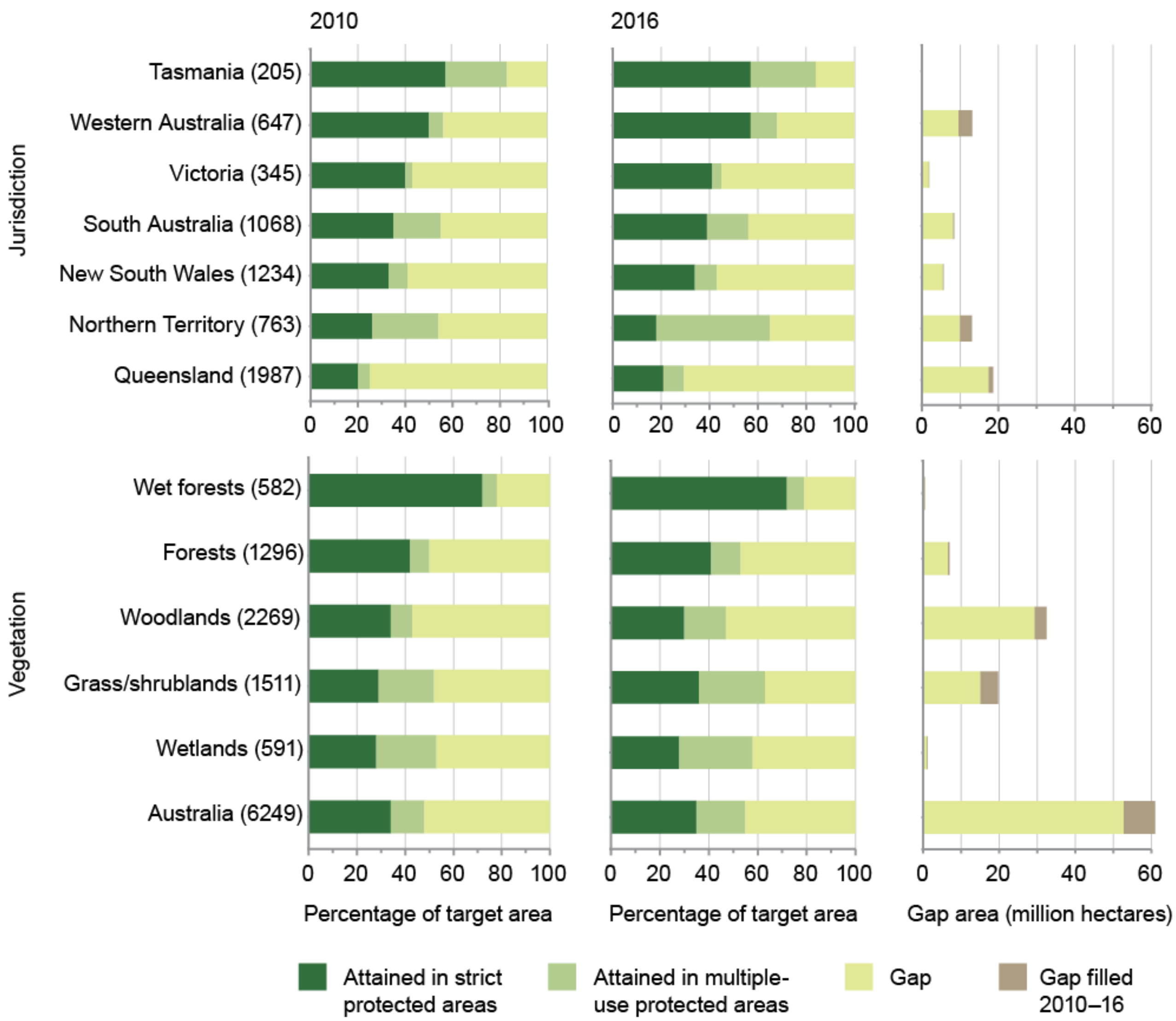
Mopsus mormon eating a cicada
Photo by Eric Vanderduys

Comprehensiveness, adequacy and representativeness of the terrestrial reserve system

WWF-Australia uses a minimum protection standard to regularly assess how well Australia's National Reserve System comprehensively, adequately and representatively protects Australia's ecosystems and species diversity (Taylor et al. 2014b). For terrestrial ecosystems, the standard is 15 per cent by area of the pre-clearing extent of each of the 6249 terrestrial ecosystems (as at 2016), with modifications for small ecosystems. This standard is considered a minimum to prevent ecosystems being converted or degraded to the point that they become endangered, or, if currently endangered, to recover to the point that they are no longer endangered.

Attainment of this standard has risen from 48 per cent in 2010 to 55 per cent in 2016, although most of the gain was not in strict protected areas (Figure BIO36). Forest ecosystems are the best protected, whereas woodland and grassland ecosystems are the least well protected. Wetlands in the arid and semi-arid zone, and aquatic ecosystems are generally poorly represented.

Despite considerable growth of protected areas during 2010–16 (42 million hectares—a 41 per cent increase), the overall gap area for ecosystem representation was only reduced by slightly more than 8 million hectares. The slow progress in representation compared with progress in gross area is a result of the dominance of recent growth in IPAs in only a small number of arid bioregions, meaning that advances in representation have been highly skewed.



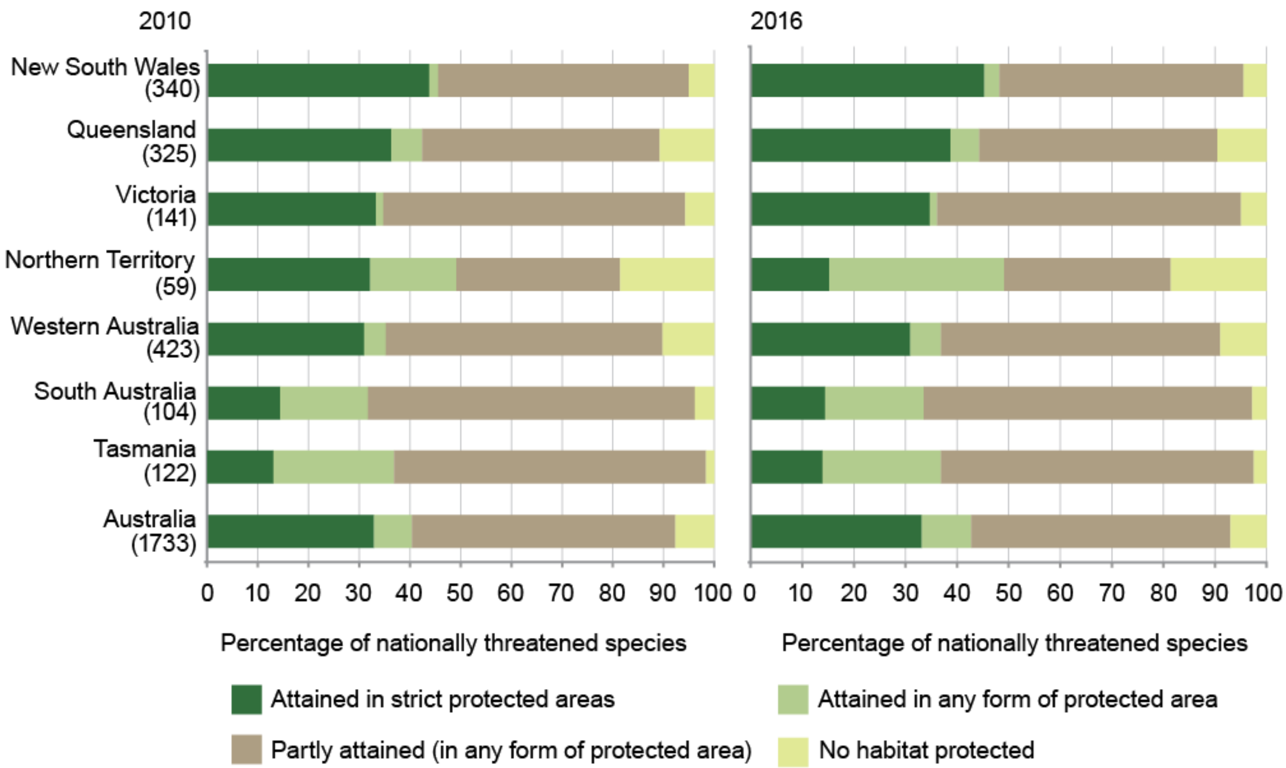
CAPAD = Collaborative Australian Protected Area Database; ha = hectare; IBRA = Interim Biogeographic Regionalisation for Australia; IUCN = International Union for Conservation of Nature

Notes: Cumulative percentages by area of 6249 terrestrial ecosystems attaining the minimum standard of 15% of original total area (with modifications for small areas, see below) in strict protected areas (i.e. IUCN categories I–II), and in other multiple-use protected areas (IUCN categories III–VI) as mapped in CAPAD 2010 (left) and interim CAPAD 2016 (middle). Protected areas III–VI are distinguished because they may allow potentially degrading activities such as livestock and, thus, need evidence to show that such activities are not impairing the conservation purpose. The remainder of the bar is the percentage of the standard aggregated across all ecosystems still needing to be protected if the 15% standard is to be met. Ecosystems were defined as intersections of 100 ha or more total area between IBRA 7 and National Vegetation Information System Major Vegetation Subgroups version 4.2 (excluding unclassified vegetation). The minimum standard for protection was set as follows: 15% of the total pre-clearing area of an ecosystem or, if this is less than 1000 ha, then at least 1000 ha. If pre-clearing extent itself is less than 1000 ha, then 100% of pre-clearing extent is the minimum ecosystem protection standard. Also shown is the cumulative gap area in 2016 and the reduction in the gap because of protected area growth since 2010 (right).

Source: Taylor (2016)

Figure BIO36 WWF-Australia’s estimates of how well area-based targets for protection of terrestrial ecosystems have been met, and how much area is still required (i.e. the gap between actual area in highly protected areas and the minimum ecosystem representation), 2010–16

The standard for a minimally adequate National Reserve System for terrestrial species protection is considered to be one that includes at least 30 per cent by area of 'known' or 'likely to occur' distributions for 1733 (as at 2016) threatened species, using the Australian Government distribution maps for such species (Taylor et al. 2014b). Proportions of species of national environmental significance (threatened or migratory) reaching the 30 per cent minimum standard of habitat representation showed only minor improvement during the period 2010–16 (Figure BIO37). Species numbers meeting the minimum habitat protection standard in any protected areas increased from 705 (40 per cent of species) to 741 (43 per cent) during the study period. There was a small (1 per cent) reduction in the species lacking habitat protection.



CAPAD = Collaborative Australian Protected Area Database; ha = hectare; IUCN = International Union for Conservation of Nature

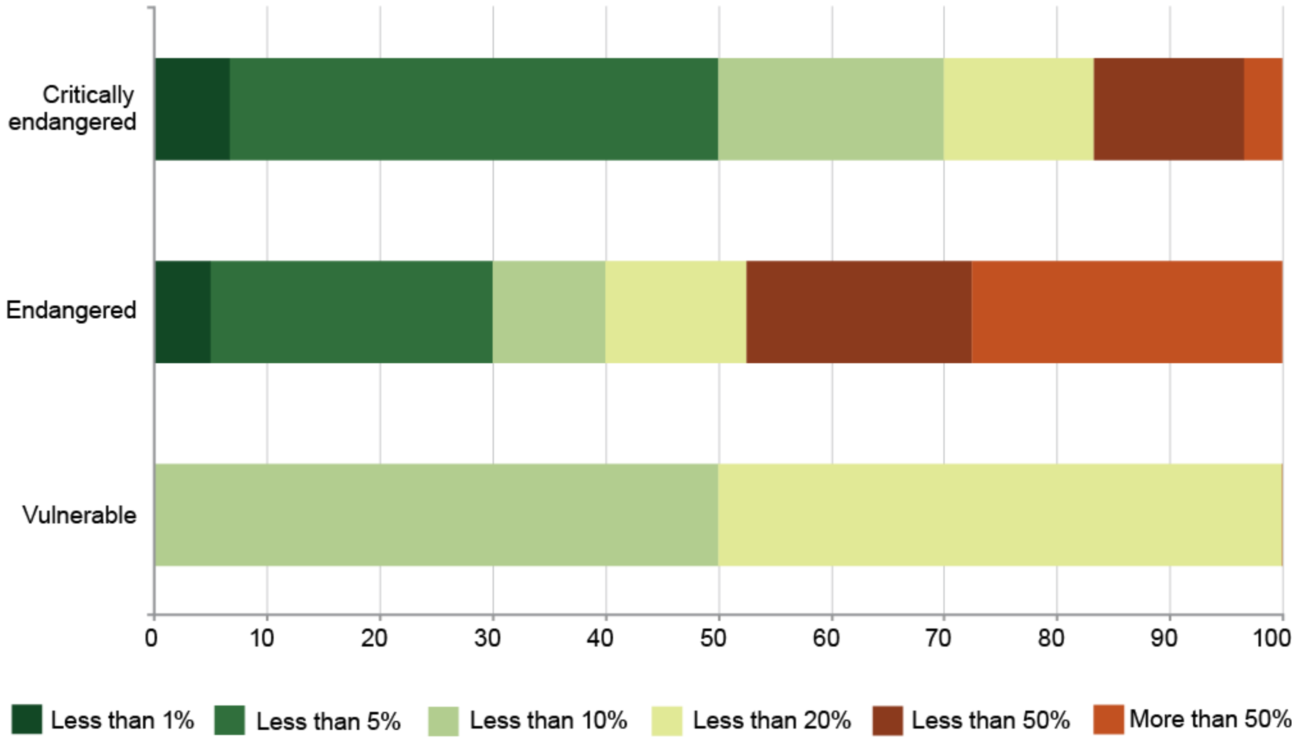
Note: Proportions of 1733 species of national environmental significance (SNES) with 30% or more of their terrestrial habitat included in strict protected areas (IUCN categories I–II); with less than 30% in strict protected areas but with 30% or more in any protected area; with less than 30% protected in any protected area; and with no representation at all in protected areas. Jurisdictions are ordered in decreasing proportions meeting the standard, with total numbers of species in brackets, for CAPAD 2010 (left) and CAPAD 2016 (right). Species primarily in external and Australian territories (160 species) or species in multiple jurisdictions (59 species) are included in the national totals but are not graphed separately. The standard for habitat protection varied depending on distribution size as follows: 30% of the mapped known or likely-to-occur habitat in the SNES database or, if this is less than 1000 ha, then at least 1000 ha. If greater than 10 million ha, the standard was capped at 10 million ha. If total habitat itself is less than 1000 ha, then 100% was the minimum habitat protection standard. Species with all 'may occur' habitat were not included, and no 'may occur' habitat was included.

Source: Taylor (2016)

Figure BIO37 Adequacy of protection of nationally threatened species, 2010–16

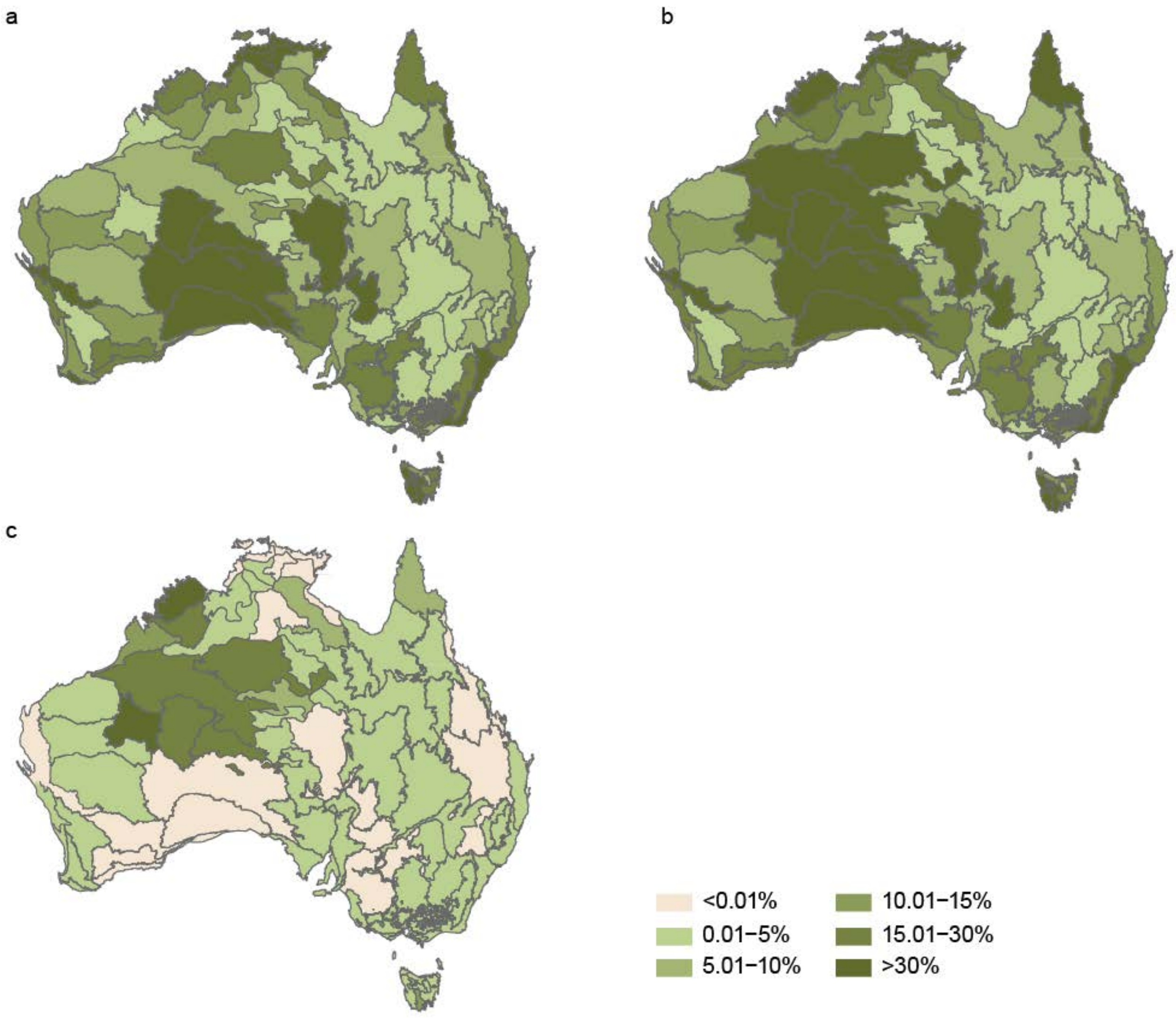
Fifty per cent of critically endangered EPBC Act–listed communities and 30 per cent of endangered communities have less than 5 per cent of their area represented in the terrestrial National Reserve System (Figure BIO38). Only 1 critically endangered community has more than 50 per cent of its area represented in the National Reserve System: the very restricted Thrombolite Community of a Coastal Brackish Lake (Lake Clifton). Nearly 30 per cent of endangered communities have more than 50 per cent representation in the National Reserve System.

The National Reserve System has grown considerably in central, western and northern parts of Australia (Figure BIO39), largely because of growth in IPAs.



Note: This analysis does not include the most recently listed ecological community: the Eucalypt Woodlands of the Western Australian Wheatbelt, listed in December 2015.
Source: Australian Government Department of the Environment and Energy

Figure BIO38 Proportion of ecological communities represented in the National Reserve System and listed under the *Environment Protection and Biodiversity Conservation Act 1999*



Source: Collaborative Australian Protected Area Database, Australian Government Department of the Environment and Energy, 2011 and 2015

Figure BIO39 Proportion of Interim Biogeographic Regionalisation for Australia regions represented in the National Reserve System in (a) 2011 and (b) 2015; (c) proportional change between 2011 and 2015

Indigenous Protected Areas

The Australian Government established the IPA program in the mid-1990s to support Indigenous Australians in managing their land for conservation as part of the National Reserve System. IPAs comprise more than 44 per cent (72 IPAs as of January 2016) of the National Reserve System—an increase of more than 20 per cent from 2010. Considering jointly managed national parks and IPAs together, Indigenous groups are involved in the management of nearly 50 per cent of the National Reserve System. IPAs fall into several IUCN protected area categories (i.e. II–VI), depending on the type of management arrangements in place. However, the majority are in IUCN category VI (multiple use), with 8.7 per cent in category II (equivalent to a national park).

Conservation outside reserves

With approximately 60 per cent of Australia's land lying in private ownership, either as freehold (20 per cent) or Crown leasehold (40 per cent), private conservation covenants are critical for meeting the challenge of expanding the National Reserve System (Craigie et al. 2015; see Box BIO14). These protected areas have restrictions on use attached to the title of freehold lands, and special conditions on leasehold lands, to enable their management as private protected areas.

All Australian states and territories have conservation covenant programs (Table BIO4), covering a total area of nearly 4.5 million hectares. Not all states or territories provide information on conservation covenants to CAPAD, and not all covenants may be accepted as part of the National Reserve System. Some nongovernment organisations own significant private reserves; the Australian Wildlife Conservancy owns and manages 23 properties covering more than 3 million hectares, and Bush Heritage owns and manages 35 reserves covering around 1 million hectares (Table BIO5).

Table BIO4 State and territory–based conservation covenant programs in Australia, as at September 2013

Jurisdiction	Program	Covenants (no.)	Area protected (ha)
New South Wales	Conservation Agreements Program	367	143,050
New South Wales	Registered property agreements	237	44,150
New South Wales	Nature Conservation Trust covenants	73	16,687
Queensland	Nature Refuges Program	453	3,438,004
Victoria	Trust for Nature Conservation Covenant Program	1,242	53,370
South Australia	Heritage Agreements	1,518	643,631
Western Australia	Conservation Covenant Program (National Trust of Australia, WA)	162	17,879
Western Australia	Nature Conservation Covenant Program (Department of Environment and Conservation)	169	17,386
Tasmania	Private Land Conservation Program	703	83,644
Northern Territory	Conservation covenants	2	640
Total		**4,926**	**4,458,441**

Source: Fitzsimons (2014)

Some other covenanting arrangements are effectively managed in the same way as conservation covenants. However, not all properties owned by private conservation trusts would necessarily qualify as private protected areas under the current National Reserve System criteria, although they are managed with this explicit intent. Several private land trusts operate revolving funds, whereby a property is purchased by a nongovernment organisation and then sold on with a conservation covenant attached. A smaller number of acquisitions have been by community groups, such as the Twin Creeks Community Conservation Reserve. Oher governance types are also emerging. For example, Fish River was purchased by the Indigenous Land Corporation with financial support from the Australian Government's National Reserve System Program and nongovernment organisations (The Nature Conservancy and Pew Environment Group) (Fitzsimons & Looker 2012). It will be handed back to the traditional owners in the future.

The size of privately protected areas varies widely. Overall, these areas make up a relatively small but growing proportion of the National Reserve System.

Table BIO5 Private reserves owned by major nonprofit conservation land-owning organisations in Australia, as at June 2013

Organisation	Properties (no.)	Total area (ha)
Bush Heritage Australia	35	960,000
Australian Wildlife Conservancy	23	>3,000,000
Trust for Nature (Victoria)	47	36,104
Nature Foundation SA	5	499,705
Nature Conservation Trust of NSW	12	10,182
Tasmanian Land Conservancy	11	7,283
South Endeavour Trust	7	80,846

Box BIO14 The Vale of Belvoir

The Vale of Belvoir property is an example of a private protected area, which was purchased by the Tasmanian Land Conservancy in 2008 to protect 476 hectares of montane grassland, wetlands and rainforest in Tasmania's Central Highlands. It is one of Australia's best examples of rare and endangered highland grasslands. It also contains unusual karst geology, and important cultural, historical and aesthetic values.

In 2010, a statutory perpetual conservation covenant was registered on the land title under the Tasmanian *Nature Conservation Act 2002*, which helps protect 6 nationally threatened flora and fauna species (paper daisy—*Leucochrysum albicans*, endangered; Tasmanian devil—*Sarcophilus harrisii*, endangered; spotted-tailed quoll—*Dasyurus maculatus*, vulnerable; eastern quoll—*D. viverrinus*, vulnerable; masked owl—*Tyto novaehollandiae castanops*, vulnerable; and ptunarra brown butterfly—*Oreixenica ptunarra*, endangered), and 1 nationally threatened vegetation community (alpine sphagnum bogs and associated fens). It also protects 3 geoconservation sites of significance, including the nationally significant Vale of Belvoir Sub-alpine Karstland, the Central Highlands Cainozoic Glacial Area and the globally significant Central Plateau Terrain.

Some 95 scientific monitoring sites have been installed across the reserve to inform management, and the national Bush Blitz program has helped identify many species from lesser known taxonomic groups, including 6 new species.

Box BIO14 (continued)

The Tasmanian Land Conservancy Vale property Belvoir

Photos: © Tasmanian Land Conservancy

Management of threatened species and ecological communities

For biodiversity, the change in number of threatened species is a widely used trend measure, and is commonly reported in each jurisdiction's SoE reporting. However, in most cases, this index is very inexact, given timelags and noncomprehensiveness in the assessment of the threatened status of species, and the lack of population monitoring for many or most threatened species (Woinarski et al. 2014).

Species listing can be a long and difficult process, and changes to listings can also take time. For instance, the extinctions during the past decade of the Christmas Island pipistrelle, Christmas Island forest skink and Bramble Cay melomys are not in any dispute, yet none are listed as extinct under the EPBC Act. In addition, delistings and uplistings make interpreting the trend in threatened species difficult.

However, the number of threatened species is Australia is clearly increasing. Of particular concern is the number of new listings and uplistings to the critically endangered category. Overall, the number of species listed in the critically endangered category under the EPBC Act rose from 150 in 2011 to 206 by the end of 2015. Increases occurred across all taxa. In part, this is a result of an improvement in the efficiency of assessments since 2011, particularly with the publication of *The action plan for Australian mammals 2012* (Woinarski et al. 2014) and the *State of Australia's birds 2015* (BirdLife Australia 2015).

During the next 5 years, we can expect to see more changes to EPBC Act and state and territory lists as a result of a common assessment method being developed for threatened species and ecological communities (see Box BIO15).

Box BIO15 A common assessment method for threatened species and ecological communities

Australian, state and territory governments currently maintain separate lists of threatened species, and some maintain lists of threatened ecological communities. The amount of overlap and commonality between the lists is very variable because of differences in methodologies for assessing species as threatened, and use of different terminologies and threat categories in legislation.

The Australian Government, and states and territories are working together to develop a nationally consistent approach to assessing risks to species and ecological communities, and assigning them to a standard set of threat categories. This common assessment method will be based on the best-practice standard established by the International Union for Conservation of Nature. The adoption of this methodology will ensure consistency in the listing process and in the outcomes of assessments.

The common assessment methodology will be applied in a hierarchical way. First, a species or community would be assessed at the national level. Species and communities that are assessed as threatened nationally would then be listed in the same category on the statutory list of all jurisdictions in which the species or community occurs. If a species or community does not meet the criteria for listing as threatened nationally, a state or territory may elect to assess and list it in a category of threat appropriate at the state or territory scale. All existing threatened species and ecological communities will be transitioned to an agreed threat category under either state or territory listings, or under the *Environment Protection and Biodiversity Conservation Act 1999*.

Threatened Species Strategy

The Threatened Species Strategy is the key Australian Government policy that outlines the government's approach to protecting and recovering threatened species, and provides an action plan for prioritising effort. Under the improving recovery practices target, each priority species identified in the strategy requires either:

- an up-to-date conservation advice, which provides guidance on immediate recovery and threat abatement activities that can be undertaken to ensure the conservation of a newly listed species or ecological community, or
- a recovery plan, which sets out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or ecological communities.

The strategy also requires that a comprehensive review and work plan is developed to ensure that recovery plans or conservation advices are up to date for other high-priority species and ecological communities.

The 5-year action plan includes key action areas and targets to measure success. It identifies 20 mammal species (Table BIO6), 20 bird species (Table BIO7) and 30 plant species (Table BIO8) targeted for recovery by 2020. It also includes ambitious targets to tackle feral cats and improve recovery practices for all threatened species, and an additional initiative for the Christmas Island frigatebird (*Fregata andrewsi*).

The Threatened Species Commissioner leads the implementation of the strategy. The commissioner was appointed in July 2014, and is tasked with raising awareness about Australia's threatened species and mobilising resources to support the fight against extinction.

Since the appointment of the commissioner and development of the strategy, more than $210 million has been mobilised towards almost 1000 projects, including work undertaken through the Green Army and the National Landcare Programme. Many projects have complemented work being undertaken by external partners. For example, in Victoria, the population of the critically endangered helmeted honeyeater has more than doubled, thanks to a project run by Zoos Victoria, which is supplemented with a $3 million government investment to rehabilitate and expand the species' habitat.

Golden-tailed gecko (*Strophurus taenicauda*)
Photo by Eric Vanderduys

Table BIO6 Threatened Species Strategy: 20 mammals by 2020

Common name	Status	Main threats
Black-footed rock wallaby	Vulnerable	Foxes, feral cats, habitat degradation, fire
Brush-tailed rabbit-rat	Vulnerable	Feral cats, fire, habitat loss
Central rock-rat[a]	Endangered	Fire, feral cats, foxes, habitat degradation by livestock and feral herbivores
Christmas Island flying fox	Critically endangered	Feral cats, disease, yellow crazy ants
Eastern barred bandicoot	Endangered on the mainland	Feral cats, foxes, disease, habitat loss
Eastern bettong	Extinct on the mainland	Feral cats, foxes, habitat loss
Eastern quoll	Endangered	Feral cats, disease
Gilbert's potoroo	Critically endangered	Feral cats, foxes, fire, wildfire
Golden bandicoot	Vulnerable	Feral cats, fire
Greater bilby	Vulnerable	Feral cats, foxes, fire
Kangaroo Island dunnart	Endangered	Feral cats, fire, habitat modification because of phytophthora
Leadbeater's possum[a]	Critically endangered	Fire regimes, wildfire, habitat loss
Mahogany glider	Endangered	Habitat loss and degradation, fire, entanglement in fencing
Mala	Endangered	Feral cats, foxes, black rats, fire
Mountain pygmy possum	Endangered	Feral cats, foxes, habitat loss, climate change, fire
Northern hopping mouse	Vulnerable	Feral cats, fire
Numbat	Vulnerable	Feral cats, foxes, habitat loss
Western quoll	Vulnerable	Feral cats, foxes
Western ringtail possum	Vulnerable	Climate change, foxes, feral cats, fire, habitat loss
Woylie	Endangered	Feral cats, foxes, fire

a Identified for emergency intervention

Table BIO7 Threatened Species Strategy: 20 birds by 2020

Common name	Status	Main threats
Australasian bittern	Endangered	Diversion of water from wetlands, habitat loss, feral cats, foxes, grazing
Eastern bristlebird	Endangered	Inappropriate fire, weeds, feral animals
Eastern curlew	Critically endangered	Human disturbance, habitat loss, degraded water quality
Golden-shouldered parrot	Endangered	Fire, fearl pigs, grazing, illegal trapping, altered land use, feral cats
Helmeted honeyeater	Critically endangered	Drought, wildfire, disease, habitat degradation, competition from other birds
Hooded plover	Vulnerable	Human pressure on nesting sites
Malle emu-wren	Endangered	Wildfire
Malleefowl	Vulnerable	Habitat loss, foxes, feral cats, grazing, fire
Night parrot	Endangered	Fire, feral cats
Norfolk Island boobook owl	Endangered	Predation
Norfolk Island green parrot	Endangered	Feral cats, rats
Orange-bellied parrot[a]	Critically endangered	Disease, competition for nesting sites, predation
Plains-wanderer	Critically endangered	Habitat degradation, grazing pressure
Red-tailed black cockatoo (south-eastern)	Endangered	Habitat loss, inappropriate fire regimes
Regent honeyeater	Critically endangered	Habitat loss and degradation, noisy miners
Southern cassowary	Endangered	Habitat loss, vehicle strikes, dog attacks
Swift parrot	Endangered	Predation by sugar gliders, habitat loss
Western ground parrot	Critically endangered	Wildfire, feral cats
White-throated grass wren	Vulnerable	Fire, weeds, feral cats, feral pigs, climate change
Yellow chat (Alligator Rivers)	Endangered	Habitat degradation from weeds, and feral herbivores and pigs

a Identified for emergency intervention

Table BIO8 Threatened Species Strategy: 30 plants by 2020

Common name	Status	Main threats
Ant plant	Vulnerable	Habitat loss, invasive weeds, removal of plants by plant and butterfly collectors
Black grevillea	Endangered	Habitat loss, invasive weeds, herbicide overspray, frequent fire, grazing, animals, phytophthora dieback
Blue-top sun-orchid	Critically endangered	Habitat loss and degradation, grazing, invasive weeds
Bulberin macadamia nut	Endangered	Changed fire regimes, weed invasion, disease, feral pigs, illegal collection, timber harvesting
Button wrinklewort	Endangered	Habitat loss, invasive weeds, changed fire regimes, grazing, herbicide and mowing impacts
Caley's grevillea	Endangered	Habitat loss, invasive weeds, changed fire regimes, human disturbance
Central Australian cabbage palm	Vulnerable	Exotic grass invasion (buffel grass and couch), increased fire exposure, changed hydrology, tourism impacts
Fairy bells	Vulnerable	Feral animal impacts, grazing, habitat loss, inappropriate fire regimes
Fitzgerald's mulla-mulla	Critically endangered	Habitat loss; salinity; waterlogging; grazing by stock, rabbits and kangaroos; invasive weeds
Fleurieu leek orchid	Critically endangered	Habitat loss and degradation, stock trampling, changed hydrology
Glossy-leaved hammer-orchid	Endangered	Habitat loss, fire, invasive weeds, grazing animals, salinity
Kakadu hibiscus	Vulnerable	Inappropriate fire regimes
Little mountain palm	Critically endangered	Predation of seed by introduced rats, invasive weeds
Magenta lilly pilly	Vulnerable	Habitat loss and fragmentation, changed fire regimes, invasive weeds
Matchstick banksia	Endangered	Phytophthora dieback, habitat fragmentation, invasive weeds, changed fire regimes
Mongarlowe mallee	Critically endangered	Phytophthora dieback, habitat loss, disturbance
Morrisby's gum	Endangered	Changed fire regimes; drought and browsing of seedlings by native animals, rabbits and insects
Mossman fairy orchid	Critically endangered	Illegal collecting, invasive weeds, site disturbance
Ormeau bottle tree	Critically endangered	Habitat loss, invasive weeds, low genetic diversity, fire, insect attack
Purple wattle	Critically endangered	Habitat loss, grazing by cattle, mining, road works, invasive weeds, illegal collecting

Table BIO8 (continued)

Common name	Status	Main threats
Scaly-leaved featherflower	Endangered	Habitat loss, invasive weeds, rabbits, inappropriate fire regimes
Shy susan	Critically endangered	Phytophthora dieback, inappropriate fire regimes, land clearance
Silver daisy-bush	Vulnerable	Livestock grazing, invasive weeds, habitat fragmentation
Silver gum	Endangered	Hybridisation, waterlogging and changes to hydrology, invasive weeds and pathogens, insect attack, grazing
Small purple pea	Endangered	Habitat loss, invasive weeds, grazing, soil erosion
Southport heath	Critically endangered	Phytophthora dieback, inappropriate fire regimes, damage from severe storms
Spiny rice-flower	Critically endangered	Invasive weeds, habitat loss and fragmentation, grazing impacts, fire
Turnip copperburr	Endangered	Invasive weeds, habitat loss and degradation, changed fire regimes, grazing, soil salinity
Vincentia banksia	Not EPBC Act listed; however, listed as critically endangered in New South Wales	Land-use change, invasive weeds, disturbance, fire
Whibley's wattle	Endangered	Habitat fragmentation, salinity, grazing pressure, invasive weeds

EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*

Recovery planning for threatened species and communities—progress in implementing recovery plans

In November 2015, 730 species of the 1770 species listed under the EPBC Act were covered by a recovery plan. This included 391 single-species plans, 43 multiple-species plans covering 218 species, and 7 regional plans covering 126 species (a few species are covered by more than 1 type of plan). Under the EPBC Act, all species and ecological communities are required to have a conservation advice in place at the time of their listing. The decision to also have a recovery plan for a listed species or ecological community is a discretionary decision by the Minister for the Environment. A decision on this is made at the level of the individual species or ecological community. So, although not all listed species or ecological communities require a recovery plan, they will have at least a conservation advice in place. Recovery plans are only prepared when the listed species or ecological community has complex management needs because of its ecology, the nature of threats affecting it, or the number of stakeholders affected by, or involved in, implementing the necessary actions.

Conservation advices are relied on where the protection needs are well understood and relatively simple. The lack of funding for the recovery of threatened species, implementation of recovery plans and monitoring of the effectiveness of recovery actions is repeatedly identified as a major problem by land and natural resource managers (SECRC 2013).

The action plan for Australian mammals 2012 (Woinarski et al. 2014) assessed the recovery plans and the degree of implementation of those plans for threatened, near threatened and data-deficient mammals. It noted that:

> *This documentation is not always straightforward to interpret because (i) we note examples of recovery plans in informal use that have not yet been formally endorsed (with many of these plans having had long informal gestation periods); (ii) at least some recovery plans are now long outdated but are still being used; (iii) there is little available documentation of the degree of implementation (and consequential benefit) for many to most recovery plans; (iv) many recovery plans have been developed only very recently and hence are unlikely to have yet been implemented or produced benefits; and (v) many threatened species (particularly those now restricted to single jurisdictions) have been managed by well established state/territory management strategies, processes or plans rather than national recovery plans made under the EPBC Act.* (Woinarski et al. 2014)

Recovery actions and investments—effectiveness of investment in recovery actions

The effectiveness of recovery planning for threatened species and communities is difficult to assess, and there is uncertainty as to whether having a recovery plan in place makes a long-term contribution to species recovery. Some recent research in Australia (Bottrill et al. 2011) suggests that there is no significant difference between change in species status (either an improvement or decline) for species with recovery plans versus those without, across a 10-year period. The presence of a recovery plan did not seem to influence the actions implemented or whether species receive conservation attention. However, a major finding of this research was that there is a lack of basic accounting of recovery planning efforts and, therefore, attempts to understand the value of recovery planning are severely hampered.

In contrast, for mammals, species with well-established and well-implemented recovery plans were more likely to have shown improvement in conservation status from 1992 to 2012 than taxa without recovery plans, or taxa with recovery plans that are very recent or have been little implemented (Woinarski et al. 2014). *The action plan for Australian mammals 2012* documents some cases where recovery planning has been instrumental in improving the conservation outlook for threatened taxa (e.g. chuditch—*Dasyurus geoffroii*, and bridled nail-tail wallaby—*Onychogalea fraenata*). However, there are also cases where recovery plans have demonstrated little success. The most extreme examples are the Christmas Island pipistrelle and the Bramble Cay melomys, where established recovery plans failed to prevent extinction. The Bramble Cay melomys population was probably less than 100 individuals, and occurred on only 1 uninhabited island in Torres Strait. The recovery plan recognised the key threats and the key factor—climate change—that appears to have resulted in the species' extinction, although, at the time, the significance of the threat was not well understood. The recovery plan states:

> *Although no specific assessment of this threat has been undertaken, the likely consequences of climate change, including sea level rise and increase in the frequency and intensity of tropical storms are unlikely to have any major impact on the survival of the Bramble Cay melomys in the life of this plan.* (Latch 2008)

Pencil pine (*Athrotaxis cupressoides*) ecosystems burned in the wildfire at Lake Mackenzie (Tasmanian Wilderness World Heritage Area) in January 2016

Photo by Chris Emms

However, very few of the actions in the recovery plan appear to have been implemented, including annual population and habitat monitoring.

Several studies have also reported bias in the types of species with recovery plans. Data current to 2010 show that amphibians and birds have the greatest percentage of species with recovery plans; invertebrates, plants and reptiles are poorly represented in the species that have plans (Walsh et al. 2013).

Researchers have also shown that overlap of threatened species ranges with highly protected areas in Australia is associated with stabilisation or recovery of threatened species populations (Taylor et al. 2011). On the other hand, there is little demonstrable relationship between recovery of threatened species populations and the number of recovery actions or natural resource conservation activities applied. Again, the lack of sufficient data on the implementation of recovery actions hampers any robust analysis of their effectiveness.

A report by the Australian Conservation Foundation, BirdLife Australia and Environmental Justice Australia (ACF et al. 2015) found that, of 120 species-specific, multispecies or regional recovery plans, 85 identified critical habitat and 80 identified habitat loss as a key threat in the recovery plan. In almost all cases, active protection of habitat is a recommended action in the recovery plan. However, only 12 plans placed any form of prescriptive limit or constraint on the future loss of habitat. The authors concluded that, given that there is some precedent for prescribing limits on habitat loss, recovery plans could be more effective if they provided unambiguous and appropriate prescriptions to prevent the loss of critical habitat.

Translocations

Conservation translocation is increasingly used as a tool in conservation management and recovery planning for threatened species. Translocation involves the intentional movement of organisms from one place to another to conserve species. This may take several forms: re-establishing a species in parts of its historical range (reintroduction), releasing individuals to bolster existing populations within the range, or establishing a species outside its historical range in response to threats such as climate change (translocation or assisted colonisation) (Armstrong et al. 2015). Another term, 'salvage translocation', is now used to refer to the relocation of individuals from an area adversely affected by development to an area reserved or protected from ongoing impacts.

Conservation translocations have a long history in Australia. The first recognised conservation translocations occurred in the late 19th and early 20th centuries, when declining marsupials were translocated to islands off Victoria and South Australia (Armstrong et al. 2015). Since the 1990s, conservation translocation has been regularly used for the conservation of threatened plants and animals. There is now a plethora of state, territory and nongovernment organisation policies and protocols reflecting the increasing range of circumstances in which translocation has been, and is being, implemented (Nally & Adams 2015). Although most translocation activities are carried out by state and territory government agencies as part of a formal recovery plan or equivalent, there is also an increasing number of private-sector and nongovernment species conservation programs using translocations, as well as partnerships between all 3 sectors (Nally & Adams 2015).

To deal with both the increasing use of salvage translocation and the need for national consistency, the Australian Government published a policy statement on how translocations would be considered under the EPBC Act in 2009, which was revised in 2013. The EPBC Act environmental offsets policy outlines the use of offsets to compensate for an action's residual significant impact that remains after avoidance and mitigation measures have been considered. This policy includes the principle that suitable offsets must effectively account for, and manage the risks of, the offset failing. The potential risks of these efforts of last resort are explained in the Policy Statement—Translocation of Listed Threatened Species, which notes:

> *The usually low prospects of achieving an ecologically beneficial salvage translocation mean that it usually represents poor compensation for the potential impacts of a proposed action. Additionally, a translocation proposal can increase the impacts of an action.* (DSEWPaC 2013)

Translocation as part of conservation activities for climate change adaptation, for threatened species recovery and for mitigation of land-use changes is also acknowledged as a high-risk, but perhaps necessary, strategy in the face of increasing pressure. Significant uncertainty exists about how best to evaluate and reduce the risks associated with translocation, particularly the ecological consequences on the recipient environment and the species living there (Seddon et al. 2015). Although the overall long-term conservation benefits of the increasing use of salvage translocations to offset development remain largely unknown (Nally & Adams 2015), there is a growing need for the private sector to use translocation to meet conservation goals established under environmental conditions of approval for development applications. Further efforts will be required to design novel practices that allay conservation concerns while futureproofing wild populations in new areas.

EPBC Act and compliance

The EPBC Act prohibits undertaking of an action that is likely to have a significant impact on matters of national environmental significance without approval from the Minister for the Environment or delegate, unless the action is exempt. The approval of controlled actions allows proponents to implement their actions, subject to the environmental safeguards put in place to protect matters of national environmental significance through approval conditions. As at May 2016, there have been approximately 850 controlled action approvals and more than 1000 'not a controlled action particular manner' (NCAPM) decisions that have been determined to not have the potential for a significant impact, on the basis that the action will be conducted in a particular manner. This has resulted in approximately 8300 conditions that have been applied to controlled action approvals and approximately 9100 particular manners attached to NCAPM decisions.

An Australian National Audit Office assessment that concluded in 2013–14 (ANAO 2014) found that any assurance that the Department of the Environment and Energy has regarding proponents' compliance with action approval conditions was limited. In particular, the audit noted that the department was not well placed to demonstrate that it is effectively targeting its compliance monitoring activities to the areas of greatest risk. The auditors found that increasing workloads of the compliance monitoring staff led to the department essentially adopting a passive approach to monitoring, and, as a result, it had limited awareness of the progress of many approved controlled actions. In many cases, instances of proponent noncompliance (mostly of a technical nature, such as a missed deadline to submit a management plan) were either not identified by staff, or were identified but not referred for assessment and possible enforcement action.

In response to the audit findings, the department implemented a suite of measures to improve its compliance monitoring function. One key measure involved development of a risk-based prioritisation model, the National Environmental Significance Threat Risk Assessment tool. The tool is used to identify projects that present the greatest risk of impact on protected matters and the greatest potential for noncompliance. Projects identified to have the highest risk against these factors are subject to increased monitoring.

In addition, in 2014, the department developed more than 60 standard operating procedures to facilitate consistency in regulatory administration, as well as guidance documentation to assist holders of approvals to comply with conditions attached to controlled action approvals. Upgrades and enhancements to information technology systems have been made to support regulatory capability and intelligence functions, and further improvements are currently under way. In 2014, the department also started additional reporting on compliance monitoring activities in an annual compliance monitoring program.

Connectivity and revegetation

Two targets in Australia's Biodiversity Conservation Strategy relate to improving connectivity:

- Target 5: By 2015, 1000 square kilometres of fragmented landscapes and aquatic systems are being restored to improve ecological connectivity.
- Target 6: By 2015, 4 collaborative continental-scale linkages are established and managed to improve ecological connectivity.

The Australian Government established a National Wildlife Corridors Plan in 2011–12. It recognised whole-of-continent ecological processes, and the potential role of large national wildlife corridors in sustaining Australia's flyways and ecological responses to the 'boom and bust' cycles of biological productivity that are in response to rainfall variability. However, with a change of government, the National Wildlife Corridors Plan and associated management arrangements were discontinued. Efforts to build connectivity on a landscape scale are now managed through the National Landcare

Programme, including the 20 Million Trees Programme, the Green Army program and other initiatives. One example is the Cumberland Conservation Corridor project, which aims to conserve and restore functioning landscapes at all levels, including local, regional and national. Although the 20 Million Trees Programme is designed to 'support the planting of native trees and associated understorey species to re-establish green corridors and urban forests' (DoE 2014b), it does not have an explicit commitment to continental, or even large-scale, linkages to improve connectivity.

In 2014, the Australian Government passed the Carbon Farming Initiative Amendment Bill 2014, which included the Emissions Reduction Fund. The government has started contributing to the re-establishment of native vegetation, particularly in western New South Wales and south-western Queensland where uptake of revegetation projects has been highest.

Corridor initiatives that have commenced in Australia include:

- the Gondwana Link in Western Australia
- the Trans-Australia Eco-Link of South Australia and the Northern Territory
- South Australia's Naturelinks
- Habitat 141° in Victoria, South Australia and New South Wales
- the Great Eastern Ranges Corridor in Australia's eastern states (see Box HER11 of the *Heritage* report)
- the Tasmanian Midlandscapes Project.

These initiatives have been established through the cooperative action of a range of parties, including the Australian Government, state and territory governments, nongovernment organisations, local communities and industry.

Managing pressures

Climate change

Several Australian Government initiatives to support climate change adaptation planning and decision-making have been implemented since 2011. For example, the Australian Government Regional Natural Resource Management Planning for Climate Change Fund (2013–16) provided funding to improve regional planning for climate change across Australia. It supported regional NRM organisations to review their regional strategies to incorporate climate change and comprised 2 streams:

- Stream 1 funding was provided directly to 53 regional NRM organisations to develop or revise their regional strategies, and enabled the regional NRM organisations to work closely with both their communities and with scientists.
- Stream 2 was delivered to operational and research organisations to support the regional NRM organisations with regionally relevant climate change information, and to deliver tools and resources that could be accessed by the regional NRM organisations and their communities to support mid-term planning.

Overall, this program enabled the update of existing regional NRM plans to:

- incorporate information and approaches on climate change mitigation and adaptation
- use the best available information to plan for the impacts of climate change
- help guide the location and nature of biodiversity and carbon farming activities in the landscape.

This investment has helped NRMs begin to build an information base for land managers to improve management using a whole-of-system approach. Although the approach taken across Australia has varied and the take-up has not been consistent by land managers, the program has significantly increased the knowledge base. For instance, the Adelaide and Mt Lofty Natural Resources Strategic Plan (AMLR NRM 2013) presents the 13 long-term targets for improving the region's natural resources. It also establishes the goals of the organisation and the mechanism for achieving the strategic objectives, including viewing the area as a set of connected subregions and developing conceptual models of how the systems that are in the region work (Daniels & Good 2015).

In December 2015, the Australian Government released a National Climate Resilience and Adaptation Strategy. The strategy sets out how Australia is managing climate risks, and identifies a set of principles to guide effective adaptation practice and resilience building. Most jurisdictions have developed climate adaptation strategies since 2011 or have plans to develop strategies (see also Box BIO16).

However, management objectives for climate adaptation for biodiversity are generally incorporated in broader biodiversity management strategies, rather than directly in climate adaptation strategies, which are focused more on assets, infrastructure, health, production systems and disaster management. The National Climate Resilience and Adaptation Strategy refers to the Australian Biodiversity Conservation Strategy and the Strategy for Australia's National Reserve System, and cites investments made through the Green Army program and the National Landcare Programme. Few quantifiable targets exist among these strategies to measure the effectiveness of management objectives designed to improve the resilience of biodiversity to climate change.

Some jurisdictions have developed more specific strategies for biodiversity. For example, the New South Wales Government has developed a statement of intent in response to the listing of climate change as a key threatening process under its *Threatened Species Conservation Act 1995*. The statement identifies priorities to support biodiversity to adapt to the impacts of climate change. Strategies identified in the statement of intent include building the protected areas system, reducing fragmentation and clearing, reducing other impacts such as invasive species, and improving connectivity.

A Productivity Commission report into barriers to effective climate change adaptation (Productivity Commission 2013) noted that barriers can arise from market failure, regulation or governance, including where:

- policies and regulations reduce the resilience of natural environments to climate change or discourage conservation activities by landowners and the community
- private activities have negative spillovers to the environment
- 'public goods', such as information and research, are not adequately provided
- environmental assets are poorly protected or valued
- conservation strategies and objectives fail to meet the community's needs in a changing climate
- policy frameworks are unresponsive to changing conditions and improved information
- financial and management resources are not allocated where the environmental benefits are greatest
- governance and institutional arrangements are fragmented or unclear.

Box BIO16 National Climate Change Adaptation Research Facility

The National Climate Change Adaptation Research Facility (NCCARF) was established in 2008 with a grant from the Australian Government of $50 million across 5 years. Its mission is to develop and communicate the knowledge needed by decision-makers to adapt effectively to climate change. During its first phase of operation, NCCARF managed a research program of $30 million and around 100 projects based at universities throughout Australia, operated 8 networks to build capacity in the research and end-user communities, and carried out numerous communication and outreach activities, including 1 international and 3 national conferences for adaptation researchers and practitioners. Three of the networks were specifically biodiversity focused: the Terrestrial Biodiversity Network, the Marine Biodiversity and Resources Network, and the Water Resources and Freshwater Biodiversity Network.

A phase 2 program to support national capacity development and deliver guidance that helps local decision-makers manage climate risks is now under way, operating under 4 networks, including a Natural Ecosystems Network. Funding for phase 2 has been provided for 3 years from 2014 to 2017, to a value of $8.8 million.

The 3 key project outcomes of phase 2 are to:

- deliver effective knowledge transfer from the adaptation research community to policy agencies and decision-makers to build Australia's capacity to manage future climate risks, particularly in the coastal zone
- achieve strong endorsement of synthesis information and tools from users, particularly from coastal users, that supports its uptake and application among policy-makers and decision-makers
- maintain Australia's adaptation research capacity and strengthen the capacity of adaptation information end-users in Australia to use adaptation research outputs, through the continued support of 4 adaptation networks, including the Natural Ecosystems Network.

Invasive species

Invasive species dominate the key threatening processes identified at both national and state and territory levels, and their impact on biodiversity is not diminishing. A lack of adequate resourcing for managing invasive species; a lack of effective and efficient monitoring; and the absence of national data collation on incursions, pathways and risks have all been highlighted as impediments to effective management.

However, where planning and resources have provided adequate concerted effort, there are many examples of effective eradication, containment or control of invasive species. For example, the sustained work of the Tasmanian and Australian governments in funding the $25 million Macquarie Island Pest Eradication Project from 2007 until 2011 has been very successful. This was the largest and most ambitious island eradication program for rabbits, rats and mice ever undertaken. There were no confirmed sightings of ship rats or house mice after July 2011, and no signs of rabbits after December 2011, which was confirmed in April 2014.

Spreading bait by helicopter with bait buckets on Macquarie Island

Photo by Keith Broome, Tasmanian Parks and Wildlife Service

The Australian Government has invested significantly in feral cat control initiatives since 2011. The Threatened Species Strategy identifies tackling feral cats as its top priority for action. It identifies a range of projects and target areas for research and management, including development and deployment of humane baits, supporting feral cat–free areas and islands, and supporting community-led initiatives and citizen science (see Box BIO17). The action plan identifies 4 feral cat targets:

- feral cats eradicated from 5 islands
- 10 feral cat–free mainland exclosures established
- best-practice feral cat control established across 10 million hectares of open landscapes
- best-practice feral cat control implemented in 2 million hectares of Commonwealth land.

Box BIO17 FeralScan—connecting communities through citizen science to improve the management of Australia's worst introduced pest animals

The FeralScan Program was developed by the Invasive Animals Cooperative Research Centre with support from the Australian Government, the New South Wales Government, catchment management organisations and landholder groups nationwide. FeralScan provides communities with an easy way of documenting pest animal problems in their local area. Information recorded by the community is delivered directly into the hands of farmers, land managers, community volunteers, Indigenous groups and biosecurity stakeholders across Australia. FeralScan has been running since 2011, and has mobilised more than 25,000 Australians as citizen scientists to contribute in a meaningful way to the management and research of pest animals.

As at June 2016, more than 55,000 new pest animal records had been made in FeralScan by community participants, making it the single largest pest animal database ever developed by the community in Australia. FeralScan can be used to record and view information for 11 of Australia's worst pest animal species: feral cats, rabbits, wild dogs, introduced pest fish, foxes, mice, feral camels, feral pigs, Indian myna birds, feral goats and European starlings.

FeralScan helps to bring citizen science centrestage, along with traditional approaches to monitoring and managing the impacts of Australia's worst introduced pest animals on biodiversity, threatened species, agricultural productivity, the environment and people. It provides new digital platform technology through purpose-built web and smart phone apps, which empower communities to be part of a solution to introduced pest animals.

Source: © Peter West, project manager, FeralScan, Invasive Animals CRC, all rights reserved

Although eradication is feasible for geographically constrained populations, the spread of many invasive species continues unabated and largely unregulated. For example, in a submission to the Australian Senate Standing Committees on Environment and Communications in 2014, the Invasive Species Council noted that 'escaped nursery plants' were listed as a 'key threatening process' under the EPBC Act, but that 'this has no practical effect in preventing the sale of unsafe plants'. No threat abatement plan has been developed, and 'trade in the majority of unsafe nursery plants remains unregulated in most state and territory jurisdictions'. By way of example, the Invasive Species Council submitted that 'of 340 ranked environmental weeds in New South Wales, about 90 per cent can be sold or planted in part or all of New South Wales'.

The Australian Weeds Strategy (AWS) (Australian Weeds Committee 2007) and a parallel Australian Pest Animal Strategy (APAS) (Vertebrate Pests Committee 2007) were endorsed by the Natural Resource Management Ministerial Council in 2007. In late 2012, the AWS and the APAS were both evaluated independently. Both reviews found that the strategies and the principles underpinning them signalled a growing awareness of the importance of building and maintaining collaborative efforts to address the problem of invasive species in Australia.

Recognising that weeds have major economic, environmental and social impacts in Australia, the AWS has 3 goals:

- to prevent new weed problems
- to reduce the impacts of existing priority weed problems
- to enhance Australia's capacity and commitment to solve weed problems.

The review of the AWS noted that the Weeds of National Significance program consistently rated highly in terms of implementation of coordinated and cost-effective solutions for management of priority weeds. However, many stakeholders who participated in the review noted that, although the AWS was useful in providing an overarching framework, there was a need to strengthen links between the strategy and policy, and the programs that facilitate on-ground action. Failings identified in implementing the strategic actions in the AWS included:

- a lack of capacity, at both national and state levels, to achieve 'early detection and rapid action against new weeds'
- failure to effectively communicate with stakeholders the importance of their engagement in addressing national weed problems
- failure to 'establish nationally consistent legislation to address weed problems'.

The review of the APAS identified similar weaknesses in terms of a lack of resources for implementing actions outlined in the strategy, resulting in the strategy being an overarching aspirational document, rather than a driver of change. The review also found a lack of engagement with stakeholders outside government; as a result, the strategy has not effectively delivered in raising awareness of pest animal issues or response requirements.

The CSIRO report *Australia's biosecurity future* (Simpson & Srinivasan 2014) noted, after extensive consultation, that the general view across the biosecurity community is that the state and territory government sector is gradually stepping away from postborder biosecurity, and pushing more responsibility onto industry to manage and invest in postborder activities. Furthermore, although the government is likely to continue to prioritise human health–related biosecurity concerns, environmental biosecurity may face an uncertain future with no industry body to lobby on its behalf and challenges in demonstrating return on investment. In addition, the Invasive Species Council noted in its submission to the inquiry into the adequacy of arrangements to prevent the entry and establishment of invasive species that:

> *Australia's poor knowledge of invasive species threats to biodiversity needs to be addressed. The demise of the Weeds Cooperative Research Centre and the loss of research staff in government agencies and CSIRO have substantially reduced research capacity.* (Invasive Species Council 2014)

Overall, it is very difficult to assess the effectiveness of management investment in invasive species and pathogens, because—although most reports highlight plans, actions, strategies and single-species, small-scale efforts—they rarely report on outputs and outcomes. Most reports conclude that there is not enough information to assess trends in distributions or impacts of invasive species. However, there are many examples of small-scale, single-species control or eradication efforts that have clear positive outcomes for biodiversity (see Boxes BIO18 and BIO19).

At the local and regional level, on-ground land managers overwhelmingly report a lack of sufficient resources to manage pest animals and weeds effectively. In 2013, the Invasive Animals Cooperative Research Centre (Marsh & Brown 2013) surveyed the staff in Australia's 54 NRM regions (with 53 responses from 49 regions) on the capacity of NRM to manage invasive animal impacts. Most respondents (48 out of 53) agreed that land and water degradation caused by pest animals is considered a big problem in their region. Most respondents (47 out of 53) also agreed that their organisation considers pest animals a high priority for work and allocation of funding. However, only 11 out of 53 respondents agreed that their organisation has adequate funding to address pest animal issues. According to most respondents, funding was the most important factor influencing the capacity of regional staff and their organisations to better manage pest animals. The extent of pest problems, the availability of skilled labour (including project managers and staff) and the available timeframe were listed as other major factors affecting the ability of NRM organisations to achieve their goals or targets relating to pest animals. Respondents said that training, greater access to pest experts, longer job contracts, and having skilled staff and ongoing support from external staff would help to improve individual staff capacity to manage pests better.

Box BIO18 Western Australian islands—safe havens for threatened species

Since the 1980s, the Western Australian Department of Parks and Wildlife and its predecessors have undertaken successful black rat and feral cat eradication programs on about 150 offshore islands, making them available for native fauna translocations. These translocations have aimed to either restore species that once occurred on the islands, or introduce threatened species to improve their conservation outlook. The most recent has been the Montebello Renewal project, which aims to reconstruct and/or conserve threaten fauna on the Montebello Islands. The Montebello Islands are an archipelago of more than 180 islands, ranging in size from only a few square metres to the 1110 hectare Hermite Island, located approximately 80 kilometres off the Western Australian coast. The archipelago has been highly disturbed, with feral cats and black rats introduced in the late 19th century, and 3 nuclear weapons tests undertaken by the British Government in 1952 and 1956. Feral cats are thought to be responsible for the local extinction of the golden bandicoot (*Isoodon auratus*) and the spectacled hare-wallaby (*Lagorchestes conspicillatus*), which were last recorded at the Montebellos in 1912 and 1914, respectively. Two species of birds—black-and-white fairy-wren (*Malurus leucopterus edouardi*) and spinifexbird (*Eremiornis carteri*)—occurred on the archipelago before 1950, and the water rat (*Hydromys chrysogaster*) persisted until the 1980s. The islands also support many nesting seabird species, which were affected by the black rats.

Between 1996 and 2001, a dedicated program of baiting, trapping and monitoring successfully eradicated feral cats and black rats from the Montebello Islands, making them available for fauna translocations. For conservation purposes, mala or rufous hare-wallaby (*Lagorchestes hirsutus*) were introduced to Trimouille Island (511 hectares) in 1998. The 2014 population estimate was about 300 individuals, making it one of the most important wild populations of this endangered species in Australia. The Shark Bay mouse (*Pseudomys fieldi*) was successfully introduced to North West Island (118 hectares) in 1999 and 2000, establishing the second population of this threatened rodent. Golden bandicoots and spectacled hare-wallabies were successfully reintroduced to Hermite Island from nearby Barrow Island in 2010, as part of the fauna reconstruction of the Montebello Islands. A conservation introduction of the burrowing bettong or boodie (*Bettongia lesueur*) was undertaken on Alpha Island (108 hectares) in 2011. Establishment of this population has helped to improve the conservation status of the species to the point where it was downlisted from vulnerable to conservation dependent in November 2015. All 3 species are now well established and occupy all suitable habitats on their respective islands.

In 2010 and 2011, the black-and-white fairy-wren and spinifexbird were also reintroduced to Hermite Island. Both bird species are now well established on the island, and spinifexbirds have self-dispersed to 5 adjacent islands in the group. This project has established secure populations of 6 species of threatened fauna and is an example of the value of islands in improving the long-term conservation prospects for Australia's unique fauna.

Box BIO18 (continued)

Release of a spectacled hare-wallaby (*Lagorchestes conspicillatus*) at Hermite Island
Photo by Department of Parks and Wildlife, Western Australia

Source: Department of Parks and Wildlife, Western Australia

Box BIO19 Using a herpesvirus to eradicate feral fish

First introduced to Australia in 1859, the common carp (or European carp—*Cyprinus carpio*) became a major pest in the 1960s after the accidental release of a strain that had been adapted for fish farming. Within a few years, they established themselves throughout the Murray–Darling Basin.

Carp now comprise up to 90 per cent of the fish biomass in parts of the Basin. This is largely attributed to female carp producing up to a million eggs per year, and to the omnivorous fish's tolerance for a wide range of habitats, including degraded water.

Cyprinid herpesvirus 3 (CyHV-3) first appeared in Israel in 1998 and quickly spread throughout the world, killing off common and koi carp. Testing of CyHV-3 in the high-security Fish Diseases Laboratory at the Australian Animal Health Laboratory has proven that the virus also kills common carp. The virus mainly damages the kidneys, skin and gills. The kidneys and skin are very important in helping the fish maintain its water balance. Damage to the gills affects the carp's ability to breathe, eventually causing its death.

The virus has been shown to pose no danger to 13 native species, such as Murray cod (*Maccullochella peelii*), various species of perch, eel and catfish, or to a crustacean (yabbies) or a non-native fish species, the rainbow trout. Further work is under way to ensure that the virus remains species specific and only affects carp. In May 2016, the Australian Government launched a nationally coordinated approach to eradicating the common carp through a $15 million National Carp Control Plan. This plan includes staged release of the carp control virus, beginning in the Murray–Darling Basin, and other complementary measures to create a long-term solution to the issue of the carp pest.

Clearing and fragmentation

Every state and territory has laws to restrict the clearing of native vegetation and conserve biodiversity, particularly by restricting actions that affect protected animals or plants, as part of Australia's 2012 Native Vegetation Framework. The overarching goal of the framework is to 'increase the national extent and connectivity of native vegetation'. These laws have had a dramatic impact in slowing habitat loss and ecosystem threat (Taylor et al. 2014a).

Although 1999–2010 was marked by increasingly tight restrictions on clearing in Australia, since then policy responses have followed a trend of weakening of legislation protecting native vegetation from clearing (Taylor 2015b, Evans 2016). The most dramatic impact of changing legislation has been seen in Queensland (see Clearing and fragmentation of native ecosystems). New South Wales and Western Australia have also implemented changes that reduce restrictions on clearing under some conditions. The impact of weakening of legislation for native vegetation clearing is not known, but indications from Queensland suggest that there may be adverse implications for biodiversity.

A recent policy development has been the use of offsetting arrangements, either as complementary policies or as conditions of clearing approvals. Offsetting policies have been put in place in most jurisdictions during the past 5 years, and, in 2012, the Australian Government introduced an environmental offsets policy under the EPBC Act. Offsetting involves compensating for the adverse impacts of an action on the environment by generating an equivalent benefit elsewhere. The overarching objective of environmental offsets is to deliver 'no net loss' or 'net gain' of a particular component of the environment. The use of offsetting for the objective of no net loss has been criticised, because the baselines used to measure the intended net outcome assume a future of biodiversity decline. Research has shown that offset policies across Australia assume up to 4.2 per cent loss of vegetation extent and/or condition per year, which is, on average, more than 5 times higher than recent rates of vegetation loss. A recent publication noted that 'the near-ubiquitous use of declining crediting baselines risks "locking in" biodiversity decline across impact and offset sites, with implications for biodiversity conservation more broadly' (Maron et al. 2015).

Fire regimes

Fire is often used as a management tool to achieve conservation goals. Planned burning (also called prescribed, controlled or hazard reduction burning) is used in some places in Australia for a range of purposes related to biodiversity conservation, including increasing the diversity of vegetation successional stages, and decreasing the intensity and size of fires. Prescribed burns also create areas with reduced fuel loads to reduce the occurrence of large-scale and high-intensity fires.

Although traditional fire management has focused on maintaining diverse patches of differing fire history, researchers are increasingly demonstrating that some vegetation age classes provide disproportionately important habitat for flora and fauna (Kelly et al. 2012). For example, in semi-arid regions of Australia, older vegetation has been shown to be disproportionately important for the conservation of birds, reptiles and small mammals. In many ecosystems, an increased frequency of fire that reduces the amount of middle and late successional vegetation is likely to negatively affect fauna populations (Kelly et al. 2015). The increase in large-scale bushfire events in Victoria means that early growth stages are now over-represented in vegetation. Of the assessed native vegetation, 35 per cent was found to be in early growth stages compared with only 25 per cent in mature or overmature stages. This has significant implications for biodiversity, especially for fauna that require older growth stages (Kelly et al. 2015). Furthermore, research on birds has shown that preserving large intact areas of habitat is important for maintaining diversity, rather than creating networks of small unburned patches (Berry et al. 2015).

Australia's savannas, which cover about 2 million square kilometres, are the most fire-prone ecosystem in the most fire-prone continent on Earth. Minimal infrastructure, combined with a very sparsely settled rural population, has resulted in a limited capacity to manage escaped fires. Fire regimes across much of the region are therefore characterised by the frequent recurrence of large (more than 1000 square kilometres), late dry-season wildfires (Russell-Smith et al. 2013). In 2012, savanna burning was included in Australia's national carbon offsets program, the Carbon Farming Initiative (CFI). Accredited offsets generated under the CFI are formally recognised by the Australian Government, and are traded in voluntary and existing international regulatory markets, as well as in the national regulatory scheme. The Savanna Burning CFI aims to reduce emissions by reducing the intensity of fires and the area burned each year. This is achieved through prescribed burning that shifts the fire regime from predominantly large and intense late dry-season wildfires to early dry-season fires. In October 2016, 69 savanna burning projects were registered; 22 of these have been approved with Indigenous control or significant involvement.

Early dry-season fires are considered to approximate traditional Aboriginal burning. Indigenous Australian fire management is thought to have influenced the patterning of biodiversity, and reinstating or maintaining traditional burning should theoretically provide greater benefit for native biodiversity that has co-evolved with this regime. Applied research is showing how the use of fire management to reduce fire frequencies, fire size and fire intensity (resulting in an increase in the area of long-unburned vegetation) can support the recovery of threatened species. (See Box HER11 of the *Heritage* report for a related case study). For example, on Mornington Wildlife Station in north-western Australia, a range of condition indices (reflecting how much stress a bird is under) of the endangered Gouldian finch (*Erythrura gouldiae*) and 2 non-threatened finches improved under the more benign fire regime (Legge et al. 2015).

Much of the frequently burned land across Australia's northern savannas is under Indigenous ownership. The *Land* report explores in more detail the role of Indigenous people in fire management across northern Australia.

New technologies, solutions and innovations

Improved tools and technical advances are becoming more available, sophisticated and cost-effective for biodiversity assessment, monitoring and management (see Box BIO20). The following are increasingly being taken up for a multitude of biodiversity monitoring requirements:

- advances in satellite telemetry, transponders, lightweight transmitters, remote cameras and remote audio devices
- enhanced capability to store, analyse and present large datasets
- developments to cost-effectively generate large-scale databases.

The past 5 years has seen a series of rapid improvements in genomic techniques that are useful for environmental studies, and that will hopefully lead to better SoE reporting. For instance, DNA barcoding methods have begun to be applied to natural history collections and biological surveys. Genetic barcoding has been fully integrated into Australia's largest species discovery project, Bush Blitz. Barcoding of pooled environmental samples ('metabarcoding') has been used routinely to evaluate diversity in soil communities for many years, and Australian researchers are now among the world leaders in cataloguing and interpreting soil microbial diversity using genetic methods (e.g. see Biome of Australia Soil Environments project).

Significant advances during the past 3–5 years have led to powerful, cost-effective methods to assess genetic diversity. These improved tools now allow us to rapidly generate large-scale genomic databases that begin to quantify the vast numbers of cryptic organisms that previously have remained unknown to humanity, yet play fundamental roles in maintaining ecological systems. Understanding this rich data source will provide much more information on the ecological roles fulfilled by these cryptic species. This will enable new scientific approaches to biodiversity management, such as incorporating genetic and evolutionary processes into threatened species recovery, and allow targeted responses for adaptation. The ability to understand the functional attributes of particular genes could lead to the selection of the best set of individuals adapted for the future.

Assessing the effectiveness of biodiversity management

Although during the past few decades significant effort has been made to understand the effectiveness of biodiversity management actions, a major issue that complicates assessment is the highly variable climatic and hydrological conditions in Australia. Not only are there real-world cost implications for understanding the value of management actions, there is also a need to plan for climate change adaptation and mitigation.

During the past 5 years, the Australian Government has invested in a NRM Monitoring, Evaluation, Reporting and Improvement Framework (MERI Framework) for monitoring, evaluating, reporting on and improving Australia's approach to managing its investment in NRM. Understanding how investments improve our NRM and biodiversity conservation will help maximise learning on where to invest to address the NRM and biodiversity conservation challenges, and will help build resilience.

Regionally, the Murray–Darling Basin Plan (which came into effect in November 2012 and will be implemented in full in 2019) has established a Basin-wide environmental watering strategy. This commits the Australian, and state and territory governments to establishing mechanisms to assess the effectiveness of their management of water for aquatic ecosystems.

Box BIO20 The Bitterns in Rice Project—a crowdfunded satellite tracking program

The Bitterns in Rice Project is a grassroots conservation initiative centred on irrigation farms in the Riverina district of New South Wales. It is a collaboration between the Ricegrowers' Association of Australia, BirdLife Australia and a wide range of other organisations, with major funding provided by Riverina Local Land Services. The project aims to identify the best ways that rice farmers can help to conserve the globally endangered Australasian bittern (*Botaurus poiciloptilus*), a poorly known, cryptic waterbird.

Research since 2012 has identified that, in most years, a breeding population of between 500 and 1000 bitterns—at least one-quarter of the global population—arrives in the rice crops around 2 months after sowing. A crowd funded satellite tracking program began in 2015 to discover where the birds go after the rice has been harvested. Funding from irrigation companies, industry groups, individual rice growers, wetland conservation organisations, birdwatching clubs and individual bird lovers was used to purchase 10 satellite transmitters and pay for the associated data download costs.

Importantly, the project built a network of followers with a strong sense of ownership and involvement in the plight of the bitterns. The first bittern to be tracked was 'Robbie', named by the Coleambally Irrigation Cooperative after a keen supporter of the project. They had bought the naming rights during the crowdfunding campaign. Nine days after the harness was attached in April 2015, Robbie dispersed from his soon-to-be-harvested rice crop to Pick Swamp on the South Australian coast. He then spent 4 months at the recently restored Long Swamp just across the border in Victoria. He returned to the Riverina in September, but most wetlands were dry, and he was too early for the rice season, so he wetland-hopped his way back to Pick Swamp and Long Swamp. His 323-day journey stitched together seemingly disparate wetlands, and created unlikely connections between people restoring wetlands in South Australia and Victoria, and rice farmers in southern New South Wales.

Australasian bittern (*Botaurus poiciloptilus*)

Photo by Matt Herring, Bitterns in Rice Project

Australasian bittern map of 'Robbie', 323 days

Image: Provided courtesy of the Bitterns in Rice Project

Source: Matt Herring, Murray Wildlife, Bitterns in Rice Project

Longhorn beetle (*Batocera boisduvali*)
Photo by Eric Vanderduys

Assessment summary 3

Effectiveness of biodiversity management

Summary	Assessment grade (Ineffective / Partially effective / Effective / Very effective)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Conservation in the National Reserve System				
Understanding: Understanding of the value and threats to the National Reserve System is generally good	Effective —			X
Planning: Policies and plans are in place to meet objectives and set targets for increasing the extent and improving the condition of protected areas, particularly through the Australian Biodiversity Conservation Strategy and Australia's Strategy for the National Reserve System. Implementation has been effective for extent targets, but implementation of targets for reducing pressures is not well linked to on-ground actions	Partially effective —			X
Inputs: Inputs have been sufficient to increase the extent of the National Reserve System since 2011. However, adequate financial and staffing resources for on-ground management are limited in some areas and funding overall for management has declined	Partially effective ↙			X
Processes: Management systems are in place across some parts of the National Reserve System	Effective —			X
Outputs and outcomes: Australia has met area-based targets for the National Reserve System. However, targets for comprehensiveness, adequacy and representation are proving more difficult to attain. Forest ecosystems are the best protected, whereas woodland and grassland ecosystems are the least well protected. Wetlands in the arid and semi-arid zone, and aquatic ecosystems are generally poorly represented. Fifty per cent of critically endangered EPBC Act–listed communities and 30 per cent of endangered communities have less than 5 per cent of their area represented in the National Reserve System	Partially effective —			X

Assessment summary 3 (continued)

Summary	Assessment grade (Ineffective / Partially effective / Effective / Very effective)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Management of threatened species				
Understanding: Understanding of the pressures affecting threatened species is good. Understanding of state and trends, and monitoring of threatened species is limited to a small proportion of species				X
Planning: Policies and plans are in place, outlining objectives for management of threatened species. The Threatened Species Strategy is a new initiative since 2011 and provides policy to guide development of recovery plans for threatened species				X
Inputs: Resources appear to be inadequate for implementing recovery plan actions, and for monitoring the state and trends of some threatened species				X
Processes: Management systems are in place for recognising threatened species and for developing recovery plans. Improvements are evident in the efficiency of listing processes. The Threatened Species Strategy improves the practice of recovery planning for high-priority species				X
Outputs and outcomes: All jurisdictions note the difficulty in assessing the management effectiveness of actions undertaken for threatened species because of a lack of monitoring data. The degree of implementation of recovery plans for threatened species is highly variable, with some species subject to very few on-ground recovery actions. Overall, the key pressures on threatened species are increasing				X

Assessment summary 3 (continued)

Summary	Assessment grade (Ineffective / Partially effective / Effective / Very effective); Confidence (In grade / In trend); Comparability (To 2011 assessment)
Climate	
Understanding: All jurisdictional reports recognise the adverse effects of climate change on biodiversity. The impacts of climate change on biodiversity are broadly understood, and strategies for management and adaptation to climate change are improving	
Planning: The Australian Government has released a National Climate Resilience and Adaptation Strategy, and most other jurisdictions have developed adaptation strategies since 2011 or have strategies in development. Adaptation objectives for biodiversity across national, and state and territory strategies are generally focused on information gathering rather than action. Emissions targets have been set, but many scientists and stakeholders argue that they are inadequate	
Inputs: Australian Government investment in climate mitigation and adaptation research has declined since 2011. The latest climate projections at state/territory and regional scale are now readily and widely available	
Processes: Governance systems provide some guidance, but are not consistently delivering on implementation actions or stakeholder engagement for biodiversity	
Outputs and outcomes: It is difficult to tell whether management objectives contained in national, and state and territory plans to improve resilience of biodiversity have been effective. Management objectives mostly relate to investigating and monitoring climate impacts, and developing options to increase resilience. Few management objectives contain quantifiable targets	

Assessment summary 3 (continued)

Summary	Assessment grade (Ineffective / Partially effective / Effective / Very effective)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Pollution				
Understanding: Understanding of the sources and impacts of pollution for terrestrial and freshwater biodiversity is well established. Understanding of sources and impacts for marine and freshwater systems is improving	Effective (—)			
Planning: Plans for addressing pollution impacts are well established for point sources, but less well established for diffuse sources such as from urban areas and production systems	Partially effective (—)			
Inputs: Inputs to management from point sources and some diffuse sources are mostly effective. Micropollutants and marine debris are receiving more attention and inputs to management	Partially effective (↗)			
Processes: Management systems provide guidance, and are well implemented across point sources and some diffuse sources. Some initiatives to limit use of plastics have been put in place	Partially effective (—)			
Outputs and outcomes: Run-off from production systems in freshwater, coastal and marine systems is still a concern for most jurisdictions. Progress has been made in understanding the impacts and sources of marine debris. Little is known about pollutant levels in the marine environment	Partially effective (—)			

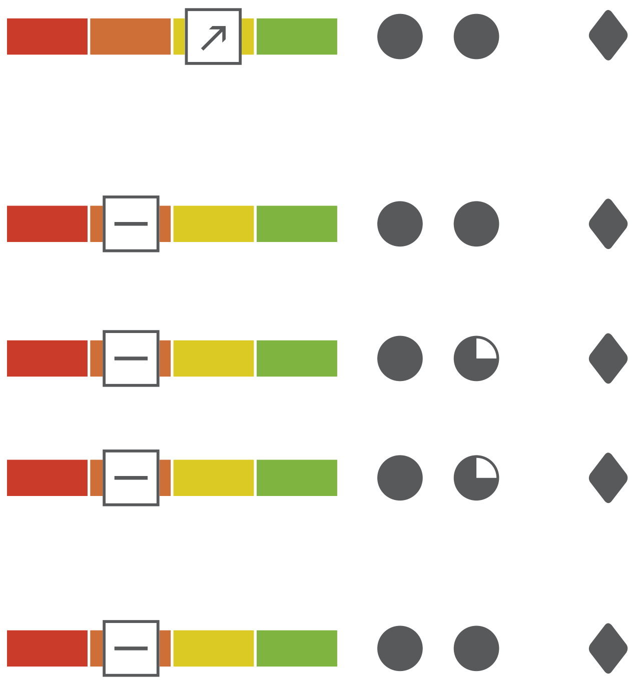
Assessment summary 3 (continued)

Summary	Assessment grade	Confidence	Comparability
	Ineffective · Partially effective · Effective · Very effective	In grade · In trend	To 2011 assessment
Consumption and extraction of biodiversity and/or other natural resources			
Understanding: Monitoring of species that are legally harvested is well established. The impact of illegal or unregulated harvesting on threatened species is poorly understood. The relationship between population growth and demand on natural resources is still poorly understood			
Planning: Plans are in place that provide objectives and targets for harvesting and water consumption. Plans to balance human population growth and consumption of natural resources are poorly developed			
Inputs: Inputs to regulating and monitoring the harvesting of species appear to be adequate			
Processes: Processes for regulating and monitoring harvesting of native species and water consumption appear to work well. Limited processes are in place for assessing and monitoring human demands on natural resources more broadly			
Outputs and outcomes: Management objectives for the harvest of native species appear to be mostly met. There has been no reduction in current pressures of human population growth on natural resources more broadly			

Assessment summary 3 (continued)

Summary	Assessment grade (Ineffective / Partially effective / Effective / Very effective)	Confidence (In grade / In trend)	Comparability (To 2011 assessment)

Clearing and fragmentation of native ecosystems



Understanding: The extent and impact of clearing and fragmentation are well understood. The acknowledged importance of this pressure has a significant impact on state/territory and national policy decisions

Planning: Legislation, policies and plans are in place in most jurisdictions, although there are regular changes to planning instruments and little certainty in their longevity in some jurisdictions. Monitoring of compliance with legislation may not always be effective

Inputs: Inputs appear to be adequate in terms of stabilising the rate of clearing in most jurisdictions

Processes: Well-established management systems are in place; however, regular changes undermine stakeholder support. Clearing rates are reported regularly across all jurisdictions

Outputs and outcomes: The rate of land clearing has decreased nationally, and in most jurisdictions except Queensland. However, fragmentation and modification of habitat remain one of the most significant pressures on biodiversity, with very high ongoing impacts

Assessment summary 3 (continued)

Summary	Assessment grade Ineffective / Partially effective / Effective / Very effective	Confidence In grade	Confidence In trend	Comparability To 2011 assessment
Pressures from livestock production				
Understanding: The impacts of livestock production systems and grazing are widely acknowledged. Impacts on ecological processes are less clear. It is increasingly recognised that livestock grazing contributes to threat syndromes, which, cumulatively, have significant biodiversity impacts				
Planning: Planning instruments that set management objectives for impacts of livestock grazing on biodiversity are deficient. Biodiversity conservation in agricultural landscapes is largely driven by voluntary actions of landholders				
Inputs: It is difficult to assess inputs to managing biodiversity by individual landholders in livestock production systems. Implementation of on-farm biodiversity management objectives requires significant financial investments by landholders. Incentives are available under some schemes, but may be difficult to access for smaller landholders	?			
Processes: Grazing is still considered a major impact on biodiversity, and its impact may be increasing in some parts of northern Australia. Adequate management systems are mostly not in place, and lack consistency and integration of management objectives across jurisdictions				
Outputs and outcomes: There is a small number of very good examples of biodiversity-friendly management regimes. For the vast majority of the livestock grazing production system in Australia, it is very difficult to assess outcomes	?			

Assessment summary 3 (continued)

Summary	Assessment grade (Ineffective / Partially effective / Effective / Very effective)	Confidence: In grade	Confidence: In trend	Comparability: To 2011 assessment
Invasive species and pathogens				
Understanding: It is broadly understood that invasive species exert a significant pressure on biodiversity. However, trends in the distribution and abundance of invasive species are not well documented				
Planning: There is a lack of nationally consistent legislation to address the impacts of invasive species. National strategic plans are in place, but there is lack of clarity on roles and responsibilities, and few quantifiable objectives on which to assess their effectiveness				
Inputs: Jurisdictions and land managers from the local to regional scale all note that lack of resources is a very significant issue, impacting their ability to manage invasive species				
Processes: Management systems and strategies provide guidance, but serve more as aspirational documents rather than drivers of on-ground action				
Outputs and outcomes: There are a few good examples of local eradication for single high-impact species, particularly vertebrates. For the vast majority of invasive species, the situation appears to be worsening				

Recent trends

- Improving
- Deteriorating
- Stable
- Unclear

Confidence

- **Adequate:** Adequate high-quality evidence **and** high level of consensus
- **Somewhat adequate:** Adequate high-quality evidence **or** high level of consensus
- **Limited:** Limited evidence **or** limited consensus
- **Very limited:** Limited evidence **and** limited consensus
- **Low:** Evidence and consensus too low to make an assessment

Comparability

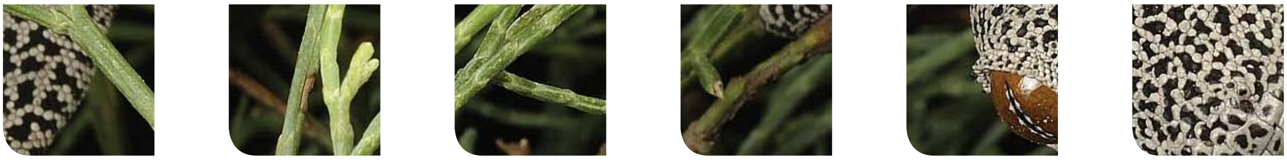
- **Comparable:** Grade and trend are comparable to the previous assessment
- **Somewhat comparable:** Grade and trend are somewhat comparable to the previous assessment
- **Not comparable:** Grade and trend are not comparable to the previous assessment
- X **Not previously assessed**

Assessment summary 3 (continued)

Management context (understanding of environmental issues; adequacy of regulatory control mechanisms and policy coverage)	
Elements of management effectiveness and assessment criteria	**Grades**
Understanding of context Decision-makers and environmental managers have a good understanding of: • environmental and socio-economic significance of environmental values, including ecosystem functions and cultural importance • current and emerging threats to values. Environmental considerations and information have a significant impact on national policy decisions across the broad range of government responsibilities	**Very effective:** Understanding of environmental and cultural systems, and factors affecting them is good for most management issues **Effective:** Understanding of environmental and cultural systems, and factors affecting them is generally good, but there is some variability across management issues **Partially effective:** Understanding of environmental and cultural systems, and factors affecting them is only fair for most management issues **Ineffective:** Understanding of environmental and cultural systems, and factors affecting them is poor for most management issues
Planning Policies and plans are in place that provide clarity on: • objectives for management actions that address major pressures and risks to environmental values • roles and responsibilities for managing environmental issues • operational procedures, and a framework for integration and consistency of planning and management across sectors and jurisdictions	**Very effective:** Effective legislation, policies and plans are in place for addressing all or most significant issues. Policies and plans clearly establish management objectives and operations targeted at major risks. Responsibility for managing issues is clearly and appropriately allocated **Effective:** Effective legislation, policies and plans are in place, and management responsibilities are allocated appropriately, for addressing many significant issues. Policies and plans clearly establish management objectives and priorities for addressing major risks, but may not specify implementation procedures **Partially effective:** Legislation, policies and planning systems are deficient, and/or there is lack of clarity about who has management responsibility, for several significant issues **Ineffective:** Legislation, policies and planning systems have not been developed to address significant issues
Management capacity (adequacy of resources, appropriateness of governance arrangements and efficiency of management processes)	
Inputs Resources are available to implement plans and policies, including: • financial resources • human resources • information	**Very effective:** Financial and staffing resources are largely adequate to address management issues. Biophysical and socio-economic information is available to inform management decisions **Effective:** Financial and staffing resources are mostly adequate to address management issues, but may not be secure. Biophysical and socio-economic information is available to inform decisions, although there may be deficiencies in some areas **Partially effective:** Financial and staffing resources are unable to address management issues in some important areas. Biophysical and socio-economic information is available to inform management decisions, although there are significant deficiencies in some areas **Ineffective:** Financial and staffing resources are unable to address management issues in many areas. Biophysical and socio-economic information to support decisions is deficient in many areas

Assessment summary 3 (continued)

Processes A governance system is in place that provides for: • appropriate stakeholder engagement in decisions and implementation of management activities • adaptive management for longer-term initiatives • transparency and accountability	**Very effective:** Well-designed management systems are being implemented for effective delivery of planned management actions, including clear governance arrangements, appropriate stakeholder engagement, active adaptive management and adequate reporting against goals **Effective:** Well-designed management systems are in place, but are not yet being fully implemented **Partially effective:** Management systems provide some guidance, but are not consistently delivering on implementation of management actions, stakeholder engagement, adaptive management or reporting **Ineffective:** Adequate management systems are not in place. Lack of consistency and integration of management activities across jurisdictions is a problem for many issues
Achievements (delivery of expected products, services and impacts)	
Elements of management effectiveness and assessment criteria	**Grades**
Outputs Management objectives are being met with regard to: • timely delivery of products and services • reduction of current pressures and emerging risks to environmental values	**Very effective:** Management responses are mostly progressing in accordance with planned programs and are achieving their desired objectives. Targeted threats are being demonstrably reduced **Effective:** Management responses are mostly progressing in accordance with planned programs and are achieving their desired objectives. Targeted threats are understood, and measures are in place to manage them **Partially effective:** Management responses are progressing and showing signs of achieving some objectives. Targeted threats are understood, and measures are being developed to manage them **Ineffective:** Management responses are either not progressing in accordance with planned programs (significant delays or incomplete actions) or the actions undertaken are not achieving their objectives. Threats are not actively being addressed
Outcomes Management objectives are being met with regard to improvements to resilience of environmental values	**Very effective:** Resilience of environmental values is being maintained or improving. Values are considered secured against known threats **Effective:** Resilience of environmental values is improving, but threats remain as significant factors affecting environmental systems **Partially effective:** The expected impacts of management measures on improving resilience of environmental values are yet to be seen. Managed threats remain as significant factors influencing environmental systems **Ineffective:** Resilience of environmental values is still low or continuing to decline. Unmitigated threats remain as significant factors influencing environmental systems



Resilience
of biodiversity

At a glance

Resilience is a key underpinning principle of Australia's Biodiversity Conservation Strategy 2010–2030, as well as state and territory, and regional biodiversity strategies. The definition of resilience in biodiversity strategies and policies is still relatively ambiguous, and needs to be more clearly quantified and articulated to measure the success of these strategies. Ecological resilience is generally defined as the ability of ecosystems to resist permanent structural change and maintain ecosystem functions.

Australia's biodiversity is well adapted to variable climate conditions and to a certain frequency of extreme events. However, the current rate and magnitude of change in climate, compounded by other pressures, are beginning to seriously challenge the natural adaptive capacity of our biodiversity. There are many initiatives and activities being undertaken across Australia, from local to national scales, that will improve the resilience of our biodiversity to future pressures. However, there is growing evidence that some vulnerable ecosystems are undergoing permanent structural change because of extreme climate impacts, signalling a clear loss of resilience in these systems. Further work is required to understand thresholds before tipping points are reached beyond which irreversible changes to ecosystems occur.

Ecosystems globally have always experienced environmental change and natural disturbances, but the effects of human activity (e.g. land conversion, carbon emissions, invasive species) are increasing both the rate and the intensity of change. Strengthening and maintaining the resilience of biodiversity to this change is a key underpinning principle of Australia's Biodiversity Conservation Strategy 2010–2030. The strategy identifies 3 national priorities for action to help stop decline in biodiversity. One of these is 'Building ecosystem resilience in a changing climate by: protecting biodiversity, maintaining and re-establishing ecosystem function, and reducing threats to biodiversity'. The management of biodiversity for resilience is also increasingly embedded in state and territory, regional and local-level biodiversity strategies.

Resilience is a concept with numerous definitions in ecological sciences. Initially, the focus of resilience was on the stability of ecosystem processes and the speed with which they recover these processes following disturbance. This has gradually been replaced by a broader concept of 'ecological resilience', defined as the ability of ecosystems to resist regime shifts and maintain ecosystem functions, potentially through internal reorganisation (i.e. their 'adaptive capacity') (Oliver et al. 2015). Regime shifts are defined as large, persistent changes in the structure and function of systems, with significant impacts on the suite of ecosystem services provided by these systems.

Although much of the discussion about resilience in policy and biodiversity management is derived from a concern about the impact of climate change, changes to climate will interact with other disturbances such as land-use change, invasive species, disease and pathogens, and other agents of change, resulting in 'threat syndromes'. Threat syndromes occur when several threats, both present and future, interact to undermine resilience and the continued persistence of certain types of biodiversity. It is most likely that changes to ecosystems and biodiversity will come about as a result of threat syndromes rather than from the operation of 1 agent (Murphy et al. 2012). Approaches to resilience that incorporate broad thinking about environmental change appear most likely to ensure good outcomes.

Evidence of past resilience

Much of Australia's biodiversity is renowned for its ability to deal with massive ecosystem shocks (e.g. fire, extended periods of dry or wet, extreme weather events such as cyclones). During the past few decades, we have learned more about the multitude of strategies used by different species that provide resilience to change. However, although our biodiversity is well adapted to past change, including a certain frequency of extreme climate events, it is not necessarily well adapted to future rates of environmental change, particularly given the often very fragmented and degraded habitat in which change now occurs.

The evolution of adaptive mechanisms in our flora and fauna provides strong evidence of past resilience. However, concern has been growing that some ecosystems are already unable to respond to ongoing global change. In south-western Australia, the past 40 years have seen a climate shift, with reduced precipitation and increasing temperatures; the period from January 2000 to the present was the driest on record (BoM & CSIRO 2014). Above and beyond this decadal trend, there have also been recent droughts, with the summer of 2010–11 being one of the driest and hottest years on record for much of the region (2013, 2014 and 2015 were even hotter). The consequence of extended periods of hot temperatures and reduced rainfall on the resilience of ecosystems is not well understood. For instance, in the wettest parts of south-western Australia, streamflow has declined by more than 50 per cent since the mid-1970s, yet we do not have the long-term data to determine biodiversity decline as a result of this phenomenon.

Other ecosystems considered to have reduced resilience include montane communities such as the Eastern Stirling Range Montane Heath and Thicket, which has been assessed as critically endangered based on its naturally limited geographic extent, in combination with the impacts of the plant pathogen *Phytophthora cinnamomi* (Barrett & Yates 2015). A strong signal for decreased resilience in south-western Australia has been recorded in species generally considered to be robust to climate impacts, such as the region's 2 dominant tree species (*Eucalyptus marginata* and *Corymbia calophylla*). More than 4 years of measurement following the 2010–11 drought showed a failure to recover structure, suggesting that repeated drought has prevented stand development from occurring, and only partial regrowth (Matusick et al. 2016).

Managing biodiversity for resilience

The ability of ecosystems to tolerate and recover from disturbance is a phenomenon that is vitally important to understand. Resilience has stimulated much valuable research that has provided new insights into the ecological processes influencing ecosystem persistence and recovery. However, use of the concept of resilience in policy and strategies is often quite ambiguous, and evidence-based approaches to its measurement are very difficult to apply (Standish et al. 2014, Newton 2016). Effectiveness of biodiversity management shows that we struggle to measure the effectiveness of our investments in biodiversity management and the reduction of pressures. Evaluating the effectiveness of any policy or management program designed to strengthen resilience will require greater clarity around how resilience is translated into action, and clearly articulated measurement and monitoring targets.

In a management context, there are several pressing questions concerning resilience. How much disturbance can an ecosystem absorb before switching to another state? Where is the threshold associated with the switch between ecosystem states? Will ecosystems recover from disturbance without intervention (Standish et al. 2014)?

Making the concept of resilience operational to management requires finding ways to quantitatively measure it. The concept of tipping points and thresholds is often linked with the measurement of resilience. The tipping point is an ecological threshold beyond which major change becomes inevitable and is often very difficult to reverse. Direct experimental data on thresholds are usually too difficult to obtain, but observational data from ecosystems in different stages post-disturbance can be used to direct management decisions and priorities. In particular, these types of observational studies may help predict the response of ecosystems to future disturbance events of a similar nature (Standish et al. 2014).

There is some evidence that climate-driven regime shifts have already occurred in Australia. For example, researchers in southern Western Australia recently documented a relatively rapid climate-driven change in the structure and composition of Australian temperate reef communities, which, during the past 5 years, have lost their defining kelp forests and become dominated by persistent seaweed turfs (Wernberg et al. 2016). An extreme marine heatwave in 2011 and warmer than average sea temperatures in 2012 and 2013 caused a 100 kilometre contraction of kelp forests, which were replaced by seaweeds, invertebrates, corals and fishes characteristic of subtropical and tropical waters. The probability of prolonged cool conditions that could reset community structure and ecological processes to facilitate the recovery of kelp forests in this region is becoming increasingly unlikely, whereas the risk of more heatwaves that will exacerbate and expand the new tropicalised ecosystem state is increasing.

Another possible indicator of climate-driven ecosystem contraction was found in south-western Australia during the record dry and hot period of 2010 and 2011. During this drought, banksia woodlands contracted by 70–80 per cent around Perth, and more than 16,000 hectares of jarrah forest suddenly collapsed, with mortality rates more than 10 times greater than normal. This, of course, has flow-on effects to the animals that depend on them. For instance, during the same period, the population of the endangered Carnaby's black cockatoo (*Calyptorhynchus latirostris*) declined by about one-third in and around Perth (Saunders et al. 2011).

At the landscape level, land managers and policy-makers are engaged in a suite of actions to build and support resilient ecosystems. These include increasing the conservation estate, reducing the impact of pressures, identifying and protecting refugia, and restoring connectivity in degraded landscapes. Land managers engaged in on-ground activities are also increasingly looking towards new approaches to improving resilience. For example, land managers involved in revegetation and restoration are beginning to incorporate 'climate-adjusted' or 'composite provenancing' strategies for a selection of species used in plantings (see Box BIO21). These strategies involve a targeted approach to enhancing the climate resilience of restoration plantings, with seed sourcing biased towards the direction of predicted climatic change (Prober et al. 2015).

Box BIO21 Rethinking revegetation resilience

SA Water undertakes revegetation work in historically cleared parts of its large (around 85,000 hectares) land holdings across South Australia. Native species are used in revegetation to concurrently achieve multiple outcomes of catchment management (water quality), biodiversity conservation, amenity and carbon sequestration. To ensure that these outcomes can be achieved in the long term despite projections of a drier climate, SA Water and its partners have taken novel steps to ensure the resilience of the revegetation plantings (Gellie et al. 2016).

Underpinned by collaborative research with the University of Adelaide, a new approach to seed sourcing has been established to help mitigate risks posed by future climate change. Previously, SA Water adhered solely to principles of 'local provenancing', which generally prescribes strict collection of seeds from areas very close to the revegetation site. However, research trials demonstrated that seeds sourced from drier parts of a local species' range produced trees that performed better in revegetation than those from the immediate surrounds. In light of these findings, SA Water has adapted its thinking and revised its revegetation strategy to use an alternative seed collection protocol termed 'composite provenancing'. This approach seeks to retain the benefits of using local species, while increasing resilience to climate change by combining seed from local populations with seed from drier parts of the species' natural range. This process attempts to mimic the original gene flow dynamics that were interrupted by land clearing and fragmentation.

Results have been positive in the short term, and monitoring for long-term effectiveness is in place. The incorporation of composite provenancing is one of a suite of design considerations used to promote resilience in SA Water's revegetation programs. These programs also include consideration of adequate diversity of plant functional groups, habitat structure (for enhanced ecosystem function), competitive exclusion of weeds and fire prevention planning.

Source: Shaun Kennedy, SA Water

A major mechanism for managing the overall resilience of biodiversity in altered landscapes is through private land conservation. Australian Government investment through NRM bodies to work with private landholders is a key factor in improving landscape function. For instance, the Victorian NRM North East Catchment Management Authority worked with private landholders to undertake a project aimed at managing approximately 600 hectares of endangered grassy woodland vegetation for biodiversity outcomes. This investment in managing threatened native vegetation on private property complements conservation through protection of remnant patches in reserves. It has been shown to support relatively species-rich assemblages of birds, including many species of conservation concern, but may have only limited benefit for protecting populations of arboreal marsupials because of the lack of hollow-bearing trees in agricultural landscapes (Michael et al. 2016).

Factors affecting resilience capacity

Multiple factors acting at various levels of organisation, from species to landscapes, will interact to determine resilience capacity. For example, a species' sensitivity to environmental change, its rate of population increase, its genetic variability and its phenotypic plasticity (i.e. the ability of a species to adjust its characteristics in response to its environment) are properties that underpin resilience (these are described in more detail in SoE 2011). At the landscape level, the amount of intact habitat, connectivity, and variation (or heterogeneity) in the landscape are important properties affecting resilience (Oliver et al. 2015; see Box BIO*22*).

Adaptive capacity, which is often used to refer to the set of preconditions that enable species and systems to respond to climate change, is a synonym for many characteristics of resilience. To be resilient, species, communities and systems must generally be able to buffer disturbance, reorganise and renew after disturbance, and learn and adapt. For some parts of Australia's biodiversity, it is changes in habitat condition that most affect their resilience, whereas in other parts of their range it is changes in habitat extent. For example, in Australia during the past 5 years, we have continued to observe continental-scale decreases in migratory shorebirds. Shorebirds migrate to Australia from Siberia and northern Alaska by a migration corridor known as the East Asian–Australasian Flyway (EAAF), which is used by more than 5 million shorebirds of almost 40 species. In 2016, an analysis of decadal timeseries of surveys of these species around Australia (Clemens et al. 2016) showed that numerous species are decreasing, some at alarming rates. The analyses examined population trends at inland and coastal sites around Australia for 19 species from 1973 to 2014. Continental-scale population decreases were identified in 12 of the 19 species, and regional-scale decreases (southern Australia) in 17 of the 19 species since 2000. Although some habitat modification has happened in Australia, vast areas of feeding grounds in Asia continue to be reclaimed, significantly reducing the ability of these birds to successfully complete their migrations (Iwamura et al. 2013; Murray et al. 2014, 2015). Tasmania is the southernmost destination in the EAAF, with observed long-term decreases exceeding those observed on the Australian mainland (see Box BIO13).

New research into climate adaptation services has identified the ecological mechanisms and traits that support the intrinsic resilience of ecosystems, and facilitate their capacity to adapt and transform in response to change (Lavorel et al. 2015). Using 4 contrasted Australian ecosystems, this research suggests that 4 main mechanisms—vegetation structural diversity, the role of keystone species or functional groups, response diversity, and landscape connectivity—underpin the maintenance of ecosystem services and the reassembly of ecological communities under increasing climate change and variability. For the grassy eucalypt woodlands of south-eastern Australia, the highest priority for anticipated future pressure is maintaining perennial vegetation to reduce the risk of future desertification. For the Littoral Rainforest and Coastal Vine Thickets of eastern Australia, the maintenance of intact, diverse, connected forest stands of good quality is considered the key management requirement to support ecosystem adaptation. For the Australian Alps and South Eastern Highlands of south-eastern Australia, a greater management focus on fire-sensitive ash-type eucalypt forests, including fire suppression, fuel reduction and reseeding, is recommended. However, novel approaches to management may need to be considered in the future, such as translocating seed from resprouting montane species rather than fire-sensitive ash species. The Murray–Darling Basin contains floodplain woodlands and forests, consisting of few flood-tolerant and droughttolerant eucalyptus and acacia species, as well as riparian woodland corridors, and chenopod shrubland and grassland in more arid regions. The study suggests that floodplain ecosystems are likely to persist under climate change, although with reduced extent and altered vegetation structure, and limits on water diversions and the restoration of water into the river systems will provide the greatest ecosystem resilience.

Australian scientists recently identified the 10 major terrestrial and marine ecosystems in Australia that they considered most vulnerable to tipping points (Laurance et al. 2011):

- elevationally restricted mountain ecosystems
- tropical savannas
- coastal floodplains and wetlands
- coral reefs
- drier rainforests
- wetlands and floodplains in the Murray–Darling Basin
- the Mediterranean ecosystems of south-western Australia
- offshore islands
- temperate eucalypt forests
- saltmarshes and mangroves.

Key factors predisposing these ecosystems to tipping points include:

- having a restricted distribution or a narrow environmental envelope
- having suffered substantial fragmentation
- relying on critical 'framework' species (such as 1 or a few species of canopy trees, or coral-building organisms)
- being constrained by close proximity to humans or human activities
- already existing close to an environmental threshold.

The researchers emphasised that most vulnerable ecosystems were influenced by multiple drivers, such as climate change and extreme events, changes in fire regimes, invasive species and land-use pressures.

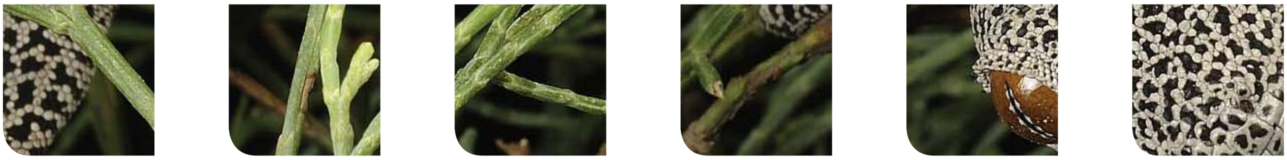
Box BIO22 Refugia and resilience

Refugia are areas of the landscape that provide protection for plants and/or animals from unsuitable or threatening conditions or events, and allow them to persist. Species can retreat to, persist in and, potentially, expand from refugia under changing climatic conditions (Reside et al. 2014). Refugial features in the landscape have been important to the persistence of native species under past natural climate change associated with glaciation and deglaciation periods. Refugia are highly likely to be of continuing importance for the resilience of biodiversity in the face of current and future pressures (Murphy et al. 2012).

The survival of some species will increasingly depend on their accessing microhabitats that are unusually cool, wet, humid or protected from fire. Such locations could include the largest rock piles and logs, caves, large hollow trees, gorges and gullies, the deepest accumulations of litter, and the shaded southern sides of steep hills. For example, 2 lizards (Black Mountain rainbow-skink—*Carlia scirtetis*, and Black Mountain gecko—*Nactus galgajuga*) and a frog (Black Mountain boulder frog—*Cophixalus saxatilis*) that are endemic to Black Mountain on Cape York Peninsula avoid high temperatures and low humidity by retreating further beneath boulders (Low 2011). Research has shown that mountain-top boulder fields in the Wet Tropics can be as much as 10 °C cooler than near-surface conditions (Shoo et al. 2010). This means that species such as the critically endangered beautiful nursery frog (*Cophixalus concinnus*) may persist longer than expected by sheltering during extreme or prolonged heat in these boulder fields.

Our understanding of conditions that provide refugia in Australia is growing but is still a challenge, given the wide range of climatic and habitat requirements that our biodiversity encompasses (Reside et al. 2014, Keppel et al. 2015). Relatively intact natural habitat, such as riparian zones, windrows, reserves, national parks and state forests, can also be thought of as environmental refuges from often highly modified contemporary landscapes.

Australia's National Reserve System is critical for maintaining resilience of biodiversity. Australia's Strategy for the National Reserve System 2009–2030 includes targets to protect critical sites for climate change resilience. These critical areas include large and small refuges, critical habitats, landscape-scale corridors, places of species and ecosystem richness, sites of endemism, sites that support threatened species and/or ecological communities, and sites important for the stages in the lifecycle of migratory or nomadic species. Integration of the National Reserve System with off-reserve conservation mechanisms, such as stewardship and incentive programs, is also highlighted in a landscape-scale approach to building ecosystem resilience.



Risks
to biodiversity

At a glance

Escalation of existing risks such as invasive species, climate change and changing fire regimes, and the interactions between these risks, will continue to exert significant and widespread changes on biodiversity.

The importance of some risks, or at least the perception of those risks, has decreased slightly. For others, it has increased. Based on a reassessment of the risks identified in 2011, the 2 highest-ranked risks in 2016 are the failure of processes for adequate data collection to provide early warning of threats and opportunities, and pressures from urban and peri-urban growth. Both are almost certain in terms of likelihood, and almost certain to have major consequences. Both have increased in likelihood since 2011, from possible to almost certain.

Ideas about 'megatrends' and 'megashocks' are new to the state of the environment biodiversity discussion in 2016. Both megatrends and megashocks have the potential to significantly change the state of Australia's biodiversity.

The previous sections outline the multiple risks to biodiversity from pressures such as fragmentation of habitat, climate change, altered fire regimes and invasive species. In addition to these known threats, the inadequacy of long-term data and monitoring means that management agencies are not well placed to understand or deal with the cumulative impacts of multiple risks. Our understanding of even the most iconic and well-known species in Australia is often patchy. Knowledge of ecosystem processes that maintain the vast majority of species that account for Australia's biodiversity is limited.

Escalation of existing pressures

It is inevitable that the impact of climate change will continue to increase, given current trajectories (see the *Drivers* and *Atmosphere* reports). The interaction of climate change with other pressures, such as invasive species and changing fire regimes, will also continue to cause significant and widespread changes in biodiversity.

Along with clearing and fragmentation, the impact of invasive species is already highlighted throughout this report as the most significant pressure faced by biodiversity in Australia. Given the overall trajectory of increasing impact, it is likely that this issue will increase in the future. CSIRO's report *Australia's biosecurity future* (Simpson & Srinivasan 2014) highlighted a number of global megatrends that are likely to escalate this existing pressure, with the potential to bring about significant change and complexity (Table BIO9).

Australia's biosecurity future (Simpson & Srinivasan 2014) also outlined several megashocks (based on what the biosecurity community identified as some of the most important threats we might face in the next 2–3 decades) that could result if we remain complacent about our future biosecurity risks. Megashocks involve significant, relatively sudden and potentially high-impact events, the timing of which is very hard to predict. Megashocks can have significant impacts across economic, environmental and/or social dimensions. They can also vary in scale, from more localised or industry-specific megashocks, through to those with impacts of national or even global significance.

The 12 megashocks presented in the report are:

- nationwide incursion of a new race of an exotic wheat stem rust (more virulent than existing races of UG99)
- nationwide loss of pollination services from feral European honeybees as a result of a multistate varroa mite incursion

- nationwide incursion of a new exotic fruit fly
- nationwide outbreak of a variant strain of foot-and-mouth disease
- bluetongue outbreak across Australia's major sheep-producing regions
- spread of highly virulent rust across multiple ecosystems
- government 'walking away' from environmental biosecurity
- successful establishment of black-striped mussel
- outbreak of infectious salmon anaemia
- nationwide zoonotic disease epidemic
- bioterrorist attack
- rapid spike in antimicrobial resistance.

The report also identifies a series of activities, across policy, science and technology, and communication and engagement, that provide a starting point for the process of strengthening our biosecurity regimes to address global challenges.

Table BIO9 Summary of biosecurity megatrends and their key implications

Megatrend	Overview	Biosecurity implications
An appetite for change	• Agriculture is intensifying to meet growing global food demands • Niche markets are growing (e.g. organics and bioproducts)	• Future focus will be on productivity improvements that could increase or decrease the strength of the biosecurity system • Land-use change associated with agricultural expansion can affect the resilience of our ecosystems • As niche markets grow, we may need to consider entirely new approaches to managing pests and diseases
The urban mindset	• Urban populations continue to grow, with increasing disconnectedness from primary industries • Consumer expectations relating to food production are growing • Urban development continues to encroach on land • Peri-urban producers are disconnected from traditional agricultural networks	• A general disconnection from primary production in Australia is leading to a lack of understanding of biosecurity issues and their impacts • The ongoing expansion of our cities is changing interactions between people, wildlife, agriculture and disease vectors, increasing risks such as zoonotic disease • It is important to engage with peri-urban and amateur producers as part of the biosecurity community to improve their understanding of biosecurity risks and their adoption of biosecurity practices
On the move	• The number of international tourist arrivals in Australia continues to increase • The movement of goods and vessels around the world and across interstate borders is increasing, in line with growing global trade	• Increased movement of people and goods can help to bring pests or diseases into the country that could affect our environment or primary industries • Greater domestic freight movements can also help pests and diseases to spread across the country • In a globalised world, bioterrorism (including agroterrorism) is a potential threat

Table BIO9 (continued)

Megatrend	Overview	Biosecurity implications
A diversity dilemma	• There is increased biodiversity loss, with many species on the brink of extinction, much of which is linked to human activity • A changing climate is causing shifts in ecosystem diversity • We are continuing to see a loss of species and genetic diversity within agriculture	• Significant biodiversity loss can decrease the resilience of our natural environment to pests and diseases • Biodiversity can provide a number of benefits, such as ecosystem services (e.g. pollination). Understanding the interconnections between biodiversity and biosecurity may therefore prove to be a vital component of biosecurity management • Climate change can facilitate the movement of pests and disease vectors into new areas • The loss of agricultural diversity can create food security risks in the case of a pest or disease outbreak • Preserving genetic diversity can help in the development of pest-resistant and disease-resistant crops and animals
The efficiency era	• An ageing population is leading to a decline in biosecurity specialists and experienced farmers, with a lack of younger talent to fill the gaps created • Biosecurity investment does not appear to be keeping pace with the growing challenges we face • Technology and innovation across surveillance and monitoring; data and analytics; communication and engagement; genetics; and smaller, smarter devices will play an important role in addressing future biosecurity challenges	• A lack of biosecurity specialists and investment could limit our ability to prevent and respond to shocks • Improvements in data modelling and visualisation, combined with increased data availability, can improve long-term decision-making • Progress in surveillance and diagnostics in genetics allows for better detection and understanding of pests and diseases, as well as opportunities to breed resistant species

Assessment summary 4

Current and emerging risks to biodiversity

In consultation with ecologists across a wide range of disciplines, we reclassified the risks presented in 2011 for likelihood and impact in 2016. Although both assessments (2011 and 2016) were qualitative and subjective, they represent a consensus of thought at the time, and it is useful to look at changes in the perceived relative importance of the various risks identified over time.

Some risks rose in importance in terms of either likelihood or significance between 2011 and 2016. For example, the 2 highest-ranked risks in 2016 (at almost certain/major) were both ranked as 'possible/major' in 2011. This suggests a greater understanding in 2016 that these 2 risks will have major impacts on biodiversity.

Several risks were ranked lower in 2016 than in 2011. The risk related to 'inadequate progress in scaling climate change models down to local scales' was among the highest ranked in 2011 (likely/major). In 2016, this risk was ranked 'possible/moderate', which most likely reflects the significant investment in developing and improving downscaled climate models that has been made during the past 5 years.

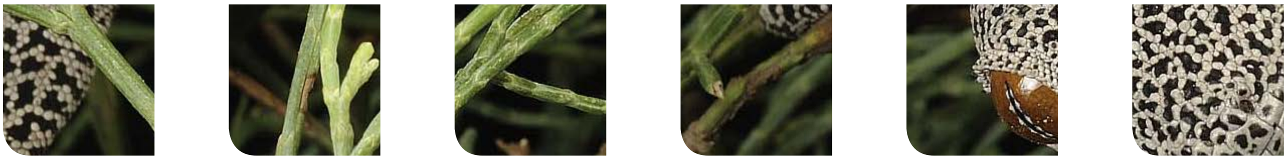
	Catastrophic	Major	Moderate	Minor	Insignificant
Almost certain		Failure to establish processes for collecting relevant and adequate data to provide early warning of threats and opportunities for biodiversity management Urban and peri-urban pressure jumping to a much higher level as a result of population growth and failure to manage human demands on the environment			
Likely		Slow progress on understanding the relationships between population, economy, technology and biodiversity, and communicating this to the public Increasing hard engineering 'solutions' to cope with rising sea levels, such as groyne and sea walls, affecting beach and intertidal diversity Crossing 1 or more major thresholds of irreversible change in soil fertility, connectedness and quality of vegetation as habitat, or ability of species to adapt to climate change			

Assessment summary 4 (continued)

	Catastrophic	Major	Moderate	Minor	Insignificant
Likely		Emergence of more unexpected effects of human activities in northern Australia Emergence of 1 or more major pests or diseases that spread widely among native plants and/or animals Change in fire regimes to the point that major trade-offs between human safety and biodiversity are necessary Increased allocation and storage of water to cope with more intense droughts Interaction of climate change and increased costs of energy creating major trade-offs between food production and biodiversity conservation Increased pressure on coastal ecosystems from rising sea level, combined with extreme events and decline of coral buffers as a result of ocean acidification Failure to achieve integrated and cooperative management of water for environment			
Possible	Climate change that is so fast and severe that mass extinctions occur	Shifts in the ‘geography’ of agriculture (e.g. increasing intensity of agriculture in the relatively intact landscapes of the north-west in response to increasing rainfall there and decreasing rainfall in the south-west and south-east)	Policy and/or technological responses to climate change and/or water shortages having unintended consequences (e.g. alternative energy technologies have impacts on biodiversity, desalination projects generate pollution)	Major changes in food-production technologies reducing the numbers of people living in regional Australia, and managing the land for personal and public benefit	Increased water allocation to artificial snowmaking in alpine areas

Assessment summary 4 (continued)

	Catastrophic	Major	Moderate	Minor	Insignificant
Possible		Deoxygenation of oceans (major effect possible in long term) Increased pressure in Australia to provide wood as deforestation is reduced in other countries Major interactions between altered ocean circulation and ocean acidification, drastically modifying marine ecosystems Pollutants currently considered minor being found to have major biodiversity impacts (e.g. hormone analogues) Failure to improve ability of regional communities to manage their links with biodiversity	Inadequate progress in scaling climate change models down to provide robust forecasts at local scales Failure of technological advances to keep pace with pressures on biodiversity Large-scale functional shifts in Australian soils Geoengineering causing unexpected and undesired effects on ecosystems Negative impacts on biodiversity from development of biofuels and biochar Unintended negative consequences of translocating species as a response to the climate change threat (e.g. competition or predation with other species at the transplant site) Market-based approaches to managing biodiversity driving decline rather than sustainability Ability to genetically engineer new species becoming widely available, and used by a range of skilled and unskilled people		
Unlikely					
Rare					



Outlook
for biodiversity

At a glance

It seems unlikely, given the current overall poor status and deteriorating trends in biodiversity and the high impact of increasing pressures, that overall biodiversity outcomes will improve in the short or medium term. Our current investments in biodiversity management are not keeping pace with the scale and magnitude of current pressures, and we are increasingly needing to adapt to a potential reduction or shift in the ecosystem services we rely on. It is anticipated that novel ecosystems with a mixture of native and exotic species will increase as the distribution and abundance of invasive species continue mostly unabated. Biodiversity and broader conservation management will require major reinvestments across long timeframes to reverse deteriorating trends.

The *Australian national outlook 2015* has indicated that it is possible to achieve a balance of sustainable environments, and economic and human population growth, but significant changes in policy, and implementation of new technology and tools will be required. For example, it is evident that market-based instruments for sustainable land management and protection of biodiversity will be increasingly important.

The co-development and application of effective research and management models with Indigenous people is key to improving management of areas that are vital for the ongoing maintenance of important elements of Australia's biodiversity. Such approaches have huge potential to improve our ability to respond to both existing and possible new impacts through participatory monitoring and impact assessment methods, leading to new ways of managing biodiversity that enable sustainable development across a wide range of tenures.

The current overall state and trend of biodiversity has not improved since 2011, and present a very mixed outlook, with many assessments showing poor status and worsening trends. In addition, the impact of many of the pressures on biodiversity is high and increasing. Current management actions and effectiveness appear insufficient to redress the declining status of biodiversity. Although the impact of pressures overall has increased, the resources available for managing biodiversity, research and monitoring have not. An increase in the area of land managed for conservation provides some increased protection for biodiversity; however, the majority of our threatened species and communities are under-represented in the conservation estate.

Australian governments and NRM bodies that manage biodiversity are now considering the adoption of environmental accounting that includes trend and condition reporting for environmental assets, to better evaluate the status of our natural capital and better assess the return on investment in the environment. A whole-of-landscape approach is required to effectively manage impacts and achieve meaningful outcomes. More and more biodiversity management in any location involves a co-investment of multiple partners, and therefore reporting needs to move to measurements that report on the outcome of the total investment.

The concept of managing for resilience is becoming more widely adopted to manage landscapes in a changing environment, so that resilient, functioning systems can provide ecosystem services and can withstand, or recover from, external pressures while maintaining ecological functions. The pressure on biodiversity from cumulative pressures, including climate extremes, is increasing, and presents a serious and ongoing threat to the viability of many ecosystems. Outputs from the AdaptNRM project suggest that the potential degree of ecological change expected under high-emissions scenarios is very high in some parts of Australia (Williams K et al. 2014). For instance, across most of Australia, only about half of the current plant species are rated as having the potential to persist in their current locations by 2050. The highest potential for change is projected for the western coastline of south-western Australia, including the coastal sand-plain region where Perth is located. In contrast, areas such as Tasmania, the Nullarbor Plain and parts of central Australia show the lowest potential for change, although some degree of change is still expected.

During the past 5 years, concerns have increased that some present-day environments may disappear or become severely restricted in Australia in the future. Although most widespread ecological communities are considered unlikely to disappear completely, there are predictions that some communities will disappear at local levels. Plants and amphibians appear to be most at risk from the potential disappearance of their environments. Novel ecological environments (new ecological communities that currently do not exist) may arise in the future; however, very few areas are expected to become completely novel under current climate change scenarios.

Across Australia, species are on the move, with changes in range that have not previously been recorded (see Box BIO23). This presents both new opportunities for conservation and new dilemmas on what to conserve and how to deal with 'newcomers'. Whether it be unwanted crocodiles moving south, or a greater variety of fish species caught by anglers, the need to manage emerging novel ecosystems will put increased pressure on our existing systems for biodiversity management.

Box BIO23 Range expansion of flying foxes

Range expansion may occur when:

- existing habitat that has not previously been colonised is reached
- appropriate conditions develop outside a species' distribution, and the species colonises this new habitat
- appropriate habitat develops within a species' range but in areas that were previously not occupied, and the species colonises this habitat.

More controversially, changes in the distribution of a species' abundance (e.g. where the abundance of a species changes in different parts of its distribution in response to changes in conditions) might also be included here. In many instances, such changes in the distribution of a species' abundance is the precursor to another form of range expansion.

Australian flying foxes (Pteropodidae, *Pteropus* spp.) are highly mobile species that exhibit all these forms of range expansion. Range expansions have occurred in several species. From the late 1800s to 2007, the black flying fox (*P. alecto*) expanded its southern range boundary polewards by 123 kilometres per decade, on average (Roberts et al. 2012). More recently, in the south of its range, the vulnerable grey-headed flying fox (*P. poliocephalus*) has established a permanently occupied breeding camp in Adelaide, some 500 kilometres from the nearest camp. In the north, newly established and permanently occupied breeding camps at Finch Hatton and Ingham are roughly 500 and 900 kilometres, respectively, outside the range boundaries. In each case, the camp is separated from the existing range, but is largely in an appropriate habitat.

Apparent expansion into adjacent but previously unoccupied habitat has been seen in the grey-headed flying fox, with apparently new camps established outside the species' range on the Western Plains and in previously unoccupied habitat within the species range (e.g. Canberra and Tumut) during the past decade. However, examination of historical records indicates that the species was present in these areas (e.g. Wellington, Goulburn) in the 1800s, suggesting that range boundaries are highly dynamic across long timeframes as conditions vary.

Box BIO23 (continued)

Grey-headed flying foxes (*Pteropus poliocephalus*)
Photo by Adam McKeown

Source: David Westcott, CSIRO

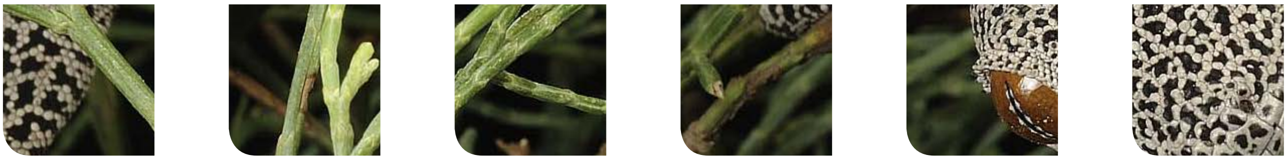
The greatest perceived threat to biodiversity is the interaction of climate change with the impact of other current pressures. For instance, the projections of changing climate in landscapes with additional pressure from clearing lead to a much more severe outlook for the intensively used agricultural zones of southern and eastern Australia, including parts of Tasmania (Williams K et al. 2014).

The pressures on biodiversity from invasive weeds and animals are increasing. Overall, the negative impacts outweigh our current management efforts, and the outlook for the future is not positive. At least 2700 plant species introduced from other countries have already established self-sustaining populations in Australia, and the rate of establishment of further species is estimated at about 12 per year (Scott et al. 2014). Additionally, approximately 26,000 other exotic species, mainly garden plants, have also been introduced into Australia, and it is likely that many new weeds are yet to emerge from this group. With such a large threat already in Australia, and global trade representing an increased risk for further introductions, weed management will increase in importance in the future. Under climate change, we should anticipate the pressure from invasive species to further increase as the suite of invasive species changes and some species become more invasive (Scott et al. 2014).

Although the outlook presented here is grim, highlighting the multiple stresses biodiversity faces in Australia, there are multiple avenues for addressing many of these challenges that help to protect the environment, as well as maintaining economic prosperity. The *Australian national outlook 2015* (CSIRO 2015) found that, across a range of future scenarios, Australia has the capacity to pursue economic growth and improved living standards while also protecting or improving the natural environment, if this is done with the right choices and technologies. For instance, new land-sector markets for carbon sequestration, energy feed stocks and voluntary conservation could be nationally transformative. Paying landholders for 'carbon farming' (sequestering carbon from the atmosphere by restoring vegetation on cleared land) is beginning to assist in controlling erosion, addressing dryland salinity and restoring native habitat. Land-sector credits will be instrumental in reducing Australia's greenhouse gas emissions, and carbon incentives could also be harnessed to restore significant areas of native habitat, reducing extinction risk by 10 per cent or more (CSIRO 2015, Hatfield-Dodds et al. 2015). This could lead to a transformation, where the problem of changed fire regimes across many parts of northern Australia could become an opportunity for landowners and land managers to take advantage of market-based incentives, and deliver improved fire and environmental management outcomes (Russell-Smith 2016).

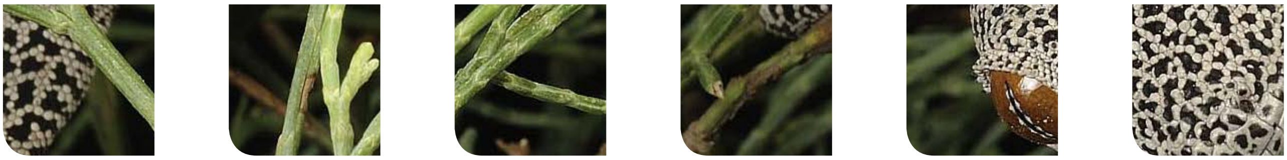
Citizen science continues to grow in Australia and has already demonstrated that it is now a key part of the management response required to halt the decline in biodiversity. The Reef Life Survey program (see Box MAR5 in the *Marine environment* report) provides a network of volunteer citizen scientists who collect species-level data for all conspicuous taxa on a cross-section of Australia's shallow rocky and coral reefs. The survey program conducted the first Australian continental-scale reef biodiversity assessment based on detailed quantitative data, as one way to monitor biodiversity trends in relation to the key pressures on the marine environment. Similarly, citizen-based birdwatching initiatives provide the most comprehensive species-level bird data available for Australia. These largely voluntary efforts significantly add to existing government and industry-led scientific programs. The overall efficacy of citizen-science efforts is difficult to quantify, because evaluations of the monitoring of data quality and data collation are often not undertaken, and it is not possible to truly gauge their importance in the overall national effort.

Innovative new tools for harvesting biodiversity observations across all environments in Australia are continuing to be developed and taken up by Australians at rates that were unprecedented 5 years ago. Combining traditional approaches with novel ways to monitor and report on the status of species and ecosystems may lead to a revolution in how we perceive the current status of Australia's biodiversity, and lead to new ways to deal with current declines in biodiversity.



Acronyms and abbreviations

Acronym or abbreviation	Definition
ALA	Atlas of Living Australia
AUSRIVAS	Australian River Assessment System
CAPAD	Collaborative Australian Protected Area Database
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DNA	deoxyribonucleic acid
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GL	gigalitre
IBRA	Interim Biogeographic Regionalisation for Australia
IPA	Indigenous Protected Area
IUCN	International Union for Conservation of Nature
NRM	natural resource management
SoE	state of the environment



Glossary

Term	Definition
adaptation	Shifts (e.g. in behaviour, management practices, biology) in response to change that support survival; responses that decrease the negative effects of change and capitalise on opportunities.
adaptive management	A systematic process for continually improving policies and practices by learning from the outcome of previously used policies and practices.
algal bloom	A sudden proliferation of algae (microscopic plants) that occurs near the surface of a body of water. Blooms can occur because of natural nutrient cycles, or can be in response to eutrophication or climate variations. *See also* eutrophication.
anthropogenic	Caused by human factors or actions.
biodiversity	The variety of all life forms. There are 3 levels of biodiversity: • genetic diversity—the variety of genetic information contained in individual plants, animals and microorganisms • species diversity—the variety of species • ecosystem diversity—the variety of habitats, ecological communities and ecological processes.
biomass	The quantity of living biological organisms in a given area or ecosystem at a given time (usually expressed as a weight per unit area or volume).
bioregion	A large geographically distinct area that has a similar climate, geology, landform, and vegetation and animal communities. The Australian land mass is divided into 89 bioregions under the Interim Biogeographic Regionalisation for Australia. Australia's marine area is divided into 41 provincial bioregions and 60 mesoscale regions on the continental shelf under the Integrated Marine and Coastal Regionalisation for Australia.
biosecurity	Processes, programs and structures to prevent entry by, or to protect people and animals from the adverse impacts of, invasive species and pathogens.
biota	Living organisms in a given area; the combination of flora, fauna, fungi and microorganisms.
carbon sequestration	Processes to remove carbon from the atmosphere, involving capturing and storing carbon in vegetation, soil, oceans or another storage facility.
caring for Country	Indigenous land and sea management.

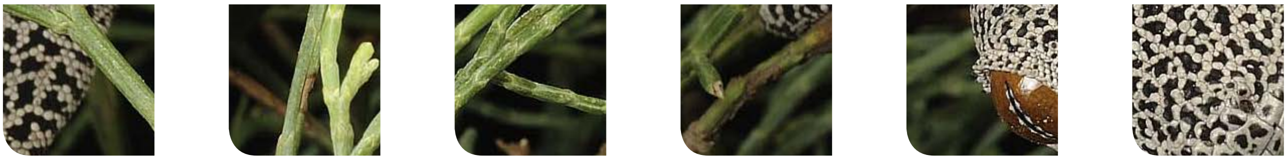
Term	Definition
Caring for our Country	The Australian Government's central environment program since 2008, which funds environmental management, protection and restoration.
catchment	An area of land determined by topographic features, within which rainfall will contribute to run-off at a particular point. The catchment for a major river and its tributaries is usually referred to as a river basin.
climate change	A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and is additional to natural climate variability observed over comparable time periods (as defined by the United Nations Framework Convention on Climate Change).
community	A naturally occurring group of species inhabiting a particular area and interacting with each other, especially through food relationships, relatively independently of other communities. Also, a group of people associated with a particular place.
condition	The 'health' of a species or community, which includes factors such as the level of disturbance from a natural state, population size, genetic diversity, and interaction with invasive species and diseases.
connectivity	Linkages between habitat areas; the extent to which particular ecosystems are joined with others; the ease with which organisms can move across the landscape.
conservation	Protection and management of living species, communities, ecosystems or heritage places; protection of a site to allow ongoing ecosystem function, or to retain natural or cultural significance (or both), and to maximise resilience to threatening processes.
coral bleaching	When the coral host expels its zooxanthellae (marine algae living in symbiosis with the coral) in response to increased water temperatures, often resulting in the death of the coral.
corridor	A linear landscape structure that links habitats and helps movement of, and genetic exchange among, organisms between these habitats.
critically endangered (species or community)	At extreme risk of extinction in the wild; the highest category for listing of a threatened species or community under the criteria established by the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
decline	When the condition of an ecosystem, species or community has decreased. It usually represents more than just a decrease in numbers of individuals, and describes the result of several interacting factors (e.g. decreasing numbers, decreasing quality or extent of habitat, increasing pressures). Where 'decline' is applied to elements of environments (e.g. condition of vegetation as habitat), it usually means that changes have been sufficient to potentially affect the viability of species relying on these elements.
disturbance	A temporary change in average environmental conditions that disrupts an ecosystem, community or population, causing short-term or long-term effects. Disturbances include naturally occurring events such as fires and floods, as well as anthropogenic disturbances such as land clearing and the introduction of invasive species.
drainage division	A major continental-scale water catchment; Australia has been classified into 12 drainage divisions.

Term	Definition
drivers	Overarching causes that can drive change in the environment; this report identifies climate change, population growth and economic growth as the main drivers of environmental change.
ecological processes	The interrelationships among organisms, their environment(s) and each other; the ways in which organisms interact, and the processes that determine the cycling of energy and nutrients through natural systems.
ecological resilience	The ability of ecosystems to resist permanent structural change and maintain ecosystem functions.
ecology	*See* ecological processes.
ecosystem	An interrelated biological system comprising living organisms in a particular area, together with physical components of the environment such as air, soil, water and sunlight.
ecosystem services	Actions or attributes of the environment of benefit to humans, including regulation of the atmosphere, maintenance of soil fertility, food production, regulation of water flows, filtration of water, pest control and waste disposal. It also includes social and cultural services, such as the opportunity for people to experience nature.
El Niño	A periodic extensive warming of the central and eastern Pacific Ocean that leads to a major shift in weather patterns across the Pacific. In Australia (particularly eastern Australia), El Niño events are associated with an increased probability of drier conditions. *See also* La Niña.
endangered (species or community)	At very high risk of extinction in the wild; in danger of extinction throughout all or a portion of its range; criteria are established by the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
endemic	Unique to a spatially defined area; in this report, used mainly to refer to large bioregions of the continent and marine environment.
endemism	The degree to which species and genes are found nowhere else; the number of endemic species in a taxonomic group or bioregion.
environmental flows	Managed freshwater flow to natural water systems designed to maintain aquatic ecosystems.
Environment Protection and Biodiversity Conservation Act 1999 (Cwlth) (EPBC Act)	The Australian Government's main environmental legislation; it provides the legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places.
eutrophication	Excessive nutrients in a body of water, often leading to algal blooms or other adverse effects. *See also* algal bloom.
extent	Areal coverage—for example, of vegetation or sea ice.
extinct (species)	When there is no reasonable doubt that the last individual has died.
feedback	Where the outputs of a process affect the process itself.
fire regime	Frequency, extent, intensity and timing of bushfires.
food web	Interconnected food chains; a system of feeding connections in an ecosystem.

Term	Definition
fragmentation	Isolation and reduction of areas of habitat, and associated ecosystems and species, often due to land clearing.
geographic range	Geographical area within which a species can be found.
greenhouse gases	Gases that contribute to the greenhouse effect, the most important of which are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), short-lived tropospheric ozone (O_3), water vapour, chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).
habitat	The environment where a plant or animal normally lives and reproduces.
hydrology	Related to water quality, movement and distribution.
Interim Biogeographic Regionalisation for Australia (IBRA)	A set of 89 bioregions within the Australian landmass, originally used as the basis for the National Reserve System's planning framework to identify land for conservation.
invasive species	Non-native plants or animals that have adverse environmental or economic effects on the regions they invade; species that dominate a region as a result of loss of natural predators or controls.
jurisdiction	An Australian state or territory, or under the control of the Australian Government.
lacustrine	Relating to lakes.
landscape	An area of land comprising land forms and interacting ecosystems; an expanse of land, usually extensive, that can be seen from a single viewpoint.
landscape processes	Processes that affect the physical aspects of the landscape (e.g. weathering of rock formations, erosion, water flow).
La Niña	A periodic extensive cooling of the central and eastern Pacific Ocean. In Australia (particularly eastern Australia), La Niña events are associated with increased probability of wetter conditions. *See also* El Niño.
megashock	A significant, relatively sudden and potentially high-impact event, the timing of which is very hard to predict.
megatrend	A significant shift in social, environmental, economic, technological or geopolitical conditions that has the potential to reshape the way an organisation, industry or society operates.
millennium drought	The recent drought in southern Australian that lasted from 2000 to 2010 (although in some areas it began as early as 1997).
mitigation	Actions intended to reduce the likelihood of change or the impacts of change.
National Reserve System	Australia's network of protected areas that conserve examples of natural landscapes, and native plants and animals; made up of national, state and territory reserves, Indigenous lands, and protected areas run by conservation organisations or individuals.
natural resource management	The management of natural resources such as land, water, soil, plants and animals, with a focus on sustainable practices.

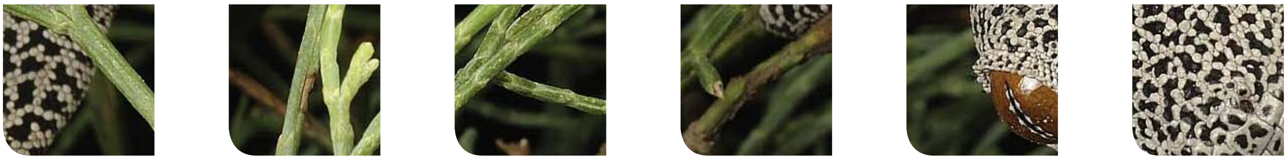
Term	Definition
novel biota	A group of organisms that is new to an ecosystem, whether by natural or human introduction (therefore covers most invasive species).
palaeoendemic	Ancient endemism.
palustrine	Relating to inland, nonflowing water.
pathogen	A microorganism that causes harm to its living host.
peri-urban	A region between the outer suburbs and the countryside.
phenology	Timing of lifecycle events.
phylogeography	Study of historical processes that result in an animal's geographic range or distribution.
pressures	Events, conditions or processes that result in degradation of the environment.
primary production	The production of organic compounds from atmospheric or aquatic carbon dioxide, principally through photosynthesis.
recruitment	Influx of new members into a population or habitat by reproduction, immigration or settlement. In fisheries management, recruitment represents influx into the fishable part of the stock of a target species.
resilience	Capacity of a system to experience shocks while retaining essentially the same function, structure and feedbacks, and therefore identity.
riparian	Related to riverbanks or lake shores.
riverine	Relating to a river or riverbank.
run-off	Movement of water from the land into streams.
sequestration	*See* carbon sequestration.
species	A group of organisms capable of interbreeding and producing fertile offspring.
sustainability, sustainable	Using 'natural resources within their capacity to sustain natural processes while maintaining the life-support systems of nature and ensuring that the benefit of the use to the present generation does not diminish the potential to meet the needs and aspirations of future generations' (*Environment Protection and Biodiversity Conservation Act 1999*, p. 815). 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (United Nations Brundtland Commission).
taxa	Groups of 1 or more organisms classified as a unit. Taxonomic categories include class, order, family, genus, species and subspecies.
taxon	One member of a group; singular of taxa.
taxonomic	Related to the classification and naming of species (taxonomy).
threatened (species or community)	Likely to become endangered in the near future.

Term	Definition
threatening process	A process or activity that 'threatens … the survival, abundance or evolutionary development of a native species or ecological community' (*Environment Protection and Biodiversity Conservation Act 1999*, p. 273) and that also may threaten the sustainability of resource use.
threshold	A boundary between 2 relatively stable states; a point where a system can go rapidly into another state, usually because of positive feedback(s).
tipping point	The threshold at which a relatively small change in conditions leads to a large change in the state of a system, such as habitat structure, species composition, community dynamics, fire regimes, carbon storage or other important functions (Laurance et al. 2011), potentially resulting in a regime shift (a large, abrupt, persistent change in the structure and function of a system).
urban footprint	The extent of area taken up by urban buildings and constructions.
value	The worth of environmental assets. Categories of environmental values include: • indirect-use values—indirect benefits arising from ecological systems (e.g. climate regulation) • direct-use values—goods and services directly consumed by users (e.g. food or medicinal products) • non-use values (e.g. benevolence) • intrinsic value (i.e. environmental assets have a worth of their own regardless of their usefulness to humans).
vulnerable (species)	At high risk of extinction in the wild; likely to become endangered unless the circumstances threatening its survival and reproduction improve.
watertable	The level below which the ground is saturated with water; the division between the subsurface region, in which the pores of soil and rocks are effectively filled only with water, and the subsurface region, in which the pores are filled with air and usually some water.
Weeds of National Significance (WoNS)	Weeds identified as a threat to Australian environments based on their invasiveness, potential for spread, and socio-economic and environmental impacts; 20 plant species are currently listed as WoNS.
wildfire	An unplanned fire, whether accidentally or deliberately lit (in contrast to a planned or managed fire lit for specific purposes such as fuel reduction).



Acknowledgements

The authors acknowledge the contributions of Damien Barrett; Geoff Barrett; Sarah Bekessy; Anthea Brecknell; Margaret Byrne; Emma Campbell; Sandy Carruthers; Coleen Cole; Fran Daniels; Luke Diddams; Raphael Didham; Michael Douglas; the Ecological Society of Australia and members; Owain Edwards; Shane Gaddes; Jo Harding; John Harkin; Steve Hatfield-Dodds; Matthew Herring; Ro Jill; Shaun Kennedy; Tania Laity; John La Salle; Jim Longworth; Mark Lound; Pethie Lyon; Peter Marsack; Tom May, and the Fungimap Biodiversity and Conservation Subcommittee; Karel Mokany; Steve Morton; Jo Neilson; Chris Pavey; Barb Skoro; state and territory agency contributors; Celine Steinfeld; the Tasmanian Land Conservancy; Martin Taylor; Eric Vanderduys; Fiona Walsh; Peter West; David Westcott; Kate Wilson; Eric Woelher; and David Yeates.



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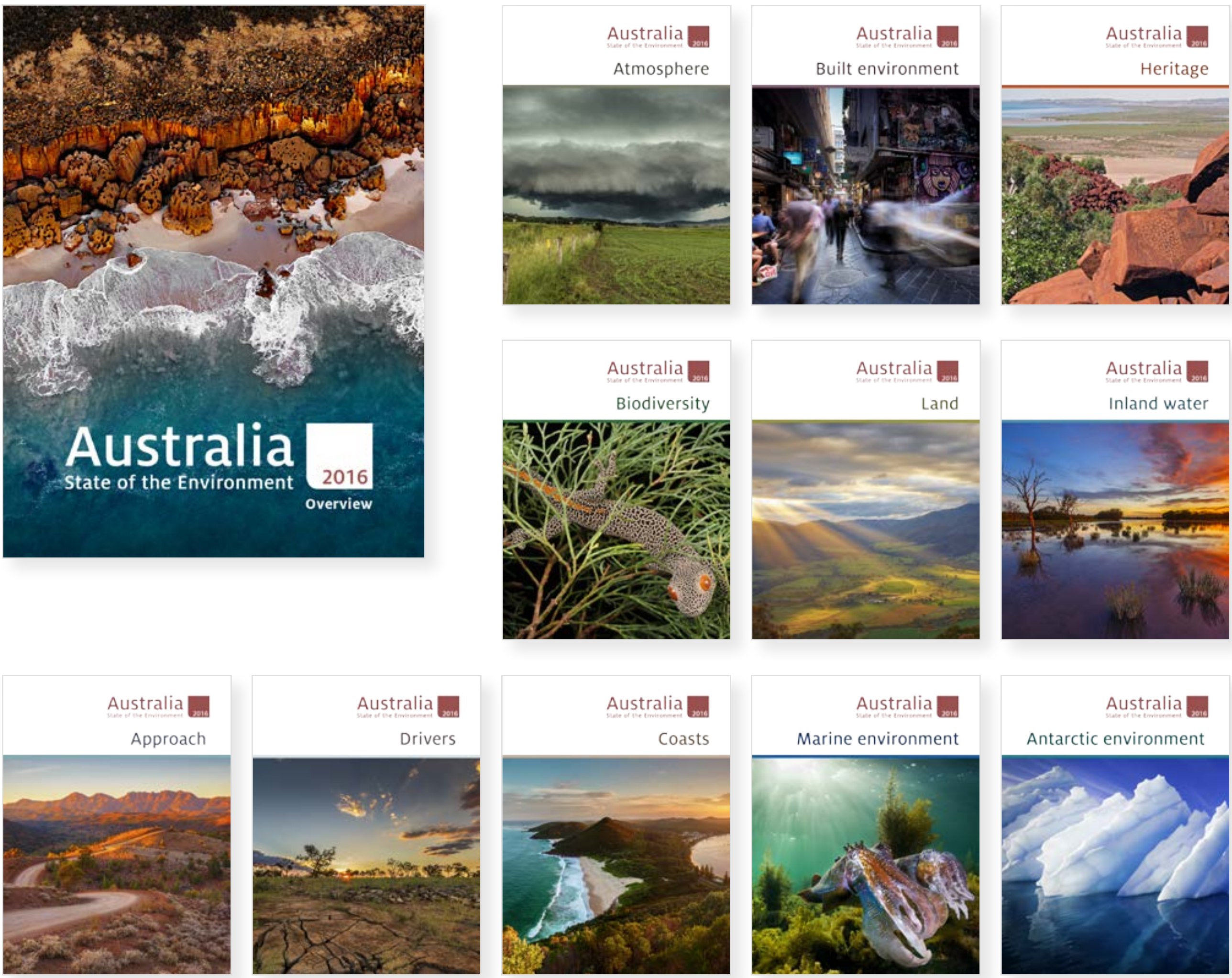

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