

Biodiversity

Australia
State of the Environment
2021

Ngala wardan windja koorl dabakan dwankaninwongka doorga, maar koorl kwenda kooriumba, gnuraren dandanginy wannang, kurrak ngaarning marril. Ngala baakan manya, ngaan bilya yinbee maambakoort gnari.

We the Wadandi People move slowly, listening to the talk of the wind, the movement of bandicoots through boronia, the rustle of Western ringtail possums in peppies, the chatter of red-tailed black cockatoos eating marri. We treat mosquito bites with bracken fern, feast on freshwater mussels and ocean salmon.

Nitja ngundabut, ngala kalleepgur nalamoort, ngala koort, ngala boodjarra.

This is life, our family's home, our heart, our Country.

Wadandi Nation

– Dr Wayne Web, Wadandi Pibulmun Yunungjarlu Elder

Australia
State of the Environment 2021

Biodiversity

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The authors acknowledge the Traditional Owners of Country throughout Australia and their continuing connection to land, sea and community. We pay our respects to them and their cultures, and to their Elders both past and present.

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Key findings

Biodiversity is essential to human survival, wellbeing and economic prosperity

In the past 10–15 years, since the Millennium Ecosystem Assessment, great progress has been made in our understanding of the importance of biodiversity and ecosystems to the quality of life of every person. Australians believe it is the responsibility of the current generation to leave nature healthy for future generations (Roy Morgan Research 2018).

Our biodiversity is declining, and the number of threatened species is increasing

Our understanding of the state and trend of terrestrial and marine threatened species in Australia has increased significantly since 2016, including our understanding of knowledge gaps. However, biodiversity overall is monitored very poorly in Australia, and we cannot assess the state and trend of most species with any confidence.

Most indicators of the state and trend of plants and animals show decline, and the number of terrestrial and marine threatened species has risen. We can expect further extinctions of Australian species over the next 2 decades unless current management effort and investment are substantially increased. Conservation actions are linked to reduced rates of decline for threatened Australian plants, mammals and birds, but they have not been sufficient to reverse declines overall.

Less investment and attention have been given to understanding the state and trend of threatened ecological communities than to threatened species, and improvements in the recovery of these communities is difficult to assess. The number of threatened ecological communities listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) continues to rise.

Climate change, habitat loss and degradation, and invasive species are the key threats to Australia's biodiversity

Many of the pressures on biodiversity in Australia have increased in intensity in the past 5 years. Habitat loss and degradation and invasive species result in persistent and sometimes irreversible impacts on biodiversity across almost all areas of Australia. Many Australian ecosystems are experiencing cumulative and compounding pressures, leading to ecosystem collapse characterised by loss of key defining features and functions.

Climate change and extreme weather events are becoming increasingly important as direct drivers of changes in biodiversity. Australian ecosystems and associated species are expected to continue to change substantially in response. Following the 2019–20 bushfire season, many species and ecosystems require rapid recovery interventions, mitigation of ongoing threats, and reassessment of their status.

Protected areas, recovery efforts and better management of pressures can help to secure our most threatened species

The extent and representativeness of the protected area system has increased through the addition of Indigenous Protected Areas. However, many threatened species and ecosystems still do not meet minimum targets in protected areas.

Indigenous rights, knowledge and values are increasingly recognised as central features of conservation management, but much more work is needed to align key legislation and policies with the aspirations of Traditional Owners for managing their land and sea Country.

Australia's key national legislation for protecting threatened species and communities, the EPBC Act, is not effective in delivering improved outcomes for biodiversity, or in arresting biodiversity declines, and does not facilitate effective management of pressures or restoration of the environment.

Recovery efforts have been successful in some cases, with threatened species persisting or increasing in abundance. Ex situ conservation and translocations are rescuing some species from extinction or providing insurance against extinction in the wild. Predator-free refuges and safe havens have been crucial in securing populations of some of our most threatened mammal species.

Outlook and impacts

Outlook

In 2019, the *Global assessment report on biodiversity and ecosystems* (IPBES 2019) assessed the status and trends of the natural world, the social implications of these trends, and their direct and indirect causes. It is the first global assessment of biodiversity and ecosystems to integrate a range of knowledge sources, and to systematically consider the contributions of Indigenous and local knowledge and practices. The key findings of the assessment were that:

- nature and its vital contributions to people, which together embody biodiversity and ecosystem functions and services, are deteriorating worldwide
- direct and indirect drivers of change have accelerated during the past 50 years
- international societal and environmental goals for conserving and sustainably using nature, such as those embedded in the Aichi Biodiversity Targets and the 2030 Agenda for Sustainable Development, cannot be met by current trajectories, and goals for 2030 and beyond may only be achieved through transformative changes across economic, social, political and technological domains
- nature can be conserved, restored and used sustainably while other global societal goals are simultaneously met through urgent and concerted efforts fostering transformative change.

The report states that, except in scenarios that include transformative change, negative trends in nature, in ecosystem functions and in many of nature's contributions to people are projected to continue to 2050 and beyond.

For the last few centuries, the intensive use and extraction of resources from land, fresh water and oceans has dominated the loss of biodiversity and the deterioration of ecosystems globally (IPBES 2019). Now, climate change is increasing in importance as a direct and indirect driver of biodiversity loss (Arneth et al. 2020).

Pressures on Australian biodiversity have not improved since the 2016 state of the environment report, and outcomes for species and ecosystems are generally poor. Our inability to adequately manage pressures will continue to result in species extinctions and deteriorating ecosystem conditions unless current management approaches and investments are substantially improved.

Multiple pressures are interacting to amplify threats to biodiversity, and abrupt changes in ecological systems are occurring. In particular, climate change and associated extreme events, compounded by other pressures, have had a major impact on biodiversity over the past 5 years, with consequences likely to be evident for many years to come. Many species and ecosystems will require their status to be assessed or reassessed in the coming years, and urgent recovery actions will be needed to avert extinction.

We are increasingly relying on measures of last resort for preventing species extinction and conserving ecosystems, including ex situ conservation, translocations, and the creation of safe havens on islands and in fenced areas. Their importance in averting extinctions in the future will only increase in the face of increasing pressures, particularly from introduced predators. Although the

methodologies and technologies for these measures are improving, they are still largely experimental and carry a high degree of risk. The growing dependency on biodiversity offsets to protect matters of national environmental significance from the impacts of development is also concerning, given the lack of demonstrated successful outcomes and inadequate oversight.

COVID-19 and biodiversity

We write this report in the midst of the COVID-19 pandemic. Already some scientists are considering the impacts of the pandemic on biodiversity conservation. For many months, although Australia has been affected relatively lightly compared with many other countries, conservation activities and management actions have been halted or greatly scaled down, biodiversity research projects and data collection have been stalled, and teaching and communication have moved online (Corlett et al. 2020). The longer-term implications of these reduced activities will take some time to manifest and are hard to calculate. Some scientists and practitioners are already expressing concern about austerity measures that are likely to be introduced once COVID-19 is under control, which may further reduce investment in conservation agencies and conservation research (Evans et al. 2020). On the other hand, some evidence suggests a lessening of human pressures on biodiversity and ecosystems as travel and tourism continue to be restricted.

Beyond these direct and immediate consequences, scientists have also begun to consider the future for emerging infectious diseases and their links with biodiversity loss, human activities and issues of sustainability. The Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services (IPBES) Workshop on Biodiversity and Pandemics (Daszak et al. 2020) describes how pandemics have their origins in diverse microbes carried by animals, but that their emergence is entirely driven by human activities, which disrupt natural interactions between species and their microbes, and increased contact among native animals, livestock, people and their pathogens. The report from the workshop embraces the need for transformative change to reduce the frequency and impact of future pandemics, including by reducing land-use change and restoring ecosystems, preventing unsustainable consumption and overuse of biodiversity, and bridging fundamental knowledge gaps on the linkages between biodiversity, anthropogenic environmental changes and pandemic risk.

Framing the value of biodiversity

Nature underpins quality of life by providing basic life support for humanity, as well as material goods and spiritual inspiration (IPBES 2019). Globally, nearly half of the human population is directly dependent on natural resources for its livelihood, and many of the most vulnerable people depend directly on biodiversity to fulfil their daily subsistence needs (SCBD n.d.).

A major challenge today and into the future is to maintain or enhance beneficial contributions of nature to quality of life and wellbeing for all people. This is among the key motivations of the IPBES, a joint global effort by governments, academia and communities to assess and promote knowledge of Earth's biodiversity and ecosystems, and their contribution to human societies, to inform policy (Díaz et al. 2018) (see case study: Ecosystem accounting in a protected area in the Land chapter).

The ecosystem services framework, which recognises the social, ecological and economic

benefits that people derive from nature, has become a cornerstone of conservation. In 2017, the IPBES introduced the term 'nature's contributions to people' (NCP), which builds on the ecosystem services framework and embraces multiple knowledge systems. In the NCP conceptual framework, culture permeates through and across all types of ecosystem services.

The NCP framework has been useful in communicating the cultural, economic and ecological value of Indigenous Protected Areas (IPAs) to Indigenous and non-Indigenous stakeholders in Western Australia. For example, the 2,005 square kilometre Yawuru Indigenous Protected Area covers terrestrial and marine environments around Broome. The IPA encompasses Ramsar wetlands, is home to migrating shorebirds, and harbours threatened and migratory species (e.g. bilbies, dugongs) and fish nurseries, as well as covering important Indigenous heritage sites. NCP were found to be prevalent across all targets in the IPA – Healthy Country Plan: 68 of the 144 IPA management objectives related directly to ecosystem goods and services (Newman et al. 2019). A process of identifying, measuring and assigning values to NCP was demonstrated, which could be applied to other protected areas.

Impacts

Impacts on the environment

The 2021 edition of the World Economic Forum's *Global risks report* (World Economic Forum 2021) identifies critical global risks. Four of the top 5 global risks are related to the environment: extreme weather, climate action failure, human environmental damage, and biodiversity loss and ecosystem collapse. Global risks are defined as uncertain events or conditions that, if they occur, can cause significant negative impact for several countries or industries within the next 10 years.

The global risk of biodiversity loss and ecosystem collapse is described as 'irreversible consequences for the environment, humankind, and economic activity, and a permanent destruction of natural capital, as a result of species extinction and/or reduction' (World Economic Forum 2021).

The report describes environmental degradation as an existential threat to humanity, with risks intersecting with societal fractures to bring about severe consequences. In addition, the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services considers that current negative trends in biodiversity and ecosystems will undermine progress towards achieving 80% (35 out of 44) of the assessed targets of the Sustainable Development Goals related to poverty, hunger, health, water, cities, climate, oceans and land (IPBES 2019).

Many of the trends we see in Australia for biodiversity are consistent with those highlighted globally. In June 2021, more than 1,900 Australian species and ecological communities were known to be threatened and at risk of extinction. Over the past 2 centuries, Australia has lost more mammal species than any other continent, and continues to have one of the highest rates of species decline among countries in the Organisation for Economic Co-operation and Development. So far, 100 Australian species are listed as Extinct or Extinct in the Wild under Australian national, state or territory legislation, and under the International Union for the Conservation of Nature: 38 vascular plants, 34 mammals, 10 invertebrates, 9 birds, 4 frogs, 3 reptiles, 1 fish and 1 protist (a single-celled organism) (Woinarski et al. 2019). The true number of extinctions is likely to be significantly higher, since many species are poorly surveyed or poorly described, or both.

Impacts on human health and wellbeing

The links between biodiversity and human health and wellbeing are becoming increasingly obvious. For example, contact with nature is associated with positive mental health benefits, and can promote physical activity and contribute to overall wellbeing. Biodiversity and green spaces in urban settings are linked to stress reduction and mood improvement (Cox et al. 2017, Schebella et al. 2019), increasing respiratory health (Liddicoat et al. 2018), lower rates of depression and high blood pressure (Shanahan et al. 2016), and overall improvements in human wellbeing (Taylor et al. 2018b). There is strong evidence that participation in Caring for Country activities by Indigenous people in Australia, as well as greater participation in cultural activities, language knowledge and belief that the land was looked after, are associated with improved health and wellbeing outcomes (Schultz et al. 2019, Larson et al. 2020) (see the Indigenous chapter).

We have looked to biodiversity for medicines for tens of thousands of years. Drug discovery from wild species will continue to be critical for most aspects of health care, wellness and disease prevention (Neergheen-Bhujun et al. 2017). Loss of biodiversity and changes in land use and food production practices are considered leading drivers of disease emergence and transmission in humans (WHO & SCBD 2015). Common land-use changes related to disease transmission include agricultural development, urbanisation, deforestation, and forest and habitat fragmentation.

Environment

Flora and fauna

Our continent supports nearly 600,000 native species, and a very high proportion of these are found nowhere else in the world (Cassis et al. 2017). For example, about 85% of Australia's plant species are endemic, and Australia is home to half of the world's marsupial species.

Taxonomists are continually discovering and describing new Australian species. In 2020, 763 new species were named, including 297 insects, 166 fungi, 77 plants, 57 spiders and 21 new vertebrates (Taxonomy Australia 2020). In some groups, there are many more species that are unknown than are known.

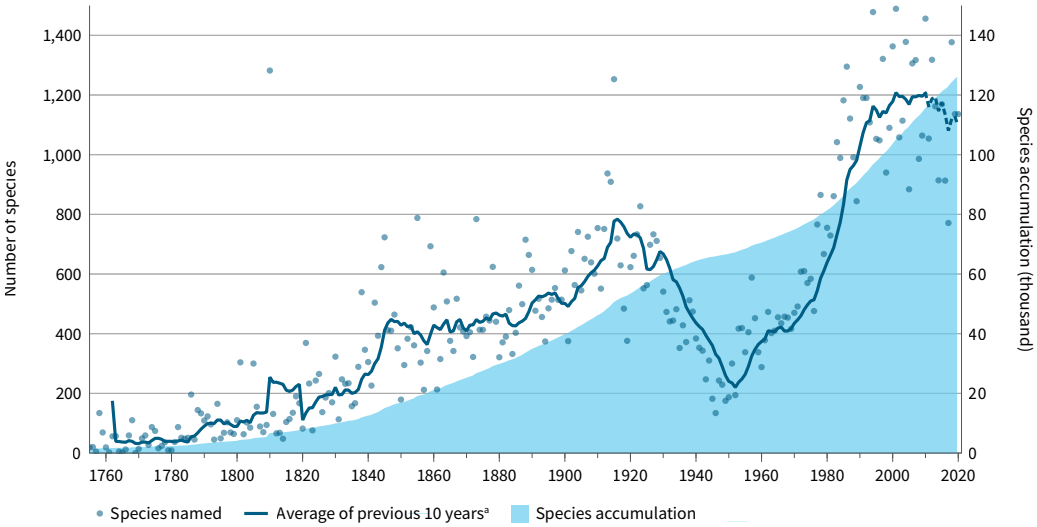
Case study Biodiversity knowledge and data discovery – 'What we do not know, we cannot protect'

Dr Kevin Thiele, Taxonomy Australia

The discovery, naming and documentation of Australian species by western scientists has been ongoing for about 3 centuries. A high point in the number of new species named each year was reached just before World War 1, followed by a decline until recovery of Australia's biodiversity science effort after the end of World War 2 (Figure 1). The establishment of the Australian Biological Resources Study in 1972 saw an increase in rate until a plateau was reached in the 1990s. Since 2000, the annual rate of naming of new species has declined, likely due to a reduction in investment in taxonomy in real terms.

Current knowledge of Australia's biodiversity is very incomplete. The best estimate is that 70% (or 420,000) of all Australian species of plants, animals, fungi and other organisms have yet to be discovered, documented, named and classified (Cassis et al. 2017). At the current rate, it will take more than 4 centuries to document Australia's biodiversity.

Of course, some groups of organisms are better documented than others. In general, species that are prominently visible (e.g. vertebrates, flowering plants) are well known, and groups that are rarely noticed (e.g. most invertebrates, fungi) are poorly known.



a Dotted section of line (after 2010) indicates extrapolated values.

Figure 1 Annual rate of naming, and the accumulation of new species of animals, plants, fungi and protists since 1753

But noticeability is not a good surrogate for ecological, economic or environmental importance. Fungi and insects, for example, are very poorly documented (less than 5–10% of Australia's species are likely to have been named) yet they provide critical ecological functions and ecosystem services, sometimes pose risks to natural and agricultural systems, and may provide important opportunities for industry and the economy.

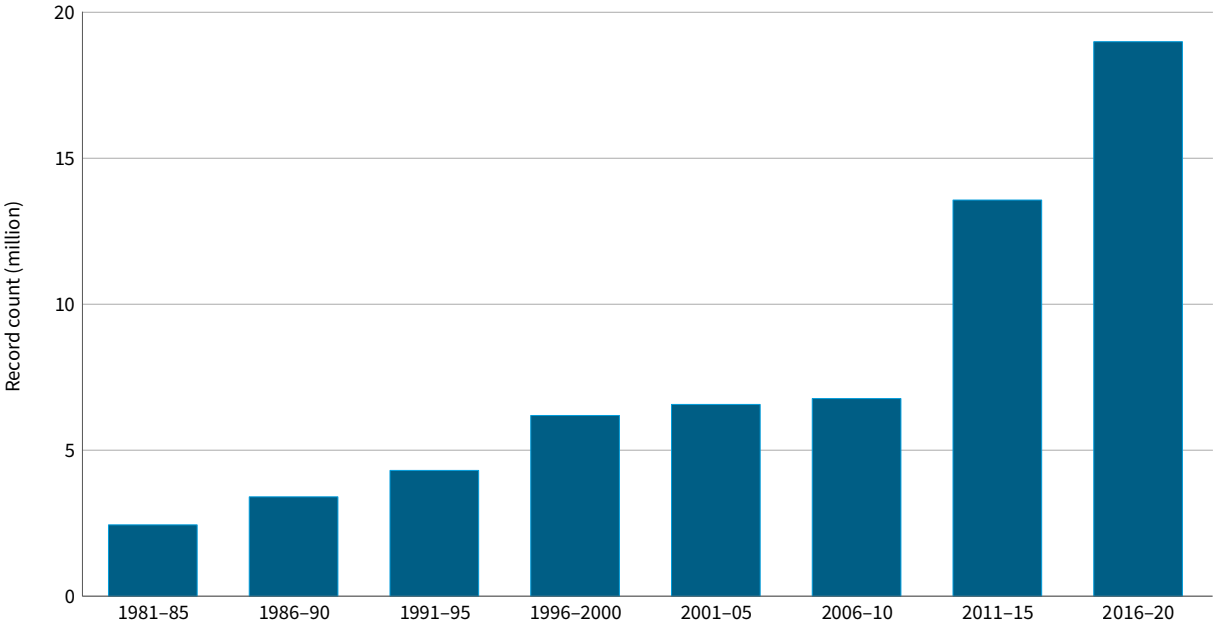
This substantial gap in our knowledge of Australia's species hinders effective management, conservation and the sustainable use of Australia's biodiversity. Although unnamed species can at times be conserved effectively through conservation of habitats, monitoring of conservation effectiveness is severely limited with so many species effectively invisible. Similarly, many unnamed species are likely to be rare and threatened, and many of these will become extinct before they can be recognised.

New technologies, including high-throughput DNA sequencing and machine learning, mean that a substantial acceleration in the discovery, naming and documentation of Australia's biodiversity is achievable. The Australian Academy of Science has proposed an ambitious mission to discover and document all remaining Australian species in a generation. A cost–benefit analysis has shown that the returns to society of achieving this goal could be 35 times greater than the investment, with benefits for biodiversity conservation as well as for biosecurity, biodiscovery, and agricultural research and development (Deloitte Access Economics 2020).

In 2010, the Bush Blitz program was established to investigate and document Australian species. Bush Blitz has discovered more than 1,735 new species; extended the known range of 250 species; and generated more than 500 records of species listed as Threatened, Vulnerable or Endangered, and more than 1,200 records of pest species. The program has also recorded more than 25,000 occurrences of plants and animals, which can be accessed by land managers, scientists and the general public using online tools such as the Atlas of Living Australia (ALA). ALA is a collaborative, digital, open infrastructure that is mobilising biodiversity data for use by research, industry and government. Its growing database holds 85 million records of more than 111,000 species from across Australia (Figures 2 and 3).

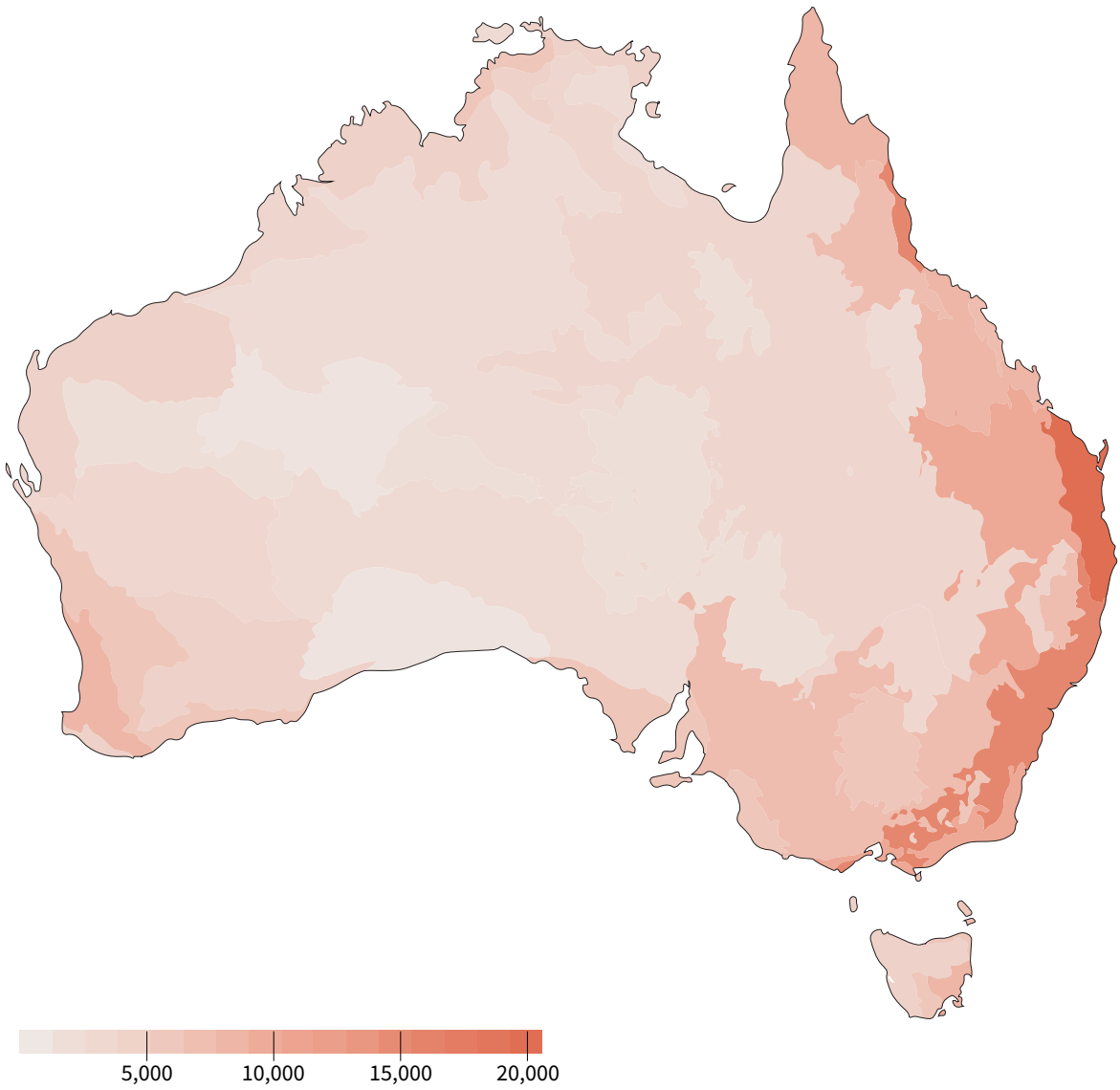
Indigenous culturally significant species

Indigenous Australians attribute tremendous spiritual, cultural and symbolic value to many animals, plants and ecological communities. Species can be spiritually or culturally important; they may be totems, provide a source of food or medicine, be used as materials for tools or implements to undertake customary activities, be indicators of health of Country, or be used in ceremonial activities. Culturally significant species feature prominently in Indigenous knowledge, including language, ceremonies, lore, identity and narratives, and are considered cultural icons (Gore-Birch et al. 2020).



ALA = Atlas of Living Australia

Figure 2 Growth in number of new records for all species held by the ALA, 1981–2020



ALA = Atlas of Living Australia; IBRA = Interim Biogeographic Regionalisation for Australia

Figure 3 Number of species recorded from each IBRA region held in the ALA, 2020

Examples of culturally significant species are highlighted throughout this chapter. The Indigenous chapter also describes Indigenous people's connection to Country through plant and animal totems, traditional food sources, use and knowledge of native plants, and through knowledge, languages and practices (see the Indigenous chapter).

Threatened species

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), Australia identifies and lists threatened species. States and territories also maintain listings of threatened species.

The number and trend of these lists can be used as a simple indication of the health of Australia's biodiversity.

In June 2021, 533 animal and 1,385 plant species were listed under the EPBC Act; 53% of the listed species are Endangered or Critically Endangered (Table 1). The number of threatened species listed under the EPBC Act has risen for almost all taxa over the past 5 years (Figures 4–6). The list includes 105 species that are Extinct or Extinct in the Wild (June 2021).

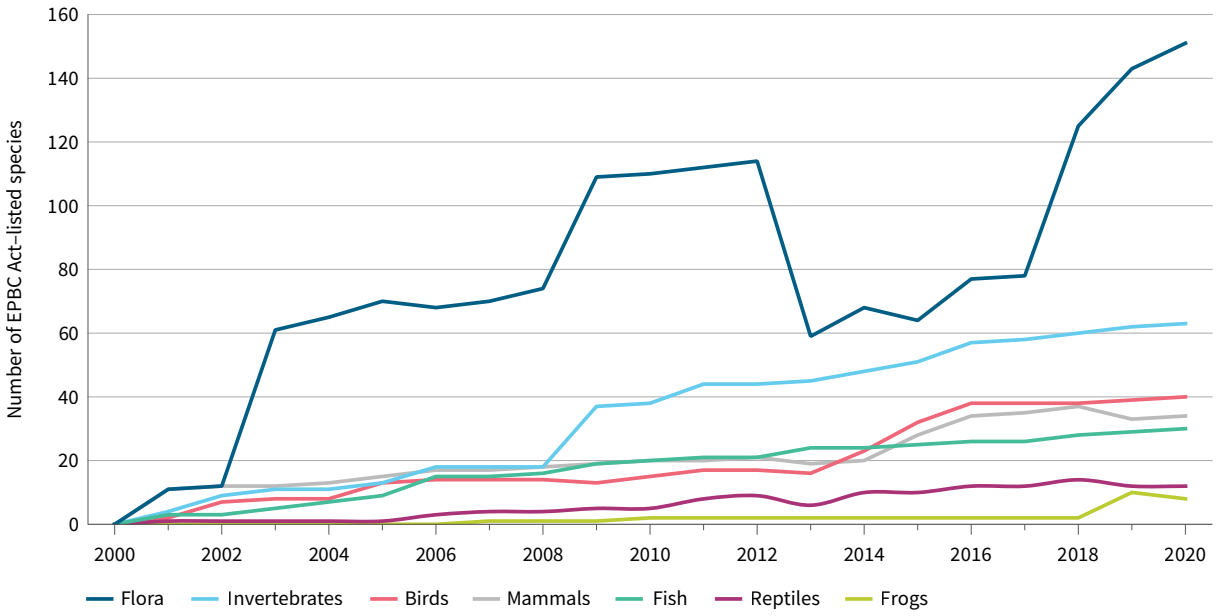
An April 2019 collation of global, national, and state and territory threatened species lists 100 Australian endemic species (38 vascular plants, 34 mammals, 10 invertebrates, 9 birds, 4 frogs, 3 reptiles, 1 fish and 1 protist) that are validly listed as Extinct or Extinct in the Wild since European settlement in 1788 (Woinarski et al. 2019), representing about 6–10% of the world's extinctions (post-1500s). This compilation highlighted deficiencies in listings for some taxa, especially invertebrates. It also showed that the number of formally listed extinct species is likely to be a substantial underestimate of actual extinctions, partly because many likely extinctions are not recognised in formal lists and others are likely to have occurred without being noticed.

Increases and decreases in threatened species listing categories sometimes reflect uplistings (where species are transferred to a higher threat category within the list) and downlistings (where species are transferred to a lower threat category). These mainly occur because more information has become available to support assessment about a

Table 1 Species listed and under assessment for listing under the EPBC Act, as at 1 January 2021

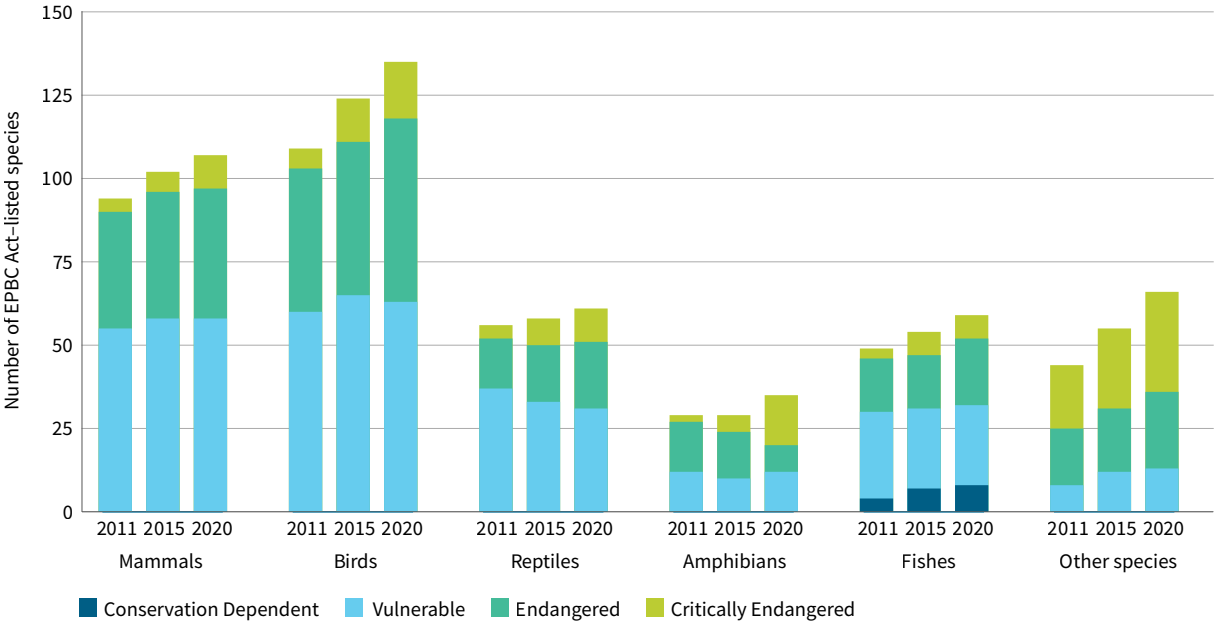
Organism	Extinct	Extinct in the Wild	Critically Endangered	Endangered	Vulnerable	Conservation Dependent	Total
Birds	22	0	17	55	63	0	157
Mammals	39	0	9	41	57	0	146
Reptiles	1	0	9	20	31	0	61
Fish	0	1	8	20	25	8	62
Frogs	4	0	15	9	12	0	40
Other animals	1	0	30	23	13	0	67
All animals	67	1	88	168	201	8	533
Plants	37	0	206	556	586	0	1,385
All threatened species	104[a]	1	294	724	787	8[a]	1,918

EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*
a Category is not a matter of national environmental significance.
Note: Includes all terrestrial, freshwater and marine species.



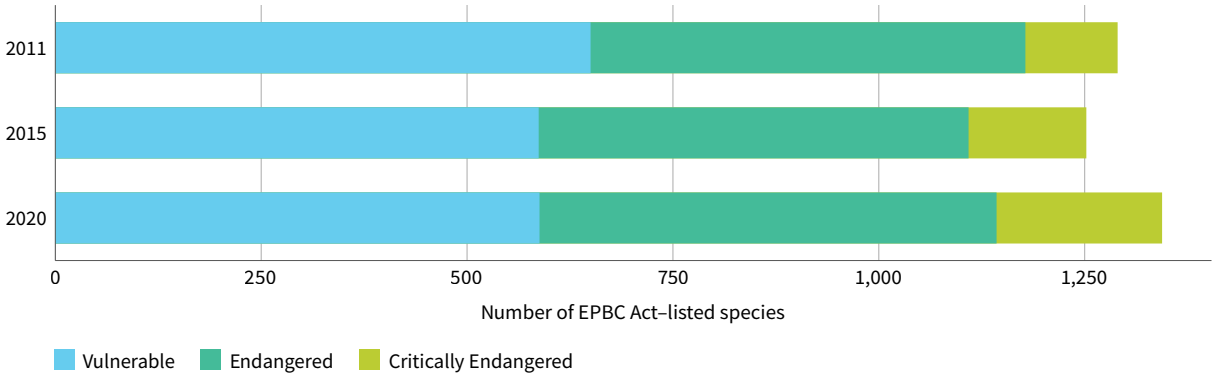
EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*
Note: Plotted values are differences from the number of species listed in 2000.

Figure 4 Number of species listed under the EPBC Act, 2000–20



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

Figure 5 Number of terrestrial and marine animal species listed under each threat category in the EPBC Act, 2011, 2015 and 2020



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

Figure 6 Number of plant species listed under each threat category in the EPBC Act, 2011, 2015 and 2020

species' vulnerability to extinction, or the application of the listing criteria has been refined, rather than true changes in status, so caution should be used in interpreting trends. A large number of plants were delisted in 2013, mainly because of changes in taxonomic understanding (Figures 4–6). The rate of change in the threatened species list is also a function of collaborations between jurisdictions on the listing process (see IUCN Red List categories).

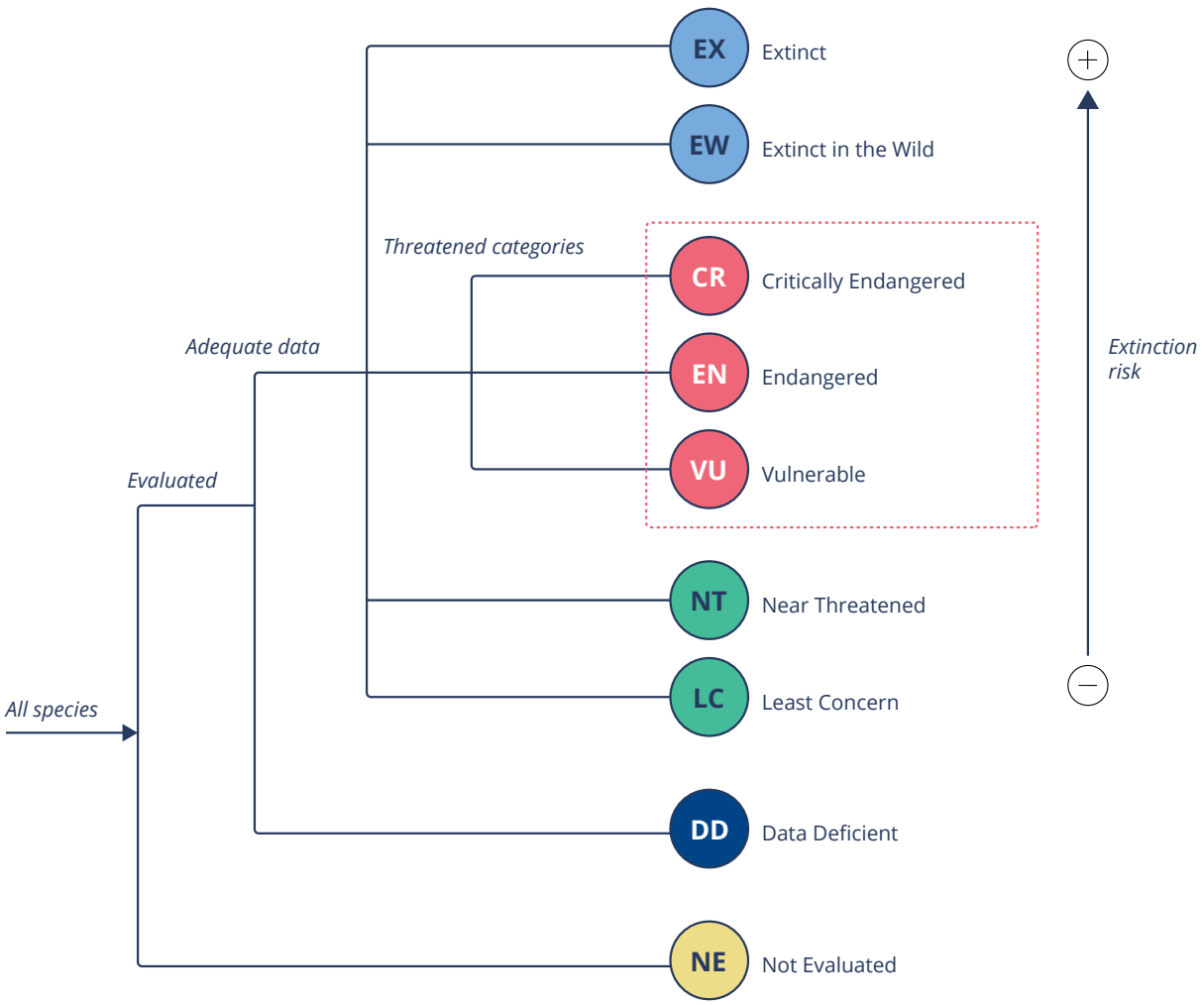
IUCN Red List categories

The global standard for assessing extinction risk is the International Union for the Conservation of Nature (IUCN) Red List criteria. Under this system, species are assigned a ranked threat category (Figure 7). Australian species have been assessed against IUCN Red List criteria several times in the past 5 years.

Since 2015, the Australian, state and territory governments have collaborated through an intergovernmental memorandum of understanding to assess and list threatened species using a listing process known as the Common Assessment Method, which is based on the IUCN Red List of Threatened Species. Species are assessed at a national level by one jurisdiction and the assessment is shared with other jurisdictions where the species occurs, and the Australian Government, and used to make consistent listing decisions. To December 2020, assessments for 125 species have been prepared by the states and territories and provided to the Australian Government to make listing decisions under the EPBC Act.

As each jurisdiction makes administrative and legislative changes to adopt the method, threatened species lists are becoming more aligned. This alignment enables IUCN assessments to guide the prioritisation of species for statutory assessment and listing. Some amendments have been made to suit the Australian context. The method does not recognise the Least Concern or Near Threatened IUCN categories. The method also includes a Conservation Dependent category for fish species that are the focus of a plan of management in force under law. This provides for management actions to halt decline and support recovery so that the chances of long-term survival in nature are maximised.

Collaboration through the method has resulted in improved efficiency and consistency in the listing process nationally. It has also initiated an increase in the rate of change in the threatened species list.



IUCN = International Union for the Conservation of Nature
Extinct: No reasonable doubt that the last individual of a species has died.
Extinct in the Wild: The species is known to survive only in cultivation, in captivity or as a naturalised population well outside the former range.
Critically Endangered: When the best available evidence indicates that a species is facing an extremely high risk of extinction in the wild.
Endangered: Best available evidence suggests that a species is facing a very high risk of extinction in the wild.
Vulnerable: When the best available evidence suggests that a species is facing a high risk of extinction in the wild.
Near Threatened: When a species does not qualify for any of the above categories but is likely to qualify in the near future.
Least Concern: When a species does not qualify in any of the above categories. Widespread and abundant species are included in this category.
Data Deficient: When there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.
Not Evaluated: A species is not evaluated when it has not yet been evaluated against the Red List criteria.

Figure 7 IUCN Red List categories

Case study A threatened species index for Australia

Reporting on the state and trend of threatened species in past state of the environment reports has relied primarily on simple changes in the number and status of threatened species and communities. This has been largely because there are very few national datasets that measure actual trends in the abundance and distribution of threatened species, or the extent and condition of threatened ecological communities. In addition, there is no system to capture reporting of this type in Australia, even where adequate data and knowledge collection do exist (Latch 2018a).

The Australian Government's National Environmental Science Program (NESP) Threatened Species Recovery Hub has developed a national Threatened Species Index by aggregating datasets from a range of programs monitoring population trends.

The NESP Threatened Mammal Index, Threatened Bird Index and Threatened Plant Index provide measures of population trends across a subset of Australia's best monitored threatened species.

The index shows the average change in population size compared with a base year, which is assigned a score of 1.0. A score below 1.0 reflects a decrease in population size compared with the base year. For example, a score of 0.5 indicates an average 50% reduction in population size. Grey shading around the trend line shows the range of trends for the individual species that make up the overall multispecies score. The shading is created by randomly sampling species trends from all possible trends in the dataset 100 times and dropping the 5 trends that are furthest from the average, resulting in a 95% 'confidence interval'.

Plants

Approximately 10% of the world's plants occur in Australia, equating to approximately 21,000 species. Many of these are endemic (Table 2). Two areas in particular, south-western Australia and the forests of eastern Australia, are considered global biodiversity hotspots due to their large concentration of endemic plant species, including many of Australia's threatened species, combined with an exceptional loss of habitat (CEPF 2021).

Across Australia, about 4,000 plant species were, and many still are, used by Indigenous people as food and medicine, equating to about 20% of named Australian vascular plants (Isaacs 1987 in Ens et al. 2017) (see the Indigenous chapter). Evidence from Madjedbebe rock-shelter in northern Australia, in the form of charred plant food remains dated to between 65,000 and 53,000 years ago, indicates that Australia's earliest known human population exploited a range of plant foods, including those requiring processing (Florin et al. 2020). Many more plant species were used as materials for tools, shelter and ceremonial items.

Table 2 State and territory native, endemic and threatened vascular plants

State or territory	Total native species	Endemic[a]	Threatened (EX, EW, CR, EN, VU)
ACT	1,088[b]	6	13[c]
NSW	Not available	1,320	671[d]
NT	4,418[e]	735[e]	81[f]
Qld	8,639[g]	3,629	775[h]
SA	3,503[i]	488	385[j]
Tas	1,920[k]	533[k]	458[lm]
Vic	Not available	408	1,243[m]
WA	11,606[n]	8,952	444[o]

ACT = Australian Capital Territory; CR = Critically Endangered; EN = Endangered; EW = Extinct in the Wild; EX = Extinct; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; VU = Vulnerable; WA = Western Australia

a Numbers are from Gallagher (2020b), unless otherwise noted.
b See Lepschi et al. (2019)
c See ACT Scientific Committee (2020)
d See NSW Threatened Species Scientific Committee (2020)
e See Cowie et al. (2017)
f See FloraNT Northern Territory Flora Online (2015); the number was correct as at October 2021.
g See Brown & Bostock (2020)
h See DES (2021)
i See eFloraSA Electronic Flora of South Australia (2021)
j See eFloraSA Electronic Flora of South Australia (2021); note this listing is for 'SA schedule 7: Endangered species (including Critically Endangered and Extinct species)' and 'Schedule 8: Vulnerable species'. It does not include 'SA Schedule 9: Rare species'. The Rare category criteria are consistent with current IUCN definitions for the Near Threatened category, and encompass species in decline and those that naturally have a limited presence.
k See de Salas & Baker (2019)
l See NRE (2021)
m Number was correct as at October 2021; see DELWP (2021).
n See Florabase (2021); the number was correct as at June 2021.
o See Threatened Species Scientific Committee (2018)

A wide diversity of plants are sources of edible seeds for Indigenous Australians; the seeds of more than 220 native plant species were traditionally ground for food (Mildwaters & Clarkson 2020). The effects that Indigenous peoples had on the distribution of species by transporting plants from their native habitats, and propagating seeds and other vegetative material is becoming increasingly apparent to the scientific community (Silcock 2018, Lullfitz et al. 2020). Recent genetic studies of some Indigenous food plants have continued to reveal distribution patterns best explained by seed being moved by humans, including boab (*Adansonia gregorii*) in the Kimberley (Rangan et al. 2015) and black bean (*Castanospermum australe*) in northern New South Wales (Rossetto et al. 2017).

Plants comprise 73% of Australia's national threatened species list, with 1,385 listed species, including 37 extinct species (Table 1). A large number of plant species are listed as Extinct, Extinct in the Wild, Critically Endangered, Endangered or Vulnerable under state and territory legislation, and many are not listed nationally. For example, in Western Australia, 9 species are listed as Extinct nationally, while the state recognises 15 species as being Extinct under the *Biodiversity Conservation Act 2016*. Similar disparities occur for Critically Endangered, Endangered and Vulnerable species, with 61, 225 and 105 species listed nationally and 160, 140 and 129 listed by Western Australia, respectively. Such discrepancies will be tempered with use of the Common Assessment Method (see IUCN Red List categories).

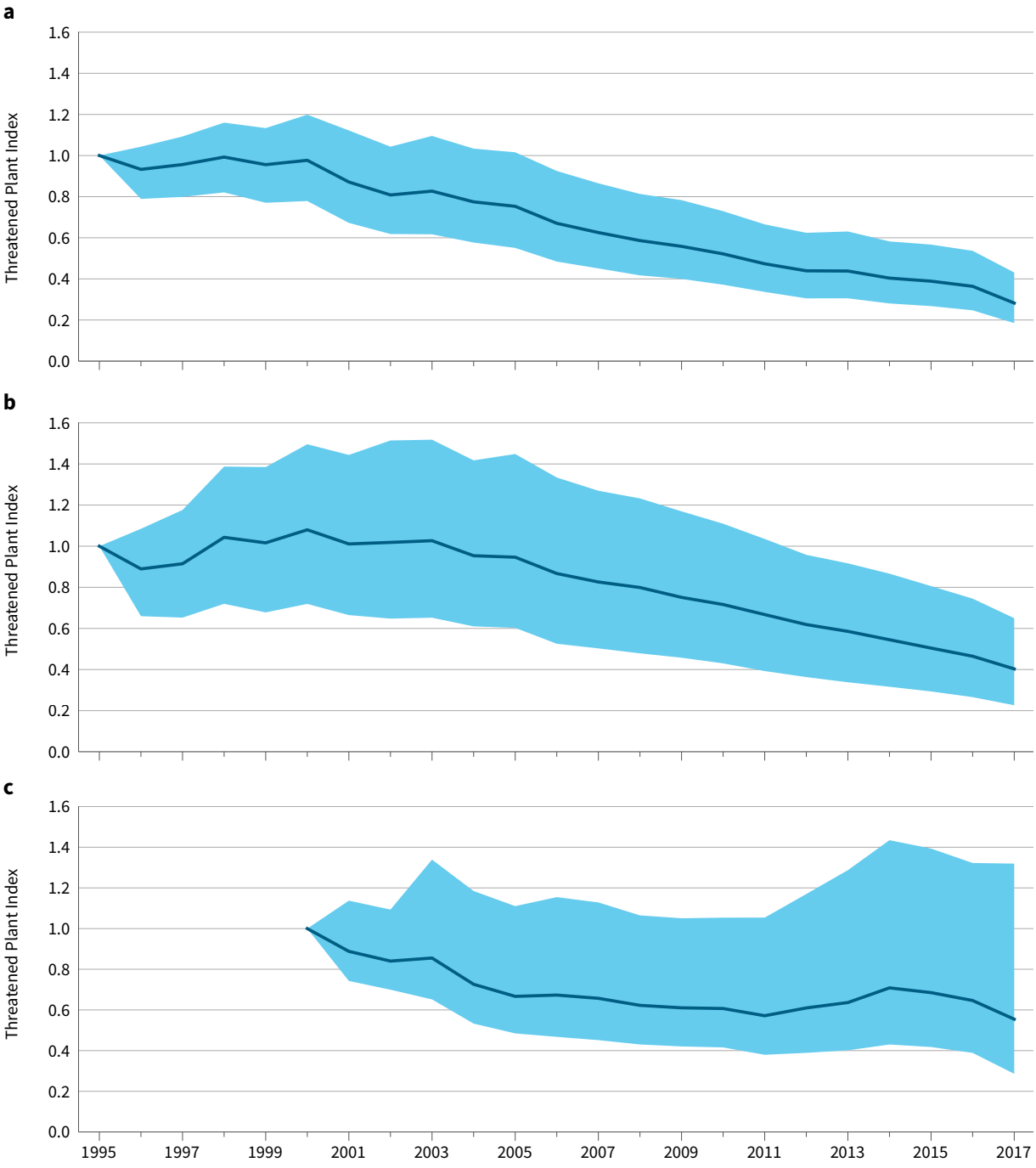
Overall, the major pressure causing population declines for threatened plant species is habitat destruction. This can leave fragmented populations in small remnants that then become vulnerable to other pressures (e.g. invasive weeds) and degradation. Thus, declining species and those at most risk of extinction are concentrated in highly modified agricultural and urban landscapes. Changes in fire regimes, either too frequent or too infrequent, are also a significant pressure for many species (see Changing fire regimes).

Trends and distribution of threatened plants

The overall Threatened Plant Index in 2017 was 0.28, indicating that, on average, the size of threatened plant populations has decreased by 72% between 1995 and 2017 (Figure 8). The index shows that management actions, such as weed or pest control, result in lower rates of decline. Populations of species that have been translocated have the slowest rates of decline.

Recently, 1,135 plant species in Australia were assessed to determine those most at risk of extinction (Silcock & Fensham 2018):

- 418 taxa were assessed as having a continuing decline and 296 species were determined to be at risk of extinction under current management regimes, including 55 at high risk of extinction.
- 12 of the 55 species determined to be at high risk of extinction are listed as Critically Endangered under the EPBC Act and 13 are not listed at all.
- 56 taxa were assessed as having no documented declines, or even as being stable or increasing, but are currently listed as Critically Endangered nationally; these are mostly narrow-ranged endemics that meet criteria for listing because of small population size, extent of occurrence or area of occupancy.
- Species predicted to be at most risk of extinction are concentrated where high areas of endemism co-occur with highly modified agricultural and urban landscapes. Very few listed or declining species are in arid and semi-arid Australia, which have been far less modified by humans (Figure 9).



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

Note: Data are primarily from monitoring sites in South Australia, Victoria and New South Wales, with a few sites in south-west Western Australia. Some plant groups such as grasses and herbs are not represented well in the data, whereas orchids are represented very well. Blue shading represents the 95% confidence interval.

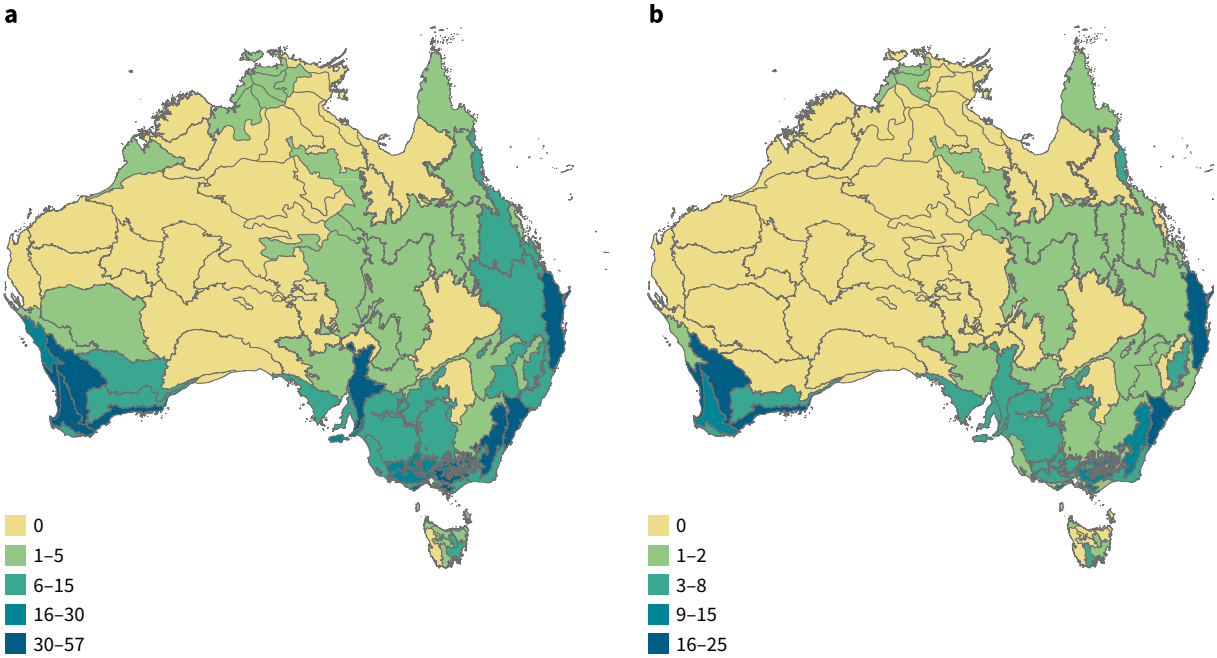
Figure 8 Threatened Plant Index for Australia (a) to 2017, with baseline from 1995 for 112 threatened plant species representing about 8% of Australia's EPBC Act–listed plants; (b) for sites where some management has occurred (64 species); (c) where translocation has occurred since 2000 (11 species)

Some plants listed as threatened may be considered 'functionally extinct', having fallen below the critical number to sustain their populations in the long term. Of the 660 species listed as Critically Endangered or Endangered at a national level, 62 are known from fewer than 50 individuals, and 300 from fewer than 250 individuals. Many of these are now restricted to tiny remnants that are vulnerable to further degradation, and where maintenance of population size and growth is unlikely (Silcock et al. 2020).

Recently, the 822 eucalypt species within Australia were assessed using IUCN criteria (see IUCN Red List categories) (Fensham et al. 2020b). Overall, 193 eucalypts qualified as threatened, most (70%) because of irreversible population declines of more than 30% (Figure 10). Habitat loss due to expanding agriculture and urbanisation was identified as the most important threat to eucalypts. The most threatened species were concentrated in south-western Australia and in other areas of Australia where intensive land use has resulted in deforestation. The remaining species qualified as threatened because they had small geographic ranges with ongoing threats, mostly mining or urbanisation.

Orchids are the most threatened group of flowering plants globally. Australia is no exception, with 10% (184 species of a total of around 1,794) of Australian orchid species listed as threatened under the EPBC Act (Wraith & Pickering 2019). The major threats to orchids are similar to those for all other species: invasive species, inappropriate fire regimes, grazing, and habitat modification, including land clearing.

Orchids in the wild have added pressures of high levels of illegal collecting, and



Note: Imperilled species include those for which continuing declines are documented, suspected or projected across all populations, and the species occurs in low numbers (typically <2,500) with extinction possible in the medium term (10–100 years) OR continuing declines are documented and the species is extremely rare (known from <250 individuals and/or a single population) with high extinction risk within the next 10 years.

Source: Silcock & Fensham (2018). Republished with the permission of CSIRO Publishing, from *Australian Journal of Botany*, CSIRO (Australia) Academy of Science, 2018; permissions conveyed through Copyright Clearance Center, Inc. © CSIRO Publishing

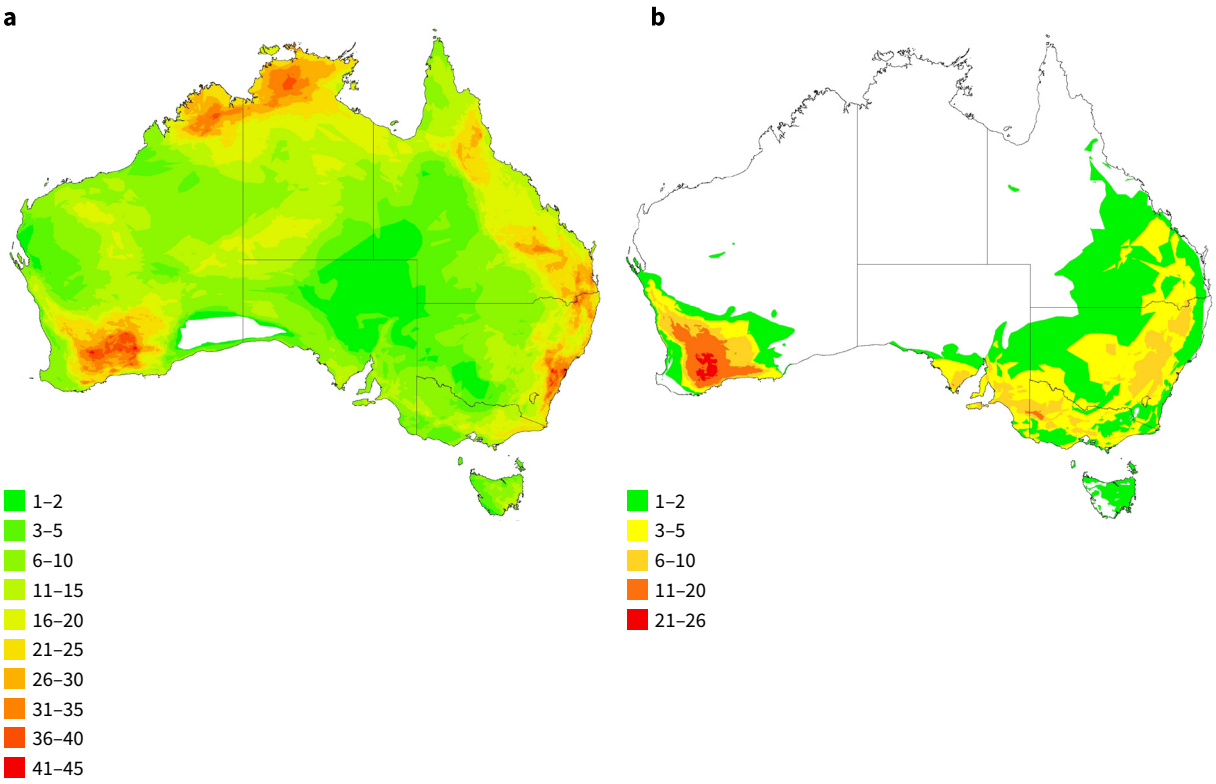
Figure 9 Numbers of (a) declining and (b) imperilled (threatened) plant species per bioregion

increasingly are the focus of specialist nature-based tourism, particularly in some protected areas. Illegal collecting, especially of epiphytes, affects around 46% of threatened species, particularly in Queensland, New South Wales and Victoria, while tourism and recreation impacts, mostly associated with trampling, affect 47% of threatened orchids (Wraith & Pickering 2019).

Plant extinctions

Plant extinctions in Australia can be difficult to verify, in part due to taxonomic uncertainty and because threatened species lists change regularly as a result of new evaluations and rediscoveries. For example, since 1984, more than 120 presumed extinct plant taxa have been rediscovered, mostly through additional field surveys; 23 taxa have been rediscovered since 2000, with 8 rediscoveries since 2010 (Silcock et al. 2020).

Fifty-one Australian plant species with sound taxonomy and unambiguous occurrence records in Australia are currently presumed extinct. Eighteen of the species are listed as Extinct under the EPBC Act and a further 14 are listed as Extinct under state legislation. However, experts consider that only 12 are probably extinct and a further 21 are possibly extinct, with the remaining 18 species possibly still occurring in Australia and requiring field surveys to assess their status (Silcock et al. 2020). Western Australia has the highest number of presumed extinct taxa (15), along with New South Wales (15) and Queensland (13). All taxa presumed extinct seem to have been rare or restricted in their historical range.



Source: Fensham et al. (2020b). Reprinted from *Biodiversity Conservation*, vol. 243, RJ Fensham, B Laffineur, TD Collingwood, E Beech, S Bell, SD Hopper, G Phillips, MC Rivers, N Walsh, M White, Rarity or decline: key concepts for the Red List of Australian eucalypts, 108455, 2020.

Figure 10 (a) Distribution of eucalypt species richness. (b) Density of threatened eucalypt species

Assessment The status of native and threatened plants

2021



Native and threatened plants are generally in a poor state and deteriorating, with increased clearing, invasive species and urban expansion among the key threats.

Related to United Nations Sustainable Development Goal targets 15.1, 15.2, 15.4, 15.5

Assessment Plants in low-density human population areas, including high-altitude areas, rangelands, northern savannas and rainforest

2021



2016



2011



Somewhat adequate confidence

Plants in low-density human population areas are impacted by extensive and persistent pressures, including competition from invasive plants, climate change and extreme events. Overall, their condition has remained poor but stable over the past 5 years; however, there are areas of very high impact, and subsequently very poor condition, due to transforming processes, including habitat conversion, extreme weather and fire events.

Assessment Plants in high-density human population areas, including urban and peri-urban areas and in intensive agricultural areas. particularly in south-east and south-west Australia



Somewhat adequate confidence

Plants in these areas are subject to ongoing, significant and extensive impacts, and persist in ecosystems with substantial loss of ecological function. Impacts such as extreme events, clearing, urban expansion, invasive plants and animals, pathogens and plant disease, and other human activities are persistent and increasing in some areas. Many threatened and at-risk plant species occur in these areas.

Assessment ratings

For assessments in the 'Environment' section

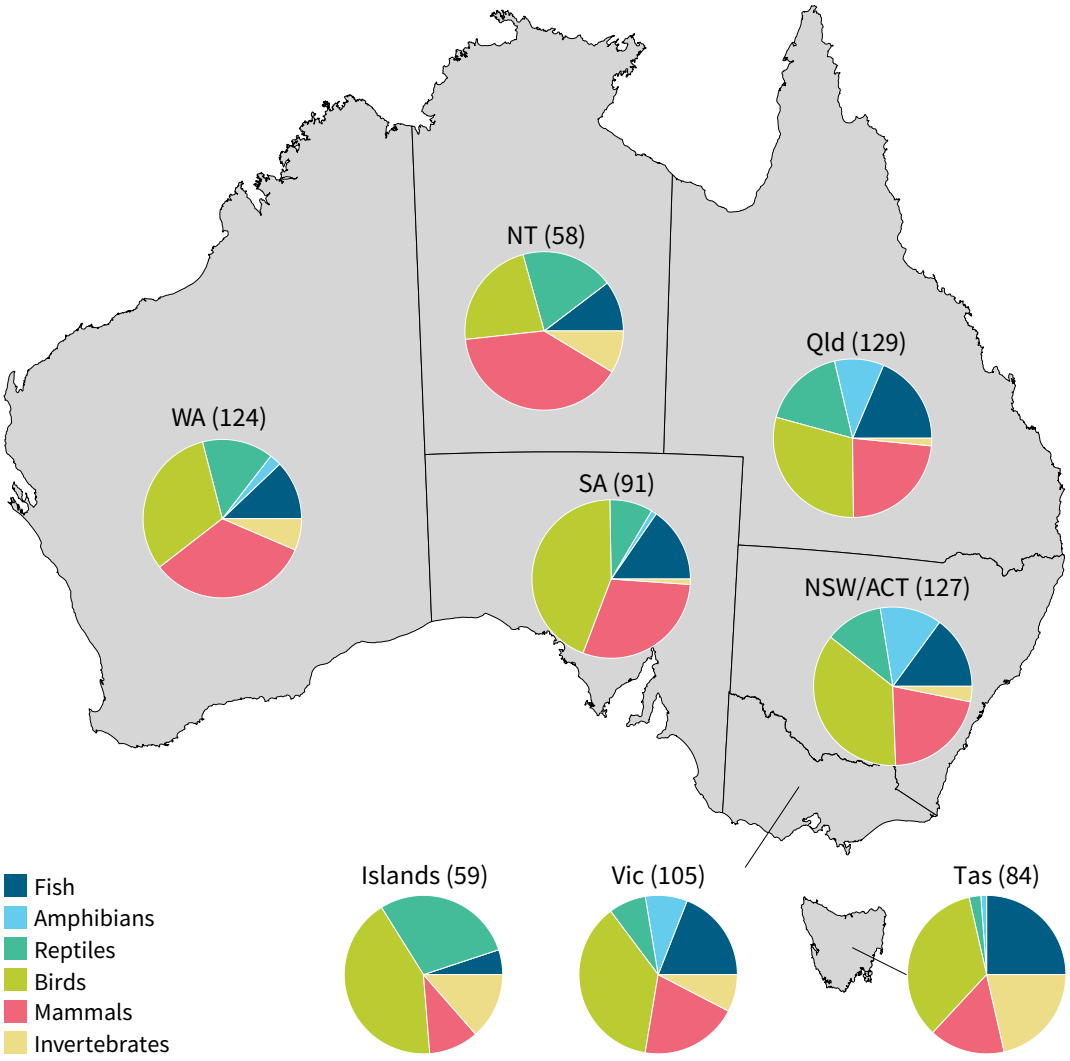
- **Very good**: The environment is in very good condition, resulting in enhanced environmental values.
- **Good:** The environment is in good condition, resulting in stable environmental values.
- **Poor:** The environment is in poor condition, and environmental values are somewhat or slowly declining.
- **Very poor:** The environment is in very poor condition, and environmental values are substantially and/or rapidly declining.

Trend

- **Improving:** The situation has improved since the previous assessment (2016 state of the environment report).
- **Stable:** The situation has been stable since the previous assessment.
- **Deteriorating:** The situation has deteriorated since the previous assessment.
- **Unclear:** It is unclear how the situation has changed since the previous assessment.

Animals

Threatened animal species are widely distributed across Australia. Most taxonomic groups are represented in threatened species lists in all states, and there is considerable regional variation in the relative proportion of different taxonomic groups (Figure 11) (Allek et al. 2018). For example, threatened amphibians occur mostly in Queensland, New South Wales and Victoria. Amphibians are extremely sensitive to changes in temperature, and climate change and extreme weather are a larger threat to them in these states than elsewhere. Birds constitute the single largest proportion of threatened animal species in all areas except the Northern Territory, where mammals make up the largest proportion.



ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: Reprinted from *Biological Conservation*, vol. 222, A Allek, AS Assis, N Eiras, TP Amaral, B Williams, N Butt, AR Renwick, JR Bennett, HL Beyer, The threats endangering Australia's at-risk fauna, 172–179, 2018, with permission from Elsevier.

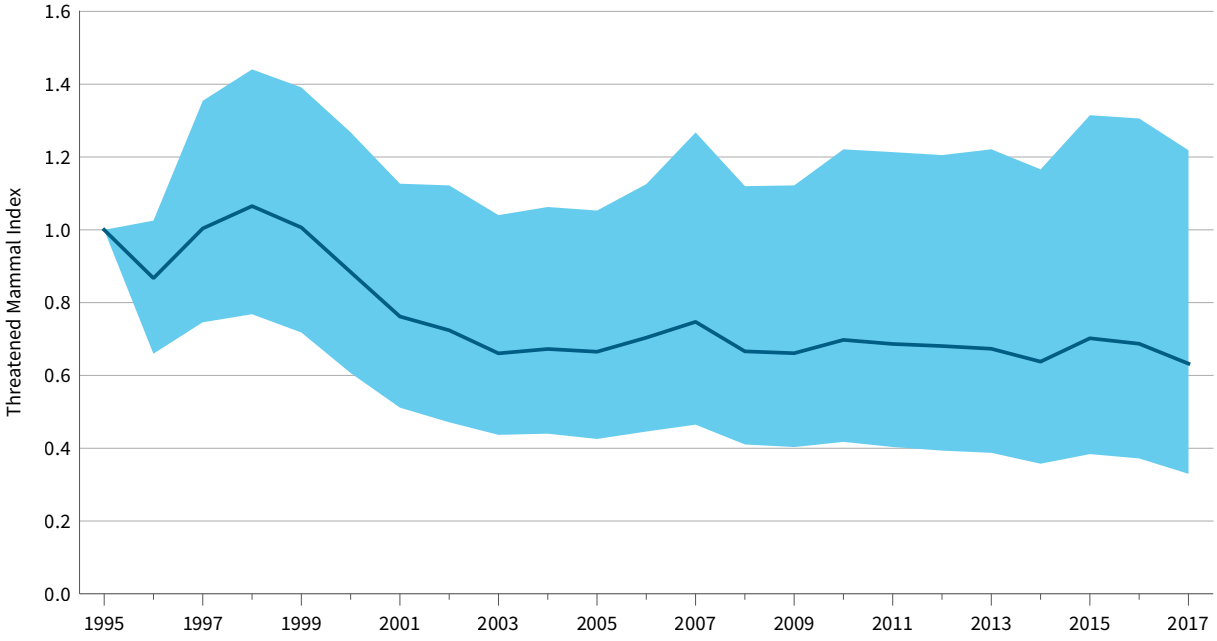
Figure 11 Relative frequency of broad taxonomic groupings of threatened animal species (including marine species) in Australia's states and territories

Mammals

Terrestrial mammals across Australia have experienced high rates of extinction, with 10% of endemic species becoming extinct over the past 200 years. Approximately 21% are now assessed as threatened (Woinarski et al. 2015, Woinarski et al. 2019). Most mammal extinctions in Australia have been driven by predation from introduced species, especially the feral cat and European red fox; extinctions have been particularly high in arid and semi-arid regions.

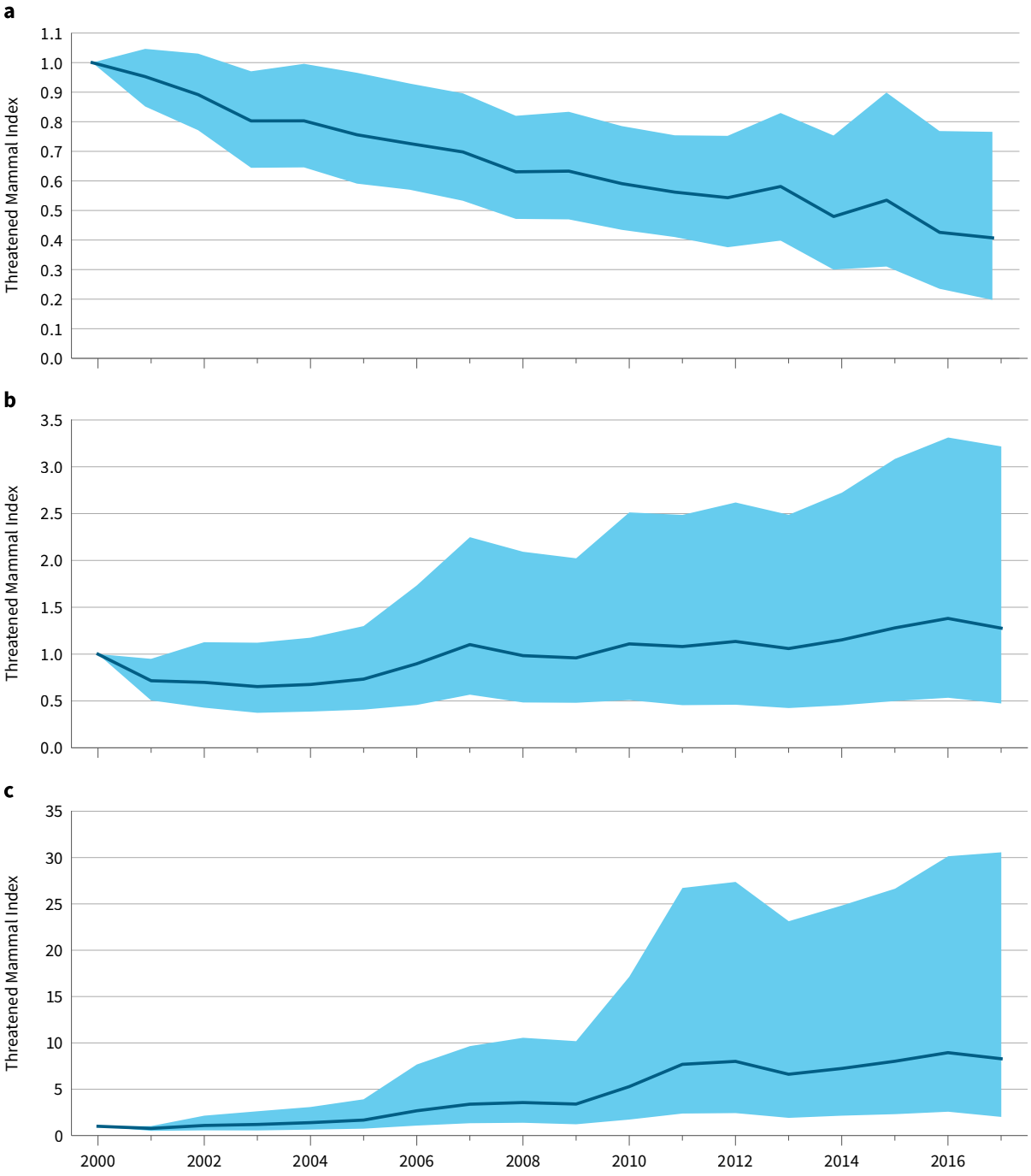
Since 2016, 2 species have been transferred from Critically Endangered to Extinct. The Christmas Island pipistrelle (*Pipistrellus murrayi*) was listed as Extinct in 2021 but experts considered it to be extinct much earlier. The last echolocation call of the species was detected in August 2009. The Bramble Cay melomys (*Melomys rubicola*) was transferred from Endangered to Extinct under the EPBC Act in 2019 but experts considered it to be extinct by 2014. Both species were reported as Extinct in the 2016 state of the environment report. Another 10 mammals were recognised as Extinct under the EPBC Act in March 2021, although all were considered to have become extinct sometime between European settlement and the 1950s.

The National Environmental Science Program's Threatened Mammal Index indicates that the abundance of many mammal species for which monitoring data are available has declined; between 1995 and 2016, the abundance of threatened mammals that have been monitored decreased by an average of 38% (Figures 12 and 13). Where no management occurs, threatened mammals have declined by an average of 60% since 2000 (Figure 13a).



Notes:
1. 61 species and subspecies
2. 76 data sources
3. Data are limited in remote areas of Australia, and some mammals, particularly bats and rodents, are under-represented. Blue shading represents the 95% confidence interval.

Figure 12 Threatened Mammal Index for Australia for all threatened species to 2017, with baseline from 1995



Note: Blue shading represents the 95% confidence interval.

Figure 13 Threatened Mammal Index for Australia to 2017, with baseline from 2000, for all threatened mammal species (a) at sites where there has been no known management (37 species); (b) at sites where there is known management of any kind (32 species); (c) at sites without introduced predators, including fenced areas and islands (17 species)

For the smaller number of species monitored at sites where activities such as baiting of predators or ecological fire management has occurred, the index shows that populations have increased by 46% on average since 2000 (Figure 13b). For sites where predators have been excluded, all species have increased in abundance since 2000 (Figure 13c).

The 20 mammal species most at risk from extinction over the next 20 years mostly occur in northern Australia and south-west Western Australia (Figure 14) (Geyle et al. 2018). Five of the 20 most at-risk mammals occur only on islands.

The mammals considered most at risk from extinction in the next 20 years are the central rock-rat (*Zyzomys pedunculatus*), the northern hopping-mouse (*Notomys aquilo*), the Carpentarian rock-rat (*Z. palatalis*), the Christmas Island flying fox (*Pteropus natalis*) and the black-footed tree-rat (*Mesembriomys gouldii gouldii*) (Geyle et al. 2018). Ten of the top 20 mammals judged most at risk from extinction are included under the 2015–20 Threatened Species Strategy.



Source: Geyle et al. (2018)

Figure 14 Numbers and locations of the 20 most threatened mammal species

The Antarctic chapter describes the state and trend of mammals, including ice-breeding seals (4 species), fur seals (3 species), sea lions (1 species) and elephant seals (1 species), that are part of the Antarctic fauna (see the Antarctic chapter). The Marine chapter describes the state and trend of the 48 species of cetaceans (whales and dolphins), 3 species of pinnipeds (seals) and the dugong that make up Australia's marine mammal fauna. Populations of marine mammals are generally in good condition, except for the Australian sea lion (*Neophoca cinerea*; very poor condition) and fur seals (poor condition) (see the Marine chapter).

Case study Detecting threatened mammals with drone technology

Accurate detection of individual animals is integral to the conservation of threatened wildlife species, but is often difficult and costly for species that occur over wide or inaccessible areas. In addition, many animals are cryptic (camouflaged) and are therefore difficult to detect and monitor effectively by traditional monitoring methods.

Technology to support the use of drones (also known as unmanned aerial vehicles or UAVs, and remotely piloted aircraft systems or RPAS) is rapidly improving and being implemented in wildlife surveys, largely because drones can cover larger areas than ground survey methods. The inclusion of thermal (heat-detecting) imaging cameras in drones offers a major advance in survey methodology, because they have the potential to provide more precise data at lower cost and with little impact on wildlife.

For example, drones have successfully been combined with thermal camera technology to detect and count koalas (*Phascolarctos cinereus*) (Beranek et al. 2021), and have been more efficient than on-ground surveys. When drones detect infrared koala-size signals, a GPS point can be collected, as well as detailed images that are then checked for accuracy.

The Australian Wildlife Conservancy is also using thermal imaging and drone technology to improve monitoring of reintroduced mammals on the Faure Island Wildlife Sanctuary. The sanctuary is a feral-free haven off the coast of Western Australia and home to critically important populations of burrowing bettong (*Bettongia lesueur*), banded hare-wallaby (*Lagostrophus fasciatus*), Shark Bay bandicoot (*Perameles bougainville*) and Shark Bay mouse (*Pseudomys fieldi*). Initial estimates of population size from drone footage are comparable to those generated from standard spotlight surveys (Australian Wildlife Conservancy).

Birds

The state and trend of many birds is relatively well studied compared with other native species. This is partly because citizens have ready access to high-quality field guides, and BirdLife Australia has been compiling and collating data collected by the public for many years (see Citizen science).

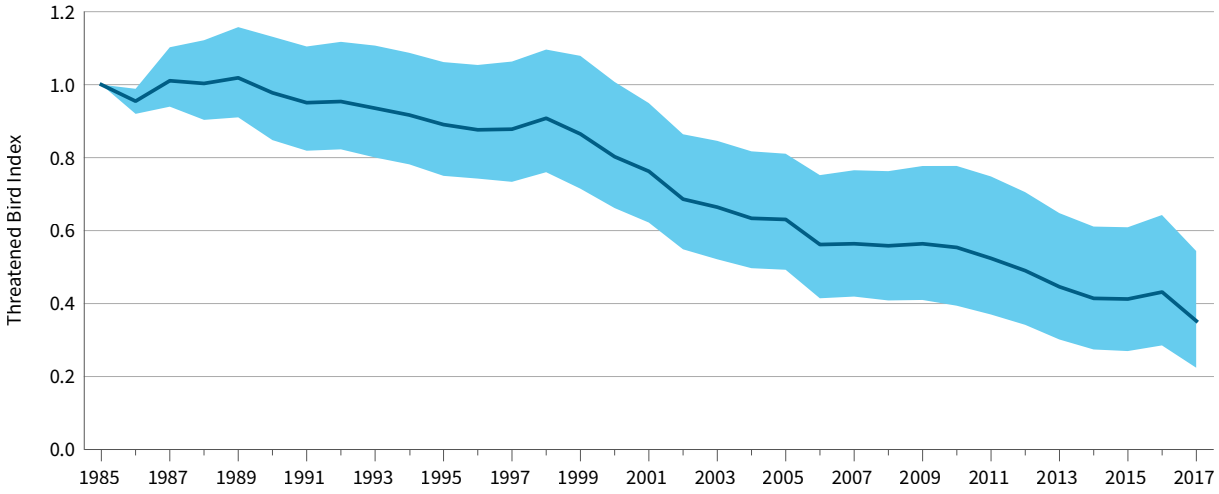
The Antarctic chapter describes the state and trend of seabirds (7 species on the Antarctic continent and 13 on subantarctic islands) and penguins (2 species on the continent and 5 on subantarctic islands) (see the Antarctic chapter). The Marine chapter discusses the overall state and trend of the approximately 60 species of seabirds that are known to breed in and around Australia and its external territories, including albatrosses, boobies, cormorants, frigatebirds, gulls, noddies, pelicans, penguins, petrels, prions, shearwaters, storm petrels, terns and tropicbirds (see the Marine chapter).

Since October 2016, 3 new bird species have been listed under the threatened species provisions of the EPBC Act. The grey falcon (*Falco hypoleucos*) and the white-throated needle-tail (*Hirundapus caudacutus*) were listed as Vulnerable, and the shy albatross (*Thalassarche cauta*) was listed as Endangered. Seven species were uplisted (were recognised as more threatened): 6 from Vulnerable to Endangered, and 1, the Tiwi Islands hooded robin (*Melanodryas cucullata melvillensis*), from Endangered to Critically Endangered.

The National Environmental Science Program Threatened Bird Index indicates significant declines in abundance of threatened birds for which monitoring data are available (Figure 15). Between 1985 and 2017, the relative abundance of threatened birds decreased by an average of more than 60%.

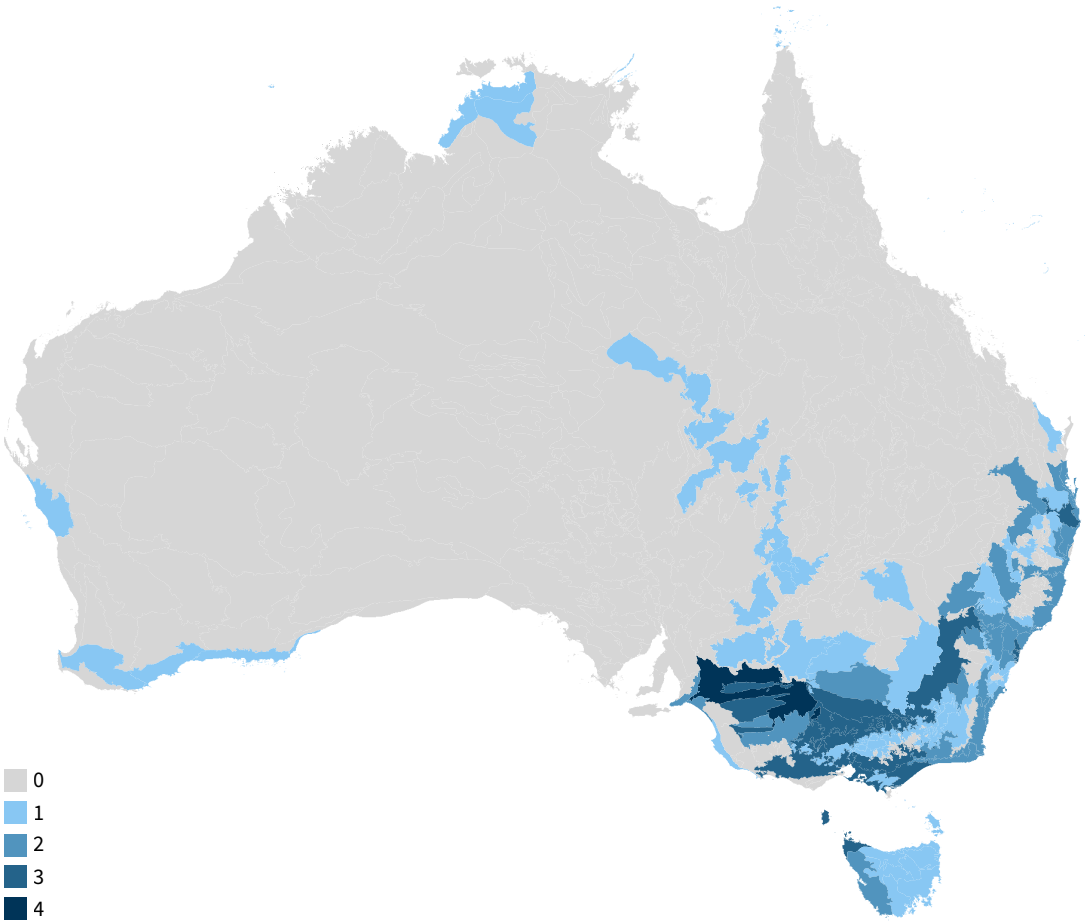
Researchers have integrated multiple approaches to assessing extinction risk, to identify the 20 Australian birds most at risk from extinction and forecast likely extinction timeframes under current management approaches. They found that many of the most at-risk bird species are found only on islands or occur in southern Australia (Figure 16) (Geyle et al. 2018).

The 5 species considered most at risk from extinction were the King Island brown thornbill



Note: Blue shading represents the 95% confidence interval.

Figure 15 Threatened Bird Index for Australia to 2017, with baseline from 1985, for 50 threatened bird species for which monitoring data are available



Source: Geyle et al. (2018)

Figure 16 Numbers and locations of the 20 most threatened bird species

(*Acanthiza pusilla archibaldi*), the orange-bellied parrot (Neophema chrysogaster), the King Island scrubtit (*Acanthornis magna greeniana*), the western ground parrot (*Pezoporus wallicus flaviventris*) and the Houtman Abrolhos painted button quail (*Turnix varius scintillans*). Ten of the 20 bird species judged at most risk of extinction are included in the 2015–20 Threatened Species Strategy (Geyle et al. 2018).

Waterbirds and shorebirds

At least 161 Australia birds depend on wetlands, waterways or shorelines for feeding or breeding habitats. Many more species also rely on these habitats for some of their needs throughout their lifecycle. Many waterbirds have been systematically surveyed across one-third of the Australian continent for more than 3 decades as part of the Eastern Australian Waterbird Survey. These data, along with numerous other datasets, give a good picture of the long-term changes in state and trend of Australian waterbirds (Clemens et al. 2019).

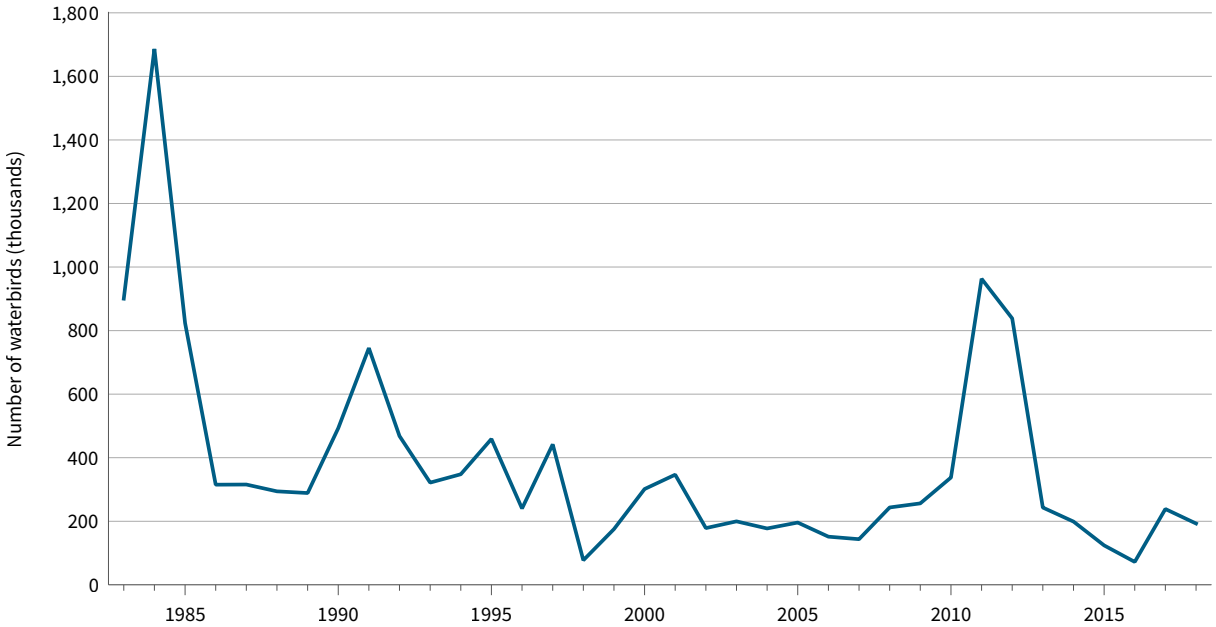
Consistent with reporting in previous state of the environment reports, waterbirds continue to show declines in abundance (Figure 17). While waterbird numbers increased after the 2011 flood in eastern Australia, they have decreased dramatically since then. At least 27 species (for which there is long-term data) show widespread long-term population

declines. A further 17 species show no long-term trend but a significant decline in the past 5 years.

Millions of migratory shorebirds fly from breeding grounds in northern China, Mongolia and Russia to East Asia and Australia each year, traversing more than 20 countries while migrating. During their nonbreeding season, from spring to autumn, 37 species regularly and predictably visit Australia.

Understanding the state and trend of migratory species and the pressures affecting them is complex and requires collation of data from hundreds of different sites across multiple countries. However, it is clear that many species are in decline, and several migratory shorebird species are globally threatened (Fuller et al. 2020) (Figure 17). The Coasts chapter contains a comprehensive account of shorebird state and trends, and the escalating pressures on shorebirds (see the Coasts chapter).

Twelve of 19 migratory shorebird species with long-term data show population decline (Clemens et al. 2019). Loss and degradation of stopover habitat is the main cause of declines of migratory shorebirds. In particular, the birds congregate at high densities on tidal mudflats in the Yellow Sea region of East Asia. This region is increasingly degraded by coastal development and has shrunk by more than 65% in recent decades. As a consequence, the populations of migratory species that rely heavily on this region to rest and refuel show significant declines. For example, populations of the great knot (*Calidris tenuirostris*) and far eastern curlew (*Numenius madagascariensis*), both of which are listed as globally threatened, have declined more than 5% per year on average since 1993 (see Figure 26 in the Coasts chapter). The far eastern curlew is one of the 20 target bird species in the 2015–20 Threatened Species Strategy.



Source: Porter et al. (2019)

Figure 17 Changes over time in the total abundance of waterbirds in the Eastern Australian Waterbird Survey, 1983–2018

Australia has entered into 3 bilateral migratory bird agreements – with Japan (Japan–Australia Migratory Bird Agreement – JAMBA), China (China–Australia Migratory Bird Agreement – CAMBA) and the Republic of Korea (Republic of Korea – Australia Migratory Bird Agreement – ROKAMBA). These agreements provide an important mechanism for pursuing conservation outcomes for migratory birds.

The Australian Government's Wildlife Conservation Plan for Migratory Shorebirds covers 35 species that regularly visit Australia. The plan outlines a national framework identifying research and management actions to protect migratory shorebirds in Australia. All 35 species covered by the plan are listed migratory species under the EPBC Act.

Many Indigenous Protected Areas (IPAs) include migratory bird habitat. At least 20 IPA management plans address threats to migratory birds and the protection of migratory bird habitats.

Reptiles

Australia is home to about 10% of the world's known reptile species, and about 90% of species are endemic. Understanding of the conservation status of reptiles has increased significantly since 2016. Key new sources of knowledge include a comprehensive assessment of the conservation status of snakes and lizards (Tingley et al. 2019, Geyle et al. 2020) and an action plan for them (Chapple et al. 2019), and specific assessments for Australian freshwater turtles (Van Dyke et al. 2018), crocodiles (Somaweera et al. 2019) and earless dragons (Melville et al. 2019). The Marine chapter describes the state and trend of the 6 species of marine turtles and 33 species of seas snakes that occur in Australian waters (see the Marine chapter).

Many of Australia's reptiles are declining, and the past decade saw the first Australian reptile extinctions in the wild. The proportion of species assessed under the EPBC Act as Critically Endangered is increasing (Figure 5). Two endemic Christmas Island species currently listed as Critically Endangered – blue-tailed skink (*Cryptoblepharus egeriae*) and Lister's gecko (*Lepidodactylus listeri*) – are only known to exist in captivity. The Christmas Island forest skink (*Emoia nativitatis*) was transferred to Extinct in March 2021. It was last seen in the wild in 2010, and the last known individual died in captivity in 2014.

A recent assessment of 948 species of Australian lizards and snakes against IUCN criteria confirmed and expanded the EPBC Act listings (Tingley et al. 2019):

- 67 species were assessed as threatened
  - 28 as Vulnerable
  - 26 as Endangered
  - 10 as Critically Endangered
  - 1 as recently Extinct (*E. nativitatis*)
  - 2 as Extinct in the Wild (*C. egeriae* and *L. listeri*)
- 19 species were classified as Near Threatened
- 819 species were classified as Least Concern
- 43 species were classified as Data Deficient.

Most species were classified in the threatened categories largely because of having a small geographic range and an ongoing threat that is likely to reduce their distribution further. The assessment found that the number of threatened species was highest in the Alps of south-eastern Australia, and in northern Australia in the vicinity of Kakadu National Park and across the Kimberley region.

Reptile experts suggest that, by 2040, up to 11 snakes and lizards, all with restricted ranges and threatened by invasive plants and animals,

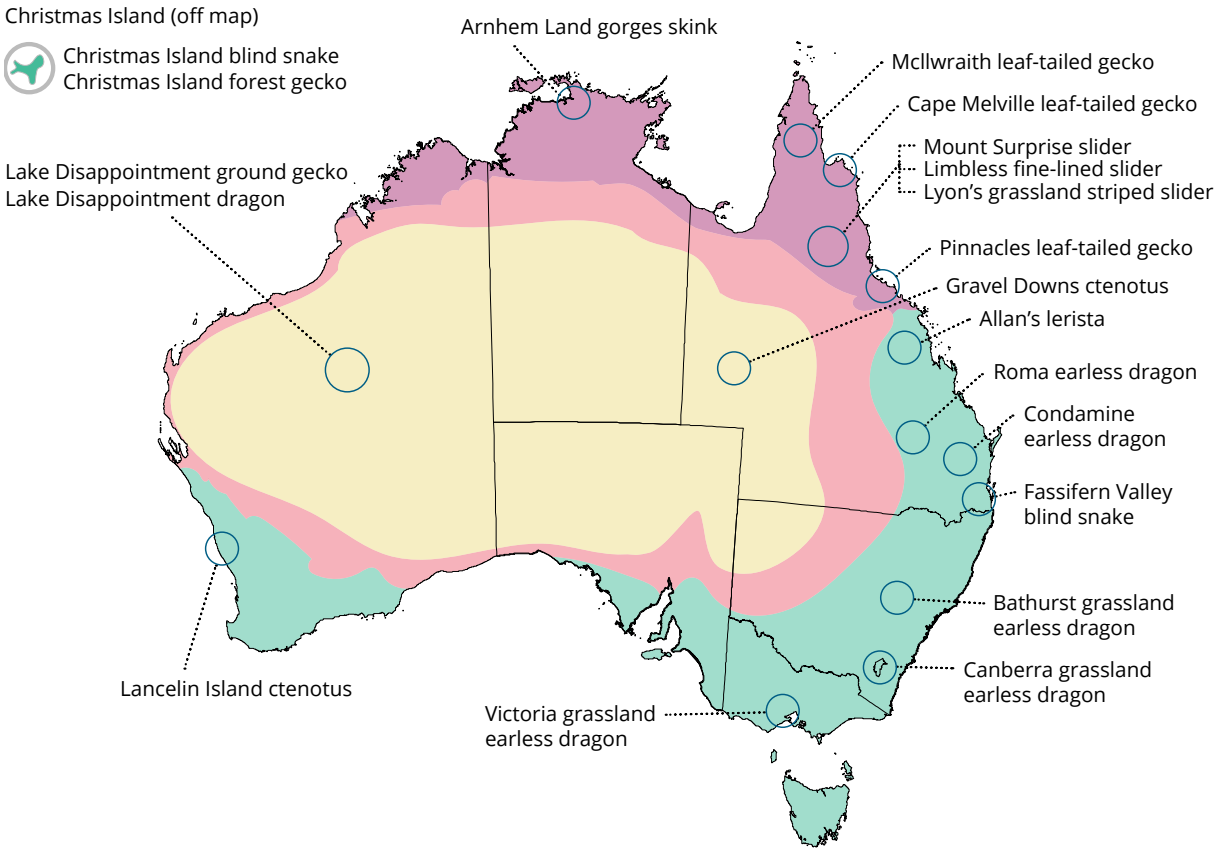
could become extinct (Geyle et al. 2020). Three of the reptiles with the highest extinction risk over the next 20 years occur only on islands, and more than half occur only in Queensland (Figure 18).

Australian reptile species are poorly taxonomically described, partly because several species are sometimes erroneously classified (and hidden) under 1 species name. For example, taxonomic uncertainties in the characterisation of grassland earless dragon lizards of southern Australia were clarified recently, resulting in the naming of 2 new species, while restricting the distribution of 1 existing species (*Tympanocryptis pinguicolla*) (Melville et al. 2019). This taxonomic revision has significant conservation implications because the last confident sighting of *T. pinguicolla* was in 1969, raising the possibility of the first extinction of a reptile on mainland Australia. The species is currently listed as Endangered under the EPBC Act.

Freshwater turtles

About half of the 25 species of Australian freshwater turtles (see the Marine chapter for details of sea turtles) are currently listed as Vulnerable, Endangered or Critically Endangered, and ongoing declines are being recorded in many parts of Australia.

Invasive predators have been highlighted as a primary threat, but drought, habitat modification and disease events are also



Credit: Jaana Dielenberg, Threatened Species Recovery Hub
Source: National Environmental Science Program Threatened Species Recovery Hub (2020)

Figure 18 Locations of the top 20 Australian snakes and lizards at risk of extinction

contributing to declines (Van Dyke et al. 2018). Nest predation by invasive foxes has driven declines in freshwater turtles in the Murray–Darling Basin (Van Dyke et al. 2019). Turtle declines of up to 91% have also been observed in sections of the Murray River because of drying caused by climate change, which may be compounded by nest predation.

A new disease caused the near-extinction of an Australian freshwater turtle – the Bellinger River snapping turtle (*Myuchelys georgesi*) – and may be a symptom of deteriorating water quality and climate change (Spencer et al. 2018).

Case study Assisted colonisation of the western swamp tortoise

Nicki Mitchell, University of Western Australia

A well-recognised response to climate change is the poleward shift of species' range limits. However, many terrestrial species are unable to shift their distribution because of the loss of connecting habitats. In south-western Australia, a marked decline in winter rainfall began in the 1970s, and this climatic shift, coupled with extensive habitat loss and fragmentation, threatens species that depend on wetlands and are incapable of migration. Consequently, some species might only persist if they can be introduced to wetter areas. This form of conservation introduction is termed 'assisted colonisation' because species are translocated beyond their native range to mitigate a major threat.

A world-leading trial of this conservation strategy as a response to climate change began in 2016 for the Critically Endangered western swamp tortoise (*Pseudemydura umbrina*) – one of Australia's rarest reptiles. In its habitat north of Perth, declining winter rainfall has shortened the period in which swamps hold water, which coincides with when tortoises grow and reproduce. Eventually, wet periods may be too short for successful recruitment of juveniles. Further, as the only viable natural population of the species at Ellen Brook Nature Reserve is threated by urbanisation and infrastructure development, translocation sites that can support additional swamp tortoise populations are urgently needed.

Wetlands near the south coast of Western Australia have longer wet periods than those near Perth, and predictive models suggest they are likely to provide ideal microclimates for swamp tortoises within 30 to 50 years (Mitchell et al. 2013, Mitchell et al. 2016). With the support of the species' recovery team, assisted colonisation trials began in 2016, aimed at testing whether wetlands more than 300 km south of the natural range could provide suitable food and microclimates for tortoise growth. Captive-bred juveniles raised at Perth Zoo were released into 2 wetlands near the south coast, as well as into an existing northern translocation site to provide a comparison. Encouragingly, at one of the southern wetlands,

tortoises grew at a similar rate to those in the north in spring–summer (Bouma et al. 2020).

In 2018, a year-long trial of assisted colonisation commenced. In this trial, captive-bred tortoises were again released, and researchers focused closely on postrelease behaviour. Based on analysis of data recorded by biotags attached to tortoises, it became clear that lower water temperatures and solar radiation in the south limited tortoise activity, and consequently their opportunity to forage. However, overall, the research suggests that tortoises can grow well in southern wetlands, provided that energy-rich food sources such as tadpoles are abundant when tortoises are warm enough to be active. The longer-term suitability of southern sites will become more evident as juveniles reach maturity, which depends on them surviving annual summer aestivation – a period when they are susceptible to predation by foxes and impacts from fire.

Selection of translocation sites for the western swamp tortoise is multifaceted (Dade et al. 2014), and an important factor to consider is the possible impact of tortoises on recipient ecosystems that support other threatened species such as the salamanderfish (*Lepidogalaxias salamandroides*) and black-stripe minnow (*Galaxiella nigrostriata*).

Current research is now focusing closely on tortoise activity and diets in southern wetlands, aided by the largest ever release of more than 70 juveniles into wetlands in the East Augusta region – including the site of the successful 2016 trial. Ultimately, due to their slow maturation and long lifespan of at least 80 years, decades of monitoring will be required to understand whether western swamp tortoise populations can establish and ultimately flourish in novel habitats.

Amphibians

The publication of the *Status of conservation and decline of amphibians in Australia, New Zealand and Pacific Islands* (Heatwole & Rowley 2018) consolidates much knowledge about the state and trend of amphibians, greatly improving our understanding of them compared with reporting in 2016.

Currently, 243 native species of frogs are known in Australia (Gillespie et al. 2020) and most of these (around 93%) are endemic (Heatwole & Rowley 2018). More species are being discovered; 21 new species, representing 9% of Australia's known frog fauna, have been discovered in the past decade alone. Most of these species were hidden within known 'species' that were found to be complexes of several, morphologically similar species (Heatwole & Rowley 2018).

The number of EPBC Act–listed species has increased since 2016 (Figure 4). Most of these additions have been to the Critically Endangered category (Figure 5).

All 243 species of Australian frogs have been recently assessed against the IUCN Red List criteria (Gillespie et al. 2020). Forty-five species (18.5%) were assessed as either extinct or threatened: 5 Extinct, 13 Critically Endangered, 11 Endangered and 16 Vulnerable. A further 4 species were considered Near Threatened,

and 7 species were considered Data Deficient. Most of the threatened frog species occur along the eastern coast of Australia and the Great Dividing Range; 23 occur in Queensland and 17 occur in New South Wales.

The high number of Critically Endangered and Endangered amphibian species in eastern Australia reflects the devastating impact of chytridiomycosis, which is caused by the invasive fungus *Batrachochytrium dendrobatidis* (chytrid fungus), on many frog species (see Animal diseases) (Allek et al. 2018). The regions affected by chytrid fungus are also among the most urbanised in Australia, and widespread loss and degradation of habitats has contributed to broadscale decline of amphibians in these areas (Heatwole & Rowley 2018).

Processes that modify the distribution, frequency and extent of available surface water in the landscape are a significant threat to amphibians across Australia. Even in arid and central Australia, where amphibians are adapted to highly variable water availability, long-term changes in patterns of rainfall as a result of climate change can be expected to be a significant ongoing pressure (Ocock & Wassens 2018).

Case study Recovering the critically endangered northern corroboree frog after the bushfires

The Wildlife and Threatened Species Bushfire Recovery Expert Panel, which was established in January 2020 to help inform the Australian Government's response to the 2019–20 bushfires, identified the northern corroboree frog (*Pseudophryne pengilleyi*) as 1 of 119 animal species in need of urgent management intervention (Figure 19).

The northern corroboree frog was considered Critically Endangered before the fires and the recent drought left the tiny frog particularly vulnerable. The frog depends on the Alpine Sphagnum Bogs and Associated Fens threatened ecological community, which was significantly impacted by the fires, and the remaining populations are at high risk of extinction. Taronga Zoo has been working to protect the frog for more than a decade, and setting up additional captive colonies was deemed critical for its recovery. The first 100 frog eggs were collected from the wild in March 2020 and were hatched successfully at the zoo.

A purpose-built facility to support conservation breeding of the species opened in March 2021. The zoo's captive breeding program will allow the experts to plan ahead, manage the production of many more eggs, and deliver offspring for translocation trials once the habitat is healthy again.



Photo: Taronga Zoo

Figure 19 Northern corroboree frog

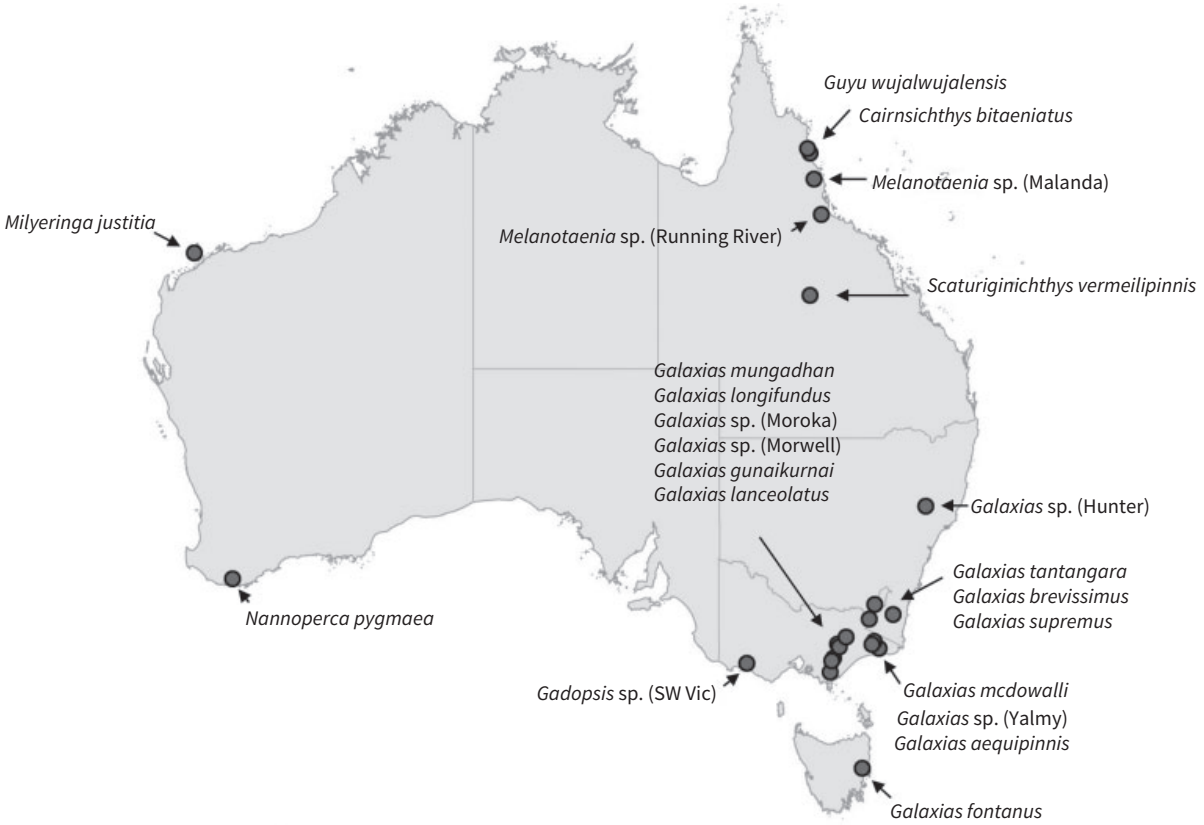
Fish

Australia is home to almost 300 bony freshwater fish species, most of which are small-bodied (less than 20 cm total length), with only 19 reaching a total length of more than 1 m (Humphries & Walker 2013).

Freshwater fishes are culturally significant to Indigenous Australians, whether for spiritual or ceremonial reasons, or simply as a stable food source (Toussaint 2014, Pyke et al. 2018, Milgin et al. 2020). Notable examples of fish with multiple societal values include the freshwater sawfish (*Pristis microdon*), which provides material for use as a weapon, is a totem, and is also believed to be a creator of rivers in northern Australia (McDavitt 2005). The iconic barramundi (*Lates calcarifer*) is another species of great cultural significance, both as a staple food source and as an ancestral being; according to Dambimangari Traditional Owners of the north-west Kimberley, 'Barramundi was splashing around and made Walcott Inlet' (D Woolagoodja, quoted in Allbrook et al. 2017).

Currently, 62 Australian fish species are listed under the EPBC Act; of these, 38 are freshwater fish (Lintermans et al. 2020). The Pedder galaxias (*Galaxias pedderensis*) is known to be extinct in the wild (Chilcott et al. 2013).

A recent analysis of 22 Australian freshwater fish species considered by experts to be most at risk of imminent extinction found that 20 have more than a 50% risk of extinction in the next 20 years (Lintermans et al. 2020) (Figure 20). But of the 22 species assessed, only 3 are listed under the EPBC Act and 7 are undescribed species, which makes them ineligible for listing.



Source: Lintermans et al. (2020). Republished with the permission of CSIRO Publishing, from *Pacific Conservation Biology*, 2020; permissions conveyed through Copyright Clearance Center, Inc

Figure 20 Locations of the 22 most imperilled fish species

Galaxiids (small, scaleless fish) dominate the list of Australia's most threatened freshwater fishes (14 of 22 species). Trout invasion is the main threat to these species because small-bodied species are most at risk of predation. This threat is compounded by inappropriate fire regimes and climate-related threats (Lintermans et al. 2020).

The 2015–20 Threatened Species Strategy did not contain any identified priority fishes for recovery actions, although the new 2021–31 strategy will include priority fish.

Prolonged drought conditions between 2017 and 2019 resulted in lower than average streamflows in rivers across much of Australia, with significant impacts on aquatic biodiversity. The interacting effects of water regulation (see Aquatic ecosystems and habitats, and the Inland water chapter) and drought conditions, combined with bushfires in the summer of 2019–20, culminated in major fish kills across the Murray–Darling Basin (Vertessy et al. 2019) (see Bushfires – summer 2019–20). The main native fish species involved included Murray cod (*Maccullochella peelii*), silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*) and bony herring (*Nematalosa erebi*), with mortality estimates in the range of hundreds of thousands to more than a million fish. Overall, deaths were reported in around 27 species of freshwater and estuarine fish, and in 4 species of crustaceans, some of which are endemic, from 15 waterways and 17 locations across New South Wales and Victoria (Silva et al. 2020). Climate change predictions indicate that such extremes will occur more frequently

and become more intense, affecting already stressed river systems.

The Marine chapter describes the state and trend of marine sharks, rays, chimaeras, tuna, billfish, reef fishes and other fish (see the Marine chapter).

Invertebrates

Australia has approximately 320,465 invertebrate species, of which about 35% have been described. More than 80% of all invertebrates are grouped into the phylum Arthropoda, which includes arachnids (spiders, ticks, mites and scorpions), crustaceans (e.g. crabs, shrimps, barnacles), centipedes, millipedes and insects. Insects are the largest class of invertebrates, accounting for more than 75% of all animal species, and include beetles, butterflies and moths, ants, bees, wasps, flies, mosquitos, bugs and grasshoppers. Australia has a rich insect biodiversity, and taxonomists estimate that there may be more than 200,000 species in Australia, although only around 62,000 have been described.

Many invertebrates are of significant cultural importance to Indigenous Australians, particularly those valued as a nutritional food source or used for medicinal purposes. Species of freshwater crayfish (marron), beetle larvae (witchetty or bardi grubs), native bees (sweat bees), sap-sucking insects (lerps), irruptive insects (swarming locusts) and mass migratory species (bogong moths) are all examples of invertebrates that are highly prized by Traditional Owners as sources of food. Many of these invertebrates and a plethora of others, such as termites, ants and processionary caterpillars, were also medicinally useful to treat various ailments and conditions (Faast & Weinstein 2020). In some instances, invertebrates were central to the ceremonies, mythology and cosmology reinforcing the connection people had to Country, and facilitated the congregation of people at feasts such as those documented for the bogong moth on Ngarigu Country in the Australia Alps, which are estimated to have been practised for more than 2,000 years (Stephenson et al. 2020).

A recent review of the conservation status of all insects and allied invertebrates in terrestrial and freshwater environments in Australia (excluding molluscs, annelids (segmented worms) and nematodes) has greatly improved knowledge about these taxa since 2016 state of the environment reporting (Taylor et al. 2018a).

A total of 285 invertebrate species are listed as threatened under various state and territory conservation Acts, the EPBC Act and the IUCN Red List (Taylor et al. 2018a), and 10 species are listed as Extinct. These known invertebrate extinctions have occurred in both terrestrial and aquatic environments, and include 2 insects, 1 isopod, 1 spider, 1 worm, 4 land snails and 1 freshwater snail (Braby 2019).

Most threatened species have been listed from the wetter areas of Australia, with particularly high concentrations of species in coastal regions of eastern Australia. There are no listed species in 40% of the bioregions in the Interim Biogeographic Regionalisation for Australia (see Ecosystems and habitats) that are mostly in semi-arid or arid areas of the continent.

Major threats to insect biodiversity come from habitat loss through broadscale clearing of native vegetation, invasion by weeds, habitat fragmentation, loss of natural corridors and inappropriate fire regimes (Braby 2019). Other threats include disturbance of plant communities on hilltops, creek embankments and in water courses; pesticides; trampling and grazing by stock and feral animals; and non-native predators (Sands 2018). Climate change affects insects that have limited thermal and moisture tolerances (climate envelopes), with changes in temperature and

rainfall potentially affecting their distribution, development and reproduction (Sands 2018).

The vast number of insect species in Australia means that most are poorly described and their ecology and distribution little understood, which has led to difficulties in distinguishing their threats. This is coupled with a gradual loss of taxonomic expertise needed for identifications and descriptions (Braby & Williams 2016). As a consequence, the conservation status and management needs of most threatened insect species are poorly understood and documented (Sands 2018). For example, despite being one of the better studied and more charismatic invertebrate groups, only 10 butterflies are currently recognised as threatened under the EPBC Act, equating to around 1.6% of the recognised 614 Australian butterfly taxa (Taylor et al. 2018a).

In addition, invertebrate species are generally not considered to be particularly charismatic, and for most species there is little public concern for their potential demise. Some are even considered largely expendable. For example, parasites of mammals and insect herbivores are rarely considered in the context of conservation, and their decline and extinction are often overlooked (Moir 2020). An Australian mealybug species (*Pseudococcus markharveyi*) was discovered and described less than 15 years ago, and was highlighted recently as one of 5 most threatened invertebrates in Australia, requiring urgent management intervention to avoid extinction (Moir 2020). Unfortunately, it may be too late. All individual plants of the Critically Endangered Stirling Range dryandra (*Banksia montana*) that were known to host the species have died as a result of the 2018 bushfires in Western Australia, and the mealybug is now likely to be extinct.

Declines in other invertebrate taxa have been documented or suggested recently, with poorly known invertebrate species disappearing 'silently'. For example, the likely decline of members of the trapdoor spiders (Mygalomorphae: Idiopidae) of southern Australia has been noted due to intensive land clearing and stocking (Rix et al. 2017). Knowledge about the distributions of this poorly taxonomically documented yet diverse assemblage of long-lived fossorial spiders is very limited, making conservation assessment impossible. Only 1 species, the shield-backed trapdoor spider (*Idiosoma nigrum*), is listed under the EPBC Act as Vulnerable.

Conversely, invertebrate species are sometimes rediscovered. The second known specimen of the bee *Hesperocolletes douglasi* was recently reported as a serendipitous find among a collection of insect pollinators from an isolated woodland remnant in the Southwest Floristic Region of Western Australia. The only other collection of this species was 80 years ago, and it was officially gazetted as presumed extinct in 1994; however, it now appears that *H. douglasi* may persist as a localised population (Arnold et al. 2019).

The Coasts chapter describes invertebrates of Australian bays and estuaries and the impacts of coastal development, catchment development, invasive species and climate change on these species (see the Coasts chapter). The Antarctic chapter describes threats to Antarctic terrestrial and Southern Ocean invertebrates (see the Antarctic chapter). The Marine chapter describes the wide range of mobile marine invertebrates, as well as habitat-forming invertebrates such as corals, sponges and bryozoans (see the Marine chapter).

Subterranean fauna

Across large parts of Australia, it has become apparent that underground aquifers and underground caves support a diverse array

of subterranean invertebrates. Troglofauna is the name given to species that live in air-filled cavities, voids or pores in rocks, typically in the unsaturated zone above the watertable; while stygofauna are aquatic species that live in the groundwater, often tens of metres below the surface.

The diversity of Australian subterranean fauna is extremely high. More than 4,100 species are estimated to occur in Western Australia alone based on the rate of species discovery in the early part of last decade (Guzik et al. 2010), in part thanks to new molecular and genomic techniques. For example, 24 new species of microcrustacean (Parabathynellidae) have been recently identified in the Pilbara, representing 22% of the world's diversity (Matthews et al. 2020). At least 3 fish species also occur in groundwater systems. The blind cave gudgeon (*Milyeringa veritas*) and the blind cave eel (*Ophisternon candidum*) are both listed as Vulnerable freshwater fish species under the EPBC Act.

However, as elsewhere, Australia's subterranean fauna is poorly known, although its role in ecosystem services is thought to be substantial (Hose & Stumpp 2019). Knowledge gained in the past decade shows that much of the Australian subterranean fauna occurs nowhere else (Mokany et al. 2019) and has highly restricted ranges (Hyde et al. 2017). For example, in south-west Western Australia, unique stygofaunal communities are associated with mats of submerged rootlets of trees in limestone caves underneath the Leeuwin–Naturaliste Ridge. Several of these communities have been listed as Endangered under the EPBC Act. Major threats to these communities include declining water levels, mainly due to groundwater abstraction for urban, rural and industry needs, and destruction or accidental damage of the tree roots. Other threats include the pollution of groundwater, cave collapse and possible introduction of species such as yabbies, which are thought to have had a serious impact on other root mat communities.

Very little is known about the basic biology and ecology of subterranean fauna (Humphreys 2018). This is a key issue for assessing and remediating impacts as part of the environmental impact assessment process, especially as poor knowledge suggests that caution should be taken with any management (the precautionary principle).

Mining activities, such as mineral exploration, resource excavation, and groundwater drawdown and reinjection, can threaten the persistence of entire populations and even entire species of subterranean fauna (Halse 2018). Injection of treated greywater or sewage water into aquifers (called managed aquifer reinjection) is also a potential threat in urban areas. Changes to microclimate, contamination from pollutants and hydrocarbons, and increased nutrient loads are added threats to subterranean fauna, especially stygofauna and other entities in groundwater-dependent ecosystems (Hose et al. 2015, Hose & Stumpp 2019, Castaño-Sánchez et al. 2020).

Assessment The status of native and threatened animals

2021



Adequate confidence

Almost all types of native and threatened animals are in a poor, or very poor and deteriorating state. The only animal species that are in a good state are fish in northern and central Australia, and subterranean invertebrates, although these are also subject to localised high impacts and poor conditions.

Related to United Nations Sustainable Development Goal targets 15.1, 15.4, 15.5

Assessment Mammals

2021



2016



2011



Adequate confidence

Mammals are subject to ongoing population declines and increases in the numbers of threatened species, including those at high risk of extinction. The impact of invasive predators is immense, extensive and persistent. Some targeted species are improving slightly in areas where the pressure from predators is decreased or removed.

Assessment Birds



Adequate confidence

There is strong evidence of population declines in threatened bird species, waterbirds and migratory birds. Various extensive and persistent impacts contribute to declines, including climate change (particularly drought) and extreme events, habitat degradation, and invasive predators. Bird species in southern Australia, and those found only on islands, experience multiple pressures, leading to high ongoing risk of decline.

Assessment Reptiles



Limited confidence

Reptiles experience high levels of ongoing pressure from invasive predators, compounded by pressure from habitat modification, climate change (particularly drought) and disease. Species at risk of extinction are increasing and are found in all areas of Australia, including islands. Reptile monitoring is exceptionally poor.

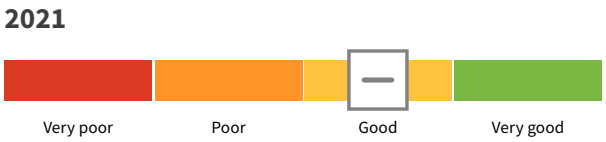
Assessment Amphibians



Limited confidence

The number of known threatened amphibian species, including those that are Critically Endangered in Australia, is increasing. Disease is a persistent pressure in eastern Australia. Drought and fire are increasing pressures. However, most of the threatened species are restricted to the south-east, wet tropics and south-west of Australia, and there is little evidence of declines in amphibians across the remainder of the continent.

Assessment Fish in northern and central Australia



Very limited confidence

Fish in northern (except the wet tropics) and central Australia persist in areas that are in relatively good condition with low levels of most pressures, notwithstanding areas of localised poorer condition with significant impacts from human activity. However, very limited information is available on the state and trend of most fish species, including threatened species.

Assessment Fish in southern, eastern and south-western Australia

2021



Limited confidence

Fish in southern, eastern and south-western Australia persist in areas that are in relatively poorer condition and are subject to multiple pressures, including from resource use, invasive species, climate change and extreme events. Limited information is available on the state and trend of most fish species, including threatened species.

Assessment Invertebrates

2021



2016



2011



Very limited confidence

The very limited information available on the vast majority of invertebrate species makes an assessment difficult. However, the pressures on invertebrates over much of Australia are substantial and persistent, including climate change, weed invasion, fire, habitat modification and loss, and other human activities.

Assessment Subterranean invertebrates and troglofauna

2021



Very limited confidence

Subterranean invertebrates, including troglofauna, are likely to be subject to localised impacts, particularly from activities such as contamination, mineral exploration, resource excavation and groundwater drawdown. Overall, their state is considered to be good. However, very little is understood about the ecology, population abundance and trends of these cryptic species.

Assessment Root mat communities

2021



Limited confidence

Root mat communities are considered to be in very poor condition, and several have been listed as Endangered over the reporting period. Impacts are mostly associated with a drying climate combined with groundwater abstraction for human activities, contamination and damage to roots – and these pressures are increasing. Little information is available except for those communities that have been extensively assessed for listing.

Fungi and other microorganisms

Australia is home to more than 15,000 known species of fungi, 8,000 of which are visible to the naked eye, with the remainder being microscopic (see Antarctic fungi and Soil microorganisms in the Antarctica chapter). Many more species, possibly tens of thousands, are undescribed. Fungi provide critical ecosystem services by decomposing the complex cellulose and lignin molecules in wood. They also provide food to a wide range of vertebrates and invertebrates. At least 30 species of Australian mammals have been found to eat fungal fruiting bodies in habitats ranging from rainforest to deserts.

Despite the very important roles that fungi and other microorganisms play in ecosystems and ecological processes, the overall level of knowledge about their taxonomy, biology and ecology is very limited. However, some regional programs are making progress in more comprehensively documenting these components of biodiversity. For example, FORESTCHECK is one of only a few programs in the world collecting regional-scale information on mosses, lichens, fungi and invertebrates, as well as the better-known components of forest biodiversity.

The IUCN Red List has 408 fungi species listed. However, with an estimated 5 million fungal species globally, there is still a very long way to go in assessing the conservation status of these critically important species. Thirty-six Australian species are listed, including 1 Critically Endangered and 4 Endangered species, which is a considerable improvement on the 1 species reported as listed in 2016. Twenty-seven of the listed species occur in temperate forest habitats. No fungi are currently listed under the EPBC Act, and only a few are listed under state conservation Acts.

Tea-tree fingers (*Hypocreopsis amplectens*) is the only species listed as Critically Endangered on the IUCN Red List. It is endemic to south-eastern Australia and the South Island of New Zealand. Despite intense survey effort for this readily recognisable and persistent fungus for more than 30 years, it has only ever been recorded at 7 sites, and it can no longer be found at some. Although the known sites are all in areas managed for nature conservation, there is continuing significant disturbance, including motorbike riding and horse riding. Fire is also considered a significant threat, especially repeated fires at short intervals.

Of the species listed on the IUCN Red List, the most frequently cited threats are housing and urban area expansion, increases in fire frequency or intensity, and tourism and recreational activities.

Aquatic microorganisms

The Marine chapter describes changes in the microbial communities of ocean waters, with significant geographic shifts in distribution of marine algae, including pathogenic and harmful algal bloom species, as ocean waters warm (see the Marine chapter).

Diatoms (Bacillariophyta) are the most species-rich group of algae on Earth, with global estimates varying between 30,000 and 200,000 taxa. The freshwater diatom flora of Australia is estimated to be about 1,400 species, of which about 200 species are endemic. The highest species richness appears to be in temperate Australia, where about 650 taxa are recorded (around 90 new taxa described in 2018); however, this may be a conservative estimate, because 609 taxa have been recorded from Tasmania alone, and 80 of these were new to science and 100 new to Australia (John 2018). Tropical Australia supports about 500 taxa, while 400 taxa are known from arid Australia; 50 and 60 taxa, respectively, are considered new to science (John 2020, John in press).

Diatoms and other freshwater microorganisms are highly sensitive to water quality and are often used as bioindicators of change in water-quality parameters. For example, in Moreton Bay in Queensland, the composition of the diatom community has shown distinct changes in relation to floods, increasing urbanisation and agriculture in the large catchment. Since the mid-20th century, the growth of bloom-forming marine planktonic diatoms has increased compared with the dominant benthic diatom. This transition is most likely due to a shift in the quality of run-off entering the bay, with run-off events in the latter half of the century characterised by increased fine sediment, nitrogen and pollutant loads (Coates-Marnane et al. 2021).

Assessment The status of native and threatened fungi and other organisms

2021



Adequate confidence

Few data are available on Australian fungi and microorganisms, but pressures in areas of high levels of human activity are likely to have a negative effect.

Related to United Nations Sustainable Development Goal targets 15.1, 15.2, 15.4, 15.5

Assessment Fungi and other microorganisms in highly modified ecosystems

2021



Low confidence

Although very little information is available, it is likely that fungi and other microorganisms that persist in highly modified ecosystems are in relatively poor condition. Pressures on fungi and other microorganisms in these areas are likely to be increasing, including the pressure from changing fire regimes, extreme fires and human activities resulting in disturbance to vegetation and soils. Very little is understood about population state and trends for the vast majority of organisms.

Assessment Fungi and other microorganisms in largely unmodified ecosystems

2021



Very limited confidence

Where natural ecosystems remain largely intact and pressures from human activities are minimised, fungi and microorganisms are likely to be in relatively good condition, notwithstanding some localised higher impacts. Very little is understood about population state and trends for the vast majority of organisms.

Ecosystems and habitats

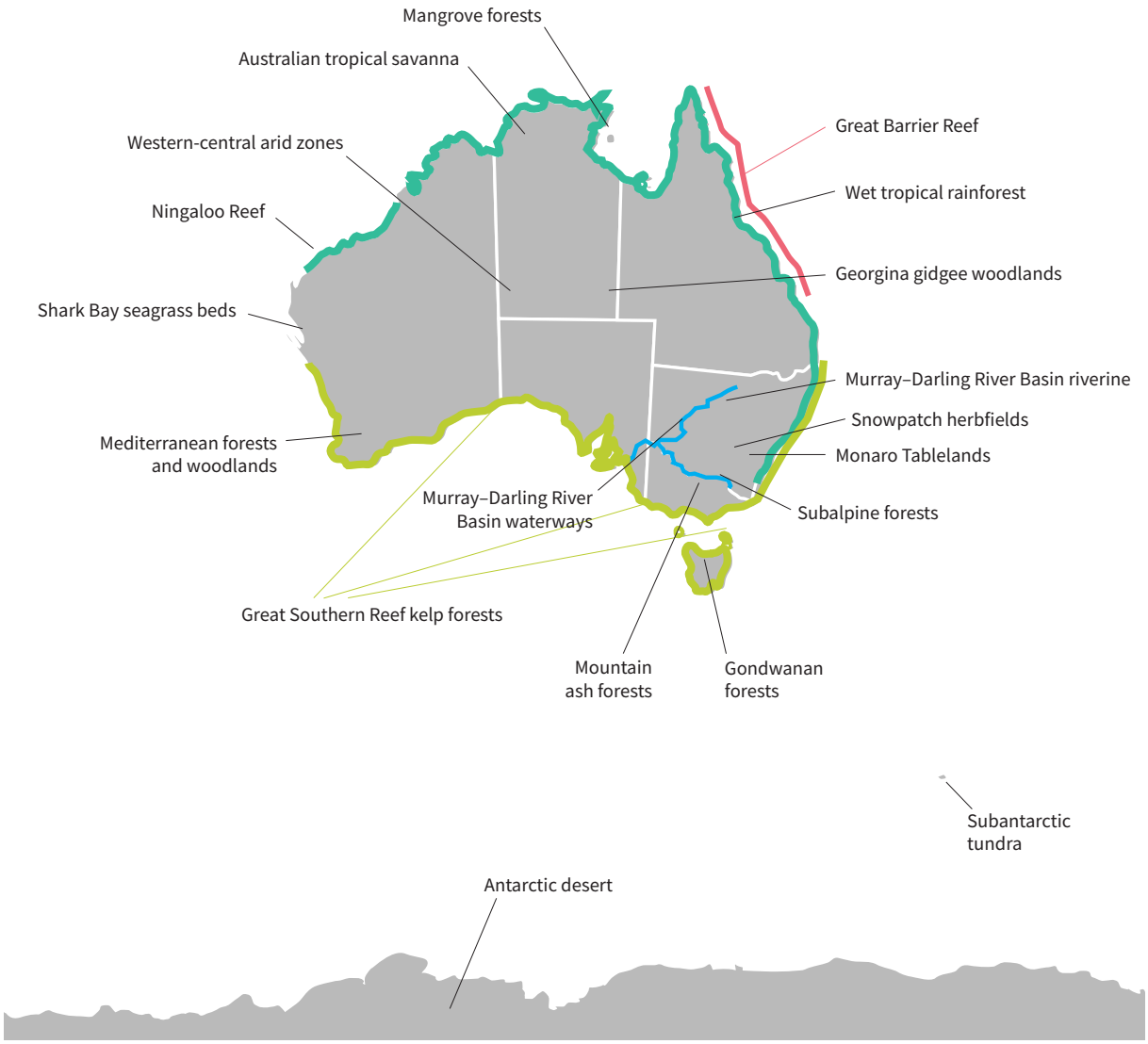
The Australian continent supports a vast array of ecosystem types. Australia's bioregion framework recognises 89 regions and 419 subregions based on common climate, geology, landform, native vegetation and species information, all of which are described in the Interim Biogeographic Regionalisation for Australia (see Native vegetation in the Land chapter). The bioregions and subregions are the reporting units for assessing the status of native ecosystems and their levels of protection in the National Reserve System (see Protected areas).

Globally, land-use change has had the largest impact on ecosystems: 75% of Earth's land surface has been significantly altered by human pressures (IPBES 2019). Climate change is exacerbating the impact of land-use change and other pressures on ecosystems (IPBES 2019).

The endpoint of disruption and degradation of ecosystems is irreversible collapse – when key defining features and functions of the ecosystem are lost. At least 19 Australian ecosystems have been reported to show signs of collapse or near-collapse, although none has yet collapsed across its entire distribution (Bergstrom et al. 2021). Ecosystems experiencing collapse span the Australian continent and include Antarctic and subantarctic ecosystems (Figure 21).

All 19 Australian ecosystems reported to be showing signs of collapse experience multiple pressures, including 12 that experience more than 10 pressures. In recent years, pressures have become more severe, widespread and more frequent. Nine ecosystems have recently experienced pressures unprecedented either in severity or spatial scale, relative to historical records (Bergstrom et al. 2021).

Habitat modification or destruction has occurred in 18 ecosystems, often at substantial levels. Climate change, primarily change in temperature, is a key pressure for 18 ecosystems, while invasive species affect 12 ecosystems, storms affect 13 ecosystems and fires affect 12 ecosystems. Assessing the risk of collapse of ecosystems provides



Source: Bergstrom et al. (2021)

Figure 21 Locations of ecosystems experiencing collapse

vital understanding about the root causes of decline and potential methods for recovery.

The Land chapter provides a detailed assessment of terrestrial ecosystem extent and condition (see the Land chapter). The state of native vegetation is described as mostly poor and deteriorating, with many native ecosystems having been extensively cleared and a large proportion of habitats degraded.

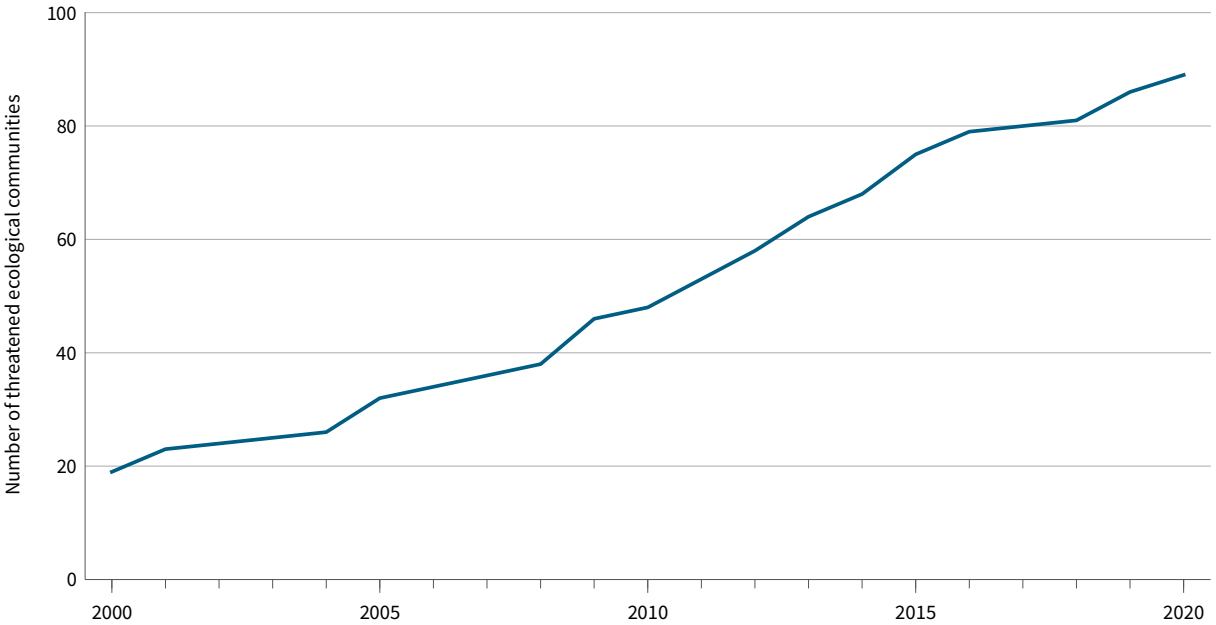
Threatened ecological communities

Threatened ecological communities are ecosystems in danger of being lost due to some threatening process, and that have been identified and listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or state legislation. Under the EPBC Act, threatened ecological communities can be listed as Vulnerable, Endangered or Critically Endangered. However, only threatened ecological communities that are Endangered or Critically Endangered are considered to be 'matters of national environmental significance' under part 3 of the EPBC Act. As a result, impacts from new development to vulnerable threatened ecological communities need not be referred to the Australian Government for assessment (Simmonds et al. 2020).

As of June 2021, 87 threatened ecological communities were listed under the EPBC Act: 41 are Critically Endangered, 44 are Endangered and 2 are Vulnerable. Since January 2016, there have been 14 new listings, including 9 in the Critically Endangered category (Figure 22).

Most listed threatened ecological communities occur in areas that have been heavily modified for agriculture or urban development. Ten of the new listings since 2016 occur in New South Wales, south-east Queensland and Victoria, 2 occur on the Swan Coastal Plain of Western Australia, and 1 each occur in South Australia and Tasmania.

The approach for listing on the International Union for Conservation of Nature (IUCN) Red List of Ecosystems is similar to the assessment process for ecosystems under the EPBC Act and consistent with assessments made according to the IUCN Red List of Species. The IUCN criteria have been used to assess 18 Australian ecosystems; 3 assessments were undertaken or led by the IUCN, and a further 15 were undertaken regionally in Australia.



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

Figure 22 Cumulative number of threatened ecological communities listed under the EPBC Act

Since 2016, 1 ecosystem has been added to the IUCN Red List: the Oyster Reef Ecosystem of Southern and Eastern Australia. The overall assessment for that ecosystem ranks the risk of collapse as Critically Endangered, with a high degree of confidence (Gillies et al. 2020) (see the Marine chapter for further details).

Soil ecosystems and biodiversity

Soils are fundamental to primary production, decomposition, and nutrient, carbon and water cycles. Below-ground organisms comprise a large fraction of global terrestrial diversity and are responsible for essential ecosystem functions and services, such as plant productivity, nutrient cycling, organic matter decomposition, pollutant degradation and pathogen control (Delgado-Baquerizo et al. 2020).

Soil microbes are vital for ecosystem health, supporting soil fertility, species diversity and resilience in natural ecosystems. Soil microbial communities and overlying vegetation are closely linked (Hamonts et al. 2017) (see case study: Vegetation cover as a national indicator of soil condition and erosion risk in the Land chapter). Soil biodiversity is also increasingly recognised as being linked to human health and wellbeing because it can suppress disease-causing soil organisms and influences the quality of food, air and water (Wall et al. 2015). Land degradation causes a decline in soil microbial activity, and agricultural practices have strong impacts on microbial community composition (Gellie et al. 2017).

Pressures on soil ecosystems are immense. Some 45% of the nation's soil is used for agricultural production, with 84% of this used for grazing, 8% for cropping, and the remainder for forestry and other practices. Demands on soil resource are increasing, such as needing to produce more food and at the same time sequester carbon to mitigate climate change (Bennett et al. 2019). The Land chapter describes the condition of soil in Australia as 'poor' and 'deteriorating', based on reductions in below-ground carbon, continued erosion and reduced groundcover (see the Land chapter).

The soil microbiome is one of the most genetically and ecologically diverse communities on Earth, but is poorly understood. However, metabarcoding of environmental DNA (eDNA) (see case study: Genetic approaches to information gathering) is increasingly proving to be an effective and efficient method to survey important groups such as soil bacteria and fungi where morphological identification is notoriously problematic. For example, scientists have recently used eDNA techniques to demonstrate the return of the native soil bacterial community in revegetated areas (Gellie et al. 2017, Yan et al. 2020).

The Australian Microbiome Initiative is a continental-scale, collaborative project aspiring to characterise the diversity and ecosystem service provision of the microorganisms inhabiting natural Australian ecosystems. It is collecting DNA sequence information about microbial community composition across a range of different sites to create a reference map of Australia's soil (see Soil in the Land chapter).

Aquatic ecosystems and habitats

The widespread rainfall deficiencies across Australia from 2017 to 2019, accompanied by high maximum and minimum temperatures, saw a return to drought conditions over much of Australia (see the Climate chapter). These conditions had a significant impact on the quantity and quality of surface water, recharge of groundwater resources, terrestrial aquatic

environments, and Indigenous water values and cultural flows. Streamflows in most rivers across south-eastern Australia were lower than average, with many rivers recording their lowest flows on record. However, heavy rainfall across the Upper Diamantina and Georgina River catchments in early 2019 generated run-off into Kati Thandi / Lake Eyre Basin. Although 2020 saw many coastal areas around Australia recovering from the drought conditions of the previous years, the Murray–Darling Basin continued to experience drought.

The Inland water chapter describes changes in water flows in Australian catchments since 2016 (see the Inland water chapter).

Australia's freshwater ecosystems and biodiversity face many pressures from humans. In much of Australia, especially the south-east, the greatest threat is the modification of water processes that has resulted from river regulation, surface water and groundwater extraction, and other water resource developments. Altered water flows, of both surface waters and groundwaters, has resulted in further changes to water and soil quality, including salination and acidification from the exposure of sulfidic sediments (Capon et al. 2017). Other pressures include barriers to fish movement, invasive species, habitat loss and alteration, and commercial and recreational fishing (Koehn et al. 2020b).

The Murray–Darling Basin spans a large area of south-eastern Australia, and is of significant environmental, cultural and economic value to Australia. It is home to 16 internationally significant wetlands, 35 endangered species and 98 different species of waterbirds. More than 2.2 million people live in the Basin, including people from 40 First Nations, and more than 4 million people depend on the Basin for everyday water needs. Basin rivers and catchments are mostly in poor and very poor condition (see the Inland water chapter), and native fish populations have declined by more than 90% in the past 150 years – a trend that appears to be continuing today (Koehn et al. 2020a).

Surface water diversions and extensive river regulation, combined with climate change, have resulted in major changes to flow and flood regimes for rivers and wetlands in the Basin. The Commonwealth *Water Act 2007* legislates for conservation of the Basin Ramsar wetlands and enacts this through the Murray–Darling Basin Plan, a statutory instrument under the Water Act for returning water to the environment by reducing the amount taken for irrigation and other consumptive uses. The environmental objectives of the Basin Plan are to protect and restore flow-, flood- and groundwater-dependent ecosystems (or 'water-dependent ecosystems' including rivers, lakes, flood plains and other wetlands) and their ecosystem functions, and ensure that they are resilient to climate change and other threats. The Basin-wide Environmental Watering Strategy (MDBA 2019) provides details of how the environmental objectives of the Basin Plan are to be implemented, including expected outcomes for river flows and connectivity, native vegetation, waterbirds, and fishes.

The 2020 Basin Plan evaluation found that its implementation over the previous 7 years was 'having a significant and positive impact on the Basin environment' (MDBA 2020). Environmental water has supported periods of re-connection of isolated reaches along river channels, and freshwater ecosystems receiving environmental water benefited from flows, with measurable improvements for flow-dependant ecosystems and species following individual watering events (Cosier et al. 2017). However, other reports have highlighted a major shortfall in restoring river flows to wetlands (Colloff et al. 2020), and the very limited monitoring of aquatic ecosystems has mostly highlighted temporary localised

positive responses (Chen et al. 2020). For example, the extent, magnitude and duration of flooding of wetland woody vegetation communities is considered to be inadequate, in most cases, to meet the ecological requirements needed to maintain their extent and condition (Chen et al. 2020).

Assessments of the state and trend of threatened species in the Basin is limited to flow-dependent fish and waterbirds, and these assessments tend to be species-specific, with a focus on particular regions. Recent assessments have shown positive outcomes for some threatened species in some locations at some points in time, but monitoring and reporting on the state and trend of threatened species in the Basin is largely inadequate for assessing whether the Basin Plan is achieving its environmental objectives (Ryan et al. 2021).

Case study Remediating erosion after bushfires

The NSW South Coast was hit hard by the January 2020 bushfires. Heavy rains immediately after the fires resulted in ashy sediment flowing rapidly into the estuaries.

With a bushfire recovery grant, Local Land Services and the Mogo and Batemans Bay Local Aboriginal Land Councils joined forces to fortify areas of high run-off in the catchments of the Clyde and Deua rivers. The team installed 300 ecologs made from 100% coconut fibre compacted into an outer mesh of bristle coir twine and jute mesh (Figure 23).

This successful project has helped alleviate damage to aquatic ecosystems, including valuable areas such as saltmarsh, mangroves and seagrass beds that provide fish habitat and are a food source.



Photo: James Cornwell, Local Land Services, New South Wales

Figure 23 Batemans Bay Local Aboriginal Land Council Ranger Group working in the Clyde Catchment to reduce effects of sedimentation on waterways

Wetlands and billabongs

There are nearly 34 million hectares of wetlands in Australia (see the Inland water chapter), covering 4.4% of the continent (Bino et al. 2016), about half of which is floodplains and swamps. Wetlands support relatively high numbers of species found nowhere else, which are at risk of extinction (Silcock & Fensham 2018).

The Convention on Wetlands of International Importance (the Ramsar Convention) is a global environmental treaty that aims to provide a framework for promoting the conservation and wise use of wetlands and their resources. Australia has 65 Ramsar sites, covering more than 8.3 million hectares (Bino et al. 2016). Wetlands often are disproportionately affected by changes in agricultural and urban landscapes (Bino et al. 2016). They have been extensively cleared, sown to pasture species, had their flows altered, and been subject to concentrated grazing pressure and weed invasion. They are also vulnerable to further hydrological changes and drying under future climate change scenarios (Finlayson et al. 2017). The return to drought conditions since 2016, in conjunction with increased consumptive water use, has resulted in decreased flows into wetlands and reduced inundation (see case study: Filling of Narran Lakes/Dharriwaa in the Inland water chapter).

Wetland ecosystems hold significant ecological, recreational, spiritual, cultural and economic significance for Indigenous Australians. In some areas of central and northern Australia, wetlands and billabongs are particularly threatened by invasive feral ungulates, including water buffalo, pigs and cattle. Researchers have been working with the Ngukurr Yangbala Indigenous rangers in the South East Arnhem Land Indigenous Protected Area to describe changes in billabong condition related to feral ungulate disturbance and the cultural impacts on local Indigenous people (Russell et al. 2021). Indigenous knowledge holders revealed that, historically, yarlbun (water lily) grew in billabongs year-round and was a staple part of people's diets. However, since the introduction of hard-hooved ungulates and their subsequent proliferation and invasion, Indigenous people report substantial declines in the yarlbun cover of billabongs in the late dry season, when water resources become scarce and animals concentrate around the persisting billabongs. Indigenous ecological knowledge suggests that some billabongs have passed an ecocultural threshold indicated by a shift from a yarlbun-dominated system to a turbid, sediment-dominated system driven by feral ungulates (Ens et al. 2016, Russell et al. 2021).

Assessment Aquatic ecosystem condition

2021



Adequate confidence

Aquatic ecosystem condition depends on the location of the ecosystem, with ecosystems in more populated regions experiencing higher pressures than those in less populated regions.

Related to United Nations Sustainable Development Goal targets 6.6, 15.1, 15.5

Assessment Aquatic ecosystem condition – northern and central Australia

2021



2016



Somewhat adequate confidence

Pressures on aquatic ecosystems in northern and central Australia are largely associated with feral animals and invasive weeds. Some localised areas experience significant very high impacts; however, in most places, impacts tend not to persist because of the episodic nature of rainfall and flow events. Aquatic ecosystems in these areas generally maintain minimum expected function, although there is reduced function, or even persistent transformation, in some localised areas.

Assessment Aquatic ecosystem condition – southern, eastern and south-western Australia

2021



2016



Adequate confidence

Pressures on aquatic ecosystems in southern, eastern and south-western Australia are persistent and extensive, resulting in very poor condition and reduced ecological function. Drought and fires over the past 5 years have compounded pressures from invasive species and human activities. River regulation and water abstraction place significant pressure on aquatic .

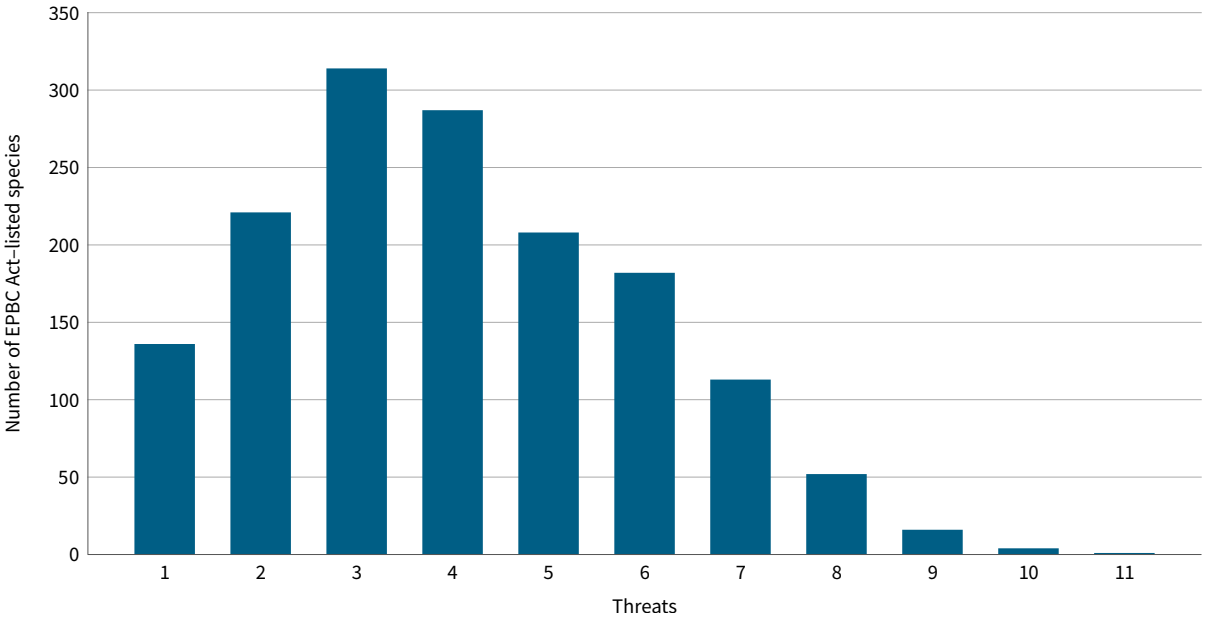
Pressures

Threats and key threatening processes

Identifying and mitigating threats is essential for recovery of threatened species and the restoration of species and their habitats. Most Australian species face multiple threats; on average, each threatened species faces around 4 different threats (Kearney et al. 2018a) (Figure 24). These threats may interact and be cumulative, such that the impacts are increased in an additive manner (see Interactions between pressures and cumulative impacts).

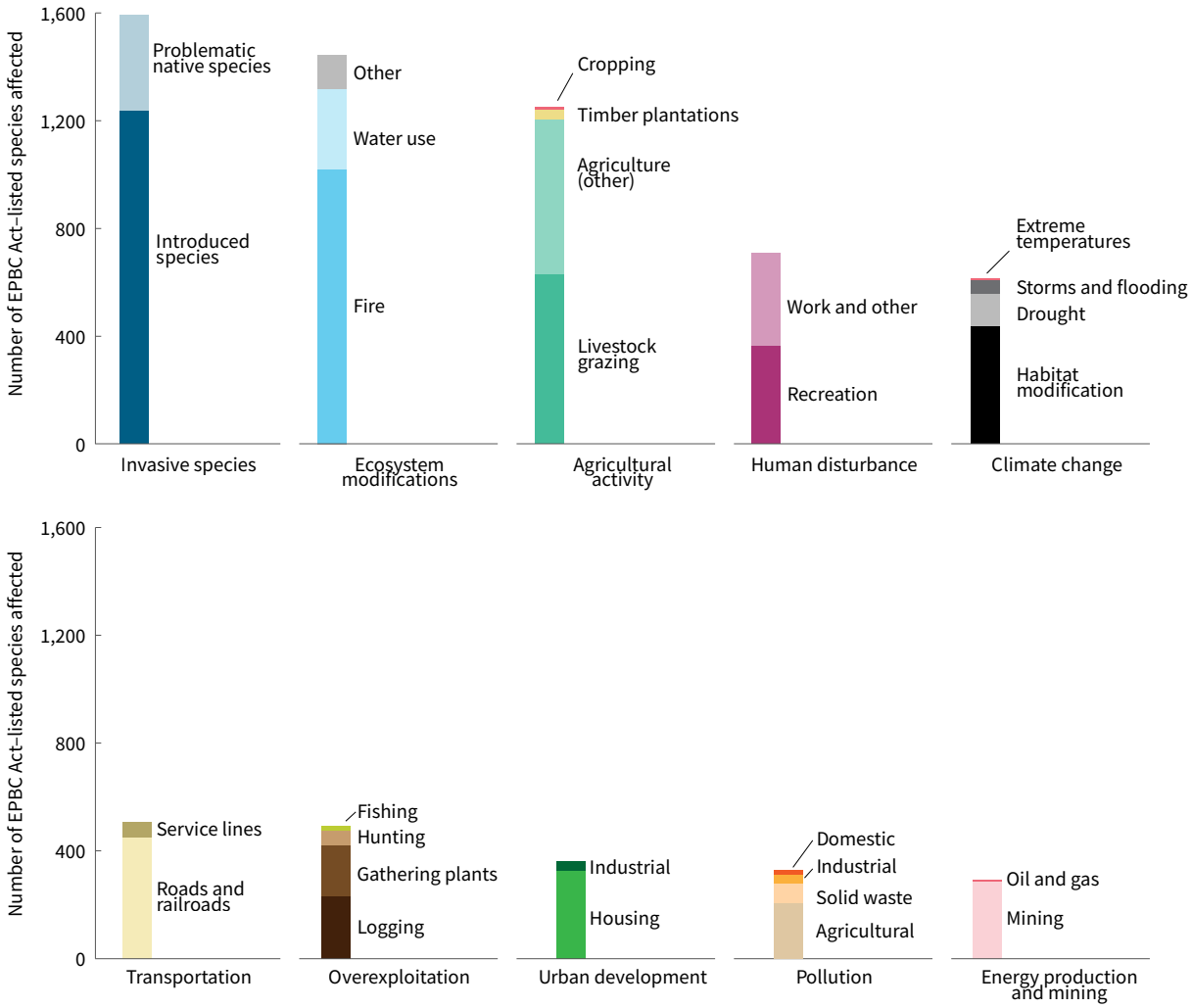
Invasive species, ecosystem modifications and agricultural activity are the threats identified in listing criteria of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as affecting the largest numbers of Australian threatened species (Figure 25) (Kearney et al 2018a).

The consequences of many threats are manifested through similar mechanisms. For example, habitat loss and degradation is the primary mechanism through which species are affected by various threats, including logging, mining, urbanisation, transportation, energy production and agricultural activity. As a result, habitat loss and degradation is the most dominant mechanism by which species are threatened in Australia, with nearly 70% of Australian threatened taxa impacted (Ward et al. 2021).



EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*
Source: Kearney et al. (2018b)

Figure 24 Number of threats listed as impacting EPBC Act–listed threatened species



EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*
Notes:
1. *n* = 1,533
2. Each graph is scaled according to the number of taxa listed under the *Environment Protection and Biodiversity Conservation Act 1999* as being affected by each threat category (e.g. Urban development). Each chart segment represents a subclass threat (e.g. Housing). The threat category 'Geological events' is not shown here because it impacts <20 species, and subclass threats that impact <5 taxa (e.g. Renewable energy) are not shown because they were too small to be displayed effectively.
3. 'Agriculture (other)' includes land clearing, habitat fragmentation and/or habitat degradation.

Source: Reproduced with permission from Kearney et al. (2018b)

Figure 25 Prevalence of threats to Australian threatened taxa

Key threatening processes

A pressure can be identified and listed under the EPBC Act as a 'key threatening process' if it threatens the survival, abundance or evolutionary development of a native species or ecological community.

Currently, 21 key threatening processes are listed under EPBC Act:

- 13 relate to pressures from invasive species
  - Aggressive exclusion of birds from potential woodland and forest habitat by over-abundant noisy miners (*Manorina melanocephala*)
  - Competition and land degradation by rabbits
  - Competition and land degradation by unmanaged goats
  - Invasion of northern Australia by Gamba grass (*Andropogon gayanus*) and other introduced grasses
  - Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants
  - Loss of biodiversity and ecosystem integrity following invasion by the yellow crazy ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean
  - Novel biota and their impact on biodiversity
  - Predation by European red fox
  - Predation by exotic rats on Australian offshore islands of less than 100,000 ha
  - Predation by feral cats
  - Predation, habitat degradation, competition and disease transmission by feral pigs
  - The biological effects, including lethal toxic ingestion, caused by cane toads (*Bufo marinus*)
  - The reduction in the biodiversity of Australian native fauna and flora due to the red fire ant (*Solenopsis invicta*)
- 3 relate to pressures from pathogens or disease
  - Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*)
  - Infection of amphibians with chytrid fungus resulting in chytridiomycosis
  - Psittacine circoviral (beak and feather) disease affecting endangered psittacine species
- 4 relate to population pressures
  - Incidental catch (bycatch) of sea turtles during coastal otter-trawling operations (which drag a large net along the ocean floor) within Australian waters north of 28 degrees South
  - Incidental catch (or bycatch) of seabirds during oceanic longline fishing operations
  - Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris
  - Land clearance
- 1 relates to climate change
  - Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases.

No new key threatening processes have been listed since 2014, although a potential key threatening process is currently under review – fire regimes that cause biodiversity decline.

Climate change

Temperatures throughout Australia are continuing their long-term increasing trend, with the strongest warming occurring in the central and eastern interior of the continent (see the Climate chapter). On the other

hand, temperatures have been locally stable or have decreased in some parts of north-west Australia where rainfall has increased substantially. Rainfall is generally decreasing in the south of Australia and increasing in the north, but with great variability over time. Severe drought affected many parts of eastern Australia from 2017 to 2019, extending to cover much of the continent in late 2018 and 2019 and easing over most areas during 2020.

Sea surface temperatures in the Australian region have also been increasing, and global sea level rise is accelerating. The impacts of climate change on Australian marine ecosystems are relatively well documented in comparison with terrestrial and freshwater systems. The Marine and Coasts chapters describe various impacts of climate change on biodiversity, such as the impact of marine heatwaves on marine ecosystems (see the Marine and Coasts chapters).

Climate impacts on terrestrial biodiversity

Useful information for Australia has been consolidated recently from local ecological knowledge and observations (Prober et al. 2019), assessment of long-term data where it exists (Greenville et al. 2018, Hoffmann et al. 2019), and direct observations of the impacts of climate change on biodiversity and ecosystems (Hughes et al. 2019). A collection of climate change anecdotes drawn from 326 observers from around Australia creates a picture of widespread, often subtle or gradual changes (lifecycle shifts, changing abundances, range expansions and contractions) across the continent, punctuated by extreme events such as fires, unprecedented droughts and other causes of mass mortality of biodiversity (Prober et al. 2019).

In many cases, the impacts of climate change on biodiversity are exacerbated by other pressures such as land clearing and invasive species, but in some cases impacts can be unequivocally attributed to climate change (Hughes et al. 2019).

Increases in extreme temperature events have been recorded across Australia. Data from the Australian Long Term Ecological Research Network have been used to examine ecosystem responses to changes in climate and disturbance regimes from plots in tropical savanna, alpine systems, temperate heathlands and temperate woodlands. A range of biodiversity responses to climate were recorded, including decreases in some species and increases in others. For example, in the Alpine Plot Network, the numbers of mountain pygmy possum (*Burramys parvus*), which is a specialised alpine species, declined significantly over the monitoring period (35 years). By contrast, the average number of bush rats (*Rattus fuscipes*), which is a generalist species that lives in many regions, almost doubled (Greenville et al. 2018).

Alpine ecosystems and biodiversity in Australia are particularly vulnerable to climate change that affects snow depth and the spatial and temporal extent of snow, which have all declined since the late 1950s (BOM & CSIRO 2020). Long-term monitoring of alpine vegetation in Australia has shown shifts in plant species composition and diversity, changes in the timing of flowering, and declines in endangered fauna such as the mountain pygmy possum (Hoffmann et al. 2019).

The ranges of the majority of Australia's eucalypt species are predicted to shrink in size over the next 60 years (González-Orozco et al. 2016). Eucalypts are mostly endemic to Australia (i.e. found nowhere else) and dominate forest canopies and ecosystems across the continent. Approximately 90% of the current areas with concentrations of palaeo-endemism (i.e. places with eucalypt species that were once widespread and are

now restricted to small ranges) are predicted to disappear or shift their location, and this is likely to have significant flow-on effects for ecosystem structure and function.

Climate change is increasingly recognised in threatened species recovery planning as a current and future risk. However, only a relatively small proportion of recovery plans that list climate change as a threat identify any specific actions to mitigate the threat, other than monitoring change (Hoeppner & Hughes 2019). Managing and reducing other threats that decrease the resilience of threatened species populations to climate change is often prioritised but rarely linked to the specific threats of climate change.

Climate impacts on aquatic biodiversity

Aquatic ecosystems and biodiversity are recognised as being among the most vulnerable to climate change. They experience both local changes and the cumulative effects of changes in the surrounding landscape, as well as exposure to a wide range of extreme climatic events such as floods and droughts. For example, between late 2015 and early 2016, mangroves along a 1,000 km stretch of coastline in the Gulf of Carpentaria in northern Australia suffered significant mortality. This happened during an underwater heatwave (which was also responsible for bleaching on the Great Barrier Reef) in combination with a severe drought and a temporary drop in sea level due to a strong El Niño event (Duke et al. 2017) (see Marine heatwaves in the Extreme events chapter).

Aquatic ecosystems in coastal areas are also affected by sea level rise and storm surge associated with intense storms. Along with structural changes and damage, these will bring changes in water salinity that can have long-term effects on wetland flora and fauna (Finlayson et al. 2017). Changes in salinity are likely to be particularly important in coastal regions because salinity tends to be a major influence on ecosystem composition, structure and function (see the Coasts chapter).

Altered water quality, as well as quantity, will be a major trigger for climate change effects on freshwater biodiversity. For example, the combination of hot conditions, low flows and significant algal blooms during the recent major drought (2018–20) resulted in mass fish kills in the Murray–Darling Basin (Koehn et al. 2020a). The recent extreme hot and dry weather events in the northern Basin have been amplified by climate change. Future changes in the global climate system are likely to have an even more profound impact on the hydrology and ecology of the Murray–Darling Basin, and increase the risk of fish deaths in the future (Vertessy et al. 2019).

Much of Australia has limited water resources, and there is limited scope for freshwater species to move to more favourable conditions as the climate changes. Species losses under future climates are likely to be high, particularly for inland regions of Australia. Climate change is predicted to cause substantial changes to the mix of species in Australian rivers well before the end of this century (James et al. 2017).

Changing fire regimes

Fire regimes across the globe are continually being modified due to changes in land use, land management and climate conditions. Fire regime components, including fire season, fire intensity and fire frequency, vary dramatically across Australia. Fire frequency can be as high as every year in some areas of the northern Australian savanna, whereas fire intervals may be measured in centuries in the highest rainfall areas of southern Australia. In the savannas, fire intensity varies with fire frequency and

season, with the most intense fires occurring late in the dry season when fuel loads are high and conditions are at their most dry. Very high-intensity fires are usually only associated with low-frequency fire intervals in the tall eucalypt forests of southern Australia (see Bushfires – summer 2019–20).

Contemporary fire regimes are increasingly impacted by human activities and climate change. A clear trend towards more dangerous weather conditions for forest fires in Australia has been observed since the mid-20th century (Harris & Lucas 2019). The Forest Fire Danger Index (FFDI) is commonly used in Australia to assess weather. Aggregated over the fire season, the FFDI shows a significant increasing trend since the 1970s over most forested areas of south-eastern and south-western Australia (Abram et al. 2021). In general, this increase comes more from a lengthening of the fire season than from an intensification of the peak of the season. However, the number of days with a fire danger of very high or above has also increased. The exceptional 2019–20 fire season in temperate Australia occurred in a period when numerous indicators of fire weather aggregated over the season were at record high levels (see Bushfires – summer 2019–20). Recent evidence also indicates a trend in coastal south-eastern Australia for more frequent dry lightning events since 1979, a key natural source of wildfire ignition (Abram et al. 2021).

Indigenous fire management

Indigenous people use fire as a tool to manage landscapes, burning in different locations and seasons, at different times of the day and under different weather conditions to achieve specific cultural objectives (Ens et al. 2017). Following European arrival and removal of Indigenous people from their traditional lands, systematic traditional landscape fire management largely ceased. In the northern savannas, regional fire regimes shifted to extensive and very hot, late-dry-season fires. Over the past decade, Indigenous cultural fire management has been revived, particularly in central and northern Australia.

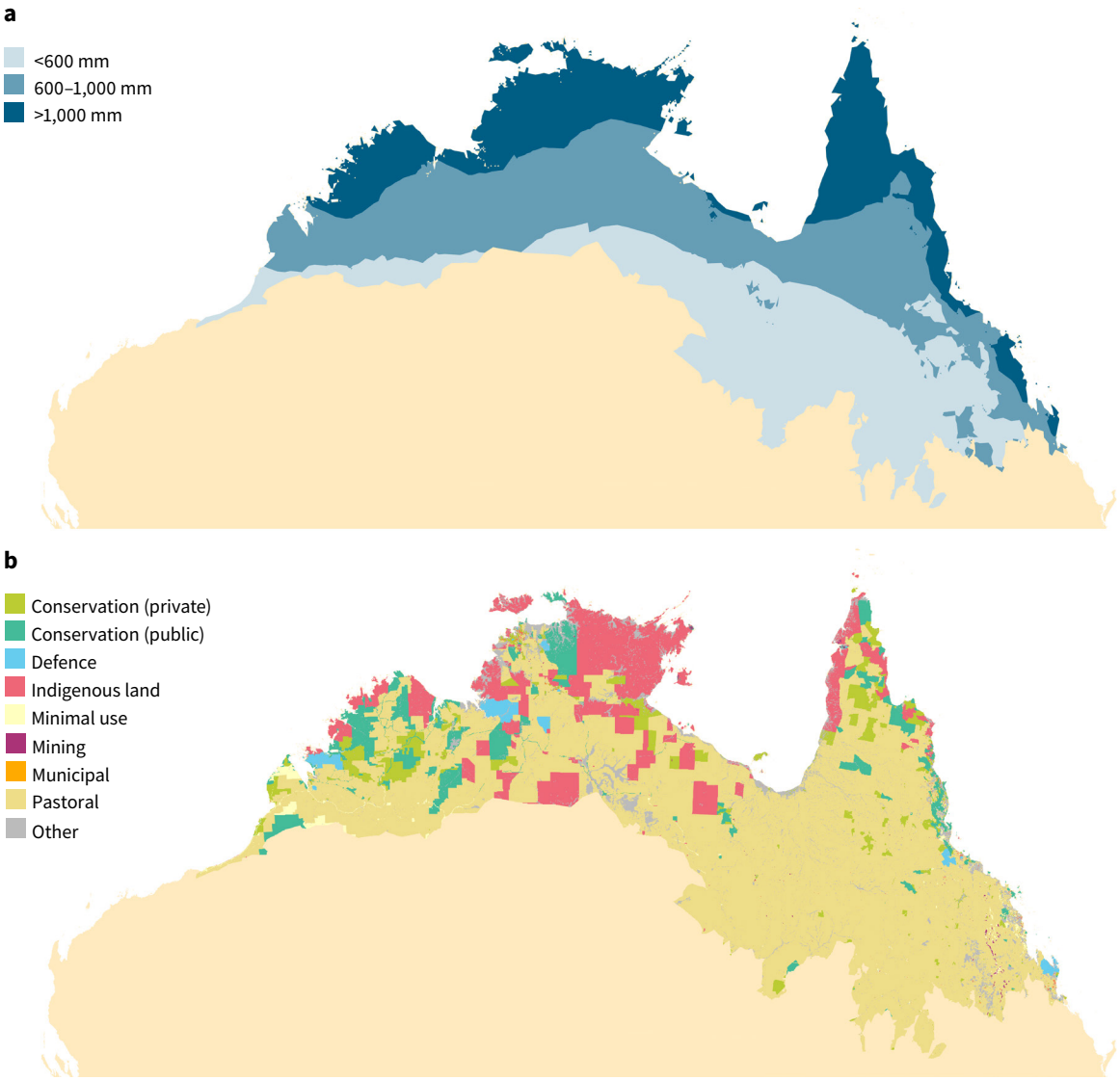
Methods to mitigate greenhouse gas emissions through shifting savanna burning to the early dry season are now being applied across northern Australia's savannas (see item case study: Western Arnhem Land Fire Abatement in the Land chapter). These methods are part of Australia's emissions reduction strategy, and provide tradeable carbon credits through the Australian Government's *Carbon Credits (Carbon Farming Initiative) Act 2011* and subsequent Emissions Reduction Fund legislation. The savanna burning methodology is validated and approved within the zones where annual rainfall is 600–1,000 mm (low-rainfall zone) and above 1,000 mm (high-rainfall zone) (Figure 26a).

Many projects are operated by Indigenous people on Indigenous lands, using local Indigenous knowledge and customary burning practices (Ansell et al. 2020). The new programs provide a major source of untied revenue and employment opportunities in community and ranger activities (Ansell et al. 2020). In recent years, the adoption of these methodologies has led to a change in fire practices across northern Australia (Ansell et al. 2020) and subsequent overall decreases in fire size (Figure 27a), intensity and seasonality, along with an increase in the number of small mosaic fires during the early dry season (Figure 27b,c).

Use of traditional fire practice has extended into management regimes across Australia. Indigenous rangers are now involved in planned burns in all states and territories, particularly in the desert bioregions and in the forests and woodlands of the Australian Capital Territory, central Victoria, New South Wales and the Midlands of Tasmania.

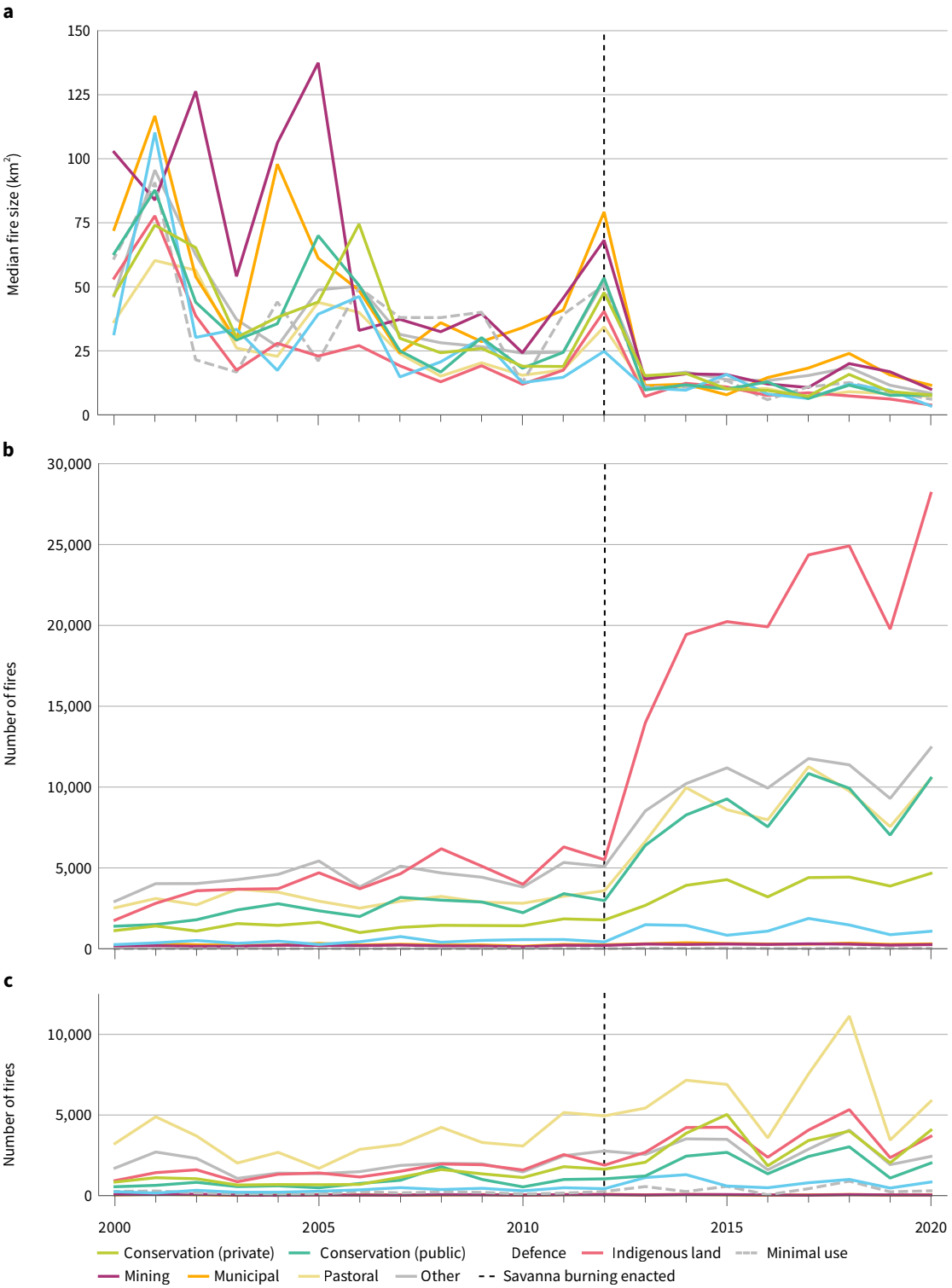
In southern Australia land tenure, habitat fragmentation and the increased risk posed by the complex mosaic of human habitation presents some unique challenges to the reinvigoration of traditional fire practices; nevertheless, programs are being implemented.

The co-benefits from savanna burning delivered to northern Australian Traditional Owners are derived through emissions abatement and carbon offset schemes, whereas in southern Australia the carbon co-benefits are through sequestration and the management of carbon stocks across the landscape. For many Traditional Owners, benefits also derive from discouraging weeds, recreating wildlife habitat, promoting bush tucker and minimising the opportunities for wildfire, all of which are culturally substantial and can be economically rewarding.



mm = millimetre
Source: Perry et al. (2021)

Figure 26 Distribution of (a) rainfall zones; (b) land tenure in the northern Australian tropical savanna region



km² = square kilometre; mm/yr = millimetres per year
Source: Perry et al. (2021)

Figure 27 Fires across land tenure types within tropical savanna in northern Australia showing (a) change in median fire size, and change in early dry season number of fires in the (b) high-rainfall (>1,000 mm/yr) and (c) low-rainfall (600–1,000 mm/yr) zones; vertical dashed lines represent the start of savanna burning in 2012

Impacts of changing fire regimes

Approximately two-thirds of species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in Australia are threatened by changing fire regimes (usually in concert with other pressures) (SG Kearney, University of Queensland, pers. comm., October 2020). The Threatened Species Scientific Committee is currently assessing 'fire regimes that cause biodiversity decline' as a key threatening process under the EPBC Act.

Although many Australian plant species are adapted to fire, sufficient fire-free intervals are needed to ensure that seed banks are adequately replenished to maintain future populations, and that juveniles of recruiting or resprouting plants become large enough to survive subsequent fires. Ongoing changes to fire conditions under future climates may expose many plant species to 'interval squeeze' – a narrowing of the favourable interval between fires, hence increasing local extinction risk by accelerating processes associated with population decline (Gallagher et al.) Conversely, the abundance of some plant species may decline where fire is excluded for too long. For example, fire intervals that are too short (less than 20 years) or too long (more than 50 years) both may result in reduced populations of the obligate seeder *Callitris verrucosa* (a conifer) within semi-arid mallee communities. Obligate seeders require fire to regenerate from seed in the soil. If fires are too frequent, juvenile plants are killed before they reach maturity to set seed; where fire intervals are too long, no new juveniles establish from seed and older plants die (Bradstock et al. 2006).

With changes in vegetation composition and structure, the suitability of vegetation for many animals species also changes (Clarke et al. 2021). For example, live mallee stems do not begin to produce hollows until 40 years after a fire, and the likelihood of mallee eucalypts containing hollows increases with age and reduces with repeat fires. Reducing the abundance of dead stems with hollows reduces the suitability of habitat for species such as microbats that depend on tree cavities in mallee vegetation (Senior et al. 2021).

However, many Australian animals are also resilient to a range of fire regimes, notwithstanding the significant immediate and long-term impacts of extreme bushfire events such as those that occurred in 2019–20 in southern Australia (see Bushfires – summer 2019–20). For example, across 6 replicated fire experiments in the savannas, very different fire regimes often had little or no detectable impact on species abundances. The most important effects of fire in the savannas was through habitat modification (Andersen 2021).

Extreme events

Many of the most significant impacts of climate change on biodiversity occur through extreme climate events. Scientists consider that trends in climate extremes may be more likely to trigger abrupt changes in ecological systems than trends in mean climate (Turner et al. 2020).

Long-term monitoring data from a wide range of Australian ecosystems show an increase in extreme climate events during the past decade (see the Extreme events chapter). Impacts can be especially severe when events are consecutive (occurring one after the other) or coincident (occurring at the same time). The increase in extreme events has resulted in many direct and indirect impacts on biodiversity (Greenville et al. 2018).

Heatwaves have intensified in Australia since 1950, with a consistent increase in peak temperature, number of events, frequency and duration (Trancoso et al. 2020). Wildlife and vegetation impacts due to extreme heat events are increasingly reported in both terrestrial

and marine systems (Ruthrof et al. 2018, Ratnayake et al. 2019). In particular, Australia has experienced several marine heatwaves over the past 5 years, and the subsequent impacts on marine fauna and ecosystems such as kelp forests and coral reefs have received much public interest, as well as attention from researchers (see case study: Marine heatwaves in the Marine chapter).

Knowledge about the impacts of extreme heat on terrestrial fauna and flora is limited to a few species, and most accounts are anecdotal through traditional or social media. Flying foxes feature prominently in reports of mass mortality from heatwaves. An extreme heatwave in north Queensland in November 2018 resulted in the deaths of an estimated 23,000 spectacled flying foxes (*Pteropus conspicillatus*) and 10,000 black flying foxes (*P. alecto*) over 2 days. The spectacled flying fox was uplisted from Vulnerable to Endangered in 2019.

The risk of bird mortality during heatwaves is predicted to increase substantially over much of Australia for the rest of this century (Conradie et al. 2020). This is compounded by unpredictable water availability under climate change, so that dehydration becomes a lethal factor. Birds may also abandon nests and lose body condition after heatwaves due to changes in food intake and because heat dissipation behaviours such as panting or wing spreading impair foraging efficiency (Sharpe et al. 2019).

Climate change is predicted to increase the intensity of tropical cyclones over the coming decades with compounding impacts from flooding rains and storm surges in coastal regions (see Coastal erosion and inundation in the Extreme events chapter, and the Coasts chapter). Extreme convective storms that are often accompanied by hail are also likely to become more frequent (Bruyère et al. 2019) (see Hail and convective storms in the Extreme events chapter).

Bushfires – summer 2019–20

The bushfires that occurred through the 'Black Summer' of 2019–20 were unprecedented in their extent and severity (see the Extreme events chapter). Native species were severely affected, and continue to be affected, in many ways. The Australian Government committed $200 million to wildlife and habitat recovery following the bushfires.

Vast swathes of land were impacted by the bushfires, with approximately 6.5 million hectares of native forest burned in New South Wales, Victoria and the Australian Capital Territory, as well as grasslands, agricultural lands, commercial forest plantations and peri-urban areas. A further 2 million hectares of forest area was burned across Queensland, South Australia, Tasmania and Western Australia. Although eucalypt forests were most affected, rainforests and vine thickets, coastal heath, and grasslands were also burned. Mediterranean, subtropical and temperate bioregions were all affected (Godfree et al. 2021). The vegetation was estimated to contain habitat for 832 species of native vertebrate fauna (Ward et al. 2020).

Whereas most fires are patchy, leaving some areas less severely burned than others and even some patches unburned, aerial reconnaissance of the megafire revealed that vast expanses of vegetation were severely burned. This included relatively well-protected habitat that usually serves as refuges for species during fires, such as deep gullies, rocky outcrops and riparian strips (Wintle et al. 2020).

It is estimated that the fires affected significant proportions of at least 3 World Heritage properties, including 54% of the Gondwana Rainforests of Australia (Queensland and New South Wales), 81% of the Greater Blue Mountains Area (New South Wales) and 99% of Old Great North Road (an Australian convict site World Heritage property in New South Wales).

The full impact of the bushfires on biodiversity will not be known for many years, and the conservation status of many species thought to be secure will need to be reassessed.

Plants

The forests most affected by the fires are dominated by eucalypts and are among the most fire-prone in the world; however, only small percentages (less than 2%) usually burn each year, even in more extreme fire seasons (Boer et al. 2020). Although many Australian plant species have evolved with fire and are highly fire-adapted, the ability of plant communities and species to recover and regenerate after bushfires of the intensity and scale that occurred in 2019–20 is poorly understood (Godfree et al. 2021).

The 2019–20 bushfires increased the extinction risk of many plant species, including many that were already listed as Endangered or Critically Endangered under the EPBC Act. An assessment of the plant species most requiring urgent management intervention after the bushfires listed 486 Endangered or Critically Endangered species from a large variety of vegetation types, spanning rainforest shrubs to herbaceous plants from subalpine areas (Gallagher 2020a). These species all had more than 80% of their range burned, were listed as Critically Endangered or Endangered under the EPBC Act or equivalent state legislation, or were identified at high risk because of characteristics known to cause decline in plant populations.

Threatened ecological communities

For threatened ecological communities, 4 were assessed as having had more than 50% of their distribution within the mapped fire extent, and a further 3 had more than 30% of their distribution within the mapped fire extent (DAWE 2020a). The 4 most affected threatened ecological communities include wet sclerophyll forest, heathland, peatland and an aquatic root mat community in the caves of the Swan Coastal Plain; all are listed as Endangered. The 3 next most affected were grassy woodland and rainforest communities, and all are listed as Critically Endangered.

Case study Recovering threatened ecological communities in Victoria's high country following the 2019–20 bushfires

Victoria's high country suffered badly in the summer bushfires of 2019–20. The region has more than 4,000 hectares of Alpine peatlands – an endangered ecological community. Alpine peatlands are crucial for providing habitat and for modulating water flow. The health of the peatlands influences the health of water further down the catchment and is therefore important for the whole community – people, plants and animals.

One bushfire recovery project in the region is working to control feral animals, to protect the peatlands from trampling and overgrazing. Invasive weeds are being removed in the Alpine National Park to protect endangered communities from further impacts. This project is being delivered by the North East Catchment Management Authority in partnership with Parks Victoria, Mount Hotham Alpine Resort Management Board and HVP Plantations, with support from the Australian Government.

Animals

Nearly 3 billion animals are estimated to have been killed or displaced during the fires (van Eeden et al. 2020), including:

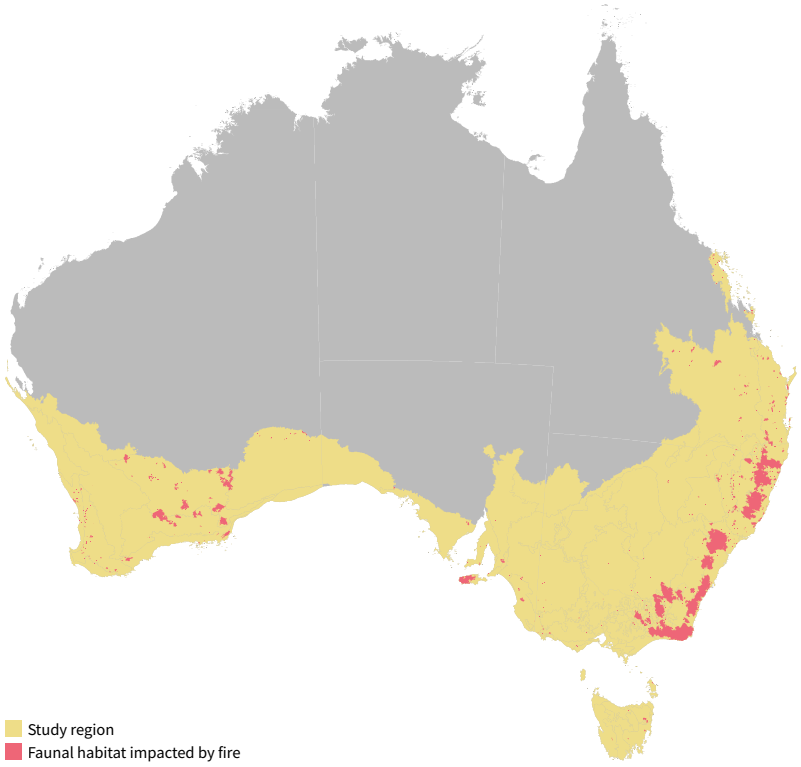
- 143 million mammals
- 2.46 billion reptiles
- 181 million birds
- 51 million frogs.

In January 2020, the Australian Government provided emergency funding support to zoos and wildlife carers to treat the injured wildlife and establish insurance populations for species at risk. Funding recipients reported that more than 9,000 animals were rescued, 3,700 treated and around 1,000 rehabilitated. More than 5,300 animals have since been released back into the wild.

The loss of food resources and shelter leaves many surviving individuals vulnerable to starvation and exposure to predators over the longer term. Increased competition with other individuals and species for the resources that remain can also affect survival.

An assessment focused on Australian fauna estimated that 378 birds, 254 reptiles, 102 frogs, 83 mammals and 15 freshwater fish have habitats in areas burned by the fires (Figure 28):

- 70 species had more than 30% of the habitat in their range burned and 21 of these were already listed as threatened
- 3 species had more than 80% of their habitat burned; 2 of these species are listed as Endangered under the EPBC Act – the Kangaroo Island dunnart (*Sminthopsis griseoventer aitkeni*) and the long-footed potoroo (*Potorous longipes*), while a third, Kate's leaf-tailed gecko (*Saltuarius kateae*) has a small range and is not listed.



Source: Ward et al. (2020)

Figure 28 Vertebrate fauna habitat burned during the 2019–20 bushfires

The Australian Government, through the work of its Wildlife and Threatened Species Bushfire Recovery Expert Panel, assessed the impacts of the bushfires on EPBC Act–listed threatened and migratory species (DAWE 2020a, DAWE 2020b). The March 2020 provisional list of animal species in need of urgent postfire management intervention covered 119 species: 23 reptile, 22 crayfish, 20 mammal, 17 bird, 16 fish, 16 frog and 5 invertebrates.

The priority animals were identified based on the extent to which their habitat has potentially been burned, whether they were already vulnerable to extinction, and the physical, behavioural and ecological traits that influence their vulnerability to fire. Preliminary assessments of species most affected indicate that 55 threatened and nonthreatened vertebrate taxa require detailed assessment or reassessment under the criteria of the EPBC Act.

Case study Recovering the Kangaroo Island dunnart

The Kangaroo Island dunnart (Figure 29) was listed as endangered before the 2019–20 bushfires, with only a few hundred estimated on the island. The bushfires were the largest in the island's recorded history – more than a third of the island and approximately 95% of the dunnart's range was burned.



Photo: Peter Hammond

Figure 29 Dunnart

The Wildlife and Threatened Species Bushfire Recovery Expert Panel, which was established to help inform the Australian Government's response to the bushfires, identified the dunnart as one of 119 animal species in need of urgent management intervention.

With bushfire recovery funding from the Australian Government, Natural Resources Kangaroo Island and the South Australian Government have been working with several partners, including Kangaroo Island Land for Wildlife, Australian Wildlife Conservancy, WWF Australia and the Foundation for Australia's Most Endangered Species, to monitor native species and put management projects in place.

A fenced safe haven and shelter tunnels were constructed on the island's west to help protect the remaining dunnart populations from feral cats. In April 2020, more than 70 infrared cameras were set up across the island to monitor both dunnart and predator movements.

Teams have now recorded the dunnart at 60 sites across the western end of the island. They have also noticed an increase in the number of smaller dunnarts, which may coincide with successful breeding during spring and summer followed by dispersal of the youngsters across the fire scar in autumn.

Although it is still a mystery how dunnarts survived in areas that were severely burned, the fact that they are returning to some of the worst affected areas is a promising sign for the future of the species, and is providing valuable information for future recovery efforts.

Invertebrates

Initial assessments by the expert panel included a small number of invertebrates and a group of spiny crayfish because there were recent comprehensive accounts of their distribution and ecology, and many spiny crayfish species were known to require urgent management intervention to prevent extinction. However, information on many other invertebrate groups is lacking, making an assessment of post-bushfire risk challenging (Wildlife and Threatened Species Bushfire Recovery Expert Panel 2020).

An assessment of the overlap of threatened invertebrate distributions with the 2019–20 bushfire areas identified 191 invertebrate species known or presumed to have been severely affected by the fires; a further 147 species are recognised as priorities for further assessment because of concern about likely impacts. The 49 threatened invertebrates that are most fire-affected (more than 30% of their range has been impacted) span an extensive taxonomic range, including freshwater mussels, shrimps, burrowing crayfish, land snails, spiders, millipedes, bees, dragonflies, caddisflies, mayflies, bugs and butterflies.

An assessment of the impact of the bushfires on invertebrates in New South Wales identified 29 species (2 dung beetles, 3 archaeid spiders, 4 spiny freshwater crayfishes, 4 drosophilid flies, 5 mygalomorphs and 11 land snails) where all known occurrences are contained within the fire zone (Hyman et al. 2020). Another 46 species had at least half of their known range contained within the fire zone. Given these

figures, the conservation status of many New South Wales species may require revision to recognise the higher level of threat, and active conservation actions will need to be taken to ensure the survival of these and other species.

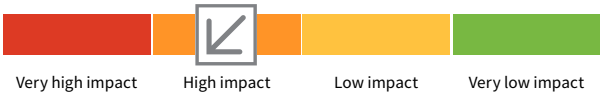
Freshwater species

The 2019–20 bushfires were followed by above-average rainfall in many catchments, which moved ash and sediment into rivers and creeks (see Bushfires in the Inland water chapter). More than 43 catchments were burned across a range of landscapes. This contamination had a major impact on freshwater species.

Kills of 27 species of freshwater and estuarine fish, along with 4 species of crustaceans were reported from New South Wales and Victoria (Silva et al. 2020). These include at least 1 species listed as Endangered (trout cod – *Maccullochella macquariensis*) and 5 species listed as Vulnerable. Almost all estuarine sites with records of fish kills in this fire season were downstream of burnt areas.

Assessment Pressures of climate change and associated extremes on biodiversity

2021



Adequate confidence

Climate change is having increasing effects on Australia's biodiversity, and the increased risk of fire and extreme events is likely to have the highest impacts.

Related to United Nations Sustainable Development Goal targets 13.1, 13.2, 15.5

Assessment Pressures from climate change on terrestrial species and ecosystems

2021



2016



2011



Adequate confidence

Pressure from climate change is increasingly recognised as a key threat to terrestrial ecosystems and species, and is projected to become more important in driving changes in terrestrial biodiversity into the future.

Assessment Pressures from climate change on aquatic species and ecosystems – southern, eastern and south-western Australia, including the Murray–Darling River

2021



Adequate confidence

The pressure from climate change on aquatic environments in southern and eastern Australia continues to have very high impact, with major effects on quantity and quality of surface water, recharge of groundwater resources, wetland environments, and Indigenous water values and cultural flows. The resilience of species and ecosystems in these environments is increasingly compromised as climate continues to change, and they are affected by extreme climate events and other pressures.

Assessment Pressures from climate change on aquatic species and ecosystems – northern and arid Australia

2021

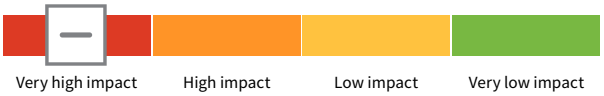


Adequate confidence

Climate change is not a strong pressure on aquatic environments over large parts of northern and central Australia, although there may be localised high impacts.

Assessment Changing fire regimes

2021



2016



2011

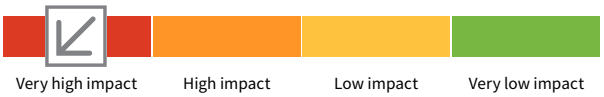


Somewhat adequate confidence

Changing fire regimes are a major pressure on Australian biodiversity, including threatened species. Climate change is resulting in more extreme fire weather conditions and changes in intensity, frequency and seasonality of fires. However, we are increasingly managing landscapes across Australia to limit the impact from wildfires through managed and prescribed burning, incorporating cultural burning practices.

Assessment Extreme events

2021



Somewhat adequate confidence

A growing body of evidence supports the very high impact of extreme events on species and ecosystems. The increasing frequency and intensity of extreme events is likely to result in persistent, extensive and cumulative very high impacts into the future.

Assessment ratings

For assessments in the ‘Pressures’ section

- **Very low impact:** Pressures do not degrade or only negligibly degrade the state of the environment.
- **Low impact:** Pressures minimally degrade the state of the environment over a small extent and/or with low severity.
- **High impact:** Pressures moderately degrade the state of the environment over a moderate extent and/or with moderate severity.
- **Very high impact:** Pressures strongly degrade the state of the environment over a large extent and with a high degree of severity.

Trend

- **Improving:** The situation has improved since the previous assessment (2016 state of the environment report).
- **Stable:** The situation has been stable since the previous assessment.
- **Deteriorating:** The situation has deteriorated since the previous assessment.
- **Unclear:** It is unclear how the situation has changed since the previous assessment.

Population

Population growth contributes to all the pressures described in this report. Each person added to our population increases demand on natural resources to provide food, shelter and materials for living.

Direct threats to biodiversity associated with human activity include those related to accommodating a growing population in cities and regional areas, with associated urban development and infrastructure for transport, power and services. Pressures also include disturbances associated with recreation and tourism, hunting, fishing and collecting, which can impact biodiversity in even the most remote areas of Australia.

Australia's population continues to increase – in September 2020 it was 25,693,059 people, with an annual growth rate of more than 220,000 people. Australia's population is growing fastest in our capital cities. Although human-dominated landscapes sometimes have high biodiversity, the mix of species is markedly different from that in natural landscapes. Globally, as a result of human-caused changes, at least 20% of species in terrestrial ecosystems are estimated to have been lost, with key areas rich in species found nowhere else (endemic hotspots) tending to have lost even more (IPBES 2019).

Urban development

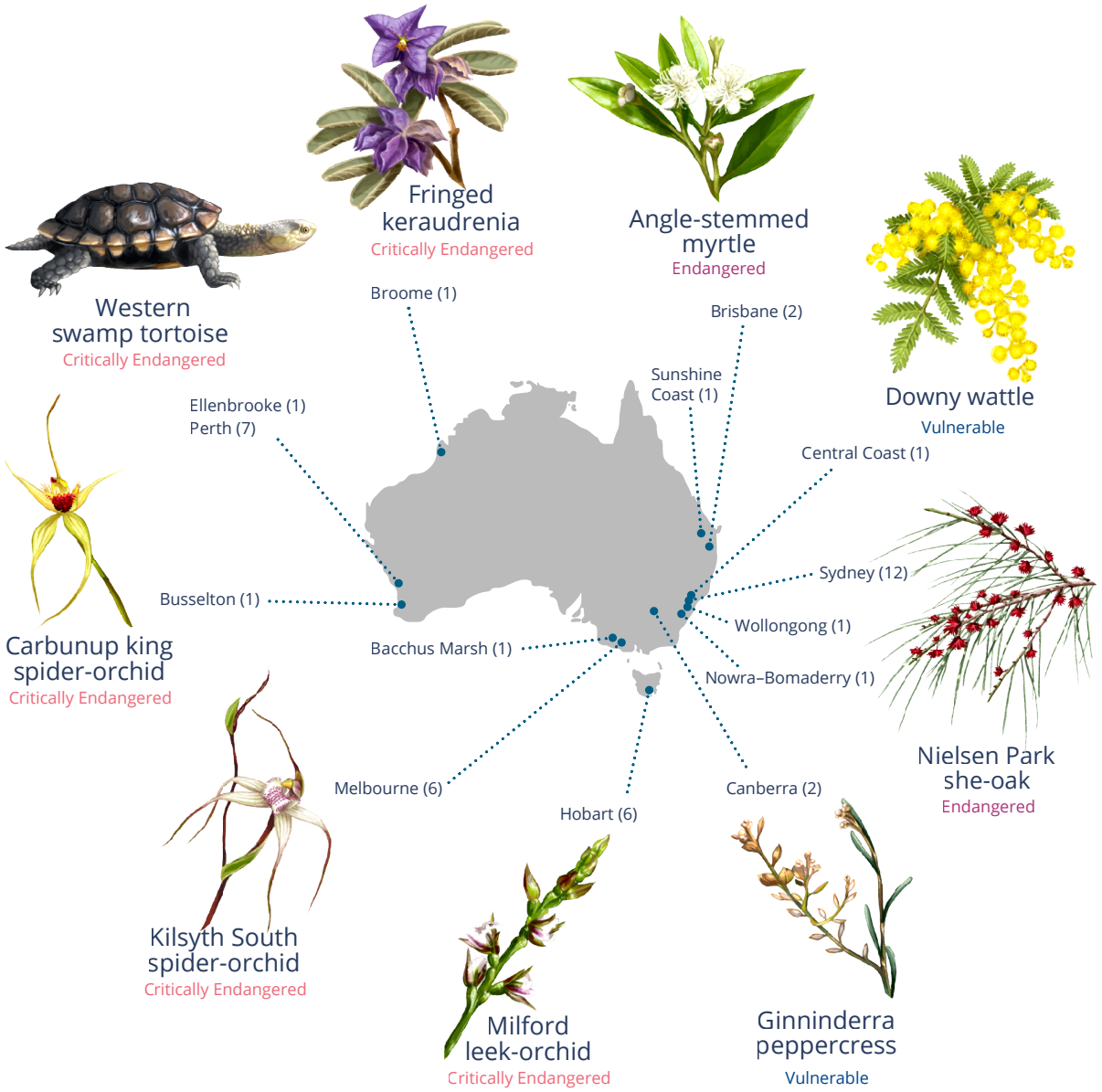
Population growth continues to put pressure on biodiversity in Australia's urban areas and in the peri-urban spaces between suburbs and rural areas. Australia's population is concentrated in our cities and this trend is increasing (see the Urban chapter). While population density is increasing in established inner urban areas, governments are supporting new greenfield developments offering larger and more affordable homes on the outskirts of urban areas. In contrast, growth in rural and remote areas of Australia is in decline.

The potential pressures from greater urban and peri-urban expansion include:

- land clearing
- less green space and tree canopy cover, at least in the early years, as existing vegetation is cleared for new development and new vegetation takes time to grow back
- smaller gardens; new suburbs in Australia have significantly less cumulative areas of private gardens than established suburbs
- greater pressure on our coasts and waterways; these high-value areas are attractive locations for homes.

The urban environment includes green spaces (e.g. parks, woodlands, nature conservation areas, gardens, sports fields) and blue spaces (e.g. creeks, rivers, dams, ponds, estuaries, wetlands). Green spaces in cities provide an important haven for biodiversity and may benefit both locally and nationally rare species (see the Urban chapter). It is estimated that 25% of all nationally listed threatened plants and 46% of nationally listed threatened animals can be found in Australia's cities and towns (ACF 2020). Thirty-nine species listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (37 plants and 2 animals) are thought to be urban-restricted in that their entire remaining distribution is contained within only 1 or 2 cities or towns (Soanes & Lentini 2019) (Figure 30). These species occur across many land types within cities, including roadsides, private land, golf courses and schools.

Increasingly, state and local governments and communities, Indigenous people, and nongovernment organisations are playing key roles in managing and improving the green



Note: The number of species per location is indicated in parentheses.
Source: Soanes & Lentini (2019)

Figure 30 Locations of urban-restricted threatened species across Australia

and blue networks in our urban environments. They are working collaboratively to reintroduce native species and plants, create urban forests, and instil principles of biodiversity-sensitive urban design in the design phase of urban infrastructure (see Bringing nature and green back in the Urban chapter).

Human activity

Increasing human activity creates demand for water, energy, fibre and timber, food products, metals, and minerals. It also generates a range of waste products at all stages of the production–consumption cycle, including solid waste, greenhouse and other gases, chemical waste, and sediment. Some of these

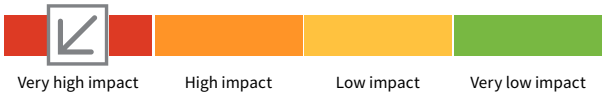
may end up as pollutants in our land, air, water or marine environments (see the Land, Air quality, Inland water and Marine chapters).

The impacts from roads, tourism, recreation, hunting, shipping, fishing and other disturbances can permeate into even the most remote protected areas. For example, millions of animals are struck and killed on Australian roads every year. Road mortality is the second biggest killer of endangered Tasmanian devils (*Sarcophilus harrisii*), with around 350 killed every year, and the largest cause of death of adult Endangered cassowaries (*Casuarius casuarius johnsonii*) in Queensland. Between 2006 and 2017, there were 31,626 admissions of 83 species of wildlife to the Australia Zoo Wildlife Hospital in Queensland (Taylor-Brown et al. 2019). Car strikes were the most common reason for admission (34.7%), with dog attacks (9.2%), entanglements (7.2%) and cat attacks (5.3%) also high.

Researchers have recently described a global restructuring of animal movement in response to human disturbances (Doherty et al. 2021). They found that human disturbance restricts the movement of some species where, for example, they encounter barriers such as roads or cannot move as efficiently through some altered habitats. On the other hand, movement may be increased if animals have to travel further to find food. For example, koala (*Phascolarctos cinereus*) movements are longer and more directed in areas where habitats are not well connected, because they have to travel further to reach food patches (Rus et al. 2021). Likewise, the daily movement distances of mountain brushtail possums (or bobuck – *Trichosurus cunninghami*) in central Victoria were 57% higher in remnant bushland along roadsides than in large forest areas. The consequences of altered movement can be profound, leading to declines in survival and reproductive rates, genetic isolation, and local extinction (Doherty et al. 2021).

Assessment Pressures from population

2021



Adequate confidence

Human activity and population growth are major drivers of many pressures on biodiversity. Impacts are associated with urban expansion, tourism, industrial expansion, pollution, fishing, hunting and development of infrastructure. The impacts from population growth are extensive and increasing in many areas.

Related to United Nations Sustainable Development Goal targets 6.3, 11.6, 12.1, 12.4

Industry

The absolute and relative extent of Australia's principal land uses, and land-use change over time, are summarised in the Land chapter (see the Land chapter). The distribution and extent of different land uses reflects the history and pattern of European settlement of Australia and the intersection of that settlement with climate and resources relevant to the production of food, goods and services. Globally, land-use change is the direct driver with the largest relative impact on terrestrial and freshwater ecosystems (IPBES 2019). In Australia, land use for production of energy and resources continues to intensify.

Production systems

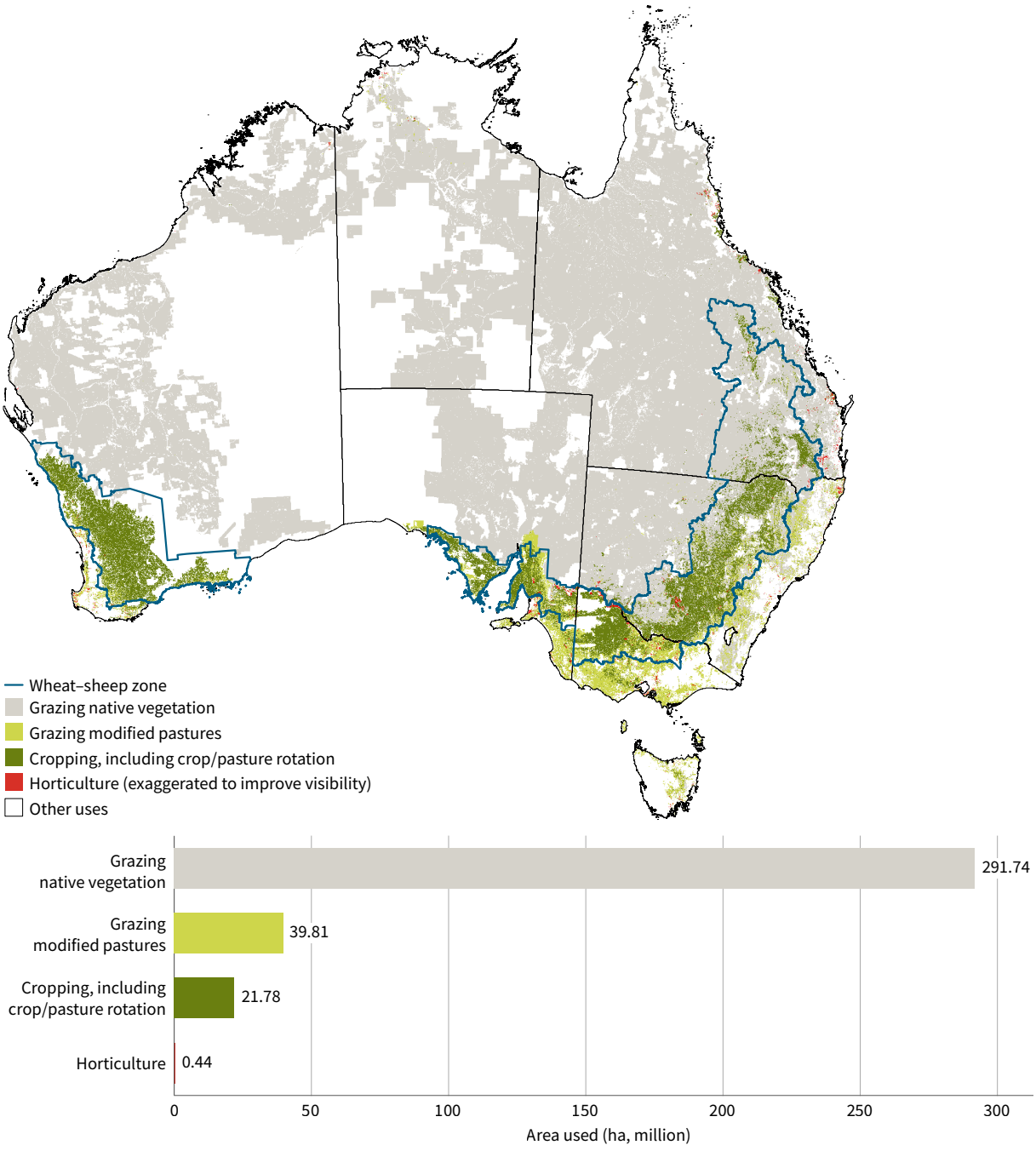
Land managed for agriculture makes up a significant component of Australia's natural infrastructure. Australian farmers and pastoralists manage approximately 353 million hectares of land (ABARES 2021) (Figure 31). Grazing native vegetation makes up the majority of Australian agriculture in terms of land area (around 82%). About 22 million hectares of land is used for cropping and horticulture. A further 1.95 million hectares of land is managed as commercial forestry plantations. Agricultural activity (e.g. cropping, livestock grazing, wood plantations) is the third most commonly listed threat to species listed under the *Environment Protection and Biodiversity Conservation Act* (EPBC Act), affecting 57% of taxa (Kearney et al 2019).

Rangelands (including grazing native vegetation) extend over approximately 80% of the continent. They comprise environments where natural ecological processes predominate, and where values and benefits are based primarily on natural resource areas that have not been intensively developed for primary production (Australian Rangeland Society 2019). Australian rangelands contain much of the continental native vegetation, areas of relatively intact biodiversity, widespread Indigenous cultures, and pastoral and mining industries. More than 10% of the rangelands are contained in the conservation estate and over one-third are under some form of exclusive Indigenous land tenure.

Historically, the rangelands have suffered significant degradation, primarily as a result of overgrazing by European herbivores, often combined with drought (Foran et al. 2019). Overgrazing has led to the loss of perennial grasses, encroachment of woody weeds, changes in species composition of faunal communities, and changes in soil structure, nutrient cycling and water infiltration (Nielsen et al. 2020) (see Agriculture in the Land chapter).

Grazing lands have been transformed by the introduction of non-native pasture grass species. For example, buffel grass (*Cenchrus ciliaris*) occurs over 60% of the continent. It directly suppresses and threatens the persistence of many native plant species, including threatened species, and impacts assemblages of native fauna that may also be threatened with extinction (Godfree et al. 2017) (see also Invasive plants).

Intensive agricultural systems generally support fewer species and simplified ecosystems, and are concentrated in south-western and south-eastern Australia. These include irrigated and non-irrigated crops, improved high-input non-native pastures, managed intensive rotational grazing systems, exotic and native forest industry tree plantations, woody or grassy crops for biofuel production (e.g. willow, poplar, switchgrass), and orchards (Godfree et al. 2017). However, even these highly modified systems can support important biodiversity values. For example, the endangered Australian bittern (*Botaurus poiciloptilus*), which was once widespread across



ha = hectare
Source: ABARES (2021)

Figure 31 Agricultural production zones in Australia

reedy wetlands of southern Australia, now nests in irrigated rice paddies in the Riverina area. Rice fields now play an integral role alongside natural wetlands in the conservation of the species (Herring et al. 2019).

Aquaculture production systems continue to expand in Australia (see Aquaculture in the Coasts chapter). Key pressures associated with aquaculture include pollution and increased nutrient loads associated with waste feed,

faeces and chemicals, and the introduction of invasive species.

Biodiversity conservation has rapidly shifted in recent decades to embrace landscape-scale conservation planning, which aims to support biodiversity alongside agricultural and other human land uses. Nearly 8 million hectares of agricultural land is set aside for protection or conservation purposes (ABS 2021). The fundamental tenet of landscape-scale conservation is that biodiversity can still persist in these landscapes if the relative composition of different land uses is carefully managed and if connectivity among elements in fragmented landscapes supports dispersal and other movement by a range of species (Godfree et al. 2017). The incorporation of conservation practices such as ecological restoration, revegetation and agroforestry is gradually transforming Australian agricultural practice, although actions are still fragmented, and many technical, socio-economic and policy challenges limit biodiversity gains in agricultural systems (Campbell et al. 2017).

Indigenous agribusiness development

A wide range of Indigenous enterprises are emerging from customary ecological knowledge, including bushfood enterprises, and from native plant–derived industries such as nurseries, seed harvesting, cut flowers, and a variety of botanical-based medicinal and beauty products (see the Indigenous chapter). The resulting enterprises are largely based on wild harvest from traditionally managed estates, but also involve different models of cultivation such as enrichment planting and horticulture (Gorman et al. 2020). Much of this activity occurs in areas under Indigenous land tenure, where Indigenous communities and Indigenous ranger groups are actively involved in land management.

'Wild foods' constitute a niche area of food production that involves production and harvest with minimal impacts and interventions on the surrounding environment while providing incentives not to clear natural habitats. For example, the Kakadu plum (*Terminalia ferdinandiana*, known as gubinge in the Kimberley, and many other Australian Indigenous language names across its range) industry across northern Australia is established and growing. The exceptional phytochemical properties of Kakadu plum, the commercial applications and market demand, and knowledge from generations of customary use, underpin an established and growing Kakadu plum supply chain (Gorman et al. 2020). Enrichment and horticultural plantings are emerging as new modes of supply for this species, with the support of regional training institutions (see case study: Indigenous-led development of bush food enterprises: The Northern Australia Aboriginal Kakadu Plum Alliance in the Land chapter).

As markets develop and demand for Kakadu plum increases, there may be a need for greater uptake of alternative production systems to complement wild harvest. Indeed, Indigenous-owned and managed 'on Country' commercial orchards at Wadeye in the Northern Territory and Bidyadanga in Western Australia have been established to moderate the impacts of harvesting on wild plants and local environments, while irrigation and plantation management practices improve the quality and quantity of fruit production.

Mining and energy production

Mining affects biodiversity at scales ranging from the site of mineral extraction to processes operating at landscape to regional scales and beyond. Currently, land from which minerals, precious stones and coal is being extracted (open-cut and deep-shaft mines, quarries, and tailings dumps and dams) and land associated with waste disposal activities (landfills, incinerators, sewerage infrastructure

and effluent ponds) comprises approximately 0.2% of the Australian continent (see the Land chapter). However, this number is growing, and much more land is under mining tenements. For example, in Western Australia in 2017–18, 44.2 million hectares of land was under mining tenements, which accounts for about 17% of the state's total land area. Approximately 2.5 million hectares of land was under active mining leases (Kragt et al. 2019).

Habitat loss and degradation are the most immediate and direct impacts at site scale, with flow-on impacts that change species distributions and ecosystem condition. At regional to landscape scales, direct impacts are associated with waste discharge and pollution (including dust and aerosols), chemical emissions and acids, and sediment transport. Impacts of mining may also be indirect, such as through associated infrastructure development, which can draw humans into otherwise remote areas and lead to invasive species incursions, or issues of overexploitation through hunting, fishing, tourism and recreation (Sonter et al. 2018).

Renewable electricity generation in Australia accounted for 23% of Australia's electricity generation in 2019–20 (DISER 2021) after more than doubling over the previous 10 years. Nearly half (45%) of all renewable energy production comes from combustion of biomass such as wood and bagasse (the remnant sugar cane pulp left after crushing).

The average annual growth of wind energy is particularly high (around 15%) (DISER 2021). At the end of 2018, 94 wind farms in Australia were delivering nearly 16 GW of wind generation capacity (ABARES 2021) and a further 8 windfarms were commissioned in 2019. The spatial footprint of wind farms is relatively large, with associated impacts of habitat loss, fragmentation, and direct and indirect impacts on biodiversity. The growth of onshore coastal wind farm developments represents a significant land-use change within the Australian coastal zone. Wind farms contribute to bird and bat mortalities although, on average, the impacts appear relatively small compared with other pressures. However, consolidated data are very limited. Coastal windfarms could have a disproportionate effect on migratory species, including endangered and critically endangered species such as the curlew sandpiper (*Calidris ferruginea*), the far eastern curlew (*Numenius madagascariensis*) and the red knot (*C. canutus*), but again, data are limited.

Australia has more than 50,000 abandoned mines, most of which are decades old and may not meet modern rehabilitation and closure standards. These sites range in size from individual shafts to large open-cut mines (ATSE 2017). The development of acceptable and achievable completion criteria is a necessary part of mine closure planning and fundamental to the successful transition of mined land to a future use (Young et al. 2019). Mine closure raises issues of environmental, social and cultural significance for a suite of stakeholders, including those Traditional Owners whose land or sea Country is impacted. The issues extend to the enduring opportunities that need to be afforded to Traditional Owners to enable them to continue their stewardship of relinquished Country and their cultural and customary practices on remediated lands, and in so doing maintain livelihoods and spiritual wellbeing long after closure.

Recent studies have identified innovative and progressive examples of Traditional Owners working with resource companies on environmental management and rehabilitation projects (Bond & Kelly 2020). For example, the closure in late 2020 of the Argyle Diamond Mine in the east Kimberley, on lands where the Traditional Owners have a connection all the way back to the 'barramundi dreaming', has

positioned the Gelganyem Trust as a lead actor in the closure and rehabilitation of the site and subsequent environmental monitoring, an outcome that will provide meaningful employment on Country for Indigenous land management and rehabilitation practitioners for a generation to come (Bradby et al. 2021). Case studies demonstrate successful collaborations with Traditional Owners where the application of traditional knowledge and traditional land management practices justify further investigation to consolidate, replicate and scale up the opportunities that could be realised (Barnes et al. 2020).

Clearing and habitat loss

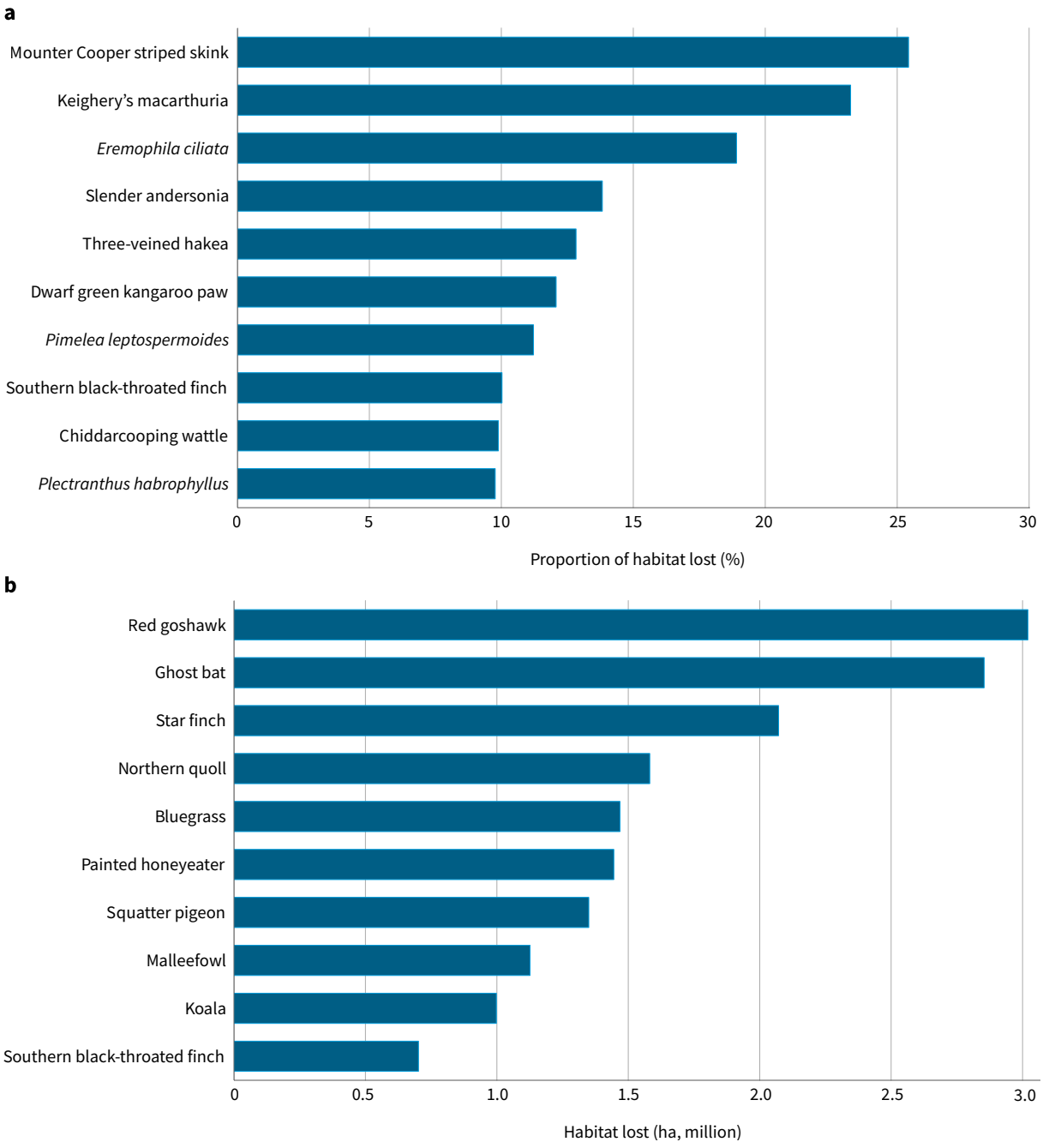
Clearing and habitat loss are a significant threat to Australian biodiversity, and the impact of tree clearing has been a key threatening process under the EPBC Act since April 2001 (see the Land chapter). More than 60% of Australia's nationally listed threatened species are recorded as being seriously affected by habitat loss (Kearney et al 2019).

Overall, 13.2% of Australia's native vegetation has been replaced for urban, production and extractive uses of the land (see Vegetation extent in the Land chapter). Some vegetation types have lost proportionally more of their historical (pre-1750) extent. For example, eucalypt woodlands have been extensively cleared, as have casuarina forests and woodlands. Of the 27 major vegetation groups (see Figure 3 in the Land chapter), 11 (41%) have lost at least 20% of their original extent, and 1 (casuarina forests and woodlands) has lost more than 40% of its original extent.

Between 2000 and 2017, 7.7 million hectares of potential habitat for terrestrial threatened species was lost, 64,000 hectares of potential habitat for terrestrial migratory species was lost, and 370,000 hectares of threatened ecological communities was lost (Ward et al. 2019). In total, 1,390 terrestrial threatened species (85%) experienced some habitat loss since 2000. Some lost substantial proportions of their potential habitat (Figure 32). For example, the threatened Mount Cooper striped skink (*Lerista vittata*) and the small shrub Keighery's macarthuria (*Macarthuria keigheryi*) both lost more than 20% of their potential habitat (Figure 32).

Nine of the 10 threatened species that have lost the most potential habitat to clearing occur in Queensland (Ward et al. 2019). In particular, the brigalow forest of north-eastern Australia has been extensively cleared over the past 60 years and the populations of most associated plant species have drastically reduced.

Of the total 7.7 million hectares cleared, 7.1 million hectares (93%) was not referred to the Australian Government for assessment. Even when clearing has been referred, most habitat loss has been approved, sometimes with conditions, resulting in large areas of cumulative habitat loss. Between 2000 and 2017, only 4 of 3,058 referred actions to remove habitat have been deemed 'clearly unacceptable' (0.1%), 2,252 have been deemed 'not a controlled action' (i.e. not requiring approval to proceed; 74%), and 806 have been deemed a 'controlled action' (26%). Cumulative losses are critical for assessing significant impact, yet currently, actions referred under the EPBC Act are individually assessed (Ward et al. 2019).

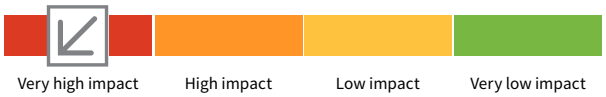


ha = hectare
Source: Ward et al. (2019)

Figure 32 The 10 threatened species that have lost (a) the largest proportion of potential habitat to land clearing since 2000; (b) the most potential habitat in area since 2000

Assessment Pressures from industry

2021



Adequate confidence

Industry pressures are highest from extensive agriculture and land clearing, which continues to remove or fragment native ecosystems.

Related to United Nations Sustainable Development Goal targets 6.3, 11.6, 12.1, 12.4

Assessment Pressures from agricultural production systems – extensive (rangeland) agricultural systems

2021

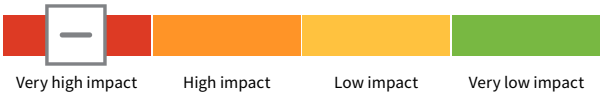


Adequate confidence

Extensive agricultural systems are subject to increasing pressure from climate change, fire and invasive species, particularly invasive grasses and feral animals. Many areas experienced drought in the past 5 years, which exacerbated pressures from invasive species – for example, around permanent water points.

Assessment Pressures from agricultural production systems – intensive agricultural systems

2021

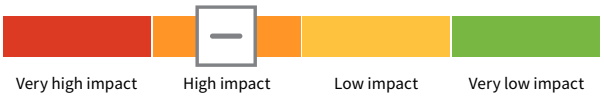


Adequate confidence

The intensive land-use zone occurs over a smaller area of Australia (compared with the area covered by extensive agricultural systems) and is already highly modified. Many impacts are an ongoing legacy of land conversion in the past.

Assessment Pressure from extractive industries

2021



2016

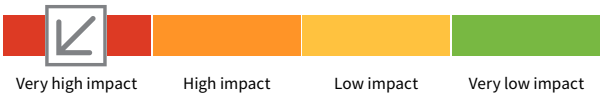


Adequate confidence

Extractive industries have very high but localised direct impacts on biodiversity that may be irreversible. Indirect impacts associated with mining infrastructure, transport and human activities, particularly in remote areas, may be extensive. Unique subterranean fauna are particularly at risk from mining activities that impact the quality and quantity of groundwater.

Assessment Clearing and fragmentation of native vegetation

2021



2016



2011



Adequate confidence

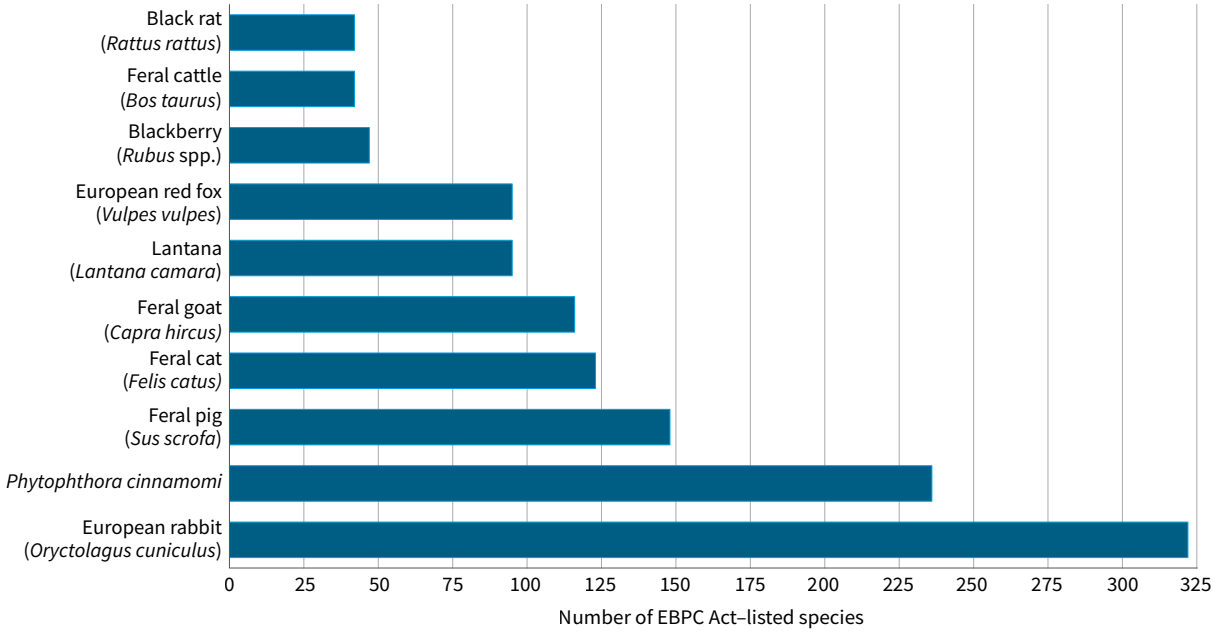
Clearing and habitat loss has very high legacy impacts on species and ecosystems. Current rates of primary, secondary and re-clearing impose significant ongoing widespread pressure across almost all areas of Australia.

Invasive species, problematic native species, and diseases

Invasive species are the most common pressure on species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), affecting 82% (1,257 of 1,533) of threatened taxa in Australia in 2018. In total, 230 invasive non-native species and 37 problematic native species (207 plants, 57 animals, 3 pathogens) are listed as affecting Australian threatened taxa (Kearney et al 2019) (Figure 33).

Invasive species are consistently identified as the most prevalent threat to Australian fauna and are a primary cause of extinction (Allek et al. 2018, Kearney et al 2019, Ward et al. 2021). The management of invasive species is clearly a significant economic burden in Australia (Hoffmann & Broadhurst 2016, Bradshaw et al. 2021). Given the difficulties and costliness of eradicating invasive species, one overriding priority for Australian biosecurity must be to prevent more harmful species arriving and establishing (see the Land chapter for details of Australia's border biosecurity efforts).

Problematic species can also be native; native species are listed as threats for one-fifth of threatened species. Grazing pressure from macropods (kangaroos and wallabies) is the most prevalent threat, listed for 152 threatened plant and 5 threatened animal taxa (Kearney et al 2019). Another problematic native species is the noisy miner (*Manorina melanocephala*). This aggressive bird species has benefited greatly from habitat degradation because they are better able to establish and defend territories that lack structurally complex vegetation. The subsequent increase in their



EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*
Note: 1,533 species
Source: Kearney et al. (2018b)

Figure 33 The 10 invasive species listed as affecting the greatest number of EPBC Act–listed threatened taxa

numbers and exclusion of other bird species from woodland remnants have resulted in them being listed as a key threatening process (Westgate et al. 2021).

Other native species become problems when introduced outside their native range in Australia. For example, redclaw crayfish (*Cherax quadricarinatus*), native to New Guinea, the Northern Territory and north Queensland, was introduced into Lake Poongkaliyarra, a major Pilbara water supply reservoir in Western Australia. The species has subsequently been introduced and established in other freshwater systems in the region, probably through deliberate releases from the lake to provide fishing opportunities in areas where public access is permitted. The potential impacts include the introduction of disease; habitat alterations (e.g. through macrophyte consumption); competition with, and predation on, native fishes and invertebrates; and the displacement of those species (Beatty et al. 2020).

Movement of native species and the occurrence of vagrants from nearby countries is a regular occurrence in Australia but may be increasing as a result of climate change. Increasingly, we may see vagrants as forerunners of climate adaptation – individuals best placed to found new populations beyond their previous range (Davis & Watson 2018). Recently, Bardi Jawi rangers in the Kimberley discovered a colourful pigeon, later identified as the Nicobar pigeon (*Caloenas nicobarica*), that is normally found on small islands and coastal regions, including the Andaman and Nicobar Islands, India, and east through the Malay Archipelago to the Solomons and Palau. It is classified as Near Threatened by the International Union for Conservation of Nature (IUCN). The captured bird was given a thorough health check and cleared of any pathogens, parasites and potential weed seeds before being transferred to Adelaide Zoo where a breeding group of Nicobar pigeons is kept and displayed (Davis & Watson 2018). The incident highlights the important role that Indigenous rangers in remote areas of northern Australia play in Australia's biosecurity system (see case study: Indigenous involvement in biosecurity in the Land chapter).

Invasive plants

Almost 3,000 non-native plant species have become naturalised (grow in the wild) in Australia (Dodd et al. 2015), several hundred of which have been formally listed as 'invasive' plants (or 'noxious', 'restricted', 'declared plants' or 'weeds') under relevant state legislations, including 32 Weeds of National Significance. This process is continuing; an estimated 20 plant species become naturalised in Australia each year (Dodd et al. 2015).

Invasive plants (see Invasive species in the Land chapter) can displace native plant species, harbour pests and diseases, and transform diverse ecological communities into homogeneous monocultures of limited productivity. Invasive plants can also threaten the integrity of nationally and globally significant sites such as Ramsar-listed wetlands, cultural heritage sites and World Heritage properties. Invasive plant control is estimated to impose an overall average annual cost of nearly $5 billion across Australia, with control in agricultural areas accounting for most costs. Around $300 million in public expenditure is estimated across national parks and Indigenous lands, and on weed research (McLeod 2018).

European blackberry (*Rubus fruticosus* aggregate) is listed as one of the top 10 invasive species impacting threatened species in Australia (Kearney et al 2019), and has been declared a Weed of National Significance. It reduces the floristic richness of more than 9 million hectares of waterways and depressions along the east and south-west

coasts. The prickly thickets can pose a fire hazard because of the dry material contained within them, and larger animals may become trapped in them. The species also provides food for introduced species such as starlings, blackbirds and foxes, causing further spread.

Invasive grasses have been intentionally introduced into Australia since European settlement (Table 3). Some species have caused profound ecosystem impacts and important conservation challenges (van Klinken & Friedel 2018). Five particularly high-impact species primarily occur across northern Australia: gamba grass (*Andropogon gayanus*), para grass (*Urochloa mutica*), olive hymenachne (*Hymenachne amplexicaulis*), mission grass (*Cenchrus polystachios* syn. *Pennisetum polystachion*) and annual mission grass (*Cenchrus pedicellatus* syn. *Pennisetum pedicellatum*). Together, these grasses have been listed as a key threatening process because they can alter nutrient cycling and water availability, and subsequently cause ecosystem degradation, habitat loss and biodiversity decline. Of particular importance is their capacity to increase fuel loads, resulting in intense fires that may subsequently lead to permanent transformation of the structure of the ecosystems they invade.

A further 12 species have been identified as high-impact species based on their dominance on land managed for environmental values in Australia (van Klinken & Friedel 2018) (Table 3). A wide range of tropical, subtropical, temperate, arid and semi-arid ecosystems have been transformed by these species. Their impacts are expected to continue to increase, with most still having relatively restricted distributions compared with their potential distribution.

Table 3 High-impact environmental grass species in Australia

Species	Common name
Ammophila arenaria	Marram grass
Andropogon gayanus	Gamba grass
Anthoxanthum odoratum	Sweet vernal grass
Cenchrus ciliaris	Buffel grass
Cenchrus pedicellatus	Annual mission grass
Cenchrus polystachios	Perennial mission grass
Cenchrus setiger	Birdwood grass
Echinochloa polystachya	Aleman grass
Ehrharta calycina	Perennial veldtgrass
Eragrostis curvula	African love grass
Hymenachne amplexicaulis	Olive hymenachne

continues

Table 3 *continued*

Species	Common name
Hyparrhenia hirta	Tambookie grass; coolatai grass
Megathyrsus maximus	Guinea grass
Melinis minutiflora	Molasses grass
Spartina anglica	Common cordgrass; rice grass
Themeda quadrivalvis	Grader grass
Urochloa mutica	Para grass

Source: van Klinken & Friedel (2018)

Invasive plant species impact how Traditional Owners use and manage their land. For example, the invasion of buffel grass (*Cenchrus ciliaris*) across arid Australia has impacted bush food collection and hunting, and access to traditional lands. It has also had cascading negative effects on cultural transmission to younger generations and maintaining cultural practices. Indigenous people of central Australia are now reluctant or unable to conduct traditional fire management due to the increased intensity of buffel grass fires and quick recovery of buffel grass after fires (Read et al. 2020).

Aquatic invasive plants

Invasive exotic freshwater plant species can have serious negative impacts on native communities and freshwater ecosystems. They may suppress native plant communities and have cascading effects on ecosystem functioning. A fundamental attribute altered by invasive plants is light availability, particularly when canopy-producing floating (e.g. water hyacinth – *Eichhornia crassipes*) or submersed species (e.g. cabomba – *Cabomba caroliniana*) reduce underwater penetration of sunlight. Invasive plants can also alter freshwater microclimates and water chemistry. Water movement may be disrupted by dense growth of non-native vegetation and sediment can be trapped at higher rates (Mayfield et al. 2021).

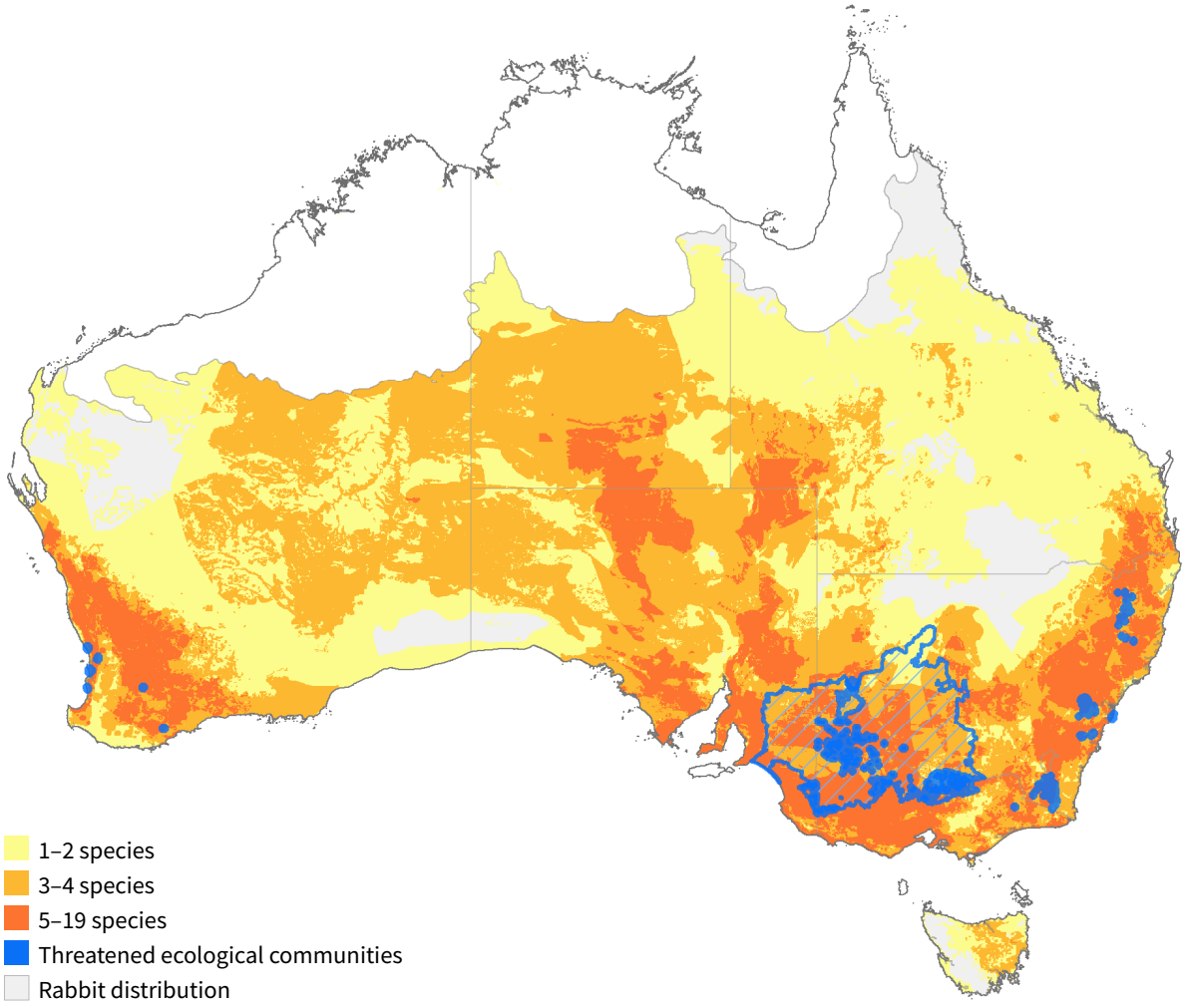
There are at least 63 freshwater plant species naturalised in Australia, many of which have been introduced through the ornamental aquarium and water garden trade (Gufu & Leishman 2018). Approximately one-third of naturalised aquatic weed species in Australia are still available for sale either by water garden nurseries or over the internet (Gufu & Leishman 2018).

More than 40% of naturalised freshwater plant species are categorised as either invasive or declared weeds, most being perennial wetland marginal plants. Even though aquatic plants make up a very small proportion of invasive plant species overall, they have widespread geographic ranges and may have disproportionally high impacts on aquatic systems. Six aquatic species are Weeds of National Significance.

Invasive animals

The most commonly cited invasive species affecting Australia's threatened species is the European rabbit (*Oryctolagus cuniculus*), which threatens 21% (322) of EPBC Act–listed species (Kearney et al 2019) (Figure 34). The feral cat (*Felis catus*), feral pig (*Sus scrofa*) and feral goat (*Capra hircus*) are cited as threatening more than 100 threatened species each (see Invasive species in the Land chapter).

The European rabbit occurs over most of Australia south of the Tropic of Capricorn, as well as some areas in north Queensland. Rabbits affect species and ecosystems by competing with native animals for food, and through gazing, browsing and ringbarking vegetation and preventing regeneration of seedlings. The decline and extinction of many mammal species has been attributed to impacts caused by rabbits, particularly in the arid and semi-arid zones. Rabbits also support



Note: Rabbit distribution is based on observed locations and climate thresholds (as limiting factors for spread across the landscape), and includes both the areas where threatened species densities and ecological communities are indicated and grey areas.
Source: DEE (2016)

Figure 34 Rabbit distribution and locations of threatened ecological communities and species that may be adversely affected by rabbits

populations of pest predators such as feral cats, foxes and wild dogs.

A Korean strain of rabbit haemorrhagic disease virus, known as RHDV1 K5, was released nationally during the first week of March 2017. This was the first time in 20 years that a new rabbit biocontrol agent had been released into Australia. However, the impact of the release of RHDV1 K5 seems to have been limited by the emergence of a competing strain, RHDV2. RHDV2 is a globally widespread rabbit virus that was first detected in Australia in 2015. It has suppressed the rabbit population by an average of 60%, with impacts most pronounced in South Australia and Western Australia (Ramsey et al. 2020).

Feral cats are believed to have been a major factor in the extinction of 30 Australian native mammals species lost since European settlement (see case study: Cats are a major threat to Australia's biodiversity). Because there is no effective broadscale control method for feral cats, they remain a major cause of decline of many Australian mammals (Legge et al. 2017) (see case study: Novel baits for feral predators). Cats have also been primary agents in the extinction of some Australian birds that were restricted to islands, such as the Macquarie Island parakeet (Cyanoramphus erythrotis) and the Macquarie Island buff-banded rail (Gallirallus philippensis macquariensis). Feral cat control has been a priority of the 2015–20 Threatened Species Strategy.

Case study Cats are a major threat to Australia's biodiversity

Source Woinarski et al. (2020)

Since cats arrived in Australia in the early 1800s, the combined population of feral and domestic cats has grown to more than 6.5 million and they are now present across 99.9% of the Australian landmass.

Both feral and pet cats continue to have an extensive and harmful impact on Australian fauna. Cats are known to eat over half of Australian mammal species, including 50 threatened species. Nearly half of all Australian bird species have been recorded as being eaten by cats, including 71 threatened species.

Feral cats in the bush kill an estimated 2,414 million animals annually – mostly native species – including:

- 769 million invertebrates
- 815 million mammals
- 466 million reptiles
- 272 million birds
- 92 million frogs.

In built environments, cats that roam kill an estimated 714 million vertebrates annually, including:

- 338 million mammals
- 162 million birds
- 213 million reptiles
- at least 1 million frogs.

Most of these kills are made by pet cats.



Figure 35 Cats have a significant impact on Australia's biodiversity

Wild dogs are also a serious predation risk to a range of native (and livestock) species. For example, dog attacks are a major contributor to koala (*Phascolarctos cinereus*) mortalities in peri-urban areas of north-eastern Australia (Gentle et al. 2019).

The feral pig is widely considered one of the worst invasive species throughout its introduced range, particularly in the tropical north. Feral pigs have a direct physical impact in natural landscapes as ecosystem engineers, as well as in the cultural landscape as pests. Rooting by feral pigs directly damages the ground and vegetation and impacts plant species richness; increases run-off, erosion and water quality; influences soil chemistry and fungal and microbial life; and slows regeneration. For remote and regional Indigenous communities, pig rooting can affect vehicle access to traditional lands, as well as the values of culturally important wetlands and places. Pigs can also predate on food sources such as yams, roots, tubers and turtles. In northern New South Wales, feral pigs predate on eggs and chicks of the culturally important coastal emu (*Dromaius novaehollandiae)*, which is at risk of local extinctions (less than 50 animals) because of the small size of the population, habitat fragmentation, and inappropriate fire regimes (Heenan 2020).

Feral vertebrate herbivores and livestock (see Production systems) are an important threat to many species and ecological communities, as well as to native vegetation broadly (see Wetlands and billabongs). The problem of feral herbivore management is complex because many have social and cultural value, and some species are considered a resource by landowners, recreational and commercial hunters, and by Indigenous communities. Feral herbivore impacts on biodiversity occur through grazing and browsing of native vegetation, trampling, compaction and rooting of soils, and competition with native herbivores for food and resources. Subsequent changes to structure and composition of vegetation can open pathways for weed invasion, increase fire risks, and affect nutrient and carbon cycling.

Feral goats are a serious threat to biodiversity over large tracts of Australia's rangelands. Methods of control are well known; however, progress in mitigating impacts has been limited, and the range of feral goats is continuing to expand in places.

Wild deer are present in every state and territory in habitats ranging from temperate forests to montane and arid woodlands, grasslands, tropical savanna and rainforest (Davis et al. 2016). The 6 wild deer species in Australia evolved in a wide range of environments, and can thus affect a wide range of natural and agricultural ecosystems. The environmental impacts of deer are not well known, which hampers the development of effective management responses. The limited ability of current control options to reduce deer populations in all but open environments means eradication is likely to be infeasible, except, perhaps, in small and isolated locations. Management of threatened flora affected by deer grazing is mainly through fencing of sites to exclude herbivores (e.g. Rathbone & Barrett 2017).

The Australian Government has recently appointed the first National Feral Deer Management Coordinator who will support community-led deer control in all states and territories and facilitate co-development of a National Feral Deer Action Plan. A similar model is in place for feral pigs, with the Australian Government providing funding to Australian Pork Limited to support a National Feral Pig Management Coordinator who will facilitate the delivery of feral pig management approaches nationally, regionally and locally scale; undertake stakeholder engagement; and raise awareness of feral pig issues. The coordinator is also leading the development and implementation of the National Feral Pig Action Plan.

Threat abatement plans under the EPBC Act are in place for key threatening processes (see Key threatening processes) arising from feral cats, the European red fox, unmanaged goats, feral rabbits, feral pigs, cane toads, and exotic rodents on offshore islands. A National Wild Dog Action Plan is in place for 2020–30 to provide a nationally agreed framework that promotes and supports a strategic and risk-based approach to wild dog management.

Invasive invertebrates

A large proportion of invasive fauna globally are invasive invertebrates. Border interception records show that the vast majority of interceptions are for invasive invertebrates (see Figure 44 in the Land chapter). In 2017 and 2018, the National Border Surveillance program detected 42 pests and diseases of environmental concern; most of these were snails (23.8%) and ants (16.6%), and all but 7 were invertebrates. However, invasive invertebrates tend to receive less attention compared with plants and vertebrates when considering their impacts on natural ecosystems and biodiversity.

Case study Novel baits for feral predators

Management and abatement of the threats posed by feral predators, in particular feral cats, has continued to improve with the ongoing development of novel baits. Currently, 2 types of bait have been developed – Eradicat® and Curiosity® – with a third in progress (Hisstory®) (Legge et al. 2020). All baits are dried meat lures. Eradicat® contains 1080 poison, Curiosity® has an encapsulated pellet (hard shell delivery vehicle, or HSDV) that contains the toxicant para-aminopropiophenone (PAPP) (Johnston et al. 2020) and Hisstory® has 1080 within an HSDV (Algar et al. 2015). Eradicat® is registered for use in south-west Western Australia, Curiosity® was registered for use in Australia in 2020 and Hisstory® is yet to be registered.

Ongoing research to quantify the potential benefits of feral cat baiting is required, especially to determine the impact on nontarget species in new areas and any mitigation required (Hohnen et al. 2019). Results from recent studies indicate little impact of Eradicat® baits on northern quolls (*Dasyurus hallucatus*) (Cowan et al. 2020). However, the mitigation options for the potential impacts on goannas and dingoes from cat baiting, in particular, warrant further consideration given the customary, cultural and spiritual values ascribed to these species by Traditional Owners.

The Felixer™ grooming trap is a novel control method for invasive red foxes and feral cats (Moseby et al. 2020). It is designed to target individual animals. Felixer™ achieves target specificity (meaning it only affects the target species) through a discriminatory sensor arrangement and algorithm, and a dosing pathway that make feral cats and foxes more vulnerable to treatment than nontarget species (Read et al. 2019). Felixer™ works by ejecting a dose of 1080 poison onto the fur of a target animal, which it subsequently ingests through grooming. Felixer™ is particularly effective in areas with limited predator immigration and has proven to be safe for nontarget threatened species such as the numbat (Myrmecobius fasciatus) (Chambers et al. 2020) and northern quoll (Dunlop et al. 2019).

The Australian Government led the $5.9 million project to develop the Curiosity® bait for feral cats and is leading the development of the Hisstory® bait.

Exotic invasive ants, also called tramp ants, are some of the world's most invasive pests because of their devastating environmental, economic and social impacts. Between 2001 and 2017 in Australia, 20 serious tramp ant incursions occurred, including 16 incursions of red imported fire ants (*Solenopsis invicta*) (Australian Government Inspector-General of Biosecurity 2019). Red imported fire ants pose a risk to human health because they are aggressive, delivering repeated painful stings that can cause anaphylactic shock. They prey on vertebrates, invertebrates and plants, and compete for food with native herbivores and insects.

The yellow crazy ant (*Anoplolepis gracilipes*) is listed as one of the top 100 worst invasive species by the IUCN and the Global Invasive Species Database. First discovered in Australia in Cairns in 2001, the ants have been found at more than 20 sites in Queensland and in a large, scattered population in Arnhem Land in the Northern Territory. On Christmas Island, yellow crazy ants have killed millions of red land crabs (*Gecarcoidea natalis*) and robber crabs (*Birgus latro*), both of which play an important role in Christmas Island's forest floor ecology.

The giant African land snail (*Achatina fulica*) is considered one of the most significant snail biosecurity threats to Australia. This snail can grow to 15 cm or more in length and has a broad diet, with the potential to feed on hundreds of plant species. The species is not currently present on mainland Australia, but has invaded Christmas Island where it occurs in high densities in rainforest. So far, it does not appear to have had major impacts on Christmas Island, feeding mostly on waste or debris material. However, Christmas Island is perhaps an unusual environment in that other land snails are absent and the interactions between the native red land crab and the invasive yellow crazy ant shape the forest understorey and structure, and litter decomposition (O'Loughlin & Green 2017). Introduction of the species to the mainland could lead to very significant impacts on natural and agricultural systems.

Case study Invasive insects and their impacts on the environment

At least 17 invasive insect species that cause significant environmental harm are already established in Australia (Invasive Species Council & Monash University 2020) (Table 4). Other non-native insect species are established, but their environmental impacts are mostly not studied. By far the most dominant group of insects that have negative impacts on the environment globally are the ants, bees and wasps (order Hymenoptera), which are social or colony-forming insects and therefore capable of forming very high densities where they occur. They also account for all but one of the non-native insect species in Australia for which there is evidence of environmental harm. These species often aggressively displace native species.

Australia is currently spending more than $60 million each year on eradication programs for 5 ant species – seeking national eradication of red imported fire ants

(*Solenopsis invicta*), electric ants (*Wasmannia auropunctata*) and browsing ants (*Lepisiota frauenfeldi*), and partial eradication of yellow crazy ants (*Anoplolepis gracilipes*) in the wet tropics and Argentine ants (*Linepithema humile*) on Norfolk Island – because of their potential for devastating harm to native animals and impacts on people.

Table 4 Insects that cause environmental harm in Australia

Order	Species	Common name	Year of first detection
Hymenoptera	*Apis mellifera*	European honey bee	1820
Hymenoptera	*Solenopsis geminata*	Tropical fire ant	1863
Hymenoptera	*Paratrechina longicornis*	Black crazy ant	1886
Hymenoptera	*Monomorium floricola*	Floral ant	1910
Hymenoptera	*Monomorium destructor*	Singapore ant	1910
Hymenoptera	*Pheidole megacephala*	African big-headed ant	1911
Coleoptera	*Heteronychus arator*	African black beetle	1920
Hymenoptera	*Linepithema humile*	Argentine ant	1939
Hymenoptera	*Vespula vulgaris*	Common wasp	1959
Hymenoptera	*Vespula germanica*	European wasp	1959
Hymenoptera	*Anoplolepis gracilipes*	Yellow crazy ant	1975
Hymenoptera	*Polistes chinensis*	Asian paper wasp	1979
Hymenoptera	*Megachile rotundata*	Leafcutting bee	1987
Hymenoptera	*Bombus terrestris*	Large earth bumblebee	1992
Hymenoptera	*Solenopsis invicta*	Red imported fire ant	2001
Hymenoptera	*Wasmannia auropunctata*	Electric ant	2006
Hymenoptera	*Apis cerana*	Asian honey bee	2007

Source: Invasive Species Council & Monash University (2020)

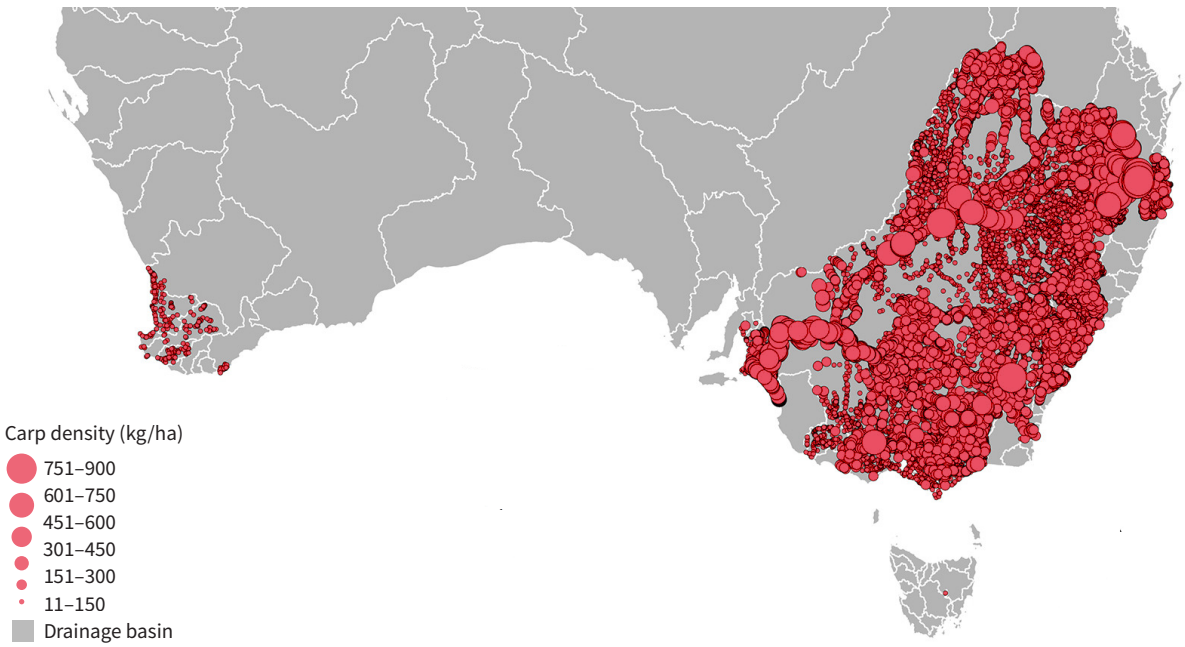
Aquatic invasive animals

At least 34 exotic freshwater fish species have established in Australia: 22 from ornamental and aquarium releases, 8 from acclimatisation, 2 from ballast water, 1 aquaculture species (carp – Cyprinus carpio) and 1 failed biocontrol (eastern gambusia – *Gambusia holbrooki*) (Lintermans 2004) (see Aquatic invasive species in the Coasts chapter).

Of the invasive species known to affect Australia's 22 most at-risk native fish species (see Fish), invasive trout (*Salmo trutta*, *Oncorhynchus mykiss*) pose the greatest threat, followed by eastern gambusia, tilapia (*Oreochromis mossambicus* and *Pelmatolapia mariae*), eastern rainbowfish (*Melanotaenia splendida*) and sooty grunter (*Hephaestus fuliginosus*) (Lintermans et al. 2020). Trout are particularly difficult to manage because they are now widespread in cool freshwater streams in south-eastern Australia, and are a popular recreational fishing target.

Common carp are a major threat to aquatic biodiversity in Australia. They occupy most aquatic habitats, from estuarine lakes to upland streams, and are at their highest densities in south-eastern Australia. When carp exceed a density-impact threshold of 80–100 kilograms per hectare (kg/ha) in wetlands and lakes, increased water turbidity caused by the carp begins to affect aquatic vegetation, native fish and invertebrates. Carp densities in Australia are commonly 200–400 kg/ha and can exceed 1,800 kg/ha in some shallow lakes, far surpassing the density-impact threshold (Figure 36) (Stuart et al. 2021).

The Australian Government has committed $15.2 million towards the development and implementation of the National Carp Control Plan. The plan is being developed to determine the feasibility of using cyprinid herpes virus 3 (the carp virus) as a biological control agent, as part of an integrated landscape-scale control effort to reduce carp below density-impact thresholds and assist ecosystem recovery (McColl & Sunarto 2020).



kg/ha = kilogram per hectare
Source: Stuart et al. (2021)

Figure 36 Density of common carp in Australian drainage basins

Animal diseases

Diseases, fungi and parasites can affect the health of native plant and animal species, reducing their ability to reproduce or survive. Wildlife Health Australia lists 41 infectious diseases in Australian animals that carry biosecurity concerns and may have significant impacts on native species or significant zoonotic (i.e. animal–human) impacts. These include 13 viruses, 12 bacteria, 6 fungi, 6 protozoa, 2 internal parasites and 2 external parasites (Wildlife Health Australia (2018); see also Viral diseases, parasitic infestations, mass die-offs in the Land chapter).

Disease in fauna can contribute to the decline and extinction of threatened species. For example, chlamydia continues to be one of the main factors threatening the long-term survival of the Vulnerable koala, sometimes causing blindness or urinary tract infections that may lead to infertility (Nyari et al. 2017).

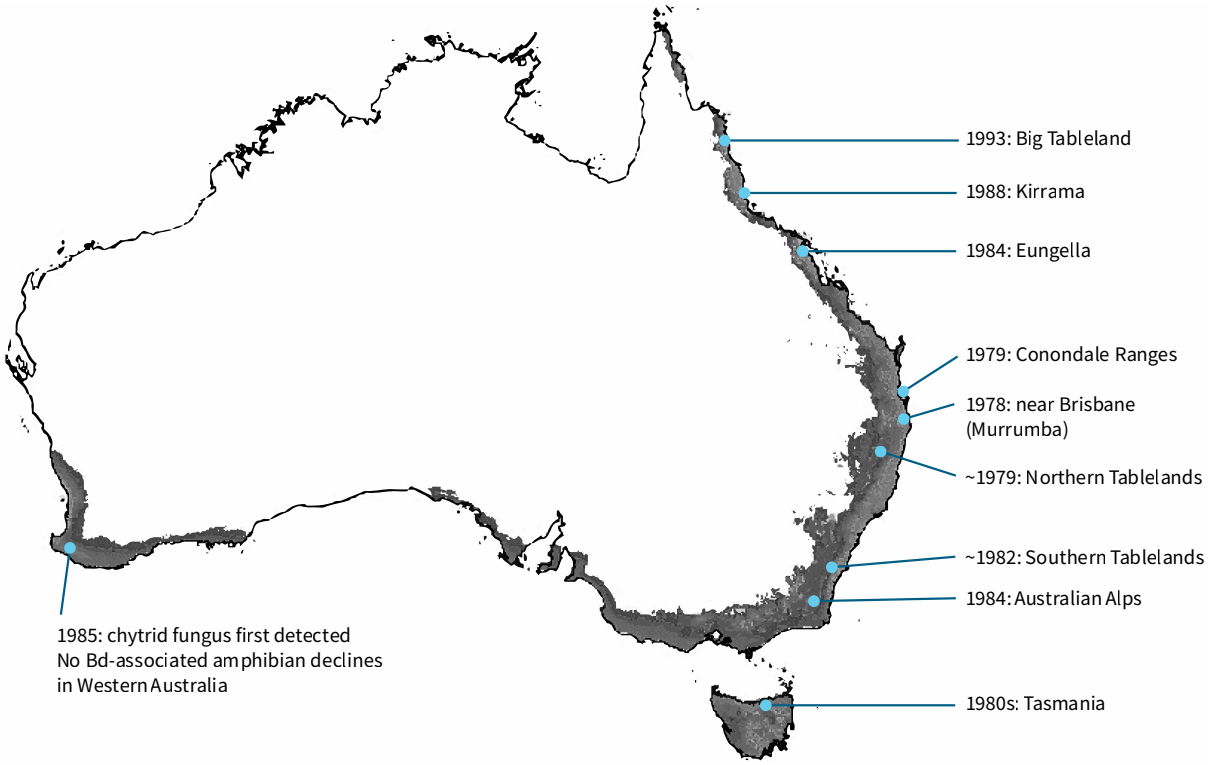
The population of the Endangered Tasmanian devil (*Sarcophilus harrisii*) has declined by up to 80% since the mid-1990s when the infectious and usually fatal cancer devil facial tumour was first detected. Devil facial tumour has now spread across 80% of Tasmania (Lazenby et al. 2018). Methods for securing healthy populations of devils in the wild either involve translocations of healthy devils to islands, or isolating populations behind barriers. In addition, the Tasmanian Government has established an 'insurance population' of Tasmanian devils free from devil facial tumour. This population now contains more than 700 animals housed in 44 institutions throughout Australia, America, Europe and New Zealand (Woods et al. 2018).

Psittacine beak and feather disease is the most common and highly infectious viral disease among parrots. It is found Australia-wide, infecting wild and captive parrots. The disease was listed as a key threatening process in 2001, and experts consider it to be a significant threat to the orange-bellied parrot (*Neophema chrysogaster*; Critically Endangered), glossy black cockatoo (*Calyptorhynchus lathami halmaturinus;* Endangered – South Australia), Norfolk Island green parrot (*Cyanoramphus cookii;* Endangered) and the western ground parrot (*Pezoporus wallicus flaviventris*; Critically Endangered), and a low to moderate threat to at least 7 other threatened species.

One of the most devastating diseases affecting fauna over recent decades is amphibian chytridiomycosis, caused by the fungal skin pathogen *Batrachochytrium dendrobatidis* (chytrid fungus). Chytrid-associated declines of Australian amphibians were first observed in Australia in 1979 and continue today; at least 36 species (of Australia's 238 amphibians) have declined and 7 have become extinct due to the disease. A further 3 species are considered at risk of future declines associated with the continued spread of the pathogen.

Hot and dry environmental conditions appear to limit the distribution of the chytrid fungus throughout much of Australia, largely restricting its impact to the cooler, wetter, mountainous areas of eastern Australia. Species declines have been restricted to eastern Australia, across upland tropical, subtropical and temperate regions (Figure 37). They have been most severe in species in high elevation areas where precipitation is high, and temperatures are moderate to cold. Eight species appear to be recovering, possibly as a result of environmental conditions that have limited chytrid fungal growth (Scheele et al. 2017).

Very little progress has been made on mitigating the impact of chytridiomycosis and stabilising declining species in the wild. As a result, conservation programs to maintain captive populations have been established at several Australian zoos and wildlife parks, targeting a variety of threatened amphibian species (see Ex situ conservation).



Source: Scheele et al. (2017)

Figure 37 Dates of some well-documented amphibian declines overlayed on a map of environmental suitability for the chytrid fungus (Batrachochytrium dendrobatidis, Bd), in Australia

Plant pathogens

A large number of plant pathogens occur in Australia. Recent research shows that 117 forest pathogens occur throughout Australia, of which nearly three-quarters are in the phylum Ascomycota (commonly known as sac fungi), including leaf spot, canker and blight (Nahrung & Carnegie 2020). Most of these plant pathogens affect exotic forestry species (e.g. pine, *Populus* spp.), although about half also have native hosts. Myrtle rust (*Austropuccinia psidii*) and the root-rot fungus *Phytophthora cinnamomi* are the 2 plant pathogens with the most significant impacts on native plant species.

Myrtle rust is an invasive species of rust fungus that affects young growing tissues of a wide range of species in the Myrtaceae family, including iconic Australian genera such as Eucalyptus, *Corymbia*, *Melaleuca* and *Leptospermum*. Suitable habitat for myrtle rust includes coastal areas of New South Wales, the Northern Territory, Queensland, Tasmania and Victoria. At least 417 species (or subspecies) have been documented as susceptible to myrtle rust, and at least 1,285 species of Myrtaceae occur in climatically suitable areas for myrtle rust (Berthon et al. 2018).

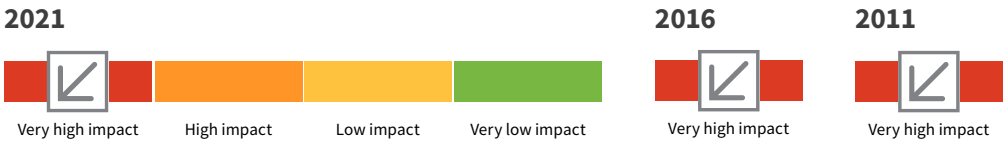
Although the national-scale impacts of myrtle rust are still not fully understood, myrtle rust has caused dramatic declines in 2 once-common Australian species (native guava – *Rhodomyrtus psidioides*, and scrub stringybark – *Rhodamnia rubescens*). Both species have subsequently been listed as Critically Endangered under the EPBC Act; native guava is at very high risk of extinction, with

only 1 surviving population – and it does not produce viable seed (Fensham et al. 2020a).

As with the extinction of any species, the loss of native guava from rainforest edges where it was formerly common could have significant long-term effects on the composition and structure of ecosystems (Fernandez-Winzer et al. 2020), and subsequently on ecosystem function. For example, the invasive species *Lantana camara* occupies the same habitat, and replacement of native guava by lantana will increase the fire hazard at rainforest margins during drought. In addition, more than 100 species of insect-feeding pollinators have been associated with native guava; these interactions between plant, pollinators and insects will be significantly disrupted with unknown, longer-term consequences (Fensham et al. 2020a).

The threat from *P. cinnamomi*, a soilborne water mould that destroys the roots of affected plants, is well documented across a range of ecosystems. This root-rot fungus is listed as threatening more than 100 EPBC Act–listed species (Kearney et al 2019). In the Eastern Stirling Range Montane Heath Community in Western Australia, numerous species found nowhere else (endemic taxa) are threatened with extinction due to *P. cinnamomi*, and, as a result, this community has been assessed as Critically Endangered under the IUCN criteria (Barrett & Yates 2015). *P. cinnamomi* has also been documented in forests and heathlands in New South Wales, Tasmania and Victoria.

Assessment Pressures from invasive species



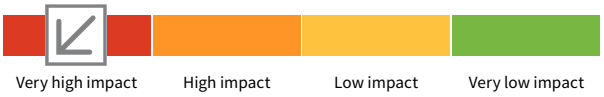
Adequate confidence

Invasive species and diseases are some of the highest pressures on Australia's biodiversity, and these pressures look set to continue and increase in the future.

Related to United Nations Sustainable Development Goal targets 15.2, 15.5, 15.8

Assessment Pressure from invasive plants and animals

2021



Adequate confidence

Invasive species impose a persistent, extensive and sometimes irreversible impact on native species and ecosystems. They are the most cited threat to threatened species, have contributed to a significant number of extinctions of Australian endemic species and dominate national key threatening processes. There is no evidence that the impact of invasive species will lessen in the future.

Assessment Pressure from diseases and pathogens

2021



Somewhat adequate confidence

The impacts from diseases and pathogens are contained to specific species in specific areas and are not yet pervasive across the entire continent. However, a small number of species and ecosystems experience very high impacts from diseases and pathogens over their entire range; some are only being rescued by methods of last resort such as relocation and establishment of insurance populations. There is high potential for ongoing future impacts from new or existing diseases and pathogens.

Interactions between pressures and cumulative impacts

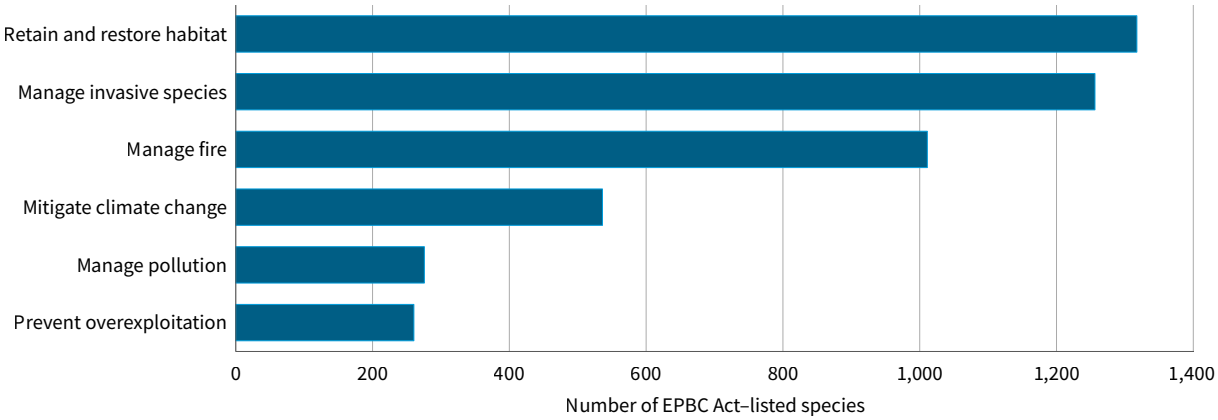
Ecosystems and species seldom respond to pressures in isolation, and the most abrupt changes in ecological systems frequently arise from interactions among multiple pressures rather than changes in a single pressure.

Similarly, most threatened species and ecosystems cannot be recovered by managing a single threat. However, many threatening processes affect species by similar mechanisms, such as through the removal or degradation of habitat. For example, 86% of Australia's threatened species are subject to multiple threats that amount to habitat destruction and degradation, including logging, mining, urbanisation and agriculture, for which the key conservation response is habitat retention and restoration (Kearney et al. 2020). Almost all species require multiple integrated management responses to address their threats (Figure 38).

Researchers have recently shown how pressures from global climate change and regional human impacts, occurring as chronic 'presses' or acute 'pulses' such as extreme events, drive ecosystem collapse. Ecosystem collapse means these places are experiencing potentially irreversible environmental changes, including loss of important species such as dominant trees, and loss of functions such as pollinators (Bergstrom et al. 2021). Local examples of ecosystem collapse can be seen across all Australian and Antarctic ecosystems, although not yet across the entire distribution of an ecosystem type.

Multiple pressures amplify effects on biodiversity in complex and sometimes unpredictable ways, and their interactions pose significant and specific challenges to natural resource management. In addition, the management of some pressures can have the unintended consequence of exacerbating other pressures. For example, in South Australia, red fox control resulted in increases in rabbit populations, which then benefited feral cats (Stobo-Wilson et al. 2020).

The interaction between invasive species and fire is of increasing concern as climate change continues to alter fire regimes (see Changing fire regimes). Invasive grasses such as gamba



EPBC Act = Environment Protection and Biodiversity Conservation Act 1999
Source: Kearney et al. (2020)

Figure 38 Number of Australian threatened species that would benefit from different conservation responses

grass and buffel grass increase fuel loads and fire intensities, sometimes dramatically altering ecosystem structure and function. These species are considered transformer species because of their ability to alter invaded environments by forming dense infestations that increase fire connectivity.

Native mammal declines, particularly in northern Australia, have drawn attention to the potential for fire to exacerbate the impacts of introduced predators. For example, feral cats are more abundant and hunt more successfully in areas that have experienced recent or severe fires (Davies et al. 2020, Legge et al. 2020). Mammals in southern Australia may also be affected by synergistic interactions between fire and introduced predators (Hradsky 2020). Fires typically cause the short-term loss of understorey vegetation, leaf litter, coarse woody debris and tree hollows, all of which provide shelter from predators for native animals.

Case study Managing interacting pressures to protect tjalapa, the great desert skink

Dr Rachel Paltridge, Kiwirrkurra Indigenous Protected Area Coordinator, Desert Support Services

Tjalapa (also known as tjakura, warrarna, mulymidji, great desert skink or *Liopholis kintorei*) is a large, orange, communally living skink that occurs in the western deserts. It is classified as Vulnerable due to a decline in range over the past 50 years. The species is of enormous cultural significance, with its own Tjukurrpa (dreaming) songs, sites and stories. It is remembered as a favoured source of meat that would be 'scaled like a fish', was efficient to harvest from the communal burrows, was soft for children to chew and like a 'stick of butter' with good fat reserves (Kiwirrkurra, Ngururrpa and Martu Traditional Owners).

Key threats to tjalapa are cat predation and inappropriate fire regimes. When burrow systems are burned the lizards become highly vulnerable to predation when they emerge to defecate in their communal latrine and forage for food, and burnt burrows generally become inactive in the year after a fire. Strategic burning to maintain spinifex cover over burrows and cat control (particularly if a fire does occur) are therefore the most important management activities to protect tjalapa.

In 2016, only 12 widely separated locations where tjalapa occurred were known, with 90% of these on Indigenous-owned or Indigenous-managed land. Four new populations have been detected in the past few years, significantly expanding both the known range and the number of individual colonies. The new colonies were found largely as a result of Indigenous rangers learning from other rangers about how to find their burrows, as well as the cultural and conservation significance of tjalapa, at a series of ranger networking events organised by the Indigenous Desert Alliance.

On the Kiwirrkurra Indigenous Protected Area, tjalapa populations are monitored as an indicator of the health of Country, and to assess the effectiveness of traditional fire management and cat control practices. Using traditional tracking

techniques, the rangers removed more than 200 feral cats from a 30 kilometre (km) radius around Kiwirrkurra between 2014 and 2020. Hundreds of small fires are lit every year to regenerate food plants and prevent big wildfires, with most fires less than 5 hectares in size.

Each year at the end of summer, the Kiwirrkurra rangers survey 3 transects, each 1 km × 300 m, to map active tjalapa burrows and assess the proportion that have any signs of disturbance from fire, predators or hunters. They also use motion-detector cameras to monitor predator visitation to tjalapa burrows in the spring. In 2021, the rangers mapped 78 burrows across 3 sites, 71 of which were active. The numbers have been gradually increasing over the 5 years of monitoring.

Kiwirrkurra school students help the rangers with their monitoring, and are familiar with tjalapa's tracks, scats and burrows; where to find it; its threats; and Tjukurrpa stories.

Management

National and international agreements and policy

Governments at local, regional, state, territory and national levels – in collaboration with partners – implement a broad range of policies and programs designed to tackle major threats to biodiversity, arrest the decline in threatened species and ecological communities, and promote their longer-term recovery (see also Management approaches in the Land chapter, National and international policy and frameworks in the Marine chapter and Coastal governance and policy in the Coasts chapter). Biodiversity management on the ground is also undertaken by thousands of landholders, Indigenous communities, nongovernment organisations, industry and volunteers.

National

Australia's Biodiversity Conservation Strategy 2010–2030 and Australia's Strategy for Nature 2019–2030

Australia's Biodiversity Conservation Strategy 2010–2030 was endorsed by all Australian governments in 2010 as the guiding framework for conserving the nation's biodiversity. The strategy set the vision that Australia's biodiversity is healthy and resilient to threats and valued both in its own right and for its essential contribution to human existence.

The strategy set 3 priorities for action: engaging all Australians, building ecosystem resilience in a changing climate and getting measurable results. Interim national targets that supported the 3 priorities for action were established before the adoption of the first strategic plan for the United Nations Convention on Biological Diversity in 2010. These targets, while not fully aligned with the global targets (see International), represented Australia's agreed approach to coordinate efforts at the national and subnational level, and across all sectors.

A review of the Biodiversity Conservation Strategy in 2015–16 found that it had not effectively influenced biodiversity conservation activities, it was not possible to report achievement against its targets, and it did not engage, guide or communicate its objectives in a useful way (Meeting of Environment Ministers Biodiversity Working Group 2016). The review report recommended that the strategy be revised, and, following extensive consultation, a new strategy was endorsed in 2019 by all Australian governments and the Australian Local Government Association: Australia's Strategy for Nature 2019–2030.

The new strategy functions as a policy umbrella over other national, state, territory and local government strategies, policies, programs and regulations. The strategy also provides the main instrument for Australia to implement its obligations under the United Nations Convention on Biological Diversity and a range of other international agreements, including the Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat, the World Heritage Convention, and the Convention on the Conservation of Migratory Species of Wild Animals.

Australia's Strategy for Nature 2019–2030 aims to:

- better align Australia's National Biodiversity Strategy with international obligations and allow flexibility to adapt to changing environments
- improve implementation and coordination of biodiversity conservation activities
- better communicate with and engage broader audiences
- include all landscapes and seascapes, including marine, aquatic, production and urban environments.

The strategy has 3 priority goals underpinned by 12 objectives, and each objective has several progress measures:

- Goal 1 – Connect all Australians with nature
  - Objective 1: Encourage Australians to get out into nature
  - Objective 2: Empower Australians to be active stewards of nature
  - Objective 3: Increase Australians' understanding of the value of nature
  - Objective 4: Respect and maintain traditional ecological knowledge and stewardship of nature
- Goal 2 – Care for nature in all its diversity
  - Objective 5: Improve conservation management of Australia's landscapes, waterways, wetlands and seascapes
  - Objective 6: Maximise the number of species secured in nature
  - Objective 7: Reduce threats and risks to nature and build resilience
  - Objective 8: Use and develop natural resources in an ecologically sustainable way
  - Objective 9: Enrich cities and towns with nature
- Goal 3 – Share and build knowledge
  - Objective 10: Increase knowledge about nature to make better decisions
  - Objective 11: Share and use information effectively
  - Objective 12: Measure collective efforts to demonstrate our progress.

The new strategy addresses some of the reported issues hindering effectiveness of the previous strategy. It is shorter, less technical, focused on communicating objectives to a broad audience, and connects people with nature more directly. It also attempts to capture and report on the suite of activities contributing to the objectives and targets of the strategy through its associated website, Australia's Nature Hub. The strategy also strives to incorporate adaptation, resilience and sustainable natural resource management in its scope.

However, the new strategy has been met with some criticism, mainly because progress measures lack detail and specific measurable targets. Various monitoring tools associated with aligned programs (such as the Threatened Species Strategy) are implicit in the strategy; however, without measurable targets and coordinated monitoring of outcomes, it is difficult to envisage how progress against the strategy will be assessed, how the strategy will support reporting against international targets, or how it will guide and drive actions to improve the state and trend of biodiversity in Australia.

Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is Australia's primary national environmental legislation. It provides for the protection of Australia's environment, especially aspects of the

environment that are matters of national environmental significance.

The complete list of matters of national environmental significance are:

- nationally threatened species and ecological communities
- migratory species
- World Heritage properties
- National Heritage places
- wetlands of international importance (often called 'Ramsar' wetlands after the international treaty under which such wetlands are listed)
- Commonwealth marine areas
- the Great Barrier Reef Marine Park
- nuclear actions (including uranium mining)
- a water resource, in relation to coal-seam gas development and large coalmining development.

The EPBC Act provides protection to Indigenous heritage through National Heritage or World Heritage listing. At the national level, Indigenous cultural heritage is protected under numerous other Commonwealth laws, including the *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (ATSIHP Act). However, the ATSIHP Act does not align with the development assessment and approval processes of the EPBC Act (see the Indigenous chapter).

The EPBC Act has undergone considerable scrutiny in the past 5 years:

- A 10-year statutory independent review commenced in 2019, and the final report was delivered in October 2020 (Samuel 2020).
- An independent review of interactions between the EPBC Act and the agriculture sector was delivered in 2018 (Craik 2018).
- The Australian National Audit Office assessed the effectiveness of the process for approval of controlled actions (ANAO 2020) and funding models for threatened species management (ANAO 2018).
- Several inquiries were conducted by parliament into aspects of environmental regulation under the EPBC Act, including an inquiry into Australia's faunal extinction crisis, the effect of red tape on environmental assessment and approvals, the construction of the Perth Freight Link in the face of significant environmental breaches, and the destruction of Indigenous heritage sites at Juukan Gorge in the Pilbara region of Western Australia (see case study: Juukan Gorge Rockshelter – Highlighting the poor protections for Indigenous heritage under current Australian Indigenous heritage legislation in the Heritage chapter).

2020 independent review of the EPBC Act

The overall finding of the 2020 review was that the EPBC Act does not enable the Australian Government to effectively protect significant and important environmental matters. Key conclusions of the review include the following:

- Good outcomes for the environment cannot be achieved under the current laws.
- Significant efforts are made to assess and list threatened species; however, once listed, not enough is done to deliver improved outcomes for them.
- Decisions that determine environmental outcomes are usually made on a project-by-project basis, and only when impacts exceed a certain size. This means that cumulative impacts on the environment are not systematically considered, and the overall result is net environmental decline, rather than protection and conservation measures.
- The EPBC Act does not facilitate the restoration of the environment, and

needs to shift from permitting gradual decline to halting decline and restoring the environment; this would allow development to continue in a sustainable way.

- Key threats to the environment are not effectively addressed under the EPBC Act. There is very limited use of comprehensive plans to adaptively manage the environment on a landscape or regional scale. Coordinated national action to address key threats – such as feral animals – are ad hoc, rather than a key national priority. Addressing the challenge of adapting to climate change is an implied, rather than a central consideration.
- Western science is heavily prioritised in the way the EPBC Act operates. Indigenous knowledge and views are diluted in the formal provision of advice to decision-makers. This reflects an overall culture of tokenism and symbolism, rather than one of genuine inclusion of Indigenous Australians.
- Fundamental reform of national environmental laws is required.

The review noted that the EPBC Act is not fulfilling its objectives as they relate to the roles of Indigenous Australians in protecting and conserving biodiversity and promoting the respectful inclusion of their knowledge, and the Act does not meet the aspirations of Traditional Owners for managing their land. In particular, the review noted that the operation of the EPBC Act Indigenous Advisory Committee (IAC) exemplifies the culture of tokenism in terms of the inclusion of Indigenous knowledge and views of Indigenous people in environmental and heritage management decisions. The Act does not require the IAC to provide decision-makers with advice. The IAC relies on the Minister for the Environment inviting its views. This is in contrast to other statutory committees, which have clearly defined and formal roles at key points in statutory processes.

Recommendations of the review include establishing legally enforceable national environmental standards that would set clear requirements for those that interact with the EPBC Act and clear bounds for decisions-makers. The review developed detailed recommended standards for:

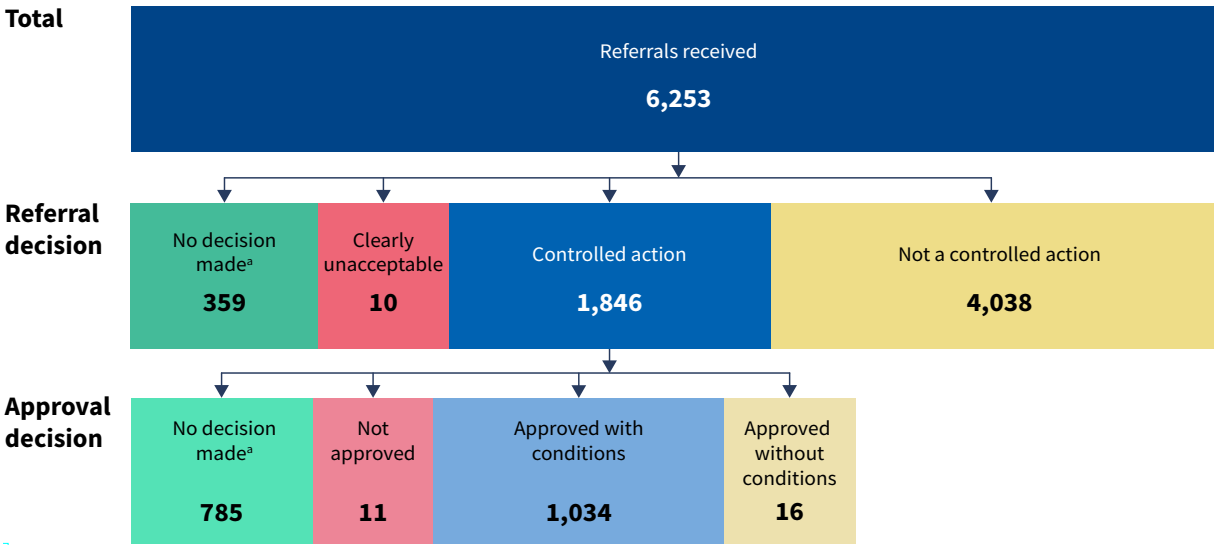
- matters of national environmental significance
- Indigenous engagement and participation in decision-making
- compliance and enforcement
- data and information.

Approvals of controlled actions under the EPBC Act

Under the EPBC Act, an action requires approval from the minister if the action has, will have or is likely to have, a significant impact on a matter of national environmental significance (defined as 'controlled actions'). The approval is received through an assessment process comprising a referral stage, an assessment stage and an approval stage (Figure 39). The Department of Agriculture, Water and the Environment is responsible for enforcing compliance with conditions attached to approvals and with the requirement not to undertake controlled actions without approval from the minister.

A recent Auditor-General report (ANAO 2020) assessed the effectiveness of the Department of Agriculture, Water and the Environment's administration of referrals, assessments and approvals of controlled actions under the EPBC Act. The report specifically assessed whether governance arrangements were sound, whether the administration of referrals and assessments was effective and efficient, and whether conditions of approval were appropriate and assessed with rigour.

Since commencement of the Act on 30 June 2019, 6,253 proposed actions have been



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

a Cases where no decision has been made may be due to the referral lapsing or being withdrawn, assessment ceasing while waiting for information from the proponent, or the assessment still being undertaken.

Source: ANAO (2020)

Figure 39 Outcomes for all referrals received under the EPBC Act to 30 June 2019

referred to the minister, with 5,088 of those actions approved, including 4,038 deemed not to be a controlled action, 1,034 controlled actions approved with conditions, and 16 controlled actions approved without conditions.

The Auditor-General reported the following conclusions:

- The administration of referrals, assessments and approvals of controlled actions under the EPBC Act is not effective.
- The department's regulatory approach is not proportionate to environmental risk.
- The administration of referrals and assessments is not effective or efficient. Regulation is not supported by appropriate systems and processes, and there are no arrangements in place to measure or improve efficiency.
- Conditions of approval are not assessed with rigour. Of the approvals examined, 79% contained conditions that were noncompliant with procedural guidance or contained clerical or administrative errors.
- Appropriate monitoring, evaluation and reporting arrangements have not been established. The department is not well positioned to measure its contribution to the objectives of the EPBC Act.

Eight recommendations were made to strengthen governance arrangements and support the effective administration of referrals, assessments and approvals, all of which were agreed to by the department.

Interactions between the EPBC Act and the agriculture sector

An independent review of interactions between the EPBC Act and the agriculture sector was completed in 2018. Key findings of the review include the following:

- There is a lack of clarity around the overarching objectives of regulation of agricultural activity and a view that it did

not efficiently meet its regulatory objectives in relation to the agriculture sector.

- Many in the agriculture sector are not sufficiently aware of their obligations under the Act or how to access and interpret relevant information.
- Environmental impact assessment processes are widely viewed as unclear and complicated, insufficiently transparent, time consuming and costly.
- There is a lack of appropriate incentives and strategic approaches to assist the agriculture sector to grow while maintaining environmental standards.

The review found that, compared with other sectors of the Australian economy, the number of referrals under the EPBC Act received from the agriculture sector has remained consistently low since 2000. Several recommendations were made, focused on reducing the burden of the regulatory obligations created by the EPBC Act on farmers without reducing environmental standards.

International

Australia is a signatory to many international agreements and conventions responding to biodiversity conservation. These agreements impose obligations on Australia and require a range of actions to be undertaken to deal with matters of concern to the international community. Key among these agreements are:

- Antarctic Treaty (see the Antarctic chapter)
- Convention on the Conservation of Antarctic Marine Living Resources (see the Antarctic chapter)
- International Convention for the Regulation of Whaling (see the Marine chapter)
- Convention on International Trade in Endangered Species of Wild Fauna and Flora
- United Nations Convention on Biological Diversity
- 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 (see the Heritage chapter)
- Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat.

One of the most significant multilateral agreements is the Convention on Biological Diversity, to which Australia has been a Contracting Party since 1993. The convention is a comprehensive, binding agreement covering the use and conservation of biodiversity. It obliges all parties to develop and implement national biodiversity strategies and action plans, and for parties to report on national implementation of the convention (Latch 2018b). Australia agreed with other countries in 2010 to implement the Strategic Plan for Biodiversity 2011–2020, including its 20 measurable, time-bound Aichi Biodiversity Targets.

Australia submitted its Sixth National Report to the Convention on Biological Diversity (2014–18) in March 2020. The report detailed a range of measures, activities and investments contributing to Australia's national targets and the global Aichi targets. During the reporting period, Australia pursued 10 interim national targets as guided by the strategic plan. Good progress was reported across targets related to protection in the terrestrial and marine National Reserve System, increased engagement with Indigenous peoples in the management of land and sea Country, increased transboundary feral animal control, and better alignment of national and subnational measures for addressing key threats to Australia's biodiversity. However, other than an increase in the coverage of the National Reserve System, progress against most measures was, at best, partial. The

report also noted that the performance assessments were largely subjective, because quantitative performance data were not available across all targets (see National).

The Convention on Biological Diversity's Strategic Plan and its Aichi targets expired in 2020. Negotiations are now underway to develop the Convention on Biological Diversity's post-2020 Global Biodiversity Framework (GBF). The GBF will set international targets for environmental action for the next decade.

The draft GBF cuts across a diverse array of policy areas, including agriculture, health, trade, education and climate change. Targets are currently being designed. Four goals corresponding to the 2050 Vision on Biodiversity are proposed, together with 21 action-oriented targets with a time horizon of 2030, many of which can be mapped onto the existing targets (Arneth et al. 2020).

Of particular importance to the state and trend of species and ecosystems is Goal A of the post-2020 GBF, which has 3 milestones to be reached by 2030:

> Goal A for 2050: The integrity of all ecosystems is enhanced, with an increase of at least 15 per cent in the area, connectivity and integrity of natural ecosystems, supporting healthy and resilient populations of all species, the rate of extinctions has been reduced at least tenfold, and the risk of species extinctions across all taxonomic and functional groups, is halved, and genetic diversity of wild and domesticated species is safeguarded, with at least 90 per cent of genetic diversity within all species maintained.

The following are the 2030 milestones for Goal A:

- Milestone A.1. Net gain in the area, connectivity and integrity of natural systems of at least 5%.
- Milestone A.2. The increase in the extinction rate is halted or reversed, and the extinction risk is reduced by at least 10%, with a decrease in the proportion of species that are threatened, and the abundance and distribution of populations of species is enhanced or at least maintained.
- Milestone A.3. Genetic diversity of wild and domesticated species is safeguarded, with an increase in the proportion of species that have at least 90% of their genetic diversity maintained.

Australia is focusing on several high-priority areas in the new GBF:

- greater representation of marine and coastal biodiversity
- effective protected area management
- control and eradication of invasive alien species
- effective targets to promote sustainable production and consumption and the circular economy, and to improve waste management
- promoting full and effective participation of Indigenous Peoples and Local Communities in the conservation and sustainable use of biodiversity.

Meeting the 2030 milestones of Goal A will require enormous management and monitoring effort and investment. It is unclear how Australia will measure progress against these milestones, given the lack of national-scale data available to assess the state and trend of the vast majority of Australian species, as we have identified throughout this report.

A significant development in international policy since the 2016 state of the environment report is Australia's commitment to the Sustainable Development Goals (SDGs) as a universal, global approach to reduce poverty, promote sustainable development, and ensure peace and prosperity.

The 2030 Agenda for Sustainable Development is consistent with the Aichi Biodiversity Targets developed under the Convention on Biological Diversity. The agenda comprises 17 SDGs and 169 targets. The most explicit consideration of biodiversity is contained in SDG 14 (Life below water) and SDG 15 (Life on land). However, biodiversity directly supports the achievement of at least 13 SDGs, rising to all 17 SDGs after indirect interactions are considered (Blicharska et al. 2019). For example, species and ecosystems contribute to physical and mental health and wellbeing (SDG 3), reduce poverty (SDG 1) and hunger (SDG 2), and can provide regulating functions relevant to climate action (SDG 13), water management (SDG 6), infrastructure (SDG 9) and energy (SDG 7).

Indigenous knowledge and land and sea management

The 2019 report from the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services notes that recognising the knowledge, innovations, practices, institutions and values of Indigenous peoples and local communities, and ensuring their inclusion and participation in environmental governance, often enhances their quality of life and the conservation, restoration and sustainable use of nature, which is relevant to broader society (IPBES 2019). The Indigenous chapter describes how connection to kin and Country is kept alive through Indigenous knowledge and actions on Country (see the Indigenous chapter).

Australian Indigenous people hold detailed information on past and current environments and trends that is increasingly informing ecological understanding and conservation management. For example, the Yolŋu Senior Knowledge Custodians of the Laynhapuy Indigenous Protected Area in northern Australia recently expressed concern about the dieback of culturally significant coastal melaleuca (paperbark) stands. Melaleuca dieback was observed in 3 species: nämbarra (*M. viridiflora*), raŋan (*M. cajuputi*) and gulun'kulun (*M. acacioides*). A partnership between senior knowledge custodians and western scientists using cross-cultural methods identified causal factors that would not have been understood without the Indigenous ecological knowledge. The declines ultimately correlated primarily with feral ungulate activity and changes in soil salinity (Sloane et al. 2018).

Cross-cultural information elicitation methods are also being used to inform improved species distribution models (Skroblin et al. 2021), drive the re-emergence of Indigenous fire practices (see case study: Arnhem Land Fire Abatement program in the Land chapter) (McKemey & Patterson 2019, McKemey et al. 2020), document species, and share traditional Indigenous names and stories of plants and animals with other Australians (ALA n.d.).

Work is ongoing to improve Indigenous participation in land management and biodiversity conservation. Successful programs rely on opportunities to provide ongoing employment, as well as knowledge exchange and cultural learning, particularly with young Indigenous peoples who may not have previously spent time on their Country. More traditional knowledge is slowly being integrated into biodiversity and land management programs, and with strong and positive results, particularly in the face of the challenges of drought, fire and climate change.

In Australia, Indigenous land and sea management (ILSM) is the fastest-growing sector for Indigenous employment. ILSM includes a range of objectives and activities: management of fire, water, weeds and feral animals; monitoring and protection of threatened species; revegetation; harvesting of bush foods; pastoralism; and artistic work

(Schultz et al. 2019). Although investment in ILSM programs was initially designed to support improved conservation and environmental management through the increased involvement of Indigenous people, over time it has been more frequently reported as being able to improve the wellbeing of Indigenous people (Larson et al. 2020). Cessation of ILSM and removal of Indigenous people from their lands contributes to both poor wellbeing outcomes and biodiversity loss.

Indigenous ranger groups are exchanging and sharing their skills and knowledge with other groups across the country and globally. For example, in Australia's desert regions, arid-zone ecologists with the Threatened Species Recovery Hub are blending Indigenous tracking skills with ecological science. More than 40 Indigenous ranger groups used sand-plot surveys to monitor the presence of animals, track changes over time and identify important environmental conditions for key species. In 2018, there were 120 active Indigenous ranger groups, and, combined with the Indigenous Protected Area (IPA) program, more than 2,900 Indigenous Australians employed in land and sea Country management ranger positions.

The 2016 *Social return on investment* study (SVA Consulting 2016) on the IPA and Working on Country programs documented success across a broad range of outcomes. This report concluded that from 2008–09 to 2014–15, an investment of $35.2 million from government and a range of third-party investors has generated social, economic, cultural and environmental outcomes with an adjusted value of $96.5 million.

Indigenous people are also contributing to research on biodiversity conservation across Australia. The National Environmental Science Program (NESP) research hubs monitor research activities against performance indicators relating to Indigenous engagement and participation in research projects, tracking how the views and traditional knowledge of Indigenous peoples and local communities are incorporated in research, identifying the co-benefits of that knowledge exchange, what employment opportunities have been realised, and how research outcomes will benefit Indigenous peoples and local communities. In 2018, more than 100 Indigenous people were employed on NESP research projects, and more than 450 Indigenous people trained in the use of biodiversity management tools and techniques on Country.

A recent review of 46 IPA management plans (Wensing & Callinan 2020) to assess the impact of NESP outcomes, which should be considered an authentic reflection of the aspiration of Indigenous Australian about their perceptions of biodiversity and the threats to their land and sea Country, identified the following topics relevant to the Biodiversity chapter, for consideration in the design of the second phase of NESP research:

- Improve biodiversity data baselines to better understand the health and value (tangible and intangible) of Country.
- Address knowledge gaps for threatened species, species of special conservation and/or cultural significance and their habitats that occur on Country.
- Continue to investigate the impacts of threats, such as
  - altered fire regimes and wildfire on Country and how to implement appropriate ecological burning regimes (mosaic/patch burning) for the enhancement of biodiversity values
  - sea level rise and tidal surge on marine turtles, dugongs, benthic habitats, and species of cultural and customary importance
  - weeds, feral animal (e.g. pigs, buffalo, deer, camels) and overabundant native species on the wellbeing of Country.

- Improve wildlife and habitat monitoring to better understand ecosystem health and the sustainable use of natural resources.
- Investigate opportunities for commercialisation of wildlife and bush harvesting.

A common tenet of all plans assessed was the need to incorporate western scientific approaches with traditional ecological knowledge (right way / 2-way science) (Lincoln et al. 2017, Woodward et al. 2020), and in so doing ensure that natural and cultural traditional knowledge about plants, animals, Country and culture were harmoniously captured and managed in ethically appropriate ways (Wensing & Callinan 2020).

Management approaches

Protected areas

Protected areas are widely considered the most effective way to protect biodiversity. They generally support higher species richness and abundance than comparable areas that are not protected (Gray et al. 2016).

However, protected areas are not immune to the ubiquitous nature of global climate change, and other pressures such as invasive species and fire cannot be excluded from most protected areas. Ten of the 19 Australia ecosystems currently experiencing collapse fall under national or international protected area management, and 7 are World Heritage properties (Bergstrom et al. 2021).

Australia's commitments to the protected area estate

Under the Convention on Biological Diversity, Australia committed in 1992 to:

> Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity (article 8A).

Australia in 2010 also committed to Aichi target 11:

> By 2020, at least 17 per cent of terrestrial and inland water areas 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 landscape and seascape.

Here, ecologically representative means:

> protected area systems should contain adequate samples of the full range of existing ecosystems and ecological processes, including at least 10% of each ecoregion within the country

and this is reflected in Australia's Strategy for the National Reserve System 2009–2030, which states:

> Priority (for expansion) will be given to under-represented IBRA bioregions with less than 10 per cent protected in the National Reserve System.

Australia's Strategy for Nature 2019–2030 also has at least 11 progress measures related to the protected area estate, although measurable and specific targets are absent from the strategy:

> 2C – Number and extent of lands managed for conservation under other effective conservation measures (privately managed protected areas, covenants or stewardship agreements)

> 4D – Number and extent of terrestrial and marine areas managed by Indigenous Protected Areas (IPAs) or other co-management arrangements

5A – Extent and representativeness of government-managed reserve estate and, where available, their condition

5B – extent and representativeness of marine protected areas, including marine Indigenous Protected Areas

5C – Number and extent of significant ecosystems protected by private landowners through stewardship or other arrangements

5D – Explicit consideration of future climate scenarios in the planning and management of protected area networks

5E – Retention, protection and/or restoration of wetland systems to maintain or improve ecological integrity and ecosystem function

6B – Number of populations of threatened or near-threatened species protected in government-managed reserves

6C – Number of populations of threatened or near-threatened species protected by private landowners through stewardship or other arrangements

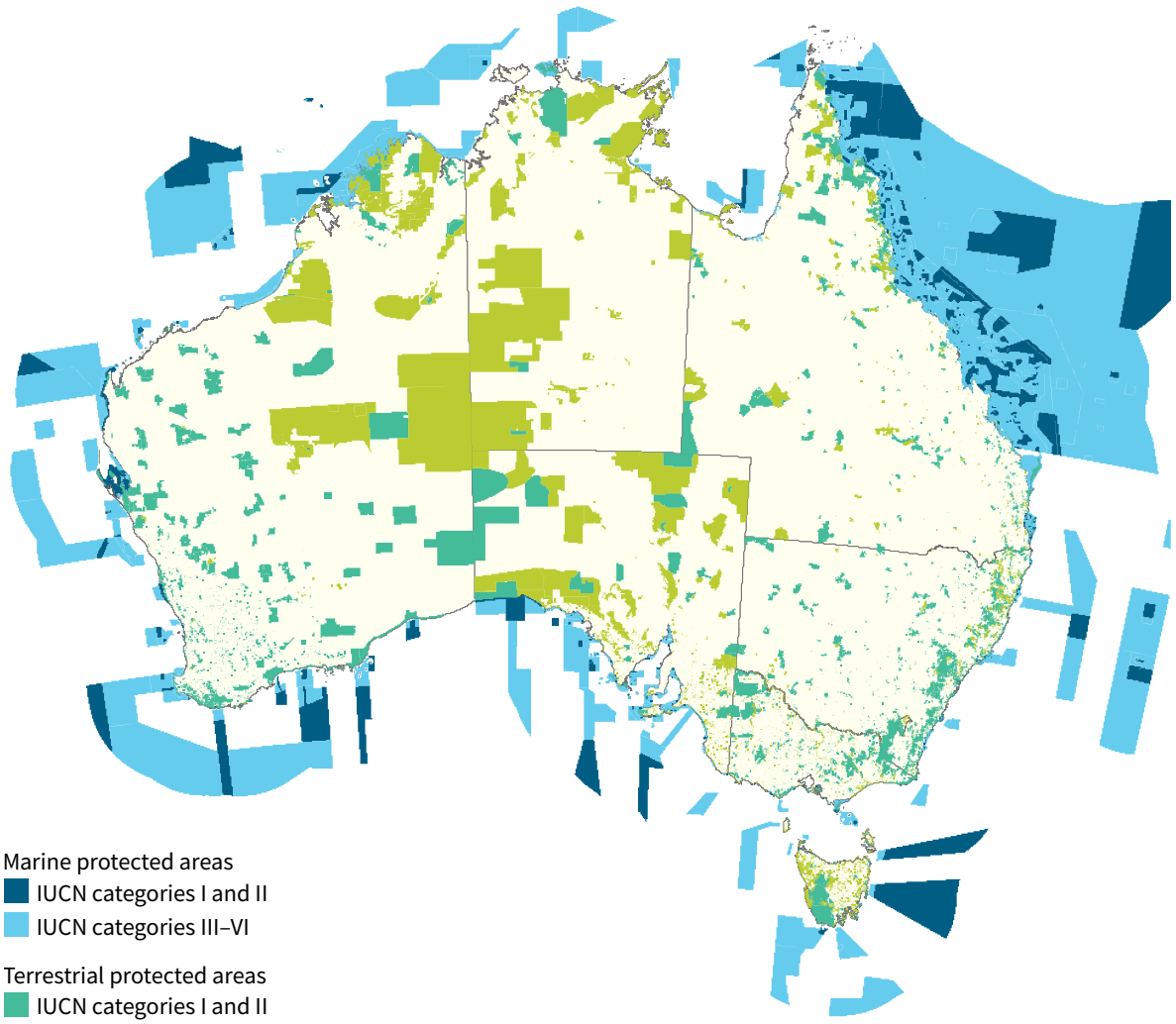
7E – Retention, protection and/or restoration of landscape-scale, native vegetation corridors

7F – Retention, protection and/or restoration of native vegetation in urban, peri-urban and agricultural contexts.

Trends in Australia's National Reserve System

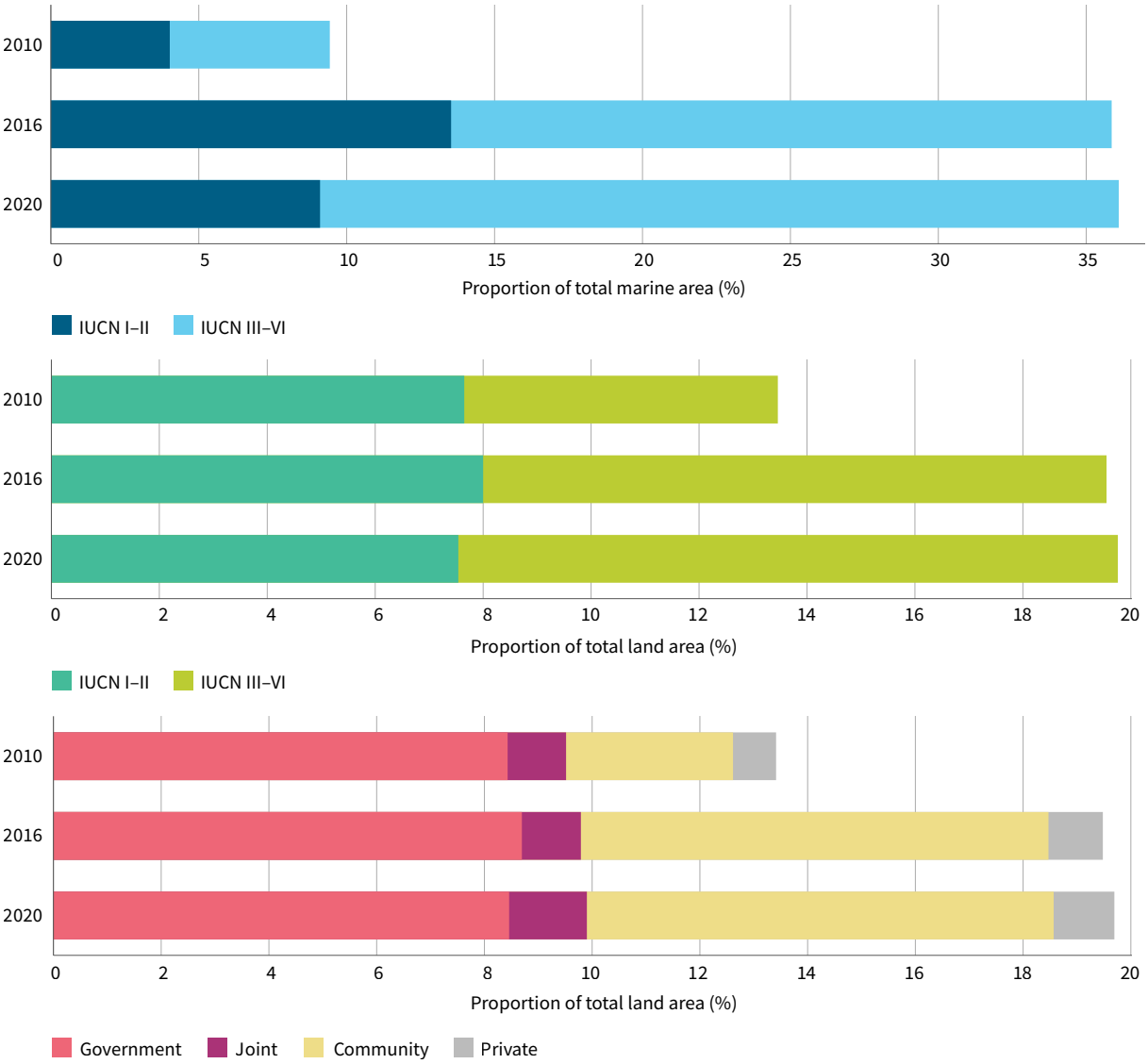
Australia's National Reserve System includes national parks, IPAs and privately protected areas. There was a large increase in the proportion of land protected between 2010 and 2016, with a relatively small increase between 2016 and 2020 driven by increases in the IPA estate. The fraction of Australia's land area protected in the National Reserve System is nearly 20% (CAPAD 2021). The marine protected area estate is now at 36.1% of all Australian waters, growing from 9.4% in 2010 (Figures 40 and 41) (Taylor 2020). The Marine chapter includes more detailed assessment of the extent and effectiveness of marine protected areas (see the Marine chapter).

The International Union for Conservation of Nature (IUCN) protected area management categories classify protected areas according to their management objectives. Categories I and II are classified as national parks in Australia and are managed to protect natural and cultural values (see Protected areas in the Heritage chapter). Categories III–VI are multi-use reserves. Low-level, non-industrial natural resource uses may be permissible in some categories of protected areas, where they are compatible with the primary purpose of nature conservation. Growth in the National Reserve System since 2010 has been almost exclusively in multi-use protected areas (IUCN categories III–VI). Terrestrial national park area actually decreased by about 1 million hectares (from 8% down to 7.5% of Australia's land area) after 2016 because management categories were re-evaluated by some jurisdictions.



IUCN = International Union for Conservation of Nature
Source: Taylor (2020), using CAPAD 2020

Figure 40 Terrestrial and marine protected areas in 2020



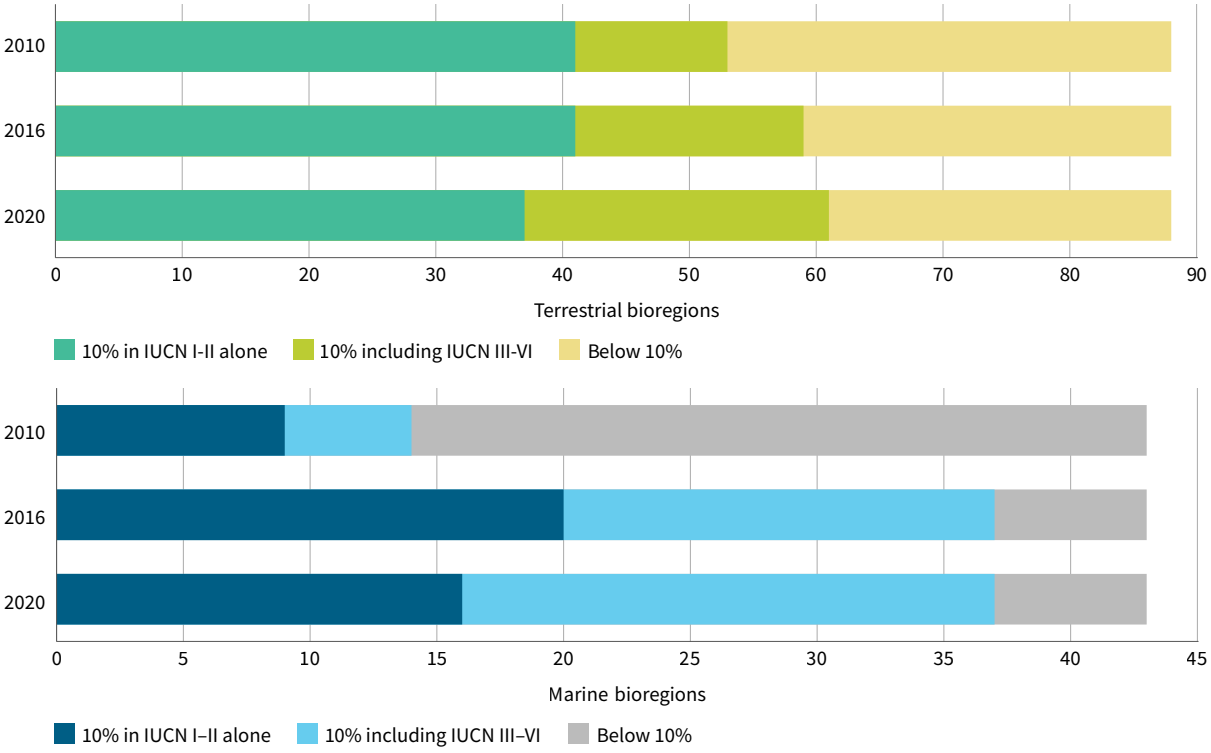
IUCN = International Union for Conservation of Nature
Source: Taylor (2020), using CAPAD 2010, 2016 and 2020

Figure 41 Changes in protected areas on land and sea by IUCN management category, and on land by governance category

The overall land and marine area protected in Australia exceeds area targets (i.e. at least 17% of terrestrial and inland water areas, and 10% of coastal and marine areas) but does not meet the Aichi target 11 'ecologically representative' criterion of 'including at least 10% of each ecoregion within the country'. In Australia, ecoregions are mapped as bioregions (Figures 42 and 43). Of 88 land bioregions (excludes the Coral Sea bioregion), 27 (31%) are still below 10% protected, mostly in inland areas, particularly in eastern Australia (Taylor 2020). Of 43 marine bioregions, 6 (14%) are still below 10%, mostly in south-eastern waters (see the Marine chapter).

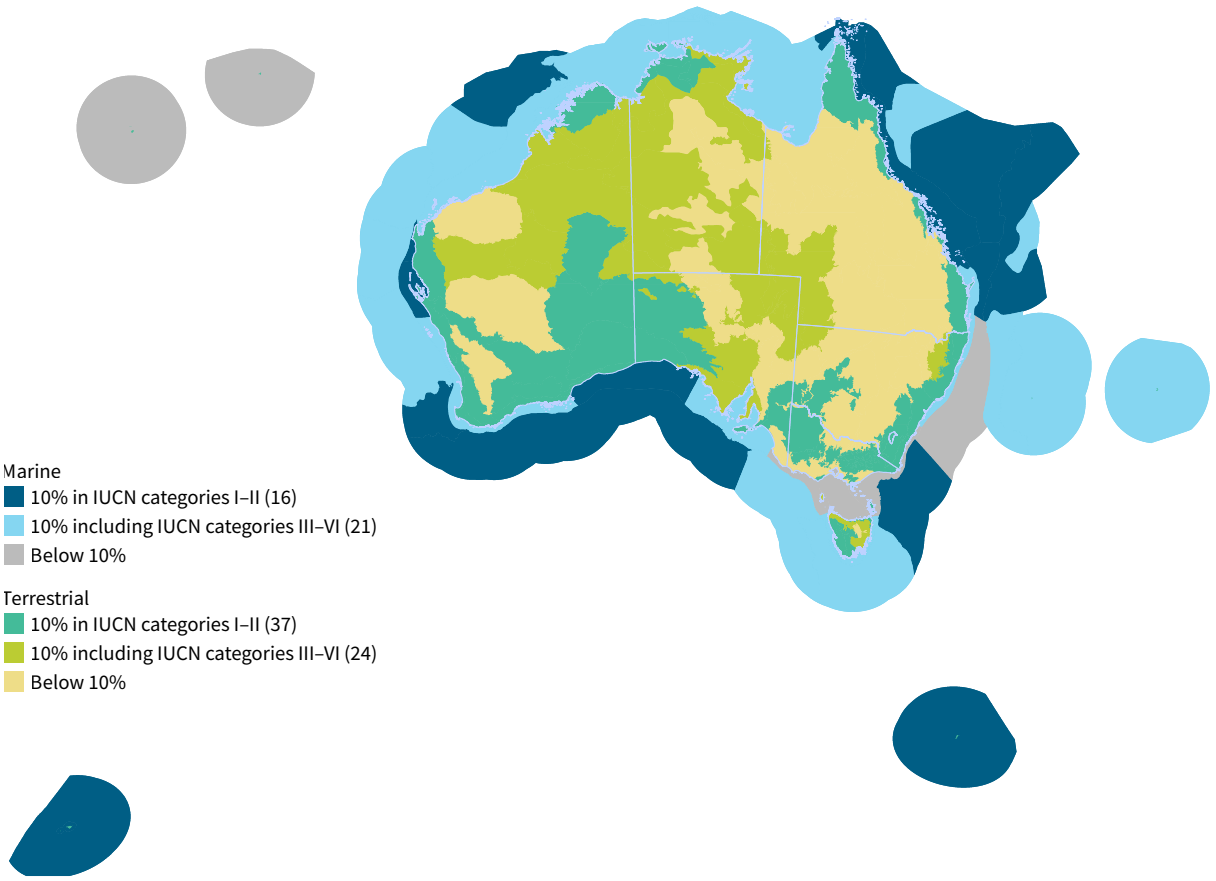
Of 191 catchments, 44 (23%) are below 10% protection (Figure 44). The level of protection given to inland waters and wetlands varies greatly, with nonperennial watercourses least protected while nonperennial inland lakes have had the highest levels and greatest advances in protection over the past 10 years, largely due to the extensive IPAs added in the arid and semi-arid zones. Protection of inland waters in national parks decreased between 2010 and 2020, largely due to revocation of 2 large nature reserves on Cape York (Taylor 2020).

Ecological representation below the bioregional scale is a commitment of Australian, state and territory governments under Australia's Strategy for the National Reserve System 2009–2030, with a target to 'Include examples of at least 80% of the number of regional ecosystems in each IBRA region' by 2030. A minimally adequate 'example' was set at 15% of the original extent of each ecosystem (ANZECC/MCFFA National



IUCN = International Union for Conservation of Nature
Source: Taylor (2020), using CAPAD 2010, 2016 and 2020

Figure 42 Proportions of 88 bioregions on land and 43 on sea meeting Aichi target 11 of 10% protection in 2010, 2016 and 2020



IUCN = International Union for Conservation of Nature

Figure 43 Terrestrial and marine bioregions reaching Aichi target 11 of 10% ecological representation, in IUCN categories I and II, and III–VI, 2020

Forest Policy Statement Implementation Sub-Committee 1997, Taylor 2020) (see also Figure 45).

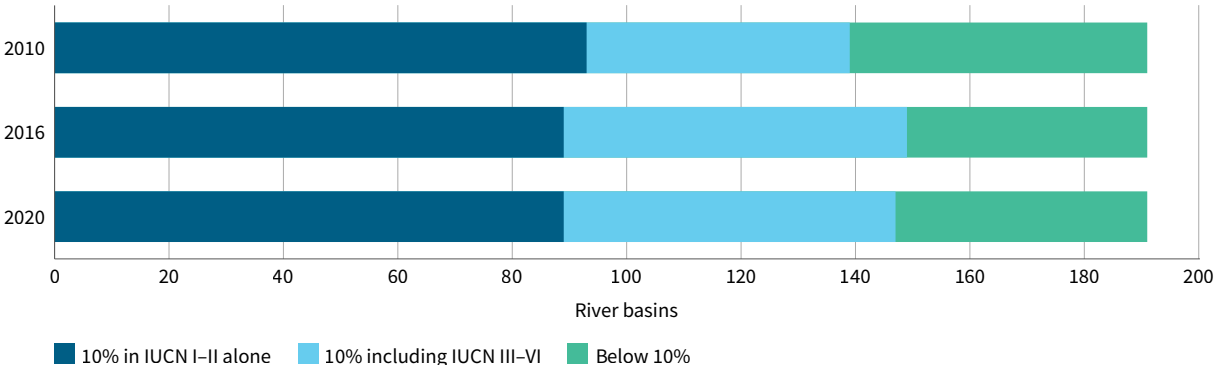
In 2020, 37% (2,218) of ecosystems were protected to a minimum standard (i.e. minimum standard met in protection under any IUCN category; Figure 45). Although this is an increase since 2010, 1,542 Australian ecosystems (26%) have no protection in the National Reserve System.

Queensland has the lowest attainment of the minimum protection of ecosystems standard. Ecosystems of small size and woodland ecosystems have high rates of no protection. The minimum target for protection of ecosystems can also be expressed in terms of area. Of a total of 115 million hectares across all ecosystems required to reach the minimum standard, 49% of the target protection has been achieved. This represents a gap in protection of about 42.8 million hectares; 15 million hectares of this gap are in Queensland.

Indigenous Protected Areas

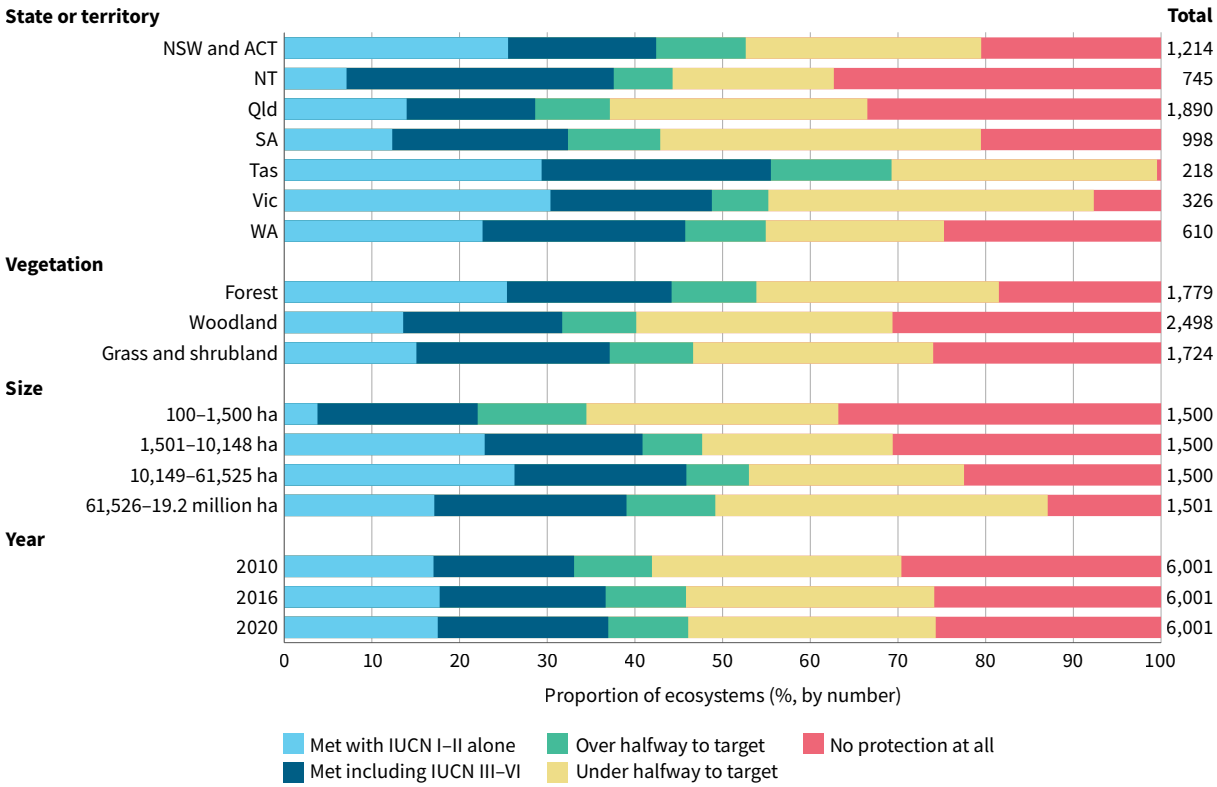
Aichi target 11 stipulated that the protected area system be 'equitable' as well as ecologically representative – that is, 'with the full participation of Indigenous and local communities, and such that costs and benefits of the areas are fairly shared'.

In 2020, there were 78 IPAs, which make up more than 46% of the National Reserve



IUCN = International Union for Conservation of Nature
Source: Taylor (2020)

Figure 44 Catchments meeting Aichi target 11 of 10% protection for inland waters, 2010, 2016, 2020



ACT = Australian Capital Territory; ha = hectare; IUCN = International Union for Conservation of Nature; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Note: A minimum adequate 'example' was set at 15% of the original extent of each ecosystem, with higher proportions for small ecosystems (100% if total area is less than 1,000 ha, and 1,000 ha minimum if 15% of total area is less than 1,000 ha). The 15% minimally adequate sample is based on the nationally agreed JANIS criteria; see ANZECC/MCFFA National Forest Policy Statement Implementation Sub-Committee (1997).
Source: Taylor (2020)

Figure 45 Number of 6,001 terrestrial proxy ecosystems sampled in protected areas to a minimum 15% standard, by IUCN category, state, type, ecosystem size and year

System (see the Land chapter). Most IPAs are dedicated under IUCN categories V and VI, which promote a balance between conservation and other sustainable uses to deliver social, cultural and economic benefits for local Indigenous communities.

The rapid growth of Indigenous sole and jointly managed protected areas from 2010 to 2020 suggests that equitability of management has increased, but several issues remain. While IPAs are recognised as part of the National Reserve System, the Australian Government offers only short-term grants to establish and manage IPAs, and invests in them at a much lower level per hectare than other protected areas (Taylor 2020). IPA 'projects' are funded through multiyear funding agreements to fulfil their management plan commitments. Government-protected areas, on the other hand, have permanent staff with ongoing salaries and operational budgets.

About 52% of the Australian continent is covered by some form of Indigenous tenure. Much of the land that is owned and managed by Indigenous people in Australia is in places that are rich in species and ecologically intact, compared with more developed, modified and heavily populated areas (Archibald et al. 2020). The retention of biodiversity on this valuable estate is highly dependent on Indigenous peoples' knowledge, practices and cultural connections to land (Renwick et al. 2017) (see Indigenous knowledge and land and sea management).

The increasing reliance on Indigenous communities to shoulder the burden of building the National Reserve System requires an increasing and appropriate investment in management and security. Short-term contracts, financial insecurity and tenure insecurity impose a high administrative burden and constrain the aspirations of Traditional Owners to care for their land over the long term.

World Heritage properties and Natural Heritage places

Australia's unique ecosystems and heritage are recognised in 20 World Heritage properties listed for their outstanding universal values: 12 are listed for their outstanding natural values, 4 for outstanding cultural values, and 4 for both cultural and natural values (see World Heritage in the Heritage chapter).

Since 2016, the Budj Bim Cultural Landscape has been added to the World Heritage List (see Budj Bim Cultural Landscape inscribed on the UNESCO World Heritage List in 2019 in the Heritage chapter), and 2 properties have been added to the Tentative List: the Murujuga Cultural Landscape and the Flinders Ranges. Murujuga, the Indigenous traditional name for the Dampier Archipelago and surrounds, including the Burrup Peninsula, is in the Pilbara region of Western Australia.

Private conservation and 'other effective area-based conservation measures'

Individuals, nongovernment organisations and businesses are increasingly purchasing and managing significant tracts of land for conservation. Australia now has one of the most expansive and long-running private protected area (PPA) programs in the world. To contribute to the Convention on Biological Diversity's Aichi target 11, areas on private land must be either PPAs or 'other effective area-based conservation measures' (OECMs) on private land. 'Other effective area-based conservation measures' is a conservation designation for areas that are achieving effective in situ conservation of biodiversity outside protected areas (see Management approaches in the Land chapter) (IUCN-WCPA Task Force on OECMs 2019).

Australia's Strategy for Nature 2019–2030 recognises the importance of OECMs to

contribute to biodiversity conservation with an explicit measure to assess progress against the 'Number and extent of lands managed for conservation under other effective conservation measures (privately managed protected areas, covenants or stewardship agreements)'. Although OECMs have been implemented in Australia for a long time, they have not traditionally been formally recognised for their conservation values. As such, there is currently no clear definition of the scope of actions and activities that constitute OECMs in Australia or a consolidated database to draw on.

All Australian states and territories have private conservation covenant programs that have contributed significantly to biodiversity conservation and increased focus on it at the national and international level in the past 5 years (Mitchell et al. 2018). A range of approaches and arrangements protect private land in Australia, including voluntary schemes, land purchase, conservation covenants and stewardship agreements.

A few nongovernment organisations own and manage a large number of properties managed for conservation. For example, the Australian Wildlife Conservancy owns, manages or works in partnership on 31 locations covering more than 6.5 million hectares. Bush Heritage owns 36 reserves covering 1.2 million hectares of land. In addition, Bush Heritage works in partnership with several Traditional Owner groups to deliver conservation and socio-economic outcomes across more than 10 million hectares.

Not all conservation covenanting programs qualify for inclusion in the National Reserve System. The determination of protected area status for private land conservation mechanisms largely involves an assessment of the strength of the legislation or legal agreements that protect that land (security), the length of time those agreements are in place (permanence), and management intent and obligations to manage the land (Mitchell et al. 2018). When not qualifying as PPAs, conservation covenanting programs may be considered OECMs.

Threatened species and ecological communities

Securing the long-term recovery of threatened species and ecological communities is a challenging task, involving many individuals, organisations and agencies. A complex framework of agreements, legislation, policy and planning regimes across Australia provides for the protection of threatened species and ecological communities. Primary among these, at the national level, are the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Threatened Species Strategy.

Species and ecological communities are listed as threatened under the EPBC Act using a rigorous scientific assessment based on internationally recognised criteria (IUCN Red List). This process is overseen by the independent Threatened Species Scientific Committee; however, the minister makes the final decision on listing. A conservation advice is prepared at the time of assessment, which includes a description of the biology, ecology and threats to the species or ecological community, and outlines priority actions for conservation, research and recovery. If listed, the minister may decide to enact a recovery plan if there are significant complexities in management needs due to the species or community ecology, threats, or the number of stakeholders involved in implementing recovery actions. Otherwise, a conservation advice is considered a more streamlined, nimble and resource-effective way to identify conservation needs and priority recovery actions.

As of June 2020, 719 recovery plans were in place for species (for 1,891 listed species), and

27 were in place for ecological communities (for 87 listed ecological communities). An approved conservation advice was in place for 1,431 species, and 71 ecological communities (DAWE 2020b). Many of these plans are out of date, have expired or will sunset in the near future. A further 142 species and 30 ecological communities were listed as requiring a recovery plan.

Conservation advices and recovery plans are critical national planning processes to facilitate national action on threatened species and ecological communities, to engage communities, to monitor progress, and to report on outcomes and conservation success. There have been many reported conservation success stories in Australia where appropriately resourced and implemented recovery programs, supported by dedicated people, have led to improved conservation outcomes (Latch 2018b).

However, there is no requirement for the Australian Government to implement or fund recovery actions for threatened species or communities, or report on progress and the outcomes achieved. This lack is repeatedly identified as a major impediment to understanding the effectiveness of conservation planning (see Information and monitoring).

Resources currently allocated to threatened species conservation by the Australian Government are considerably less than the estimates of the funding needed to avoid extinction and recover threatened species (Wintle et al. 2019) (see Management investment). The recent review of the EPBC Act noted that considerable effort given to the assessment and listing process is not matched by attention and resources dedicated to effective recovery (Samuel 2020). Experts have forecast that another 7 Australian mammals and 10 Australian birds will be extinct within 20 years unless management is greatly improved (Geyle et al. 2018).

Threatened Species Strategy

In response to ongoing concerns about the state of threatened species, and acknowledging that a more strategic response was needed, the Australian Government appointed a Threatened Species Commissioner in 2014 and implemented a Threatened Species Strategy in 2015 with a 5-year action plan. The strategy concluded in June 2020, and the results against targets were reviewed (Table 5).

Overall, 5 of the 13 targets in the strategy were met. Good progress was made against a further 3 targets (i.e. 'partially met'). Targets that reflected recovery action being undertaken were generally met; however, those that reflected actual changes in threatened species trajectories were largely not met. For some species, population trajectories will respond to on-ground actions over longer timeframes and ongoing robust monitoring will be required to assess the effectiveness of the strategy.

There was no target reflecting improved trajectories for threatened ecological communities, and it is difficult to understand whether the actions taken for those communities have been effective in improving condition or extent. Targets to reduce the impact of feral cats were largely achieved, or good progress was made.

Where targets have been achieved, some additional conservation programs are already being implemented and conservation benefits realised. For example, a program to reintroduce threatened fauna has commenced on Dirk Hartog Island following successful cat eradication. Rufous (*Lagorchestes hirsutus*) and banded hare-wallabies (*Lagostrophus fasciatus*) were released in 2017, followed by dibblers (*Parantechinus apicalis*) and Shark Bay bandicoots (*Perameles bougainville*) in 2019.

Table 5 Summary of results against targets of the Threatened Species Strategy 2015–20

Type of target	5-year target	Overall result	Summary
Species trajectory targets	20 priority birds have improved trajectories	Not met	21 bird species were listed as priority species. Over the strategy period: • 6 species improved • 6 species deteriorated • 4 were reasonably stable • 5 had trajectories that may have changed but not significantly so. Following the 2019–20 bushfires, 3 of the 21 priority bird species – the regent honeyeater (*Anthochaera phrygia*), the eastern bristlebird (*Dasyornis brachypterus*) and the western ground parrot (*Pezoporus flaviventris*) – were identified as priorities for urgent management intervention by the Wildlife and Threatened Species Bushfire Recovery Expert Panel. These species are now receiving targeted support for recovery.
Species trajectory targets	20 priority mammals have improved trajectories	Not met	20 mammal species were listed as priority species. Over the strategy period: • 8 species improved • 5 species deteriorated • 1 was reasonably stable • 6 had trajectories that may have changed but not significantly so. On-ground recovery actions to protect Australia's mammals include monitoring, habitat restoration, and reducing the impact of predators such as feral cats and red foxes. Where threats in the wild are too great for threatened mammals to persist, establishing ex situ populations in predator-free safe havens has been supported through funding for captive breeding and translocation programs.

continues

Table 5 *continued*

Type of target	5-year target	Overall result	Summary
Species trajectory targets	30 priority plant species have improved trajectories	Not met	30 plant species were listed as priority species. Over the strategy period: • 10 species improved • 4 species deteriorated • 16 species were reasonably stable or had a nonsignificant change in trajectory. Increasing monitoring efforts over 2015–20 led to discoveries of new populations of some plants, revealing them to be more common than originally assessed (e.g. Fitzgerald's mulla-mulla – *Ptilotus fasciculatus*, which has since been de-listed under the EPBC Act, and the purple-flowered wattle – *Acacia purpureopetala*). For 4 of the 30 priority plant species, considerable doubts were raised about their taxonomic validity: *Banksia vincentia*, blue-top sun-orchid (*Thelymitra cyanapicata*), silver daisy bush (*Olearia pannosa* subsp. *pannosa*) and scaly-leaved featherflower (*Verticordia spicata* subsp. *squamosa*).
Species trajectory targets	100% of Australia's known threatened plant species are stored in 1 or more of Australia's conservation seed banks	Not met	Approximately 67% of Australia's listed threatened species (930 of 1,373 species) are now stored in conservation seed banks. Recent research suggests that some of the remaining species may not be amenable to traditional seed-banking methods. Although some threatened species are represented by multiple collections of suitable size, many species are represented by collections of fewer than 500 seeds.
Species trajectory targets	Recovery actions underway for at least 50 plants	Met	Recovery actions are underway for all 30 plant species targeted by the strategy. The 5-year report notes that hundreds of other listed plant species also have recovery actions underway through a range of government and nongovernment programs and initiatives.

continues

Table 5 *continued*

Type of target	5-year target	Overall result	Summary
Species trajectory targets	Recovery actions underway for at least 60 threatened ecological communities	Met	Recovery actions are underway for more than 60 threatened ecological communities through programs such as 20 Million Trees (at least 54 sites), Regional Land Partnerships (32 different communities) and bushfire recovery programs (16 priority threatened ecological communities).
Feral cat targets	Feral cats eradicated from 5 islands	Not met	Eradication was achieved on Dirk Hartog Island in Western Australia only. Progress has been made towards eradication on Bruny Island, French Island, Kangaroo Island and Christmas Island. Funding to support eradication efforts continues through the Regional Land Partnerships and Environment Restoration Fund programs through to June 2023.
Feral cat targets	10 feral-free mainland exclosures established	Met	Between July 2015 and July 2020, 10 feral cat-free mainland exclosures were completed or were in the final stages of completion. In 2019, the Australian Government boosted efforts to establish a national network of safe havens through a $10 million commitment under the Environment Restoration Fund. The commitment includes a focus on increasing the number of species not currently represented in the safe havens network, drawing on research from the National Environmental Science Program Threatened Species Recovery Hub.
Feral cat targets	10 million hectares of best-practice feral cat management	Met	Feral cat control has been undertaken (at least once) across more than 18 million hectares. Feral cat management has focused on delivering humane and best-practice control across high conservation value areas. This includes the repetitive deployment of feral cat control tools so that feral cat densities are maintained at low levels, reducing predation pressure on recovering native wildlife.

continues

Table 5 *continued*

Type of target	5-year target	Overall result	Summary
Feral cat targets	Best-practice feral cat action implemented across 2 million hectares of Commonwealth land	Partially met	Best-practice feral cat control has been implemented across more than 1.9 million hectares of Commonwealth land, including Department of Defence and Parks Australia estates.
Feral cat targets	2 million feral cats culled	Partially met	The estimated number of cats culled over the 5-year strategy is nearly 1.6 million. When the target to cull 2 million feral cats was set in 2015, the national feral cat population was estimated to be 15–20 million cats. Research under the National Environmental Science Program Threatened Species Recovery Hub has since revised down the estimate of feral cats to 2.1 million when environmental conditions limit available resources, and up to 6.3 million in times of plenty. This has increased the level of difficulty in meeting this target. Shooters, hunters and farmers are estimated to be the most significant cohort of feral cat cullers, removing more than 85% of the cats culled over the 5-year period.
Improved recovery practices targets	All states and territories operate under the common assessment methodology for species listing	Met	All jurisdictions are actively involved in implementing the Common Assessment Method.
Improved recovery practices targets	Based on updated work plans, effective and up-to-date recovery plans, conservation advices and threat abatement plans are in place for all priority species and threats	Not met	All listed priority threatened species had a recovery plan and/or conservation advice in force but not all were up to date as of 30 June 2020. Up-to-date plans (that were approved or updated within the 5-year period) were in place for 9 mammals, 13 birds and 10 plants as of 30 June 2020.

continues

Traditional knowledge is informing management of priority species in the Threatened Species Strategy across Australia. For example, Indigenous rangers and Traditional Owners are working with Territory Natural Resource Management to improve knowledge on the condition of the central Australian cabbage palm (*Livistona mariae*), one of the strategy's priority threatened plant species and a culturally significant species to central Australian Indigenous groups. Indigenous rangers are undertaking on-ground management, and traditional knowledge is informing the development of management plans to ensure the long-term viability of the species and implement strategic actions to prevent further population decline.

A new Threatened Species Strategy 2021–2031 was released in May 2021. It builds on the model of the previous strategy and continues to focus on some of the established priorities, but also addresses new and emerging challenges. The 2 high-level objectives guiding the strategy are to improve the trajectories of priority threatened species by 2031, and to improve the conditions of priority places by 2031.

The strategy will be underpinned by consecutive 5-year action plans. These plans will be published as addendums to the strategy, with the first to be released in the second half of 2021. Projects delivering outcomes for threatened species are continuing under the Australian Government's National Landcare Program: Regional Land Partnerships, Environment Restoration Fund, the Wildlife and Habitat Bushfire Recovery Program, and the second phase of the National Environmental Science Program.

The new strategy has introduced new elements:

- Broadening the priority species to include reptiles, frogs, insects and fish to add to the priority birds, mammals and plants identified in the first strategy – including marine and freshwater species, as well as those from the land. Prioritisation of species and places will be based on 6 principles
  - species and places under severe and imminent threat
  - where recovery action will benefit other species
  - where action can make a difference and is cost-effective
  - culturally significant species and places
  - unique species and places
  - achieving balance in selected species and places.
- A new focus on 'priority places' to expand the strategy's influence across landscapes and seascapes. The new priority places will include sites where threat mitigation and habitat protection efforts will benefit multiple threatened species and ecological communities.
- Expanding the number of key action areas to focus efforts on landscape-scale actions that are fundamental to the recovery of threatened species. These include tackling more of the major threats such as weeds and diseases, and developing and using new tools and technologies to improve the effectiveness of managing feral pests and weeds.

Other focus areas include improving habitat to support species recovery, planning and coordinating action at the right scale, and forging stronger partnerships to use resources to their best effect.

Protection of threatened species in the National Reserve System

The Australian Government produces maps of known or likely-to-occur distributions for threatened species and ecological communities listed under the EPBC Act. These maps reflect the current much-reduced

distribution of species and communities that are now threatened with extinction. The extent to which the habitat of threatened species and communities overlaps with the National Reserve System was tested using a minimum protection standard of 30% (Taylor 2020). This standard is higher than that for ecoregions (10%) in recognition that these current mapped distributions are likely to be much more restricted than the original distributions (before species and communities were threatened).

The protection of threatened species within the National Reserve System has improved over the past decade: 92 EPBC Act–listed species attained minimum protection standards between 2010 and 2020, and 27 species went from being totally unprotected to having some level of protection (Figure 46). However, 129 species still lack any protection and a further 541 are below halfway to meeting the standard.

Critically Endangered species have the lowest levels of attainment of the minimum standard in the National Reserve System; 42 Critically Endangered species have no protection. This also correlates with the fact that species with the smallest ranges are least well protected and are the most likely to have no protection. Mammals and birds are relatively well protected in the National Reserve System, and invertebrates and plants are the least well protected. Marine, migratory and coastal species are better protected in the National Reserve System than terrestrial or freshwater species.

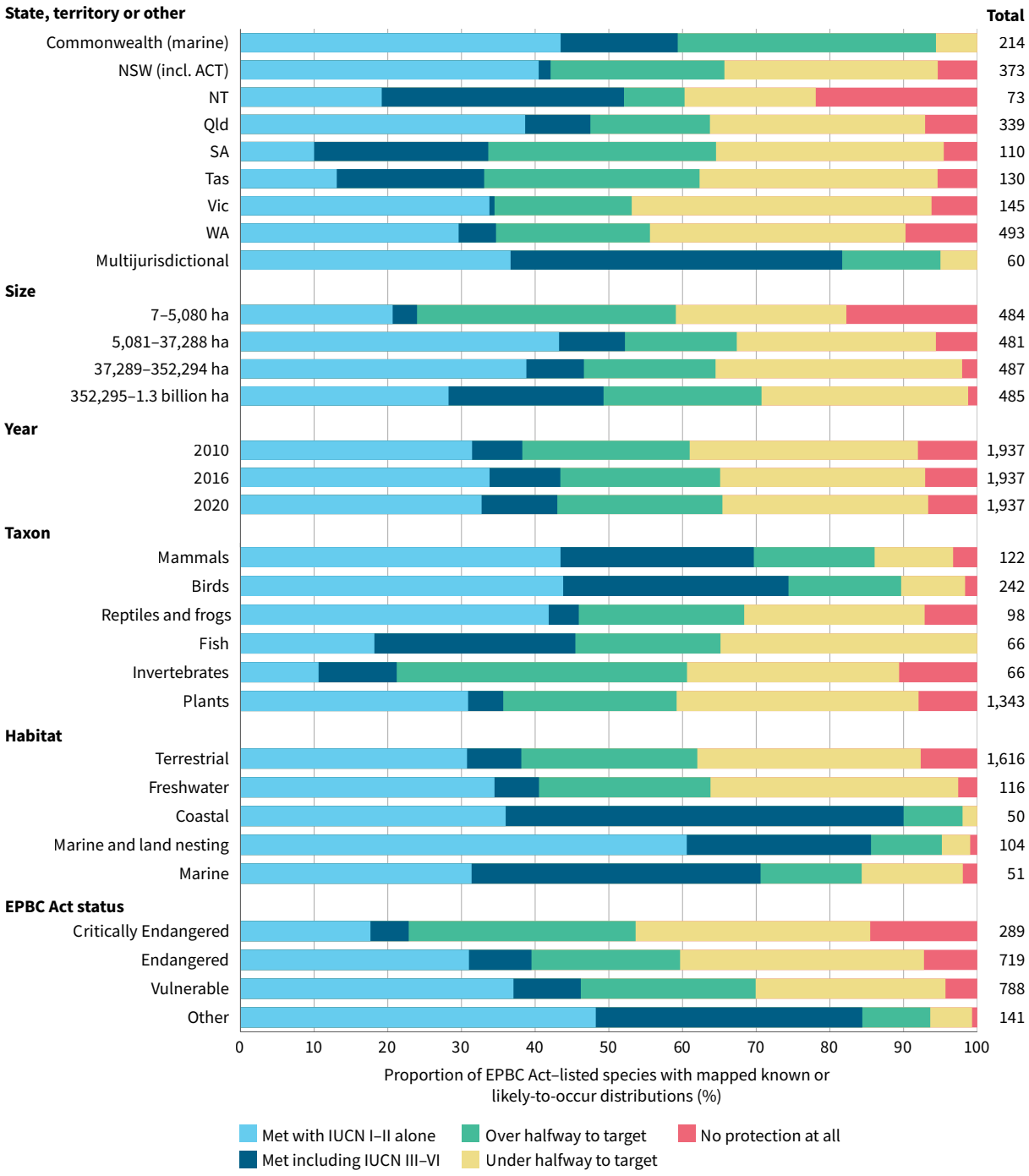
These analyses of representativeness of threatened species within the National Reserve System are based on the extent to which the National Reserve System overlaps with areas of known or likely occurrence for those species. However, because most species require the protection of sufficiently large and connected areas of suitable habitat to maintain viable population sizes, representation-based assessments are likely to overestimate the long-term success of the protected area estate in conserving species (Clements et al. 2018).

When more refined measures of representativeness were assessed for 90 Australian mammal species, the conservation capacity of the protected area estate declines. Although all 90 mammal ranges were represented within the National Reserve System, protection was insufficient for up to one-third of species based on a ‘persistence target’ of 10 viable, protected populations as adequate insurance against threats (Clements et al. 2018). For threatened species, 25 of 37 species assessed did not meet this ‘persistence’ target.

Systematic conservation planning has led to improvements in the placement of protected areas in Australia. In 2000, the Australian Government adopted a series of systematic conservation planning principles based on comprehensiveness and representation of ecosystems and threatened species, to guide further expansion of its National Reserve System. Before 2000, protected areas were more likely to be placed in areas with steep slopes and low human population density. Since 2000, protected areas are being increasingly placed in human-dominated landscapes with high numbers of threatened species and high human population density (Barr et al. 2016).

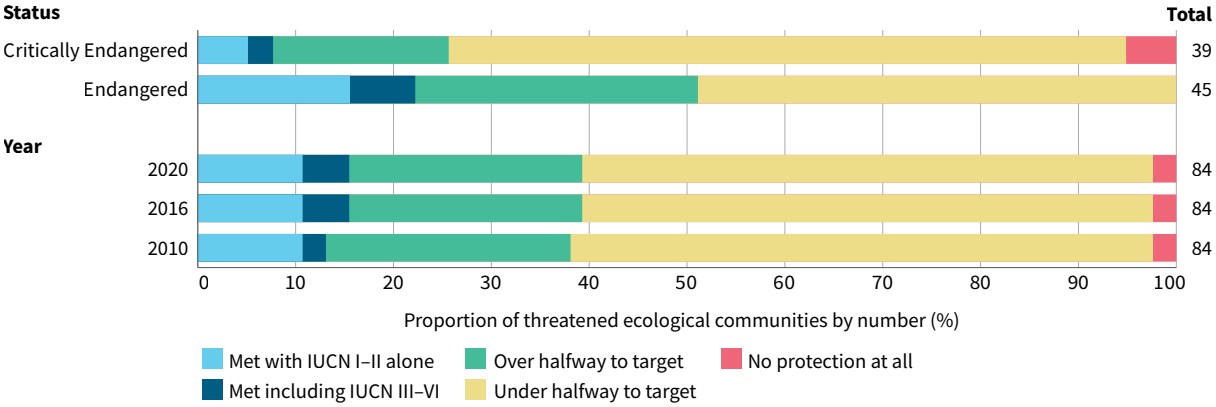
Threatened ecological communities protection in the National Reserve System

Only 16% (13 of 84) of threatened ecological communities meet a 30% minimum protection standard in the National Reserve System (Figure 47) (Taylor 2020). Attainment of the minimum protection standard is quite low and has not really improved since 2010. No



ACT = Australian Capital Territory; EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*; ha = hectare; IUCN = International Union for Conservation of Nature; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia
Note: 'Other' includes migratory or marine-listed species. May-occur habitat is much more extensive than known or likely habitat, and represents mostly the outer envelope of the species or threatened ecological community range. For this reason, may-occur habitat was excluded from the minimum standard.
Source: Taylor (2020)

Figure 46 Numbers of species of national significance sampled in protected areas to a minimum 30% standard, by taxon, habitat and EPBC Act status



IUCN = International Union for Conservation of Nature
Note: May-occur habitat is much more extensive than known or likely habitat, and represents mostly the outer envelope of the species or threatened ecological communities range. For this reason, may-occur habitat was excluded from the minimum standard.
Source: Taylor (2020)

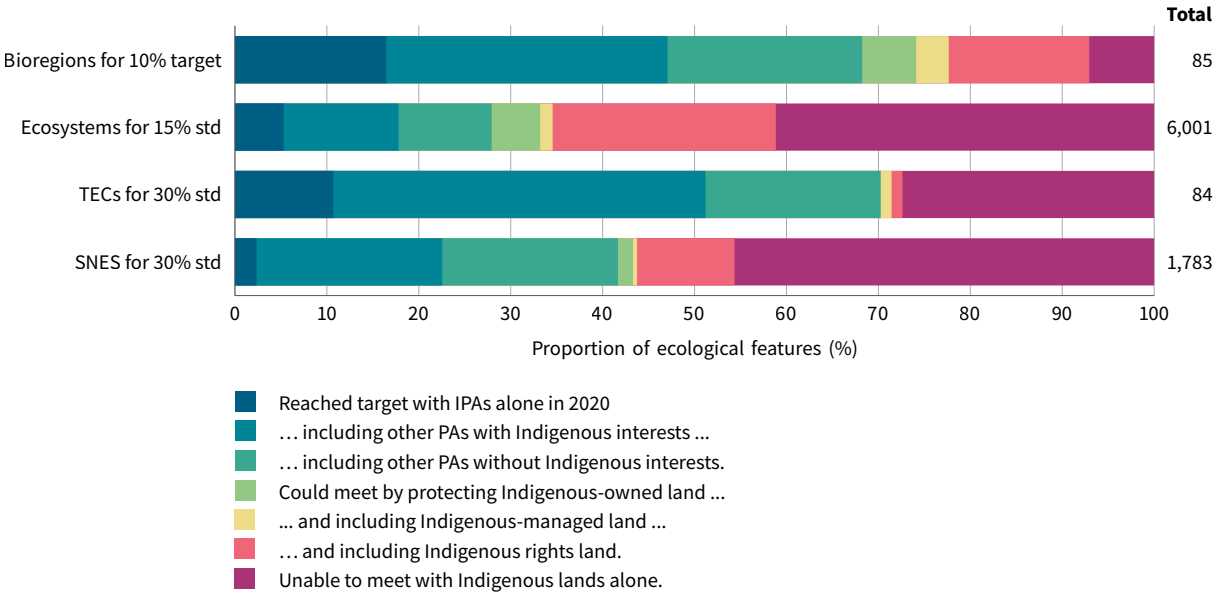
Figure 47 Numbers of threatened ecological communities meeting 30% minimum protection standards

protection of habitat is in place for 2 Critically Endangered communities with small areas of known or likely-to-occur habitat: Hunter Valley Weeping Myall (*Acacia pendula*) Woodland with only 21 ha of known or likely habitat, and Elderslie Banksia Scrub Forest in the Sydney Basin Bioregion with only 621 ha. A third community has only may-occur habitat mapped and is therefore not included in this analysis (the Critically Endangered Warkworth Sands Woodland of the Hunter Valley).

Indigenous land management and threatened species protection

Indigenous lands in Australia support a high proportion of threatened species. Approximately three-quarters of Australia's terrestrial or freshwater vertebrate species that are listed as threatened under the EPBC Act have ranges that overlap Indigenous lands. Twenty-two threatened species have more than 75% of their range on Indigenous land, including 5 species with more than 99% of their range on Indigenous land: Gawler Ranges short-tailed grasswren (*Amytornis merrotsyi pedleri*), northern hairy-nosed wombat (*Lasiorhinus krefftii*), Flinders Ranges mogurnda (fish; *Mogurnda clivicola*), Arnhem Land rock-rat (*Zyzomys maini*) and Carpentarian rock-rat (*Zyzomys palatalis*). Hotspots of threatened species overlapping with the Indigenous estate occur in coastal areas and in northern Australia (Renwick et al. 2017).

Indigenous interest lands are much more constrained in meeting minimum standards for protection for finer-scaled ecosystems, threatened ecological communities and species, mainly because they tend to be located in more remote areas of the country. IPAs and protected areas with Indigenous interests account for only 18% of ecosystems, 11% of threatened ecological communities and 22% of threatened species meeting their respective minimum protection targets. There is additional capacity for land that is Indigenous owned or has Indigenous interests, but is not currently in the National Reserve System, to contribute to meeting targets if Traditional Owners determine management for conservation is appropriate over that land (Figure 48) (Taylor 2020).



IPA= Indigenous Protected Area; PA = protected area; SNES = species of national ecological significance; std =standard; TEC = threatened ecological community
Note: May-occur habitat is much more extensive than known or likely habitat, and represents mostly the outer envelope of the species or threatened ecological community range. For this reason, may-occur habitat was excluded from the minimum standard.
Source: Taylor (2020)

Figure 48 Numbers of terrestrial bioregions, ecosystems, TECs and species of national significance meeting respective standards within Indigenous-associated protected areas

Case study The growth of Indigenous-led survey effort for the night parrot (*Pezoporus occidentalis*)

Malcolm Lindsay (Environs Kimberley), Rachel Paltridge (Kiwirrkurra – Desert Support Services) and Angie Reid (Ngururrpa – Desert Support Services).

After the night parrot's rediscovery in Queensland in 2013, a lot of effort was devoted across Australia to find more populations. Development by scientific experts Nick Leseberg, Steve Murphy and Nigel Jackett of techniques to record and analyse recorded bird calls provided the technology that could be combined with Indigenous knowledge of habitats, food and water resources to conduct targeted surveys for this extremely cryptic species.

The third night parrot population in Australia was discovered by the Paruku Rangers in 2017 in the Great Sandy Desert, with support from Environs Kimberley and WWF Australia. The Paruku Rangers had long conversations with their Tjurabalan community about whether to release the news, with fears of being swamped by birders or wildlife traffickers, but eventually decided to make the information public to celebrate their work, keeping the location vague. This fantastic news encouraged other desert ranger groups to search for their own night

parrot populations by talking to their old people, learning from others about what to look for and conducting surveys on their Country.

In the Kimberley, to make sure any research activities were Indigenous-led, desert ranger groups formed the Kimberley Night Parrot Working Group, coordinated by Environs Kimberley with support from the Kimberley Land Council, WWF Australia, and the Department of Biodiversity, Conservation and Attractions. This group successfully met to learn from the Paruku Rangers and scientists, share knowledge and equipment, plan surveys and make sure proper Indigenous engagement was occurring; and organised a night parrot workshop hosted by Paruku Rangers and attended by 6 ranger groups. The Indigenous Desert Alliance became the main forum and host for increasing Indigenous-led night parrot activity across all of desert and rangeland Australia. This culminated in the large Species of the Desert Festival, also hosted by the Paruku Rangers (supported by Rangelands NRM through funding from the Australian Government's National Landcare Program), where a real buzz and excitement was created for rangers to talk to their communities and start looking for their own 'fat budgie'.

Since 2017, 12 Ranger groups from Western Australia, South Australia and the Northern Territory have completed standardised night parrot surveys, with 4 confirming night parrot populations on their Country (Paruku/Ngurra Kayanta, Ngururrpa, Kanyirninpa Jukurrpa and Birriliburu). Since late 2020, in partnership with Rangelands NRM's Night Parrot project (funded through the National Landcare Program's Regional Land Partnerships), new and existing ranger-led night parrot surveys have been supported across the southern Kimberley and western deserts; 2 hubs have been created, led by Desert Support Services (southern deserts hub) and Environs Kimberley (northern desert hub). As a result of these new resources, the Ngururrpa Rangers have recently confirmed multiple populations across their Indigenous Protected Area, making the area covering Ngururrpa, Paruku and Ngurra Kayanta Country a critically important region for the species. These results demonstrate the significant conservation gains and effort that can occur if Traditional Owner rangers are treated as experts and lead efforts, their cultural knowledge is prioritised alongside scientific knowledge, and they are given important forums to learn and be inspired from other rangers and scientists.

We believe that this model of Indigenous-led threatened species management, supported by working groups or alliances, is a new way of working that needs investing in because it not only produces major conservation benefits for minimal cost, but empowers and gives rightful respect to Indigenous land management and stewardship of Country, traditional knowledge and culture.

Other management initiatives

A variety of restoration management initiatives are used in Australia to mitigate pressures or protect species. Restoration can happen in many ways, including through actively planting (revegetation) or by removing pressures so that ecosystems can return to an improved state. For example, across all Regional Land Partnerships projects (as part of Australia's National Landcare Program) the most common management interventions are weed control, feral animal control and habitat improvement/regeneration (Capon et al. 2020).

Restoration often involves a large number and diversity of stakeholders, since many restoration activities are delivered by locally based groups. Community and landholder engagement, communication, education and awareness raising are therefore also important aspects of restoration activities.

At times, management to restore ecosystems is not sufficient to rescue species from extinction and new developments cannot avoid significant further impacts. In these cases, biodiversity offsets, translocations and ex situ conservation may be used to arrest further losses.

Case study The Warru Project

The Warru Project is a longstanding collaboration between the Martu rangers of Kanyirninpa Jukurrpa (KJ) and the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA).

KJ is a Martu organisation that operates a suite of environmental, cultural and social programs in Martu communities and across the Martu Native Title Determination and Karlamilyi National Park, collectively known as Martu Country. Established in 2009, the ranger program employs more than 350 Martu and has built strong partnerships with the DBCA, and neighbouring Indigenous ranger groups and supporting NGOs, such as the 10 Deserts Project and the Indigenous Desert Alliance.

Warru (black-flanked rock-wallaby – *Petrogale lateralis*) were common across the arid zone until pressure from feral predators and changed fire regimes reduced their range to isolated refuges in rocky ranges. Several populations occur on Martu Country, and for more than 10 years Martu rangers have been managing them with support from DBCA.

The project is guided and supported by Martu Elders, ensuring it meets the priorities of Traditional Owners. Warru is a significant species to Martu, and the gorges and waterholes that sustain warru are often places of deep cultural significance. Management activities, such as prescribed burning, are implemented to protect both cultural significance sites and warru. 'The future generations should be working to look after Country, burning the right way, looking after rock-wallabies and waterholes,' said Muuki Taylor OAM, KJ's Senior Cultural Advisor. The guidance of desert-born Martu Elders has proven crucial to finding warru, with their

knowledge of suitable habitat and historical populations allowing Martu rangers to confirm the presence of the species at several locations on Martu Country.

DBCA provides scientific support and specialist skills to complement the rangers' local knowledge. In 2014, a population of warru was translocated from Kaalpi / Calvert Range to Pinpi / Durba Hills to insure against local extinction. DBCA scientists oversaw the capture, transport and release of 26 animals, which quickly established a breeding population at the new site. Since then, the population has been monitored, with Martu rangers trapping animals to obtain genetic samples. In addition, predator baiting has been conducted annually and predators monitored to assess the impact of baiting.

Mitigating the impact of wildfires is also critical to managing warru. Rangers regularly undertake prescribed burning in the winter months, establishing firebreaks along the base of the ranges and conducting landscape-scale aerial burning further afield. The rangers aim to reduce fuel loads and increase pyro-diversity, mirroring a traditional Martu-driven fire regime. A preliminary evaluation of fire management around warru habitat indicates that management has reduced the extent of fires generally, as well as limiting the number of hot, summer wildfires.

Monitoring and active management of warru has seen the populations on Martu Country not only survive but expand. By using Martu rangers' knowledge of Country and the DBCA's scientific expertise, the Warru Project is ensuring the future of the species on Martu Country.

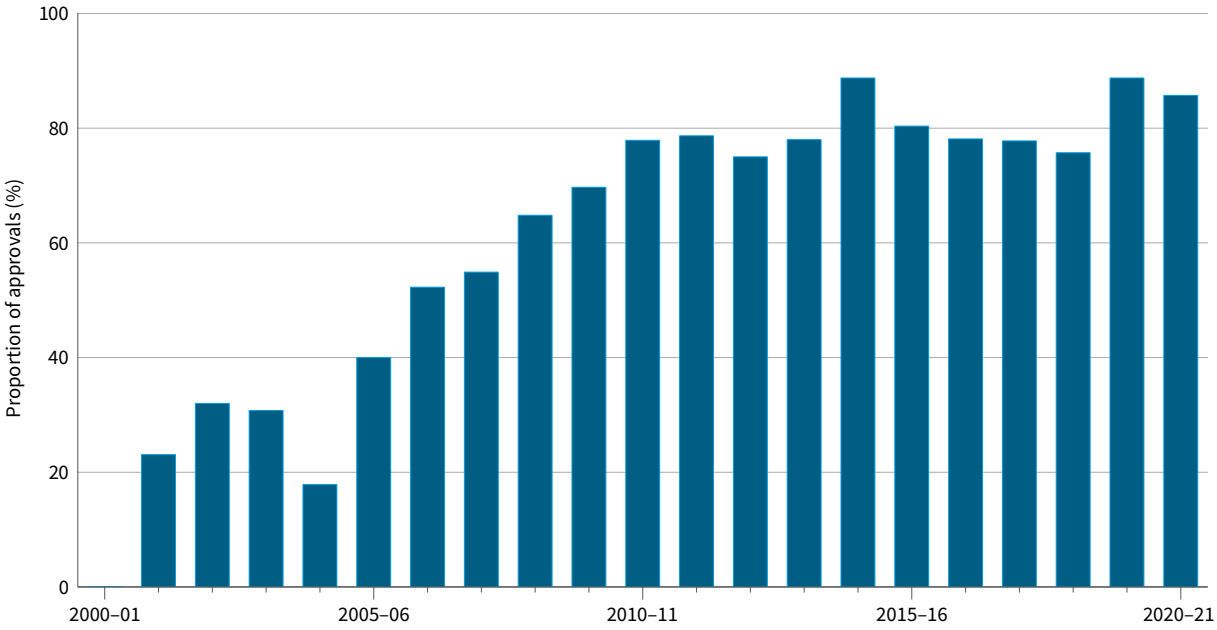
Biodiversity offsets

Sometimes, measures to avoid or mitigate the significant impacts of a controlled action on a 'matter of national environmental significance' are not able to sufficiently mitigate all impacts. Environmental offsets are increasingly used to compensate for these residual impacts and are considered as part of the decision to approve or not approve a proposed action under the EPBC Act (Figure 49) and most state legislation.

More than 70% of development proposals assessed under the EPBC Act now include offsets as a condition of approval. The Australian National Audit Office identified several concerns with increased reliance of offsets to achieve the objectives of the EPBC Act (ANAO 2020). For example, there is no departmental guidance for reviewing offsets, no quality assurance process for reviewing approved offset plans, no agreed method for estimating averted risk, and no appropriate systems to map offsets for internal or external use.

The effectiveness of offsets is often not evaluated after they are implemented, and it is becoming clear that some types of impacts can be difficult to offset and that the underlying principle of 'no net loss' can often not be demonstrated (Gibbons et al. 2018).

For example, the loss of 587 tree hollows as a result of a freeway upgrade in southern Australia was offset by the placement of 587 nest boxes in nearby woodland. The New South Wales policy guiding the offset stated



EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*
Source: Data for 2000–01 to 2019–19 from ANAO (2020); data for 2019–20 and 2020–21 from the Australian Government Department of Agriculture, Water and the Environment

Figure 49 Proportion of approvals with offset conditions since the commencement of the EPBC Act

that nest boxes must provide suitable habitat until such time that retained trees close to the highway realignment developed nest hollows and cavities to replace those lost. The offset targeted 3 threatened vertebrates: superb parrot (*Polytelis swainsonii*), brown treecreeper (*Climacteris picumnus*), and squirrel glider (*Petaurus norfolcensis*). However, nest boxes were shown to have both very low usage by the target species (or no usage in the case of the superb parrot) compared with use of natural hollows and cavities, and high rates of deterioration and permanent loss. The offset of hollow-bearing trees by the equivalent number of nest boxes, while compliant with the development approval, was largely considered to have failed from an ecological perspective (Lindenmayer et al. 2017).

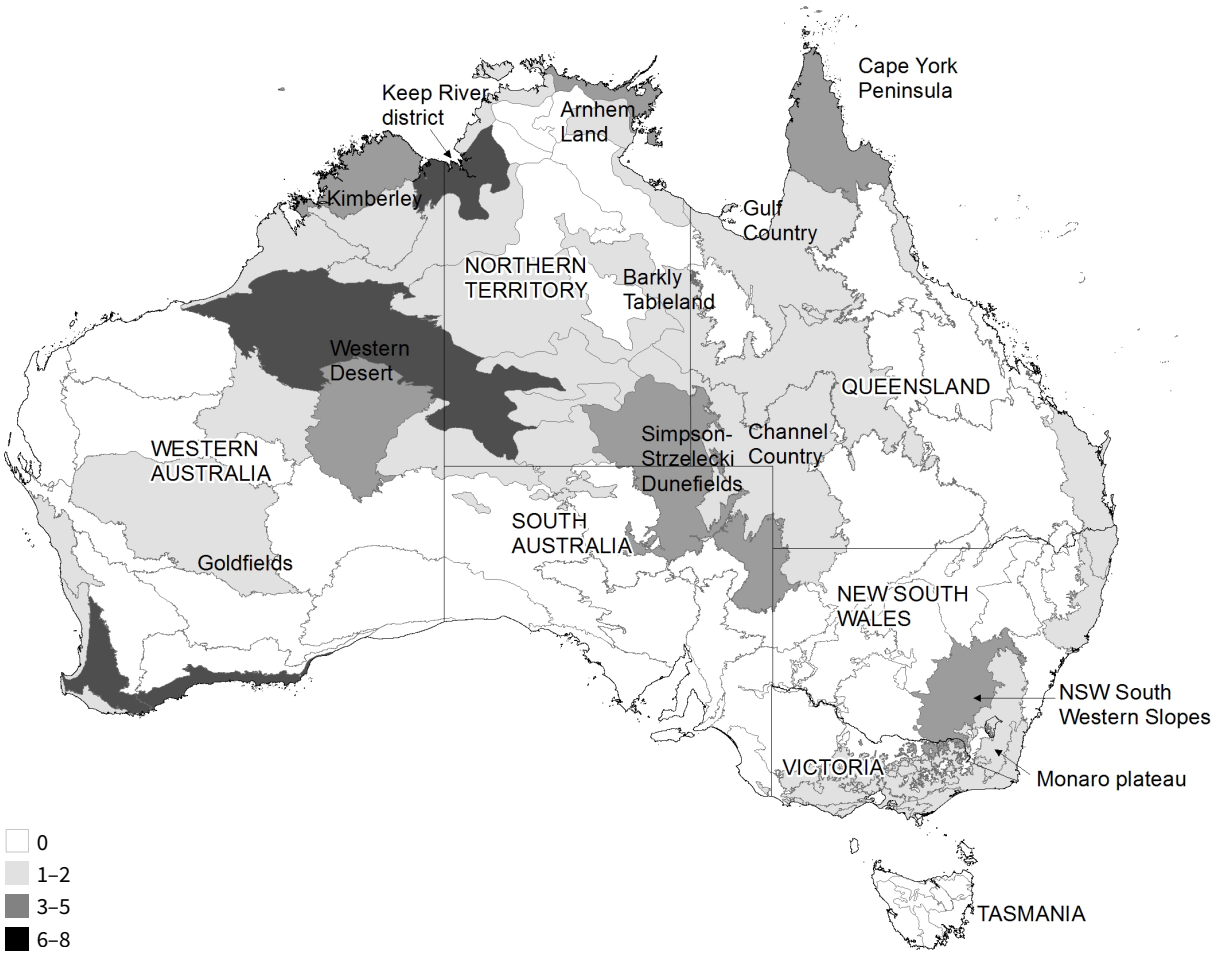
Of 74 fully implemented offsets approved in Western Australia between 2004 and 2015, only 39% demonstrated a successful implementation outcome (May et al. 2017). Land acquisition offsets most reliably delivered offset outcomes, at least on paper, through a change of tenure. However, these offsets do not necessarily include management of threats, or ongoing management and monitoring. The offsets that did not result in an outcome arose from a combination of non-implementation and failure according to completion criteria or goals. The low rate of success is striking because the assessment focused only on implementation and did not assess the degree to which offsets were adequate or appropriate, or the ecological equivalence of impacts and the outcomes. It is likely that the effectiveness of these offsets in terms of achieving no net loss of biodiversity is considerably lower than the implementation effectiveness. However, the researchers observed significant improvements in the clarity of offset approval conditions over the time of the study.

Translocations

Ethnographic records show that Indigenous Australians regularly and deliberately translocated plant species. Translocations spanned much of the continent and numerous lifeforms and plant uses (Figure 50). Replanting sections of tubers (including yams, lilies, sedges, legumes, ground orchids and numerous other plant groups) after harvesting is documented throughout Australia, and is by far the most well-known and widely practised example of translocation (Silcock 2018).

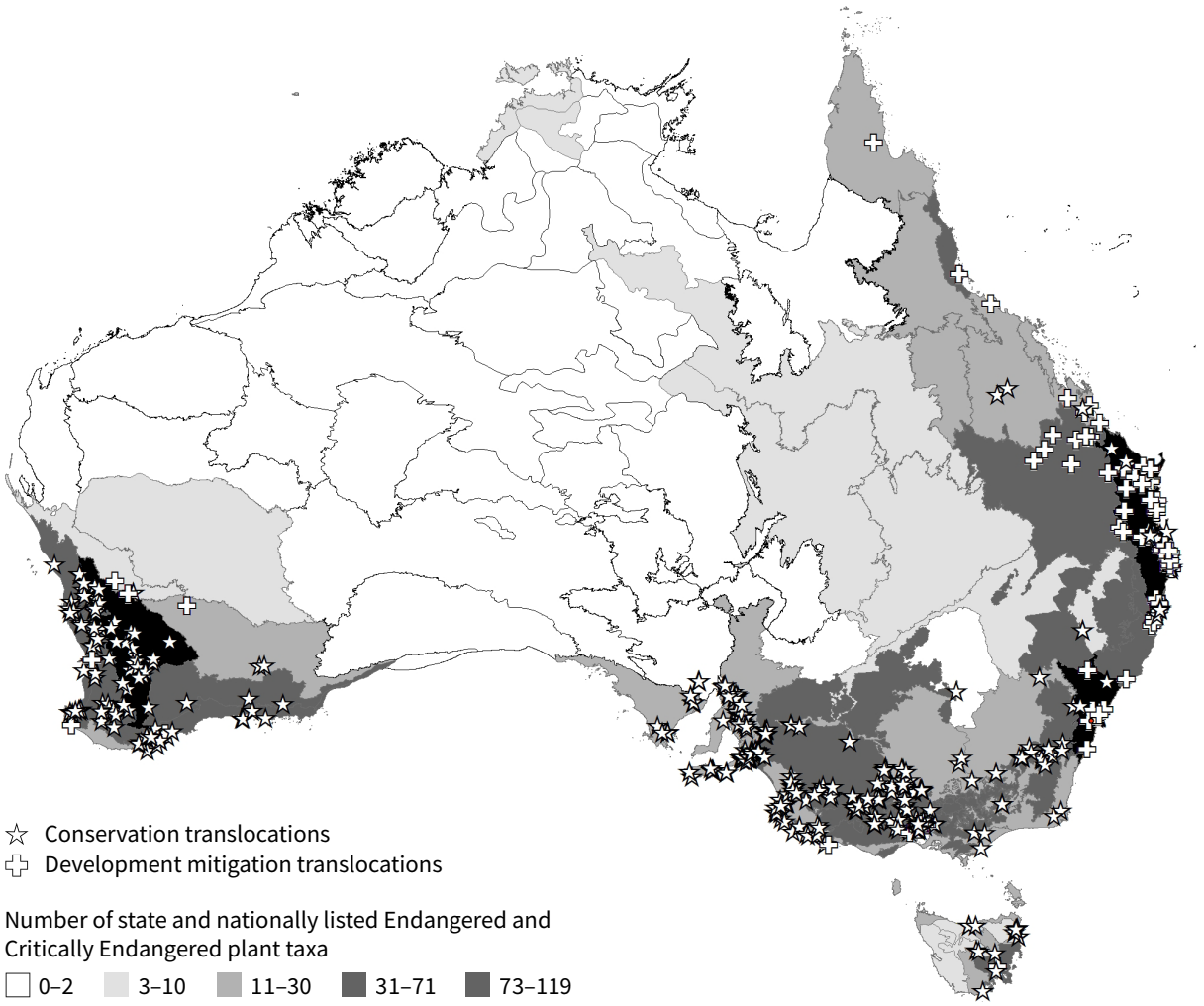
Translocations of threatened plant species are now commonly used to mitigate the impacts of development projects on rare and threatened plant species in Australia. At least 1,001 translocations of threatened plant species, involving 376 taxa, spanning all Australian states and territories except the Northern Territory, are known to have occurred since 1950 (Silcock et al. 2019), with more than 85% of these occurring since 2000. Translocations have been concentrated in regions with high numbers of threatened species, particularly south-western Australia, the south-eastern corner of Australia and the east coast (Figure 51).

For 724 Australian threatened plant translocations for which data on survival have been recorded, 135 (19%) had no plants surviving. Only 13% are considered to have



Source: Silcock et al. (2019)

Figure 50 Numbers of Indigenous translocations documented, by biogeographic region



Source: Silcock et al. (2019)

Figure 51 Translocations documented in Australia

sufficient plants surviving along with some recruitment of new individuals, indicating the potential to sustain a viable population (Silcock et al. 2019). These findings suggest that translocation for threatened plant species in Australia is still largely at the experimental phase, and relying on translocation to save threatened plant species in the face of development carries a high degree of risk.

Nevertheless, even when translocations are perceived to have failed in terms of plant survival and recruitment, an adaptive management approach and a commitment to ongoing monitoring mean that much can be learned to inform future activities. Some of the most successful translocations are those that have applied the lessons learned from past translocations. In 2018, the Australian Network for Plant Conservation published the third edition of *Guidelines for the translocation of threatened plants in Australia*, which provides a step-by-step best-practice guide for conservation translocation of Australian plants (Commander et al. 2018).

Ex situ conservation

Until recently, much of the conservation of threatened species in Australia has focused on in situ (conservation in place) approaches such

as management and protection of vegetation and habitat, and managing and mitigating threatening processes (Broadhurst & Coates 2017). These approaches are effective and considered preferable in most cases.

However, it is becoming clear that some species require ex situ (offsite) conservation to insure against extinction. As well as insuring against imminent extinction, ex situ conservation programs may serve several other purposes, including producing offspring for conservation research, restorations or reintroductions, and for education and fundraising. Common ex situ programs for biodiversity in Australia include seed banking for plants, captive breeding for animals, and establishing populations in zoos, aquariums and botanic gardens. However, for ex situ management to be an effective species recovery action, it needs to be coupled with specific in situ management to reduce threats responsible for declines.

Seed banking provides an insurance policy against the loss of plant species; once seeds are collected and stored appropriately, they can be used for restoration and translocation and for scientific research. The Australian Seed Bank Partnership (ATSP) is an alliance of 13 organisations that deliver a national program of work focused on ex situ plant conservation and research. At the end of June 2018, 20,296 collections of more than 13,300 native Australian plant species were stored in the ATSP seed banks throughout Australia. More than 13,336 of these collections are considered to be unique accessions, with the remaining 6,960 representing duplicate collections secured across the represented species range, bolstering the genetic diversity of collections held throughout Australia.

The 2015–20 Threatened Species Strategy had a target of '100% of Australia's known threatened plant species stored in conservation seed bank'. A total of 930, or 67.7%, of our nationally listed threatened flora species are currently represented in Australia's ex situ conservation seed banks, with many of these having already been accessed to support recovery and restoration programs. However, many of the threatened species held in Australian seed banks are represented by very small collections – in some cases fewer than 50 seeds. For some of Australia's threatened species, there is simply not enough seed available in situ to make a sufficient conservation collection (Australian Seed Bank Partnership 2019).

Ex situ conservation of amphibians, such as captive breeding or establishment of populations in zoos or aquariums, has risen in urgency over the past decade with the rapid decline and disappearance of many species as a result of the chytrid fugus (see Animal diseases).

Australia has become one of the world's leading countries in advancing the contribution of ex situ amphibian populations to species conservation. Nationwide, 14 threatened amphibian species are being held in biosecure facilities in zoological institutions; most of these directly assist conservation efforts to secure these species in the wild (McFadden et al. 2018). The greatest focus on ex situ amphibian conservation has been in south-eastern Australia, where there is a large number of threatened species and the greatest proportion of participating institutions. Successful ex situ conservation and breeding for insurance populations of the Critically Endangered southern and northern corroboree frogs (*Pseudophryne corroboree* and *P. pengilleyi*) has resulted in trial reintroduction programs in the wild (see case study: Recovering the critically endangered northern corroboree frog after the bushfires).

Safe havens and refuges

Offshore islands have been crucial for avoiding extinction for 9 Australian mammal species whose previous distributions included the mainland. For example, the greater stick-nest rat (or wopilkara – *Leporillus conditor*) once occurred widely in semi-arid and arid Australia but was extinct on the mainland by 1930s due to predation by feral and native predators. It survived total extinction because it persisted on the uninhabited Franklin Islands in the Nuyts Archipelago in South Australia. The species has since been translocated to 10 locations (4 islands and 6 mainland reserves), with 3 island and 1 mainland translocation successful, 5 unsuccessful and 1 as yet undetermined (Short et al. 2019).

Increasingly, 'mainland islands' – fenced areas from which predators are excluded – have featured prominently in threatened mammal conservation (Legge et al. 2018c). By the end of 2017, 17 fenced areas with predator-proof boundaries on the Australian mainland and 101 cat- and fox-free island havens were supporting 188 populations of 38 species of threatened mammals susceptible to predators (Legge et al. 2019) (Figure 52). However, 29 threatened species that are at a high risk of extinction from predators are not yet represented in any haven and new havens established since 2010 are mostly increasing protection for species that are already represented in existing havens (Legge et al. 2018c). Fourteen new havens are in planning or construction phases.

Threatened mammal translocations to islands have a relatively high success rate (around 86% of 35 translocations). The number of translocations to fenced areas is higher, but the success rate is lower (70% of 60 translocations).

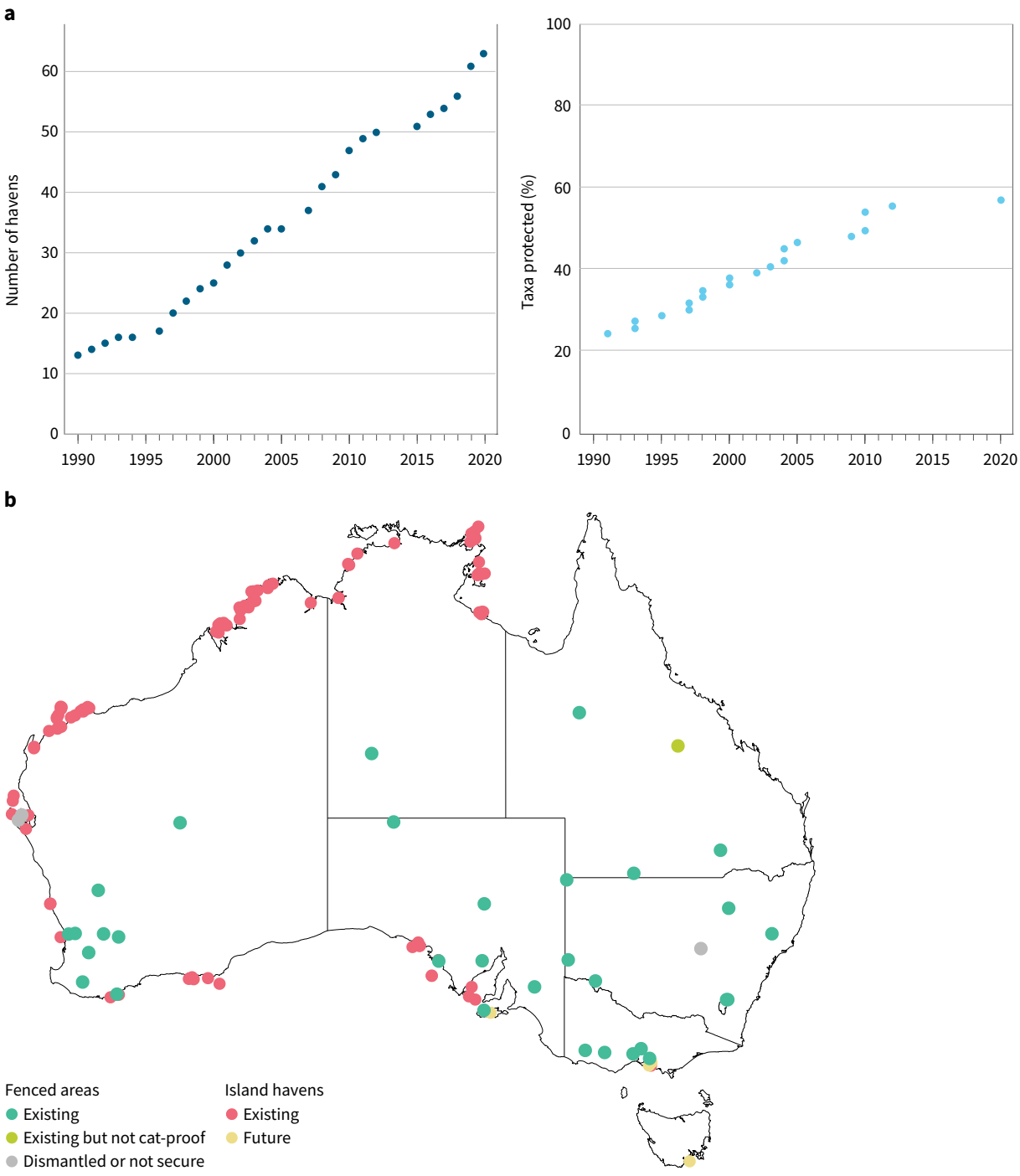
Predator-free islands have even more potential to serve as havens for in situ conservation or translocation of threatened mammals. Researchers have estimated that there are 590 known potential island havens that have potential to support threatened mammal populations (Legge et al. 2018c).

Management investment

Investment in biodiversity conservation and research is undertaken through a range of efforts, at federal, state and local government level, and through nongovernment, not-for-profit and philanthropic organisations, community groups and industry, Indigenous rangers and Traditional Owners, and land managers across Australia. Many of these investments have direct outcomes for biodiversity and many more on-ground land management efforts have important flow-on benefits. As a result, it is very difficult to understand the full extent of investment benefiting Australian biodiversity.

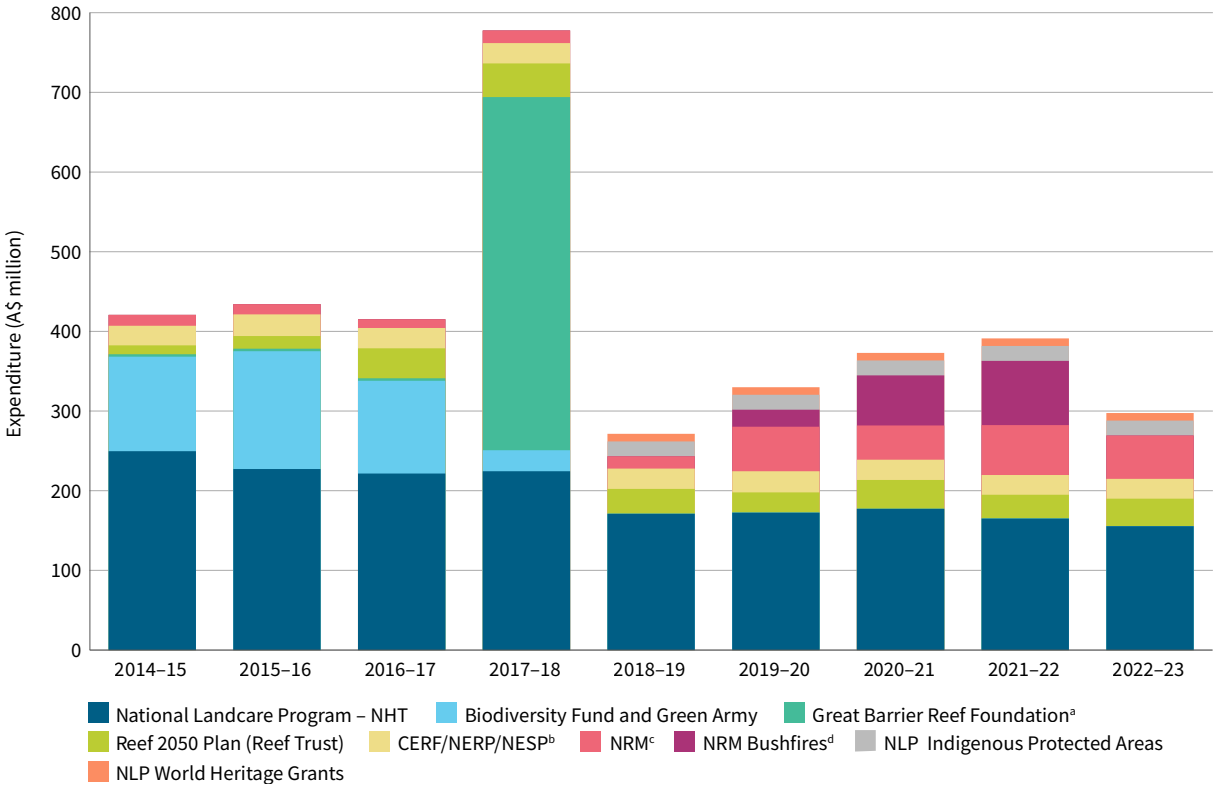
The Overview chapter provides a summary of Australian Government investment in the environment. The Biodiversity Conservation Division of the Department of Agriculture, Water and the Environment funds the major programs of work with the most direct benefits for conservation of Australian species and ecosystems (excluding Antarctica). The Australian Government also funds programs that contribute to biodiversity outcomes (directly and indirectly) through several other divisions in the department and across a number of portfolios, including the Director of National Parks, Heritage, Reef and Ocean Division, and the Commonwealth Environmental Water Office.

Since 2016–17, overall investment in programs that have the most direct outcomes for biodiversity has declined (Figure 53). A major one-off investment of $443 million was made to the Great Barrier Reef Foundation Partnership, which resulted in a spike of



Note: Locations of the 101 existing island havens, future island projects, and functional, nonfunctional and future fenced havens.

Figure 52 (a) Increase in the number of safe havens and the species represented in them since 1990. (b) Locations of havens for threatened mammals that are susceptible to predation by cats and foxes



CERF = Commonwealth Environmental Research Facilities program; NERP = National Environmental Research Program; NESP = National Environmental Science Program; NHT = National Heritage Trust; NLP = National Landcare Program; NRM = national resource management

a Includes funding the foundation, and water quality and crown-of-thorns control funding.

b Includes NERP (to 2014–15) and NESP (2015–23), which are not funded through the Biodiversity Conservation Division.

c Includes NRM Planning for Climate Change Stream 1 and 2; NRM programs for Improving Your Local Parks and Environment, environmental accounts capital, Communities Environment Program and Environment Restoration Fund; and NRM Oceans Leadership Package and NRM Raine Island Recovery Project.

d Includes NRM Bushfire Wildlife and Habitat Recovery programs and Bushfire Recovery for Species and Landscapes programs.

Note: Excludes most funding outside the Biodiversity Conservation Division (with the exception of CERF/NERP/NESP funding).
Source: Department of Agriculture, Water and the Environment, May 2021

Figure 53 Expenditure on biodiversity conservation and research programs by the Department of Agriculture, Water and the Environment, 2013–14 to 2022–23

funding in 2017–18. Apart from this specific research and management investment in the Reef, the remaining investment was $334 million in 2017–18 and $271 million in 2018–19, declining from an average of $437 million per year between 2013 and 2017. A further investment in bushfire recovery funding between 2019 and 2021 raised the total investment in those years, but the overall investment is still down from pre-2017 levels.

The recent review of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Samuel 2020) noted that:

> The current streams of Australian Government funding allocated towards environmental protection, conservation and restoration, despite being aligned with MNES (matters of national environmental significance), are not comprehensively coordinated to prioritise investment in a way that achieves the greatest possible biodiversity benefits. Funding is often

spread thinly across the nation, and the link between the investment of program funds on a particular project and outcomes for MNES can be difficult to discern.

Of concern is that scientists have estimated that the cost of recovery of threatened species in Australia is much greater than the amount we spend. Wintle et al. (2019) estimated the cost to be close to $1.69 billion dollars per year, compared with an estimated $49.6 million spent by the Australian Government on targeted threatened species in 2018–19. This spending includes programs that supported activities such as captive breeding of a threatened species or targeted threat management (e.g. fox control) to secure a population of a threatened species.

Indirect spending, including activities such as general weed or predator control, may also benefit a threatened species without being expressly for that purpose. Including both targeted expenditure and other relevant expenditures, the estimated upper limit of investment by the Australian Government in threatened species conservation in 2018–19 was about $391 million. Estimated spending by state and territory governments on targeted threatened species recovery in Australia is $72.4 million per year.

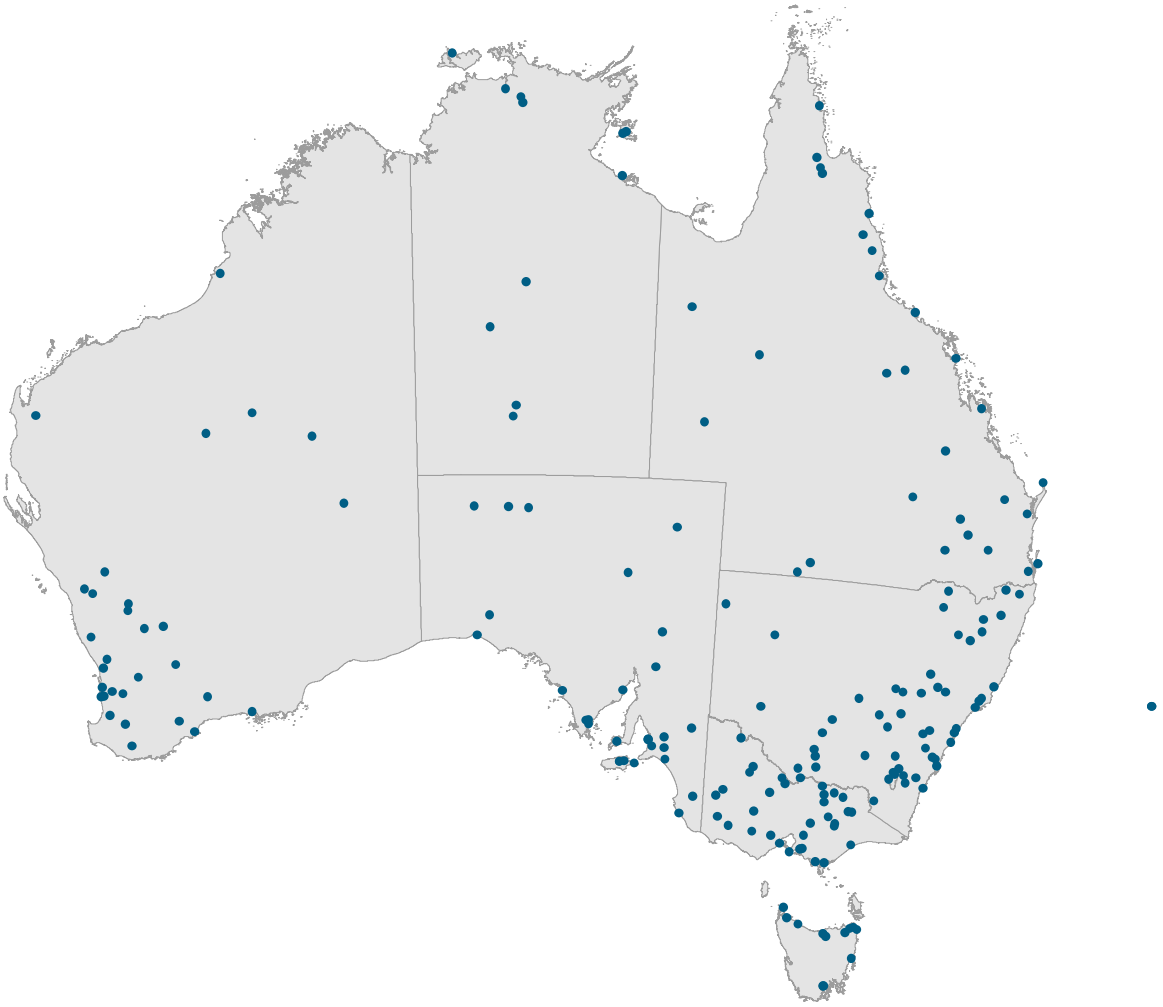
The efforts of the private sector, local government, nongovernment organisations and private citizens undoubtedly make a significant contribution to threatened species recovery but are not included in the estimates in Wintle et al. (2019). There are also many caveats associated with the estimates, in part because clear reporting on expenditure is not available, and the costs of managing pressures are very difficult to estimate. However, the overall message is that there is a significant shortfall in the investment required to secure threatened species. This is borne out in the declining trajectories of many species and in the increasing extent and magnitude of threatening processes and pressures.

Other experts suggest that the shortfall in restoration funding more broadly in Australia is $10 billion annually (Ward & Lassen 2018). Samuel (2020) noted that while it is unrealistic to expect government and the taxpayer to fund this level of investment, attracting greater private investment in natural capital and restoration of the environment requires federal leadership.

Natural resource management and biodiversity programs

The National Landcare Program Phase 1 commenced in 2014, with Phase 2 commencing during 2017–18 and being delivered through 2023. This funding provides key measures that include many practical, on-ground elements of natural resource management, mostly focused on maintaining and improving agricultural landscapes. It includes funding to address issues such as loss of vegetation, soil degradation, invasive species, water quality and flows, and changing fire regimes, which have beneficial flow-on effects for biodiversity in the broader landscape.

Regional Land Partnerships is the largest subprogram under Phase 2 of the National Landcare Program, with projects currently running across Australia (Figure 54). The program is investing in 120 threatened species, particularly birds and mammals (Figure 55), and 42 threatened ecological communities through actions such as weed control, pest fauna control, habitat improvement and community engagement. The program also contributes towards sustainable agricultural outcomes, including improving soil, biodiversity and vegetation. There are 74 Regional Land Partnerships projects benefiting 47 priority threatened species targeted for recovery under the Threatened



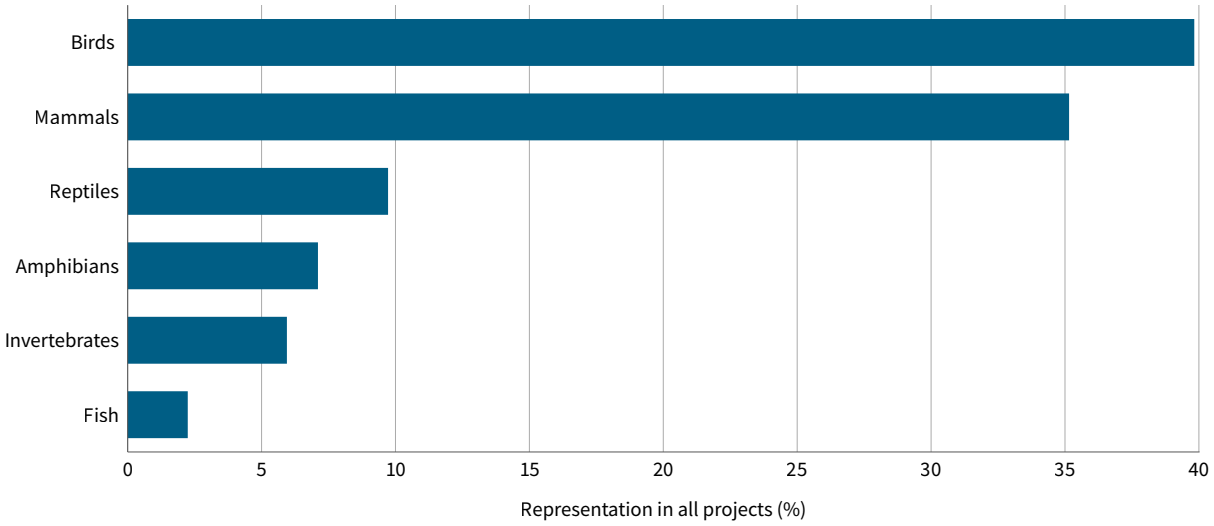
Source: Capon et al. (2020)

Figure 54 Locations of Regional Land Partnerships projects

Species Strategy: 17 mammals, 18 bird species and 12 plant species. Many of these species, including malleefowl (*Leipoa ocellata*), eastern hooded plover (*Thinornis cucullatus cucullatus*) and greater bilby (*Macrotis lagotis*), have multiple projects being undertaken across regional and state boundaries. There are also 78 Regional Land Partnerships projects improving the condition of threatened ecological communities. The total investment between 2018 and 2023 was $443 million.

Specific programs under the National Landcare Program Phase 2 that benefit biodiversity include:

- the Environment Restoration Fund (DAWE 2021b), which commenced in 2019–20 and runs for 4 years until 2023. Projects focus on 3 key areas: protecting threatened and migratory species; protecting coasts, oceans and waterways; and the clean-up and recovery of waste. Projects are being delivered through a mixture of grants, procurement and specific-purpose payments to the states. There will be a $10 million Environment Restoration Fund open grants round for projects tied to the release of the Threatened Species Strategy's 2021–2031 first action plan. The Environment Restoration Fund complements the Communities Environment Program (DAWE 2021f), which focuses on small-scale grants supporting community groups that may not be able to compete in larger and more



Source: Capon et al. (2020)

Figure 55 Taxa targeted by Regional Land Partnerships projects

competitive programs. Funding for these 2 programs combined is nearly $110 million over the 4 years

- the 20 Million Trees Program (DAWE 2021e), which will conclude in 2020–21; approximately 27 million trees were planted over the 5 years of this program
- implementation of the Reef 2050 Plan (DAWE 2021c), which focuses on addressing land-based run-off, coastal development and direct human use of the Great Barrier Reef
- World Heritage grants (National Landcare Program n.d.), which focus on addressing critical threats such as invasive species and changed fire regimes
- the Smart Farms program, which includes $136 million over 5 years to support the development and uptake of best-practice management, tools and technologies for farmers, fishers, foresters and regional communities to improve the protection, resilience and productive capacity of soils, water and vegetation
- support for efforts to control yellow crazy ants (*Anoplolepis gracilipes*) and for the Centre for Invasive Species Solutions, which is focused on invasive species management, research development and extension activities. The centre has continued the collaborative investment that the Invasive Animals Cooperative Research Centre had begun in invasive species management before its funding concluded in June 2017.

In 2020, the Australian Government announced a total investment of $200 million to support native species and their habitats to recover from the impacts of the 2019–20 bushfires. The work of the Wildlife and Threatened Species Bushfire Recovery Expert Panel has helped guide these investments; $164 million was delivered through the NRM Bushfire Wildlife and Habitat Recovery fund (Figure 54). Additional funding is delivered through the National Environmental Science Program (NESP) Threatened Species Recovery Program, the National Landcare Program and the Environment Restoration Fund.

Following back-to-back coral bleaching events in 2016 and 2017, and tropical cyclone Debbie in March and April 2017, the 2018–19 Budget included $535.8 million over 5 years from 2017–18 to accelerate delivery of activities under the joint Australian and Queensland governments' Reef 2050 Long-Term

Sustainability Plan (DAWE 2021d). The relevant budget measure included a one-off investment of $443.3 million in 2017–18 for a partnership grant to the Great Barrier Reef Foundation, and $5.2 million to the Department of the Environment and Energy to cover its costs of developing and oversighting the grant to the foundation. Subsequently, in July 2021 an additional $9 million was invested in the Reef for Traditional Owner–led projects to protect and manage existing Reef programs, including coastline management, weed and feral animal control, Indigenous fire management, and protection of threatened species.

In April 2021, the government announced a $100 million Ocean Leadership package. Over the next 4 years, $18 million of this will target practical actions to protect iconic marine species, improve the sustainability of our fisheries through reducing bycatch, commence national ocean accounting and encourage investment in our marine ecosystems. The Ocean Leadership package will also support the restoration of seagrass and mangrove communities ($30.6 million) to deliver blue carbon dividends and the expansion of the Australian Marine Park network to 45% of our marine waters ($39.9 million).

Indigenous Protected Areas and ranger programs

Funding for Indigenous Protected Areas (IPAs) is also delivered through Phase 2 of the National Landcare Program. This includes $93 million between 2018 and 2023 for management of the IPA estate, administered in partnership with the National Indigenous Australian Agency (NIAA). In 2017, an additional $15 million was committed under the New Indigenous Protected Areas Program for establishment of new IPAs. In April 2021, the Australian Government also committed $11.6 million over 2 years to June 2023 from its Oceans Leadership Package to expand IPAs to include additional sea Country (that funding is not reflected in Figure 53). On-ground activities by Indigenous communities and ranger groups are also supported through programs such as the Environment Restoration Fund and Regional Land Partnerships, as well as through partnerships with research, education, philanthropic and commercial organisations.

The Indigenous Ranger Program is currently funded through the Department of Prime Minister and Cabinet and administered by NIAA (also not included in Figure 53). Funding for this program has recently been extended from 2021 through 2028 at $102 million per year (indexed). This is an important development because it is the first time that Indigenous rangers funded by the Australian Government have had longer-term funding security. This program supports a range of activities that protect and manage land and sea Country and culture, including fire management, protection of threatened species and biosecurity compliance. However, while the funding supports existing ranger teams, it does not allow for growth or for new ranger teams to be established. New funding opportunities and initiatives will be required to support the demand for and growth in IPAs, particularly in southern Australia, and the increasing interest and value placed on traditional knowledge and engagement in biodiversity conservation, land management and research.

In concert with the Australian Government's investment in ranger programs, jurisdictional support for Indigenous land and sea management practitioners has continued to grow. For example, in Western Australia, the state government invested $20 million over 5 years from 2017 into an Aboriginal Ranger Program that resulted in more than 300 full-time-equivalent people being employed across 35 projects. Subsequently, the Western Australian Government has committed $50 million over 2021–25 to expand the Aboriginal Ranger Program so that

more Indigenous organisations can employ and train rangers to manage Country, and build community leadership, wellbeing and resilience. Along similar lines, in February 2021, the Queensland Government committed to doubling the number of Land and Sea Rangers to 200 positions at a cost of an additional $24 million.

Research

The Australian Government funds biodiversity and environmental research programs through the National Collaborative Research Infrastructure Strategy (NCRIS). The Terrestrial Ecosystem Research Network, the Integrated Marine Observing System, Bioplatforms Australia and the Atlas of Living Australia are NCRIS facilities supporting biodiversity and environmental programs.

Investment is also made into NESP, which funds environment and climate research to provide evidence for policy and on-ground management of the environment. The first phase invested $145 million (2014–15 to 2020–21) into 6 research hubs; the second phase will invest $149 million (2020–21 to 2026–27) into 4 new research hubs (DAWE 2021a). NESP research generated through Phase 1 has provided important content used throughout this report. A cross-hub Indigenous Facilitation Network is working to drive increased Indigenous inclusion in research through NESP Phase 2.

The Department of Agriculture, Water and the Environment partners with not-for-profit organisations, nongovernment organisations, the corporate sector and philanthropists to undertake biodiversity and environmental research. Examples include the Bush Blitz program, which is an $11 million joint partnership between the Australian Government through Parks Australia and the Australian Biological Resources Study, major corporate sponsor BHP and Earthwatch Australia. With the collaboration and participation of BHP employees, teachers, students, Indigenous rangers, Traditional Owners, park rangers, biological researchers and other land management practitioners, Bush Blitz has discovered more than 1,735 new species across Australia in the past decade. The 10 Deserts Project and the Australian Seed Bank Partnership are also examples of successful research partnerships.

Information and monitoring

Compared with state of the environment reporting in 2016 and 2011, our knowledge of the state and trend of biodiversity as well as the knowledge gaps, particularly for threatened species, has significantly increased in the past 5 years.

The work of the National Environmental Science Program (NESP) has greatly improved knowledge about key threats to biodiversity, the state and trend of threatened species and ecosystems, and the actions needed to support their recovery (particularly the Threatened Species Recovery Hub, the Marine Biodiversity Hub and the Northern Australia Environmental Resources Hub). The NESP research hubs of the first phase of the program (2014–15 to 2020–21) are delivering the culmination of 7 years work into this state of the environment report. The next phase of NESP commenced in 2021 and will deliver further refined data, tools and knowledge to support reporting in the future.

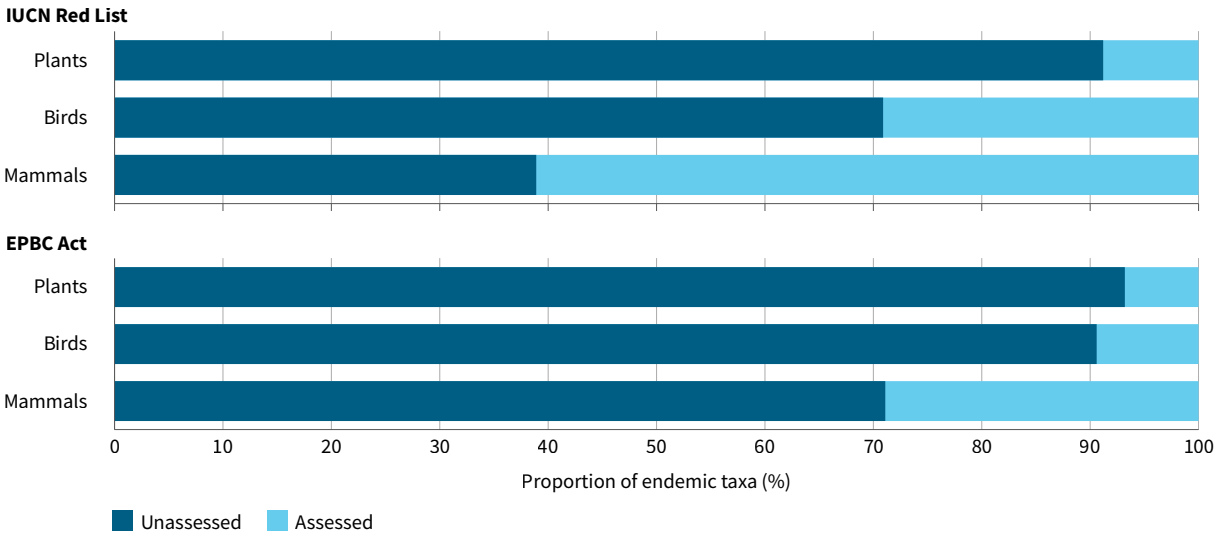
However, there are still very large gaps in our understanding of the state and trend of the vast majority of native Australian species, including those that are at most risk of extinction. The absence of reliable data on numerous threatened species severely limits

our ability to allocate conservation resources in an informed and effective manner (Allek et al. 2018).

Extinction risks have been assessed for a smaller proportion of Australian endemic plants than Australian mammals or birds (Figure 56) (Alfonzetti et al. 2020). This means there are likely many more threatened plants in Australia than we currently have adequate knowledge about. Even for many listed plants, there are taxonomic uncertainty and limited knowledge of population state and trend (Silcock & Fensham 2018). One of the obstacles to effective plant conservation is a decline in taxonomic skills and the ability to readily identify plants in the field, as well as a dearth of biological and ecological knowledge for the vast majority of species (Broadhurst & Coates 2017).

Monitoring is an essential element of the conservation management of Australia's threatened species and communities as well as nonthreatened biodiversity. Monitoring data underpins species and community conservation status, is used to evaluate the effectiveness of management investments, and indicate the urgency of management interventions (Legge et al. 2018a). A sample of 10 of the 25 recovery plans adopted under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for threatened ecological communities all included monitoring of some aspect of biodiversity as a priority action, and some also included monitoring of threats (Keith et al. 2018). Few of the plans provided guidance on how monitoring was to be done, although some recovery plans identified actions to develop methods. Monitoring of threatened ecological communities is also carried out as a reporting requirement for natural resource management funding programs such as Landcare. However, the design, detail and rigour of these projects varies widely, and the data and outcomes from monitoring are rarely published in discoverable sources.

Several government-funded initiatives have sought to deliver greater national coordination

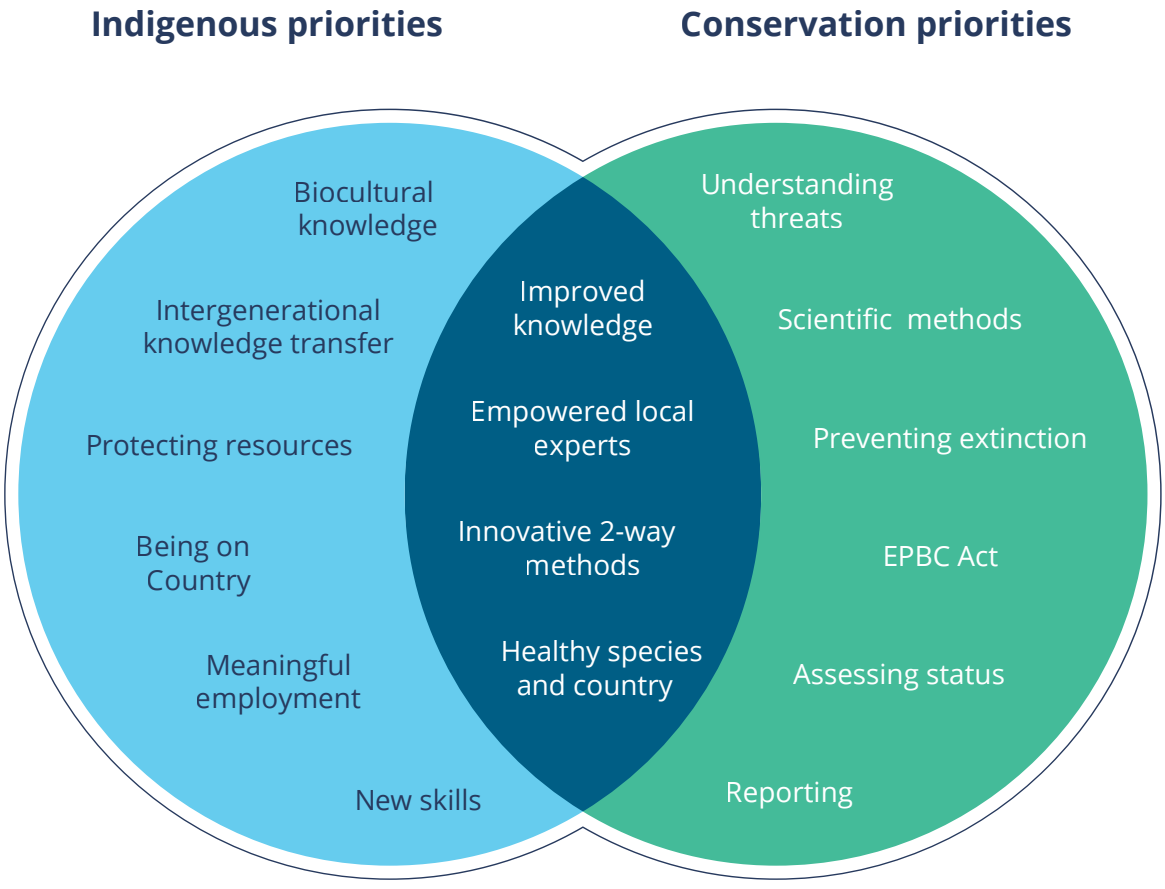


EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*; IUCN = International Union for Conservation of Nature
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Figure 56 Proportions of endemic Australian plants, birds and mammals assessed under the IUCN Red List and the EPBC Act

and standardisation of environmental data. These include the Terrestrial Ecosystem Research Network, the Atlas of Living Australia, Digital Earth Australia and the Australian Biological Resources Study. However, no single organisation has clear responsibility or adequate and ongoing funding for stewardship and coordination across the breadth of national environmental information. The lack of coordination drives higher costs and derives fewer benefits from the investments that are made in information collection and curation (Samuel 2020).

Indigenous Australians play an important role in environmental monitoring, particularly for threatened species that occur on their lands and in remote areas. Such monitoring is a key driver for many funding programs supported by the Australian Government. Respectful, bottom-up, collaborative approaches that incorporate local skills and interests are fundamental to the success of such monitoring programs (Paltridge & Skroblin 2018). Adopting 2-way approaches where non-Indigenous views and methods do not dominate but are used to support traditional knowledge and the aspirations of Traditional Owners to manage their Country has been demonstrated to lead to long-lasting and successful outcomes (Figure 57).



EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*
Source: Paltridge & Skroblin (2018)

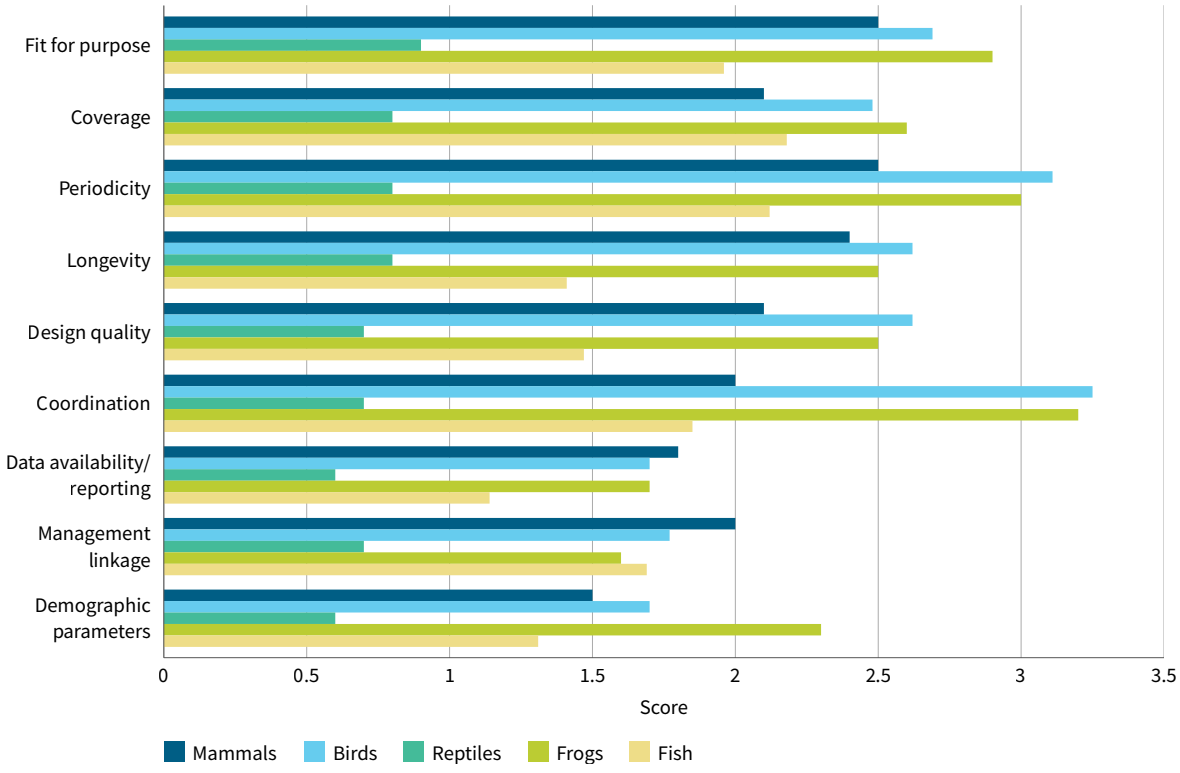
Figure 57 Outcomes from 2-way monitoring of threatened species

Availability of information and monitoring of threatened species

Researchers have recently published comprehensive assessments of monitoring extent and adequacy of threatened vertebrate species (Legge et al. 2018a), threatened plant species (Lavery et al. 2021) and threatened ecological communities in Australia (Legge et al. 2018a). The assessments demonstrate that monitoring of threatened species and communities is mostly inadequate, and that 21–46% of threatened vertebrates, 69% of threatened plants and 70% of threatened ecological communities are not monitored at all. Where monitoring does occur, quality in terms of national extent and adequacy is generally poor.

Adequacy was assessed against 9 metrics of monitoring activity (Figure 58):

- Fit for purpose – the monitoring protocol and design should have a sampling methodology and timing targeted optimally to detect the species.
- Coverage – monitoring sites should be located representatively across the species' habitat and distributional extent.
- Sampling periodicity – monitoring should occur at appropriate intervals, and with appropriate periodicity.
- Longevity – monitoring should occur over appropriate timeframes, with some future security.
- Design quality – monitoring design should have sufficient statistical power to detect trends of conservation concern.



Source: Woinarski 2018a. Republished with the permission of CSIRO Publishing, from Monitoring threatened species and ecological communities, 2018; permissions conveyed through Copyright Clearance Center, Inc

Figure 58 Average scores out of 5 for each of 9 metrics for the extent and adequacy of monitoring, evaluated for all threatened taxa in 5 vertebrate groups

- Coordination – monitoring should be coordinated across relevant jurisdictions and stakeholder groups.
- Data availability and reporting – monitoring data and their interpretation should be readily accessible to all parties, and there should be clear responsibility assigned, and capability, for long-term database management, and capacity and planning for any needed data migration to future platforms.
- Management linkage – monitoring should involve, and be meaningful to, relevant managers and be embedded in management planning; it should provide a measure of management effectiveness; and monitoring information should be adopted to enhance management.
- Demographic parameters – monitoring programs should involve assessment of critical demographic parameters, rather than relative abundance alone.

The adequacy of monitoring for different vertebrate species groups were assessed as follows:

- Mammals (Woinarski 2018b). The assessment covered 167 terrestrial species, which included all taxa that were listed as Threatened, Near Threatened or Data Deficient by the International Union for Conservation of Nature (IUCN), listed as threatened under the EPBC Act, or that may now be eligible for these conservation status categories.
  Some monitoring activity occurs for 79% of species. For the species for which some monitoring occurs, most rated low across the 9 metrics. In particular, most monitoring simply reported abundance without demographic parameters, most monitoring results were not readily accessible, and coordination was lacking.
- Birds (Garnett & Geyle 2018). The assessment covered Australian bird taxa listed as threatened under the EPBC Act (in 2017) or as Threatened or Near Threatened after assessment against the IUCN Red List criteria (n = 222).
  Birds are among the best monitored of the animal groups in Australia. Some form of monitoring occurred for 71% of threatened taxa. Of the 222 taxa considered, those that are more threatened, with larger populations, in more accessible sites and with a recovery plan were more likely to be monitored. For many taxa, monitoring scores were particularly high for the first 6 metrics, especially periodicity and coordination, but poor for data availability and reporting, the links to management and whether the monitoring assessed life history parameters or just population size.
- Frogs (Scheele & Gillespie 2018). The assessment covered 33 EPBC Act–listed frog species; 4 species listed as Extinct under the EPBC Act were included because of uncertainty over whether these species are truly extinct.
  More than one-quarter of Australia's 33 threatened frog fauna receive no targeted monitoring (27%). Monitoring programs rarely provided thorough information on demographic parameters. Few programs had strong links to management (only 9% of species scored the highest mark for this metric) and 24% of species with some form of monitoring received no management.
- Reptiles (Woinarski 2018a). The assessment covered the 69 reptile taxa listed as threatened nationally under the EPBC Act (56 species and 4 subspecies) or listed globally by the IUCN (44 species) (as of December 2016). This comprised 43 lizards, 10 terrestrial snakes, 7 freshwater turtles, 6 marine turtles and 3 sea snakes.
  Reptile monitoring is exceptionally poor and reptiles score lowest on every metric compared with other taxa. No evidence

of monitoring activity was found for 26 threatened species, and very limited monitoring for most other species. Terrestrial squamate and freshwater turtle species, species without recovery plans and species of lower conservation status were most likely to have little or no monitoring.

- Freshwater fish (Lintermans & Robinson 2018). The assessment covered 57 threatened freshwater fish, including 38 taxa listed under the EPBC Act plus another 19 listed by the Australian Society for Fish Biology (and likely to be eligible for listing under the EPBC Act in the future). Fish are relatively poorly monitored compared with other taxa. Only 31 taxa in total and 22 of the EPBC Act–listed taxa had national monitoring programs. The monitoring programs that do exist scored best for coverage, sampling periodicity and being fit for purpose, but were mostly poor in data availability and reporting, the inclusion of demographic parameters, longevity of monitoring program, and design quality.
- Plants (Lavery et al. 2021). An assessment of the adequacy of monitoring for threatened plants considered the same 9 criteria for 839 EPBC Act–listed taxa (of 1,336 listed in November 2019). Of the threatened plant species assessed, 37.2% (312) were monitored; however, monitoring quality was generally low. Plants with more imperilled conservation status were more likely to be monitored and tended to have higher-quality monitoring. Plants with recovery plans were more likely to be monitored than those without. Monitoring coverage, data availability, management linkages (integration of monitoring and management actions) and demographic parameters were better for plants than for vertebrates. The longevity of monitoring was better for vertebrates than for plants.

Case study Genetic approaches to information gathering

Advances in the application of genetic and molecular tools and associated bioinformatic analyses has contributed to major advances in our knowledge of Australia biodiversity since the 2016 state of the environment report. Metabarcoding and next generation sequencing approaches are revolutionising our understanding of species, their distributions, ecology and their capacity to adapt to a changing environment (Dormontt et al. 2018).

Approaches such as genome skimming are facilitating the rapid, reliable and repeatable identification of plant species in the Pilbara (Nevill et al. 2020), while another approach – genotyping by sequencing – has resolved the species identification and evolutionary pattern in the taxonomically challenging *Triodia basedowii* complex and the description of 8 new species, some of which are of conservation concern (Anderson et al. 2017).

The use of eDNA to detect cryptic species such as the blind cave eel (*Ophisternon candidum*) (White et al. 2020) or to quantify the presence of a threatened highly mobile species across a landscape (Gouldian finch – *Erythrura gouldiae*) (Day et al.

2019) or seascape (largetooth sawfish – *Pristis pristis*) (Simpfendorfer et al. 2016) has provided important new insights.

Similarly, investigation into the diet of the Vulnerable ghost bat (*Macroderma gigas*) in the Pilbara through DNA metabarcoding analysis of faecal pellets identified 14 new prey items not previously reported in the diet as determined from the analysis of dried food remains (Claramunt et al. 2019). Such new insight will provide managers with information to ensure the continued persistence of the ghost bat. It may also allow us to see how any declines relate to dietary shifts (e.g. changes in diet that may result from incursions of invasive species, such as buffel grass or cane toads).

Availability of information and monitoring of threatened ecological communities

A recent review of monitoring programs discoverable through publications and reports suggests that biodiversity is monitored in around 24 (30%) of the 80 threatened ecological communities listed under the EPBC Act (in 2017) (Keith et al. 2018, Legge et al. 2018b). Eight of these are monitored only for changes in land cover by remotely sensed data; ground-based monitoring is more limited. Several of the most rigorously designed projects belong to Australia's Long Term Ecological Research Network. Most of the monitoring programs have key limitations, such as poor coverage across the threatened ecological communities' range, poor design (constraining the potential for detecting trends or diagnosing causes of change), no links to management, and poor data coordination, availability and reporting.

Case study Using artificial intelligence to inform biodiversity management

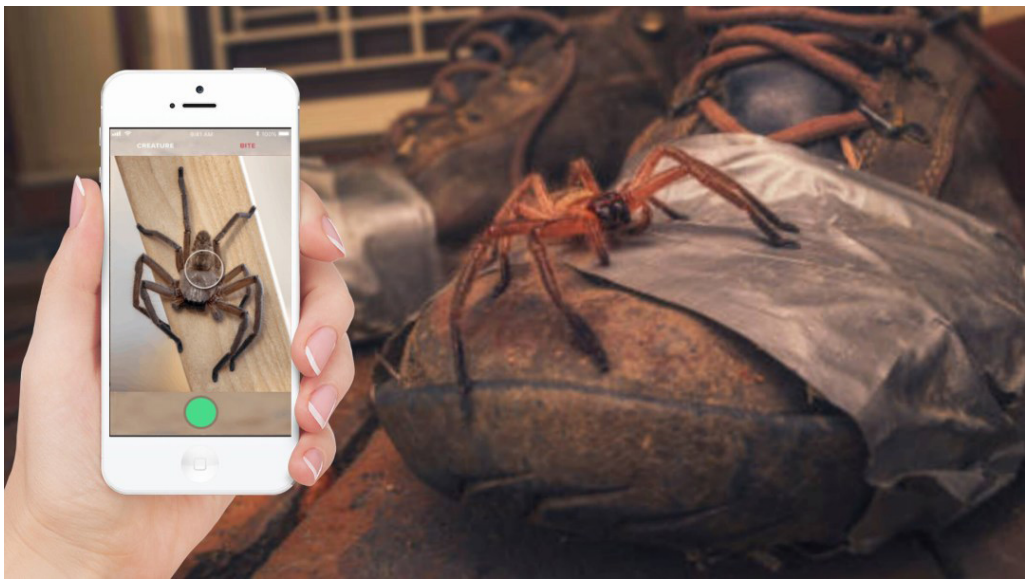
Rapidly increasing computing power and the ability to gather and store large quantities of data are leading to promising new tools and approaches for understanding and conserving biodiversity. Artificial Intelligence (AI) technologies offer the potential to address complex problems several ways (Nishant et al. 2020). First, AI permits the automation of repetitive and time-consuming tasks, allowing humans to focus on higher-value work. Second, AI reveals insights that are otherwise trapped in massive amounts of unstructured data that once required human analysis, such as data generated by videos or photos. Third, AI can integrate thousands of computers and other resources to solve complex problems.

The application of AI for better natural resource management has been identified as an emerging potential specialisation for Australia (Hajkowicz et al. 2019). AI can provide enhanced systems for monitoring the condition of biodiversity and

ecological assets. AI can also drive robotic systems for predicting, detecting and physically managing threats such as invasive plants and animals.

AI is being used in combination with Indigenous knowledge in Kakadu National Park to monitor invasion of para grass, which displaces habitat for magpie geese. A drone is flown over the landscape by an Indigenous ranger and data from the drone are downloaded, stored in a file and used to construct models that interpret the data, taking account of Indigenous knowledge of the environment and its different seasons. In this context, AI is removing the need for people to physically collect and then review thousands of hours of video to count animals and identify para grass (Cranney 2019).

In other applications, hundreds of sensor cameras are being deployed to monitor species in areas impacted by bushfires, and AI technology is being used to automatically identify species (WWF-Australia 2020). AI-powered platforms are also increasingly being used in citizen science applications and for biodiversity education resources. For example, Critterpedia is an AI-powered app to identify spider and snake species using photos (Figure 59) (Critterpedia 2021).



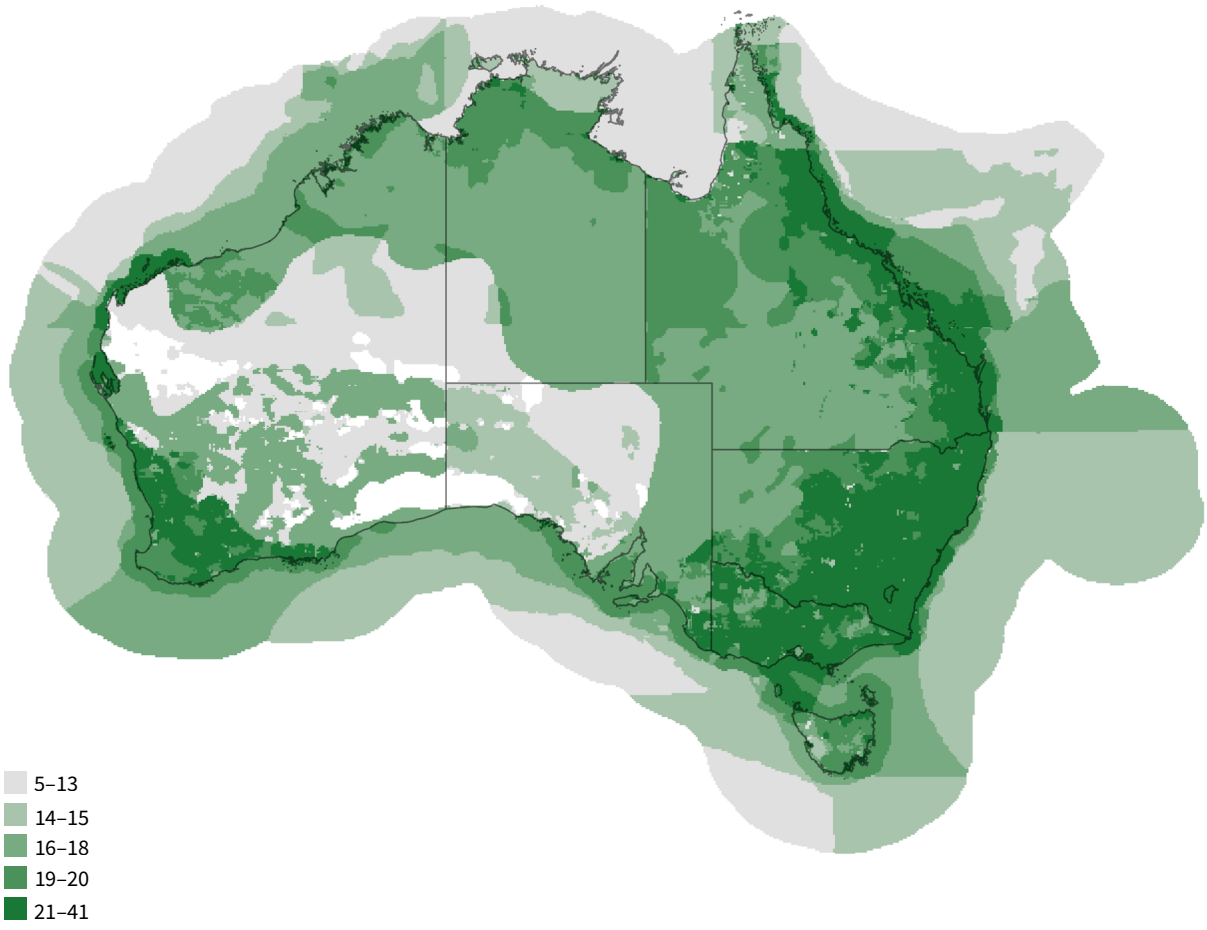
Source: Donnellan (2020)

Figure 59 Critterpedia photos

Citizen science

Monitoring Australian biodiversity efficiently and at the necessary spatial and temporal scales cannot be achieved by professionals and institutions alone. Citizen science is a term used to describe the collection and analysis of scientific data, performed predominantly by citizens, usually in collaboration with scientists and field experts. Citizen science programs can have many positive outcomes, including improving knowledge, informing conservation questions about where to carry out management, and improving public awareness about Australia's biodiversity (Steven et al. 2019). In addition, biodiversity-focused citizen science projects can potentially persist much longer than conventional research projects by leveraging community support in place of limited research funding cycles.

In 2017, at least 133 citizen science projects, coordinated by 93 separate organisations, were contributing to threatened species monitoring or conservation action in both terrestrial and marine environments (Lloyd et al. 2020) (Figure 60). Of these, 15 projects had the potential to benefit more than 100 species, 81 projects were relevant for 10 species or fewer, and 45 projects covered 1 species. Of the projects contributing to 1 taxonomic group (96 projects), 44.8%



km = kilometre
Source: Lloyd et al. (2020)

Figure 60 Density of citizen science programs for threatened species in Australia, per 10 km × 10 km grid cell, to 2017

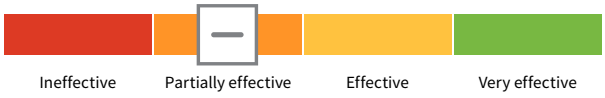
focused on birds and 34.4% on mammals, while 9.4% focused on fishes, 5.2% on frogs, 5.2% on reptiles and 1% on plants. The widespread overlap of citizen science projects with many areas where the number of threatened species is high demonstrates the great potential for citizen science as a tool to support conservation efforts for threatened species (Lloyd et al. 2020).

However, data quality is an important consideration in all forms of data collection. Evaluations of best-practice design in citizen science projects suggests some principles of best practice are widely achieved while there is scope to improve others (Steven et al. 2019). For example, only 2% of (133) projects stated clear research questions, although approximately 86% had implied project objectives of threatened species conservation. Training, or provision of training resources, was offered by most projects and most data from most projects were contributed to Australia's national biodiversity data repository, the Atlas of Living Australia. Many projects have engaged with social media to promote their activities and recruit, yet many did not share project findings or summaries of citizen-collected data, which could help to further raise awareness and improve ongoing engagement (Steven et al. 2019).

Several Australian organisations are advocating citizen science and adoption of best practices. The Australian Citizen Science Association began in 2014, and members have worked at local, state, federal and international levels to increase capacity for citizen science projects to work cooperatively, exchange knowledge and make scientific discoveries. The Atlas of Living Australia has developed the online platform BioCollect, which has enabled local nongovernment organisations and community groups to have access to project-specific webpages that have guidance and infrastructure for data collection protocols, data entry and data sharing to the Atlas of Living Australia itself. Facilitation bodies such as these have a key role to play, acting as conduits between the many groups and participants within the citizen science landscape in Australia and globally (Steven et al. 2019).

Assessment Effective management of biodiversity

2021



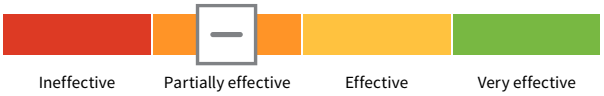
Adequate confidence

A new strategy has been developed to manage and protect Australia's biodiversity, but the strategy lacks detailed targets. Increased monitoring and investment are needed to protect many of our most threatened species and ecosystems.

Related to United Nations Sustainable Development Goal targets 11.4, 14.5, 15.a, 15.1, 15.5, 17.16

Assessment Progress towards national targets

2021

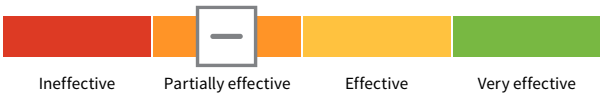


Somewhat adequate confidence

Measuring progress towards national targets associated with biodiversity has been an ongoing challenge for Australia. Very few quantitative assessments are available. Subjective assessments of performance against global targets in international agreements generally indicate that programs are in place and investments are being made, but outcomes are rarely measured or understood. Australia's Strategy for Nature 2019–2030 replaced the Biodiversity Conservation Strategy 2010–2030, partly because a review showed that it was not possible to report on the level of achievement against targets. However, the new strategy also lacks detailed, specific and measurable targets.

Assessment The conservation estate

2021



2016

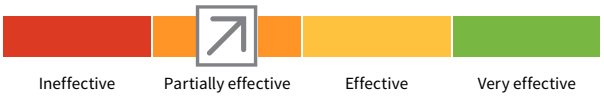


Adequate confidence

The conservation estate in Australia has achieved area-based targets; however, targets for representation and adequacy of the estate for protection of species and ecosystems are not being met for many species. Growth in the conservation estate has been primarily in Indigenous Protected Areas in central and arid Australia. Financial and tenure insecurity, along with lower levels of investment in management, constrain the aspirations of Traditional Owners in management of their land for conservation over the long term.

Assessment Threatened species and ecosystems identified

2021



2016

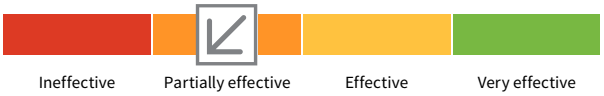


Adequate confidence

The identification of threatened species has improved over the reporting period, with a range of IUCN assessments completed. The Common Assessment Method has led to better coordination and efficiency in assessments between the states and the Australian Government, and a range of research products have identified Red Hot Lists and urgent intervention lists of species threatened by extinction following the 2019–20 bushfires. Although technologies for resolving taxonomy are improving, a potential future decline in taxonomic expertise has been noted, which could lead to a deterioration in identification progress in the future.

Assessment Threatened species and ecosystems protected

2021



2016

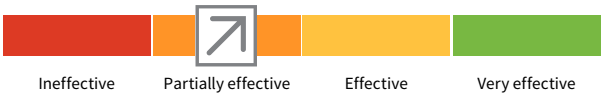


Adequate confidence

The pressures on threatened species and ecosystems are relatively well understood; however, the outlook for recovery of many species is not positive. Recovery planning is failing to keep pace with the number of new listings, recovery actions are not resourced for most species and ecosystems, and many threatened species and ecosystems lack adequate protection in the National Reserve System. However, translocations, safe havens and refuges, and ex situ conservation are reducing the rate of decline of a small number of species, and recovery successes are evident where species benefit from adequate investment in recovery plans, recovery teams, communication, research and monitoring.

Assessment Identification and protection of culturally significant species

2021

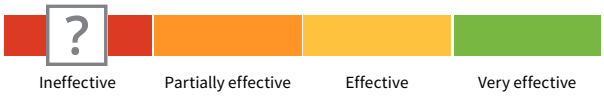


Limited confidence

The past 5 years have seen an increase in the recognition of the cultural significance of species by governments, communities and land managers. However, there are limited statutory mechanisms for their protection unless they are also listed as threatened species. Listing advices and subsequent conservation advices and recovery planning are increasingly assessing cultural significance, but the practice is still patchy. A lack of a clear definition of culturally significant species hinders further applications.

Assessment Monitoring of threatened species and ecosystems

2021

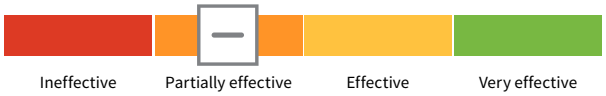


Adequate confidence

The current level of monitoring of threatened species and communities is inadequate to inform their management and track state and trends. Although some species are monitored better than others (e.g. birds), many threatened species and communities are not monitored at all, and most are not monitored well across a range of metrics. There are very few examples of consolidated and coordinated national monitoring data for even the best-known species. Citizen science and remote monitoring technology are contributing to better data for some species.

Assessment Management investment

2021



Limited confidence

The total magnitude of investment in biodiversity conservation is difficult to determine. Turnover in funding programs and limited monitoring of outcomes means long-term effectiveness of investments is also difficult to measure. However, a flexible investment approach remains vital to enable rapid deployment of funding to respond to opportunities or events such as the 2019–20 bushfires. Our assessments throughout this report indicate an increase in pressures and that the current level of investment is not sufficient to arrest resulting declines in biodiversity. Investments into the future will need to increase to keep pace with increasing pressures.

Assessment ratings

For assessments in the 'Management' section

- **Very effective:** Management measures maintain or improve the state of environment and secure it against known pressures.
- **Effective:** Management measures maintain or improve the state of the environment, but pressures remain as significant factors that degrade environment values.
- **Partially effective:** Management measures have limited impact on maintaining or improving the state of the environment.
- **Ineffective:** Management measures are failing to stop substantial declines in the state of the environment.

Trend

- **Improving:** The situation has improved since the previous assessment (2016 state of the environment report).
- **Stable:** The situation has been stable since the previous assessment.
- **Deteriorating:** The situation has deteriorated since the previous assessment.
- **Unclear:** It is unclear how the situation has changed since the previous assessment.

Authors and acknowledgements

Authors



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Dr Helen Murphy is a Principal Research Scientist at CSIRO Land and Water. She leads research focused on understanding the scale and magnitude of individual and cumulative threats to Australian biodiversity and the effectiveness of management interventions. She has a background in plant ecology and collaborates across domains spanning conservation, natural resource management, biosecurity and health, and sustainable development. Dr Murphy is based in north Queensland and maintains a strong research interest in tropical ecosystem dynamics. A particular focus is the impacts of invasive species, climate change and extreme climate events on the composition, structure and function of tropical forests.



Stephen van Leeuwen

Professor Stephen van Leeuwen, Australia's first Indigenous Chair of Biodiversity and Environmental Science at Curtin University, is a proud Wardandi Noongar with strong connections to Country in the Busselton – Margaret River region of Western Australia. As a botanical ecologist, research scientist and executive manager, Professor van Leeuwen has established a diverse pedigree across biodiversity inventory, landscape ecology, threat mitigation, nature conservation and sustainable land management domains. He is empowered with the skills to combine his broad scientific competencies with a commitment to leadership in environmental research. Professor van Leeuwen is a member of the Indigenous Advisory Committee of the Department of Agriculture, Water and the Environment, and Senior Indigenous Facilitator and Deputy Hub Leader of the National Environmental Science Program's Resilient Landscape Hub. He also contributes to the Threatened Species Scientific Committee, the National Landcare Review Expert Reference Panel, and other national, state and nongovernment committees. Professor van Leeuwen is passionate about Closing the Gap on Indigenous disadvantage and achieving self-determination. He believes that, to realise self-determination, it is critical that decisions about the livelihoods and wellbeing of Indigenous Australians and most importantly their cultures, customs, heritage and stewardship of land, water and sea Country are made with, if not by, them – Always Was, Always Will Be.

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Approach

All chapters of the state of the environment report contain content relating directly or indirectly to biodiversity in its broadest sense. The scope of the 'Biodiversity' chapter is focused on content that explicitly speaks to the state and trend of species and ecosystems. Thus, key topics for this chapter are flora and fauna, including threatened species, and ecosystems and habitats, including threatened ecological communities. We include content relating to terrestrial and aquatic (freshwater) species and ecosystems, and cross-reference content in the Coasts, Marine and Antarctic chapters for assessments of species and ecosystems that occur primarily in those domains. The Biodiversity chapter also complements, and links to, content in every other chapter.

The report draws on a wide range of published and grey literature with a focus on changes in the states and trends of species and ecosystems over the past 5 years. We did not conduct original analysis although we have requested specific, sometimes unpublished, content for use in illustrative case studies or where the most up-to-date information was held by agencies such as the Department of Agriculture, Water and the Environment or the Atlas of Living Australia.

We found that, compared with reporting in 2016, there was a much larger base of published literature to draw on for this report. Research funded by the National Environmental Science Program, and research and on-ground work conducted as part of the Australian Government's Wildlife and Threatened Species Bushfire Recovery efforts and Threatened Species Strategy in particular, have contributed greatly to our knowledge about the threats to, and the status of, threatened species and ecosystems. As a result, there is disproportionately more content about species and ecosystems listed under the *Environment Protection and Biodiversity Conservation Act 1999* than for nonlisted species in our report. However, it is also true that our knowledge about biodiversity more generally has improved over the past 5 years as a result of these programs and other research efforts undertaken by a range of agencies and institutions, and in collaboration with Traditional Owners.

Our assessment summaries use the 2016 report as a baseline, and we reflect on changes since 2016 that have led to an improvement or deterioration in state and trend of species and ecosystems, or the magnitude of pressures on biodiversity. Assessment summaries on the state and trend of biodiversity draw on content from across the entire report, rather than solely from the content in the section immediately preceding them. We have endeavoured to consider 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 is available on which to make objective quantitative analysis for most assessments, elements of this report, including the assessment summaries, are subjective opinions based on our best synthesis and judgement of the multiple lines of evidence, and considering Indigenous and non-Indigenous perspectives and knowledge.

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