



INVASIVE SPECIES

2017
FEBRUARY

A leading threat to Australia's wildlife



INVASIVE SPECIES

A leading threat to Australia's wildlife

Report author: Tim Low

© 2017 Invasive Species Council

Report design: John Sampson, Ecotype.

Cover photos: Feral cat graphic based on photo by Mick Davis, Invasive Animals CRC; Cassowary chick, Emmagen Creek (Dan Gordon - Flickr | CC BY-NC 2.0).

Contact

Andrew Cox, CEO

All material in this publication is licensed under a Creative Commons Attribution 3.0 Australia licence, save for the ISC logo and third party content. You are free to use this publication in accordance with the licence terms, attributing the Invasive Species Council and keeping intact the original copyright notice.



invasive
species council



Report author Tim Low

Introduction

Australia has an invidious reputation as a place of extinction, having lost more mammal species than any other country. Foxes and feral cats are blamed for most of the losses. Australia's smaller mammals proved very vulnerable after evolving in isolation on a continent lacking carnivores that operate like these. The same isolation has left Australia's wildlife susceptible to any number of introduced organisms, including cane toads with their unusual toxins, trout released into rivers, hoofed animals, wolf snakes on Christmas Island, and exotic diseases. Weeds too have caused much harm, displacing rare plants and transforming threatened ecological communities.

Habitat loss is often assumed to be the main threatening process in Australia, but the evidence indicates that invasive species have caused the most animal extinctions, and pose the main threat to some animal groups. The evidence for this comes from a number of sources and is summarised here, firstly as it applies to threatened species (drawing upon three studies), secondly to threatened ecological communities, and thirdly to extinct animals. The global extinction record is also mentioned.

A fox on the hunt in Edithvale wetlands, Victoria.
Photo: Frankzed – Flickr | creativecommons.org/licenses/by/2.0/



Threatened species

The problems facing Australia's threatened species were assessed by seven university researchers in a detailed study published in 2011¹. They started with the 1700 species of animals and plants listed by the Australian Government as threatened under the Environmental Protection and Biodiversity Conservation Act. They obtained information about threats from a wide range of documents, including recovery plans, threat abatement plans and species profiles. Data was available for 1137 species.

Threats were ordered into eight categories. These included 'Introduced species' and 'Disease'. Because most diseases are caused by introduced pathogens, these qualify as a subset of invasive organisms. The three disease-causing organisms doing the most harm to native species – the chytrid fungus (*Batrachochytrium dendrobatidis*) that has caused frog extinctions, root rot or dieback fungus (*Phytophthora cinnamomi*), and myrtle rust (*Uredo rangelii*) – are all introduced.

The top five threats are shown in Table 1. Introduced plants and animals threaten more than three-quarters of the listed amphibians, birds and mammals and more than half the plants, fish, reptiles and invertebrates. They pose the second highest level of threat for all categories, except frogs (amphibians), for which they rate highest. Had diseases been grouped with introduced species, invasive organisms would probably have emerged as the number one category for mammals as well as frogs. (Most species face more than one threat, so adding Introduced species to Disease would double-count some species. It is also

the case that some diseases, such as Psittacine circoviral disease of parrots, and Tasmanian devil facial tumour disease, are not introduced.)

The researchers noted that the number of threatened species in Australia suffering from introduced plants or animals, almost two-thirds of the total, is much higher than in most countries.

The difficulties faced by Australia's mammals were comprehensively reviewed in a major book, *The Action Plan for Australian Mammals 2012*, written by three leading mammalogists and sponsored by the Australian environment department². Noting that many threatened species are declining for multiple reasons, the authors developed a scoring system to assess level of impact. Invasive animals pose such a high level of threat that several of them (cats, red foxes, cane toads, black rats, dingoes/wild dogs) were scored individually and ranked in a table³ that compared the major threats.

Feral cats emerged as the number one problem for Australia's threatened mammals, with red foxes in third place. (Inappropriate fire regimes came second and habitat loss fourth.) Of the top ten threats, another three involve invasive species: dingoes/wild dogs (7th place), habitat degradation by livestock and feral herbivores (8th) and poisoning by cane toads (9th).

The threats facing plants were assessed in a 2007 study by five academics⁴. They found that habitat loss was the main threat to plants in the past, matching the 2011 study. But they analysed their data by separating past threats from current and future threats, and here a different picture emerged. About 250 plant species are

The three disease-causing organisms doing the most harm to native species – the chytrid fungus, root rot and myrtle rust – are all introduced.



Chytrid fungus has caused six frog extinctions in recent decades, including those of the northern gastric brooding frog (*Rheobatrachus vitellinus*), and southern day frog (*Taudactylus diurnus*), both found in Queensland rainforest, the latter close to Brisbane. Photos: Hal Cogger



Feral cats are the number one problem for Australia's threatened mammals.
Photo: Mark Marathon | creativecommons.org/licenses/by-sa/4.0/deed.en

currently threatened by land clearing, compared to about 175 threatened by weed invasion, some 120 threatened by feral grazing, and about 80 threatened by disease (namely introduced *Phytophthora*⁵). Many plants face multiple threats, so it is not possible to add numbers together and conclude that invasive species threaten more species than habitat loss, though that is likely to be the case.

The stark difference between past and current and future threats applies because land clearing has declined over time, while the impacts of invasive species have increased as their numbers and distributions increased. South-western Australia is one region where this is very apparent. Past clearing for wheat and sheep left many plant species surviving precariously on roadsides and in small reserves, where, although protected from further clearing, they face serious threats from weed invasion and *Phytophthora* infection. Unfortunately the phosphite spray used to kill *Phytophthora* fertilises the soil, increasing weed invasion.

Climate change is often not included as a threat category in Australian assessments. It was included in the mammal assessment, but ranked much lower than cats and other invasive species. Its omission from plant assessments was noted in the 2007 study.

In combination these studies show that invasive species are the top- or second-rated threat for Australia's plants and animals listed as nationally threatened.





TABLE 1. PERCENTAGE OF SPECIES HARMED BY THE MAJOR THREATS TO AUSTRALIAN BIODIVERSITY

	Taxonomic group							Habitat		
	Vascular plants (n=975)	Amphibians (n=22)	Birds (n=104)	Fish (n=43)	Mammals (n=84)	Reptiles (n=48)	Invertebrates (n=22)	Terrestrial (n=1157)	Freshwater (n=82)	Marine (n=60)
Habitat loss	79.8	72.7	87.5	81.4	79.8	91.7	77.3	81.2	80.5	76.7
Introduced species	56.4	86.4	80.8	67.4	76.2	70.8	54.5	59.9	74.4	65
Inappropriate fire regimes	45.9	36.4	42.3	-	44	31.3	54.5	47.3	19.5	1.7
Disease	13.9	72.7	29.8	7	11.9	6.3	-	13.9	23.2	31.7
Pollution	10.9	31.8	22.1	32.6	9.5	27.1	22.7	9.3	36.6	63.3
Over-exploitation	14.8	18.2	49	41.9	27.4	27.1	22.7	16.8	18.3	80

Table 3. Summary of the prevalence of eight major threats to Australia's threatened species, expressed as the percentage of species affected by taxonomic group and habitat.

Threatened ecological communities

A typical plight for ecological communities is that small remnants survive land clearing, only to succumb to weed invasion and diseases. Australia has about 80 communities on the EPBC Act list of Endangered Ecological Communities, and to gain an indication of how many face threats from invasive species, the first 30 listed alphabetically as at May 2016 were considered.

The review of these listings and the associated recovery plan shows that all but six of these face threats from invasive species. Weeds were listed as a threat to 20 of the 30 communities. Other threats include *Phytophthora*, rabbits, feral horses and myrtle rust. Of the six communities in the sample that do not face threats from invasive species, four are root mat communities confined to caves.

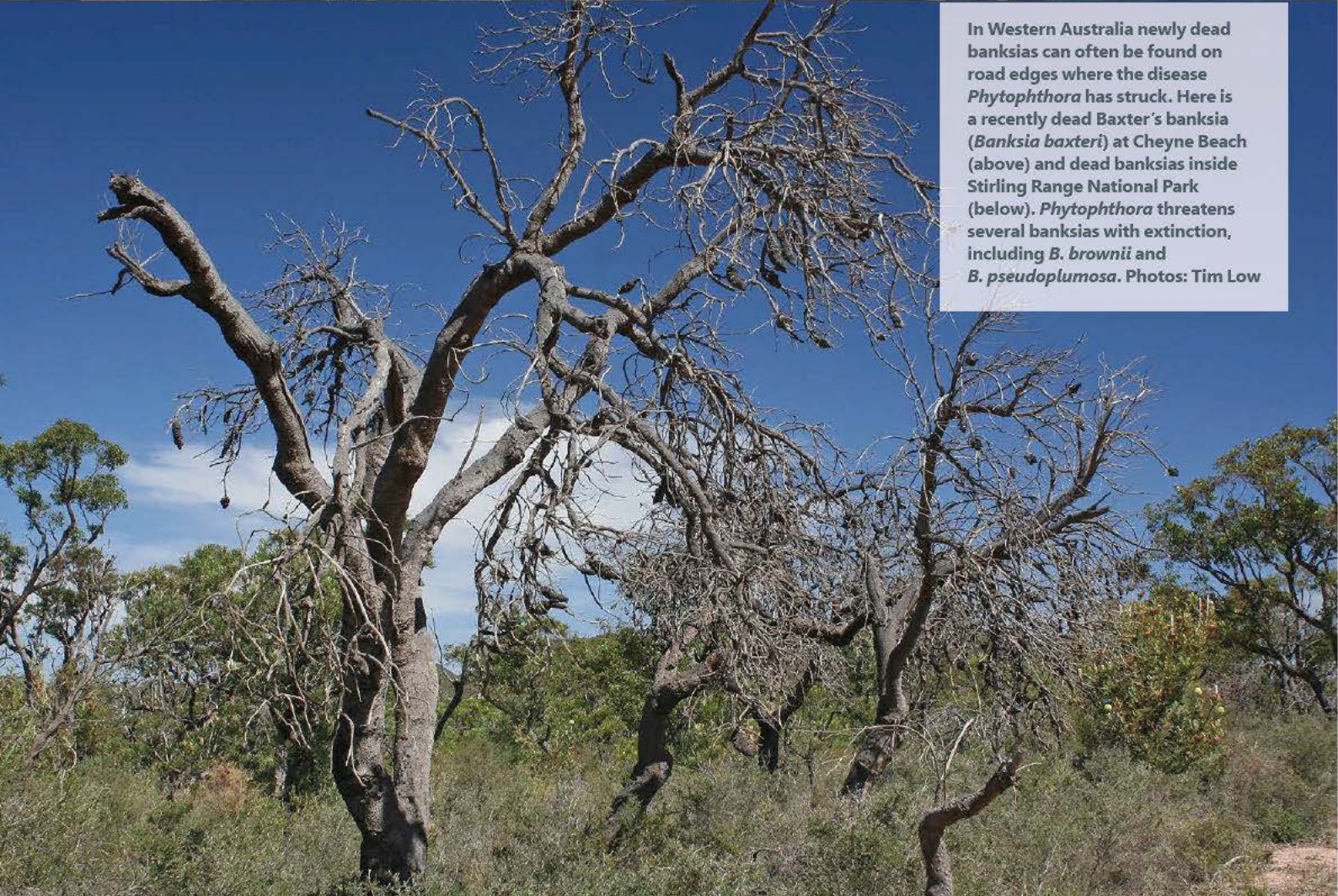
Examples of ecological communities under threat from invasive species include the Banksia Woodlands of the Swan Coastal Plain (endangered), the Blue Gum High Forest of the Sydney Basin Bioregion (critically endangered), and Brigalow (endangered). Invasive species often interact with other threats. In Brigalow, for example, fires that kill the trees are a problem, but only because remnant brigalow stands are invaded by highly flammable introduced grasses such as buffel grass (*Pennisetum ciliare*), Rhodes grass (*Chloris gayana*) and green panic grass (*Megathyrsus maximus*).



Weeds were listed as a threat to 20 of the 30 communities. Other threats include *Phytophthora*, rabbits, feral horses and myrtle rust.



In Western Australia newly dead banksias can often be found on road edges where the disease *Phytophthora* has struck. Here is a recently dead Baxter's banksia (*Banksia baxteri*) at Cheyne Beach (above) and dead banksias inside Stirling Range National Park (below). *Phytophthora* threatens several banksias with extinction, including *B. brownii* and *B. pseudoplumosa*. Photos: Tim Low



Extinct animals

The Action Plan for Australian Mammals 2012 provides the most up to date list of extinct mammals, and also analyses extinction causes⁷. Of the 28 completely extinct mammals it lists, no evidence is available to explain one extinction (Dusky flying-fox), although disease was mentioned as a possibility. Of the 27 species for which an interpretation was possible, invasive species was the main cause of extinction for 22, and a probable or possible factor in the extinction of all the others. Cats and foxes are blamed for most extinctions, although an invasive pathogen caused the demise of two island rodents⁸. Habitat loss was the main cause of extinction of only one species, the Toolache wallaby. Habitat degradation caused by livestock and feral herbivores is thought to have contributed to a number of extinctions in a subsidiary role.

Australia's extinct birds are listed on the Australian Department of the Environment's website as part of the EPBC Act List of Threatened Fauna⁹. Australia has seven bird species listed as extinct under the EPBC Act (this excludes extinct subspecies, and species that survive overseas)¹⁰. The threats to these birds are listed under recovery plans (see Table 3) and they show that black rats have been the main cause of extinction of birds in Australia.

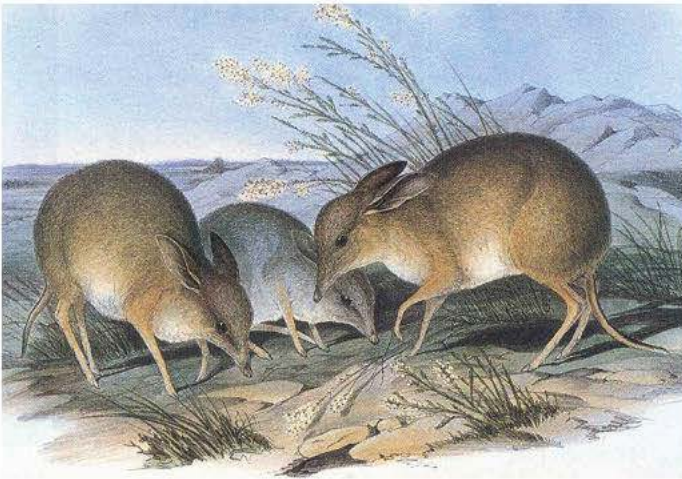
This is consistent with a study of bird extinctions around the world since the year 1500, which found that invasive species had caused more extinctions of bird species and subspecies (58.2 per cent altogether) than any other cause.¹¹ Hunting and

trapping caused the second largest number of extinctions. Rats and feral cats on islands were the introduced species responsible for most losses.

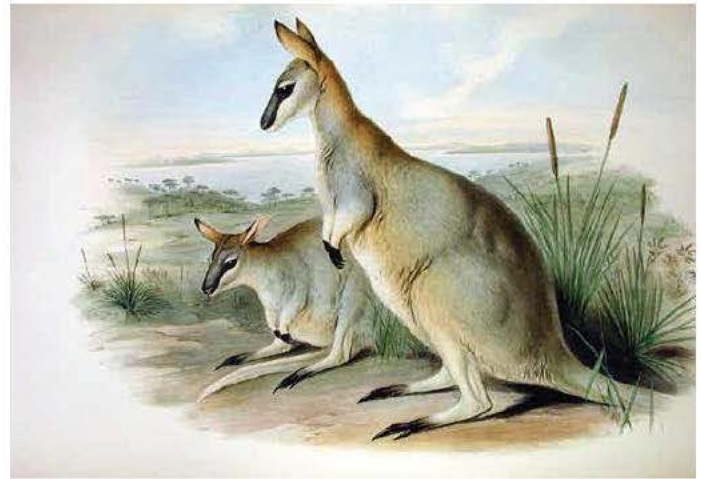
Australia has one completely extinct reptile and another two species that are extinct in the wild but survive in captivity. These reptiles, all from Christmas Island, do not yet appear on the EPBC Act list of extinct species but their demise is well-documented by biologists¹² so it is included here. They are the Christmas Island forest skink (*Emoia nativitatus*) and blue-tailed skink (*Cryptoblepharus egeriae*), last seen in the wild in 2010, and Lister's gecko (*Lepidodactylus listeri*), which disappeared a year or so later. The forest skink is completely extinct but the other two species survive in captive colonies. A fourth lizard, the Coastal Skink (*Emoia atrocostata*), also disappeared from the island, but this species, as currently defined, survives in north Queensland, New Guinea and Asia. There are suspicions that the Christmas Island form represented a separate species, but this cannot be confirmed because no specimens were collected before its demise.

A team of eight biologists who analysed the lizard declines blame their demise on introduced predators.¹³ Three Asian wolf snakes (*Lycodon capucinus*) captured a few weeks before blue-tailed skinks were last seen in the wild had the skinks in their stomachs. A Lister's gecko was also found in a wolf snake's stomach, at the last site from which both lizard species were seen. Wolf snakes were first reported on the island in the 1980s, and

Three Asian wolf snakes (*Lycodon capucinus*) captured a few weeks before blue-tailed skinks were last seen in the wild had the skinks in their stomachs. A Lister's gecko was also found in a wolf snake's stomach, at the last site from which both lizard species were seen.



Pig-footed bandicoot. Illustration: John



Toolache wallaby. Illustration: John Gould

Extinct Mammals	Main Proposed Threats
Thylacine (<i>Thylacinus cynocephalus</i>)	Hunting
Pig-footed bandicoot (<i>Chaeropus ecaudatus</i>)	Cats, foxes
Desert bandicoot (<i>Perameles eremiana</i>)	Foxes, cats
Yallara (lesser bilby) (<i>Macrotis leucura</i>)	Foxes, cats
Desert bettong (<i>Bettongia anhydra</i>)	Foxes, cats
Nullarbor dwarf bettong (<i>Bettongia pusilla</i>)	Cats, foxes
Desert rat-kangaroo (<i>Caloprymnus campestris</i>)	Foxes, cats
Broad-faced potoroo (<i>Potorous platyops</i>)	Cats, exotic disease
Central hare-wallaby (<i>Lagorchestes asomatus</i>)	Foxes, cats
Eastern hare-wallaby (<i>Lagorchestes leporides</i>)	Foxes
Toolache wallaby (<i>Macropus greyi</i>)	Habitat loss
Crescent nailtail wallaby (<i>Onychogalea lunata</i>)	Foxes, cats
Dusky flying-fox (<i>Pteropus brunneus</i>)	Hunting, habitat loss
Lord Howe long-eared bat (<i>Nyctophilus howensis</i>)	Black rats
Christmas Island pipistrelle (<i>Pipistrellus murrayi</i>)	Invasive species & poisoning
White-footed rabbit-rat (<i>Conilurus albipes</i>)	Cats
Capricorn rabbit-rat (<i>Conilurus capricornensis</i>)	Cats
Lesser stick-nest rat (<i>Leporillus apicalis</i>)	Cats
Short-tailed hopping-mouse (<i>Notomys amplius</i>)	Cats
Long-tailed hopping-mouse (<i>Notomys longicaudatus</i>)	Cats
Large-eared hopping-mouse (<i>Notomys macrotis</i>)	Cats
Darling Downs hopping-mouse (<i>Notomys mordax</i>)	Cats
Broad-cheeked hopping-mouse (<i>Notomys robustus</i>)	Cats, habitat degradation
Long-eared mouse (<i>Pseudomys auritus</i>)	Cats
Blue-gray mouse (<i>Pseudomys glaucus</i>)	Habitat loss, cats
Gould's mouse (<i>Pseudomys gouldii</i>)	Cats
Maclear's rat (<i>Rattus macleari</i>)	Trypanosome disease

Table 2. Australia's Extinct Mammals. The main proposed threats are those listed as having the highest consequence rating (usually 'catastrophic'). The common names used follow Strahan and Van Dyck (2008).

blue-tailed skinks began declining from near the port soon after. Cats, black rats and Asian giant centipedes were blamed for contributing to the decline, perhaps operating in concert as a 'super predator'. That all four lizards disappeared from inside a large national park provides a graphic

example of how habitat protection does not guarantee species survival if invasive species run free.

The EPBC Act lists four frogs as extinct – the southern gastric brooding frog (*Rheobatrachus*

Extinct Birds	Main Threat
Tasman Starling	Black rat
Lord Howe Gerygone	Black rats, or introduced disease
Norfolk Island Kaka	Hunting
White Gallinule	Hunting
Paradise Parrot	Burning, overgrazing, drought, etc.
White-chested White-eye	Black rats and habitat loss
Robust White-eye	Black rats



White-chested white-eye. Illustration: John Gould

Table 3. Australia's Extinct Bird Species.

silus), northern gastric brooding frog (*Rheobatrachus vitellinus*), sharp-snouted day frog (*Taudactylus acutirostris*) and southern day frog (*T. diurnus*). The Australian threat abatement plan for Chytridiomycosis, the disease caused by chytrid fungus, says the loss of all four species is consistent with an epidemic of chytridiomycosis.¹⁴ Another two species, the mountain mist frog (*Litoria nyakalensis*), not seen since 1990, and the northern tinker frog (*T. rheodactylus*), are also feared extinct due to the disease.¹⁵

Chytrid fungus is recognised as an agent of extinction in Central and South America as well as Australia¹⁶, with claims it represents the 'greatest threat to biodiversity of any known disease'¹⁷. The Australian government has produced a threat abatement plan to tackle it.

The EPBC Act lists one fish as extinct in the wild, the Pedder galaxias (*Galaxias pedderensis*). It thrived after the flooding of Lake Pedder, until the water body was invaded by introduced brown trout and native climbing galaxias, neither fish having occurred in the lake before¹⁸. This disappearance can be largely attributed to invasive trout, which are blamed for several dramatic galaxias declines¹⁹, although the Pedder galaxias did not go extinct because some were released in Lake Oberon where they survive today in the absence of trout.

The EPBC Act lists only one extinct invertebrate (an earthworm), but this underestimates the situation. To give one example, the Lord Howe Island Biodiversity Plan (2007) mentions ten extinct beetles and an extinct snail in its own genus (*Epiglypta howinsulae*)²⁰. This plan blames black rats for the extinction of the snail, and mentions them as a possible explanation for the loss of the beetles.



Black rats are considered a serious threat to endangered snails on Lord Howe Island. One that is extinct already is *Epiglypta howinsulae*. Photo: Toby Hudson

In the absence of proper data it is not possible to assess the main cause of invertebrate extinctions in Australia.

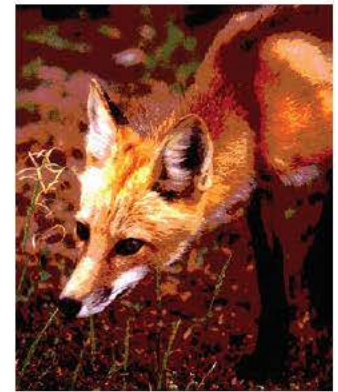
No analysis is provided here of extinct plants, because of difficulties in assessing threatening processes. Consistent with the analysis by Burgman et al. (2007), any such assessment would probably conclude that habitat loss has been the major cause of plant extinctions.

Table 4 shows the extinctions caused by invasive species by category. Only those extinctions attributed mainly to invasive species are included. Only one vertebrate species, the toolache wallaby, has succumbed mainly to habitat loss.

i) The NEBRA sets out emergency response arrangements, including cost-sharing arrangements, for biosecurity incidents which predominantly affect the environment and/or social amenity, and where the response is largely for public benefit. This includes marine pest incidents.

Threat	Species Lost	Percentage of all recognised extinctions
Cats and/or red foxes	18-20 mammals	64-71% of mammals
Black rats	3-4 birds 1 mammal 1 snail	43-57% of birds 4% of mammals
Chytrid fungus	4-6 frogs	100% of frogs
Trypanosome disease	2 mammals	7% of mammals
Wolf snake & other predators	1-4 lizards	100% of lizards
Total	30-38	~75% (vertebrates)

Table 4. Invasive Species and Number of Extinctions they have caused in Australia.



Fox. Terry Spivey Photography

The table shows that invasive species have been overwhelmingly the main cause of animal extinctions in Australia, primarily responsible for at least three-quarters of the mammal losses, about half the bird losses and all frog and lizard losses.

Under the EPBC Act, 37 plant species are listed as extinct. For 33 species, the reasons for extinction are unknown or not recorded. Loss of habitat, changes to hydrology, grazing and small populations are variously noted as the likely causes for extinction of the other four species.

Introduced species also rank very highly as a cause of global extinctions. A study of extinctions since AD 1500 of plants, amphibians, reptiles, birds and mammals, using data from the IUCN Red List, found that introduced species were 'the second most common threat associated with species that have gone completely extinct'²¹. They rated as the most common threat blamed for extinctions of mammals, reptiles and amphibians, and for vertebrates generally.

A 2016 review of the IUCN Red list found that invasive predators were implicated in extinctions around the world of 87 birds, 45 mammals and 10 reptiles – representing 58% of these groups' contemporary extinctions. Invasive mammalian predators endanger a further 596 species at risk of extinction, with cats, rodents, dogs, and pigs threatening the most species overall.²²

Threats over time

The foxes and cats that have caused so many extinctions and declines were introduced well over a hundred years ago, before Australia implemented a coherent quarantine system. The same is true of black rats and Phytophthora. These examples could create the impression that Australia's invasive species problems are a legacy of a pre-quarantine past.

But several threats have arrived more recently. The chytrid fungus that caused frog extinctions can be traced back in Australia no further than 1978²³. In 2015 15 frog biologists warned of seven frog species 'in need of urgent intervention to reduce their extinction risk' from this disease²⁴. The wolf snake that caused lizard extinctions was first recorded on Christmas Island in 1988²⁵.

The myrtle rust that arrived in 2010 is a very recent invader to raise fears about extinction. The narrow-leaved malletwood (*Rhodamnia angustifolia*) is known from fewer than 30 wild trees, and specimens in cultivation have died within two years of becoming infected with the rust²⁶. Emergency action will be required if the wild trees become infected. The angle-stemmed myrtle (*Gossia gonoclada*) and Stony Creek Backhousia (*Backhousia oligantha*) are another two endangered species with small populations that are highly susceptible²⁷. A survey of two common rainforest

trees affected by the disease – native guava (*Rhodomyrtus psidioides*) and brush turpentine (*Rhodamnia rubescens*) – found 'Severe infection and crown loss, dieback and tree mortality ... across their entire native range', resulting in 57% of native guava trees that were inspected dying in less than five years²⁸. The authors of this study raised the prospect that both trees will be listed as threatened, even though they are currently common. There are other forms of myrtle rust that may enter Australia in future and kill other plants, including young eucalypts, as is happening in plantations in South America, where the rust originated.

Another serious disease has arrived even more recently. An unidentified bacterial infection is killing critically endangered Lister's geckoes (*Lepidodactylus listeri*) on Christmas Island. Recorded in October 2014, this pathogen was not detected on the island during a disease assessment conducted by Taronga Zoo in 2010. As noted earlier, Lister's gecko recently became extinct in the wild, with Asian wolf snakes attracting most blame, and the species survives only in two captive colonies, one on the island and the other at Taronga Zoo. Forty captive geckoes on the island have died, representing a 100% mortality rate among those infected. There are now fears this disease will reach mainland Australia.



The chytrid fungus that caused frog extinctions can be traced back in Australia no further than 1978. In 2015 15 frog biologists warned of seven frog species 'in need of urgent intervention to reduce their extinction risk' from this disease.



The Christmas Island forest skink (*Eomoia nativitatis*) became extinct in May 2014 when the last individual died in captivity. Abundant in the 1990s, when 80 could be seen around a single fallen tree, it went into freefall after Asian wolf snakes appeared on the island in the 1980s. Photo: Hal Cogger

Conclusion

As shown above, analyses of available information indicate that invasive species are the main threat facing Australia's declining mammals and frogs, and possibly its plants. Invasive species have been the main cause of extinction of Australia's mammals, birds, reptiles and frogs, and of animals generally. The invasive species causing the most extinctions have been feral cats, red foxes, black rats, chytrid fungus and a trypanosome disease. A wide range of other invasive species are thought to have contributed to some extinctions. This compares with only one vertebrate extinction blamed mainly on habitat loss, that of the toolache wallaby.

If greenhouse emissions are not curbed, climate change may one day overtake invasive species as a cause of extinctions. However, many of its impacts on biodiversity are likely to come by exacerbating invasive species threats. Australia's 2011 state of the environment report said that under climate change the 'current replacement of native species with a smaller number of introduced species capable of supporting a narrower range of ecological functions will intensify. An explosion in the number and impacts of invasive species is plausible'²⁹ This report notes that the most frequently cited threats in listings under the EPBC Act and in resulting recovery plans are habitat fragmentation and invasive species.

The evidence provided here justifies a stronger focus on invasive species by governments and conservation groups. A very strong focus on

biosecurity is justified to prevent future threats. Although some of the species causing and threatening extinctions arrived in Australia a long time ago others are more recent, having entered in the 1970s, 1980s and within the last decade.

The purpose of this report is not to rank threats precisely, but to demonstrate the major role of invasive species in biodiversity loss, and highlight a point often made: that invasive species, along with habitat loss and potentially climate change, represent the three main threats to biodiversity. Before climate change became a front-line issue invasive species were ranked one of the top two threats³⁰. Climate change represents a growing threat to Australia's wildlife, and the same holds true of invasive species, since their numbers keep increasing and their impacts keep expanding.

The evidence provided here justifies a stronger focus on invasive species by governments and conservation groups. A very strong focus on biosecurity is justified to prevent future threats.



Scrub myrtle (*Rhodamnia rubescens*) has been so badly hit by myrtle rust since the disease reached Australia in 2010 that it was nominated for listing as critically endangered. Photo: Tim Low

Endnotes

- 1 Evans et al. (2011)
- 2 Woinarski, Burbidge and Harrison (2014)
- 3 Page 871 of Woinarski, Burbidge and Harrison (2014)
- 4 Burgman et al. (2007)
- 5 The Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* lists more than 80 plants threatened by this introduced pathogen (see <http://www.environment.gov.au/biodiversity/threatened/publications/threat-abatement-plan-disease-natural-ecosystems-caused-phytophthora-cinnamomi>)
- 6 Johnson (2006)
- 7 Woinarski, Burbidge and Harrison (2014)
- 8 Wyatt et al. (2008)
- 9 <http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna>
- 10 Two dwarf island emus are not included here given evidence they qualify as subspecies of the living emu (Heupink et al. 2011)
- 11 Szabo et al. (2012)
- 12 Smith et al. (2012), Director of National Parks (2014), Low (2013), Woinarski et al. (2014)
- 13 Smith et al. (2012)
- 14 Department of the Environment and Heritage (2006)
- 15 Low (2013)
- 16 Berger et al. (1998), Lips et al. 2006, Skerratt et al. (2007), Berger et al. (1999)
- 17 Wake and Vredenburg (2008)
- 18 Crook et al. (1997), <http://www.environment.gov.au/node/16477>
- 19 Crook et al. (1997)
- 20 Department of Environment and Climate Change (2007)
- 21 Bellard et al. (2015)
- 22 Doherty et al. (2016)
- 23 Weldon et al. (2004) examined museum frog specimens to arrive at this date.
- 24 Skerratt et al. (2016)
- 25 Fritts (1993)
- 26 Pegg et al. (2014)
- 27 Pegg et al. (2014)
- 28 Carnegie et al. (2015)
- 29 SoE report
- 30 Wilcove et al. (1998), Walker & Steffen (1997), Sandlove et al. (2001), World Resources Institute (1992)



References

- Bellard C, Cassey P, and Blackburn TM (2016) Alien species as a driver of recent extinctions. *Biology Letters* 12: 20150623. <http://dx.doi.org/10.1098/rsbl.2015.0623>.
- Berger L, Speare R, Daszak P, Green DE, Cunningham AA, Goggin CL, Slocombe R, Ragan MA, Hyatt AD, McDonald KR, Hines HB, Lips KR, Marantelli G, Parkes H. (1998) Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. *Proceedings of the National Academy of Sciences, USA*. 95: 9031–6.
- Berger L, Speare R, and Hyatt A. (1999) Chytrid fungi and amphibian declines: overview, implications and future directions. In: *Declines and Disappearances of Australian Frogs*. Ed A. Campbell. *Environment Australia, Canberra*. 1999: 23–33.
- Carnegie AJ, Kathuria A, Pegg GS, Entwistle P, Nagel M, and Giblin FR (2015) Impact of the invasive rust *Puccinia psidii* (myrtle rust) on native Myrtaceae in natural ecosystems in Australia. *Biological Invasions* 1-18.
- Crook D and Sanger A (1997). *Recovery Plan for the Pedder, Swan, Clarence, Swamp and Saddled Galaxias - 1999-2004*. TAS Inland Fisheries Commission. At <http://www.environment.gov.au/biodiversity/threatened/publications/recovery/tas-galaxids/index.html>
- Department of Environment and Climate Change (NSW) (2007), *Lord Howe Island Biodiversity Management Plan*, Department of Environment and Climate Change (NSW), Sydney.
- Department of Sustainability, Environment, Water, Population and Communities (No date) Chytridiomycosis (Amphibian Chytrid Fungus Disease) At https://www.environment.gov.au/system/files/resources/279bf387-09e0-433f-8973-3e18158febb6/files/c-disease_1.pdf
- Director of National Parks (2014) *Christmas Island Biodiversity Conservation Plan*. Department of the Environment, Canberra. At <http://www.environment.gov.au/system/files/resources/fad62818-2f56-454c-9848-a291d24996a8/files/christmas-island-biodiversity-conservation-plan.pdf>
- Fritts TH, (1993). *The Common Wolf Snake, Lycodon aulicus capucinus, a recent colonist of Christmas Island in the Indian Ocean*. *Wildlife Research* 20: 216–266.
- Heupink TH, Huynen L and Lambert DM (2011) Ancient DNA Suggests Dwarf and 'Giant' Emu Are Conspecific. *PLoS ONE* 6(4): e18728.
- Johnson C (2006) *Australia's Mammal Extinctions: A 50 000 year history*: Cambridge University Press.
- Lips KR, Brem F, Brenes R, Reeve JD, Alford RA, Voyles J, Carey C, Livo L, Pessier AP and Collins JP (2006) Emerging infectious disease and the loss of biodiversity in a Neotropical amphibian community. *Proceedings of the National Academy of Sciences of the United States of America*, 103 (9): 3165–3170.
- Pegg GS, Giblin FR, McTaggart AR, Guymer GP, Taylor H, Ireland HK, Shivas RG and Perry S, (2014) *Puccinia psidii* in Queensland, Australia: disease symptoms, distribution and impact. *Plant Pathology* 63(5): 1005–1021
- Sandlund OT, Schei PJ, Vilken A. (2001) *Introduction: the many aspects of the invasive alien species problem*. *Invasive Species and Biodiversity Management*. Dordrecht, Kluwer.
- Skerratt LF, Berger L, Speare R, Cashins S, McDonald KR, Phillott AD, Hines HB, and Kenyon N (2007) Spread of chytridiomycosis has caused the rapid global decline and extinction of frogs. *EcoHealth* 4: 125–134.
- Skerratt LF, Berger L, Speare R, Clemann N, Hunter DH, Marantelli G, Newell DA, Philips A, McFadden M, Hines HB, Scheele BC, Brannelly LA, Speare R, Versteegen S, Cashin SD and West M (2016) Priorities for management of chytridiomycosis in Australia: saving frogs from extinction *Wildlife Research* 43: 105–120.
- Smith MJ, Cogger H, Tiernan B, Maple D, Boland C, Napier F, Detto T and Smith P (2012) An oceanic island reptile community under threat: the decline of reptiles on Christmas Island, Indian Ocean. *Herpetological Conservation and Biology* 7: 206–218. http://herpconbio.org/Volume_7/Issue_2/Smith_etal_2012.pdf
- Strahan R and van Dyck S (1995) *The Mammals of Australia*. Chatswood: Reed Books.
- Woinarski JCJ, Burbidge AA, and Harrison P (2012) *The Action Plan for Australian Mammals 2012*. Collingwood: CSIRO Publishing.
- Wake DB and Vredenburg VT (2008) Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *Proceedings of the National Academy of Sciences USA* 105: 11466–11473.
- Walker B and Steffen W (1997) An overview of the implications of global change for natural and managed terrestrial ecosystems. *Conservation Ecology [online]* 1(2): 2 [online]
- Wilcove DS, Rothstein J, Dubow J, Phillips A, and Losos E (1998) Quantifying threats to imperilled species in the United States. *Bioscience* 48: 607–615.
- Weldon C, du Preez LH, Hyatt AD, Muller R and Speare R. (2004) Origin of the amphibian chytrid fungus. *Emerging Infectious Diseases* 10: 2100–2105.
- Woinarski J, Driscoll D and Cogger H (2014) 'Vale 'Gump', the last known Christmas Island Forest Skink', *The Conversation* At <<http://theconversation.com/vale-gump-the-last-known-christmas-island-forest-skink-30252>>.
- World Resources Institute, The World Conservation Union, United Nations Environment Program (1992) *Global Biodiversity Strategy: Guidelines for action to save, study and use the earth's biotic wealth sustainably and equitably*. Washington: WRI, IUCN, UNEP.
- Wyatt KB, Campos PF, Gilbert MT, Kolokotronis S-O, Hynes WH, DeSalle R, Daszak P, MacPhee RD, and Greenwood AD (2008) Historical mammal extinction on Christmas Island (Indian Ocean) correlates with introduced infectious disease. *PLoS ONE* 3: e3602.

CONTACT US

• web: invasives.org.au



@ISCAustralia



[facebook.com/
invasivespeciescouncil](https://facebook.com/invasivespeciescouncil)

