

Invasive species: One of the top three threats to Australian biodiversity

By the time every invader has gone everywhere it can go Australia will look very different.

– Tim Low, Feral Future¹

Introduction

In Australia, invasive species are one of the most ubiquitous and severe threats to biodiversity. We are notorious for having lost by far the highest number of mammals in recent times, with foxes or cats (and rabbits to some degree) implicated in most of these extinctions. Many bird species on islands have been wiped out by introduced rats, and an exotic fungus has killed off frogs.

Invasive species are an escalating threat: just one exotic pathogen *Phytophthora cinnamomi* threatens hundreds of endemic plant species; foxes and cats threaten the existence of many more mammals; and weeds are increasingly dominating numerous ecosystems, fundamentally altering their composition and function.

Globally, invasive species have been recognized as the most serious threat to biodiversity after habitat loss.² Climate change is also recognized as an extremely serious looming threat.³

The impacts of invasive species have been more severe in Australia than on any other continent. In its vulnerability, the 'island continent' is more island than continent. And the worst is yet to come with most invasive species having occupied only a portion of their potential range, and interactions with climate change likely to considerably worsen their impacts.

The Invasive Species Council contends that along with habitat loss, and now climate change, invasive species constitute the greatest threat to Australia's native species, ecosystems and ecosystem processes. It is important to understand the relative severity of impacts of invasive species because this category of threat often doesn't attract sufficient conservation focus.

Here is some of the evidence sustaining the contention that invasive species are one of the top threats to Australian biodiversity.

1 Low (1999)

2 World Resources Institute et al. (1992); Walker and Steffen (1997); Sandlund et al. (2001).

3 Thomas et al. (2004).

Extinctions

It is becoming increasingly clear that predation from red foxes and, importantly, feral cats, played a decisive role in the great majority of the [mammal] extinctions. To the extent that other factors contributed, it was mainly by amplifying the effects of predation by foxes and cats.

– Chris Johnson, Australia's Mammal Extinctions⁴

The extinction toll of vertebrate animals in the past two centuries largely attributed to invasive species in Australia includes:

- 22 mammals (16 species, 6 subspecies) due largely to predation by foxes and/or cats, with rabbits also implicated as a contributing factor in some cases.⁵ Across much of Australia all native mammals weighing between 35 grams and 5.5 kilograms have disappeared. Nine species survive only on cat- and fox-free islands.
- 13 island birds (3 species, 10 subspecies) due to predation by black rats (*Rattus rattus*), cats and pigs, and competition from introduced birds and honeybees.⁶
- 4 (but probably 6) frogs due to infection by chytrid fungus (*Batrachochytrium dendrobatidis*) in eastern Australia.⁷
- 2 endemic rodents on Christmas Island due to infection by a trypanosome blood parasite from introduced black rats.⁸

Invasive species have been the primary cause of animal

4 Johnson (2006).

5 Johnson (2006); and information on subspecies from Strahan (1995).^{*} Johnson notes that Australia's mammal extinctions were at their worst in parts of the country that was not cleared and where human populations were least.

6 Garnett and Crowley (2000).

7 Department of the Environment and Heritage (2006); EPBC listings at www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna

8 Wyatt et al. (2008)

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Mammals	
Darling Downs hopping-mouse	<i>Notomys mordax</i>
Big-eared hopping-mouse	<i>Notomys macrotis</i>
White-footed tree-rat	<i>Conilurus albigipes</i>
Great hopping-mouse	<i>Notomys sp.</i>
Gould's mouse	<i>Pseudomys gouldii</i>
Broad-faced potoroo	<i>Potorous platyops</i>
Eastern hare-wallaby	<i>Lagorchestes leporides</i>
Short-tailed hopping-mouse	<i>Notomys amplus</i>
Long-tailed hopping-mouse	<i>Notomys longicaudatus</i>
Lesser stick-nest rat	<i>Leporillus apicalis</i>
Desert rat-kangaroo	<i>Caloprymnus campestris</i>
Pig-footed bandicoot	<i>Chaeropus ecaudatus</i>
Crescent nailtail wallaby	<i>Onychogalea lunata</i>
Central hare-wallaby	<i>Lagorchestes asomatus</i>
Desert bandicoot	<i>Perameles eremiana</i>
Lesser bilby	<i>Macrotis leucura</i>
Eastern bettong (mainland)	<i>Bettongia gaimardi gaimardi</i>
Burrowing bettong (inland)	<i>Bettongia lesueur graii</i>
Brush-tailed bettong (south-east mainland)	<i>Bettongia penicillata penicillata</i>
Rufous hare-wallaby (south-west mainland)	<i>Lagorchestes hirsutus hirsutus</i>
Banded hare-wallaby	<i>Lagostrophus fasciatus albipilis</i>
Western barred-bandicoot	<i>Perameles bougainville fasciata</i>
Christmas Island rat	<i>Rattus macleari</i>
Christmas Island rat	<i>Rattus nativitatis</i>

Birds	
Vinous-tinted thrush	<i>Turdus poliocephalus vinitinctus</i>
Robust white-eye	<i>Zosterops strenuus</i>
Lord Howe gerygone	<i>Gerygone insularis</i>
Grey fantail (Lord Howe Island)	<i>Rhipidura fuliginosa cervina</i>
Norfolk Island ground-dove	<i>Gallicolumba norfolciensis</i>
Tasman starling (Lord Howe Island)	<i>Aplonis fusca huiiana</i>
Tasman starling (Norfolk Island)	<i>Aplonis fusca fusca</i>
Grey-headed blackbird	<i>Turdus poliocephalus poliocephalus</i>
Southern boobook (Norfolk Island)	<i>Ninox novaeseelandiae undulata</i>
Southern boobook (Lord Howe Island)	<i>Ninox novaeseelandiae albaria</i>
Long-tailed triller (Norfolk Island)	<i>Lalage leucopygia eucopygia</i>
Red-crowned parakeet (Macquarie Island)	<i>Cyanoramphus Novaeseelandiae erythrotis</i>
Buff-banded rail (Macquarie Island)	<i>Gallirallus philippensis macquariensis</i>

Frogs	
Southern platypus frog	<i>Rheobatrachus silus</i>
Northern platypus frog	<i>Rheobatrachus vitellinus</i>
Sharp-snouted day frog	<i>Taudactylus acutirostris</i>
Southern day frog	<i>Taudactylus diurnus</i>
Northern tinker frog*	<i>Taudactylus rheophilus</i>
Mountain mistfrog*	<i>Litoria nyakalensis</i>

Table 1: Extinctions of Australian vertebrate animals attributed substantially to invasive species⁴².

*presumed extinct, but not yet listed as such – last seen in 1991 and 1990 respectively

extinctions in Australia (see Table 1 for full list).⁹ They are to blame (at least in large part) for about three-quarters of the vertebrate animal extinctions since European colonization, and about one-third of the combined flora and fauna (vertebrates) species extinctions.¹⁰

There have also been extinctions of invertebrates caused by invasive species, but these are not listed under the federal environmental legislation. For example, the loss of two snail and 10 beetle species from Lord Howe Island is attributed to predation by black rats.

Threats to species

There are two main threats to the continuation of species in Australia...

- loss of habitat – this may result from climate change, activities of humans or natural events;
 - the introduction of alien species which prey on and compete with native species for food and habitat
- Australian Academy of Science¹¹

Threatened species at risk from invasive species have not been comprehensively identified. A 2006 state of environment theme report noted a total of 95 threatened animals and 68 plant species (those listed as threatened under federal environmental legislation) at risk from at least one invasive species.¹² But a brief review by Paul Downey identified 291 federally listed species at risk just from weed invasions, so the total number of federally threatened species at risk from invasive species would be much larger.¹³

9 Australian Biosecurity Group (2005).

10 Forty-nine plant species are listed as extinct under the EPBC Act (http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=flora#FLORA_EXTINCT)

Fifty-four animal species (23 birds, 4 frogs, and 27 mammal species) are listed as extinct under the EPBC Act (<http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna>).

11 Beckman and Australian Academy of Science staff (1997).

12 Cork et al. (2006).

13 Downey (2008).

	Threatened plant species	Threatened animal species	Endangered ecological communities	Total*
Anthropogenic destruction & disturbance of native vegetation	495	225	69 (96%)	820 (87%)
Introduction of alien species	362	200	68 (94%)	657 (70%)
Anthropogenic modification and degradation of abiotic factors	343	177	66 (92%)	611 (65%)
'Natural' phenomena	336	85	15 (21%)	449 (48%)
Anthropogenic destruction & disturbance of native fauna	0	121	4 (6%)	133 (14%)
Diseases	29	34	8 (11%)	75 (8%)
Other threats	16	0	6 (8%)	2 (2%)

Table 2: Threatened biodiversity in New South Wales encompassed by each of the seven major threat categories in the threat hierarchy (Coutts-Smith and Downey 2006). *Note the total also includes threatened populations, which were not included in this table.

This conclusion is supported by a cursory review of the listing advice for just the critically endangered plants and animals listed under federal environmental legislation. Of 34 critically endangered animal taxa listed under the EPBC Act,¹⁴ about three-quarters (n=26) have invasive species listed as a threat. Of 81 critically endangered plant species listed under the EPBC Act, close to half (n=38) have invasive species listed as a threat (the remainder are mostly threatened by disturbance or stochastic events because they have very small populations and are highly restricted in distribution).¹⁵

A 2006 NSW study by Aaron Coutts-Smith and Paul Downey found that invasive species was the second highest broad threat category for biodiversity, affecting 70 per cent of the species and ecological communities examined (those listed under NSW legislation)¹⁶ (see Table 2). The highest threat category – anthropogenic destruction and disturbance of native vegetation – affected 87 per cent. However, when compared with individual threats such as land clearing, invasive species was the greatest threat. Close to half of threatened species (45 per cent) were threatened by weed invasion, and 38 per cent by feral animals.¹⁷

Threats by invasive species are highly ubiquitous – one of the top three, based on frequency across Australian bioregions (see Table 3). Analysis of data from the 2002 National Land and Water Resources Audit found that feral animals were the highest threat based on

the number of biogeographic subregions reporting the threat and the third-highest threat based on numbers of species per subregion reported to be threatened. Exotic weeds were the fourth-highest threat according to the number of bioregions reporting the threat.¹⁸

Threats to ecological communities

A very large proportion of threatened ecological communities are at risk from invasive species. Of the 44 listed under the EPBC Act, more than 80 per cent (n=36) have invasive species noted as a threat in the listing advice. According to data from the 2002 Land and Water Resources Audit, feral animals and exotic weeds were the second and third highest threat respectively for threatened ecosystems based on the number of biogeographical subregions reporting the threat (see Table 3).

In the 2006 study by Coutts-Smith and Downey, 94 per cent of endangered NSW ecological communities were adversely affected by invasive species, predominantly by weeds.¹⁹

A very common threat scenario for ecological communities is that they have been greatly reduced in extent by land clearing and that fragments are then highly susceptible to weed invasion.

Threats to islands

The majority of the threatened or extinct taxa [of birds] are on islands where predators, often facilitated by habitat destruction, have caused or are causing massive declines.

– Stephen Garnett and Gabriel Crowley, The Action Plan for Australian Birds²⁰

14 The EPBC Act is the *Environmental Protection and Biodiversity Conservation Act 1999*.

15 Listings often provide fairly cursory information about threats, or the threats are poorly known, so they are indicative only. The levels of threat are consistent with those in the US. A study of species listed under the US Endangered Species Act 1973 found that habitat degradation or loss threatened 85 per cent of species examined, and that alien species were the second major threat, affecting 49 per cent of the total (Wilcover et al. 1998).

16 Coutts-Smith and Downey (2006).

17 Although salinity has received much greater attention with dedicated NRM programs, it was found to threaten only four species.

18 Cork et al. (2006).

19 Coutts-Smith and Downey (2006).

20 Garnett and Crowley (2000).

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Threatened species	Threatened species	Threatened ecosystems	Riparian zones	DIWA wetlands
• Feral animals • Changed fire regimes • Grazing pressure • Exotic weeds • Other • Increasing fragmentation • Vegetation clearing • Changed hydrology • Pollution • Pathogens • Firewood collection	• Vegetation clearing • Grazing pressure • Feral animals • Changed fire regimes • Increasing fragmentation • Changed hydrology • Exotic weeds • Pollution • Salinity	• Grazing pressure • Feral animals • Exotic weeds • Changed fire regimes • Increasing fragmentation • Vegetation clearing • Changed hydrology • Salinity • Firewood collection	• Grazing pressure • Exotic weeds • Feral animals • Changed hydrology • Increasing fragmentation • Changed fire regimes	• Grazing pressure • Exotic weeds • Feral animals • Changed hydrology • Pollution • Salinity

Table 3: Ranking of threats to aspects of biodiversity (Cork et al. 2006, citing Tait, unpublished report, drawing on NLWRA 2002). For columns 1, 3, 4 and 5 the ranking was based on the number of subregions reporting the threat. For column 2 the ranking was based on numbers of species per subregion reported to be threatened; DIWA = Directory of Important Wetlands in Australia.

Globally, invasive species are typically the most serious threat to island biodiversity.²¹ Some islands are vulnerable because they have many endemic species with only small populations and small ranges, which can be overwhelmed by weeds or pests.²² One recent example of islands' potential for catastrophe is the extinction of nine of the 11 native bird species and five species of lizard on Guam due to the brown tree snake, introduced accidentally in the 1940s.

Invasive species count as the dominant threat for Australian island biodiversity, and numerous extinctions, particularly of birds, have already occurred. On Lord Howe Island, weeds outnumber native plants (271 v 239 vascular plants), and 17 animal species/subspecies are thought to have been wiped out mainly by rats, with many others surviving only on rat-free islands nearby.²³ Populations of numerous endemic species on Christmas Island are currently undergoing precipitous declines most likely due to invasive species that include yellow crazy ants (*Anoplolepis gracilipes*), black rats, cats, and south east Asian wolf snakes (*Lycodon aulicus capucinus*).²⁴ Four mammals, two reptiles, and four birds (all endemic) are either extinct or highly threatened.

Other islands sometimes serve as vital refuges from invasive species, and are playing that role for many mammals that have been wiped out by foxes and cats on the mainland. They are, however, highly vulnerable to the deliberate or accidental introduction of these predators, as exemplified by the recent introduction of foxes to Tasmania.

Threats to inland aquatic ecosystems

According to data from the 2002 Land and Water Resources Audit, exotic weeds and feral animals were the second and third highest threat respectively (after grazing pressure) to riparian zones and nationally important wetlands, based on the number of subregions reporting the threat.²⁵

In a 2007 snapshot assessment of Australia's 64 Ramsar-listed wetlands²⁶ invasive species were identified as one of the top five threats at more than half the inland Ramsar sites (17 of 31 wetlands). Increased weed abundance was one of the top five impacts at 18 sites (the fourth most frequent key impact noted) and increased pest animals was one of the top five impacts at 14 sites.

Introduced fish have major impacts on biodiversity, and greatly outnumber native fish along large sections of some catchments. More than 16 per cent of native fish species are considered to be under serious conservation threat,²⁷ and invasive species are a threat for 77 per cent of them.²⁸

In the lower Murray-Darling catchment, exotic species make up 23 per cent of species and 56 per cent of the total biomass of fish,²⁹ and carp (*Cyprinus carpio*) constitute 70-90 per cent of biomass in many stretches of the Murray River. In Tasmania, trout threaten the survival of several native fish species now confined to streams inaccessible to brown trout (*Salmo trutta*) and other invasive fish.³⁰

25 Cork et al. (2006).

26 BMT WBM Pty Ltd (2007). Site managers rated the top known threats within each site, but the magnitude of the impact was not assessed.

27 Australian Society for Fish Biology (2001).

28 Jackson et al. (1993).

29 Gilligan (2005).

30 Threatened Species Section (2006).

21 Eg. Dovey et al. (2003) regarding Pacific islands.

22 Johnson (2006).

23 Department of Environment and Climate Change (NSW) (2007).

24 Environment Australia (2002).

Ecological processes	Examples of compromise by invasive species
Climatic processes: flows of energy and matter through the atmosphere that drive precipitation, air temperature cycles and atmospheric pressure systems.	The spread of flammable pasture grasses and other weeds increase greenhouse gas emissions, eg. gamba grass fuels fires up to 8 times hotter than natural fires, killing trees.
Land system productivity: the rate of energy flows through ecosystems, beginning with conversion of solar energy through photosynthesis, into chemical energy in plant tissues.	Herbivores such as rabbits and goats can greatly deplete plant mass and productivity.
Hydrological processes associated with surface and sub-surface water flows.	Weeds that dominate wetlands and waterways (eg. hymenachne) can alter hydrological processes, as can invasive trees (eg. willows) that take over river banks. Carp reduce water quality by stirring up mud and cause erosion of stream banks.
Formation of biophysical habitats through processes involving geological substrates, soils, vegetation and water.	Nitrogen-fixing weeds and invasive invertebrates in the leaf litter can alter nutrient cycles in the soil.
Interactions between species in food webs and in competition for space and resources	Foxes and cats are harmful predators, often sustained by high rabbit populations; weeds often outcompete other plants, and invasive animals exert heavy competition for resources such as food, hollows and drought refugia.
Movement of animals and seeds	Degradation of habitats by invasive species can compromise the movement of migrating animals, and many invasive animals affect the dispersal of seeds, either by reducing seed dispersers or dispersing seeds themselves.
Coastal zone fluxes: movements of energy and nutrients between land and sea, and sea and land.	Weeds such as bitou bush affect coastal zone fluxes by changing dune dynamics.

Table 4: Invasive species and ecological processes.⁴³

Key threatening processes

Invasive species have the potential for catastrophic impacts on biodiversity because they can affect multiple species and ecosystems. More than 2000 plant species in Australia's premier hotspot for plant diversity in south-west Western Australia are regarded as susceptible to the dieback pathogen *Phytophthora cinnamomi*.³¹ Eucalyptus rust (caused by *Puccinia psidii*) could also have a dire impact if it was introduced.³² It infects plants of the family Myrtaceae, which includes about 3000 tree and shrub species in Australia, including eucalypts and tea trees. Introduced foxes have already had catastrophic impacts on mainland mammals, and will threaten 78 vertebrates, including 12 threatened species, in Tasmania if not eradicated.³³ Weeds also have the potential for widespread impacts – a particularly severe threat is introduced flammable pasture grasses that fuel intense fires that can eliminate woodlands over vast areas in northern Australia and fire-sensitive ecological communities elsewhere.³⁴

The potential of invasive species for widespread impacts is recognized by their domination of key threatening

processes listed by the federal and state governments. Of 17 currently listed key threatening processes under the EPBC Act, 12 involve invasive species (seven for vertebrate pests, two for invertebrate pests and three for pathogens). Of 31 key threatening processes listed in NSW, 21 involve invasive species (with some including multiple invasive species, such as 'Invasion of native plant communities by exotic perennial grasses').³⁵

Threats to ecosystem processes

Invasive species compromise ecological processes, which are defined as 'the interactions and connections between living and non-living systems, including movements of energy, nutrients and other chemical substances such as carbon, and organisms and seeds.'³⁶ In particular, invasive species greatly affect 'interactions between species' by predation and competition. Foxes and cats are the dominant predators in numerous ecosystems, weeds often outcompete other plants and dominate landscapes, and invasive species exert heavy competition for resources such as food, hollows and drought refugia. As a dominant food source in many areas, rabbits can sustain high levels of foxes and cats, which in turn impact on other species. Invasive species also compromise all the other ecosystem processes in various ways, as exemplified in Table 4.

31 Commonwealth of Australia (2007). Recent research has found that the disease is likely to get much worse under climate change. See <http://double-troublebulletin.wordpress.com/double-trouble-issue-1/double-trouble-issue-1/killer-plan-disease-could-devastate-wa-biodiversity-hotspots/>.

32 Glen et al. (2007).

33 Department of Primary Industries and Water (2009).

34 Csurhes (2005); NSW Scientific Committee (2003).

35 See <http://www.environment.nsw.gov.au/threatenedspecies/KeyThreateningProcessesByDoctype.htm>.

36 McGregor et al. (2008).

Trends and interactions

*Australia is in the throes of ecological upheaval, and most of this change is coming not from new invaders but from old pests tightening their grip on the land. It is important to understand that most pests in Australia have yet to occupy their full range; they are still migrating outwards or increasing in density (infilling) or both.*³⁷

– Tim Low, Feral Future

The full impacts of most invasive species already in Australia are yet to be seen. It will take centuries for many to establish and then reach their full range.³⁸ Moreover, new invaders are continually taking hold – an estimated 20 new weeds, pests and diseases are establishing each year, according to CSIRO.³⁹ The establishment of an invasive species is often irreversible.

It is impossible to predict the impacts of many invasive species, in part because of interactions with other factors. Invasive species often benefit from disturbance, so when vegetation is cleared or burnt, weeds often take the place of native species. As climate change increases the severity of droughts, cyclones and other extreme events, many invasive species will find new opportunities to establish and spread, and stressed native species will become more vulnerable.⁴⁰ Some invasive species will extend their range because of warmer temperatures.

Implications

Because there has been very limited assessment of the overall impacts of invasive species on Australian biodiversity, they tend to be under-rated in popular perception as a threat category. The authors of the one comprehensive review of threatened species adversely affected by weeds (in NSW) found that the impacts had been “grossly under-estimated”, and the species at risk were tenfold greater than previously estimated.

The underestimation of invasive species threats has implications for conservation focus and spending. While there has been strong public support for controls on what is widely accepted as the major threat category – land clearing – there has been limited public pressure on governments to enact controls on invasive species. There are no regulatory controls over the majority of invasive species harmful to biodiversity – gardeners and farmers can freely plant hundreds of weeds that will end

up in natural bushland as threats to biodiversity. And as the authors of the 2006 theme report on biodiversity for Australia’s state of environment report, Cork and colleagues comment:⁴¹

It has been noted that public resources committed to invasive organisms appear to be small, particularly compared with expenditure on other natural resource management issues, the economic and environmental impacts of invasives compared with other issues, and the relatively high benefit-cost ratios reported from analyses of research and development on invasive organisms (Agtrans Research and Dawson 2005).

There is no one indicator of threats to biodiversity by which different categories of threat can be compared. But the weight of evidence presented here of the ubiquity of impacts of invasive species on species, ecosystems and ecological processes strongly suggests they are one of the top threats to biodiversity, along with habitat loss as the other major existing threat and climate change as the major looming threat.

It is important to more comprehensively assess the threats of invasive species, as wider recognition of the losses and degradation they cause is necessary as a basis for improving legislation, funding and focus.

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37 Low (1999).

38 Caley et al. (2008) found that the average time of naturalization for shrubs and trees in South Australia was likely to be in the order of centuries, as the 8.4 per cent of introduced species that have naturalized over 160 years represent only half the species that are likely to naturalise over time.

39 CSIRO (2003).

40 Low (2008).

41 Cork et al. (2006).

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