BACKGROUNDER

ISC Invasive Species Council AUSTRALIA

April 2009 Web: www.invasives.org.au Email: isc@invasives.org.au

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 Future[1]

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, for due to evolutionary isolation and restricted distributions, island species tend to be susceptible to being overwhelmed by invasive species. And the worst for Australia 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 to show that invasive species are one of the top threats to Australian biodiversity.

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 Extinctions[4]

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

1 Low (1999)

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

3 Thomas et al. (2004).

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

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

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

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

Table 1: Extinctions of Australian vertebrate animals attributed substantially to invasive species[42].
***presumed extinct, but not yet listed as such – last seen in 1991 and 1990 respectively**

introduced black rats.[8]

Invasive species have been the primary cause of animal 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 Science[11]

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

8 Wyatt et al. (2008)

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).

	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.

threatened species at risk from invasive species would be much larger.[13]

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

13 Downey (2008).

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).

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

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.

causing massive declines.

– Stephen Garnett and Gabriel Crowley, The Action Plan for Australian Birds[20]

All over the world, 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 the 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 are the main conservation problem on Australian islands, and numerous extinctions, particularly of birds, have already occurred. On Lord Howe Island, weeds outnumber native plants (271 to 239 plants), and 17 animal species/subspecies are thought to have been wiped out mainly by rats, with many others surviving only on rocky islets 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*), centipedes, black rats, cats, and south east Asian wolf snakes (*Lycodon aulicus capucinus*).[24] Four mammals and four reptiles 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 wetlands[26] 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] Along many stretches of the

20 Garnett and Crowley (2000).

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).

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).

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 and marram grass affect coastal zone fluxes by changing dune dynamics.

Table 4: Invasive species and ecological processes.[43]

Murray River carp (*Cyprinus carpio*) constitute 70-90 per cent of the fish biomass. In Tasmania, trout threaten the survival of several native fish species now confined to small streams inaccessible to brown trout (*Salmo trutta*) and other invasive fish.[30]

Key threatening processes

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 (such as foxes and pigs), two for invertebrate pests (two ant species), and three for pathogens (of frogs, plants and parrots). 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'.[31]

Those invasive species that affect multiple species and ecosystems can have catastrophic impacts on biodiversity. 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*, some highly so.[32]

Within three months of infection, populations of endangered Banksia brownii suffer 80 per cent mortality, for example. The loss of shelter and nesting sites and food sources has flow-on effects on threatened animal species such as the critically endangered Gilberts potoroo (Potorous gilbertii). Dieback is likely to get much worse under climate change in southwest Western Australia.[33]

Introduced foxes have already had catastrophic impacts on mainland mammals, and if not eradicated in Tasmania are expected to threaten 78 vertebrates, including 12 already threatened species[34]. Many weeds, listed under various state legislation as threats, 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.[35]

Threats to ecosystem processes

Invasive species compromise ecological processes, which are defined as 'the interactions and connec-

30 Threatened Species Section (2006).

31 See http://www.environment.nsw.gov.au/threatenedspecies/KeyThreateningProcessesByDoctype.htm.

32 Commonwealth of Australia (2007).

33 See http://doubletroublebulletin.wordpress.com/double-trouble-issue-1/double-trouble-issue-1/killer-plan-disease-could-devastate-wa-biodiversity-hotspots/.

34 Department of Primary Industries and Water (2009).

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

tions 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.

Other ecosystem processes are affected when willows (Salix spp.) alter stream banks and water flows, when marram grass (Ammophila arenaria) on dunes traps sand, starving backdune plant communities of sand and altering coastal dynamics, and when exotic grasses alter fire regimes (see Table 4 for more examples).

Trends and implicatoins

> *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 usually irreversible.

Despite reformed quarantine laws, new invaders are still arriving as imports or accidentally. Australia allows the importation of multiple strains of existing weeds and pests which can greatly exacerbate invasiveness by providing them with high competitiveness and capacity for adaptation.[40]

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 global warming changes weather patterns, and 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.[41]

> *Climate change will significantly alter the nature, mix and impact of many threats facing biodiversity …. Climate may affect the threats themselves, e.g. changing weed, pest and pathogen growth rates, abundance or distributions; or it may affect the sensitivity to threats, e.g. environmentally stressed organisms being more susceptible to pathogens or less able to compete for resources.*
> – Michael Dunlop and Peter Brown, Implications of climate change for Australia's National Reserve System

Some invasive species will extend their range because of warmer temperatures.

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:

> *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, ecosys-

36 McGregor et al. (2008).

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 See http://doubletroublebulletin.wordpress.com/double-trouble-issue-1/double-trouble-edition-2-may-2009/australian-quarantine-holes-could-unleash-climate-change-super-invaders/.

41 Low (2008).

tems and ecological processes strongly suggests they are one of the top three 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.

References

Australian Biosecurity Group. 2005. Invasive Weeds, Pests and Diseases: Solutions to Secure Australia. Canberra: CRC for Pest Animal Control, CRC for Australian Weed Management and WWF Australia. http://www.wwf.org.au/publications/ABGInvasiveSolutions/.

Australian Society for Fish Biology. 2001. Threatened species supplement. Australian Society for Fish Biology Newsletter 31: 37-41.

Beckman R, Australian Academy of Science staff. 1997. Australia's threatened species. Australian Academy of Science. http://www.science.org.au/nova/010/010key.htm.

BMT WBM Pty Ltd. 2007. The Ramsar Snapshot Study - Final Report Canberra: Department of the Environment and Water Resources. http://www.environment.gov.au/water/publications/environmental/wetlands/ramsar-snapshot-study.html.

Caley P, Groves RH, Barker R. 2008. Estimating the invasion success of introduced plants. Diversity and Distributions 14: 196-203.

Commonwealth of Australia. 2007. Draft background document for the threat abatement plan: Disease in natural ecosysstems caused by *Phytophthora cinnamomi*. Canberra: Department of Water, Heritage and the Arts.

Cork S, Sallter P, Alexandra J. 2006. Biodiversity theme commentary prepared for the 2006 Australian State of the Environment Committee. Canberra: Department of the Environment and Heritage.

CSIRO. 2003. Submission to the Federal Senate inquiry into the regulation, control and management of invasive species and the Environment Protection and Biodiversity Conservation Amendment (Invasive Species) Bill 2002. Canberra: Parliament of Australia. www.aph.gov.au/senate/committee/ecita_ctte/completed_inquiries/2004-07/invasive_species/submissions/sub34.doc.

Csurhes S. 2005. An assessment of the potential impact of *Andropogon gayanus* (gamba grass) on the economy, environment and people of Queensland. Brisbane: Queensland Department of Natural Resources.

Department of Environment and Climate Change (NSW). 2007. Lord Howe Island Biodiversity Management Plan. Sydney: NSW Government.

Department of Primary Industries and Water. 2009. Foxes in Tasmania - A grave threat to our wildlife. http://www.dipw.tas.gov.au/inter.nsf/WebPages/SJON-52J8U3

Department of the Environment and Heritage. 2006. Background document for the threat abatement plan: infection of amphibians with chytrid fungus resulting in chytridiomycosis. Canberra: DEH, Australian Government.

Dovey L, Orapa W, Randall S. 2003. The need to build biological control capacity in the Pacific. In . Editors: in Cullen JM, Briese DT, Kriticos DJ, Lonsdale WM, Morin L, Scott JK, eds. Proceedings of the XI International Symposium on Biological Control of Weeds, Canberra, Australia, 27 April - 2 May, 2003.

Downey PO. 2008. Determination and management of alien plant impacts on biodiversity: examples from New South Wales, Australia. Pages 454-457 in Tokarska-Guzik B, Brock J, Brundu G, Child L, daehler C, Pysek P, eds. Plant invasions: human perception, ecological impacts and management. Leiden: Backhuys Publishers.

Environment Australia. 2002. Christmas Island National Park Management Plan. Canberra: Australian Government. http://www.environment.gov.au/parks/publications/christmas/management-plan.html.

Garnett ST, Crowley GM. 2000. The Action Plan for Australian Birds. Canberra: Environment Australia.

Gilligan D. 2005. Fish communities of the Lower Murray-Darling catchment: Status and trends. Narrandera: NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/research/areas/systems-research/aquatic-ecosystems/outputs/2005/output-664.

Glen M, Alfenas AC, Zauza EAV, Wingfield MJ, Mohammed C. 2007. Puccinia psidii: a threat to the Australian environment and economy - a review. Australasian Plant Pathology 36: 1-16.

Jackson PD, Koehn JD, Wager R. 1993. Australia's threatened fishes 1992 listing - Australian Society for Fish Biology in Hancock E, ed. Sustainable Fisheries through Sustaining Fish Habitats. Australian Society for Fish Biology Workshop Proceedings, Victor Harbour, SA, 12-13 August. Canberra: Bureau of Resource Sciences.

Johnson C. 2006. Australia's Mammal Extinctions: A 50 000 year history: Cambridge University Press.

Low T. 1999. Feral Future: The Untold Story of Australia's Exotic Invaders. Melbourne: Penguin.

—. 2008. Climate change and invasive species: a review of interactions. Canberra: Department of the Environment, Heritage, Water and the Arts. www.environ-

ment.gov.au/biodiversity/publications/interactions-cc-invasive.html.

McGregor A, Coffey B, Deutsch C, Wescott G, Robinson J. 2008. Ecological processes in Victoria: policy priorities for sustaining biodiversity. Victoria Naturally Alliance.

NSW Scientific Committee. 2003. Invasion of native plant communities by exotic perennial grasses - key threatening process listing. NSW Government Department of Environment and Climate Change. http://www.environment.nsw.gov.au/determinations/ExoticPerennialGrassesKTPListing.htm.

Sandlund OT, Schei PJ, Vilken A. 2001. Introduction: the many aspects of the invasive alien species problem. Pages 1-10. Invasive Species and Biodiversity Management: Springer.

Strahan R. 1995. The Mammals of Australia. Chatswood: Reed Books.

Thomas CD, et al. 2004. Extinction risk for climate change. Nature 427: 145-148.

Threatened Species Section. 2006. Recovery Plan: Tasmanian Galaxiidae 2006-2010. Hobart: Department of Primary Industries, Water.

Walker B, Steffen W. 1997. An overview of the implications of global change for natural and managed terrestrial ecosystems. Conservation Ecology [online] 1: 2.

Wilcover DS, Rothstein J, Dubow J, Phillips A, Losos E. 1998. Quantifying threats to imperilled species in the United States. Bioscience 48: 607-615.

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, Greenwood AD. 2008. Historical mammal extinction on Christmas Island (Indian Ocean) correlates wtih introduced infectious disease. PLoS ONE 3: e3602.