Invasive Animals Cooperative Research Centre

The threat posed by pest animals to biodiversity in New South Wales

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Department of **Environment & Climate Change** NSW

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Invasive Animals Cooperative Research Centre

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Front cover: Pest animals that threaten biodiversity in New South Wales, from left to right – feral pig ©Steven Lapidge (IA CRC), feral cat and red fox ©NSW Department of Environment and Climate Change (DECC), and feral rabbit ©Brian Cooke (IA CRC).

Inside cover: Threatened species in New South Wales at risk from pest animals, from top to bottom – broad-headed snake (Image: Stuart Cohen), Australian bustard (Image: Graham Robertson), Hastings River mouse (Image: Ed Slater), Monaro golden daisy (Image: John Briggs). All images ©NSW DECC.

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Contents

Summary

Alien species (pest animals and weeds) are acknowledged widely as a major cause of global biodiversity decline. However, there are very few studies that have quantified the specific biodiversity at risk from alien species, or the alien species posing the threat. This lack of knowledge has hampered policy development and alien species management directed at biodiversity conservation.

This report quantifies the threat posed by alien animals (hereafter referred to as pest animals) on a broad cross-section of biodiversity in New South Wales. This assessment was achieved by examining the described threats to 972 threatened species in New South Wales, being those species (ie mammals, birds, fish, insects, plants, fungi and algae), populations and ecological communities listed under the NSW *Threatened Species Conservation Act 1995* and the NSW *Fisheries Management Act 1994*; approximately half of which are also listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*. Information on threats was compiled from a vast range of sources (spanning over 2000 documents) to establish the full range of threats to each species. These data sources included NSW Scientific Committee determinations, fact sheets, threatened species books, recovery and threat abatement plans and scientific studies. Less than 2% of the data was derived from peer-reviewed scientific studies, highlighting the ongoing need for scientific research in this area. A total of 5666 threat descriptions were identified across all threatened species, many of which were similar in nature (ie they used different terms to describe the same threat), so a hierarchy and standard terms were developed to group threats of a similar nature, and to analyse the relative impact of each type of threat.

The development of the threat hierarchy highlighted a significant problem in the description of threats. Many similar threats were described using a wide range of analogous words that made direct comparison of threats difficult. Further, many threat descriptions failed to include critical information (ie the name of the pest animal species posing the threat). A standardised system needs to be developed to describe threats which would improve assessments of threats similar to that presented here.

Comparisons of all threats showed that pest animals are contributing significantly to biodiversity decline in New South Wales, posing the fourth greatest threat, behind land clearing, altered fire regimes and weeds. Collectively, alien species (pest animals and weeds) pose the second greatest threat. Pest animals also rank highly when compared with broader processes threatening biodiversity (as outlined in the threat hierarchy developed here), such as the destruction and modification of native vegetation.

Pest animals pose a threat to 40% of the threatened biodiversity in New South Wales. These 388 threatened species at risk include 154 plants, 186 animals, 17 endangered populations and 31 endangered ecological communities. A total of 29 individual pest animal species were identified as placing 322 threatened species at risk. A specific pest animal species could not be determined for the other 66 threatened species at risk from pest animals, as the threat was poorly articulated or described (for example, described as 'introduced predators' or as a group of alien animals such as rodents or deer).

The majority of the 29 pest animals could be classified as either predators, herbivores or fishes. Feral cats, red foxes and wild dogs are the main alien predators threatening biodiversity, while feral goats, rabbits and feral pigs are the main alien herbivores. The main alien freshwater fishes threatening biodiversity are gambusia, redfin perch and European carp.

Spatial comparisons of the distribution of threatened species at risk from pest animals was undertaken using the 13 natural resource management (NRM) regions in New South Wales, as well as three broad geographic zones based on an amalgamation of these NRM regions, being coastal, central and western. This analysis showed that the number of species at risk from pest animals increases from east to west, although there was variation between individual pest animal species.

Many of the pest animals present in New South Wales were not documented as a threat to threatened biodiversity, perhaps because many have naturalised recently and/or are not yet widespread. Of particular concern is the growing number of alien fish species that have naturalised since the 1970s, many of which were imported for ornamental purposes (ie aquarium trade). Thus, the threat of pest animals on biodiversity is likely to increase in the future.

Although this review has some limitations, it provides a long-overdue baseline of the biodiversity threatened by pest animals that can be used to make informed future management and policy decisions. Given the potential application of this information to conservation managers, the approach could be used in other states and territories as well as for Commonwealth threatened species, to give a national picture of biodiversity threatened by pest animals. However, this study investigated only threatened species in New South Wales, which account for about 13% of all the plant and animal species in that state.

Addressing the impacts of pest animal species such as feral cats, red foxes, feral pigs and European carp is a high priority for the Invasive Animals CRC. This report provides further evidence for the urgent need to reduce the threats posed by such alien pest species.

Recommendations

This study identifed seven key recommendations, being the need for:

1. A national assessment of threats posed by pest animals to biodiversity.
2. An assessment of pest animal threats on non-threatened species.
3. Standardised terms to describe threats (including naming the pest animal species).
4. Measures to limit the impact of new naturalisations on biodiversity.
5. Monitoring programs to be established for pest animal control programs that assess the response of native species to control.
6. Scientific studies on the impacts of pest animal to native species.
7. Information on the biodiversity at risk to be integrated into pest animal management and policy.

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List of Acronyms, Abbreviations and Definitions

BGT	Botanic Gardens Trust (NSW)
CMA	Catchment Management Authority
DEC	NSW Department of Environment and Conservation (now Department of Environment and Climate Change)
DECC	NSW Department of Environment and Climate Change (formerly NSW Department of Environment and Conservation)
DPI	NSW Department of Primary Industries
EEC	endangered ecological community, as described under the TSC and EPBC Act
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FM Act	NSW *Fisheries Management Act 1994*
Fox TAP	Fox Threat Abatement Plan (see NPWS 2001)
IUCN	International Union for the Conservation of Nature
KTP	key threatening process, as defined under the TSC, FM and EPBC Acts
NSW	New South Wales
NSW SC	New South Wales Scientific Committee
NRM	natural resource management regions used collectively to refer to the 13 CMAs
pest animal	alien or introduced animals in Australia
RLP Act	Rural Lands Protection Act 1998
spp.	species, with reference to all species in a particular genus
TAP	threat abatement plan (eg the Fox TAP)
threatened species	for ease of reading, the term 'threatened species' is used in this report to refer to all biodiversity listed as threatened (ie species, populations and ecological communities) in the TSC, FM and EPBC Acts, unless otherwise specified.
TSC Act	NSW *Threatened Species Conservation Act 1995*

1. Introduction: biodiversity decline and pest animals

1.1 Causes of biodiversity decline

The world's biodiversity is in decline, with forecasts predicting that more than one fifth of all current plant and animal species will become extinct by the year 2020 (Wilson 1992). The main causes attributed for biodiversity decline (most of which are attributed to human [or anthropogenic] actions) are:

- habitat destruction (loss and fragmentation)
- accelerated rate of introduction of alien species
- habitat modification (eg altered fire regimes or desertification)
- pollution
- over-consumption and unsustainable use of natural resources
- climate change
- combinations of these (WRI et al 1992).

Despite the identification and acknowledgement of these actions as major causes of global biodiversity loss, little information has been compiled worldwide on the biodiversity at risk from each action.

One of the few attempts to determine the threat posed by these actions on biodiversity was based on an examination of the threats to species listed as threatened under the United States *Endangered Species Act 1973*. Habitat degradation or loss posed a threat to 85% of the 1880 species examined, while alien species were the second major threat, affecting almost half of the species (Wilcove et al 1998). A similar study of New South Wales' *Threatened Species Conservation Act 1995* also found that alien species posed the second greatest threat, but the percentage of species at risk was much higher (70% of the 945 species examined; Coutts-Smith and Downey 2006: note this report is a sister study to the current report).

1.2 Introduced alien species

One of the greatest environmental challenges facing the planet is the loss of biodiversity caused by the accelerated introduction of alien species, or as Wilson (1992) states, the homogenisation of the global flora and fauna, through the mass movement of species. Plants and animals can naturally spread vast distances to new environments (Ridley 1930), but human actions provide the most important dispersal mechanism (Heywood 1989, Lodge 1993, Panetta and Scanlan 1995, Enserink 1999). The accidental or deliberate movement of species by humans has dramatically increased the scale and rate of dispersal events, especially over the last 200 years (Reichard and Hamilton 1997, di Castri 1998, Atkinson 1989). With respect to the movement of animal species, the import of alien animals as pets in recent decades has contributed significantly to the increase. For example, approximately 1.7 million reptiles are imported annually for the pet trade in the United States alone (Franke and Telecky 2001).

Significant progress has been made towards understanding the ecology of alien species invasions (Elton 1958, Dickman 1996a). However, little is known about the specific biodiversity threatened by alien species, with the exception of several key species, and what information is available is restricted to specific groups of native species (eg Dickman 1996a) or for extinctions, particularly on islands (eg Atkinson 1989). Alien species pose both a direct and indirect threat to native species, through competition, predation, grazing

or alteration of disturbance regimes (Vitousek 1986, Gordon 1998, Mack and D'Antonio 1998). The majority of alien species introductions are irreversible, with most ecosystems at risk of invasion (Lonsdale 1999). Only new incursions or invasions on islands are likely to be at a stage of invasion where eradication is still possible (Myers et al 2000, Rejmánek 2001, Bax et al 2002, Timmins et al 2002). Successful eradications have been typically the result of early detection (Myers et al 2000, Veitch and Clout 2002).

Initial declines associated with alien animals (pest animals) were wrought largely by feral cats and rats, which were transported to novel environments on ships — either accidentally, in the case of rats, or deliberately, in the case of cats used to control ship rats (Atkinson 1989). These two alien species were thus introduced to many islands, where they caused local extinctions, including numerous island endemics (Atkinson 1989).

1.3 Alien pest animals: an Australian perspective

Since the European settlement of Australia 220 years ago, more than 650 species of terrestrial vertebrates have been brought into Australia (VPC 2006). While the majority were brought to Australia for exhibition and conservation in zoos, the species that have established wild populations were brought largely for consumption, companionship or sport (Bomford and Hart 2002). Ninety-two of these species have established wild populations — 26 mammals, 27 birds, 4 reptiles, 1 amphibian (Bomford and Hart 2002) and 34 fishes (Lintermans 2004). This figure could have been much higher as several species established wild populations that later became extinct, and many other alien species failed to establish in the wild (Bomford 2003). Not all of these 92 species are likely to threaten biodiversity, however (eg 40% of alien mammals: Wilson et al 1992, Clarke et al 2001; and 55% of alien birds: Long 1981). Irrespective, those that do pose a threat have been implicated in the extinction of many native species, and in the decline of many others (Burbidge and McKenzie 1989, Dickman et al 1993, Dickman 1996a, Short 1998). The scale of the alien animal problem is reflected by the large number of these animals listed nationally as key threatening processes under the Commonwealth *Environment and Protection and Biodiversity Conservation Act 1999*.

In addition to vertebrate animals, many insects have also been introduced to Australia, both deliberately (eg for biological control of weeds) or accidentally (eg in shipping containers or packaging, Navaratnam and Catley 1986). The exact number of alien insects in Australia is not known (Canyon et al 2002), partly because those that do not pose a threat to human health or agricultural production are less likely to be detected (Swincer 1986). Irrespective, few alien insects had established prior to 1960, but since then the number had increased steadily until 1985 when a major assessment was undertaken (Swincer 1986).

1.4 Assessing the threats posed by alien pest animals to biodiversity

Although the main threats to biodiversity have been identified (see above), there is little detailed information on the biodiversity threatened by each and their relative importance. To date, attempts to assess the impacts of alien pest animals on biodiversity have been through studies of specific interactions between alien species and native species (Landsberg et al 2003), extinction rates (Atkinson 1989), systematic reviews of species declines (Burbidge and McKenzie 1989), the impacts of a specific alien pest animal (Dickman 1996b) or through reviews of such studies (Olsen 1998, McLeod 2004). Studies so far have focused on the 'major' alien pest animals (eg rabbits, red foxes, cats, goats, igs, etc). Very few studies have investigated the impacts on native species across a broad cross-section of biodiversity or to qualify the full range of native species at risk

(see NPWS 2001). A review of the impacts of all alien pest animals across a range of biodiversity is needed. To illustrate this point, two recent studies that examined alien pest animal control programs across Australia showed that while biodiversity conservation was a stated objective of many control programs, very few undertook monitoring to determine the response of native species to control measures (Reddiex et al 2006, Reddiex and Forsyth 2006). This is concerning, given that over 1900 programs were examined for six of the major alien pest animal species, over a 13 year period (1990–2003). One of the problems contributing to this result is that the native species at risk from each alien pest animal species have not been identified, and thus control and monitoring programs could not be developed with a specific response (ie to biodiversity) in mind. Rather, they tend to be based on an assumption that control alone will lead to recovery of native species (Downey in press). However, where pest animal control programs have clear conservation objectives (eg saving a particular species) such problems can be avoided (Mahon 2000).

1.5 Overview of report

This report looks at the threat posed by pest animals to biodiversity in New South Wales, Australia. First, it provides an overview of threatened biodiversity in the state (Chapter 2). Then, the methods used in this study are outlined, including the development of the data set of threats to biodiversity and the threat hierarchy created specifically to analyse the data set (Chapter 3). Analysis of the data focuses initially on the major processes that threaten biodiversity in New South Wales (Chapter 4), and then more specifically focuses on the impact of pest animals on threatened species (Chapter 5). Subsequent analysis provides an examination of the threat posed by alien predators (Chapter 6), herbivores (Chapter 7) and fishes (Chapter 8). The final chapter discusses the results and implications for pest management strategies. A full list of the pest animals posing a threat to biodiversity in New South Wales and the biodiversity at risk are presented in the appendices.

1.6 Terminology used for pest animals

The term ‘pest animals’, as used in this report, refers to alien animal species, being those animal species that have been introduced to Australia. Native animal species that are considered by some as pest species are not considered in this report, except in the context of total grazing pressure in Chapter 7. In addition, invertebrates are not included unless specifically mentioned.

2. Threatened biodiversity in New South Wales

An overview of the biodiversity listed as threatened in New South Wales is provided here as background information to the current study. This chapter outlines the threatened species legislation and the status of biodiversity listed in the legislation as threatened. The next chapter provides information on how these threatened species were used to assess the impact of pest animals (and other threats) to biodiversity in New South Wales.

2.1 Overview of the threatened species legislation

New South Wales threatened species legislation

The threatened species legislation in New South Wales deals with the identification, conservation and recovery of threatened species, populations and ecological communities listed under the schedules of the state's *Threatened Species Conservation Act 1995* (TSC Act, listing terrestrial biodiversity) and *Fisheries Management Act 1994* (FM Act, listing aquatic biodiversity). For ease of reading, these Acts will collectively be referred to hereafter as the NSW threatened species legislation.

The conservation and recovery objectives of the NSW threatened species legislation are achieved primarily through recovery plans and the priorities action statements. In addition the impact of key threats to biodiversity is reduced by listing such threatening processes and preparing threat abatement plans.

National threatened species legislation

Biodiversity can be listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) if such biodiversity is deemed to be nationally at risk, or of national significance.

Schedules of threatened species

Information on listing species, populations and ecological communities as threatened is provided elsewhere (ie TSC Act, NPWS 2004; FM Act, DPI 2005; and EPBC Act, DEH 2005). Of relevance to this study however, is that during the listing process, an assessment is made as to the degree a species, population or ecological community is threatened, as well as their ability to recover. This assessment is based on criteria and threat categories outlined in the World Conservation Union's Red List of threatened species (IUCN 2004). The threat categories used in New South Wales are 'presumed extinct', 'critically endangered', 'endangered' and 'vulnerable', with critically endangered being the most at risk. The combination of biodiversity and their threatened status form the basis of the schedules of the TSC and FM Acts. Schedule 1 of the TSC Act and Schedule 4 of the FM Act contain species listed as endangered and presumed extinct, as well as populations and ecological communities listed as endangered. Schedule 2 of the TSC Act and Schedule 5 of the FM Act contain species listed as vulnerable. Schedule 3 of the TSC Act and Schedule 6 of the FM Act encompass threats listed as key threatening processes.

Table 2.1 The status of threatened biodiversity listed under the Commonwealth threatened species legislation at 1 January 2006

Geographic breakdown	Threatened species listed under the EPBC Act [a, b]	Number listed as: [c]				Total
		Presumed extinct	Critically endangered	Endangered	Vulnerable	
Australia	Plant species	60	57	507	674	1298
	Animal species	55	14	120	193	382
	Ecological communities	0	6	27	1	34
	Total	**115**	**77**	**654**	**868**	**1714**
New South Wales [d]	Plant species	11	5	122	211	349
	Animal species	20	4	34	65	123
	Ecological communities	0	3	9	0	12
	Total	**31**	**12** [e]	**165**	**276**	**484**

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), as at 1 January 2006.

[b] Invertebrates are included within the animal values, while the plant values exclude fungi and algae, as none were listed under the EPBC Act at the time of writing.

[c] The definition of each category is given in the EPBC Act (see Attorney-General's Department 2006), based on definitions in the IUCN Red List of threatened species (IUCN 2004).

[d] EPBC Act listings that occur in New South Wales.

[e] Eight of these nine critically endangered species and all three ecological communities are listed as endangered under the TSC Act. The remaining species was not listed under the TSC Act.

Differences between the New South Wales and national threatened species legislation

There are a number of key differences between the NSW threatened species legislation and the national legislation. For instance, until recently, species could be listed as critically endangered under the EPBC Act, but not under the NSW legislation. However, no species had been listed as critically endangered under the TSC Act in New South Wales at 1 January 2006.

Conversely, individual plant and animal populations can be listed under the TSC and FM Acts, but cannot be listed under the EPBC Act.

2.2 Nationally threatened species that occur within New South Wales

As at 1 January 2006, there were 1680 species and 34 ecological communities listed under the Commonwealth EPBC Act. Of these threatened species, 484 (28%) occur or occurred (extinct species) in New South Wales (Table 2.1). This percentage for New South Wales is high; given that the state's relative landmass is 11% of Australia.

Fifty-one of these species were not listed under the NSW legislation. Their absence may be an artefact of the listing process, rather than a discrepancy between the different legislations. For example, once a species is listed under the EPBC Act, the NSW Scientific Committee decides whether or not to list it under the NSW legislation.

As outlined above, at 1 January 2006, there were no species or ecological communities listed as critically endangered under the TSC Act or FM Act. However, there were nine species and three ecological communities that occurred in New South Wales which were

listed as critically endangered under the EPBC Act (Table 2.1). Of these nine species, eight were listed as endangered under the TSC Act and one was not listed in New South Wales at all. The three ecological communities were all listed as endangered under the TSC Act.

Table 2.2 The status of threatened biodiversity listed under the New South Wales threatened species legislation at 1 January 2006

Threatened species listed under the TSC and FM Acts [a]	Number listed as: [b]			Total [c]	
	Presumed extinct	Endangered	Vulnerable [d]	Excl. presumed extinct species	Incl. presumed extinct species
Plant species (incl. fungi and algae)	35	349	229	578	(613)
Animal species (incl. invertebrates)	40	99	177	276	(316)
Total species	**75**	**448**	**406**	**854**	**(929)**
Plant populations	na	19	0	19	(19)
Animal populations	na	18	0	18	(18)
Total populations	**na**	**37**	**0**	**37**	**(37)**
Ecological communities	na	81	na	81	(81)
Total	**75**	**566**	**406**	**972**	**(1047)**

na: Populations and ecological communities cannot be listed as 'presumed extinct'. In addition, ecological communities could not be listed as 'vulnerable', as at 1 January 2006.

[a] Threatened species refers to all biodiversity (ie species, populations and ecological communities) listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994* (FM Act), as at 1 January 2006.

[b] The definition of 'presumed extinct', 'endangered' and 'vulnerable' is given in the TSC Act (see PCO 2003), based on definitions in the IUCN Red List of threatened species (IUCN 2004).

[c] As the current study did not investigate the threat of pest animals on presumed extinct species (see Chapter 3), two sets of total values are given; the values in brackets include presumed extinct species while the other totals excluded presumed extinct species (the latter are used in this study).

[d] Although populations may be listed as vulnerable following an amendment to the TSC Act in 2004, none were listed as such at 1 January 2006.

2.3 Biodiversity listed under the New South Wales threatened species legislation

As at 1 January 2006, there were 1027 species listed under the TSC Act and 20 species listed under the FM Act, making a combined total of 1047 threatened species (Table 2.2). Of these species, 75 were listed as presumed extinct, 448 as endangered, 406 as vulnerable, 37 as endangered populations (of plants and animals) and 81 as endangered ecological communities (Table 2.2). These threatened species account for about a quarter of the native vertebrates and one tenth of the native terrestrial vascular plants in New South Wales.

Species presumed extinct

Since European settlement of Australia, as many as 115 native species (60 plant and 55 animal species, excluding subspecies) have become extinct (ie they have not been observed for more than 50 years: NPWS 2004). Of these presumed extinct species listed under the EPBC Act, 31 (11 plant and 20 animal species) were formerly distributed within New South Wales (Table 2.1). Another 44 species that once occurred in New South Wales are also listed as presumed extinct under the NSW threatened species legislation, making a total of 75 presumed extinct species in this state (Table 2.2). More animal species

than plant species are listed as presumed extinct, both in terms of total numbers and percentages of species listed as threatened. Such biases have been discussed in the literature (eg starting with Burbidge and McKenzie 1989).

Endangered and vulnerable species

Plants classified as endangered comprise more than half (60%) of the threatened plant species in New South Wales, while the majority of animal species (64%) are classified as vulnerable (Table 2.3). This result suggests that a large proportion of the threatened plant species are at a high risk of extinction, whereas the majority of threatened animal species face a lower risk of extinction. However, as outlined above, more animals than plants are listed as presumed extinct, thus many of the animals that faced extinction since European arrival may have already disappeared. Plants may be more greatly affected by localised threats because they can't move. In addition, threatened plants comprise a smaller percentage of the total flora, compared to the percentage that threatened animals comprise of the total fauna (Table 2.3).

Endangered populations

Individual populations of species that are of conservation significance can also be listed under the NSW threatened species legislation, irrespective of the threatened status of the species as a whole. To date, populations have only been listed as endangered. At 1 January 2006, 37 endangered populations were listed under the NSW legislation. Just over half of these were threatened plant populations (Table 2.2). Such populations typically contain rare forms of species that are only known from one location (eg the broad-leafed form of *Glycine clandestina* growing in coastal grasslands at Scotts Head: see NSW SC 2001a), or are geographically isolated populations of a species (eg North Head long-nosed bandicoot population: see NSW SC 1997).

Endangered ecological communities

Of the 81 endangered ecological communities (EECs) listed at 1 January 2006, all were classed as endangered, despite recent amendments (in 2002 and 2004) to the TSC Act that enable EECs to be listed as critically endangered or vulnerable. The vast majority of EECs were listed in the period 2002–2004. This shows a recent move towards listing entire ecological communities, rather than individual species. In addition, the vast majority of EECs listed are located either within the Sydney Basin or along the coast of New South Wales. Not all of the species present in an EEC are necessarily threatened, but rather it is the main species that characterise the ecological community, or the combination of the species present that are at risk. These species are not necessarily listed separately as threatened. For example, there are 82 species identified in the listing for montane peat lands and swamps, of which 24 are listed as threatened, but not one is characteristic of the community (NSW SC 2004a).

Table 2.3 Status of specific groups of threatened plant and animal species in New South Wales

Threatened species listed under the TSC and FM Acts [a]	Taxonomic grouping	Number listed as: [b]			Total number threatened in NSW	Total number of species in NSW incl. presumed extinct [d]	Percentage threatened (%) excl. presumed extinct
		Presumed extinct	Endangered	Vulnerable			
Plant species	Algae, mosses and lichens	0	1	0	1	na	na
	Aquatic plants	0	3	1	4	na	na
	Dicotyledons	32	271	187	490	3742	13
	Ferns and allies	1	14	2	17	177	9
	Fungi	0	5	4	9	na	na
	Gymnosperms	0	5	1	6	27	22
	Monocotyledons	2	50	34	86	1302	7
	Total plants	**35**	**349**	**229**	**613**	**5248** [c]	**11**
Animal species	Amphibians	0	15	12	27	74	36
	Aquatic invertebrates	0	1	2	3	na	na
	Birds	12	27	87	126	472	24
	Fish	0	7	5	12	na	na
	Invertebrates	1	14	0	15	na	na
	Mammals	26	17	40	83	147	39
	Marine mammals	0	2	5	7	37	19
	Reptile	1	16	26	43	208	20
	Total animals	**40**	**99**	**177**	**316**	**938** [c]	**26**
Total		**75**	**448**	**406**	**929**	**6186** [c]	**13**

na: the exact number of species is unknown. As such, these groups have been excluded from calculation of percentages for the totals.

[a] Threatened species refers to plant and animal species listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994* (FM Act), as at 1 January 2006.

[b] The definition of 'presumed extinct', 'endangered' and 'vulnerable' is given in the TSC Act (see PCO 2003), based on definitions in the IUCN Red List of threatened species (IUCN 2004).

[c] Excludes those species marked with 'na' as there was insufficient information on the numbers of species present in New South Wales.

[d] The total number of species in New South Wales was derived from several sources (BGT 2005, DEC 2005, also see Chapter 3). Presumed extinct species were derived from the TSC and FM Acts.

3. Development of a data set on the threats to biodiversity within New South Wales

In order to assess the threat of pest animals to biodiversity, a list of taxonomically diverse native species is needed for which information on their threats is readily available. Such lists exist as the schedules of the state and Commonwealth threatened species legislation. In New South Wales, threatened biodiversity is listed in schedules of the *Threatened Species Conservation Act 1995* (TSC Act), *Fisheries Management Act 1994* (FM Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Threatened species are also used here because they are considered by the NSW Scientific Committee to be at risk of extinction and thus they should be given conservation priority. The previous chapter presented an overview of the threatened biodiversity and legislation in New South Wales, which forms the basis of the data set used in this report.

The methods used to collate, verify and assess the data on threats to biodiversity listed as threatened in New South Wales are outlined below. While this approach led to a data set on all threats to threatened species, this report focuses primarily on the threat posed by pest animals, despite occuring ini the State.

3.1 The data set

Compiling a list of biodiversity

The schedules of the TSC Act make a suitable list of biodiversity for which threats could be examined, because:

- the species are identified as threatened
- information on their threats is documented as part of the justification for them being listed as threatened (NPWS 2004)
- these listings provide the full extent of threats across a broad range of biodiversity (ie flora, fauna, populations and ecological communities) for which comparisons can be made.

The list of threatened species in schedules of the TSC Act was supplemented with the list of species in the schedules of the FM Act, to ensure that aquatic organisms such as fish and invertebrates were included in the list of biodiversity to be examined. The combined list of biodiversity was compared with the biodiversity in the schedules of the Commonwealth EPBC Act for species which occurred in New South Wales. As outlined above (Chapter 2), 51 threatened species listed in schedules of the EPBC Act were not listed in the New South Wales legislation.

Biodiversity excluded

The 75 species listed as presumed extinct in New South Wales were excluded from the data set, as information on the cause of their presumed extinction could not be ascertained.

During the analysis of the data set, some groups of threatened species were also excluded at times. These groups include those with very few species listed as threatened, and where the exact number of native species is unknown. For example, there are only 17 threatened invertebrates and the exact number present in New South Wales is unknown. Other periodically excluded groups include fishes (12 threatened), fungi (9 threatened), algae (1 threatened) and aquatic plants (4 threatened).

The list of biodiversity examined

As outlined in Chapter 2, 1023 threatened species occur in New South Wales, including 51 species listed under the EPBC Act. These 1023 species comprised the list of biodiversity examined here.

Sources of threat information examined

Information was assembled on the threats for each species, population and ecological community in the list of threatened biodiversity, by examining a wide range of data sources. Threat information was derived from:

- determinations made by the NSW Scientific Committee as part of the listing process for each threatened species (eg NSW SC 2001a, 2002)
- fact sheets (eg NPWS 2002a)
- species profiles (eg NPWS 1999)
- fish notes (eg NSW Fisheries 2002)
- recovery plans (eg NPWS 2002b)
- threat abatement plans (eg NPWS 2001)
- threatened species books (eg NPWS 2002c, d)
- scientific studies (eg Fletcher at al 1985, Dickman 1996a).

A total of 2138 data sources were examined for the threatened species examined (Table 3.1). On average, threat information for each threatened species was obtained from at least two different sources.

Biodiversity excluded after examination of threats

As the level of threat information available for the 51 threatened species listed under the EPBC Act but not in the NSW threatened species legislation was not equivalent to the rest of the species examined, they were excluded from the data set. For example, Commonwealth Scientific Committee determinations were not easily accessible and species profiles were not available for many of these 51 species.

In addition, despite extensive investigation, threat information was not available for four threatened plant species listed in the NSW threatened species legislation (Appendix 1). All four plant species were transferred from the Rare or Threatened Australian Plants (ROTAP) list (see Briggs and Leigh 1996) to the schedules of the TSC Act when the Act came into force in 1996. The NSW Scientific Committee undertook no further evaluation of these species at the time. Given that no additional information could be obtained here, it appears that no other evaluations have occurred in the intervening period. Thus, four species were excluded, thereby reducing the list of biodiversity examined to 968 threatened species.

Table 3.1 A breakdown of the threats derived from each data source

Sources of threat information	Number examined		Number of threat descriptions identified	
	n	%	n	%
NSW Scientific Committee determinations	1002	47	1552	27
Fact sheets, fish notes and species profiles	972	45	2804	49
NSW recovery plans	118	6	444	8
NSW threat abatement plans	3	<0.1	45	<1
Scientific studies	43	2	821	14

Variation in the source information

The different sources of data varied in the amount of information they contained on threats, the quality of this information, and the actual description of each threat. Almost half of the threat information was derived from fact sheets, species profiles and fish notes collectively, while determinations by the NSW Scientific Committee contributed only 27% (Table 3.1). Less than 2% of the sources examined were peer-reviewed scientific studies, highlighting the scarcity of scientific research in this area, despite a need for such information (see Chapter 1).

Threat information

The threat information compiled for the 968 threatened species revealed a total of 5666 individual threat descriptions (eg habitat degradation by feral goats). This equates to an average of six different threats per threatened species. However, many threats were similar in nature, but were identified separately due to the wording used to describe each threat. For example, the threat descriptions 'trampling by feral goats' and 'goats trample seedlings' describe the same threat posed by goats to different threatened species, which could not be easily matched electronically. Thus, threats which are similar in nature needed to be grouped before further analysis could be undertaken.

Each of the endangered ecological communities (EECs) listed under the TSC Act contains many diverse species, and the threats described do not identify the components (or specific species) of the EEC at risk. Thus it was assumed that all species present in each EEC are affected equally by the threats identified (ie the whole community is at risk).

Limitations to the data

There are some important limitations to the data examined. The attribution of a specific threat was typically based on expert judgement, which may not have been based on experimental evidence or quantitative data, as such data rarely existed. Therefore, the quality of the threat information contained within each of the different data sources examined varied. An assessment of the quality and accuracy of each data source is summarised below:

- **Scientific studies:** Threat information derived from scientific studies of impacts has the highest level of credibility/accuracy. In many cases, this information is subjected to peer review before publication.
- **NSW Scientific Committee determinations:** Threat information outlined within each determination, while not always based on scientific studies, is reviewed and assessed by a range of experts with specialised knowledge (eg NSW SC 2004). All determinations are also subjected to public exhibition before listing. It is therefore assumed that the information within each determination was accurate and credible at the time of gazettal.
- **Recovery plans and threat abatement plans:** Threat information contained within recovery plans and threat abatement plans has been subjected to extensive investigation, consultation, assessment and review, based on information derived from the determinations by the NSW Scientific Committee. It is therefore assumed that the information provided, while not necessarily collected from scientific experiments, is accurate and credible.

- **Fact sheets, species profiles, fish notes and threatened species books:** The same level of scientific scrutiny cannot be assured for the information contained within these data sources. The information in these data sources was typically prepared by person/s having specific knowledge of the threatened species, populations or ecological communities. Therefore, it is assumed that this information was accurate at the time of writing, although it was not always verifiable.

3.2 Development of a threat hierarchy

The terminology used to describe individual threats (or threat descriptions) varied greatly between the different data sources (see above), and resulted in different ways to describe the same or similar threats for each listing. This variation hindered analysis of the data set. To account for this variability in threat descriptions, a threat hierarchy was devised. The hierarchy grouped similar threat descriptions using standardised terminology, and separated the specific threats into a hierarchical order, based around standard terms or descriptions.

The threat hierarchy

The concept of threat hierarchies is not new, and several examples already exist (Wilcove et al 1998, Lawler et al 2002, IUCN 2004). While hierarchies have been used to assess threats to biodiversity, they have not been used to compare individual threats, such as the impact of alien species on biodiversity, or specific threats (eg rabbit gazing on native plants). For example, Wilcove et al (1998) described only the major threat categories, while Lawler et al (2002) included a list of the threats that are encompassed within each major category. These hierarchies were also developed for different purposes. In an attempt to obtain information on the major threats to biodiversity Wilcove et al (1998) examined 2500 threatened species in the United States to determine which species were affected by five broad categories of threats. In contrast, Lawler et al (2002) examined the threats outlined within 181 recovery plans for threatened species in the United States to ascertain how threats were addressed across multiple species and recovery plans. The system developed here encompassed all threats described for all listed threatened species which has led to the examination of more than just the broad categories (see Table 3.2).

The threat hierarchy developed here therefore varies from those already established in that the nature of the threat forms the upper levels of the hierarchy and the agents responsible for each action form the lower levels (see below). It should be noted that this threat hierarchy, as well as those already established, are based on subjective assessments of groups of threats; these threats could be grouped in a different manner by different assessors.

The initial stage in the development of the threat hierarchy involved grouping all threats into a core set of major threats. The threat hierarchy established seven major categories, six of which are based on the specific nature of the threat, with the seventh category encompassing the remaining unrelated threats. Comparison of the seven major threat categories developed here with those developed by Wilcove et al (1998) and Lawler et al (2002) illustrates how variable such hierarchies can be. In addition, the threat hierarchy developed here encompasses a broader range of threats (Table 3.2).

The process of grouping similar threats was repeated within each major threat category, to create sub-categories. This process was then repeated within these subsequent sub-categories, until the threat description could not be broken down further. The threat hierarchy thus contained a series of sub-categories nested within each of the major threat categories, which resulted in a four-level hierarchical structure.

Each sub-category allowed each threat to be broken down into specific groups based on the nature of the threat. The sub-categories used represent the mode of the action, type of agent posing the threat, and specific agent posing the threat (see Table 3.3). For example, a threat described as 'predation by foxes' was broken down as: introduction of alien species (main category), predation (1st sub-category: mode of action), animal (2nd sub-category: type of agent), and fox (3rd sub-category: specific agent posing the threat). A complete outline of the threat hierarchy developed is presented in Appendix 2.

Applying the threat hierarchy to the data set

The 5666 threat descriptions were systematically allocated to one of the seven major categories, and then into the respective nested sub-categories based on the description of the threat (see Appendix 2 for details). Information was not always available to allocate every threat to the third sub-category, because some threat descriptions were poorly articulated (eg at risk from rabbits), too broad (eg grazing by feral herbivores) or lacking information (eg threatened by introduced animals). Despite these limitations, 84% (n = 4734) of threat descriptions could be allocated to a third sub-category and 93% (n = 5250) to a second sub-category.

Using the threat hierarchy, the 5666 threat descriptions were condensed into 384 threat categories (see Appendix 2). This number is inflated since the third sub-category contains the names of individual alien species as separate agents posing a threat (see Table 3.4). Of the 315 specific agents identified in the third sub-category of the hierarchy, alien species accounted for 170 (134 plant and 36 animal species).

Threat descriptions identified under more than one threat category

The allocation of a threat into a major or sub-category within the threat hierarchy is not exclusive. Thus, where possible, the threat was allocated according to the primary nature of the threat. In some cases, the threat could not be categorised into just one category and so such threats were allocated to more than one. For example, impacts from domesticated livestock (eg sheep, cattle and goats) could be categorised into three of the six major categories, being: (i) anthropogenic destruction and disturbance of native vegetation, (ii) anthropogenic modification of abiotic factors, and (iii) introduction of alien species. As the focus of this study was on the threat from alien pest animals (ie those that have established wild populations) to threatened species, domesticated livestock were excluded from the alien species threat category.

Table 3.2 The seven main threat categories used in the threat hierarchy developed here, compared with those used by Wilcove et al (1998) and Lawler et al (2002)

The major threat categories in the threat hierarchy developed here	The equivalent threat category of Wilcove et al (1998)	The equivalent threat category of Lawler et al (2002)
Anthropogenic destruction and disturbance of native vegetation	Habitat loss, over-exploitation	Resource use, construction, agriculture, and altered habitat dynamics
Anthropogenic destruction and disturbance of native fauna	Over-exploitation	Resource use
Anthropogenic modification of abiotic factors	Habitat degradation, pollution	Water diversions, altered habitat dynamics, pollution
Introduction of alien species	Alien species	Exotic species
Diseases	Disease	No category described
'Natural' phenomena	No category described	Species interactions, and other factors
Other threats [a]	No category described	Other factors

[a] Other threats: eg not in a formal reserve/conservation or protected area.

At the higher levels of the threat hierarchy, some threats were listed more than once. For example, the threat category 'clearing of native vegetation' could be listed under both the agriculture and development sub-categories of the major category of anthropogenic destruction and disturbance of native vegetation. So when it came to creating lists of biodiversity under each major or sub-category, duplicate threatened species at risk were removed to prevent the double counting of the same species under one action.

3.3 Analysis of the data set

Statistical analysis

Statistical analysis of the data set was restricted to comparisons of percentages. Formal tests of significance were not used, because of the subjective nature of the threat descriptions used in the data set and because all threatened species were sampled (ie there was no sampling of the data, rather the entire information was examined). In addition, the process of public nomination for listing threatened biodiversity is inherently biased, as it is not based on a systematic census of all biodiversity.

Grouping the threatened biodiversity

The 968 threatened species were grouped based on taxonomic classifications to allow broader trends to be established. Animal species were grouped into amphibians, birds, reptiles, mammals, marine mammals, fish and invertebrates. Plants were grouped into fungi, algae, aquatic, ferns and fern allies, gymnosperms, monocotyledons and dicotyledons.

Table 3.3 The structure of the threat hierarchy using alien species threats as an example

Major threat category [a]	**1st sub-category (mode of action)**	**2nd sub-category (type of agent)**	**3rd sub-category (specific agent posing the threat)** [b]
Introduction of alien species	Predation	Animal	Fox
			Undetermined [c]
	Competition	Animal	Gambusia
		Plant	Lantana
	Grazing/browsing	Animal	Rabbit
	Degradation of habitat	Animal	Goat
		Plant	Salvinia
	Control of alien species	Animal	Accidental bait take
		Plant	Accidental herbicide application
	New association (ie poor pollination)	Insect	Honey bee
	Undetermined [c]	na	na

na: insufficient information to sub-divide the threat further.

[a] The full threat hierarchy is presented in Appendix 2.

[b] Common names are used here for presentation, but the data set used both scientific and common names for each alien species.

[c] For each sub-category the classification 'undetermined' is used to encompass generic threats which could not be broken down further. This classification is presented once only in each sub-category as an example; for the full breakdown see Appendix 2.

Table 3.4 The number of threats within each threat category

	Structure of the threat hierarchy			
Major threat category [a]	**Number of threats in 1st sub-category (mode of action) [b]**	**Number of threats in 2nd sub-category (type of agent) [c]**	**Number of threats in 3rd sub-category (specific agent posing the threat) [d]**	**Total number of threats encompassed [e]**
Anthropogenic destruction and disturbance of native vegetation	5	20	21	39
Anthropogenic destruction and disturbance of native fauna	3	12	28	33
Anthropogenic modification of abiotic factors	3	9	48	51
Introduction of alien species	7	11	181 [f]	203
Diseases	5	15	2	18
'Natural' phenomena	4	21	19	38
Other threats	2	0	0	2
Total	**29**	**112**	**315**	**384**

[a] Total number of threat descriptions examined is 5666.

[b] Total number of threat descriptions examined is 5631.

[c] Total number of threat descriptions examined is 5250.

[d] Total number of threat descriptions examined is 4734.

[e] Values are not cumulative (either down or across columns) since not all threats are broken down to the third sub-category.

[f] Value includes 170 different alien species, including 134 plant and 36 animal species, plus 11 unspecified or broad threats.

Reclassifying the data set to compare pest animal threats with other threat categories

As outlined above, there were other approaches to grouping threats or constructing threat hierarchies. In order to compare the threats within the data set with other conventional threat categories (eg land clearing), the data set was reclassified. The reclassification was based on the threats listed as key threatening processes (KTPs) in New South Wales under Schedule 3 of the TSC Act and Schedule 6 of the FM Act. Using this threat classification, the representative nature of KTP listings with respect to the threats contained within the data set could be assessed (eg which threatened species could be allocated into each KTP category, rather than those that were actually allocated under the specific KTP listings).

On 1 January 2006 there were 30 KTPs listed in New South Wales. These KTPs were grouped into seven threat categories, distinct from the seven threat categories we used in the threat hierarchy, based on the similar nature of the threat. These KTP categories are: (1) clearing of native vegetation, (2) changes to natural fire regimes, (3) changes to hydrology, (4) competition from, and predation by alien species, (5) climate change, (6) pollution and (7) diseases. Some of these KTP categories encompassed multiple KTP listings. For example, the alien species category encompassed 13 specific pest animal species, two weed species/groups, and a generic listing for alien fish listed as KTPs.

3.4 Spatial analysis of threatened and non-threatened species

Natural resource management regions in New South Wales

New South Wales is divided into 13 natural resources management (NRM) regions, or Catchment Management Authorities (CMA, Figure 3.1a). These regions were used to undertake spatial analysis of the data set, in terms of the distribution of native species, threatened species and pest animal threats. Each of the native vertebrate animals and vascular plants (both threatened and non-threatened) present in New South Wales were assigned to their respective NRM region based on their known distributions. Species from Lord Howe Island and species whose distributions were unclear were excluded.

In addition, the 13 NRM regions were grouped into three geographic zones: coastal, central (tablelands and slopes) and western (rangelands) (Figure 3.1b). This zoning enabled spatial assessments at a level between the entire state and individual NRM regions.

Determining the distribution of native species

Spatial information on all terrestrial native vertebrate animals and the vascular plants in New South Wales was collated to illustrate the likely broader trends of this study to biodiversity as a whole (ie other than formally listed threatened species). Floristic data were obtained from the New South Wales flora census and herbarium records (BGT 2005), while the faunal data were obtained from the Department of Environment and Conservation's Atlas of New South Wales Wildlife (DEC 2005) and supplemented with other sources of information (eg Cogger 1994, Strahan 1995, Simpson and Day 1996). The number of species examined for the spatial analysis excludes those groups of species for which distribution data are unavailable (eg fish, marine mammals, invertebrates, aquatic plants, and fungi). In addition, populations and ecological communities were not considered for spatial analysis, as distribution data of ecological communities were insufficient to allow an accurate assessment, while populations only occurred in one location.

Spatial analysis of threats

As very few threat descriptions (eg impact of pest animals) contained geographically specific information on where the threat was active, a discrete spatial analysis of threats could not be achieved. However, a surrogate assessment was made by allocating each threatened species to their respective NRM region/s or geographic zones, as outlined above. Caution should be used when interpreting this spatial data, as it needs to be matched with the distribution of pest animals and the degree of impact present (see below).

Spatial analysis of pest animals impacts

Distribution and abundance data for a select number of pest animal species were obtained from the NSW Department of Primary Industries. These animals were: wild dogs, feral goats, feral pigs, feral deer and feral rabbits. The data were derived from a subjective measure of pest animal abundance (absent, low, medium and high) and so may not accurately show variations in abundance across New South Wales. Feral cats and red foxes were excluded because they are cryptic animals and thus it is difficult to ascertain abundance patterns. In addition, the impacts of pest animals on biodiversity are not uniform across the landscape and thus not all threatened species are necessarily at risk through their entire distribution range.

(a)

(b)

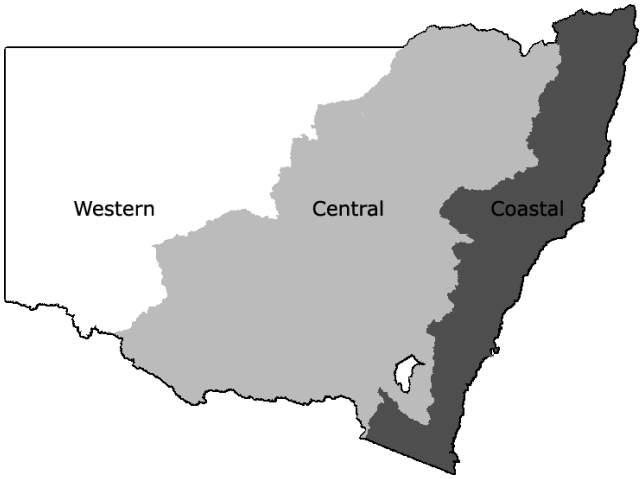

Figure 3.1 Natural resource management (NRM) or Catchment Management Authority regions within New South Wales. (a) Boundaries of the 13 NRM regions within New South Wales, and (b) the 13 NRM regions grouped into three geographic zones: coastal, central and western.

Spatial overview of native and threatened species

There are more native species (both plant and animal) present in the coastal zone of New South Wales than in the western and central zones. A similar trend was also observed for the percentage of threatened species present in each of these three geographic zones (Figure 3.2a and 3.2b). While the proportions of the total number of native plant and animal species present are similar in the coastal zone (78% of plant species and 81% of animal species), the proportions are higher for animal species (46%) than plant species (25%) in the western zone.

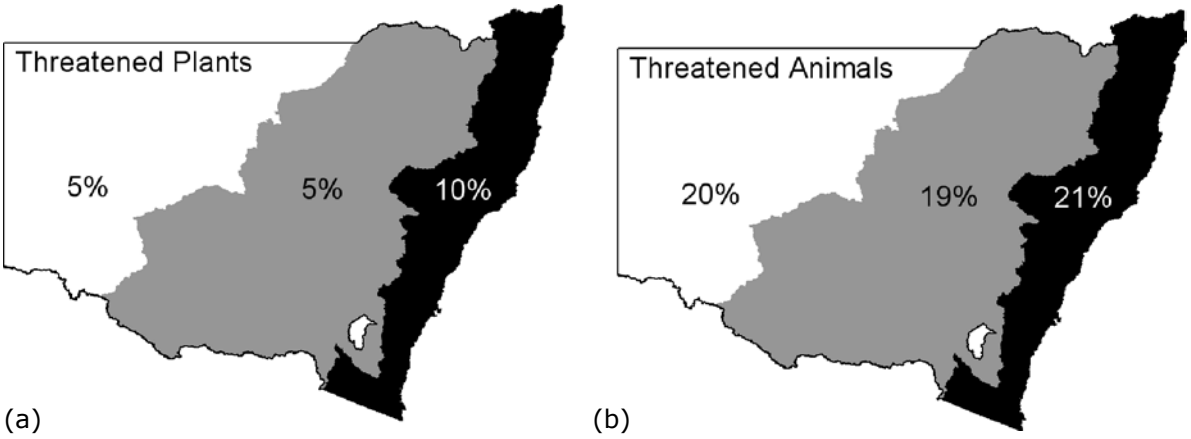

Figure 3.2 The proportion of native (a) terrestrial vascular plants and (b) vertebrates listed as threatened in each of the three geographic zones of New South Wales (coastal, central and western).

The proportions of native plant and animal species present in each NRM region are greatest in the north coast of the state (ie the Northern Rivers CMA: see Table 3.5). The smallest proportion occurs in the south-west of the state (ie the Lower Murray–Darling CMA). The northern coastal NRM regions also contain the most threatened species (plant and animal) and the south-west NRM regions the least. This trend is less clear when the actual proportions of threatened plant and animal species are examined (Table 3.5).

Table 3.5 The proportions of native species in each of the 13 natural resource management regions listed as threatened in New South Wales

Natural resource management regions in NSW [a]	Number of native plants present	Number of threatened plants [b]	Proportion of native plants listed as threatened (%) [b]	Number of native animals present	Number of threatened animals [c]	Proportion of native animals listed as threatened (%) [c]
Northern Rivers CMA	2655	209	8	695	137	20
Hunter Central Rivers CMA	2313	87	4	610	108	18
Hawkesbury–Nepean CMA	2279	132	6	538	94	17
Sydney Metropolitan CMA	1598	53	3	519	74	14
Southern Rivers CMA	2330	109	5	545	97	18
Border Rivers–Gwydir CMA	1602	59	4	481	68	14
Namoi CMA	1442	24	2	470	64	14
Central West CMA	1695	45	3	517	64	12
Lachlan CMA	1334	33	3	485	67	14
Murrumbidgee CMA	1628	48	3	488	75	15
Murray CMA	1202	31	3	432	61	14
Western CMA	1221	49	4	446	71	16
Lower Murray–Darling CMA	709	25	4	394	57	14
Total [d]	**5248**	**564**	**11**	**901**	**239**	**27**

[a] CMA = Catchment Management Authority.

[b] Threatened plants refers only to terrestrial vascular plant species listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act).

[c] Threatened animals refers only to terrestrial vertebrate animal species listed under the TSC Act.

[d] Values are not cumulative as many species occur in more than one natural resource management region.

4. An overview of the major threats to biodiversity in New South Wales

This chapter presents an analysis of the major threats to biodiversity in New South Wales. The relative importance of each threat was determined, along with the vulnerability of different taxonomic groups to each threat. Two sets of threat categories were used, being those outlined in the threat hierarchy and the reclassified data set aligned with the key threatening processes (KTPs) categories listed in New South Wales (see Chapter 3).

4.1 Analysis of the major threat categories (threat hierarchy)

An assessment of the threatened biodiversity in New South Wales

The number of threatened species at risk from each of the seven major threat categories, as outlined in the threat hierarchy, varies dramatically (Figure 4.1). Of these threats, the anthropogenic destruction and disturbance of native vegetation represents the greatest threat to biodiversity, affecting 87% of all the threatened species examined. This threat category encompasses large-scale threats such as land clearing, which is recognised as the greatest cause of biodiversity decline globally (WRI et al 1992). The introduction of alien species (pest animals and weeds) poses the second greatest threat, affecting 70%. Again, this threat is recognised as a major cause of biodiversity decline globally. The only other major category to threaten more than half the biodiversity examined is anthropogenic modification of abiotic factors (affecting 65%), illustrating the importance of abiotic factors to biological processes.

The threat posed by 'natural' phenomena to biodiversity is driven by the potential effects of stochastic events (eg drought, flood and fire) on small or isolated populations of threatened species. If these populations are excluded, the threat posed by 'natural' phenomena affects only 9% of the biodiversity examined, as opposed to almost half.

An assessment of impact to threatened plant and animal species

The level of vulnerability of threatened plant and animal species to each threat was examined. The threat from anthropogenic destruction and disturbance of native vegetation affects more than twice as many plant species than animal species, and three times more endangered plant species than animal species. However, as a proportion of the total number of species in each group, the impacts are very similar (Table 4.1). The proportions of endangered populations and endangered ecological communities (EECs) at risk from this process are also high (83–100%), highlighting how extensive the impact of this threat to biodiversity is. In contrast, anthropogenic destruction and disturbance of native fauna only affects animal species (Table 4.1). While such disturbances to fauna may have flow-on effects to native plants, these effects are not well known or documented. This is illustrated by only one plant species being affected by threats within this category.

An assessment of the different taxonomic groups of plants and animals

The majority of the major taxonomic groups of plants and animals—with the exception of fungi, amphibians, marine mammals and monocotyledons—are more at risk from the anthropogenic destruction and modification of native vegetation than from any other major threat (Table 4.2). The anthropogenic modification of abiotic factors poses the greatest threat to fungi, monocotyledons and amphibians (Table 4.2). This result was not unexpected, as both fungi and amphibians are sensitive to chemical changes in their environment (Mann and Bidwell 1999, NSW SC 2000).

The threat posed by the introduction of alien species is consistently high across all types of biodiversity examined (Table 4.2). A further breakdown of the impact of pest animals on each plant and animal group is presented in Chapter 5.

The anthropogenic modification of abiotic factors also poses a significant threat across all the threatened biodiversity. The impact of 'natural' phenomena is more skewed, being greatest on endangered plant and animal species (Table 4.1). As outlined above, many of the species at risk from 'natural' phenomena have small and/or isolated populations and thus are more likely to be prone to the impacts from stochastic events.

The two taxonomic groups affected most by diseases are amphibians and dicotyledons—primarily the result of the introduced Chytrid fungus and *Phytophthora cinnamomi* respectively (Berger et al 1999, NSW SC 2002). 'Natural' phenomena were most commonly identified as affecting dicotyledons (Table 4.2), in part because many of the species are naturally rare. Alien species were identified as a threat most frequently to dicotyledons, after which the threat was constant across the majority of plant and animal groups, with the exception of marine mammals and aquatic invertebrates (Table 4.2).

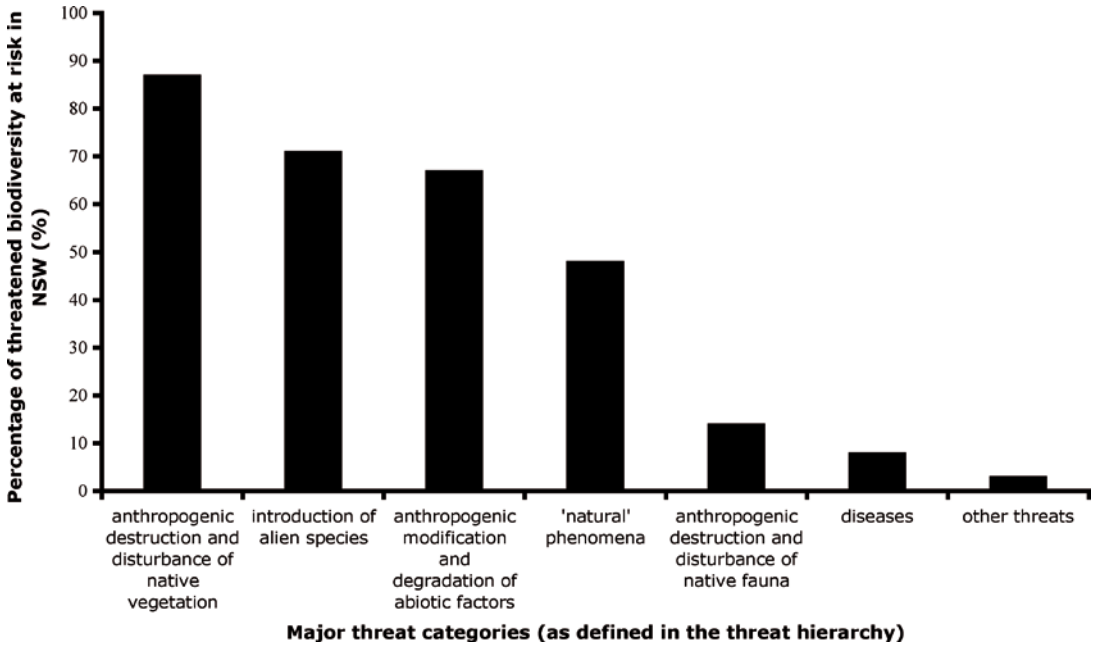

Figure 4.1 The threatened biodiversity in New South Wales at risk from threats encompassed by each of the major threat categories (Note: values are not cumulative as many threatened species face more than one threat)

Table 4.1 The impact of the seven major groups of threats on threatened biodiversity in New South Wales

Major threat category [a]		Number of threatened species at risk [b, c]							Total number of threatened species [b]
		Endangered species		Vulnerable species		Endangered populations		Endangered ecological communities	
		plant [d]	animal	plant [d]	animal	plant	animal		
Anthropogenic destruction and disturbance of native vegetation	n	306	78	197	154	19	15	76	845
	%	88	79	86	87	100	83	94	87
Anthropogenic destruction and disturbance of native fauna	n	1	48	0	74	0	8	4	135
	%	<1	48	0	42	0	44	5	14
Anthropogenic modification of abiotic factors	n	209	67	149	123	13	13	71	645
	%	60	68	65	69	68	72	88	67
Introduction of alien species	n	231	84	139	116	15	15	75	688
	%	66	85	63	69	79	83	93	71
'Natural' phenomena	n	239	41	106	48	8	9	17	468
	%	68	41	46	28	42	50	21	48
Diseases	n	16	22	14	15	1	4	8	80
	%	5	22	6	8	5	22	10	8
Other threats	n	16	0	4	0	1	0	6	27
	%	5	0	2	0	5	0	7	3
Total [e]		**349**	**99**	**229**	**177**	**19**	**18**	**81**	**968**

[a] The major threat categories as outlined in the threat hierarchy (see Chapter 3).

[b] Threatened species refers to all biodiversity as listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006. The definition of endangered, vulnerable, populations and ecological communities are given in the former Act (see PCO 2003), based on definitions in the IUCN Red List of threatened species (IUCN 2004).

[c] The percentages of the total are presented below the number.

[d] The nine species of fungi have been included within the plant totals.

[e] The totals exclude the four plant species for which no threats were determined: three endangered and one vulnerable species.

4.2 Examination of the data set using the key threatening process categories in New South Wales

The KTP categories are based on the currently listed KTPs (see Chapter 3), expanded to include the generic threat posed rather than the specific KTP listing. For example, the KTP category for pest animals includes all pest animal species, whereas only a few pest animal species are actually listed as KTPs. This allows for a greater comparison of the data set: if for example the specific KTP pest animal listings (eg red foxes, cats, goats etc) were examined using the data set, 335 threatened species were identified as being at risk, but if the pest animal category was examined, this number increased to 388. Using this approach, the 30 KTP categories encompassed 94% of the data set (or 912 threatened species). Thus, 6% of the threatened species examined are not currently accounted for under a KTP listing. However, this percentage is likely to be much higher, since these KTP categories include more KTPs than those actually listed (eg especially for alien species), and thus a greater number of threatened species at risk.

Table 4.2 The threat posed by each of the seven major threats to specific groups of threatened species in New South Wales

Threatened species in NSW [a]	Taxonomic grouping	Number of threatened species at risk from: [a, b]						
		Anthropogenic destruction and disturbance of native vegetation	Anthropogenic destruction and disturbance of native fauna	Anthropogenic modification of abiotic factors	Introduction of alien species	'Natural' phenomena	Diseases	Other threats
Plant species	Algae	0	0	1	1	0	0	0
	Aquatic plants	3	0	4	3	1	0	0
	Dicotyledons	402	1	284	299	276	28	18
	Ferns and fern allies	14	0	8	7	9	0	1
	Fungi	0	0	9	9	0	0	0
	Gymnosperms	5	0	6	4	5	1	0
	Monocotyledons	79	0	46	53	54	1	1
Animal species	Amphibians	24	6	27	19	11	20	0
	Aquatic invertebrates	1	0	2	0	2	0	0
	Birds	9	52	77	85	39	7	0
	Fish	6	9	6	7	4	3	0
	Invertebrates	13	5	10	13	5	1	0
	Mammals	56	32	35	43	10	5	0
	Marine mammals	1	7	6	0	4	0	0
	Reptiles	32	11	27	40	14	1	0
Total		**735**	**123**	**548**	**583**	**434**	**67**	**20**

[a] Threatened species as listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006. Values for populations and ecological communities are presented in Table 4.1.

[b] The major threat categories as outlined in the threat hierarchy (see Chapter 3).

Analysis of the KTP categories revealed that alien species pose the greatest threat to biodiversity in New South Wales as a single process (affecting 583 species, 30 populations and 75 EECs: Figure 4.2). The second highest threat is from land clearing. This result

differs from the previous analysis of the threat hierarchy (see above), as here 'land clearing' did not include the associated or related threats such as habitat degradation, which have been incorporated elsewhere into a single larger threat (eg WRI et al 1992, Wilcove et al 1998, and in the threat hierarchy).

The third greatest threat is from altered fire regimes, affecting 46% of threatened species (Figure 4.2). Again, the threat was encompassed within a broad group of related threats in the threat hierarchy, being anthropogenic modification of abiotic factors (see Section 3.2). The threat of altered fire regimes contributes significantly to the number of plant species impacted within this major threat category.

Less than 10% of the threatened biodiversity in New South Wales is threatened by climate change (Figure 4.2). However, this value may be an underestimate as the process has been described and documented recently. Climate change may be affecting species presently but an assessment of this threat has not been undertaken. For example, there is no formal mechanism to revise the threats identified for threatened species (in the NSW Scientific Committee determinations) once they have been listed, highlighted by the fact that no threat could be determined for four species listed as threatened in 1996 under the TSC Act (see Chapter 3). Thus, climate change could be affecting more species, but such information has not been documented, and could potentially affect all biodiversity in the future (NRMMC 2004). This possibility should be considered when discussing the broader implications of these results. A similar result was observed for salinity, a further discussion on which is presented by Coutts-Smith and Downey (2006).

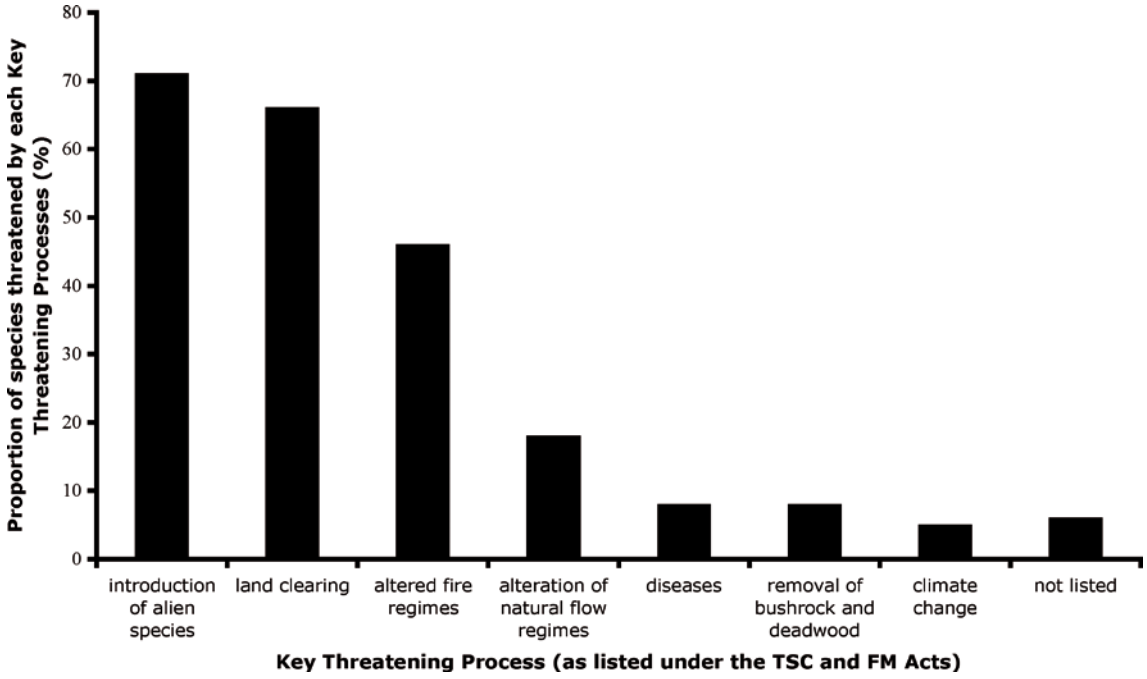

Figure 4.2 The threatened biodiversity at risk from the key threatening processes grouped into categories of related threats (Note: values are not cumulative as many threatened species face more than one threat)

5. The threat posed by pest animals to threatened biodiversity

Alien species pose a significant threat to biodiversity, with 688 threatened species, populations and ecological communities at risk (see Chapter 4). This chapter examines the threat posed by pest animals relative to other threatening processes and other alien species. In addition, the various taxonomic groups of native flora and fauna most affected by pest animals and the processes by which pest animals pose the threat (eg competition and predation) are examined. The distributions of native species at risk from pest animals are also described. Lastly, an overview of the three major groups of pest animals is presented as a lead into the following three chapters, which investigate the specific threat posed by these groups.

5.1 Contribution of pest animals to the threat posed from all alien species

The alien species identified in the data set were divided into two groups, being pest animals and weeds. Pest animals threaten 388 (40%) threatened species in New South Wales, while weeds threaten 431 (44%) threatened species (Figure 5.1). Twenty-nine pest animal species were identified as posing a threat, compared with 127 weed species. The impact of weeds on biodiversity in New South Wales has been investigated in more detail elsewhere (see Coutts-Smith and Downey 2006).

The number of species identified here as being at risk from pest animals in New South Wales is an order of magnitude greater than previous attempts to illustrate the threat posed by pest animals to biodiversity. For example, McLeod (2004) only identified 35 native species as being at risk from pest animals in New South Wales. A similar increase compared with previous attempts was also recorded when using the current process to assess the number of species threatened by weeds (see Coutts-Smith and Downey 2006). In addition, when the number of native species identified by the NSW Scientific Committee as being at risk from pest animal species listed as key threatening processes (KTPs) in New South Wales was compared with the current process, many more species were identified as being at risk (Table 5.1).

Of the threatened species at risk from pest animals, 134 are also threatened by weeds (Figure 5.1). For example, the striated fieldwren (*Calamanthus fuliginosus*) is threatened by both predation from feral cats and habitat degradation from weed invasion.

5.2 The relative threat posed by pest animals compared to other threats

The threat posed by pest animals to biodiversity was compared with the threat from the major categories identified in the threat hierarchy. Pest animals pose the fourth greatest threat to biodiversity, behind (i) anthropogenic destruction and disturbance of native vegetation, (ii) anthropogenic modification of abiotic factors, and (iii) introduction of weed species. Using the KTP categories (see Chapter 3 for further details) instead of the threat hierarchy revealed the same result, in that pest animals pose the fourth greatest threat behind land clearing, altered fire regimes and weeds (Table 5.1). These results illustrate the significance of pest animals to biodiversity decline in New South Wales.

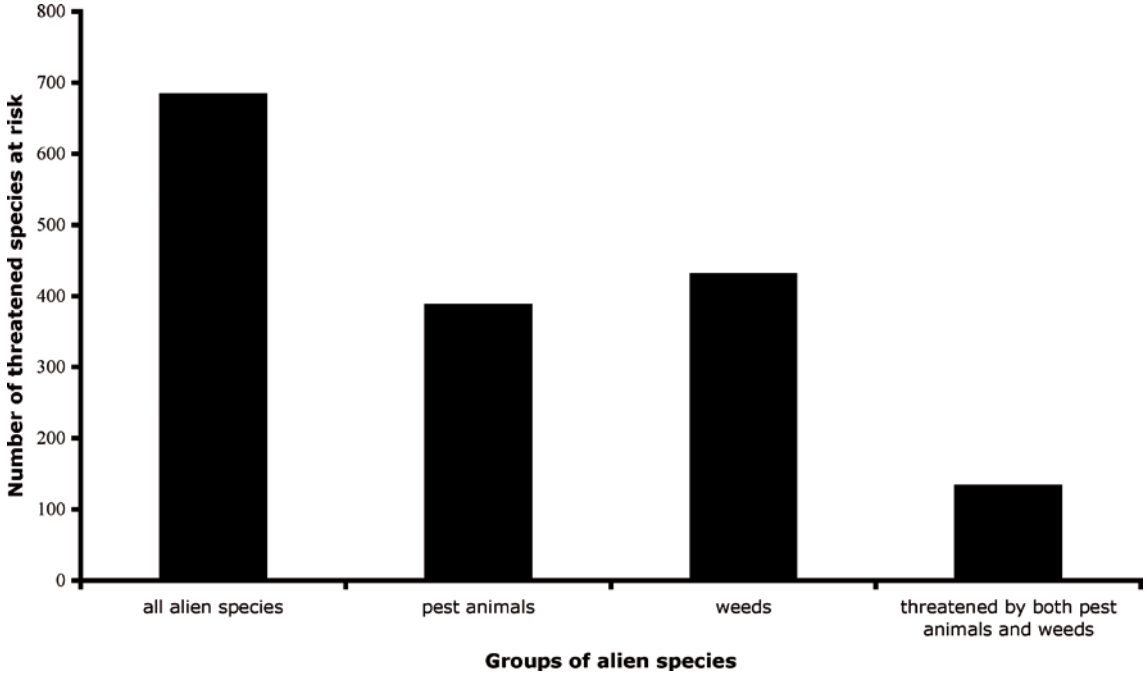

Figure 5.1 A comparison of biodiversity in New South Wales threatened by alien species, pest animals and/or weeds

Table 5.1 The relative threat posed by pest animals to biodiversity in New South Wales compared with other categories of key threatening processes

Categories of key threatening processes (KTPs) [a]	Number of threatened species at risk [b]	Number of KTPs encompassed [c]	Number of species identified as being at risk in KTP determinations [d]
Land clearing	636	2	0
Altered fire regime	446	1	66
Weeds	431	2	24
Pest animals	388	14	118
Altered natural flow regimes	177	1	10
Disease	80	3	18
Removal of bushrock and deadwood	80	2	49
Climate change [e]	56	1	16

[a] Categories of KTPs are based on collective threats listed under Schedule 3 of the NSW *Threatened Species Conservation Act 1995* and Schedule 6 of the NSW *Fisheries Management Act 1994*. See Chapter 3 for further details.

[b] Values are not cumulative, as many species are threatened by more than one process. Total: *n* = 968 threatened species.

[c] The KTP categories encompass related KTP determinations (ie red foxes and rabbits are both included under the KTP category of pest animals).

[d] The key threatening process determinations include a lists of species at risk as well as generic statements that encompass other species. For example, 'many species not currently listed as threatened could become so if the threat is not addressed'. Thus, only the actual number of species identified is presented here.

[e] The numbers presented here are for those species identified in the data set as being at risk currently, but potentially all biodiversity could be at risk in the future (NRMMC 2004).

Pest animals actually listed as key threatening processes

As at 1 January 2006, there were 14 pest animal species or groups of species (eg deer, and introduced fish) listed as KTPs under the New South Wales threatened species legislation. Eleven of these pose a threat to biodiversity listed as threatened in New South Wales (Table 5.2). The remaining three species, being the yellow crazy ant, red imported fire ant and large earth bumblebee, are not established in New South Wales and thus pose no threat at present. However, they have the potential to threaten many species, if they establish. Only 118 threatened species were identified as at risk in the determinations for these 14 KTPs (Table 5.2), implying that determinations are not necessarily comprehensive in identifying all the species at risk. The number of species at risk almost triples to 342 species (or 88% of all species at risk from pest animals) when the value is derived from the current data set.

A further 12 pest animal species that are not listed as a KTP were identified in the data set as posing a threat to biodiversity, in addition to black rats (ship rats) that pose a threat in New South Wales outside of Lord Howe Island. The full list of 29 pest animals threatening biodiversity is presented in Table 5.3 and the species/groups at risk in Appendix 3. These 12 species and the more generic threats (eg 'introduced herbivores') account for an additional 46 threatened species being identified as at risk from pest animals, or 12% of all species at risk from pest animals.

Table 5.2 Number of native species in New South Wales threatened by pest animals listed as key threatening processes

Pest animal key threatening processes (KTPs) [a]	Number of threatened species at risk as identified in the [b]	
	KTP listing [c]	Data set [c]
Predation by feral cats	13	117
Predation by the European red fox	10	111
Competition and habitat degradation by feral goats	23	94
Competition and grazing by the feral European rabbit	10	86
Feral pigs	46	81
Introduction of fish to fresh waters within a river catchment outside their natural range	0	26
Predation by the plague minnow (*Gambusia holbrookii*)	2	19
Herbivory and environmental degradation caused by feral deer	18	19
Competition from feral honey bees	11	14
Invasion and establishment of the cane toad	7	10
Predation by the ship rat on Lord Howe Island	4	8
Introduction of the large earth bumblebee (*Bombus terrestris*) [d]	0[e]	0
Invasion of the yellow crazy ant [d]	0	0
Importation of red imported fire ants into NSW [d]	0	0
Total	**118**	**342** [f]

[a] KTPs as listed in Schedule 3 of the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Schedule 6 of the NSW *Fisheries Management Act 1994* (FM Act).

[b] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the TSC Act and Schedules 4 and 5 of the FM Act, as at 1 January 2006.

[c] Values are not cumulative as many species are threatened by more than one KTP.

[d] These species are not currently posing a threat to native species in New South Wales, but are listed based on their potential impact.

[e] Four species were identified as being potentially at risk if bumblebees were to establish in New South Wales.

[f] An extra 46 species are affected by the pest animal species not listed as KTPs, but identified in the data set.

Table 5.3 The 29 pest animal species posing a threat to native species in New South Wales

Pest animal species identified as posing a threat to threatened species [a]	Number of threatened species at risk [a]
Amniataba percoides (banded grunter)	1
Apis mellifera (honeybee)	14
Bufo marinus (cane toad)	9
Canis lupus familiaris (wild dog)	39
Capra hircus (feral goat)	94
Carassius auratus (goldfish)	2
Columba livia (feral pigeon)	1
Cyprinus carpio (European carp)	5
Equus caballus (feral horse)	15
Felis catus (feral cat)	117
Gallirallus philippensis (buff banded rail)	1
Gambusia holbrookii (gambusia)	19
Lygosoma bowringii (grass skink)	2
Misgurnus anquillicaudatus (Oriental weatherloach)	2
Mus domesticus (house mouse)	4
Ochrogaster lunifer (bag-shelter moth)	1
Onchorhyncus mykiss (rainbow trout)	2
Oryctolagus cuniculus (feral rabbit)	86
Perca fluviatalis (redfin perch)	9
Physa acuta [a freshwater snail]	2
Rattus norvegicus (brown rat)	3
Rattus rattus (black rat)	5
Salmo trutta (brown trout)	2
Sus scrofa (feral pig)	81
Tinca tinca (tench)	1
Turdus merula (blackbird)	2
Turdus philomelos (song thrush)	2
Tyto novaehollandiae (masked owl)	2
Vulpes vulpes (red fox)	111

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

5.3 The threat posed by pest animals to specific groups of threatened species

Of the 388 threatened species listed as at risk from pest animals, 154 are plant species, 186 animal species, 17 threatened populations of plants or animals, and 31 endangered ecological communities (EECs). A further examination of each of these groups, as well as the categories of threat (ie endangered and vulnerable), are presented below.

Endangered and vulnerable species

Threatened species in New South Wales are categorised based on the degree to which they are threatened, using the internationally accepted IUCN Red List classifications of 'endangered' or 'vulnerable' (see IUCN 2004). Pest animals pose a threat to 38% of all

native species listed as endangered and 42% of species listed as vulnerable in New South Wales (Table 5.4). This equates to 26% and 27% of endangered and vulnerable plant species, respectively, and 77% and 62% of endangered and vulnerable animal species, respectively.

Threatened plant species

Of the 5248 vascular plant species (excluding algae, aquatic plants and fungi for which accurate numbers are not available) that occur in New South Wales, 564 are listed as threatened. Of these, 154 are at risk from pest animals (Table 5.5). Dicotyledons are the most frequently identified group of plants at risk, with 122 species threatened by pest animals. However, as a proportion, monocotyledons are the most at risk with 35% of all threatened monocotyledons at risk from pest animals (Table 5.5).

Threatened animal species

Of the 938 vertebrate animals (excluding fish and invertebrates for which accurate numbers are not available) that occur in New South Wales, 247 are listed as threatened. Of these vertebrate animal species, 171 are at risk from pest animals. An additional 15 threatened species are included when fish and invertebrates at risk from pest animals are included (revised total = 186, see Table 5.5). Pest animals pose a threat to two thirds of the animal species and 83% of the animal populations listed as threatened in New South Wales (Table 5.5). Birds were identified most frequently as being at risk, with 74 species threatened by pest animals. However, as a proportion, reptiles are the most at risk with 93% of all threatened reptiles at risk from pest animals (Table 5.5).

Threatened plant and animal populations and ecological communities

Pest animals pose a threat to 83% of the endangered animal populations (Table 5.5). The types of animal populations at risk include mammals, frogs, fish and birds. In contrast, pest animals pose a threat to only 11% of threatened plant populations. Pest animals also pose a threat to 31 EECs, or 38% of all EECs in New South Wales.

Table 5.4 Endangered and vulnerable species threatened by pest animals in New South Wales

Threatened species [a]	Number threatened by pest animals						Total number of threatened species [b, d]
	Endangered species [b, c]		Vulnerable species [b, c]		Total [c]		
	n	%	n	%	n	%	
Plant species (incl. fungi and algae)	92	26	62	27	154	27	578
Animal species (incl. invertebrates)	76	77	110	62	186	67	276
Total	**168**	**38**	**172**	**42**	**340**	**40**	**854**

[a] Threatened species refers to those plant and animal species listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] The definition of 'endangered' and 'vulnerable' is given in the TSC Act (see PCO 2003), based on definitions in the IUCN Red List of threatened species (IUCN 2004).

[c] Percentages are of the total species listed in each threat category. The total number of endangered species is 448, being 349 plants and 99 animals. The total number of vulnerable species is 406, being 229 plants and 177 animals (also see Table 2.2).

[d] Excludes the four species for which threats could not be determined (see Chapter 3 for further details).

Table 5.5 The threat posed by pest animals to specific groups of threatened species in New South Wales

Threatened species [a]	Taxonomic grouping	Number of threatened species examined [a]	Number of threatened species at risk from pest animals [a]	Percentage of species threatened by pest animals (%)
Plant species	Algae	1	nr	na
	Aquatic plants	4	1	25
	Dicotyledons	458	122	27
	Fern or allies	16	1	6
	Fungi	9	nr	na
	Gymnosperms	6	1	17
	Monocotyledons	84	29	35
	Total	**578** [b]	**154**	**27**
Animal species	Amphibians	27	19	70
	Aquatic Invertebrates	3	nr	na
	Bird	114	74	65
	Fish	12	7	58
	Invertebrate	14	8	57
	Mammal	57	39	68
	Marine mammals	7	nr	na
	Reptile	42	39	93
	Total	**276**	**186**	**67**
Plant populations		19	2	11
Animal populations		18	15	83
Ecological communities		81	31	38
Total		**972** [b]	**388**	**40**

na: not applicable

nr: none recorded

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] Excludes the four species for which threats could not be determined (see Chapter 3 for further details).

5.4 Distribution of species threatened by pest animals

All of the 13 natural resource management (NRM) regions in New South Wales contain significant proportions of threatened species at risk from pest animals, ranging from 32% in the Northern Rivers Catchment Management Authority (CMA) to 68% in the Western CMA (Figure 5.2 and Table 5.6). However, when the numbers of species at risk were examined, the order changed, with the Northern Rivers CMA having the greatest number at risk, and the Murray CMA the lowest (Table 5.6). When the NRM regions are grouped into the three geographical zones — coastal, central and western zones — the proportion of threatened species at risk increases from east to west across the state, being 31%, 53% and 68% of threatened species at risk from pest animals respectively.

It should be noted that the impact (and threat posed) by individual pest animal species to threatened species will vary greatly within and between each NRM region. Thus, detailed examinations are needed that match the distribution of the threatened species at risk with that of the pest animals posing the threat, which is then combined with an assessment of the actual impact present. Caution should be taken when interpreting the results presented here relating to distributions of species threatened by pest animals.

Eleven out of the 16 threatened species that occur on Lord Howe Island are threatened by pest animals. This high proportion (69%) illustrates the impacts that pest animals can have on island ecosystems, which are highly invasible and have high levels of endemism.

Table 5.6 Number and proportion of threatened species at risk from pest animals within each of the 13 natural resource management regions in New South Wales

Natural resource management regions of NSW [a]	Number of threatened species at risk from pest animals [b, c]		Total number of threatened species present [b]
	n	%	
Northern Rivers CMA	110	32	346
Hunter Central Rivers CMA	89	45	197
Hawkesbury–Nepean CMA	92	40	228
Sydney Metropolitan CMA	65	51	127
Southern Rivers CMA	98	47	208
Border Rivers–Gwydir CMA	70	55	128
Namoi CMA	52	58	89
Central West CMA	55	50	109
Lachlan CMA	58	57	101
Murrumbidgee CMA	75	60	124
Murray CMA	51	55	93
Western CMA	83	68	122
Lower Murray–Darling CMA	52	63	82
Total [d]	**319**	**39**	**809**

[a] CMA = Catchment Management Authority.

b Threatened species refers to terrestrial plants and vertebrates only (ie excludes invertebrates, fish and marine mammals, as distributional data was not available) listed in Schedules 1 and 2 of the NSW Threatened Species Conservation Act 1995 and Schedules 4 and 5 of the NSW Fisheries Management Act 1994, as at 1 January 2006. Species from Lord Howe Island and species whose distributions were unclear are excluded. Hence, totals differ from earlier tables.

[c] Percentages are of the total number of threatened species present.

[d] Values are not cumulative as many species occur in more than one CMA.

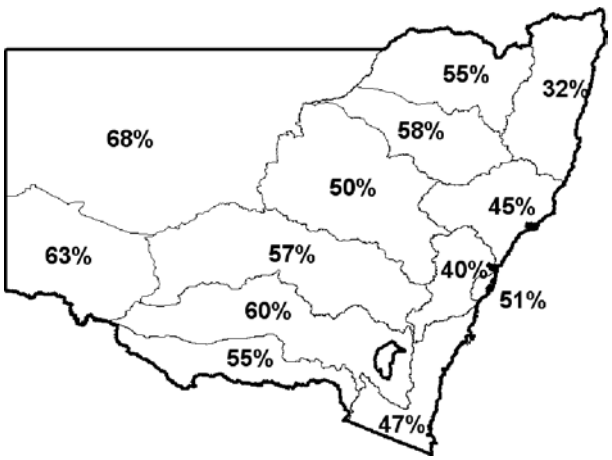

Figure 5.2 Proportion of threatened species in each natural resource management region at risk from pest animals in New South Wales

5.5 Actions by which pest animals threaten biodiversity

The second level of the threat hierarchy (ie the first threat sub-category: see Chapter 3) was used to identify the actions by which a particular pest animal species threaten biodiversity in New South Wales. A total of eight different actions were identified: predation, herbivory (ie grazing and browsing), habitat degradation, competition, non-target effects associated with pest animal control, vectors for diseases, ingestion of alien animals (ie ingestion of cane toads) and new associations (eg honey bees being poor pollinators of geebungs *Persoonia* sp.). The three main actions identified were predation, herbivory and habitat degradation, which pose a threat to 45%, 38% and 37% of threatened species at risk from pest animals respectively (Table 5.7).

5.6 Overview of the major pest animal groups which threaten biodiversity

Most of the pest animal species that pose a threat to biodiversity in New South Wales can be classified into one of three broad groups: terrestrial predators, terrestrial herbivores, or fish (including all the aquatic alien species). Several species in the data set could not be classified into any one of these groups, so were simply grouped as 'other' alien species (see Table 5.8).

Examination of these major groups of pest animals revealed that alien herbivores threaten 63% of species at risk from pest animals, yet predation threatens 45% (Table 5.7), fish 7%, and remaining pest animal threats 5% (Table 5.9). Alien herbivores pose the main pest animal threat to endangered and vulnerable plant species, as well as plant populations and ecological communities. Alien predators pose the main threat to endangered and vulnerable animal species, as well as animal populations (Table 5.9).

Table 5.7 Actions by which pest animals threaten biodiversity in New South Wales

Threatening actions [a]	**Number of threatened species at risk** [b, c]	
	n	**%**
Competition	44	11
Control (off-target effects)	15	4
Herbivory (grazing / browsing)	148	38
Habitat degradation	144	37
Ingestion of alien animals	3	1
New associations	8	2
Predation	176	45
Vectors of disease	4	1
Total [d]	**388**	**100**

[a] Threatening actions for pest animals were derived from level 2 of the threat hierarchy (see Chapter 3).

[b] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[c] Percentages are of the total number of threatened species at risk from pest animals.

[d] Values are not cumulative as some species were threatened by more than one action.

The specific impacts of alien predators, herbivores and fish are examined further in the next three chapters respectively. Impacts from omnivorous species (eg pigs) are included in both predator and herbivore assessments. However, information on the history and spatial impact of feral pigs is presented in Chapter 7 only, as herbivory was their main threatening action. The pest animals in the 'other alien species' group are not discussed further in this report, but are listed in Appendix 3 along with the species at risk. Each of these pest animals threatened less than two threatened species (except honey bees, which threatened 14 species), and collectively only threatened 5% of the species at risk, many of which were also threatened by other pest animals.

Table 5.8 A breakdown of the pest animal species threatening biodiversity in New South Wales

Groups of pest animal species threatening biodiversity in New South Wales			
Predators	**Herbivores**	**Fish**	**Other**
Feral cats	Feral goats	Gambusia	Honey bees
Red foxes	Feral rabbits	Redfin perch	Grass skink
Feral pigs [a]	Feral pigs [a]	European carp	Feral pigeon
Wild dogs	Feral deer [b]	Goldfish	Buff banded rail
Black rat	Feral horses	Tench	Introduced worms
Brown rat		Weatherloach	Black ants
House mouse		Rainbow trout	
Cane toads		Brown trout	
Masked owl		Banded grunter	
Blackbird			
Song thrush			

[a] Feral pigs are omnivorous and thus are included under both predators and herbivores.

[b] A total of six feral deer species are known to have established wild populations in New South Wales, but none were specifically identified as a threat — instead, the threat was generically listed as 'deer'.

Table 5.9 Number of threatened species at risk from the major pest animal groups

Groups of pest animals	Number of threatened species at risk [a, b]							Total number of threatened species at risk [a, c]	
	Endangered species		Vulnerable species		Populations		Ecological communities		
	plant	animal	plant	animal	plant	animal		n	%
Predators	0	57	0	95	0	11	7	170	44
Herbivores	89	41	59	21	2	4	28	243	63
Fish	0	12	0	8	0	3	3	26	7
Other alien species [d]	5	4	2	10	0	1	0	20	5
Total [e]	**92**	**76**	**62**	**110**	**2**	**15**	**31**	**388**	**100**

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] The definition of 'endangered', 'vulnerable', 'populations' and 'ecological communities' is given in the TSC Act (see PCO 2003), based on definitions in the IUCN Red List of threatened species (IUCN 2004).

[c] Percentages are of the total number of threatened species at risk from pest animals.

[d] The pest animal species listed as 'other' in Table 5.8.

[e] Values are not cumulative as many threatened species are threatened by more than one group of pest animals.

6. Alien predators

The threat posed by pest animals to biodiversity listed as threatened in New South Wales was described in Chapter 5 in terms of the number of species at risk and the processes by which pest animals pose a threat. This chapter focuses on the threat posed by a specific group of pest animals, namely terrestrial alien predators (hereafter referred to as alien predators).

6.1 Alien predators and threatened biodiversity in New South Wales

Predation by alien pest animals was identified as a threat to 163 of the 968 species, populations and ecological communities listed under the New South Wales threatened species legislation (Table 6.1). This accounts for 42% of the threatened biodiversity affected by pest animals collectively. Seventy-eight percent of the animal species threatened by pest animals are threatened through predation.

Examination by taxonomic class reveals that predation by alien pest animals threatens three-quarters of reptiles, two-thirds of mammals, and approximately half of the bird and terrestrial invertebrate species listed as threatened (Table 6.2). This is interesting because while declines in mammals and ground-nesting birds have often been attributed to alien predators, evidence of significant impacts on reptiles has been limited largely to turtles (eg Dickman 1996a). However, the number of mammal species threatened by predation represents a quarter of *all* mammals in New South Wales (ie both threatened and non-threatened), while the 32 reptile species identified as at risk represent only 15% of all reptiles present. A third of all threatened amphibians were identified as at risk from predation by alien pests (Table 6.2).

Table 6.1 Status of threatened species at risk from predation by alien pests in New South Wales

Threatened species [a]	Threatened species at risk from all pest animals [a]	Number at risk from predation by alien pests		Total threatened species at risk from predation by alien pests [a, c]	
		Endangered [b]	Vulnerable [b]	n	%
Plant species	154	0	0	0	
Animal species	186	57	89	146	78
Plant populations	2	0	na	0	
Animal populations	15	11	na	11	73
Ecological communities	31	6	0	6	19
Total	**388**	**74**	**89**	**163**	**42**

na: populations can not be listed as vulnerable (see Chapter 2 for further details).

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] The definition of 'endangered' and 'vulnerable' is given in the TSC Act (see PCO 2003), based on definitions in the IUCN Red List of threatened species (IUCN 2004).

[c] Percentages are of the total threatened species at risk from all pest animals.

6.2 Specific alien predator threats to biodiversity in New South Wales

Eleven species of introduced terrestrial vertebrates were identified as posing a threat to biodiversity through predation (Table 6.3). These are the feral cat (*Felis catus*), red fox (*Vulpes vulpes*), wild dog (*Canis lupus dingo and C. l. familiaris*), feral pig (*Sus scrofa*), cane toad (*Bufo marinus*), black rat (*Rattus rattus*), brown rat (*Rattus norvegicus*), house mouse (*Mus domesticus*), blackbird (*Turdus merula*), song thrush (*Turdus philomelos*) and the masked owl (*Tyto novaehollandiae*). Note that the masked owl is native to mainland Australia. It was introduced into Lord Howe Island sometime in or after 1918, where it threatens the endemic Lord Howe Island woodhen and white tern.

Several of these alien predators were identified as posing a threat through other processes in addition to predation. Thus, while predation by feral pigs was identified as a threat to 10 species, grazing, competition and/or habitat degradation by pigs were identified as a threat to a further 71 species; these latter effects are discussed in Chapter 7. Feral cats were identified as a threat to quolls via transmission of disease, while cane toads were identified as a threat to quolls and two species of broad-headed snake via poisoning. Non-target poisoning linked to the control of wild dogs was identified as a threat to several species of small mammals, while secondary poisoning linked to the control of introduced rodents was identified as a threat to several native predators including owls. The threat action of alien predators to each native threatened species is listed in Appendix 3.

Table 6.2 Numbers of animal species for which predation by alien pests was identified as a threat in New South Wales

Threatened species [a]	Total species present [b]	Number listed as threatened [a]	Number threatened by predation by alien pests [c]	
			n	%
Amphibians	70	27	9	33
Birds	472	114	61	54
Invertebrates (terrestrial)	na	14	7	50
Mammals	147	57	37	65
Reptiles	208	42	32	76
Total	**897**	**254**	**146**	**57**

na: the exact number of species is unknown.

[a] Threatened species refers to all animals listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995*, as at 1 January 2006, with the exclusion of marine mammals (*n* = 7), as they are not threatened by terrestrial alien predators.

[b] The total number of animal species present in New South Wales was derived from several sources (see Chapter 3 for further details).

[c] Percentages are of the number of threatened species listed in New South Wales.

Table 6.3 The threat of specific predators to threatened biodiversity in New South Wales

Alien predators	Threatened species at risk [a, b]					Ecological communities	Total threatened by predation	Total threatened through all actions
	Amphibians	Birds	Invertebrates	Mammals	Reptiles			
Feral cats	3	46 (+3)	2	35 (+5)	20	3	117	117
Red foxes	3	38 (+3)	0	34 (+5)	25	3	111	111
Wild dogs	0	15 (+3)	0	11 (+4)	2	1	36	39
Rodents [c]	1	12	4	0	2	0	19	31
Feral pigs	2	3 (+1)	0	1	3	0	10	81
Cane toads	4	0	0	1	0	1	6	9
Alien birds [d]	0	2	2	0	0	0	4	6
Unspecified [e]	1	7	1	0	2	1	12	12
Total [f]	**9**	**61 (+4)**	**7**	**37 (+7)**	**32**	**6**	**163**	**239**

[a] Threatened species refers to all animals, animal populations and ecological communities listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006, with the exclusion of fish (n = 12), marine mammals (n = 7) and aquatic invertebrates (n = 3), as they are not threatened by alien predators.

[b] The number of threatened animal populations are presented in brackets (n = 11). The cumulative value is used to derive the total threatened by predation.

[c] 'Rodents' encompasses the threat from three alien species, being: black rat, brown rat and house mouse, as well as the generic threat from 'rodents' and 'rats' (see text for further details).

[d] 'Alien birds' encompasses the threat from three alien species, being blackbird, song thrush and Australian masked owl (see text for further details).

[e] 'Unspecified' alien predators encompasses generic or broad threat descriptions (eg 'predation by introduced species': see text for further details).

[f] Totals are not cumulative as a species, population or ecological community may be threatened by more than one pest animal.

Feral cats

Cats were brought into eastern Australia as domestic pets by European settlers in the late 1700's and likely established wild populations soon after. It is possible that they were introduced by explorers and traders into Western Australia much earlier, although it is unlikely that they established widely (Abbott 2002). Feral cats were widespread by the mid 1800's, by which time they had probably caused the continental extinction of seven species of native mammals and regional extinctions of a further six species of mammals and four species of ground-nesting birds (Dickman et al 1993, Smith et al 1994, Dickman 1996a). Mammal and bird extinctions from many of Australia's off-shore islands were also reported following the introduction of cats (Dickman 1996a, 1996b).

At present, feral cats are identified as a threat to 117 listed species; more than any other alien pest animal or weed (cf. Coutts-Smith and Downey 2006). Species threatened are mostly birds, mammals and reptiles, although some amphibians, invertebrates and ecological communities are also at risk (Table 6.3). The majority of impacts from feral cats are wrought through predation, although quolls were identified as at risk from diseases spread by feral cats.

Within mammals, feral cats were identified most frequently as a threat to medium-sized (0.45–5kg) species (82%; Table 6.4), although the distribution between size classes was not significantly different from random (χ^2=3.0, df=2, p>0.05). This is unexpected, because most of the species that have declined due to cat predation are or were small (<220g; Dickman 1996a).

Table 6.4 Proportion of threatened terrestrial mammal species across three weight ranges threatened by various alien predators

Native mammals of NSW by mass	Extinct	Extant	Listed as threatened [a]	Number identified as threatened by [b]					
				Feral cats		Red foxes		Wild dogs	
				n	%	n	%	n	%
Less than 0.45 kg	14	75	42	24	57	22	52	6	14
0.45–5 kg	10	21	11	9	82	9	82	3	27
Greater than 5 kg	1	13	5	2	40	3	60	2	40
Total	**25**	**109**	**58**	**35**		**34**		**11**	

[a] Threatened species refers to all terrestrial mammals listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* as at 1 January 2006.

[b] Percentages are of the number listed as threatened.

Red foxes

Red foxes were introduced successfully into Australia in 1871 for recreational hunting, and they spread rapidly across the continent following the spread of the European rabbit (Rolls 1969). They are now distributed across most of mainland Australia, being absent only from the far north (Saunders et al 1995). Foxes were recently introduced into Tasmania, but remain absent from some offshore islands. They are found in all environments, but appear to be most common in fragmented agricultural lands (Saunders et al 1995). The spread of foxes across Australia coincided with declines and extinctions of a broad range of native fauna, especially among medium-sized (0.45–5kg) ground-dwelling and semi-arboreal mammals, ground-nesting birds and freshwater turtles (Dickman 1996a). Recent experimental studies have shown that foxes continue to suppress many similar species. In contrast, foxes may have beneficial impacts on native species through the suppression of rabbits (Newsome et al 1989, Banks et al 1998) and feral cats (Risbey et al 1999).

A total of 111 threatened species in New South Wales were identified as at risk from foxes, more than for any other alien pest except feral cats (Table 6.3). Again, the large majority of these species are birds, mammals or reptiles, although some amphibians and ecological communities are also at risk. All of the species threatened by foxes were deemed to be at risk as a result of predation, although quolls are also threatened by direct competition from foxes (for the full list of threatened species at risk, see Appendix 3).

Within mammals, foxes were identified most frequently as a threat to medium-sized (0.45–5kg) species (82%; Table 6.4), consistent with the historical and experimental evidence that foxes have had greater impacts on these species. Again, however, the distribution of species at risk between size classes was not significantly different from random (χ^2=2.9, df=2, p>0.05).

Wild dogs

Dingos (*Canis lupus dingo*) were introduced into Australia approximately 3,700 years ago (Corbett 1995), where they probably caused the extinctions of Tasmanian devils and the thylacine on the mainland (Dickman 1996a). Domestic dogs (*Canis lupus familiaris*) were introduced by European settlers in 1788, with wild populations establishing through the accidental and deliberate release of animals (Fleming et al 2001). The two subspecies have hybridised in many areas where they overlap, such that pure dingos are now restricted largely to remote parts of the mainland and Fraser Island (NPWS 2003a). Predation by wild dogs appears to impact mostly on large mammals such as kangaroos and wallabies, and large birds including emus (Dickman 1996a). Wild dogs also prey on livestock and

significant impacts on lambing productivity have been reported (Fleming et al 2001). Wild dogs (including dingos) are thus listed as a pest species under the NSW *Rural Lands Protection Act 1998*, and as such they are subject to intensive control over large parts of New South Wales. As a result, populations are restricted largely to forested areas of the Great Divide and to the far northwest of the state (West and Saunders 2003). Wild dogs have the potential to benefit biodiversity through the suppression of native and exotic herbivores in fragile semi-arid and arid rangelands (Caughley et al 1980, Pople et al 2000), thereby reducing the impacts of overgrazing (Ludwig et al 1997).

Predation by wild dogs was identified as a threat to 36 species listed as threatened in New South Wales (Table 6.3). Most of the species at risk are mammals or ground-nesting birds (for the full list of threatened species at risk, see Appendix 3). Within mammals, wild dogs were identified most frequently as a threat to large (>5kg) species (40%; Table 6.4), consistent with the historical and experimental evidence for greater impacts on these species. Again, however, the distribution of species at risk between size classes was not significantly different from random (χ^2=2.4, df=2, p>0.05).

Rodents

Black rats, brown rats and house mice probably arrived in Australia in the late 1700's aboard the ships of the first European settlers (Strahan 1995). Black rats and brown rats remain restricted largely to urban areas (Watts 1995, Caughley et al 1998). In contrast, house mice are widespread and are often abundant in agricultural areas. Black rats were introduced into Lord Howe Island in 1918, where they have been implicated in the decline or extinction of endemic birds (eg Lord Howe Island placostylus *Placostylus bivaricosus*, and robust silvereye *Zosterops lateralis tephropleura*), reptiles (eg Lord Howe Island gecko *Christinus guentheri*) and invertebrates.

Predation by black rats was identified as a threat to five threatened species in New South Wales, while predation by brown rats was identified as a threat to three threatened species. Predation by 'rats' or 'rodents' was identified as a threat to a further 11 species. Competition, especially between house mice and native mice, and secondary poisoning of native predators during the control of introduced rodents threatens a further 11 native animals, while grazing by rats has been identified as a threat to one listed plant species. For the full list of threatened species at risk, see Appendix 3.

Feral pigs

Pigs were introduced into Australia by European settlers as domestic stock, although they may have also been introduced into northern Australia from Timor and New Guinea (Choquenot et al 1996, Pavlov 2000). Feral pigs are found across most of the Australian mainland, with the highest densities in New South Wales, Queensland and northern Australia including the Kimberley region (NSW SC 2004c). They occur across about 60% of New South Wales and the Australian Capital Territory (West and Saunders 2003). Pigs are omnivorous, preying on mammals, small ground-nesting birds and their eggs, lizards, turtles and their eggs, and frogs. Feral pigs have been implicated as a major cause of declines in some populations of ground-nesting birds (NSW SC 2004c). However, relative to the main alien carnivores, there is little information on the impacts of predation by feral pigs on native fauna.

Feral pigs were identified as a threat to 81 threatened species in New South Wales, although only 10 of these species were identified as threatened through predation (Table 6.3). Species identified include large forest frogs, marine turtles and ground-nesting birds (for the full list of threatened species at risk, see Appendix 3).

Cane toads

Cane toads were introduced into Queensland in 1935 in an attempt to control cane beetles (NSW SC 2006). They have spread across much of northern Australia, having established recently in Western Australia. They have spread south down the eastern seaboard as far as Port Macquarie in New South Wales (Taylor and Edwards 2005), although occasional sightings have been made in the Sydney region. It is likely that cane toads have yet to reach their full range in Australia.

Impacts from cane toads on biodiversity may be wrought through two processes. Firstly, they prey on small mammals, invertebrates and native amphibians. Secondly, the toxins in their skin can kill native species that prey on them (referred to here as ingestion of alien species, Catling et al 1999). These toxins are present in the egg, tadpole and adult stages (Taylor and Edwards 2005), thereby posing a threat to predators of each stage of the toad's lifecycle.

Cane toads were identified as a threat to six listed species through predation (Table 6.3), including amphibians, a mammal and an ecological community. A further three species are threatened through ingestion of toxins, namely the spotted tailed quoll, Stephen's python and the pale-headed snake (for the full list of threatened species at risk, see Appendix 3).

Alien birds

There are 20 species of alien birds in New South Wales. However, only two of these species and a translocated native bird have been identified as a threat to listed biodiversity, and only on Lord Howe Island. Collectively, these three alien birds threaten four listed species, all via predation. The blackbird and song thrush threaten the same two native species, while the Australian masked owl, translocated from the mainland in an attempt to control black rats, threatens the endemic Lord Howe Island woodhen and white tern. It has also been implicated in the extinction of the Lord Howe Island sub-species of the Southern Boobook.

That only three alien bird species were identified as threatening biodiversity, none of which occur on the mainland, is surprising given that many alien birds have expanded their distributions significantly in recent years (eg Indian mynas; Tidemann 2006).

Other alien predators

'Unspecified alien predators' (ie the threat was described as introduced predators) were identified as a threat to 7% of the species threatened by alien predators (for the full list of threatened species at risk, see Appendix 3).

6.3 The distribution of biodiversity threatened by alien predators

The distributions of species threatened by each of the three main predators, feral cats, red foxes and wild dogs, were examined. In particular, the number and proportion of threatened terrestrial vertebrate species that were identified as at risk from each of these predators were calculated for each of the 13 natural resource management (NRM) regions, as described in Section 3.4. These data show that the species at risk occur across all management regions (Table 6.5). The proportion of threatened vertebrates identified as at risk from feral cats was highest in the Western CMA region (51%) and lowest in the Murray CMA (35%). The proportion of threatened vertebrates identified as at risk from red foxes was highest in the Western CMA (53%) and lowest in the Murray CMA (33%). The proportion of threatened vertebrates identified as at risk from wild dogs was highest in Southern Rivers CMA (24%) and lowest in Lower Murray-Darling and Namoi CMAS (11%).

Similar comparisons between the three geographic zones (Table 6.6) revealed that the proportion of threatened vertebrate species identified at risk from cats was higher in the western zone (48%) compared to the other zones, although the distribution between zones was not significantly different from random (χ^2=1.8, df=2, p>0.05). Similarly, the proportion of threatened vertebrate species identified at risk from red foxes was higher in the western zone (51%) compared to the other zones, although the distribution between zones was not significantly different from random (χ^2=4.5, df=2, p>0.05). This is not unexpected because extinctions and declines of native vertebrates have been more pronounced in the arid and semi-arid rangelands of Australia and predation by feral cats and red foxes has been identified as a significant factor in these declines (Burbidge and McKenzie 1989, Morton 1990, Smith and Quin 1996). The proportion of threatened vertebrate species identified at risk from wild dogs was higher in the coastal zone (16%) compared to the other zones, although the distribution between zones was not significantly different from random (χ^2=2.6, df=2, p>0.05).

These simplistic analyses do not consider variation in the threat posed by feral cats, red foxes and wild dogs across the distribution of native species identified as at risk. Clearly, variation in predator densities must also be considered. This is most obvious for wild dogs, which are largely absent from the central zone (West and Saunders 2003), yet 11 species identified as at risk from wild dogs persist there. Similarly, red fox predation has been identified as a critical factor limiting the recovery of the brush-tailed rock wallaby (Lunney et al 1995). In New South Wales, this species has declined to near extinction through the southern half of its range where foxes are common, and remains abundant in the northeast of the state where foxes are rare (Short and Milkovits 1990). Other factors, such as habitat fragmentation, may also significantly modify the impacts of these predators (Dickman 1996a).

Planning for the control of alien predators must therefore consider not only what native species are likely to be impacted by predation, but also the site-specific probability of impact (Mahon 2000). This approach underpins the prioritisation of fox control for biodiversity conservation articulated in the NSW Fox Threat Abatement Plan (NPWS 2001).

Table 6.5 The number and proportion of threatened species within the 13 natural resource management regions at risk from alien predators

Natural resource management regions of NSW [a]	Threatened terrestrial vertebrate species present [b]	Number of species threatened by [b, c]					
		Feral cats		Red foxes		Wild dogs	
		n	%	n	%	n	%
Northern Rivers CMA	124	46	37	45	36	17	14
Hunter Central Rivers CMA	98	41	42	36	37	15	15
Hawkesbury–Nepean CMA	84	37	44	28	33	16	19
Sydney Metropolitan CMA	64	31	48	23	36	13	20
Southern Rivers CMA	88	44	50	36	41	21	24
Border Rivers–Gwydir CMA	67	25	37	26	39	8	12
Namoi CMA	63	24	38	25	40	7	11
Central West CMA	64	24	38	24	38	8	13
Lachlan CMA	66	26	39	26	39	8	12
Murrumbidgee CMA	74	30	41	29	39	10	14
Murray CMA	60	21	35	20	33	8	13
Western CMA	70	36	51	37	53	9	13
Lower Murray–Darling CMA	56	23	41	26	46	6	11
Total [d]	**215**	**100**	**47**	**98**	**46**	**31**	**14**

[a] CMA = Catchment Management Authority.

[b] Threatened species refers to all terrestrial vertebrates listed on Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* as at 1 January 2006. Species from Lord Howe Island and species whose distributions were unclear are excluded. Hence totals differ from earlier tables.

[c] Percentages are of the number of threatened animals present.

[d] Values are not cumulative as many threatened species occur in more than one natural resource management region.

Table 6.6 Number and proportion of threatened species within the three geographical zones at risk from alien predators

Geographic zones in New South Wales [a]	Threatened terrestrial vertebrate species present [b]	Number of threatened terrestrial vertebrate species threatened by [b, c]					
		Feral cats		Red foxes		Wild dogs	
		n	%	n	%	n	%
Coastal	151	60	40	56	37	24	16
Central	116	46	40	49	42	11	9
Western	88	42	48	45	51	10	11
State wide [d]	**215**	**100**	**47**	**98**	**46**	**31**	**14**

[a] Geographic zones comprising groups of natural resource management regions in New South Wales (see Chapter 3 for further details).

[b] Threatened species refers to all terrestrial vertebrates listed on Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* as at 1 January 2006. Species from Lord Howe Island and species whose distributions were unclear were excluded. Hence totals differ from earlier tables.

[c] Percentages are of the total number of threatened terrestrial vertebrates in each zone.

[d] State-wide values are not cumulative as a native species may occur in more than one zone.

7. Alien herbivores

The threat of pest animals, as a collective, on threatened biodiversity in New South Wales has been quantified in terms of the number of species, populations and ecological communities threatened, and the actions by which pest animals pose the threat (Chapter 5). Alien herbivores were identified as one of the three main groups of pest animals posing a threat. This chapter identifies the alien pest herbivores threatening biodiversity, the threatening actions of each and the number and type of species threatened. Finally, the spatial distribution of native species is compared with the distribution and abundance of the major alien pest herbivores threatening them. The threats posed by domesticated alien herbivores (eg farmed livestock) are excluded here, except in terms of total grazing pressure (ie where the combined effects of all alien herbivores are examined).

7.1 The threat posed by alien pest herbivores

Since the European settlement of Australia, approximately 68 alien herbivore species have been introduced (VPC 2006), and at least 16 have established wild populations (Bomford 2003). The liberation of many of these alien herbivores in Australia has been attributable to acclimatisation societies (Bentley 1998), escapes from farmed livestock (Williams et al 1995, Choquenot et al 1996), translocation for hunting (Low 1999) and emergency food supplies (Rolls 1969). The establishment of wild populations of alien herbivores has contributed to the decline of many native species, through:

- grazing/browsing palatable native plant species (Braysher 1993)
- competing with native herbivores for resources (Dawson and Ellis 1979)
- degrading habitats, via compaction, facilitation of erosion, spread of weeds and wallowing (Hone 2002), and
- spreading diseases (DEH 2003).

Threat to biodiversity

Collectively, herbivory by pest animals poses a threat to 243 threatened species, or 25% of all threatened species in New South Wales (Table 7.1). The majority of species threatened by alien herbivores are native plants. However, the risk to threatened native animals is also high, with 62 species being threatened by alien herbivores (Table 7.1). When expressed as a proportion of the total threatened species examined, the values for plant species, animal species, and animal populations are similar. While proportionally endangered ecological communities are under the greatest threat (35%), threatened plant populations are the least affected (Table 7.1). Over half of these threatened species are listed as endangered plants and animals (129 of 243), and a third are listed as vulnerable plants and animals (80 of 243; see Table 7.1).

Threat to native plant and animal species

Threatened plant species

Of the 5248 species of native terrestrial vascular plants recorded in New South Wales, 564 (or 11%) are listed as threatened under the NSW *Threatened Species Conservation Act 1995* (TSC Act). Of these threatened plants, approximately a quarter are threatened by alien pest herbivores (Tables 7.1 and 7.2). Although the majority of threatened plant species at risk from alien herbivores are dicotyledons, (80% or 117 of 147), proportionally, monocotyledons are more threatened by alien herbivores than any other plant group, with one third of threatened monocotyledons being at risk (Table 7.2).

Threatened animal species

Of the 897 native terrestrial vertebrate species recorded in New South Wales, 240 (or 30%) are listed as threatened under the TSC Act. As with threatened plants, about a quarter of the vertebrates are threatened by alien pest herbivores (Tables 7.1 and 7.2). The threat posed by alien herbivores to specific animal groups is greatest for native birds, affecting 37% (23 of 62) of all threatened animals at risk from alien herbivores (Table 7.2). Most of the bird species threatened by alien herbivores are ground-dwelling or ground-nesting species (see Appendix 3). Reptiles are also significantly affected, with almost half of the threatened reptiles in New South Wales being at risk from alien herbivores (Table 7.2).

Table 7.1 The threatened status of species threatened by alien pest herbivores

Threatened species [a]	Number of threatened species [a]	Number threatened by pest alien herbivores [b]			Percentage (%) threatened by alien pest herbivores
		Endangered	Vulnerable	Total	
Plant species (incl. fungi, algae and aquatics)	578	88	59	147	26
Animal species (incl. invertebrates, fish and marine mammals)	276	41	21	62	22
Plant populations	18	2	na	2	11
Animal populations	19	4	na	4	21
Ecological communities	81	28	0	28	35
Total	**972**	**163**	**80**	**243**	**25**

na: Threatened populations are currently not able to be listed as vulnerable.

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] The definition of 'endangered', and 'vulnerable' is given in the TSC Act (see PCO 2003), based on definitions in the IUCN Red List of threatened species (IUCN 2004).

Table 7.2 Threat posed by alien pest herbivores to individual groups of threatened plants and animals in New South Wales

Threatened species [a]	Taxonomic grouping [b]	Number of native species present in NSW [c]	Number of threatened species [a]	Number of species threatened by alien pest herbivores	
				n	% [d]
Plant species	Algae	na	1	0	0
	Aquatic plants	na	4	0	0
	Dicotyledons	3742	458	117	26
	Fern or allies	177	16	1	6
	Fungi	na	9	0	0
	Gymnosperms	27	6	1	17
	Monocotyledons	1302	84	28	33
	Total	**5248** [e]	**578**	**147**	**26**
Animal species	Amphibians	72	27	3	11
	Birds	472	114	23	20
	Fish	na	12	0	0
	Invertebrates	na	17	1	6
	Mammals	147	57	15	26
	Marine mammals	37	7	0	0
	Reptiles	208	42	20	48
	Total	**899** [e]	**276**	**62**	**22**
Total		**6147** [e]	**854**	**209**	**24**

na: Total number of native species in New South Wales is not known.

[a] Threatened species refers to plant and animal species listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] Information on non-vascular plants (mosses, lichen and liverworts) are not presented, as none are listed as threatened.

[c] The total number of native species in New South Wales was derived from several sources for example BGT (2005) and DEC (2005) — see Chapter 3 for further details.

[d] Percentages are of the number of threatened species.

[e] Values exclude fungi, algae, aquatic plants, fish, invertebrates and marine mammals, because the exact number could not be determined.

Actions through which alien herbivores threaten biodiversity

The action by which a particular alien herbivore poses a threat to biodiversity was identified in the second level of the threat hierarchy (see Chapter 3 and Appendix 2). Four main threatening actions were identified in the threat hierarchy for alien herbivores:

(i) grazing/browsing

(ii) degradation of habitat

(iii) competition

(iv) inadvertent impacts from alien herbivore control.

Omnivorous species (eg feral pigs) also pose a threat through predation; the species at risk from predation are discussed in Chapter 6.

Of the actions listed above, grazing/browsing and habitat degradation are the main actions by which alien herbivores were reported to pose a threat to biodiversity in New South Wales (Table 7.3). Competition and control impacts combined pose a threat to less than one tenth of threatened species at risk from alien herbivores. While the impacts of grazing/browsing and habitat degradation are inter-linked, they will be treated separately in this chapter, as the data is not robust enough to explore such links with confidence.

Table 7.3 The actions by which alien pest herbivores pose a threat to biodiversity within New South Wales

Threatened species [a]	Number at risk from alien pest herbivores through [b]				Total number at risk from alien pest herbivores [c]
	Grazing/ browsing	Degradation of habitat	Competition	Control	
Plant species	111	85	0	0	147
Animal species	16	39	13	2	62
Plant populations	1	0	0	0	2 [d]
Animal populations	1	1	2	0	4
Ecological communities	17	18	2	0	28
Total	**146**	**143**	**17**	**2**	**243**

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] Threat actions are derived from the second level of the threat hierarchy (see Chapter 3 for further details).

[c] Values are not cumulative as each threatened species may be threatened by more than one action.

[d] An additional plant population is threatened by goats, but the threat action was not identified.

7.2 Impacts of grazing and habitat degradation on threatened biodiversity

Overview of grazing/browsing impacts

Excessive grazing/browsing pressure by herbivores (native or alien) can result in a significant decrease in vegetation cover. Such reductions in cover are typically episodic, with plants recovering between grazing events. When excessive grazing pressure is maintained, however, plant mortality is inevitable. Broad-scale plant mortality due to over-grazing can result in desiccation of soils and erosion (both by wind and water), the effects of which are exacerbated during times of drought. Excessive grazing/browsing pressure can also lead to major declines in palatable plant species through the selective removal of adult plants and seedlings. This selective removal potentially promotes the growth of unpalatable species and reduces the carrying capacity of the land (Moore 1969, Harrington et al 1979, Harrington et al 1984).

Over-grazing/browsing often occurs around permanent water sources. Most herbivores need to drink on a regular basis, so watering points receive a greater concentration of herbivore activity. The introduction of artificial permanent water sources in Australia, as elsewhere, has lead to significant changes in grazing/browsing patterns, as areas once subjected to light or sporadic grazing pressure now experience higher levels (ie in the semi-arid regions of New South Wales; Parkes et al 1996). However, recent surveys have revealed that the area between watering points may experience higher grazing/browsing pressure than that around such watering points (see Gaylard et al 2003).

Grazing/browsing impacts may be the result of native herbivores (eg kangaroos, wallabies), domesticated herbivores (eg farmed livestock) and/or alien herbivores that have established wild populations (eg feral goats, rabbits, feral pigs, deer and feral horses). Thus, alien herbivore impacts are contrasted here with other groups of herbivores that exist in the Australian landscape, and combined to illustrate the collective effect of grazing/browsing pressure.

Threat of grazing/browsing on biodiversity

Grazing/browsing pressure threatens approximately a third of all threatened species in New South Wales: 148 of these species are at risk from alien pest herbivores, compared with 222 from domesticated alien herbivores and 30 from native herbivores. When combined, these three sources of grazing/browsing impact on 305 threatened species, populations and ecological communities (Table 7.4).

Overview of the impacts from herbivore-related habitat degradation

Many of the alien herbivores in Australia are hard-hoofed ungulates (eg goats, deer and horses). Ungulates are a class of animals that did not occur in Australia prior to European settlement. In addition to grazing/browsing pressure, significant environmental impacts (eg to soil profiles and structure) have been attributed to these animals, as no native species have hard hooves. The degradation of soils by these hard-hoofed herbivores has been exacerbated by their high densities, excessive grazing/browsing of vegetative cover, and habit of using regular pathways. The creation of permanent water sources has also exacerbated the impacts, enabling alien herbivores to persist in areas that would otherwise be uninhabitable.

Threat of herbivore-related habitat degradation on biodiversity

Habitat degradation relating to total grazing pressure from alien pest, native and domesticated alien herbivores threatens approximately 30% of threatened species in New South Wales. Individually, domesticated alien herbivores were identified as posing the greatest threat, followed closely by alien pest herbivores, while native herbivores impact very few threatened species (Table 7.4).

Table 7.4 The threat from different herbivore groups on threatened species in New South Wales

Herbivore group	Number of threatened species at risk from [d, e]		Total number at risk [f]	
	Grazing/browsing	Habitat degradation	n	% [g]
Alien pest [a]	146	143	226	23
Domesticated [b]	222	194	337	35
Native [c]	30	3	32	3
Total [f]	**305**	**278**	**435**	**45**

[a] Alien pest herbivores include naturalised animals such as goats, rabbits, horses, pigs and deer.

[b] Domesticated herbivores include farmed livestock such as sheep and cattle.

[c] Native herbivores include species native to New South Wales such as kangaroos and wallabies.

[d] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[e] Excluding the threat from competition and the adverse impacts of controlling herbivores, as these threats were only recorded for alien herbivores in the data set – these threats accounted for 17 threatened species (see Table 7.3).

[f] Values are not cumulative, as threatened species may be threatened by more than one category of herbivore or threat action.

[g] Percentages of the 972 threatened species in New South Wales.

Combined threat of grazing/browsing and habitat degradation

The effects of grazing/browsing by alien pest herbivores and associated habitat degradation pose a direct threat to almost a quarter of all threatened species in New South Wales (Table 7.4). The number of threatened species affected by alien herbivores accounts for just over half of the species affected by grazing/browsing and associated habitat degradation, when all herbivores are considered. Almost half of the threatened species in New South Wales are at risk of extinction, because of grazing/browsing and habitat degradation caused by total herbivore pressure (Table 7.4). Grazing and habitat degradation caused by native herbivores threatens 32 listed species, but alien herbivores threaten seven times as many species, and domesticated herbivores threaten ten times as many.

7.3 The alien pest herbivores threatening biodiversity

Overview of the threat

Of the pest animal species posing a threat to biodiversity in New South Wales, alien herbivores account for almost a quarter of the species identified (ie 7 of 29 pest animal species). These seven alien herbivores collectively threaten 63% of the threatened species at risk from pest animals in New South Wales. However, these values could be much higher, since they do not comprise alien species described generically, for example, 'deer' (for which there are six species naturalised in New South Wales), 'unspecified alien herbivores', or other generic threats or the species at risk (see Appendix 3).

The main alien pest herbivore species posing a threat to biodiversity in New South Wales are feral goats (*Capra hircus*), feral rabbits (*Oryctolagus cuniculus*), feral pigs (*Sus scrofa*), feral deer (generically) and feral horses (*Equus caballus*). These five alien herbivores collectively threaten 194 terrestrial vascular plants and vertebrate animals. In addition, several other alien herbivore species were identified as posing a threat to biodiversity, being the buff banded rail (*Gallirallus philippensis*), a freshwater snail *Physa acuta* and bag-shelter moth (*Ochrogaster lunifer*), as well as generic listings for snails and slugs. However, as these herbivores pose a risk to fewer than two threatened species each, they are not discussed further, but are presented in Appendix 3.

Threats attributed to 'unspecified alien herbivores' (ie the threat was described as introduced herbivores) affect 13% of the species threatened by alien herbivores. Given the number of these unspecified threats, and generic pest animal threats, ranking these alien species based on their potential threat to threatened species is not advised, as these unspecified values could alter such a ranking. Instead, alien herbivores are described in terms of how often they were identified as a threat. Feral goats are the most recorded alien pest herbivore threat, followed by rabbits and feral pigs (Table 7.5). Feral goats are also the third most recorded pest animal species overall. A short discussion on the threat posed by each of the main alien pest herbivores to biodiversity is presented below.

Feral goats

Goats are a hard-hoofed ungulate that were introduced into Australia with the first European settlers for milk and meat (Rolls 1969). The first recorded release of goats into the wild was during the 1800s. This was a deliberate attempt by mariners to establish an emergency food source on islands and the mainland (Parkes et al 1996). On the mainland, these attempts to establish wild populations were largely unsuccessful, with escapes from domesticated stock being considered as the most likely source of today's feral goat populations (Parkes et al 1996). The persistence of wild populations was facilitated by: (i) their adaptability to rugged terrain, (ii) their ability to survive on fibrous vegetation low in

nutrients (Doyle et al 1984), (iii) the farming of wild populations, and (iv) limited effort of eradication. Other factors that have allowed goats to establish extensive wild populations are, the establishment of artificial water sources, especially in western New South Wales, and the removal of predators such as wild dogs (Parkes et al 1996).

Feral goats were identified here as posing a threat to 94 threatened species in New South Wales, or 39% of the threatened species at risk from alien herbivore pests (Table 7.5 and Appendix 3 for the list of species at risk). The impact of feral goats on native species and ecosystems can be attributed to: (i) the large and diverse number of plant species palatable to goats, (ii) excessive grazing/browsing pressure associated with a high density of goats (Bayne et al 2004), (iii) disturbance and compaction of soils as a result of their hard hoofs, and (iv) concentrated activity around watering points. These processes were grouped into three categories in the threat hierarchy, being: grazing/browsing, habitat degradation and competition. Grazing/browsing and habitat degradation are the most threatening activities by which feral goats pose a threat (Table 7.5). Feral goats were identified as a threat to more threatened species as a result of grazing/browsing than any other alien pest herbivore (Table 7.5).

Table 7.5 The main actions by which alien pest herbivores threaten species in New South Wales

Alien herbivores	Number of threatened species at risk from alien pest herbivores due to [a, b]				Total number of threatened species at risk from alien pest herbivore [a, c]
	Grazing/ browsing	Degradation of habitat	Competition	Control	
Feral goat	59	56	4	0	94
Rabbit	53	24	10	2	86
Feral pig	23	58	3	0	81 [d]
Deer	15	8	0	0	19
Feral horse	8	10	0	0	15
Other [e]	2	0	3	0	5
Unspecified [f]	15	18	2	0	31
Total [c]	**146**	**143**	**17**	**2**	**243**

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] Threat actions as identified from the second level of the threat hierarchy (see Chapter 3 for further details).

[c] Values are not cumulative, as many species are threatened by more than one action, and alien herbivore.

[d] Feral pigs also threaten 10 species through predation (see Chapter 6 for further details).

[e] 'Other' herbivores include the buff banded rail, a freshwater snail and bag-shelter moth, as well as generic listings for snails and slugs (see Appendix 3).

[f] 'Unspecified' alien herbivores encompasses the generic threat descriptions (eg grazing by feral herbivores: see text for further details).

Feral rabbits

The rabbit is a burrowing mammal that was introduced to Australia by the first fleet. The first wild populations were not reported, however, until 1827, and these were observed in Tasmania. On the mainland, wild populations of rabbits were not observed until 1859, following repeated attempts by the Victorian Acclimatisation Society to establish them in the wild (Williams et al 1995). The naturalisation of rabbits in Australia was aided by: (i) their high fecundity, (ii) destruction of native predators, (iii) the presence of burrows created by native species, and (iv) habitats modified for farming (Williams et al 1995).

The rate of spread of rabbits in Australia was the fastest of any alien mammal colonisation anywhere in the world. Rabbits took just 50 years to spread over the majority of the Australian mainland (Williams et al 1995). With the exception of north of the Tropic of Capricorn; rabbits still occur throughout most of Australia.

Historically, the extent of the impact of feral rabbits was due to their extremely high abundance in the early 1900s. However, in 1950 the biological control agent myxomatosis was introduced, and resulted in reductions in rabbit numbers of up to 95% (Myers 1962). Since then, rabbit numbers gradually increased until a second biological agent, rabbit haemorrhagic disease virus (RHDV), was accidentally released in 1995, prior to an official release. Rabbit densities have been reduced between 43% and 94% following the release of RHDV (Story et al 2004). Even at their current densities, grazing/browsing by feral rabbits in combination with other alien herbivores severely limit the recruitment of many native plant species (Denham and Auld 2004). In addition, over-grazing/browsing by feral rabbits leaves soil denuded of vegetation, facilitating erosion (Ludwig et al 1997).

Feral rabbits were identified here as posing a threat to 86 threatened species in New South Wales, or 36% of the threatened species at risk from alien herbivores (Table 7.5 and Appendix 3 for the list of species at risk). The impact of feral rabbits on native species and ecosystems can be attributed to: (i) excessive grazing/browsing pressure associated with a high density of rabbits, (ii) competition with native species for food, and (iii) disturbance of soils as a result of digging burrows. These processes were grouped into three categories in the threat hierarchy, being: grazing/browsing, habitat degradation and competition. Grazing/browsing is the action by which rabbits pose the greatest threat, followed by habitat degradation (Table 7.5). The action of rabbits competing with threatened species was higher than competition by any other alien herbivores (Table 7.5).

Feral pigs

The pig is an omnivorous mammal that was first introduced into Australia with the first fleet (Rolls 1969). Pigs were first recorded as a nuisance around the settlement of Sydney Cove in 1795, although this population was not considered to be truly wild. Exactly when the first wild population established is not known, but is believed to be around the 1850s. Similarly, the source of escape and rate of spread of feral pigs in Australia is unclear. However, escapes of domesticated stock are likely to have contributed significantly to the establishment of wild pig populations (Pullar 1953).

Feral pigs are now widely distributed across New South Wales, Queensland and the Northern Territory (Choquenot et al 1996), and while they can persist in a wide range of habitats, they prefer swamps, wet sclerophyll forests and forested gullies (NSW SC 2004c). Pigs are able to reproduce rapidly, which allows them to increase their abundance and distribution under favourable environmental conditions.

Historically, feral pig impacts on biodiversity have not been well understood (McLeod 2004). Pigs are omnivorous, and while they prey on native animals and graze/browse on native plants, the majority of their impacts are through rooting and wallowing. These two actions are collectively encompassed under the term 'habitat degradation' used here. Their rooting and wallowing behaviour can promote erosion and reduce water quality (Hone 2002). Such impacts are exacerbated in fragile high-altitude wetlands such as the montane peatlands and swamps.

Feral pigs were identified here as posing a threat to 81 threatened species in New South Wales, or one third of the threatened species at risk from alien herbivores (Table 7.5 and Appendix 3 for the list of species at risk). The impact of feral pigs on native species and ecosystems can be attributed to: (i) predation, (ii) grazing/browsing pressure, (iii) destruction of habitats and water quality through rooting and wallowing, and (iv) competition with native species.

These processes were grouped into four categories in the threat hierarchy, being: grazing/browsing, habitat degradation, competition and predation. Habitat degradation by feral pigs poses the greatest threat, followed by grazing (Table 7.5). Feral pigs were identified as a threat to more threatened species as a result of habitat degradation that any other alien herbivore (Table 7.5).

Feral deer [collectively]

Deer are hard-hoofed ungulates that were first introduced into Australia by acclimatisation societies in the 1800s. An estimated 85% of the present deer population in Australia is descended from these introductions, while the rest are thought to be derived from animals that escaped from deer farms, or were deliberately released for hunting purposes (Moriarty 2004). Deer currently occur in a number of habitats, ranging from arid woodlands to rainforests (Moriarty 2004). Six species of deer have established wild populations in Australia, all of which occur in New South Wales, being:

- chital deer *(Axis axis)*
- fallow deer *(Dama dama)*
- hog deer *(Axis porcinus)*
- red deer *(Cervus elaphus)*
- rusa deer *(Cervus timorensis)*
- sambar deer *(Cervus unicolor)*.

No specific deer species was identified here as posing a threat to biodiversity. However, the generic threat of deer was identified as a threat to 19 threatened species, or 8% of those threatened by alien herbivores in New South Wales (Table 7.5 and Appendix 3 for the list of species at risk). The impact of deer on native species and ecosystems can be attributed to: (i) trampling native vegetation, (ii) grazing/browsing pressure, (iii) destruction of habitats through accelerate erosion, and (iv) dispersal of weed species (NSW SC 2005).

These processes were grouped into two categories in the threat hierarchy, being: grazing/browsing and habitat degradation. Habitat degradation by deer poses a threat to almost double the number of species as grazing/browsing by deer in New South Wales (Table 7.5).

Feral horses

Horses were introduced to Australia in 1788 with Europeans. The first report of wild horses was observed in 1804 (Rolls 1969). Feral herds, however, were not recognised before the 1860's (Dobbie et al 1993). Currently, the main populations of feral horses in New South Wales occur in the Snowy Mountains, the Shoalhaven, Barrington Tops and the far northwest of the state (DPI unpublished data).

Feral horses were identified here as posing a threat to 15 threatened species in New South Wales, or 6% of the threatened species at risk from alien herbivores (Table 7.5). The impact of feral horses on native species and ecosystems can be attributed to: (i) grazing pressure, and (ii) habitat destruction. In the sub-alpine and montane regions of southern New South Wales, feral horses have contributed to soil compaction, a lower abundance of native plants and fewer plant species, as well as a higher diversity of weed species (Drying 1991). These processes were grouped into two categories in the threat hierarchy, being: grazing/browsing and habitat degradation. Habitat degradation by feral horses poses the greater threat in New South Wales (Table 7.5).

7.4 Spatial threat

Spatial threat of herbivores on threatened species

The threat of all herbivores collectively on threatened terrestrial animal and plant species increases from coastal to arid New South Wales, in terms of the *proportion* of threatened species at risk (Table 7.6). However, the reverse situation occurs when the *numbers* of threatened species at risk are examined (Table 7.6). That is, a higher proportion of the threatened terrestrial species in the western zone are at risk from herbivores than in the coastal zone, but a higher total number of species is threatened in the coastal zone (Table 7.6).

Spatial patterning of alien herbivores

The threat posed by alien herbivores decreases from east to west New South Wales, in terms of the number of threatened species at risk, but as a proportion of the threatened species present, the threat increases (Table 7.7). The threat from feral goats and rabbits increases from east to west New South Wales, both in terms of the percentage and the number of threatened species at risk (Table 7.7). Of all alien herbivores examined, feral pigs pose the greatest threat to threatened species in the coastal zone.

Table 7.6 The spatial threat of all herbivores (alien, domesticated and native) on terrestrial threatened species in New South Wales

Geographic zones in NSW [a]	Number of threatened species present [b]	Threatened species at risk from herbivores [b, c]	
		n	%
Coastal	588	217	37
Central	275	164	60
Western	155	121	78
State wide [d]	**809**	**368**	**45**

[a] Geographic zones are based on a collective of the natural resource management regions (see Chapter 3 for further details).

[b] Threatened species refers only to terrestrial vascular plant and terrestrial vertebrate animals listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* as at 1 January 2006. This excludes invertebrates, fish, marine mammals, fungi, aquatic plants and algae, as the number and distribution of these groups were not known. Species from Lord Howe Island and species whose distributions were unclear were excluded. Hence totals differ from earlier tables.

[c] 'Herbivores' refers to the combined threat posed by all herbivores (eg alien, domesticated and native herbivores) through all threat actions. Percentages are of total threatened species present.

[d] Values are not cumulative, as many threatened species occur in more than one geographic zone.

To help illustrate the spatial threat of alien herbivores, distribution maps are presented below for the main species. It should be noted that these distribution maps are derived from perceptions of the species density, collected from survey data, rather than actual densities of animals per unit area. The distribution patterns of specific alien herbivores are compared with the threatened species at risk in each natural resource management (NRM) region.

Table 7.7 The spatial threat of alien herbivores on terrestrial threatened species in New South Wales

Geographic zones in NSW [a]	Number of threatened species present [b]	Number of threatened species threatened by feral [b, c]										Total threatened species at risk from alien pest herbivores [b, c, d]	
		Goats		Rabbits		Pigs		Deer [e]		Horses			
		n	%	n	%	n	%	n	%	n	%	n	%
Coastal	588	31	5	27	5	41	7	12	2	9	2	106	18
Central	275	38	14	41	15	28	10	1	<1	9	3	88	32
Western	155	41	26	46	30	11	7	0	0	1	1	65	42
State wide [d]	**809**	**85**	**11**	**78**	**10**	**58**	**7**	**12**	**1**	**12**	**1**	**194**	**24**

[a] Geographic zones are based on a collective of the natural resource management regions (see Chapter 3 for further details).

[b] Threatened species refers only to terrestrial vascular plant and terrestrial vertebrate animals listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* as at 1 January 2006. This excludes invertebrates, fish, marine mammals, fungi, aquatic plants and algae, as the number and distribution of these groups were not known. Species from Lord Howe Island and species whose distributions were unclear were excluded. Hence totals differ from earlier tables.

[c] Percentages of the number of terrestrial threatened species present in each zone.

[d] Values are not cumulative, as many species are threatened by more than one alien herbivore, and occur in more than one geographic zone.

[e] Deer refers to the collective threat from deer *per se* rather than from any one of the six specific species of deer present.

Feral goats

Feral goats are distributed across all of New South Wales. The highest abundance of feral goats is in the rangelands, where water is readily accessible, predators are largely absent and, ironically, goats are also considered an economic resource (Figure 7.1). Where predators occur in higher numbers (ie in eastern part of the state) feral goats tend to be restricted to rugged areas where they are able to escape predation. In the cleared areas of central New South Wales, feral goats tend to be restricted to isolated patches of remnant vegetation.

The spatial threat from feral goats on threatened species in many NRM regions or Catchment Management Authorities (CMAs) aligns with the density data of feral goats in New South Wales, with higher number of species at risk and goat densities in the western part of the state (Table 7.8). In addition, the density of feral goats in the Murray CMA is very low and there were no threatened species at risk (see Table 7.8 and Figure 7.1).

Table 7.8 Number and proportion of threatened species at risk from alien herbivores within each natural resource management region in New South Wales

Natural resource management regions in NSW [a]	Number of threatened species present [b]	Number of threatened species threatened by feral [b, c]									
		Goats		Rabbits		Pigs		Deer [d]		Horses	
		n	%	n	%	n	%	n	%	n	%
Northern Rivers CMA	346	17	5	16	5	23	7	0	0	2	1
Hunter Central Rivers CMA	197	8	4	14	7	16	8	5	3	2	1
Hawkesbury–Nepean CMA	228	10	4	13	6	14	6	10	4	1	1
Sydney Metropolitan CMA	127	8	6	9	7	8	6	10	8	1	1
Southern Rivers CMA	208	15	7	16	8	17	8	9	4	7	3
Border Rivers–Gwydir CMA	128	22	17	16	13	11	9	0	0	1	1
Namoi CMA	89	10	11	14	16	6	7	0	0	0	0
Central West CMA	109	7	6	12	11	5	5	1	1	0	0
Lachlan CMA	101	9	9	20	20	7	7	0	0	1	1
Murrumbidgee CMA	124	8	6	22	18	15	12	1	1	7	6
Murray CMA	93	0	0	15	16	7	8	0	0	6	6
Western CMA	122	33	27	33	27	8	7	0	0	1	1
Lower Murray–Darling CMA	82	14	17	21	26	6	7	0	0	0	0
Total [c]	**809**	**85**	**11**	**78**	**10**	**58**	**7**	**12**	**1**	**12**	**1**

[a] CMA = Catchment Management Authority.

[b] Threatened species refers only to terrestrial vascular plant and vertebrate animal species listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* as at 1 January 2006. This excludes invertebrates, fish, marine mammals, fungi, aquatic plants and algae, as the number and distribution of these groups were not known. Species from Lord Howe Island and species whose distributions were unclear were excluded. Hence totals differ from earlier tables.

[c] Values are not cumulative, as many threatened species occur in more than one natural resource management region and many species are threatened by more than one alien herbivore.

[d] Deer refers to the collective threat from deer *per se* rather than from any one of the six specific species of deer present.

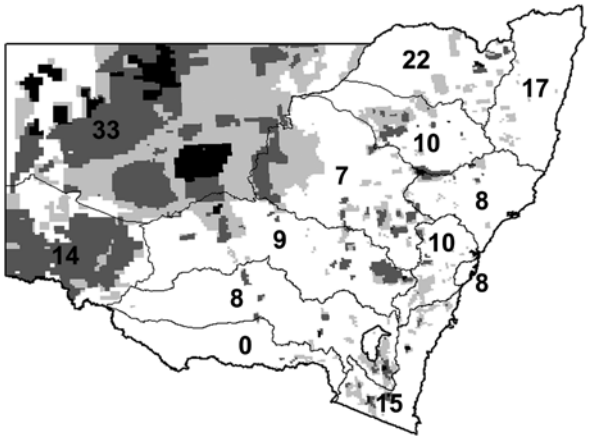

Figure 7.1 Distribution and abundance of feral goats, and proportions of native species threatened by feral goats in New South Wales. Colours indicate goat abundance as: absence (white), low (light grey), medium (mid grey) and high (black). Abundance data was supplied by NSW Department of Primary Industry (unpublished data).

Feral rabbits

Feral rabbits have a relatively uniform abundance across New South Wales, but the threat they pose to threatened species does not appear to be linked with density (Figure 7.2 and Table 7.8). For example, the feral rabbit threat to threatened species increases from the coastal zone to the western zone (Table 7.7). This trend is accentuated when individual NRM regions or CMAs are examined relative to density patterns, with the greatest threat occurring in the Western CMA but the highest densities occuring elsewhere (see Table 7.8 and Figure 7.2).

Feral pigs

Feral pigs are distributed across the whole of New South Wales (Figure 7.3), although on a localised scale their abundance is greatest around watercourses. Unlike feral goats and feral rabbits, feral pigs showed no obvious spatial trend in species they threaten across New South Wales. Proportions of threatened species at risk were similar across all three geographic zones, despite more than three times the number of species at risk in the coastal zone (Table 7.7). The density of feral pigs does not appear to be correlated with the species at risk, with higher pig densities in the western part of the state, but greater species at risk in the eastern part (Table 7.8 and Figure 7.3).

Feral deer

At present, feral deer are mainly restricted to the eastern half of New South Wales, with the majority of the population being found along the coast and Great Dividing Range (Figure 7.4). This is illustrated by all 12 of the threatened terrestrial vascular plant and vertebrate animal species at risk from feral deer occurring in the coastal zone (Table 7.7). At the individual NRM region or CMA level, however, feral deer did not pose a risk to threatened species in all coastal CMAs (ie no species were at risk in the Northern Rivers CMA, Table 7.8). In addition, the number of species threatened did not appear to be related to density (Table 7.8 and Figure 7.4).

Feral horses

Unlike the other major alien herbivores, data on the distribution and abundance of feral horses in New South Wales has not been compiled. However, based on available data, feral horses appear to be distributed across most of the state (albeit in very low numbers), with major populations in the southern alpine plateau country, Barrington Tops region and north-western New South Wales (West and Saunders 2003). Information on the threatened species at risk from feral horses showed that the majority are concentrated in the coastal and central zones of New South Wales (Table 7.7). At the individual NRM region (or CMA), the spatial threat of feral horses is very patchy (see Table 7.8). However, the greatest risk to native species matches the known wild populations (eg in alpine regions, which are encompassed by the Murray, Murrumbidgee and Southern Rivers CMAs).

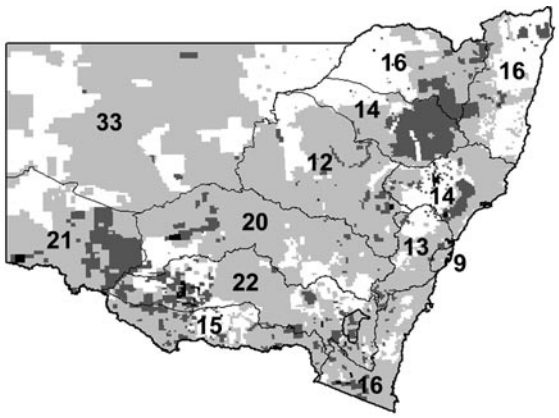

Figure 7.2 Distribution and abundance of feral rabbits, and proportions of native species threatened by feral rabbits in New South Wales. Colours indicate rabbit abundance as: absence (white), low (light grey), medium (mid grey) and high (black). Abundance data was supplied by NSW Department of Primary Industry (unpublished data).

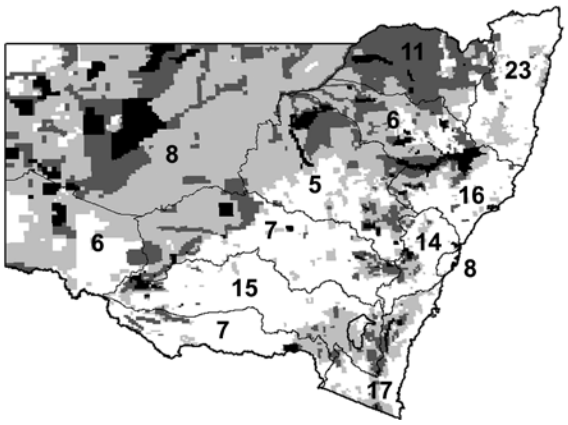

Figure 7.3 Distribution and abundance of feral pigs, and proportions of native species threatened by feral pigs in New South Wales. Colours indicate pig abundance as: absence (white), low (light grey), medium (mid grey) and high (black). Abundance data was supplied by NSW Department of Primary Industry (unpublished data).

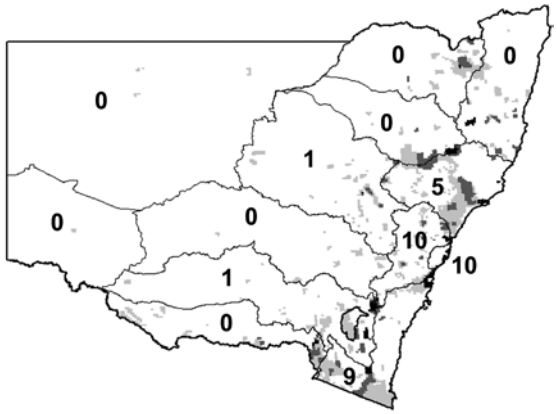

Figure 7.4 Distribution and abundance of feral deer, and proportions of native species threatened by feral deer in New South Wales. Colours indicate deer abundance as: absence (white), low (light grey), medium (mid grey) and high (black). Abundance data was supplied by NSW Department of Primary Industry (unpublished data).

8. Alien fishes

Widespread acknowledgement of the impact that alien fishes are having on Australia's freshwater ecosystems has only been a recent occurrence (Wager and Jackson 1993), despite several previous assessments (eg Fletcher 1986, Arthington 1989). This acknowledgement is, in part, due to observations from major freshwater fish surveys that showed the number of native fish species have significantly declined (eg between Llewellyn (1983) and Faragher and Lintermans (1997)), while the number of naturalisations of alien fishes has increased. For example, the number of alien fish species has increased from 10 to 34 in the past 50 years; a rate of one new species every two years (Lintermans 2004). Interestingly, the number of alien freshwater fish species had remained stable for the 40 year period prior to this point (ie since the 1920s). The majority of alien freshwater fishes in Australia have been deliberately introduced through:

- ornamental trade (eg aquarium trade)
- recreational usage (eg trout fishing)
- aquaculture, and
- biological control (eg to control mosquitoes).

However, at least two freshwater fishes arrived here accidentally through ballast water (Lintermans 2004). Ironically, two alien fishes, Atlantic salmon (*Salmo salar*) and quinnat salmon (*Oncorhynchus tshawytscha*), are known not to breed in Australia; rather their populations are maintained through constant deliberate introductions for recreational fishing purposes only. The majority of recent naturalisation has, however, occurred following the dumping of unwanted aquarium species and escapes from outside dams and ponds (Lintermans 2004). Those fish that have established wild populations threaten many of our native freshwater fish, frogs, aquatic plants, aquatic invertebrates and their respective ecosystems. In addition, at least 53 native fishes have been translocated within Australia to new environments (Lintermans 2004); many of these species are likely to pose a similar threat to biodiversity as the alien species.

Alien fishes were one of the main groups of pest animals that were identified in Chapter 5 as posing a threat to threatened biodiversity in New South Wales. This chapter closely examines the alien fish species threatening biodiversity, the species they threaten and the actions by which they pose the threat.

Terminology

No alien marine organisms were identified in the data set (see Chapter 3 for further details), so only alien freshwater fish species are presented and discussed here. In addition, one translocated native fish species was also identified. Thus, the term 'alien fish' as used here refers to alien freshwater fish and translocated native freshwater fish species only.

8.1 An overview of alien fishes in New South Wales

Surveys and assessments of freshwater fish populations in New South Wales have been undertaken at sporadic intervals (eg Llewellyn 1983, Faragher and Lintermans 1997). These surveys have contributed to our understanding of alien fish populations, species diversity and likely impacts, as well as changes over time. For example, while alien fishes were recorded in low numbers in the earlier survey (ie 1983), they comprised 18% of the fish species caught in the last survey (Faragher and Lintermans 1997). At the same time, there was a decline in the number of native fishes, with 16 of the 55 species predicted to occur in New South Wales being absent; nine more species than were absent in the earlier survey in 1983 (Schiller et al 1997). Not every alien fish species present in New South Wales was recorded in these surveys; in part because these surveys only assessed a sub-set of the rivers. For example, only six of the 11 alien fishes present in New South Wales were recorded in the last major fish survey (see Faragher and Lintermans 1997).

A recent review identified the number of alien fishes that have established in Australia since European settlement. This review found that 18 of the 34 alien fish species occur in New South Wales (Lintermans 2004). The review also identified the 12 pathways by which these alien fishes have invaded and their introduction sources. A further 53 native species, which have been translocated within Australia, were also identified. However, their distribution was not broken down by state or territory.

Table 8.1 The threat from alien fish species, and the action by which they pose the threat to threatened species

Alien fish species	Number of threatened species at risk from alien fishes through [a, b]			Total number of threatened species at risk [a, c]
	Predation	Competition	Disease	
Gambusia holbrookii (gambusia)	15	8	1	19
Perca fluviatalis (redfin perch)	6	7	1	9
Cyprinus carpio (carp)	4	3	0	5
Trout spp. [d]	3	1	0	4
Salmo trutta (brown trout)	2	0	0	2
Onchorhyncus mykiss (rainbow trout)	2	0	0	2
Carrasius auratus (gold fish)	2	2	0	2
Tinca tinca (tench)	1	0	0	1
Misgurnus anguillicaudatus (weatherloach)	1	0	0	1
Unspecified [e]	4	0	0	4
Translocated native fish species				
Amniataba percoides (banded grunter) [f]	1	1	0	1
Total [c]	**22**	**9**	**2**	**26**

[a] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994*, as at 1 January 2006.

[b] Threat actions are derived from the second level of the threat hierarchy (see Chapter 3 for further details).

[c] Values are not cumulative, as each threatened species maybe threatened by more than one action, and many species are threatened by more than one alien fish species.

[d] No specific trout species were reported, rather the threat was described as predation or competition by trout.

[e] 'Unspecified' alien fish encompasses the generic threat descriptions (eg predation by introduced fish: see text for further details).

[f] This species is native to northern Australia only and has been translocated to New South Wales (see Lintermans 2004).

8.2 Alien fishes threatening biodiversity in New South Wales

Number of alien fish threatening biodiversity

Almost half of the 18 alien fish species present in New South Wales (see Lintermans 2004) were identified here as posing a threat to threatened species. In addition to these eight alien fish species, one translocated native species was also identified as posing a threat to threatened species (Table 8.1 and Appendix 3). Other alien fishes may also be posing a threat to threatened species, as four threatened species are threatened by the generic threat of alien fish, or from other poorly articulated threat descriptions which did not describe a specific fish species (eg 'predation by introduced fish' or 'by trout'). The four species threatened by unspecified alien fish are not threatened by any of the nine alien fishes identified here. The remaining ten alien fishes present in New South Wales, but not identified here as posing a threat to threatened species, are presented in Appendix 4 for future reference.

The threat from alien fishes to threatened biodiversity

Collectively, alien fish species pose a threat to 26 threatened species in New South Wales (Table 8.1). While this number only equates to 3% of all threatened species listed in the state, it represents almost three quarters of the number of threatened aquatic organisms. The actions by which alien fishes pose a threat were derived from the second level of the threat hierarchy (see Chapter 3 for further details). Predation was revealed as the main threat action, affecting 85% of the species threatened by alien fishes (Table 8.1). In addition, predation was identified as a threat action for all nine alien fish species, and 17 of the threatened species at risk from predation by alien fishes are not threatened by any other action (Table 8.1). Competition, however, was only identified as a threat to five threatened species. The spread of the epizootic haematopoietic necrosis virus by the alien fish gambusia and redfin perch poses a threat to two species.

The threat of alien fishes to native plants and animals

Of the 26 threatened species identified as being threatened by alien fishes, the majority are animals (Table 8.2). Of the 20 animals at risk, two thirds are frogs and the other third are native freshwater fishes. These proportions are reversed when threatened frog and fish *populations* are examined (Table 8.2). In terms of the proportion of the total threatened species in New South Wales at risk from alien fishes, however, 88% of freshwater fishes are threatened compared to 48% of frog species (Table 8.2). The high number of frog species at risk is also reflected in the breakdown of threat actions, with the majority being threatened by predation, while the majority of native fishes at risk are threatened by competition. Nine of the 13 frog species threatened by alien fishes are all in the genus *Litoria,* highlighting their susceptibility to alien fishes.

No threatened aquatic plants, algae, or aquatic invertebrates were identified as being individually threatened by alien fishes in New South Wales. However, all three of the endangered ecological communities (EECs) identified as threatened by alien fishes contain both aquatic plants and invertebrates as a component of their species lists.

The threatened biodiversity most at risk from alien fishes collectively, is the EEC 'Aquatic ecological community in the natural drainage system of the lower Murray River catchment'. This EEC is threatened by six of the nine alien fish species identified here, plus the generic threat of 'trout'. The next threatened species most at risk is the EEC 'Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River' and the frog *Litoria daviesae*, which are both threatened by four alien fish species.

Table 8.2 Threatened species threatened by alien fish species in New South Wales

Threatened species listed [a]	Taxonomic grouping	Number of species present in NSW [b]	Number listed as threatened [a]	Threatened by alien fishes [c]	
				n	%
Animal species	Frog	74	27	13	48
	Freshwater fish	55	8	7	88
	Total	**129**	**35**	**20**	**57**
Animal populations	Frog	na	1	1	100
	Freshwater fish	na	2	2	100
	Total	**na**	**3**	**3**	**100**
Ecological Communities		na	81	3	4
			Total	**26**	

na: a value was not available, as the total number in New South Wales could not be determined.

[a] Threatened species refers to all biodiversity (ie species, populations and ecological communities) listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the *NSW Fisheries Management Act 1994*, as at 1 January 2006.

[b] The number of native species present in New South Wales was derived from several sources (see Chapter 3 for details).

[c] Percentages are of threatened species in New South Wales.

The introduction source of alien fishes

Of the 18 naturalised alien fish species in New South Wales, eight were introduced through the ornamental fish industry, or aquarium trade. Of these ornamental species, two were identified here as posing a threat to biodiversity (Tables 8.3 and 8.4). The next biggest introduction source of alien fishes was for acclimatisation purposes, accounting for seven species in New South Wales, and eight nationally. Half of these acclimatisation introductions threaten biodiversity (Table 8.3).

Only one of the alien fish species in New South Wales was not deliberately introduced, arriving in ballast water (Table 8.3). A single species (gambusia, *Gambusia holbrookii*) has been introduced nationally for biological control purposes, and it now poses a significant threat to biodiversity (Tables 8.3 and 8.4). However, this result reflects a potential bias in the data set, as gambusia has been the subject of a threat abatement plan (TAP; see NPWS 2003b): thus, its impacts on threatened biodiversity are potentially better understood than any other alien fish species in New South Wales.

The majority of alien fishes posing a threat to biodiversity were introduced in 1850–1900 (Table 8.4). Most of the alien fishes for which no threat to biodiversity was observed here, were introduced after 1960 (Appendix 4), suggesting a possible time lag between introduction and posing a threat to biodiversity. In addition, all alien fishes threatening biodiversity are now widely distributed in Australia (ie occur in more than three other states or territories: Table 8.4), whereas those fishes which were not identified as posing a threat are not widely distributed (Appendix 4).

Table 8.3 The introduction sources of alien fish species in New South Wales and the threat posed to biodiversity

Introduction source	Number of alien fish species in Australia	Number of alien fish species in NSW	Number of alien fish species threatening biodiversity in NSW [a]	Number of threatened species at risk [b]
Acclimatisation	8	7	4	13
Aquaculture	1	1	1	6
Ballast water	2	1	0	0
Biological control	1	1	1	19
Ornamental trade	22	8	2	2
Total	**34**	**18**	**8**	**22** [c]

Source: Lintermans (2004).

[a] Alien fish species as identified in the dataset. Data excludes the translocated Australian native species (eg banded grunter).

[b] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the *NSW Fisheries Management Act 1994*, as at 1 January 2006.

[c] Values are not cumulative, as some threatened species are impacted by more than one alien fish, and data excludes the four species threatened by the generic threat of 'alien fish' or unspecific fish species (see text for further details).

Table 8.4 The introduction source, date, distribution and biodiversity threatened by alien fish species in New South Wales

Alien fish species recorded in NSW [a]	Date first recorded as naturalised in Australia	Other states/ territories present	Introduction source	Total number of threatened species at risk [b]
Carrasius auratus (gold fish)	1876	Vic, Qld, SA, WA, ACT, Tas	Ornamental	2
Cyprinus carpio (carp)	1850–80	Vic, Qld, SA, WA, ACT, Tas	Aquaculture	5
Gambusia holbrookii (gambusia)	1925	Vic, Qld, SA, WA, Act, NT, Tas	Biological control	19
Misgurnus anguillicaudatus (weatherloach)	1984	Vic, SA, ACT	Ornamental	1
Onchorhyncus mykiss (rainbow trout)	1894	Vic, Qld, SA, WA, ACT, Tas	Acclimatisation	2
Perca fluviatalis (redfin perch)	1862	Vic, SA, WA, ACT, Tas	Acclimatisation	9
Salmo trutta (brown trout)	1864	Vic, SA, WA, ACT, Tas	Acclimatisation	2
Tinca tinca (tench)	1876	Vic, SA, Tas	Acclimatisation	1

Source: Lintermans (2004)

[a] Those alien fish species for which no impact to biodiversity was observed in New South Wales are presented in Appendix 4.

[b] Threatened species refers to all biodiversity listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the *NSW Fisheries Management Act 1994*, as at 1 January 2006.

Dispersal pathways

The alien fishes posing a threat to biodiversity in New South Wales were identified to disperse through nine of the twelve pathways identified by Lintermans (2004), with many species being dispersed through several pathways (Table 8.5). Conversely, alien fishes not observed in this report to pose a threat to biodiversity were dispersed by only three different pathways, and each fish species was dispersed by one pathway only. In addition, an extra pathway was used by these alien fishes not posing a threat to biodiversity (Table 8.5). No dispersal pathways were identified for four alien fish species not threatening biodiversity. Again, this suggests a correlation between invasion history and posing a threat to biodiversity.

Table 8.5 The dispersal pathways of alien fish species in New South Wales

Alien fish species present in NSW	Dispersal pathways [a]										Total
	Deliberate legal stocking	Contaminant of fish stocking	Bait bucket introductions	Discarding of aquarium fish	Escape from aqua-culture facilities	Deliberate introductions for biological control	Deliberate illegal stocking	Escape from outside ponds and dams	Transfer on commercial fishing gear	Contaminants of ballast water	
Threatening biodiversity											
Amniataba percoides		1									1
Carrasius auratus			1								1
Cyprinus carpio		1					1	1			3
Gambusia holbrookii						1		1			2
Misgurnus anguillicaudatus			1	1							2
Onchorhyncus mykiss	1										1
Perca fluviatalis	1	1	1				1	1	1		6
Salmo trutta	1				1						1
Total	**3**	**3**	**3**	**1**	**1**	**1**	**2**	**3**	**1**		**9** [b]
No threat recorded											
Acanthogobius flavimanus										1	1
Phalloceros caudimaculatus				1							1
Salmo salar	1										1
Salvelinus fontinalis	1										1
Xiphophorus hellerii				1							1
Xiphophorus maculatus				1							1
Total	**2**			**3**						**1**	**6**
Total	**5**	**3**	**3**	**4**	**1**	**1**	**2**	**3**	**1**	**1**	**10** [b]

Source: Lintermans (2004).

[a] Two additional dispersal pathways were identified by Lintermans (2004), but none of the alien species in New South Wales were observed to use them, being: (i) 'transfers via water diversions', and (ii) 'deliberate release for cultural reasons'.

[b] The total is not cumulative, but rather a count of the number of pathways used.

8.3 The alien fishes posing a threat to biodiversity

Gambusia

In 1925, gambusia was deliberately introduced to Australia as a biological control agent to reduce mosquito numbers (McKay 1984). Today, this alien fish is widespread and common throughout most of the freshwater ways of New South Wales (Wilson 1960, Faragher and Lintermans 1997, NPWS 2003b). In the latest New South Wales freshwater fish survey, gambusia was identified as the dominant alien fish species in the Northern Rivers and Hunter–Central River Catchment Management Authorities (CMAs) (Faragher and Lintermans 1997). Gambusia poses a threat to native fish through direct competition for resources, and to native frogs through predation of eggs and tadpoles (NPWS 2003b). Ironically, gambusia was not considered to be a successful biocontrol agent (NPWS 2003b).

Gambusia was identified here as posing a threat to 19 threatened species in New South Wales, or almost three quarters of the threatened species at risk from alien fishes (Table 8.1 and Appendix 3 for the list of species at risk). The highest impact of gambusia on threatened species occurs through predation, followed by competition and as a vector of disease (Table 8.1). Predation by gambusia threatens eight frog species, two fish species and two EECs, while competition threatens six fish species and two EECs (Appendix 3). One of the fish species at risk from competition was also identified to be at risk from diseases carried by gambusia (Appendix 3). Gambusia is listed as a key threatening process under Schedule 3 of the NSW *Threatened Species Conservation Act 1995* (TSC Act; NSW SC 1999), because of its impacts to native species in New South Wales. As mentioned above, a TAP has been prepared for gambusia, identifying a range of species at risk (NPWS 2003b), and thus the impact of gambusia is potentially better understood than any other alien fish species identified here.

Redfin perch

Redfin perch were introduced from Europe to Australia in 1862, for recreational fishing (Lintermans 2004), and have now become widespread throughout freshwater ways in south-eastern New South Wales (Kailola 2000). In the latest New South Wales freshwater fish survey, redfin perch was identified as an abundant alien fish species in the Southern Rivers, Lachlan, Murrumbidgee, Murray and part of the Lower Murray–Darling CMAs, and was present in all the other CMAs except Northern Rivers and Hunter Central Rivers (Faragher and Lintermans 1997).

Negative impacts of redfin perch invasions occur on small native fish mainly through predation (Lever 1996), and a significant threat to native fish through the spread of epizootic haematopoietic necrosis (EHN) virus (Lever 1996). Several native fish species are highly vulnerable to EHN virus, including the Macquarie perch (*Macquaria australasica*), silver perch (*Bidyanus bidyanus*) and some native galaxia species (Langdon 1990, Faragher and Lintermans 1997).

Redfin perch were identified here as posing a threat to nine threatened species in New South Wales or just over a third of the threatened species at risk from alien fishes (Table 8.1 and Appendix 3 for the list of species at risk). The greatest impact of redfin perch on threatened species occurs through competition, followed by predation, then as the vector of disease (Table 8.1). Threatened fish comprise seven of the species at risk from redfin perch, and the remaining biodiversity at risk is in two aquatic EECs listed under the NSW *Fisheries Management Act 1994* (FM Act; Appendix 3). The threat from redfin perch to these EECs was attributed to the vulnerability of their invertebrate communities to predation.

Rainbow and Brown Trout

Two species of trout were identified as posing a threat to threatened species in New South Wales, along with the generic threat of 'trout' collectively. These two species are rainbow trout (*Onchorhyncus mykiss*) and brown trout (*Salmo trutta*), which were introduced to Australia for acclimatisation purposes (ie for sport fishing) — the brown trout in 1864 and the rainbow trout in 1894 (Lintermans 2004). Both species are now widespread throughout the cooler, upland waters of south-eastern Australia (Kailola 2000). In the latest New South Wales freshwater fish survey, brown trout accounted for almost 9% of the fish caught during the survey (Faragher and Lintermans 1997). In addition, trout were present in the upland reaches of rivers in all CMAs except the Northern Rivers, Hunter Central Rivers, Western and Lower Murray–Darling CMAs (Faragher and Lintermans 1997).

Trout are aggressive competitors, and prey on native invertebrates and fish. In particular, they have severely affected populations of small-sized native fishes in Australia (Lintermans 2001). They have major effects in species-poor streams and other water bodies, because they are large, top-level predators and lack predators of their own (excluding humans).

The collective threat of trout (ie rainbow, brown and the generic threat of trout) posed a threat to six threatened species, being four species by 'trout' and two species each by both rainbow and brown trout (Table 8.1 and Appendix 3 for the list of species at risk), threatening the same two frog species. While the general threat of 'trout' threatened two additional species (one frog and one fish), one population and an aquatic EEC (Appendix 3).

European Carp

Carp are an ornamental species originating in Asia. Various strains have been liberated into New South Wales rivers, with the first recorded release being in Sydney sometime between 1850 and 1860 (Kailola 2000). A strain of koi carp was accidentally released into the Murrumbidgee in 1876 (DPI 2006). Carp are now the most abundant fish species of the Murray River system, comprising 40% of the catch in the last major New South Wales freshwater fish survey (Faragher and Lintermans 1997). The Murray River system corresponds to the Lachlan, Murrumbidgee and Murray CMAs. Carp contribute to poor water quality by uprooting vegetation and stirring up sediments during feeding, leading to increased turbidity (DPI 2006). However, there is much debate as to whether turbidity in waters occupied by carp is the result of their feeding habits or other environmental factors (ie Tilzey 1980).

Carp were identified here as a threat to five threatened species in New South Wales or 19% of the threatened species at risk from alien fishes (Table 8.1 and Appendix 3 for the list of species at risk). The native species threatened by carp includes two frog species, one fish species and two aquatic EECs (Appendix 3). Predation and competition were identified as the main threatening actions here. Interestingly, habitat degradation by carp was not recorded as a threat here.

Goldfish

Goldfish were introduced to Australia in 1876 and are now present in most permanent freshwater ways in southern Australia extending from the Fitzroy, Dawson and Burnett Rivers in Queensland to the southwest of Western Australia (Kailola 2000). Little research, however, has been conducted on the biology and environmental effects of goldfish, although they are known to prey on microcrustaceans (Kailola 2000).

Goldfish were identified here as a threat to two threatened species in New South Wales or 8% of the threatened species at risk from alien fishes (Table 8.1 and Appendix 3 for the list of species at risk). Both threatened species at risk are aquatic EECs (Appendix 3). The goldfish ulcer disease (GUD) is transmitted by goldfish, but was not identified here as a threat to any species.

Tench

Tench were first introduced into the Murray River in 1876 (Lintermans 2004) and have subsequently spread rapidly throughout the Murray–Darling river system. The numbers of tench, however, have been reduced drastically since the establishment of carp (Lever 1996). Consequently, in comparison to other alien fish species, tench are now believed not to be as serious a threat to native fishes as they once were (Kailola 2000). Comparisons between introduction date, spread and impact support this view (see Table 8.4).

Tench were identified here as a threat to only one aquatic EEC in New South Wales or 4% of the threatened species at risk from alien fishes (Table 8.1 and Appendix 3 for the list of species at risk).

Weatherloach

Weatherloach were introduced into Australia in 1984 for ornamental purposes (Lintermans 2004). Outside of New South Wales, weatherloaches occur in Victoria, South Australia and the Australian Capital Territory. Interactions with native fishes include competition for spawning sites, disturbance and/or predation of eggs, competition for food (particularly plankton, which may be important for larval fish), competition for shelter, alteration of native habitat, and transmission of disease (Langdon 1988). Here, weatherloach were identified as a threat to one aquatic EEC (Table 8.1 and Appendix 3 for the list of species at risk).

8.4 Distribution of threatened species at risk from alien fish species

The threatened species identified here as being at risk from alien fishes occur in all 13 CMAs in New South Wales, with the number of threatened species per CMA ranging from two to 12 (Table 8.6). The Northern Rivers CMA has the largest number of threatened species (12) at risk from alien fishes, seven of which are threatened frogs. Most of the species at risk are threatened by gambusia. However, the Northern Rivers CMA has the least number of alien fish species present posing a threat to biodiversity, suggesting that those that are present pose a significant threat. The threat posed by alien fishes is not spatially distributed; for example, all seven threatened fish species impacted by redfin perch occur in the Murray region where redfin perch are very abundant (Faragher and Lintermans 1997).

No single CMA contains all the alien fish species reported to threaten biodiversity (Table 8.6). In addition, not all nine alien fish species could be examined spatially for their impacts, as some only threaten EECs and spatial information on EECs was not available.

Table 8.6 Number of threatened aquatic species at risk from alien fishes within each natural resource management region in New South Wales

Natural resource management regions of NSW [a]	Number of threatened aquatic species present [b]	Number of alien fish threatening biodiversity present [c]	Number of threatened species threatened by alien fish [b]
Northern Rivers CMA	21	2	12
Hunter Central Rivers CMA	12	2	5
Hawkesbury–Nepean CMA	10	3	8
Sydney Metropolitan CMA	8	3	5
Southern Rivers CMA	11	3	5
Border Rivers–Gwydir CMA	6	3	6
Namoi CMA	4	3	4
Central West CMA	5	3	5
Lachlan CMA	7	4	6
Murrumbidgee CMA	12	4	7
Murray CMA	10	4	6
Western CMA	1	2	1
Lower Murray–Darling CMA	3	2	3
Total [d]	**35**	**5**	**22**

[a] CMA = Catchment Management Authority.

[b] 'Threatened aquatic species' refers only to frog and fish species listed in Schedules 1 and 2 of the NSW *Threatened Species Conservation Act 1995* and Schedules 4 and 5 of the *NSW Fisheries Management Act 1994*, as at 1 January 2006.

[c] Not all alien fish species threatening biodiversity in New South Wales are presented here, as some threatened only EECs and thus could not easily be allocated to a CMA.

[d] Values are not cumulative, as many threatened species occur in more than one natural resource management region, and many species are threatened by more than one alien fish species.

9. Discussion and implications

The threat posed by pest animals to threatened biodiversity in New South Wales has been described in the previous four chapters, with respect to the threat relative to other threatening processes (Chapter 5), alien predators (Chapter 6), alien herbivores (Chapter 7) and alien freshwater fishes (Chapter 8). In this chapter, the implications of these findings are discussed with emphasis on pest management and biodiversity conservation. A series of recommendations is presented at the end.

This study found that alien pest animals pose a significant threat to biodiversity in New South Wales, in term of threatened species listed under the NSW *Threatened Species Conservation Act 1995*, and the NSW *Fisheries Management Act 1994*, with 40% of these species at risk. Of the 29 pest animal species identifed as posing a threat to biodiversity, the major threats were predation by feral cats, and red foxes, herbivory and associated habitat destruction by feral goats, rabbits and pigs. Also eight alien fishes were identified as posing a threat.

9.1 The relative threat of pest animals compared with other threatening processes

Human activity has greatly accelerated the rate of alien species introductions (pest animals and weeds), especially in the last 200 years. These introduced alien species are now considered to be a major cause of global biodiversity decline (WRI et al 1992). Despite such an acknowledgment, there have not been significant changes to policy, management, or funding for alien species in relation to reducing their impact to biodiversity. One reason for this failure is that there is limited quantitative data or analysis of the actual species at risk (Downey in press).

A recent report established a process to address such failures by compiling information on the species at risk from weeds in New South Wales (Coutts-Smith and Downey 2006). This assessment found that alien species posed the second greatest threat to native threatened species after habitat clearing, with alien species threatening 70% of species examined, and the number of species at risk from weeds was an order of magnitude greater than previous attempts (eg Vidler 2004). The present analysis used an updated version of the data set (ie new threatened species listings and threat information) created by Coutts-Smith and Downey (2006) to examine the threat of alien pest animals on biodiversity in New South Wales. This analysis revealed that alien species are still the second greatest threat to biodiversity; however, the number is slightly higher (ie up 1% to 71%).

The threat posed by pest animals alone was identified as the fourth major threat to biodiversity in New South Wales, behind land clearing, weeds and altered fire regimes, in terms of the total number of species at risk. Interestingly, salinity, which is one of the major natural resource management issues in Australia, and considered to be a significant threat to biodiversity, was identified as a threat to only a small proportion (0.4%) of threatened species in New South Wales, with a similar result observed for climate change.

Comparisons between these two assessments of alien species groups (ie weeds and pest animals) illustrate the relative threat of each group to biodiversity. Weeds pose a greater threat to biodiversity than pest animals, with 44% and 40% of species at risk respectively. This may, in part, be due to the vastly different numbers of alien species posing a threat to biodiversity, being 127 weed species compared to 29 pest animal species. Interestingly, as proportions of the number of naturalised species in New South

Wales, a greater percentage of naturalised pest animals pose a threat to biodiversity (58%, or 29 of 50 species), than weeds (9%, or 127 of 1380 species). In addition, the two groups posed different levels of threat to native plants and animals, with pest animals threatening 27% of threatened plant species and 70% of threatened animal species, and weeds threatening 49% and 23% respectively.

9.2 Assessing the impact of pest animals on biodiversity

The impact of pest animals on biodiversity has been examined more than for any other threat to biodiversity. These studies have examined the actual impact (eg Dickman 1996a, Catling et al 1999), specific interactions between pest animals and native species (eg Fisher 1998), as well as the causes of native species extinctions (eg Burbidge and McKenzie 1989, Dickman et al 1993, Dickman 1996a, Short 1998). In addition, there have been reviews of existing information (eg McLeod 2004).

These studies typically ignore 'grey literature' sources, and while this gives greater scientific integrity to the information on impacts, it ignores possible impacts to species that have not been the focus of scientific studies. In addition, impacts tend to be restricted to taxonomically discrete groups that are easily sampled, such as non-threatened mammals. This restricted knowledge base can have deleterious consequences, because the perceived threat of a pest animal species influences policy development and management decisions, and so far has been restricted to a few groups of pest animals. For example, the impact of alien carnivores such as feral cats and red foxes on native species is reasonably well understood (see Dickman 1996a, NPWS 2001). However, assessments have not occurred for the majority of other pest animal species.

In fact, information on impacts to native species at risk is available for only a few pest animal species (McLeod 2004). A recent review of the impacts of pest animals in Australia, using triple-bottom-line analysis (consisting of economic, environmental and social impacts) of 11 major alien vertebrate species, presented information on the native species at risk for seven pest animal species, based on information contained in national threat abatement plans (TAPs, see McLeod 2004 and further discussion in section below). The author, however, made no attempt to compare the native species at risk from each pest animal species or analyse the data in any further way.

Given that there are over 90 naturalised species of alien animals in Australia (see Bomford and Hart 2002, Lintermans 2004) information on their impacts to native species is lacking for the vast majority and is desperately needed. As outlined in Chapter 8, impacts may be time dependent, with the majority of alien fish that threaten biodiversity having first naturalised long ago, compared with few of the recently naturalised species which threaten biodiversity. Thus, mechanisms to assess pest animal impacts to native species need to be developed that encompass the array of pest animal species, especially recently naturalised species. Studies like the current report highlight the degree to which some of the less well-known alien animals can threaten biodiversity (see Appendix 3).

The limited knowledge of the native species at risk has hindered our ability to direct conservation objectives through pest animal management programs. For example, very few pest animal control programs in Australia undertake monitoring programs to determine the response of native species following control measures, despite a large number of these programs having biodiversity conservation as an objective (Reddiex et al 2006, Reddiex and Forsyth 2006). This situation arises in part because of the lack of understanding on which native species are at risk. Thus, monitoring programs are not designed to determine specific biodiversity outcomes such as increased fecundity or fledgling success. Where monitoring programs have been specifically designed to assess the recovery of native species, these programs have resulted in the recovery of native species (eg Western Shield in Western Australia, and New South Wales Fox TAP, NPWS 2001).

In addition, by knowing the native species at risk, pest animal control and monitoring programs can be tailored to help determine both pest animal declines and native species recovery following control measures. Also contributing to the problem is that, historically, monitoring has not been considered to be a critical aspect of pest animal control programs. Other factors that limit the uptake of monitoring programs include resource limitations (ie funds), and a general lack of expertise by people undertaking the control programs to design and undertake monitoring programs.

While the available data contributes to our understanding of the impact of pest animals on native species, a broad assessment across many taxonomic groups is required to influence management and policy initiatives (Downey in press). The biodiversity listed under the schedules of threatened species legislation enabled such an assessment to be undertaken, as these lists are taxonomically diverse (containing a range of native plant and animal species) and information on the threats to each listed species is readily available. These schedules were recently assessed to determine the threat of weeds on biodiversity in New South Wales (see Coutts-Smith and Downey 2006). The present study builds on the approach used by Coutts-Smith and Downey to examine the threat posed by pest animals. These studies confirm the value of threatened species lists in assessing the threat to biodiversity from alien species, despite some authors criticising their value for decision making (Possingham et al 2002).

Assessing impacts

The current assessment outlines the threat posed by pest animals to threatened species. However, this does not necessarily translate into an impact, which requires detailed scientific examination. Thus, the list of species identified here as being at risk needs to be examined to determine the exact impact of pest animals. For example, there is a great degree of overlap between the species at risk from red foxes and feral cats, which is at odds with the literature (eg Dickman 1996a). This overlap, combined with the number of species for which the pest animal threat was poorly articulated, highlight a major problem with how threats are described, which may not be based on accurate assessments.

Assessing the threat to biodiversity nationally

While the assessments undertaken by Coutts-Smith and Downey (2006) and here provide a good baseline on the threat of alien species in New South Wales, the approach needs to be expanded to encompass those species listed under other states' and the Commonwealth's threatened species legislation. Virtually all of these alien species examined are not restricted to New South Wales and thus are likely to pose a threat to native species elsewhere in Australia. While the Commonwealth legislation (*Environment Protection and Biodiversity Conservation Act 1999*, or EPBC Act) encompasses nationally threatened biodiversity, it does not cover all the threatened biodiversity in Australia. For example, half of the threatened species listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) were not listed under the EPBC Act when this study was undertaken. In addition, the state's threatened species legislation does not encompass all the biodiversity contained under the EPBC Act (eg RAMSAR wetlands). A national assessment would provide a more comprehensive picture of the threat posed by alien species to biodiversity in Australia, the alien species posing the threat, and more complete lists of the native species at risk.

The current study provides a baseline overview of the threatened species at risk from pest animals in New South Wales, as well as a comprehensive list of the pest animal species posing the threat. This process identified 29 pest animal species from a variety of taxonomic groups (ie amphibians, birds, fish, invertebrates, mammals and reptiles), along with several groups of alien animals (eg deer). However, the number of pest animal

species identified represents only 31% of those naturalised in Australia, again highlighting the need for a national study.

Limitations of the current approach

A limitation to the current approach is that the data are not based on an assessment of pest animal impacts, but rather on threats to threatened species. In addition, the data was derived from a number of different sources, the reliability of which could not always be verified (see Chapter 3). Thus, it is important that studies of individual species are still undertaken to determine the full extent of the pest animal problem and the exact nature of the impacts. Such studies can significantly contribute to analyses like the current analysis as well as to pest animal management.

Another limitation is that for many native species threatened by pest animals, information on the specific alien animal posing the threat could not be identified. While not as great a problem as that for weeds (ie 51% — see Coutts-Smith and Downey 2006) it was nonetheless significant. This supports findings from the United States in which a review of threatened species showed that many listings lacked important information on threats (Easter-Pilcher 1996). This problem can undermine recovery efforts (Lawler et al 2002) and management of threats like alien species (Coutts-Smith and Downey 2006).

While this project provides an assessment of the impacts of pest animals on the biodiversity listed under Schedules 1 and 2 of the TSC Act and Schedules 3 and 4 of the *Fisheries Management Act 1994* (FM Act) in New South Wales, these threatened species account for only 13% (790 of 6147) of the total biodiversity (vascular plants and vertebrates) present in the New South Wales. For example, there are 4689 native plant species in New South Wales that are not listed as threatened. Therefore, in order to understand the full extent of the threat posed by pest animals or other threatening processes to biodiversity, a measure is needed of the likely threat posed to species not currently listed as threatened.

A system has recently been developed for weeds that examines all plant species at risk. The Weed Impacts to Native Species (WINS) assessment process (Downey 2006) was developed during the production of the NSW Bitou Bush TAP. Of the plant species identified using the WINS system to be at risk, 65% were not formally listed as threatened under the TSC Act (DEC 2006). This process could be adapted for use in determining the impacts for some pest animal species (eg herbivores such as goats and rabbits) where the threat to native plants not listed as threatened are likely to be extensive, but as yet are relatively unquantified.

9.3 The threat posed by pest animals to biodiversity

Pest animals pose a major threat to Australia's agricultural industries and the environment (Bomford 2003, McLeod 2004). The cost of 11 major alien vertebrates (Table 9.1) was estimated at $720 million per year, based on a triple-bottom-line approach (see McLeod 2004). A closer examination of this approach revealed that environmental costs were difficult to ascertain and could only be calculated for three species, being red foxes, feral cats and carp. The combined estimated total of these three alien species on the environment was $346 million or 48% of the total cost annually, and with all three species, the environmental cost far outweighed the economic cost (McLeod 2004).

An analysis of threats to biodiversity in the United States revealed that alien predators and herbivores posed the primary threat to 15.8% of threatened species (Simberloff 1996). The current analysis of threats to threatened species in New South Wales could not reliably distinguish between primary, secondary or other level threats to biodiversity, thus the 40% of species at risk from alien animals encompasses all levels of threats.

Another analysis of threatened species in the United States revealed that after habitat destruction, alien species posed the next greatest threat, affecting 57% of threatened species (Wilcove et al 1998); these results match those presented here.

In terms of the threat to biodiversity, McLeod (2004) attempted to compile a list of native species at risk for each of the 11 alien animals nationally, to illustrate the likely impact on biodiversity. For 10 of these 11 alien animal species, the current study identified greater numbers of native species at risk in New South Wales alone (see Table 9.1). The only exception was camels, which are not widespread in New South Wales and thus were not recorded in the data set; interestingly, McLeod (2004) did not identify any species at risk from camels either. The difference between the numbers of species at risk here and those presented by McLeod is not a reflection of a sudden increase in the threat of alien pest animals to biodiversity, but rather represents a more in-depth analysis of the threats.

Only 29 of the 111 native species identified by McLeod (2004) were identified as being at risk in our data set for New South Wales. Thus, an additional 205 native species were identified here as being at risk from just 10 pest animal species. Again, this result highlights the need for a national assessment. Of the 111 native species listed by McLeod (2004) as being at risk, 45 were plant species and 66 were animal species. In comparison, of the 388 species identified here, 154 were plant species and 186 animal species, and the remainder were threatened populations and ecological communities.

Table 9.1 Number of native species at risk from 11 major alien vertebrates, prior to and after the current study

Alien animal species	Number of native species at risk nationally (after McLeod 2004)	Number of native species at risk in New South Wales (ie as present in Appendix 3)	Additional native species identified as being at risk between the two studies
Feral cat	36	117	81
Red fox	34	111	77
Feral pig	34	81	44
Feral rabbit	42	86	83
Feral goat	13	96	2
Carp	3	5	8
Cane toad	1	9	9
Mouse	na	4	4
Dogs	na [a]	39 [b]	39
Camel	na	0 [c]	0
Feral horse	na	15	15
Total	**111**	**287**	**205**

na: no value presented

[a] McLeod (2004) included both wild dogs and dingos under the heading of dogs.

[b] The current report only presented data on wild dogs. Information on dingos was not considered.

[c] Camels are not widely distributed in New South Wales.

Subsequent reanalysis of McLeod's (2004) data as presented here, revealed that seven pest animal species threaten the 111 natives species at risk, and that 78 of these are threatened by one pest animal species (Table 9.2). The remaining species are threatened by up to four pest animal species (Table 9.2). Both the brush-tailed rock wallaby (*Petrogale penicillata*) and malleefowl (*Leipoa ocellata*) are threatened by the same four pest animal species, being: feral cats, feral goats, red foxes and rabbits.

Comparing this reanalysis with the data presented here revealed that 29 pest animal species pose a collective threat to 287 native species in New South Wales alone. In addition, 141 are only threatened by one pest animal species, with the remainder being threatened by up to five pest animal species (Table 9.2). Eleven native species are threatened by four pest animal species. Two native species — the skink *Cyclodomorphus venustus* and the black-striped wallaby (*Macropus dorsalis*) — are threatened by five pest animals (neither of these two species were identified by McLeod). The current study also found that brush-tailed rock wallabies and malleefowls are threatened by three pest animal species.

Table 9.2 Number of native species at risk and the number of pest animals threatening them

Analysis of pest animal impacts to biodiversity	Number of pest animal species posing a threat and the number of species at risk [a]					Total native species at risk [a]
	1	2	3	4	5	
McLeod (2004)	78	20	11	2	0	111
The current study	141	102	31	11	2	287

[a] Based on the 11 alien animals described in Table 9.1

While a review of alien freshwater fish in Australia set out to examine the impact to biodiversity, the impacts to native species were typically described in generic terms, rather than identifying specific native fish species at risk (Kailola 2000): again supporting our call for a standardised approach to describing species at risk and threats. Irrespective, (Kailola 2000) managed to identify a number of native species at risk, most of which were from studies outside of New South Wales (eg the impact of Gambusia in the Brisbane region, Arthington et al 1983). Such information highlights the impact of alien fish to biodiversity and the need for a national assessment. For example, (Kailola 2000) identified at least 12 native fish species at risk from gambusia nationally, few of which are recorded in the data set presented here (ie in Appendix 3).

9.4 The threat posed by each of the three main groups of pest animals

Alien predators

Alien predators are known to kill and maim native animals (Jones and Coman 1981, Hornsby 1982, Tisdell 1982, Thompson 1983, Triggs et al 1984, Ebenhard 1988, Saunders et al 1995, Choquenot et al 1996). But simply because an alien predator preys on a particular native species, this does not automatically result in a population-level impact or the potential for the prey's extinction (Ebenhard 1988). Rather, predators have to alter their prey's abundance and home range before population-level effects occur. For example, such population effects have been recorded as a result of predation by feral cats (Dickman 1996b) and red foxes (NPWS 2001, Kinnear et al 2002). In addition, alien predators that have a strict diet may have a greater effect on prey populations than omnivorous predators (Ebenhard 1988). Alien predators are believed to have caused the extinction of almost half of Australia's extinct birds (greater than any other threat), threaten a third of the currently threatened bird species (Garnett 1992, Garnett and Crowley 2000), and are a major threat to mammals (Kennedy 1992). Macdonald et al (1989) showed that native mammals, birds and reptiles in Australia are more at risk from alien species than on any other continent.

While the current study identified 163 threatened species at risk from alien predators in New South Wales, this analysis could not determine whether alien predators have

population-level or more localised impacts. Thus, scientific examination of some of the native species identified as being at risk from alien predators is required to determine the exact level of impact.

The review of the species impacted by red foxes in the Fox TAP (NPWS 2001) identified 34 threatened species at risk, while the current data set identified 111 as potentially being at risk. This discrepancy arises in the different approaches undertaken and the reliability of the data used, one being a review of impacts (Fox TAP), the other an assessment of threats. As noted above, the high degree of overlap between species at risk from red foxes and feral cats in our data set suggests that such assessments of threats need to be examined against actual impacts.

The combined impacts of alien herbivores

The impact of alien herbivores on threatened biodiversity occurs through two main actions. The first is grazing and browsing. The second action is habitat degradation due to trampling (eg feral goats, Parkes et al 1996), digging (eg rabbits, Williams et al 1995) and rooting (eg feral pigs, Tisdell 1982).The number of threatened species at risk from each action is almost equal (ie 146 and 143, respectively). Thus, any management measures to reduce the impacts of alien herbivores on biodiversity need to address both grazing/browsing and habitat degradation together, which differ between alien herbivore species. A similar result was also observed for domesticated herbivores, with slightly more species at risk from grazing than from habitat degradation. The species at risk are greatest in the western part of New South Wales, where 78% of terrestrial threatened species are at risk from grazing/browsing and habitat degradation by herbivores.

The impact of alien herbivore grazing and browsing can lead to declines in the abundance and range of native plants, and in some cases localised extinction (Ebenhard 1988, Atkinson 1989, Leigh and Briggs 1992). Grazing/browsing can lead to preventing the regeneration of tree species (Ebenhard 1989) as well as promoting the growth of perennials over annuals (Williams et al 1995, Parkes et al 1996). However, studies on the impacts of grazing/browsing on native species are rare (James et al 1995, Landsberg et al 1997, Read 2002, James 2003), despite grazing/browsing being widely cited as a process contributing to native species declines (Maxwell et al 1996), with many of the impacts being derived from anecdotal observations (eg Lunney 2001) or inferred from vegetation studies (Morton 1990) or dietary overlap (Dawson and Ellis 1979, Edwards et al 1996).

There is a growing appreciation that the management of alien herbivores cannot occur in isolation (Ludwig et al 1997, Fisher et al 2004). The impact of this total grazing pressure is not necessarily related to individual differences between herbivore species; instead it is attributed to the combined effect of grazing at certain times and places (Freudenberger et al 1997). The data presented here supports this view of total grazing pressure with respect to biodiversity conservation, in that both domesticated livestock and native herbivores pose a threat to threatened species in New South Wales. For example, alien herbivores threaten 23% of threatened biodiversity, while the combined effects of all herbivores (ie total grazing pressure) threaten 45%. In addition, many of the threatened species at risk from alien herbivores are also threatened by domesticated livestock.

In addition, there are suites of indirect effects that accompany farming of domesticated livestock. These effects include the development of infrastructure (eg roads, fences, pipelines, etc), clearing of native vegetation, alterations to fire regimes, and addition of artificial water sources (Ludwig et al 1997). Other indirect effects are (i) the removal of predators such as dingos, and (ii) pasture improvement (ie introduction of alien grasses that go wild, and nutrient addition through fertilizers). Determining the impacts of such processes was beyond the scope of this study, but they add to the stresses on threatened species.

Alien fishes

Freshwater environments worldwide are under threat from aquatic alien species (Moyle and Light 1996). For example, these invaders contributed to over two thirds of fish extinctions in the United States over the last 100 years (Miller et al 1989). In Australia, alien fish species pose a threat to the recovery of 42% of threatened fish species (Wager and Jackson 1993) with several alien fish threatening native species (Kailola 2000). Managing alien fish species requires a better understanding of invasion and spread pathways, as highlighted by Lintermans (2004).

There are 34 alien fish species that have established wild populations in Australia, along with 53 native species that have been translocated to new locations within Australia (Lintermans 2004). Of the alien fish species, 22 were deliberately introduced through the ornamental fish industry as aquarium pets, and a further 11 fish species for acclimatisation, aquaculture, and biological control. Only two species have been accidentally introduced, via ballast water (Lintermans 2004). In New South Wales alone, 18 alien fish species have been recorded, eight of which were identified here as posing a threat to biodiversity.

Re-analysis of Lintermans (2004) data combined with this data set revealed that few of the recently naturalised alien fish species pose a threat to biodiversity, compared with the majority of long-established species, which do pose a threat. One of the exceptions is tench, which was recorded as naturalised over 100 years ago and threatens only one species. While widely established, tench have not become a dominant species, and this may explain their limited impact. Also, their numbers may be limited by other alien fish species (eg carp).

Most of the newly naturalised alien fish species are escaped ornamental species. Given the relatively unregulated importation of alien fish through the aquarium trade, combined with the number of species imported to date (ie over 1100 species: McNee 2002), many more are likely to be reported as naturalised in the coming years. This would add to the already significant increase in alien fish naturalisations since the 1960s (see Lintermans 2004). Such increases are likely to result in a greater threat to threatened species.

9.5 Implications for managing pest animal threats under the *Threatened Species Conservation Act 1995*

Pest animals listed as key threatening processes

The scale of the impact of pest animals on biodiversity has, to a large degree, been reflected in the number of pest animal species which are listed as key threatening processes (KTPs) under both the New South Wales and Commonwealth threatened species legislation. Presently in New South Wales, 13 pest animal species are listed as KTPs under the TSC Act (including cane toads, which were listed in June 2006: see NSW SC 2006) and one generic fish listing under the FM Act. Eight of these pest animals are also listed nationally (ie under the EPBC Act) as KTPs, being: red foxes, feral cats, feral pigs, feral goats, feral rabbits, cane toads, yellow crazy ants, and red fire ants. Those not listed nationally are: ship rats (black rats), gambusia (and other alien fish), feral deer, honeybees and bumble bees.

The KTPs currently listed in Schedule 3 of the TSC Act and Schedule 6 of the FM Act were not derived from any form of assessment of the biodiversity listed in the other Schedules of these Acts. Rather, they are based on demonstrable impacts of specific pest animals to threatened species (Catling et al 1999), or specific interactions between pest animals and native species (Fisher 1998). However, this approach ignores those pest animal species whose impacts to native species have not been examined. In addition, information on

the full gamut of species at risk from those pest animals listed as a KTP has not been examined, as the requirements for listing only require information on two species (eg NPWS 2005).

The present threat assessment identified several pest animal species that are not currently listed as a KTP, along with the native species currently at risk from them. This information can be used to prepare nominations and help with the determination of KTP listings in the future. Five pest animal species were identified here that satisfy the criteria for KTP nomination, being: wild dogs (threatening 39 species), feral horses (threatening 15), black rats (threatening 5 — outside of Lord Howe Island), house mouse (threatening 4) and brown rats (threatening 3). A further five pest animal species identified here pose a threat to two threatened species (see Appendix 3).

While several alien fish species could be listed as separate KTPs, they are encompassed under a generic KTP listing under the FM Act. This listing is 'introduction of fish to fresh waters within a river catchment outside their natural range' (NSW FSC 2001). Such a generic listing will also capture future threats from alien fish. However, it does not give the flexibility to target specific alien fish species in the same way as individual KTPs listing; in part, as each fish species requires a different management solution, and impacts on different native species.

Describing and documenting threats

During the compilation of the threats data set it quickly became apparent that there was no consistency in the way in which threats were documented and described, even by the NSW Scientific Committee. Many threat descriptions were often either poorly articulated or inadequate for analysis or management; for example using general statements such as the species was threatened by 'feral animals' or 'by exotic pests'. Indeed, four native species were listed for which no threat could be determined, despite extensive examination. The identification of at least the main pest animal species is crucial for informing pest management programs. The percentage of species at risk from the generic threat of pest animals is significantly less than that for species threatened by weeds (Coutts-Smith and Downey 2006). A review of threats to threatened species in the United States found a similar trend, with 39% of threats containing insufficient information (Lawler et al 2002).

A recommendation of this report is that the description of threats be standardised, not just in New South Wales, but whenever a threat is described (see below). The minimum requirement for describing a threat should include, for a threatening biological organism, the name of the species posing the threat (eg feral goats or *C. hircus*), and a meaningful description of the action by which the threat occurs (eg soil compaction and browsing by feral goats). Inadequate description of threats is detrimental to the recovery of threatened species, as well as the management of pest animals, because actions to abate the threat cannot be threat specific. If the specifics are unknown then investigations must be carried out or, in certain circumstances, descriptions might be accompanied by caveats to reflect the likely threat, such as 'it is suspected that competition by feral goats has led to the decline in this species'.

Threat abatement plans

A recent review of recovery plans prepared under the US *Endangered Species Act 1973* found that multiple-species recovery plans should be based on threatened species with similar threats, rather than on species with similar geography (Clark and Harvey 2002). Such plans would make it easier to manage a single common threat, rather than multiple threats to multiple species. The threat abatement planning process in New South Wales does exactly this, through the development of strategies to reduce the impact of significant KTPs to biodiversity. To reduce, abate or ameliorate the threat posed by a KTP listed under the TSC Act, TAPs are prepared in accordance with the Act. At present, there are two approved pest animal TAPs, being the Fox TAP (NPWS 2001) and Gambusia TAP (NPWS 2003b). There is currently only one weed TAP: the Bitou TAP (DEC 2006). These three plans are separated into two groups based on (i) the level of available information on the biodiversity at risk, and (ii) the presence of effective broad-scale control options available. TAPs for which there are either limited information on the impacts and/or no effective controls aim to address such deficiencies (eg the Gambusia TAP). The other group of TAPs establishes an on-ground strategy that merges alien species management and biodiversity conservation (eg Fox and Bitou TAPs: see Downey et al 2004 for further discussion), because information on the species at risk could be tied to specific sites for control.

The Fox TAP (NPWS 2001) uses a series of models to assess the ecology and distribution of foxes and their prey species in New South Wales. The use of such models allowed assessments to be made in the absence of published studies on impacts. These models identified 34 high-priority threatened species as being susceptible to fox predation and a total of 81 priority sites where these species occur, independent of land tenure. Fox control at these sites will have the greatest benefit to biodiversity threatened by foxes. In addition to fox control, the TAP outlines a rigorous monitoring program to determine population responses of threatened biodiversity to fox control at priority sites. This program ensures that fox control is not adhoc and monitoring assesses the recovery of targeted species. A five-year review of the Fox TAP is currently underway and assessments will be released in the near future.

The Gambusia TAP (NPWS 2003b) undertook a preliminary assessment of the likely impacts of gambusia on biodiversity (primarily frogs), which increased our understanding of their impacts. However, a full assessment is still needed across a broader range of species. As effective broad-scale control measures are not available or practical at present, no priority sites were identified in the TAP for gambusia control. Thus, actions are aimed more at developing control options and identifying sites to trial such options. Given the increase in the number of species thought to be at risk from gambusia during the development of the TAP, it is likely that similar increases in the native species at risk from other alien fish species would occur if such an assessment was undertaken.

9.6 Limiting future impacts

Identifying the source of pest animal invasions

At least 92 alien animal species have established wild populations in Australia, either on the mainland or on off-shore islands. These animals include 25 mammals, 20 birds, four reptiles and one amphibian on the mainland, and an extra seven birds and one mammal on off-shore islands (Bomford 2003), and 34 species of fish have also established in Australia's inland waterways (Lintermans 2004). The number could have been greater than 92, as five alien bird species and two mammal species established wild populations that later became extinct (eg red vented bulbul *Pycnonotus cafer* and eastern grey squirrel *Sciurus carolinensis*), and a further 26 bird, six mammal and two reptile species were released but

failed to establish in the wild (Bomford 2003). However, not all of these naturalised alien animals are serious pest species. For example, only 60% of alien mammals (Wilson et al 1992, Clarke et al 2001) and 45% of alien birds (Long 1981) are considered serious pest species, although these numbers could be much higher since many other species have the potential to become serious pests.

Deliberately introduced animal species account for the majority of the alien pest animal species in Australia today. These species were first introduced for the purpose of:

- domesticated pets and livestock (eg ornamental fish, cats, goats)
- release by acclimatisation societies (eg sambar deer, red foxes, red-whiskered bulbul)
- biological control (eg cane toad and gambusia), and
- accidental releases (eg rats and mice).

However, many more alien animal species could naturalise, given that over 650 alien vertebrate animal species have been imported to Australia (VPC 2006); this list does not include aquatic vertebrates, and at least 210 fish species from 32 families and 47 genera are currently on the list of species suitable for live import into Australia. However, McNee (2002) suggests that the number of alien fish species imported into Australia exceeds 1100 species. Zoos contain the majority of imported vertebrate species in Australia that have not naturalised, but the escape and naturalisation of alien animals from zoos is unlikely. However, the establishment of wild populations following escapes from zoos has been recorded. For example, Indian palm squirrels escaped from the grounds of the south Perth zoo, where they spread to surrounding areas, colonising an area up to 30 square kilometres with occasional individuals being captured outside of the Perth area; all these animals have now been eradicated (AWA 2005).

While the threat from pest animals is mostly a legacy of past deliberate introductions (eg by acclimatisation societies), such deliberate introductions are unlikely to occur in the future. Thus, the threat of future naturalisations of new alien animals is most likely to come from animals held as pets or animals used in the agricultural industry or accidental introductions (eg insects). The threat of new incursions from these sectors is high, especially with respect to several groups of alien animals (eg fish imported for aquariums). These animal species, currently kept in captivity or newly imported, have established wild populations at alarming rates in recent decades. For example, the number of new alien fish naturalisations has increased from one every two years since the 1960s, to seven in the decade 1990–2000 and six between 2000 and 2004 (Lintermans 2004). The majority of these fish were originally imported for ornamental purposes. Lintermans (2004) identified 12 invasion pathways to help limit future invasions.

Many insects (invertebrates) have also been introduced to Australia (Canyon et al 2002), both deliberately (eg for biological control of weeds) or accidentally (eg in shipping containers or packaging: see Navaratnam and Catley 1986). The exact number of alien insects in Australia is not known, partly because those that do not pose a threat to human health or agricultural production are less likely to be detected (Swincer 1986). Irrespective, few alien insects had established prior to 1960, but since then the number has increased steadily (Swincer 1986, Canyon et al 2002).

To limit new incursions of pest animals, a risk assessment process has now been developed in Australia for importing and keeping alien vertebrates (Bomford 2003) and freshwater finfish (Bomford and Glover 2004). While this goes a long way towards limiting the importation of known alien animals, it does not deal with invertebrates, which could pose a major threat, or those species that are already here and not yet naturalised.

Preventing future pest animal threats

There is a constant risk that new alien species could naturalise and become problematic in Australia, and while we cannot predict what the future alien pest animals will be, we can identify species that are likely to become pests. There are many factors that influence the establishment of pest animals in the wild, but the key determinants are the frequency and size of release events, climatic suitability and history of invasiveness (ie in other countries). Two recent reports describe the attributes of a species that determine the likelihood of establishing wild populations (Bomford 2003, Bomford and Glover 2004). These reports are intended to be used as a guide for agencies that manage the import of live animals into and within Australia. As outlined above, this risk assessment process does not cover invertebrates, which are likely to contribute new pest threats in the future, or those species already present. In addition, these reports do not specifically assess impacts to biodiversity. A similar problem exists for the current weed risk assessment process (Downey in press).

Value of scientific research in making predictions

It is widely acknowledged that pest animals have led to declines in Australian biodiversity (Dickman 1996a). However, there are many gaps in the scientific analysis of impacts posed by pest animals, highlighted by the fact that less than 2% of threat information collated here was derived from scientific papers, but contained 14% of the threat descriptions (see Chapter 3). Further scientific research is needed in a number of key areas, particularly in relation to:

- determining the exact nature of pest animal impacts to threatened species
- determining impacts of pest animals other than to the major species
- monitoring following control programs (see Reddiex and Forsyth 2006, Reddiex et al 2006).

This current study provides a baseline upon which rigorous scientific examination is now needed in these and other areas of pest animal impacts.

9.7 Integration of biodiversity at risk into pest animal management and policy

Information on the biodiversity at risk from pest animals needs to be better integrated into pest animal management, conservation and the associated policies to improve conservation planning and biodiversity outcomes. In part, the lack of information on what is at risk has hampered this, combined with the assumption that control alone will lead to biodiversity conservation; this is not necessarily the case. This report will help to address this issue by providing information on the native species at risk and which pest animals pose the threat.

In addition, information is still needed to determine the spatial relationship between pest animal distribution and impacts to native species. The NSW Fox TAP (NPWS 2001) provides a model for achieving this, which could be adopted more broadly for establishing conservation priorities, both in terms of selecting species and sites for control. The Fox TAP also outlines monitoring programs which are critical to determine the success of such control programs.

9.8 Conclusion

The current study has quantified the threat of pest animals on threatened biodiversity in New South Wales. Part of this analysis included an assessment of the relative importance of pest animals compared to other threats on biodiversity, which showed that pest animals are considered a major cause of biodiversity decline in New South Wales. In addition, this study has illustrated the scale of the pest animal problem in terms of the number and diversity of species at risk and the alien animals posing the threat. While the data have some limitations, the information presented provides a long-overdue baseline from which informed management and policy decisions can now be made, as well as scientific examinations. It is anticipated that the information presented here will stimulate robust discussions on the management of pest animal threats and impacts on biodiversity, which should include the description of threats. Finally, while the data illustrates the pest animal problem for New South Wales at a specific point in time, what is actually required is a national analysis including every state and territory and the Commonwealth, with regular revisions and updates.

9.9 Recommendations

Recommendation 1. A national assessment is needed.

The current assessment only examined threatened species in New South Wales. However, this approach has outlined a process that could be undertaken either in other states or nationally. While the EPBC Act encompasses nationally threatened biodiversity, it does not cover all the threatened biodiversity in Australia and the state's threatened species legislation also does not encompass all the biodiversity contained under the EPBC Act (eg RAMSAR wetlands).

Recommendation 2. An assessment on non-threatened species is needed.

The current study examined threatened species; however, threatened species only account for a small percentage of the native species present in New South Wales that could potentially be at risk from pest animals.

Recommendation 3. Standardised terms are needed to describe threats (including naming the pest animal species).

Standard terms must be used to describe threats, which must include information on the action by which a specific pest animal species poses the threat.

Threat descriptions need to describe specific pest animal species; many of the threat descriptions examined here did not contain information on the specific pest animal threat.

Recommendation 4. Measures are needed to limit the impact of new naturalisations on biodiversity.

As documented for alien fish species, few of the recently naturalised species were recognised as posing a threat to biodiversity, compared to the number of long naturalised species. This implies a lag between naturalisation and impacts to biodiversity. Thus, increased effort is needed to limit the spread of new and recently naturalised pest animal species, particularly fish, before they pose a significant threat to biodiversity.

Recommendation 5. Monitoring programs need to be established for pest animal control programs that assess the response of native species.

Several recent studies highlight the findings of this study, in that there are few data on the response of native species following pest animal control. This is perplexing given the number of pest animal control programs undertaken annually in Australia. Such information is vital for assessing the effectiveness of alien animal control as well as determining the response if native species to control. In addition, such information needs to be stored centrally in order to undertake analysis like the current study.

Recommendation 6. Scientific studies on the impacts of pest animals on native species are needed.

While the current study provides a baseline, a small proportion of the information was based on scientific studies of impacts. In addition, the list of species presented here has not been assessed in the field to determine errors or omissions. Thus these lists should be used as a basis for future scientific investigation.

Recommendation 7. Information on the biodiversity at risk needs to be integrated into pest animal management and policy.

Now that information is available on the threat of pest animals on biodiversity, it should be used to influence future directions in pest animal management (ie ensuring that biodiversity conservation is an outcome) and policies at all levels.

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Appendix 1

Threatened species for which no threat information could be found

Table A Threatened species for which no threat information could be found

Scientific name	Common name	Plant type	Threatened Status under the TSC Act
Babingtonia granitica	granite babingtonia	shrub	Vulnerable
Lastreopsis hispida	bristly shield fern	fern	Endangered
Senecio squarrosus	swamp groundsel	herb	Endangered
Viola cleistogamoides	hidden violet	herb	Endangered

Appendix 2

Threat hierarchy

Explanatory notes on the threat hierarchy

1. The threat hierarchy is outlined in Chapter 3.
2. The numerical representation for each threat category (eg [4]) is used only to make comparisons within the text and is not a representation of order or ranking.
3. When a sub-category of the threat hierarchy could not be determined the letter '**X**' followed by the word 'unspecified' was used.
4. For ease of presentation the individual alien species identified in the 3rd sub-category of the alien species category [4] were truncated to animals and/or plants. The number of each is presented in brackets after the word 'animals' or 'plants' in the outline of the hierarchy below.

Structure of the threat hierarchy

[1] Anthropogenic destruction and disturbance of native vegetation

- 1.1 Destruction (clearing)
  - 1.1.1 Agriculture
  - 1.1.2 Urban and industrial development
  - 1.1.3 Forestry/logging
  - 1.1.4 Mining
  - 1.1.5 Infrastructure development
    - 1.1.5.1 Roads
    - 1.1.5.2 Powerlines
    - 1.1.5.3 Pipelines
    - 1.1.5.X Unspecified
  - 1.1.6 Private landholders
  - 1.1.X Unspecified
- 1.2 Disturbance/modification
  - 1.2.1 Agriculture
    - 1.2.1.1 Grazing
    - 1.2.1.2 Ploughing
    - 1.2.1.X Unspecified
  - 1.2.2 Development
  - 1.2.3 Infrastructure maintenance
    - 1.2.3.1 Roads
    - 1.2.3.2 Powerlines
    - 1.2.3.X Unspecified
  - 1.2.4 Forestry/logging
  - 1.2.5 Human activity
    - 1.2.5.1 Use of vehicles
    - 1.2.5.2 Visitation
    - 1.2.5.3 Recreation
    - 1.2.5.4 Access
    - 1.2.5.5 Illegal tracks
    - 1.2.5.6 Mowing
    - 1.2.5.7 Vandalism
    - 1.2.5.X Unspecified
  - 1.2.6 Mining
  - 1.2.X Unspecified
- 1.3 Collection
  - 1.3.1 Plants
  - 1.3.2 Seeds
  - 1.3.3 Flowers
- 1.4 Other
- 1.X Unspecified

[2] Anthropogenic destruction and disturbance of native fauna

- 2.1 Destruction
  - 2.1.1 Hunting
  - 2.1.2 Fishing
    - 2.1.2.1 Bycatch
    - 2.1.2.2 Commercial
    - 2.1.2.3 Recreational
    - 2.1.2.4 Entanglement
    - 2.1.2.5 Illegal
  - 2.1.3 Human Activity
    - 2.1.3.1 Boat mortality
    - 2.1.3.2 Road mortality
    - 2.1.3.3 Shark nets
  - 2.1.4 Pest Control
    - 2.1.4.1 Targeted
    - 2.1.4.2 Non-targeted
  - 2.1.5 Other
    - 2.1.5.1 Electrocution
    - 2.1.5.2 Collision with powerlines
    - 2.1.5.3 Military operations
    - 2.1.5.4 Food source
    - 2.1.5.5 Loss of pollinator
- 2.2 Disturbance
  - 2.2.1 Roosting
    - 2.2.1.1 Human activity
    - 2.2.1.2 Mining
    - 2.2.1.3 Domestic animals
  - 2.2.2 Nesting
    - 2.2.2.1 Human activity
    - 2.2.2.2 Domestic animals
    - 2.2.2.3 Aircraft
  - 2.2.3 Competition
    - 2.2.3.1 Livestock
    - 2.2.3.2 Unspecified
  - 2.2.X Unspecified
    - 2.2.X.1 A human activity
    - 2.2.X.2 Mining
    - 2.2.X.3 Livestock
    - 2.2.X.4 Domestic dogs
- 2.3 Collection
  - 2.3.1 Eggs
    - 2.3.2.1 Illegal
  - 2.3.2 Individuals
    - 2.3.2.1 Illegal
    - 2.3.2.2 Scientific
    - 2.3.2.X Unspecified
  - 2.3.3 Feathers

Structure of the threat hierarchy

[3] Anthropogenic modification of physical factors

- 3.1 Modification
  - 3.1.1 Hydrology
    - 3.1.1.1 Wetland/swamp drainage
    - 3.1.1.2 Infilling/reclamation wetlands/ swamps
    - 3.1.1.3 Tidal flow regulation
    - 3.1.1.4 River flow/drainage regulation (dams and weirs)
    - 3.1.1.5 Flood regime (mitigation)
    - 3.1.1.6 Up/downstream access
    - 3.1.1.7 Water extraction
    - 3.1.1.8 Debris removal
    - 3.1.1.9 Altered
    - 3.1.1.10 Dumping
    - 3.1.1.11 Permanent water
  - 3.1.2 Geomorphology
    - 3.1.2.1 Erosion
    - 3.1.2.2 Soil moisture levels
    - 3.1.2.3 Removal of ground cover
    - 3.1.2.4 Soil compaction (livestock trampling)
  - 3.1.3 Fire regime
    - 3.1.3.1 Altered
    - 3.1.3.2 Inappropriate
    - 3.1.3.3 Hazard reduction
    - 3.1.3.4 Fire suppression
    - 3.1.3.5 High intensity
    - 3.1.3.6 Too infrequent
    - 3.1.3.7 Too frequent
    - 3.1.3.8 Management
    - 3.1.3.9 Fire/wildfire
    - 3.1.3.10 Arson
    - 3.1.3.11 Peat fire
- 3.2 Degradation (Pollution)
  - 3.2.1 Air pollution
    - 3.2.1.1 Global warming/climate change
    - 3.2.1.2 Ozone depletion
    - 3.2.1.3 Atmospheric
  - 3.2.2 Water pollution
    - 3.2.2.1 Chemical – heavy metals or organo-chlorines
    - 3.2.2.2 Nutrients
    - 3.2.2.3 Sediment/siltation
    - 3.2.2.4 Oil spills
    - 3.2.2.5 Marine pollution
    - 3.2.2.6 Thermal pollution
    - 3.2.2.7 Runoff
    - 3.2.2.8 Pesticide/herbicide
    - 3.2.2.9 Unspecified
  - 3.2.3 Land pollution
    - 3.2.3.1 Nutrients
    - 3.2.3.2 Rubbish/waste dumping and landfill
    - 3.2.3.3 Salinity
    - 3.2.3.4 Acid sulfate soil
    - 3.2.3.5 Sediment
  - 3.2.X Unspecified
    - 3.2.X.1 Herbicides and pesticides
    - 3.2.X.2 Nutrients
    - 3.2.X.3 Runoff/stormwater
- 3.3 Collection
  - 3.3.1 Dead wood/dead trees
  - 3.3.2 Bush rock

[4] Introduction of alien species

- 4.1 Predation
  - 4.1.1 Animals (23 species)
  - 4.1.X Unspecified
- 4.2 Competition
  - 4.2.1 Animals (18 species)
  - 4.2.2 Plants (124 species)
  - 4.2.X Unspecified
- 4.3 Grazing/browsing
  - 4.3.1 Animals (6 species)
  - 4.3.X Unspecified
- 4.4 Degradation by trampling, compaction and invasion and disturbance
  - 4.4.1 Animals (6 species)
  - 4.4.2 Plants (34 species)
  - 4.4.X Unspecified
- 4.5 Control of introduced alien species
  - 4.5.1 Manual control of introduced alien species
    - 4.5.1.1 Bush regeneration
    - 4.5.1.2 Weed control
    - 4.5.1.3 Rabbits control – burrow ripping
    - 4.5.1.4 Mis-identification
  - 4.5.2 Chemical control of introduced alien species
    - 4.5.2.1 Dog and fox baiting (1080)
    - 4.5.2.2 Pesticides (insect and herb)
    - 4.5.2.3 Rodents
- 4.6 New associations
  - 4.6.1 Dependence on introduced alien species
  - 4.6.2 Poor pollinator
- 4.X Unspecified
  - 4.X.1 Mammals
    - 4.X.1.1 Rabbits
    - 4.X.1.2 Pigs
    - 4.X.1.3 Goats

[5] Diseases

- 5.1 Alien
  - 5.1.1 Chytrid fungus
  - 5.1.2 *Phytophthora cinnamomi*
  - 5.1.3 Psittacine circoviral (Beak and Feather)
  - 5.1.4 Unspecified
    - 5.1.4.1 Cats
    - 5.1.4.2 Introduced pathogen
  - 5.1.5 Toxoplasmosis
- 5.2 Native
  - 5.2.1 Dieback – Noisy miner
  - 5.2.2 EHNV – Epizootic haematopoietic necrosis
  - 5.2.3 Chlamydia
- 5.3 Undetermined
  - 5.3.1 Soil borne pathogens
  - 5.3.2 Causes growths
  - 5.3.3 Dieback
- 5.X Unspecified

Structure of the threat hierarchy

[6] Natural Phenomena
- 6.1 Stochastic Events
  - 6.1.1 Flood
  - 6.1.2 Drought
  - 6.1.3 Extreme temperature
  - 6.1.4 Landslip/rockfalls
  - 6.1.5 Cyclone
- 6.2 Native Species
  - 6.2.1 Competition
  - 6.2.2 Grazing
  - 6.2.3 Predation
  - 6.2.4 Habitat degradation
- 6.3 Unnatural native animal effects
  - 6.3.1 Expansion of native ranges
    - 6.3.1.1 Animals
    - 6.3.1.2 Plants
  - 6.3.2 Abnormal increases in native abundance
    - 6.3.2.1 Animals
- 6.4 Intrinsic factors
  - 6.4.1 Low genetic diversity
  - 6.4.2 Low population
  - 6.4.3 Limited distribution
  - 6.4.4 Limited suitable habitat
  - 6.4.5 Poor reproductivity
  - 6.4.6 Low seed viability/production
  - 6.4.7 Remnant populations
  - 6.4.8 Low regenerative capacity
  - 6.4.9 Hybridisation

[7] Other
- 7.1 Lack of knowledge
- 7.2 Outside of conservation area

Appendix 3

Pest animal species identified as posing a threat to threatened biodiversity in New South Wales

Information on pest animal threats to threatened biodiversity in New South Wales listed under the NSW *Threatened Species Conservation Act 1995* and NSW *Fisheries Management Act 1994* was compiled from a wide range of sources (see Chapter 3 for further information). The pest animal species identified and the biodiversity threatened by each is presented in Table B, along with information on whether the pest animal species is listed as a Key Threatening Process [in New South Wales] and the action through which the pest animal species posed the threat to each specific threatened species.

Note: The list of pest animal species presented in Table B only accounts for 322 of the 388 threatened species threatened by pest animals, the remaining 66 were only identified as being at threat from pest animals generically and are presented in Table C below.

Table B Pest animal species identified in the data set as impacting on threatened biodiversity in New South Wales and the biodiversity identified as at risk

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Amniataba percoides (banded grunter)	y	c, p	**1**	Animal	*Maccullochella ikei*
Apis mellifera (honey bee)	y	c	**14**	Animal	*Cacatua leadbeateri*
		c		Animal	*Calyptorhychus lathami*
		c		Animal	*Ninox connivens*
		c		Animal	*Petaurus australis*
		c		Animal	*Petaurus norfolcensis*
		c		Animal	*Phascogale tapoatafa*
		c		Animal	*Polytelis anthopeplus*
		c		Animal	*Polytelis swainsonii*
		po		Plant	*Persoonia acerosa*
		po		Plant	*Persoonia bargoensis*
		po		Plant	*Persoonia glaucescens*
		po		Plant	*Persoonia hirsuta*
		po		Plant	*Persoonia marginata*
		c		Popn	*Calyptorhyncus lathami*
Bufo marinus (cane toad)	y	p	**9**	Animal	*Crinia tinnula*
		i		Animal	*Dasyurus maculatus*
		i		Animal	*Hoplocephalus bitorquatus*
		i		Animal	*Hoplocephalus stephensii*
		p		Animal	*Litoria aurea*
		p		Animal	*Litoria brevipalmata*
		p		Animal	*Litoria olongburensis*
		p		Animal	*Planigale maculata*
		p		EEC	Freshwater wetlands on coastal floodplains
Canis lupus familiaris (wild dog)	n	cn	**39**	Animal	*Antechinomys laniger*
		p		Animal	*Burhinus grallarius*
		p		Animal	*Cercartetus nanus*
		p		Animal	*Esacus neglectus*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Canis lupus familiaris (wild dog) [continued]	n	p	**39**	Animal	*Gallirallus sylvestris*
		p		Animal	*Grus rubicunda*
		p		Animal	*Haematopus fuliginosus*
		p		Animal	*Haematopus longirostris*
		p		Animal	*Isoodon obesulus*
		p		Animal	*Menura alberti*
		p		Animal	*Ninox strenua*
		p		Animal	*Notomys fuscus*
		p		Animal	*Petrogale penicillata*
		p		Animal	*Phaethon rubricauda*
		p		Animal	*Phascolarctos cinereus* (2 populations - Hawks Nest and Teas Gardens)
		p		Animal	*Potorous longipes*
		p		Animal	*Potorous tridactylus*
		p, cn		Animal	*Pseudomys apodemoides*
		cn		Animal	*Pseudomys bolami*
		cn		Animal	*Pseudomys hermannsburgensis*
		p		Animal	*Pseudomys fumeus*
		p		Animal	*Pseudomys gracilicaudatus*
		p		Animal	*Puffinus assimilus*
		p		Animal	*Puffinus carneipes*
		p		Animal	*Pyrrholaemus sagittata*
		p		Animal	*Sminthopsis leucopus*
		p		Animal	*Sterna albifrons*
		p		Animal	*Sterna fuscata*
		p		Animal	*Thinornis rubricollis*
		p		Animal	*Tympanocryptus pinguicolla*
		p		Animal	*Varanus rosenbergi*
		p		Popn	*Alectura lathami*
		p		Popn	*Dromaius novaehollandiae*
		p		Popn	*Eudyptula minor*
		p		Popn	*Perameles nasuta*
		p		Popn	*Petaurus norfolcensis*
		p		Popn	*Phascolarctos cinereus*
		p		EEC	Byron Bay Dwarf Graminoid Clay Heath
Capra hircus (feral goat)	y	h	**94**	Animal	*Amytornis textilis*
		h		Animal	*Aprasia inaurita*
		h		Animal	*Ctenophorus decresii*
		h		Animal	*Ctenotus pantherinus ocellifer*
		h		Animal	*Cyclodomorphus melanops elongata*
		h		Animal	*Cyclodomorphus venustus*
		h		Animal	*Delma australis*
		h		Animal	*Diplodactylus elderi*
		h		Animal	*Echiopsis curta*
		h		Animal	*Egernia margaretae*
		h		Animal	*Hoplocephalus bungaroides*
		c		Animal	*Leggadina forresti*
		h		Animal	*Leipoa ocellata*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Capra hircus (feral goat) [continued]	y	h	**94**	Animal	*Lerista xanthura*
		h		Animal	*Macropus dorsalis*
		h		Animal	*Paralucia spinifera*
		c		Animal	*Petrogale penicillata*
		c		Animal	*Petrogale xanthopus*
		c		Animal	*Pseudomys hermannsburgensis*
		h		Animal	*Pterodroma neglecta*
		h		Animal	*Pterodroma nigripennis*
		h		Animal	*Pterodroma solandri*
		h		Animal	*Ramphotyphlops endoterus*
		h		Animal	*Underwoodisaurus sphyrurus*
		g		Plant	*Acacia carneorum*
		g, h		Plant	*Acacia curranii*
		h		Plant	*Acacia notabilis*
		h		Plant	*Acacia petraea*
		g		Plant	*Acacia pycnostachya*
		g		Plant	*Angophora exul*
		g, h		Plant	*Astrotricha roddii*
		g, h		Plant	*Bertya ingramii*
		g		Plant	*Bertya* sp. A Cobar-Coolabah
		g		Plant	*Boronia boliviensis*
		g		Plant	*Boronia granitica*
		g		Plant	*Boronia ruppii*
		g, h		Plant	*Cadellia pentastylis*
		g		Plant	*Callitris oblonga*
		h		Plant	*Capparis loranthifolia* var. *loranthifolia*
		g, h		Plant	*Cheilanthes sieberi* subsp. *pseudovellea*
		g, h		Plant	*Cratystylis conocephala*
		g		Plant	*Crotalaria cunninghamii*
		g		Plant	*Cynanchum elegans*
		h		Plant	*Dipteracanthus australasicus* subsp. *corynothecus*
		g		Plant	*Diuris aequalis*
		h		Plant	*Diuris tricolor*
		g, h		Plant	*Dodonaea microzyga*
		g, h		Plant	*Dodonaea sinuolata* subsp. *acrodentata*
		g		Plant	*Dodonaea stenozyga*
		h		Plant	*Eriocaulon carsonii*
		g, h		Plant	*Goodenia occidentalis*
		g, h		Plant	*Grevillea beadleana*
		g		Plant	*Grevillea iaspicula*
		g		Plant	*Grevillea kennedyana*
		g		Plant	*Hakea fraseri*
		g		Plant	*Homoranthus binghiensis*
		g, h		Plant	*Homoranthus bornhardtiensis*
		g, h		Plant	*Homoranthus croftianus*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Capra hircus (feral goat) [continued]	y	g, h	**94**	Plant	*Homoranthus lunatus*
		g, h		Plant	*Homoranthus prolixus*
		g, h		Plant	*Indigofera helmsii*
		h		Plant	*Indigofera leucotricha*
		h		Plant	*Indigofera longibractea*
		g		Plant	*Leionema ralstonii*
		g		Plant	*Leucopogon confertus*
		g, h		Plant	*Micromyrtus grandis*
		g		Plant	*Microtis angusii*
		g, h		Plant	*Monotaxis macrophylla*
		g, h		Plant	*Phebalium glandulosum* subsp. *eglandosum*
		g, h		Plant	*Pimelea venosa*
		g		Plant	*Polygala linariifolia*
		g		Plant	*Pomaderris pallida*
		g, h		Plant	*Prostanthera staurophylla*
		g, h		Plant	*Pseudanthus ovalifolius*
		g, h		Plant	*Pterostylis cobarensis*
		g		Plant	*Pultenaea* sp. Genowlan Point
		g		Plant	*Swainsona adenophylla*
		g, h		Plant	*Swainsona colutoides*
		g, h		Plant	*Swainsona pyrophila*
		g		Plant	*Swainsona viridis*
		g		Plant	*Westringia kydrensis*
		g, h		Plant	*Xerothamnella parvifolia*
		h		Plant	*Zieria adenophora*
		g		Plant	*Zieria buxijugum*
		g		Plant	*Zieria floydii*
		g		Plant	*Zieria parrisiae*
		g		Popn	*Calyptorhyncus lathami*
		u		Popn	*Darwinia fascicularis* subsp. *oligantha*
		g		EEC	*Acacia loderi* Shrublands
		g		EEC	Artesian Springs Ecological Community
		g		EEC	Brigalow-Gidgee woodland/ shrubland
		g, h		EEC	*Cadellia pentastylis* (Ooline) community
		g		EEC	Howell Shrublands
		h		EEC	Montane peatlands and swamps
Carassius auratus (goldfish)	y	c, p	**2**	EEC	Aquatic ecological community in the natural drainage system of the lower Murray River catchment
		c, p		EEC	Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River
Columba livia (feral pigeon)	n	c	**1**	Animal	*Procelsterna cerulea*
Cyprinus carpio (European carp)	y	c	**5**	Animal	*Bidyanus bidyanus*
		p		Animal	*Litoria daviesae*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Cyprinus carpio (European carp) [continued]	y	p	**5**	Animal	*Litoria raniformis*
		c, p		EEC	Aquatic ecological community in the natural drainage system of the lower Murray River catchment
		c, p		EEC	Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River
Equus caballus (feral horse)	n	h	**15**	Animal	*Litoria verreuxii alpina*
		h		Animal	*Pseudophryne corroboree*
		h		Animal	*Pseudophryne pengilleyi*
		g, h		Plant	*Carex archeri*
		h		Plant	*Carex raleighii nelmes*
		g		Plant	*Dipteracanthus australasicus* subsp. *corynothecus*
		g		Plant	*Diuris aequalis*
		h		Plant	*Euchiton nitidulus*
		g		Plant	*Euphrasia ciliolata*
		h		Plant	*Prasophyllum bagoensis*
		g		Plant	*Ranunculus anemoneus*
		g, h		Plant	*Tasmannia glaucifolia*
		g, h		EEC	Eastern Suburbs Banksia Scrub
		h		EEC	Montane peatlands and swamps
		g		EEC	Sun Valley Cabbage Gum Forest
Felis catus (feral cat)	y	p	**117**	Animal	*Aepyprymnus rufescens*
		p		Animal	*Amaurornis olivaceaus*
		p		Animal	*Amytornis barbatus*
		p		Animal	*Amytornis striatus*
		p		Animal	*Amytornis textilis*
		p		Animal	*Antechinomys laniger*
		p		Animal	*Ardeotis australis*
		p		Animal	*Aspidites ramsayi*
		p		Animal	*Atrichornis rufescens*
		p		Animal	*Botaurus poiciloptilus*
		p		Animal	*Burhinus grallarius*
		p		Animal	*Burramys parvus*
		p		Animal	*Calamanthus cautus*
		p		Animal	*Calamanthus fuliginosus*
		p		Animal	*Cercartetus concinnus*
		p		Animal	*Cercartetus nanus*
		p		Animal	*Chalinolobus picatus*
		p		Animal	*Cinclosoma castanotus*
		p		Animal	*Ctenophorus decresii*
		p		Animal	*Ctenotus brooksi*
		p		Animal	*Ctenotus pantherinus ocellifer*
		p		Animal	*Cyclodomorphus venustus*
		p		Animal	*Dasyornis brachypterus*
		c, d, p		Animal	*Dasyurus maculatus*
		c, d, p		Animal	*Dasyurus viverrinus*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Felis catus (feral cat) [continued]	y	p	**117**	Animal	*Demansia torquata*
		p		Animal	*Diomedea gibsoni*
		p		Animal	*Diplodactylus elderi*
		p		Animal	*Diplodactylus stenodactylus*
		p		Animal	*Drymodes brunneopygia*
		p		Animal	*Esacus neglectus*
		p		Animal	*Eulamprus leuraensis*
		p		Animal	*Fregetta grallaria*
		p		Animal	*Gallirallus sylvestris*
		p		Animal	*Geophaps scripta*
		p		Animal	*Gygis alba*
		p		Animal	*Haematopus fuliginosus*
		p		Animal	*Haematopus longirostris*
		p		Animal	*Hoplocephalus bungaroides*
		p		Animal	*Isoodon obesulus*
		p		Animal	*Ixobrychus flavicollis*
		p		Animal	*Leggadina forresti*
		p		Animal	*Lerista xanthura*
		p		Animal	*Liasis stimsoni*
		p		Animal	*Litoria aurea*
		p		Animal	*Litoria castanea*
		p		Animal	*Macronectes giganteus*
		p		Animal	*Macronectes halli*
		p		Animal	*Macropus dorsalis*
		p		Animal	*Macropus parma*
		p		Animal	*Mastacomys fuscus*
		p		Animal	*Menura alberti*
		p		Animal	*Miniopterus schreibersii oceanensis*
		p		Animal	*Neobatrachus pictus*
		p		Animal	*Neophema chrysogaster*
		p		Animal	*Neophema pulchella*
		p		Animal	*Ninox connivens*
		p		Animal	*Ninox strenua*
		p		Animal	*Notomys fuscus*
		p		Animal	*Nurus atlas*
		p		Animal	*Nurus brevis*
		p		Animal	*Oedura rhombif*
		p		Animal	*Pachycephala olivacea*
		p		Animal	*Pachycephala rufogularis*
		p		Animal	*Petaurus australis*
		p		Animal	*Petaurus norfolcensis*
		p		Animal	*Petrogale xanthopus*
		p		Animal	*Pezoporus wallicus*
		p		Animal	*Phaethon rubricauda*
		p		Animal	*Phaps histrionica*
		p		Animal	*Phascogale tapoatafa*
		p		Animal	*Planigale maculata*
		p		Animal	*Potorous longipes*
		p		Animal	*Potorous tridactylus*
		p		Animal	*Pseudomys apodemoides*
		p		Animal	*Pseudomys bolami*
		p		Animal	*Pseudomys delicatus*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Felis catus (feral cat) [continued]	y	p	**117**	Animal	*Pseudomys fumeus*
		p		Animal	*Pseudomys gracilicaudatus*
		p		Animal	*Pseudomys hermannsburgensis*
		p		Animal	*Pseudomys oralis*
		p		Animal	*Pseudomys pilligaensis*
		p		Animal	*Pseudonaja modesta*
		p		Animal	*Pterodroma neglecta*
		p		Animal	*Pterodroma nigripennis*
		p		Animal	*Pterodroma solandri*
		p		Animal	*Puffinus assimilus*
		p		Animal	*Puffinus carneipes*
		p		Animal	*Pyrrholaemus brunneus*
		p		Animal	*Pyrrholaemus sagittata*
		p		Animal	*Rostratula benghalensis*
		p		Animal	*Simoselaps fasciolatus*
		p		Animal	*Sminthopsis leucopus*
		p		Animal	*Sminthopsis macroura*
		p		Animal	*Sterna albifrons*
		p		Animal	*Thinornis rubricollis*
		p		Animal	*Thylogale stigmatica*
		p		Animal	*Tiliqua mutifasciata*
		p		Animal	*Tiliqua occipitalis*
		p		Animal	*Turnix melanogaster*
		p		Animal	*Tympanocryptus pinguicolla*
		p		Animal	*Underwoodisaurus sphyrurus*
		p		Animal	*Varanus rosenbergi*
		p		Animal	*Vespadelus baverstocki*
		p		Animal	*Vespadelus troughtoni*
		p		Popn	*Alectura lathami*
		p		Popn	*Callocephalon fimbriatum*
		p		Popn	*Dromaius novaehollandiae*
		p		Popn	*Eudyptula minor*
		p		Popn	*Mastacomys fuscus*
		p		Popn	*Perameles nasuta*
		p		Popn	*Petaurus norfolcensis* (2 populations - Barrenjoey Peninsula and Wagga Wagga)
		p		Popn	*Potorus tridactylus*
		p		EEC	Brigalow within the Brigalow Belt South Nandewar and Darling Riverine Plains
		p		EEC	Brigalow-Gidgee woodland/ shrubland
		p		EEC	Byron Bay Dwarf Graminoid Clay Heath
Gallirallus philippensis (buff banded rail)	n	c	**1**	Animal	*Gallirallus sylvestris*
Gambusia holbrookii (gambusia)		c		Animal	*Bidyanus bidyanus*
		c, p		Animal	*Craterocephalus fluviatilis*
		p		Animal	*Crinia tinnula*
		p		Animal	*Litoria aurea*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Gambusia holbrookii (gambusia) [continued]	y	p	**19**	Animal	*Litoria castanea*
		p		Animal	*Litoria daviesae*
		p		Animal	*Litoria olongburensis*
		p		Animal	*Litoria raniformis*
		c		Animal	*Maccullochella macquariensis*
		c		Animal	*Macquaria australasica*
		p		Animal	*Mixophyes balbus*
		c, p		Animal	*Nannoperca australis*
		c		Animal	*Nonnoperca oxleyana*
		p		Popn	*Adelotus brevis*
		p		Popn	*Ambassis agassizii*
		p		Popn	*Mogurnda adspersa*
		c, p		EEC	Aquatic ecological community in the natural drainage system of the lower Murray River catchment
		c, p		EEC	Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River
		p		EEC	Freshwater wetlands on coastal floodplains
Lygosoma bowringii (grass skink)	n	c	**2**	Animal	*Christinus guentheri*
		c		Animal	*Cyclodina lichenigera*
Misgurnus anquillicaudatus (Oriental weatherloach)	y	c, p	**1**	EEC	Aquatic ecological community in the natural drainage system of the lower Murray River catchment
Mus domesticus (house mouse)	n	c	**4**	Animal	*Leggadina forresti*
		c		Animal	*Pseudomys bolami*
		c		Animal	*Pseudomys hermannsburgensis*
		c		Animal	*Pseudomys pilligaensis*
Ochrogaster lunifer (bag-shelter moth)	n	g	**1**	EEC	Myall Woodland
Onchorhyncus mykiss (rainbow trout)	y	p	**2**	Animal	*Litoria booroolongensis*
		p		Animal	*Litoria daviesae*
Oryctolagus cuniculus (feral rabbit)	y	c	**86**	Animal	*Aepyprymnus rufescens*
		h		Animal	*Amytornis textilis*
		g		Animal	*Aprasia inaurita*
		g		Animal	*Aprasia parapulchella*
		cn		Animal	*Ardeotis australis*
		g		Animal	*Cercartetus nanus*
		g		Animal	*Ctenophorus decresii*
		g		Animal	*Cyclodomorphus melanops elongata*
		g		Animal	*Cyclodomorphus venustus*
		g		Animal	*Delma australis*
		g		Animal	*Delma impar*
		g		Animal	*Echiopsis curta*
		g		Animal	*Geophaps scripta*
		h		Animal	*Lasiorhinus latifrons*
		c		Animal	*Leggadina forresti*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Oryctolagus cuniculus (feral rabbit) [continued]	y	c	**86**	Animal	*Leipoa ocellata*
		g		Animal	*Macronectes giganteus*
		h		Animal	*Macronectes halli*
		h		Animal	*Macropus dorsalis*
		h		Animal	*Notomys fuscus*
		c		Animal	*Pedionomus torquatus*
		c		Animal	*Petrogale penicillata*
		c		Animal	*Petrogale xanthopus*
		g		Animal	*Phaps histrionica*
		h		Animal	*Poephila cincta*
		cn		Animal	*Polytelis anthopeplus*
		c		Animal	*Pseudomys apodemoides*
		h		Animal	*Pseudomys bolami*
		c		Animal	*Pseudomys fumeus*
		c		Animal	*Pseudomys hermannsburgensis*
		g		Animal	*Pterodroma leucoptera leucoptera*
		h		Animal	*Pterodroma neglecta*
		h		Animal	*Rattus villosissimus*
		g		Animal	*Tympanocryptus pinguicolla*
		g		Animal	*Xanthomyza phrygia*
		g, h		Plant	*Acacia carneorum*
		g		Plant	*Acacia curranii*
		g, h		Plant	*Atriplex infrequens*
		g		Plant	*Atriplex sturtii*
		g, h		Plant	*Austrostipa metatoris*
		g, h		Plant	*Austrostipa nullanulla*
		g		Plant	*Austrostipa wakoolica*
		u		Plant	*Caladenia concolor*
		g		Plant	*Callitris oblonga*
		h		Plant	*Capparis loranthifolia var. loranthifolia*
		h		Plant	*Casuarina obesa*
		g, h		Plant	*Cratystylis conocephala*
		h		Plant	*Crotalaria cunninghamii*
		g		Plant	*Cynanchum elegans*
		g		Plant	*Dichanthium setosum*
		h		Plant	*Diuris tricolor*
		u		Plant	*Eleocharis obicis*
		h		Plant	*Erodiophyllum elderi*
		g		Plant	*Gentiana wissmannii*
		g		Plant	*Grevillea kennedyana*
		g		Plant	*Hakea pulvinifera*
		g		Plant	*Homoranthus bornhardtiensis*
		g		Plant	*Homoranthus croftianus*
		u		Plant	*Homoranthus darwinioides*
		g		Plant	*Indigofera helmsii*
		g		Plant	*Indigofera longibractea*
		g, h		Plant	*Ipomoea polymorpha*
		g		Plant	*Lepidium aschersonii*
		g		Plant	*Lepidium hyssopifolium*
		g		Plant	*Lepidium monoplocoides*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Oryctolagus cuniculus (feral rabbit) [continued]	y	g	**86**	Plant	*Micromyrtus grandis*
		g		Plant	*Microtis angusii*
		h		Plant	*Pimelea elongata*
		g		Plant	*Polygala linariifolia*
		g		Plant	*Prasophyllum petilum*
		g		Plant	*Ranunculus anemoneus*
		h		Plant	*Swainsona colutoides*
		g		Plant	*Swainsona murrayana*
		g, h		Plant	*Swainsona pyrophila*
		g		Plant	*Swainsona viridis*
		g		Plant	*Thesium australe*
		h		Plant	*Xerothamnella parvifolia*
		g		Plant	*Zieria baeuerlenii*
		g		Popn	*Calyptorhyncus lathami*
		c		Popn	*Mastacomys fuscus*
		g		EEC	*Acacia loderi* Shrublands
		g		EEC	Artesian Springs Ecological Community
		g		EEC	Dry Rainforest of the South East Forests
		g		EEC	Eastern Suburbs Banksia Scrub
		u		EEC	Howell Shrublands
		g		EEC	*Melaleuca armillaris* Tall Shrubland Illawarra Subtropical Rainforest
Perca fluviatalis (redfin perch)	y	c, d	**9**	Animal	*Bidyanus bidyanus*
		c, p		Animal	*Craterocephalus fluviatilis*
		c		Animal	*Maccullochella macquariensis*
		c, d		Animal	*Macquaria australasica*
		c, p		Animal	*Nannoperca australis*
		p		Popn	*Ambassis agassizii*
		p		Popn	*Mogurnda adspersa*
		c, p		EEC	Aquatic ecological community in the natural drainage system of the lower Murray River catchment
		c, p		EEC	Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River
Physa acuta [a freshwater snail]	n	c, p	**2**	EEC	Aquatic ecological community in the natural drainage system of the lower Murray River catchment
Physa acuta [a freshwater snail] [continued]	n	c, p	**2**	EEC	Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River
Rattus norvegicus (brown rat)	n	p	**3**	Animal	*Pterodroma neglecta*
		p		Animal	*Pterodroma nigripennis*
		p		Animal	*Puffinus assimilus*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Rattus rattus (black rat)	y	p	**5**	Animal	*Christinus guentheri*
		p		Animal	*Dryococelus australis*
		p		Animal	*Macronectes halli*
		P		Animal	*Placostylus bivaricosus*
		P		Animal	*Cyclodina lichenigera*
Salmo trutta (brown trout)	y	p	**2**	Animal	*Litoria booroolongensis*
		p		Animal	*Litoria daviesae*
Sus scrofa (feral pig)	y	c	**81**	Animal	*Aepyprymnus rufescens*
		g		Animal	*Aprasia inaurita*
		p		Animal	*Burhinus grallarius*
		p		Animal	*Caretta caretta*
		p		Animal	*Chelonia mydas*
		h		Animal	*Cyclodomorphus melanops elongata*
		h		Animal	*Cyclodomorphus venustus*
		h		Animal	*Dasyornis brachypterus*
		h		Animal	*Delma australis*
		p		Animal	*Dermochelys coriacea*
		p		Animal	*Diomedea antipodensis*
		p		Animal	*Diomedea gibsoni*
		h		Animal	*Echiopsis curta*
		h		Animal	*Esacus neglectus*
		h		Animal	*Grus rubicunda*
		h		Animal	*Isoodon obesulus*
		p		Animal	*Mixophyes fleayi*
		p		Animal	*Mixophyes iteratus*
		h		Animal	*Paralucia spinifera*
		c		Animal	*Potorous longipes*
		p		Animal	*Pseudomys pilligaensis*
		h		Animal	*Pseudophryne corroboree*
		h		Animal	*Pseudophryne pengilleyi*
		h		Animal	*Pterodroma nigripennis*
		h		Animal	*Pterodroma solandri*
		h		Animal	*Turnix maculosa*
		h		Plant	*Acacia clunies rossiae*
		h		Plant	*Almaleea cambagei*
		h		Plant	*Asterolasia* sp. Dungowan Creek
		h		Plant	*Baloskion longipes*
		h		Plant	*Boronia deanei*
		h		Plant	*Calotis glandulosa*
		h		Plant	*Calotis pubescens*
		h		Plant	*Carex raleighii*
		g, h		Plant	*Chiloglottis anaticeps*
		g, h		Plant	*Chiloglottis platyptera*
		g, h		Plant	*Cryptostylis hunteriana*
		h		Plant	*Cullen parvum*
		g		Plant	*Cynanchum elegans*
		g, h		Plant	*Diuris pedunculata*
		g		Plant	*Diuris venosa*
		u		Plant	*Eleocharis obicis*
		h		Plant	*Eriocaulon carsonii*
		h		Plant	*Eucalyptus camphora* subsp. *relicta*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Sus scrofa (feral pig) [continued]	y	g, h	**81**	Plant	*Euphrasia ciliolata*
		g		Plant	*Euphrasia orthocheila* subsp. *peraspera*
		h		Plant	*Euphrasia scabra*
		h		Plant	*Gentiana bredboensis*
		h		Plant	*Gentiana wissmannii*
		h		Plant	*Goodenia macbarronii*
		h		Plant	*Grevillea scortechinii* subsp. *sarmentosa*
		h		Plant	*Homoranthus prolixus*
		g		Plant	*Lepidium monoplocoides*
		g, h		Plant	*Osteocarpum scleropterum*
		g, h		Plant	*Phaius australis*
		g, h		Plant	*Phaius tankarvilleae*
		h		Plant	*Philotheca myoporoides* subsp. *obovatifolia*
		h		Plant	*Prasophyllum bagoensis*
		h		Plant	*Prasophyllum morganii*
		h		Plant	*Pterostylis cucullata*
		g		Plant	*Pterostylis elegans*
		g		Plant	*Pterostylis saxicola*
		h		Plant	*Pultenaea parrisiae* subsp. *parrisiae*
		h		Plant	*Rutidosis leiolepis*
		g, h		Plant	*Tasmannia glaucifolia*
		h		Plant	*Tasmannia purpurascens*
		g		Plant	*Tetratheca juncea*
		g		Plant	*Trachymene saniculifolia*
		h		Popn	*Alectura lathami*
		p		Popn	*Dromaius novaehollandiae*
		c		Popn	*Potorus tridactylus*
		g, h		EEC	Artesian Springs Ecological Community
		h		EEC	Ben Halls Gap National Park Sphagnum Moss Cool Temperate Rainforest
		h		EEC	Freshwater wetlands on coastal floodplains
		h		EEC	Montane peatlands and swamps
		g, h		EEC	River-flat eucalypt forest on coastal floodplains
		h		EEC	Semi-evergreen Vine Thicket
		g, h		EEC	Sub-tropical Coastal floodplain forest
		g, h		EEC	Swamp sclerophyll forest on the coastal floodplains
	y	g, h		EEC	Swamp-oak floodplain forest
		h		EEC	White Box Yellow Box Blakely's Red Gum Woodland
Tinca tinca (tench)	y	c, p	**1**	EEC	Aquatic ecological community in the natural drainage system of the lower Murray River catchment

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Turdus merula (blackbird)	n	p	**2**	Animal	*Pericryptodrilus nanus*
		p		Animal	*Placostylus bivaricosus*
Turdus philomelos (song thrush)	n	p	**2**	Animal	*Pericryptodrilus nanus*
		p		Animal	*Placostylus bivaricosus*
Tyto novaehollandiae (masked owl)	n	p	**2**	Animal	*Gallirallus sylvestris*
		p		Animal	*Gygis alba*
Vulpes vulpes (red fox)	y	p	**111**	Animal	*Aepyprymnus rufescens*
		p		Animal	*Amaurornis olivaceaus*
		p		Animal	*Amytornis barbatus*
		p		Animal	*Amytornis striatus*
		p		Animal	*Amytornis textilis*
		p		Animal	*Anseranas semipalmata*
		p		Animal	*Antechinomys laniger*
		p		Animal	*Ardeotis australis*
		p		Animal	*Aspidites ramsayi*
		p		Animal	*Atrichornis rufescens*
		p		Animal	*Botaurus poiciloptilus*
		p		Animal	*Burhinus grallarius*
		p		Animal	*Burramys parvus*
		p		Animal	*Calamanthus cautus*
		p		Animal	*Calamanthus fuliginosus*
		p		Animal	*Caretta caretta*
		p		Animal	*Cercartetus concinnus*
		p		Animal	*Cercartetus nanus*
		p		Animal	*Chelonia mydas*
		p		Animal	*Cinclosoma castanotus*
		p		Animal	*Ctenophorus decresii*
		p		Animal	*Ctenotus brooksi*
		p		Animal	*Ctenotus pantherinus ocellifer*
		p		Animal	*Cyclodomorphus melanops elongata*
		p		Animal	*Cyclodomorphus venustus*
		p		Animal	*Dasyornis brachypterus*
		c, p		Animal	*Dasyurus maculatus*
		c, p		Animal	*Dasyurus viverrinus*
		p		Animal	*Delma australis*
		p		Animal	*Demansia torquata*
		p		Animal	*Dermochelys coriacea*
		p		Animal	*Diplodactylus elderi*
		p		Animal	*Diplodactylus stenodactylus*
		p		Animal	*Drymodes brunneopygia*
		p		Animal	*Echiopsis curta*
		p		Animal	*Elseya belli*
		p		Animal	*Emydura macquarii*
		p		Animal	*Erythrotriorchis radiatus*
		p		Animal	*Geophaps scripta*
		p		Animal	*Haematopus fuliginosus*
		p		Animal	*Haematopus longirostris*
		p		Animal	*Hoplocephalus bungaroides*
		p		Animal	*Isoodon obesulus*
		p		Animal	*Ixobrychus flavicollis*
		p		Animal	*Leggadina forresti*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Vulpes vulpes (red fox) [continued]	y	p	**111**	Animal	*Leipoa ocellata*
		p		Animal	*Lerista xanthura*
		p		Animal	*Liasis stimsoni*
		p		Animal	*Litoria aurea*
		p		Animal	*Litoria castanea*
		p		Animal	*Macronectes giganteus*
		p		Animal	*Macropus dorsalis*
		p		Animal	*Macropus parma*
		p		Animal	*Mastacomys fuscus*
		p		Animal	*Menura alberti*
		p		Animal	*Miniopterus schreibersii oceanensis*
		p		Animal	*Neobatrachus pictus*
		p		Animal	*Neophema chrysogaster*
		p		Animal	*Neophema pulchella*
		p		Animal	*Ninox connivens*
		p		Animal	*Ninox strenua*
		p		Animal	*Notomys fuscus*
		p		Animal	*Oedura rhombif*
		p		Animal	*Pachycephala olivacea*
		p		Animal	*Pachycephala rufogularis*
		p		Animal	*Pedionomus torquatus*
		p		Animal	*Petaurus australis*
		p		Animal	*Petaurus norfolcensis*
		p		Animal	*Petrogale penicillata*
		p		Animal	*Petrogale xanthopus*
		p		Animal	*Pezoporus wallicus*
		p		Animal	*Phaethon rubricauda*
		p		Animal	*Phaps histrionica*
		p		Animal	*Phascogale tapoatafa*
		p		Animal	*Planigale maculata*
		p		Animal	*Potorous longipes*
		p		Animal	*Potorous tridactylus*
		p		Animal	*Pseudomys apodemoides*
		p		Animal	*Pseudomys bolami*
		p		Animal	*Pseudomys delicatus*
		p		Animal	*Pseudomys fumeus*
		p		Animal	*Pseudomys gracilicaudatus*
		p		Animal	*Pseudomys hermannsburgensis*
		p		Animal	*Pseudomys oralis*
		p		Animal	*Pseudomys pilligaensis*
		p		Animal	*Pseudonaja modesta*
		p		Animal	*Puffinus carneipes*
		p		Animal	*Pyrrholaemus sagittata*
		p		Animal	*Rostratula benghalensis*
		p		Animal	*Simoselaps fasciolatus*
		p		Animal	*Sminthopsis leucopus*
		p		Animal	*Sminthopsis macroura*
		p		Animal	*Sterna albifrons*
		p		Animal	*Thinornis rubricollis*
		p		Animal	*Thylogale stigmatica*
		p		Animal	*Tiliqua mutifasciata*

Pest animal species identified as posing a threat to biodiversity in New South Wales [a]	Species listed as a KTP [b]	Threat action [c]	Total biodiversity threatened	Type [d]	Threatened Species at risk [e, f]
Vulpes vulpes (red fox) [continued]	y	p	**111**	Animal	*Tiliqua occipitalis*
		p		Animal	*Turnix melanogaster*
		p		Animal	*Underwoodisaurus sphyrurus*
		p		Animal	*Vespadelus troughtoni*
		p		Popn	*Alectura lathami*
		p		Popn	*Dromaius novaehollandiae*
		p		Popn	*Eudyptula minor*
		p		Popn	*Mastacomys fuscus*
		p		Popn	*Perameles nasuta*
		p		Popn	*Petaurus norfolcensis* (2 populations - Barrenjoey Peninsula and Wagga Wagga)
		p		Popn	*Potorus tridactylus*
		p		EEC	Brigalow with in the Brigalow Belt South Nandewar and Darling Riverine Plains
		p		EEC	Brigalow-Gidgee woodland/ shrubland
		p		EEC	Byron Bay Dwarf Graminoid Clay Heath

[a] Pest animal species posing a threat to biodiversity as identified in the data set (see Chapter 3 for further details). Pest animal species are presented in alphabetical order scientific name (common name) format.

[b] Whether the pest animal species was listed as a Key Threatening Process under the NSW *Threatened Species Conservation Act 1995* (TSC Act), as at 1 January 2006.

[c] The actions identified in the data set by which each pest animal threatened biodiversity in New South Wales (see Chapter 3 for further details). The threat actions are: **c** = competition, **cn** = control, **d** = disease, **g** = grazing/ browsing, **h** = habitat degradation, **i** = ingestion of alien species, **p** = predation, **po** = poor pollinator and, **u** = action not specified.

[d] The type of biodiversity is described as: **Plant** = plant species, **Animal** = animal species, **Popn** = Threatened Population, and **EEC** = Endangered Ecological Community, based on listings under the TSC and FM Acts (see below)

[e] Threatened Species refers to all biodiversity (ie species, populations and ecological communities) listed in Schedules 1 and 2 of the TSC Act and Schedules 4 and 5 of the NSW *Fisheries Management Act 1994* (FM Act), as at January 1 2006.

[f] For all threatened animal species that are described to subspecies level the three names are present without the word subspecies, consistent with the literature, however, for all such threatened plant species the words 'subsp.' or 'var.' have been used to distinguish the 'subspecies' and 'variety', again consistent with the literature.

Table C Pest animals that were impacting on threatened biodiversity in New South Wales which were identified in the data set as general groups only.

Generic pest animal group identified as posing a threat to biodiversity [a]	Total biodiversity threatened	Threat action [c]	Type [d]	Threatened Species at risk [e, f]
animals	**22**	p	Animal	*Delma impar*
		p	Animal	*Grus rubicunda*
		p	Animal	*Heleioporus australiacus*
		p	Animal	*Pachycephala pectoralis contempa*
		p	Animal	*Suta flagellum*
		g	Plant	*Acacia phasmoides*
		g, h	Plant	*Asterolasia elegans*
		g	Plant	*Caladenia arenaria*
		g	Plant	*Callitriche cyclocarpa*
		g, h	Plant	*Homoranthus darwinioides*
		g	Plant	*Pimelea curviflora* var. *curviflora*
		g, h	Plant	*Prostanthera cryptandroides*
		g, h	Plant	*Prostanthera stricta*
		h	Plant	*Swainsona flavicarinata*
		h	Plant	*Swainsona viridis*
		g	Plant	*Westringia davidii*
		g	Plant	*Zieria involucrata*
		h	EEC	Bega Dry Grass Forest
		h	EEC	Candelo Dry Grass Forest
		h	EEC	Coastal Saltmarsh
		g	EEC	Illawarra Subtropical Rainforest
		p	EEC	Littoral Rainforest
birds	**1**	c	Animal	*Neophema chrysogaster*
black ant spp.	**1**	p	Animal	*Gygis alba*
deer [g]	**19**	h	Animal	*Isoodon obesulus*
		g	Animal	*Potorous longipes*
		g	Plant	*Acacia bynoeana*
		g	Plant	*Eucalyptus camfieldii*
		h	Plant	*Euphrasia scabra*
		g	Plant	*Genoplesium baueri*
		g	Plant	*Leucopogon exolasius*
		g	Plant	*Melaleuca deanei*
		g	Plant	*Persoonia hirsuta*
		g	Plant	*Prostanthera densa*
		g	Plant	*Pultenaea aristata*
		g	Plant	*Syzygium paniculatum*
		g	Popn	*Callitris endlicheri*
		g, h	EEC	Freshwater wetlands on coastal floodplains
		g, h	EEC	Littoral rainforest
		h	EEC	Montane peatlands and swamps
		h	EEC	O'Hares Creek Shale Forest
		g, h	EEC	River-flat eucalypt forest on coastal floodplains
		g, h	EEC	Swamp sclerophyll forest on the coastal floodplains

Generic pest animal group identified as posing a threat to biodiversity [a]	Total biodiversity threatened	Threat action [c]	Type [d]	Threatened Species at risk [e, f]
fish	**4**	p	Animal	*Litoria littlejohni*
		p	Animal	*Litoria piperata*
		p	Animal	*Mixophyes iteratus*
		p	Animal	*Neobatrachus pictus*
feral chicken	**1**	p	Animal	*Placostylus bivaricosus*
frogs	**1**	c, p	Animal	*Dryococelus australis*
herbivores	**14**	h	Animal	*Ctenotus brooksi*
		h	Animal	*Diplodactylus conspicillatus*
		h	Animal	*Manorina melanotis*
		c	Animal	*Neophema splendida*
		h	Animal	*Pseudonaja modesta*
		h	Animal	*Tiliqua mutifasciata*
		h	Plant	*Eriocaulon carsonii*
		h	Plant	*Euphrasia collina* subsp. *muelleri*
		u	Plant	*Grevillea kennedyana*
		g, h	Plant	*Irenepharsus trypherus*
		g	Plant	*Lepidium peregrinum*
		g	Plant	*Lysimachia vulgaris* var. *davurica*
		g	Plant	*Mitrasacme pygmaea*
		g	EEC	Myall Woodland
predators	**6**	p	Animal	*Poephila cincta*
		p	Animal	*Thalassarche cauta*
		p	Animal	*Thalassarche melanophris*
		p	Animal	*Thersites mitchellae*
		p	Animal	*Turnix maculosa*
		p	Animal	*Zosterops lateralis tephropleura*
rats	**12**	p	Animal	*Dryococelus australis*
		p	Animal	*Fregetta grallaria*
		p	Animal	*Gallirallus sylvestris*
		p	Animal	*Neobatrachus pictus*
		p	Animal	*Panesthia lata*
		p	Animal	*Pericryptodrilus nanus*
		p	Animal	*Phoebetria fusca*
		p	Animal	*Pterodroma solandri*
		p	Animal	*Sterna albifrons*
		p	Animal	*Sterna fuscata*
		p	Animal	*Sula dactylatra*
		g	Plant	*Carmichaelia exsul*
rodents	**8**	cn	Animal	*Falco hypoleucos*
		cn	Animal	*Burramys parvus*
		p	Animal	*Procelsterna cerulea*
		cn	Animal	*Strepera graculina crissalis*
		cn	Animal	*Tyto capensis*
		cn	Animal	*Tyto novaehollandiae*
		cn	Animal	*Tyto tenebricosa*
		c	Popn	*Mastacomys fuscus*
skinks	**1**	c, p	Animal	*Dryococelus australis*

Generic pest animal group identified as posing a threat to biodiversity [a]	Total biodiversity threatened	Threat action [c]	Type [d]	Threatened Species at risk [e, f]
snails and slugs	**1**	g	Plant	*Lepidium aschersonii*
trout	**4**	p	Animal	*Litoria spenceri*
		c	Animal	*Maccullochella macquariensis*
		p	Popn	*Adelotus brevis*
		p	EEC	Aquatic ecological community in the natural drainage system of the lower Murray River catchment
worms	**1**	c	Animal	*Pericryptodrilus nanus*

Footnotes as per Table B with the exception of the following:

[a] These pest animal threats were identified as general groups only and are not an amalgamation of all the species in these groups within the data set (see Chapter 3 for further details).

[g] There are six deer species with naturalised populations in New South Wales, being *Axis axis*, *Axis procinus*, *Cervus elaphus*, *Cervus timorensis*, *Cervus unicolor* and *Dama dama*, but there was no mention of specific deer species in the data set.

Appendix 4

Alien freshwater fish species present in New South Wales, but not currently recorded as posing a threat to biodiversity

There are 18 alien freshwater fish species present in New South Wales, along with numerous native species that have been translocated to new locations. Of these 18 species, eight are known to pose a threat to threatened species listed under the TSC or FM Acts and are discussed in Chapter 8. The remaining 10 species are presented here to help raise awareness, and assist with determining impacts in the future. For example, several threatened species were threatened by alien fish generically; most of these threatened species were not threatened by any of the specific alien fish species identified in this report (see Appendix 3).

Table D Alien fish species present in New South Wales but not currently identified as a threat to biodiversity.

Alien fish species recorded in New South Wales [a]	Date first recorded as naturalised in Australia	Other states/ territories present	Introduction source
Acanthogobius flavimanus (yellowfin goby)	1971	Vic	ballast water
Cichlasoma octofasciatum (Jack Dempsey)	2004	na	ornamental
Phalloceros caudimaculatus (one-spot livebearer/speckled mosquitofish)	1970s	WA	ornamental
Poecilia reticulata (guppy)	1970s	Qld, NT	ornamental
Rutilus rutilus (roach)	1860-80	Vic	acclimatisation
Salmo salar (Atlantic salmon) [b]	1963	Vic, Tas	acclimatisation
Salvelinus fontinalis (brook trout)	1883	Tas	acclimatisation
Tanichthys albonubes (white cloud mountain minnow)	2003	Qld	ornamental
Xiphophorus hellerii (green swordtail)	1965	Qld, WA, NT	ornamental
Xiphophorus maculatus (platy)	1970s	Qld, NT	ornamental

Source: Lintermans (2004)

[a] Those alien fish species identified as posing a threat to threatened biodiversity in New South Wales are presented in Chapter 8.

[b] This species does not reproduce in the wild and is maintained by constant releases (see Lintermans 2004).

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