Australian Government

National Land & Water Resources Audit

Assessing invasive animals in Australia 2008

Invasive Animals Cooperative Research Centre

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The National Land & Water Resources Audit ('the Audit') provides data, information and nation-wide assessments of Australia's land, water and biological resources to support sustainable development. It commenced in 1997 and published the first set of detailed assessment reports in 2002.

The Audit (2003–08) has six key areas of activity:

- developing a consistent national reporting mechanism for collating natural resource information collected under the National Natural Resource Management Monitoring and Evaluation Framework
- collating information to support the national State of the Environment (SoE) reports
- developing nationally consistent, but regionally relevant integrated resource condition reports
- facilitating reporting on the ongoing collection of natural resource information for key theme areas, including those related to the National Natural Resource Management Monitoring and Evaluation Framework
- reporting on national data and information management (in collaboration with ANZLIC — the Spatial Information Council)
- developing national assessments (as requested) and supporting program evaluations.

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About the Invasive Animals Cooperative Research Centre

The Invasive Animals Cooperative Research Centre (IA CRC) was funded by the Australian Government in 2004 and builds on the strong foundation provided by the previous Pest Animal Control CRC. The IA CRC aims to counteract the impact of invasive animals through the development and application of new technologies and by integrating approaches across agencies and jurisdictions. Through the IA CRC, participants from research, industry, environmental, commercial and government agencies work together to create and apply solutions for invasive animal threats. A total of 41 organisations are participating in the Invasive Animals CRC. By combining national and international skills in science, management, commerce and industry, this unique partnership will deliver the means to combat existing high-profile invasive animal pests that have the potential to cause catastrophic impacts in the future.

The IA CRC aims to:

- develop new tools and strategies to control invasive animals
- develop new services to take more effective action against invasive animals
- advance understanding of the nature and behaviour of Australia's invasive animals
- build greater capacity to anticipate, detect, prevent, limit or manage the impacts of existing or new invasive animals.

For further information see http://www.invasiveanimals.com

Assessing invasive animals in Australia 2008

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Foreword

Invasive animals cause enormous damage to Australia's economy, environment and society. *Assessing Invasive Animals in Australia 2008* presents, for the first time, consistent national information on the distribution and abundance of significant invasive animals in Australia.

This report is the result of collaboration between the National Land & Water Resources Audit, the Invasive Animals Cooperative Research Centre, and all states and territories. It reports on indicators of the extent and impact of 10 invasive animal species, which have been compiled from existing datasets using nationally agreed methods. Where available, information on trends was collated and reported, and potential distribution information was modelled for species that are still spreading.

The work is an important step in laying the foundations for ongoing monitoring of invasive animals — and this ongoing monitoring should be an essential component of all future programs that invest in controlling these invasive species.

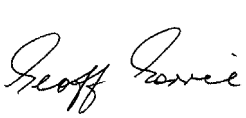
Key findings presented in the report include:

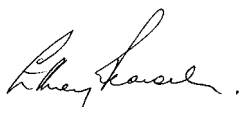
- Invasive animals are a national issue because they inhabit all areas of mainland Australia and many islands.
- About 73 invasive animal species have established wild populations in Australia and several inhabit over 70% of the continent.
- Invasive animals are estimated to cause losses in excess of one billion dollars per year through environmental and economic damage.
- Invasive animals are listed in the top three greatest threats to threatened species and ecosystems, and they continue to colonise new areas.
- Many species are already widespread and established; however, new and emerging pest species, particularly alien fish, could establish wild populations, and managers must remain vigilant for possible incursions.

The report identifies the need to:

- implement consistent monitoring techniques to measure change in pest populations
- develop mechanisms to monitor and respond to new pest incursions
- include new and emerging species, as well as alien fish species, in monitoring and reporting activities and in future assessment reports
- conduct further research to identify the magnitude of impacts of invasive animals in Australia and to improve tools and techniques to monitor impacts
- collate information on investment and management activities, the impacts of species on assets, and the effectiveness of management
- develop a national information system for invasive animals that addresses the needs of each state and territory, and provides detailed and consistent reporting
- continue coordinated efforts between governments at all levels, research, industry groups, suppliers of innovative control technologies, landholders and the broader community to address the escalating problems caused by invasive animals in Australia.

The Audit Advisory Council and the Invasive Animals Cooperative Research Centre view this report as a substantial contribution to information regarding natural resource management in Australia.





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Acronyms and abbreviations

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
ALUM	Australian Land Use and Management
APDS	Annual Pest Distribution Survey
ARO	Australia's Resources Online
AWC	Australian Weeds Committee
BioSIRT	Biosecurity, Surveillance, Incident Response and Tracing
BRS	Bureau of Rural Sciences
CMA	Catchment Management Authority
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
GIS	geographic information system
IA CRC	Invasive Animals Cooperative Research Centre
MERI	monitoring, evaluation, reporting and program improvement
National M&E Framework	National Natural Resource Management Monitoring and Evaluation Framework
NFACP	National Feral Animal Control Program
NLWRA	National Land & Water Resources Audit (the Audit)
NRM	natural resource management
NRMMC	Natural Resource Management Ministerial Council
NSW	New South Wales
NT	Northern Territory
Qld	Queensland
RHD	rabbit haemorrhagic disease
SA	South Australia
Tas	Tasmania
Vic	Victoria
VPC	Australian Vertebrate Pests Committee, operating under the Natural Resource Management Ministerial Council
WA	Western Australia

Executive summary

Invasive pest animals cause enormous damage to Australia's economy, environment and society. They impact on primary production industries, cause land degradation, threaten biodiversity, contribute to human health problems and damage our dwindling water resources.

Previous estimates suggest that about 73 invasive pest animal species (comprising mammals, birds, fish, reptiles and amphibians) have established wild populations in Australia (Bomford 2003). Many species were introduced during the 1800s, such as rabbits, feral deer, foxes, camels and feral pigs. However, a number of new pest species have emerged as pests in our changing environment such as common starlings, red-eared slider turtles, Indian myna birds and tilapia. In most cases, the impacts of pest species in Australia have not been fully identified, and there is ongoing risk that new invasive species (such as alien fish) could establish in the wild. As a result, we urgently need mechanisms to prevent and respond to pest incursions.

Invasive pest animals in Australia are estimated to cause losses in excess of one billion dollars per year through environmental and economic damage (McLeod 2004, Tracey et al 2007). The main culprits are feral pigs, rabbits, foxes, feral cats and pest birds. Apart from the direct losses associated with damage caused by invasive animals, there are additional costs associated with their control. These are estimated to exceed $60 million per year, with a further $20 million per year allocated to essential research.

Significant gaps in research knowledge, especially regarding social impacts (Norris et al 2006), combined with the fact that many of the impacts of invasive animals are long term, limit our ability to accurately estimate the total impact cost of invasive animals in Australia. As a result, although current national estimates of impacts provide an insight into the scale of the invasive animal problem, these are conservative estimates of the real damage caused by invasive animals each year.

Feral pigs (*Sus scrofa*) are a major agricultural and environmental pest (photo by Glen Saunders)

Not surprisingly, invasive animals are also particularly destructive to Australia's wildlife and the environment. They are listed in the top three greatest threats to threatened species and ecosystems, riparian environments and important wetlands of Australia (Tait 2005). Their significance is duly reflected in the Commonwealth's environment and biodiversity conservation legislation (*Environment Protection and Biodiversity Conservation Act 1999*), in which 7 (41%) of the 17 listed 'key threatening processes' for nationally listed threatened biodiversity are invasive animals. In New South Wales (NSW) alone, invasive animals pose a risk to 40% of threatened biodiversity, representing 388 listed threatened species and 157 nationally listed threatened species.

Invasive animals are also known to threaten many of Australia's Matters of National Environmental Significance. These pests seriously impact on threatened species and ecological communities, and listed migratory species (eg little tern predation by foxes). They threaten marine species and environments (eg grey-headed albatross on Macquarie Island), and wetlands of international importance (eg feral pigs in the Macquarie Marshes Ramsar wetland in NSW). Invasive animals are a notable major threat in almost all World Heritage Areas in Australia, ranging from cane toads in Kakadu to rabbits on Macquarie Island to feral pigs in the wet tropics.

Intended audience and overall objective

This Assessment is intended for managers within government, regional groups, and non-government bodies who are responsible for invasive animal monitoring, reporting and evaluating activities, and related management programs. It presents, for the first time, consistent national information on the distribution and abundance of significant invasive animals in Australia as a baseline for ongoing monitoring and reporting activities. Continued collection of data to address gaps will provide improved information for future assessments. Where available, information on trend was collated and is reported, and potential distribution information was modelled for species that are still spreading.

Key findings

Ten nationally significant invasive animals were addressed as part of this Australia-wide Assessment under the National Monitoring and Evaluation Framework (National M&E Framework). The 10 significant invasive animals are feral pigs, feral goats, feral deer, rabbits, foxes, wild dogs (including dingoes), feral cats, common starlings, common carp and cane toads.

This Assessment reports on indicators of the extent and impact of these species, which have been compiled from existing datasets using nationally agreed monitoring protocols and data standards.

This Assessment of 10 of Australia's significant pest species indicates that:

- Invasive animals are a national issue because they inhabit all state and territory jurisdictions and all natural resource management (NRM) regions.
- They cause damage valued at more than one billion dollars per year through economic, environmental and social impacts (McLeod 2004, Tracey et al 2007).
- The highest concentrations of invasive animal species occur in the eastern regions of Queensland, NSW and Victoria, where more than 7 of the 10 nationally significant invasive animal species occur.
- All areas of mainland Australia contain a number of nationally significant invasive animals and four nationally significant species — foxes, rabbits, wild dogs and feral cats — inhabit more than 70% of the country.
- Feral deer, cane toads, common carp and common starlings are all colonising new areas, and modelling predictions suggest that many other species are still capable of invading new areas throughout Australia. Thus, management authorities need to remain vigilant.
- The rapid spread of cane toads across northern Australia in recent years towards the Western Australian border requires a nationally coordinated response (such as a national cane toad management strategy) to minimise further invasion by cane toads and lessen their impacts, particularly to species of conservation significance.
- Many coastal and offshore islands contain large populations of invasive animals, many of which threaten native species and communities.
- The adverse impacts of invasive animals are significant at the national scale, but are generally not well identified.
- Impact case studies report that invasive animals threaten 40% of biodiversity in NSW, are a major threat to environmental assets, cause significant production losses, prevent recovery of native vegetation, and threaten native fauna. All NRM regions in NSW contain threatened species at risk by invasive animals.

- There is a significant overlap between where invasive animal populations are located and nationally important environmental assets in all states and territories of Australia.
- There are significant gaps in knowledge that must be addressed for future reporting activities.

Key findings for each species are summarised in Table 1. See Chapter 3 for detailed information on the distribution and abundance of these 10 invasive pest species and Chapter 4 for case studies on the impacts and monitoring of some of these species.

Table 1 Summary of extent, trend, potential range and impacts of invasive species

Invasive animal	Extent	Trend	Potential range	Impact	Other information
Feral pigs	Occupy 45% of Australia All states and territories, and some large islands Most abundant in NSW, Qld and NT	Limited information at the national scale	Have expanded beyond their predicted limits, possibly because of access to water sources and land use practices	$106.5 million per year (McLeod 2004) Impacts reported to newborn lambs, sugar cane, banana crops, threatened sea turtles Occur at high densities where environmental assets are abundant	Listed under the EPBC Act as a 'key threatening process'. Pose a serious exotic disease management threat, damage sensitive wetlands through wallowing and rooting, and are a risk to numerous threatened plant and animal species
Feral goats	Occupy 28% of Australia All states and territories and many offshore islands; most abundant in NSW, Qld, SA and WA Can reach very high densities	Limited information at the national scale, some information at local scale, possibly decreasing in SA	Suitable climate in most of the mainland Limited by occurrence of predators (wild dogs and dingoes), land use practices and human activity	$7.7 million per year (McLeod 2004) Degrade native vegetation and compete for pasture Occur at moderate densities where environmental assets are abundant	Listed under the EPBC Act as a 'key threatening process' Can withstand drought for extended periods and can increase in number rapidly when food is available Commercial resource and valuable meat and fibre source (Ramsay 1994)
Feral deer Six species assessed: fallow deer, red deer, sambar, rusa, chital and hog deer	Occupy 9% of Australia All states and territories, and on some islands Widespread in parts of Vic, Tas, Qld and SA	Largely unavailable at the national scale Reported as increasing in SA, Tas and NSW	Not determined Tend to occupy medium to high rainfall areas in temperate Australia Some prefer northern Australian climates (eg rusa deer in the NT)	No annual estimated cost of impacts Can carry livestock diseases, can damage native vegetation and crops, and are a motor vehicle hazard	Listed under some state and territory legislation as a 'key threatening process' Also present a serious risk for exotic disease maintenance and transmission, such as foot-and-mouth disease

Table 1 Continued

Invasive animal	Extent	Trend	Potential range	Impact	Other information
Wild dogs, including dingoes	Occupy 83% of Australia All states and territories except Tas Common throughout most of range and most abundant in arid and northern areas	Limited information at the national scale Stable in SA and the NT, possibly stable throughout entire range Numbers fluctuate locally with prey availability	Have possibly reached their limit in Australia Restricted by the wild dog/dingo fence	$66.3 million per year (McLeod 2004) Main impact is predation and injury of livestock and native fauna Primary host of hydatid parasites	Potential transmitters of rabies if introduced to Australia, and have been known to be a threat to humans in some situations
Rabbits	Occupy 70% of Australia Occur in all states and territories, and some islands Mainly absent north of the Tropic of Capricorn Moderate densities where abundant environmental assets exist in Vic, SA and WA	Limited information at the national scale Research indicates their numbers declined as a result of RHD but are recovering in many regions	Expected to have been reached throughout the country	$113.1 million per year (McLeod 2004) Reported to prevent regeneration of mulga and threatened acacias Recognised threat to 157 threatened species (121 plants, 17 birds, 13 mammals, 4 reptiles, 1 fish and 1 insect species) (DEWHA 2008b) Occur at moderate densities where environmental assets are abundant	Major agricultural pest Listed under the EPBC Act as a 'key threatening process' RHD in 1996 reduced numbers in many areas, allowing regeneration of native species and revealing many new rabbit impacts Serious risk to threatened bilbies in western Qld
Foxes	Occupy 76% of Australia Occur in all states and territories; recently illegally introduced to Tas Abundant throughout most of their range Mainly absent north of the Tropic of Capricorn	Limited information at the national scale Stable in SA and the NT, possibly throughout most of the country Increasing at northern limit of distribution in the NT	Expected to have been reached throughout the country, except in Tas	$227.5 million per year (McLeod 2004) Significant impact on lamb production Reported to impact on native fauna, including potoroos and bandicoots in Vic, and shorebirds in NSW	Major agricultural pest Listed under the EPBC Act as a 'key threatening process' Cause significant declines and regional extinctions of native wildlife (eg ground-dwelling and semi-arboreal mammals, ground-nesting birds and freshwater turtles)

Table 1 Continued

Invasive animal	Extent	Trend	Potential range	Impact	Other information
Feral cats	Occupy 99% of Australia Common throughout range and inhabit many islands Recently eradicated from Macquarie Island	Limited information at the national scale Increasing in Tas, stable in SA and the NT	Have most likely reached their limit Numbers fluctuate with prey availability	$144 million per year (McLeod 2004) Highly effective predators of 38 mammalian species, 47 bird species, 48 reptile species and amphibians (Dickman 1996) Cited in extinctions of small mammals and ground-nesting birds	Listed under the EPBC Act as a 'key threatening process' Contributed to failures in several endangered species reintroduction programs Stray and domestic cats are a threat to urban wildlife
Common starlings	Occupy 21% of Australia All states and territories except NT, and some islands Abundant in agricultural areas	Limited information at the national scale Increases noted in some areas of SA	Have not reached their limits Potential for expansion into WA and tropics, especially in agricultural areas	Contribute to $290 million per year loss to horticulture industries (Tracey et al 2007) Compete with native birds for nesting hollows Carry parasites and disease	Contained by intensive control programs in WA
Common carp	Occupy rivers in 11.5% of Australia Occur mainly in Murray-Darling Basin Isolated populations in Qld, WA and Tas	Limited information at the national scale Monitored closely at local level throughout Murray-Darling Basin	Climate predictions suggest most of southern half of continent suitable for expansion, but require suitable river systems	$15.8 million per year (McLeod 2004) Reduce water quality, alter fish species composition, cause bank erosion, reduce aquatic plant growth, elevate water turbidity levels	Can represent most of the fish biomass in rivers
Cane toads	Occupy 20% of Australia Occur in Qld, NT and NSW	Recently spread in northern Australia from east to west at 27–50 km/year Expected to reach WA by 2008–2010 (Peacock 2007)	Have not reached their limits Climate and habitat predictions suggest further spread into NSW, central Qld and northern Australia, including WA	Conservatively estimated to cause $0.5 million damage per year (McLeod 2004) Threat to wildlife and pets through toxins Impact on native predators (Molloy and Henderson 2006, Doody et al 2007) Prey on insects, reptiles and frogs	Listed under the EPBC Act as a 'key threatening process' Potential impact has prompted the Australian Government to allocate $18 million to research and control since 1985 Better estimates of impacts are needed

EPBC = *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*; NSW = New South Wales; Qld = Queensland; Vic = Victoria; Tas = Tasmania; SA = South Australia; NT = Northern Territory; WA = Western Australia; RHD = rabbit haemorrhagic disease

Functions of this Assessment

This Assessment provides valuable information on invasive animals and their impacts in Australia. The findings should be used as one of many mechanisms to evaluate investment programs, including NRM or future Caring for our Country initiative. Along with appropriate supporting information, the findings may identify priorities for future investment, control activities, management planning and research.

The case studies reported in Chapter 4 present a snapshot of information about impacts that may provide valuable reference points to help define the problems caused by invasive animals in Australia. Information on the distribution and abundance of invasive animals should be considered in this process.

This Assessment has developed consistent monitoring protocols for collection, collation and reporting of national-scale information. Although ongoing monitoring and reporting activities at the local and regional scale are needed to underpin information for national reporting, a process of consolidating data into state, territory and national formats is still needed, and should be developed through ongoing assessments.

Suggestions for implementation and coordination

There is a clear need for a coordinated effort between governments at all levels, research, industry groups, producers of innovative technology, landholders and the broader community to address the escalating problems caused by invasive animals in Australia. Further implementation of consistent national monitoring protocols and future assessments will provide improved information to assess the effectiveness of management actions and investment programs.

Commitment of resources to monitoring

Significant planning, coordination and resources are required to address the large-scale problems caused by invasive animals, and a commitment is required by state, territory and Australian governments to ongoing and improved monitoring of invasive animals and their impacts.

The fox (*Vulpes vulpes*) is a significant predator of native wildlife and causes substantial losses to lamb production industries (photo supplied by Invasive Animals CRC)

Further data collection

Fundamental information on the extent and impacts of pest species is necessary at the state, territory and national levels to guide policy, evaluate management, develop appropriate management and biosecurity strategies, and measure the effectiveness of investment to address the adverse impacts of pests.

Further research is required to identify the magnitude of impacts of invasive animals in Australia and to improve the tools and techniques to monitor these impacts. Management programs rely on accurate, timely and precise information on impacts, and monitoring is required where investment is allocated to evaluate the effectiveness of funding programs.

National information system for monitoring

A national information system is urgently needed for monitoring and reporting activities for invasive species under the National M&E Framework, and to address the needs of each state and territory government regarding reporting on invasive species matters. A national information system is also vital to address many additional needs, including information on new and emerging species, areas of investment,

Feral cats (*Felis catus*) are a major predator of Australian wildlife and inhabit the entire continent (photo by K Gillett)

control activities, impacts on assets, and areas of active management. There is also a critical need for consistency in the way information is collected and reported for delivery of meaningful state, territory and national products for decision-makers and policy development. A national information system for invasive animals may also provide a means for consolidating all state and territory data.

It is important to identify a clear strategy for the development (or adoption) of a national system for managing information about invasive species. To progress this, the Assessment's team and the Australian Vertebrate Pests Committee (VPC) recommended a detailed assessment of the suitability of existing systems for routine monitoring and reporting of invasive animals.

Future directions

We offer the following recommendations to address the problems of invasive species on the national, state, territory and local levels.

New and emerging species should be monitored

In future assessments, and as part of routine management programs, a more comprehensive range of established invasive animal species, as well as new and emerging species (including a range of alien fish and pest bird species) should be included in monitoring and reporting activities under the National M&E Framework.

To enable management programs to accurately target species and mitigate their impacts in Australia, it is critical that a representative group of species is included in monitoring and reporting. Monitoring of new and emerging species will help identify the mechanisms by which species are spreading and help to identify their short and long-term impacts.

Additional information should be collected in future assessments

Future national assessments will build on the achievements of this Assessment and, with adoption of relevant monitoring protocols, will provide

fundamental information on invasive animals and their impacts that is needed to evaluate the effectiveness of management programs and investment. Future assessments should include additional information on assets, investment, impacts, management actions, and the occurrence of new and emerging species. Although beyond the scope of this Assessment, coastal and offshore islands should be considered in future assessments because many islands are heavily populated by invasive animal species that impact on threatened and migratory species and other Matters of National Environmental Significance.

The next assessment should be undertaken before 2011

Future assessments should be undertaken as recommended by the relevant national coordinating committee, being VPC. As a guide, we recommend that the next assessment should be undertaken within two to three years to supply information for the 2011 National State of the Environment Report. At that time, the respective indicators and monitoring protocols should be reviewed for their capacity to assess the status of invasive animals and their impacts in Australia and to evaluate the effectiveness of management and investments over time.

All stakeholders should be engaged in the process

Relevant stakeholders, including state and territory authorities, regional NRM groups and experts need to be further engaged to incorporate detailed local- and regional- level information. This will ensure that an enduring process is accepted for ongoing monitoring and reporting in Australia. Adequate resources are required for stakeholders, particularly NRM regional bodies, to develop and implement invasive animal monitoring strategies.

Coordinated monitoring and reporting for cost-effective investment

Implementation of national monitoring protocols will provide detailed and consistent information on invasive animal populations and their impacts over time. Investment in coordinated monitoring and reporting will provide information for more cost-effective investment and will facilitate the evaluation of investment strategies. A commitment from all governments is required to implement consistent monitoring and reporting.

Monitoring and impact assessment can be improved

Monitoring the distribution and abundance of invasive animals in Australia can be improved with further adoption of field-based monitoring techniques at local and regional levels. Adoption of a finer reporting scale for monitoring and reporting activities will help to maintain accurate information in national datasets.

Impact monitoring is needed to assess the effectiveness of investments. Development of improved impact-monitoring techniques and an impact-monitoring framework will allow assessment of management programs and the effectiveness of investment. Further, it will help to set management priorities, increase the effectiveness of best-practice control strategies, and increase awareness of invasive animals and their impacts in Australia.

A national information system for invasive species to be used by states, territories and NRM regions will facilitate ongoing monitoring, evaluation, reporting and program improvement. Formalised data-access arrangements are required between the state and territory jurisdictions and the Australian Government for ongoing monitoring and reporting, and future assessments.

Government commitment is needed

To address the increasing problems caused by invasive animals in Australia, a commitment is required through government NRM programs, such as the new Caring for our Country initiative, to fund essential monitoring, evaluation, reporting and program improvement activities at state and national levels.

Funding of this Assessment

This Assessment was funded through the National Land & Water Resources Audit and the Invasive Animals Cooperative Research Centre. It was endorsed by VPC and was supported by all states and territories; the Australian Government Department of Agriculture, Fisheries and Forestry; and the Department of the Environment, Water, Heritage and the Arts.

1 Introduction

Invasive animals cause enormous damage, on several levels, throughout Australia. Their management relies on having accurate and meaningful information on the extent of their distribution and their impacts. Such information can identify where management should be focused; measure the effectiveness of programs and investment; and notify managers of emerging issues.

Assessing Invasive Animals in Australia 2008 (referred to as 'the Assessment') addresses a number of nationally significant invasive animals that have an adverse impact, or have the potential to adversely impact, on social, environmental and economic assets or values. This Assessment provides the first detailed national assessment of the distribution, abundance and impacts of nationally significant invasive animals using a standardised approach throughout Australia. It presents consistent information to build on previous initiatives and to facilitate comparison of information between regions and jurisdictions. The Assessment identifies areas where our knowledge and information can be improved for future monitoring and reporting activities.

This Assessment is intended for managers who are responsible for monitoring, reporting and evaluating invasive animal programs in various organisations and government departments, as well as regional groups, non-government bodies and the general community. It aims to present consistent national information on the distribution and abundance of significant invasive animals in Australia as a baseline for ongoing monitoring and reporting activities.

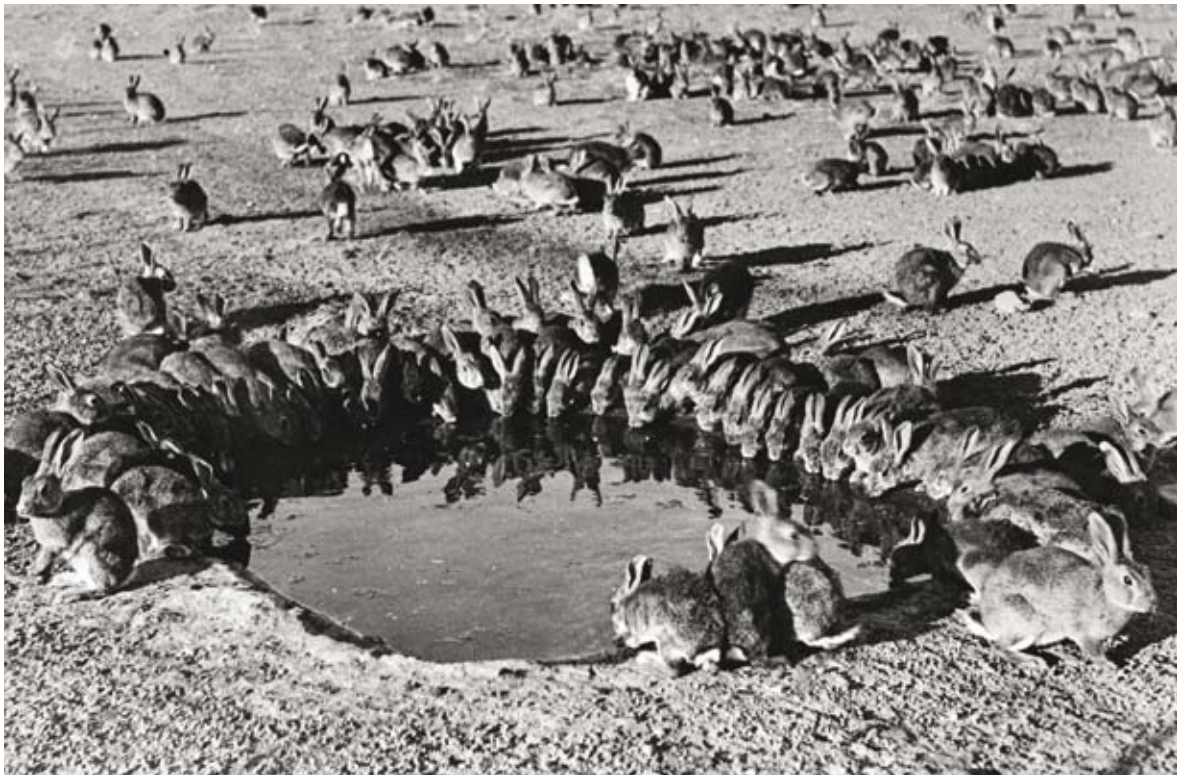
This Assessment provides valuable information on invasive animals and their impacts in Australia as a tool for evaluating investment programs, such as natural resource management (NRM) programs and future Caring for our Country[1] initiatives and can be used to identify priorities for future investment, control activities, management planning and research. However, this Assessment must be used in conjunction with other information and mechanisms to evaluate investment programs and to identify future priorities.

Foxes are opportunistic predators and scavengers with no specialised food requirements (photo by Peter Fleming)

This Assessment follows the development of a national invasive animals work plan recommended by the Australian Vertebrate Pests Committee (VPC) and its implementation during 2006 and 2007 by the National Land & Water Resources Audit ('the Audit'), the Invasive Animals Cooperative Research Centre (IA CRC), and all state and territory governments. The Natural Resource Management Ministerial Council (NRMMC) established a national framework to assess progress towards improved natural resource condition through the development of accurate, cost-effective and timely information on natural resource condition. The national invasive animals assessment work plan was designed to ensure that vital information on the status of invasive animals and their impacts is available to report through the National Natural Resource Management Monitoring and Evaluation Framework (National M&E Framework). This document represents a summation of findings from the implementation of the national work plan to achieve this objective.

The section that follows highlights the importance of this national Assessment in addressing the fundamental information required to consider invasive animals in Australia as a component of the National M&E Framework.

[1] Caring for our Country initiatives commence 1 July 2008



Rabbit numbers can reach plague proportions, as observed on Spencer's Gulf in 1963 (photo by National Archives of Australia)

Invasive animal pests

Many vertebrate species that have been deliberately or accidentally introduced to mainland Australia have established wild populations. These include mammals, birds, fish, reptiles and amphibians (Bomford 2003). The main reasons for their introduction have been for farming and domestic purposes; social acclimatisation; hunting and fishing; biological control; fisheries and aquaculture; and the pet and aquarium industry. Many other species have been accidentally introduced to Australia or have escaped captivity and are now difficult to control.

Not all past introductions of species have resulted in animals becoming pests (Olsen 1998). In many cases, species have been introduced but have failed to establish wild populations. Invasive animals are those that have spread beyond their normal range and that cause adverse impacts or have the potential to cause adverse impacts to social, environmental or economic assets or values. Previous estimates indicate that 73 vertebrate species have established wild populations and are considered pests in Australia (Bomford 2003).

Invasive animals cause enormous damage to Australia's environmental assets, primary production, and human health and safety. Most agricultural sectors suffer economic losses through impacts such as predation of livestock, damage to crops and horticulture, and competition for feed. Invasive animals also threaten native species, cause land degradation, degrade water resources, reduce tourism potential and are often a nuisance to people. Recent estimates of their total cost impact suggests that 11 of Australia's 73 invasive animals cause losses of $720 million each year through environmental, economic and social damage, and that pest birds cause losses to horticulture industries equating to almost $300 million each year (McLeod 2004, Tracey et al 2007).

Both private and public landowners allocate substantial resources and spend considerable time addressing or preventing the damage caused by invasive animals. The costs associated with controlling invasive animals was estimated to exceed $60 million per year, and research to find better control methods was estimated to cost over $20 million per year (McLeod 2004). While these figures are alarming, they are also likely to be conservative, placing the real total costs of

invasive animals well above acceptable levels. As a whole, invasive animals impose an enormous strain on regional economies, human health and environmental sustainability.

Many of the widespread and established invasive animal species in Australia are those that have received the most attention as pests per se, including feral pigs, feral goats, feral deer, foxes, rabbits, wild dogs, feral cats, cane toads, common starlings, house mice, camels, donkeys, water buffalo, Indian myna birds, feral horses and common carp. An additional group of invasive animal species are those considered new and emerging, such as the red-eared slider turtle, tilapia, oriental weatherloach, ferret, Asian house gecko, Indian palm squirrel and many deer species. Several native species are also considered pests in certain circumstances, such as flying foxes in orchards and kangaroos in grazing land. However, new species are being introduced regularly to Australia and present a serious threat to industries and the environment. Animals kept in captivity such as ornamental freshwater finfish also present a serious threat if deliberately or unintentionally released into the wild.[2]

Current management

To combat the adverse effects of invasive animals, governments, industry, community groups and landholders invest valuable resources and time in managing and controlling pest populations. Their goal is to reduce the adverse impacts of pest species. However, managing pests requires significant resources and planning within a broad NRM context, and management strategies need to recognise that invasive animals are one of many interrelated natural resource elements.

Throughout Australia, there is considerable variation in the way invasive animals are managed and monitored. There is no definitive national list of invasive animal species from which national monitoring and reporting activities are prioritised or regulated. As such, management and monitoring are guided largely by state and territory invasive species plans, pest animal strategies and federal legislation.

The recently released *Australian Pest Animals Strategy* is a vital part of Australia's integrated approach to national biosecurity and provides a framework for the strategic management of invasive animals across all jurisdictions and management areas (DEW 2007).

Assessing Invasive Animals in Australia 2008 aims to complement the *Australian Pest Animals Strategy* by providing vital information on 10 nationally significant invasive animal species that were nominated by VPC and state and territory governments. Each of the 10 selected species occupies multiple jurisdictions and is known to cause substantial impacts to economic, environmental and social assets throughout Australia. Importantly, the Assessment includes several species listed as a 'key threatening process' for biodiversity conservation under federal legislation, for which there are accompanying national threat abatement plans.

To address the problems caused by invasive animals, a series of national management guidelines and strategies were developed for Australia's most significant species, namely feral pigs, feral goats, foxes, rabbits, dingoes and other wild dogs, rodents, common carp, feral horses and common starlings (see References and further reading). Although these guidelines help managers implement effective management strategies and control programs, it is imperative that monitoring and reporting are major components of management to ensure that we reach the most cost-effective solutions to the problems caused by invasive animals in Australia.

A guide for future management

Funding for invasive animal control activities is directed largely through state and territory government programs and national NRM programs such as the National Feral Animal Control Program. Landholders and the community are also responsible for implementing control programs and are often supported by local authorities. However, regional NRM groups, also referred to in some areas as catchment management authorities, are being asked to take on a critical role in ongoing management (including monitoring) of invasive animal species, and a coordinated effort between all stakeholders is needed.

2 For more information on invasive animal species in Australia, see http://www.feral.org.au (Accessed 15 May 2008)

Feral goats (*Capra hircus*) in arid areas often move to areas where permanent water is available (photo by Robert Henzell)

Information is required on the impacts, distribution and abundance of invasive animals to efficiently focus funding initiatives on priority areas. Such information is needed to assess the effectiveness of management strategies and investment programs, which in turn need to be evaluated against broad NRM targets.

Under guidance from VPC and working in partnership with all states, territories and the Australian Government, the Audit and the IA CRC have in this Assessment aimed to:

- address fundamental information needs and priorities for invasive animal species management
- develop a consistent state, territory and national dataset, and facilitate the reporting on pest species of national significance
- provide a benchmark for future monitoring, reporting and evaluation
- determine the requirements for national information management of invasive animals.

This Assessment provides an important part of state, territory and national reporting, and presents for the first time detailed national information on the current occurrence, distribution and abundance of nationally significant invasive animal species in Australia using a consistent methodology and data standards. To report the damage caused by invasive animals to our economy, environment and society, the Assessment also provides detailed information on the impacts of pests, compiled from existing management and research programs.

This Assessment presents consistent protocols for ongoing monitoring and reporting and detailed information as a benchmark for future assessments of invasive animals and their impacts.

Building on previous initiatives

Building on existing information is fundamental to improving the management of invasive animals and natural resources in Australia. The current Assessment significantly builds on previous national initiatives and captures more detailed information on invasive animal species of national importance.

State-based initiatives

There have been a number of significant coordinated state-wide initiatives to monitor and report invasive animals in Australia. These have generally targeted key pest species relevant to the respective jurisdictions and have led to the development of management plans, targeted control and surveillance programs, allocation of funds to programs, prioritisation and planning. They have also supported State of the Environment reporting processes. The three main recent initiatives coordinated by state governments that are relevant to this Assessment include:

- Queensland (Qld) government's pest surveys, referred to as the Annual Pest Distribution Surveys, that are coordinated annually across the entire state
- New South Wales (NSW) government's pest animal surveys, previously coordinated state-wide in 2002 and in 2005–06 (see West and Saunders 2003, 2007)
- Western Australia (WA) government's state-wide pest animal distribution and abundance surveys, last coordinated during 2005 (see Woolnough et al 2005).

These initiatives have developed and utilised comparable methods to survey pest species and have provided a platform for the approach adopted in this Assessment to facilitate information reporting at the national level. A number of additional broad-scale surveys have been conducted in other jurisdictions, but are usually restricted to a few species or to specific regions.

Each of these initiatives has provided significant information and data that underpin this national Assessment.

National initiatives

At the national level, there have been a number of similar attempts to develop national-scale mapping products for invasive animals in Australia. During 1992, the then Bureau of Resources Sciences (now Bureau of Rural Sciences, BRS) prepared the earliest series of national descriptive maps for invasive animals in consultation with VPC and member agencies within the states and territories (see Wilson et al 1992). Since then, the Australian Government, in consultation with relevant state and territory agencies, has developed similar national-scale products for key pest species.

The Audit has also addressed similar requirements. In 2001 and 2002, it published two significant assessments that reported information on invasive animals. These were:

- *Landscape Health in Australia: A Rapid Assessment of the Relative Condition of Australia's Bioregions and Subregions* (NLWRA 2001)
- *Australian Terrestrial Biodiversity Assessment 2002* (NLWRA 2002).

The first gave an assessment of landscape health and identified the distribution and density of a number of invasive animals within subregions and bioregions of Australia (Figure 1.1). The second recognised the threatening processes to biodiversity conservation and listed invasive animals as a significant threat throughout Australia. The latter document also included a series of invasive animal density maps prepared through consultation with relevant groups and reported at the bioregional level.

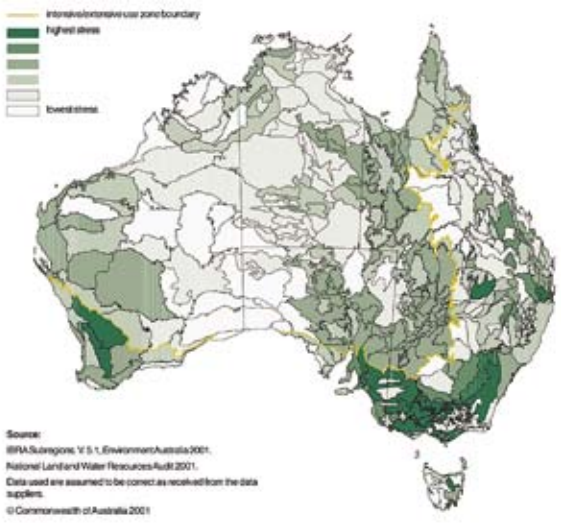
Definitions

Invasive animals — this assessment addresses nationally significant invasive vertebrate pests that have an adverse impact, or the potential to cause adverse impacts, on social, environmental or economic assets and values. Other terms are defined in the Glossary.

The national assessment work plan

The NRMMC established a national framework to assess progress towards improved natural resource condition through the development of accurate, cost-effective and timely information on it and the performance of programs, strategies and policy (see Chapter 2). To address requirements under the framework, the Audit, the IA CRC, and VPC, as the National Coordinating Committee for invasive species in Australia, developed the national invasive animals assessment work plan in 2006 to address national data, infrastructure, monitoring and reporting priorities.

Figure 1.1 Landscape health in bioregions and subregions of Australia



Source: NLWRA (2001)

The work plan was also developed to complement both the Australian Pest Animals Strategy and the National Framework for Invasive Species Management. The goals of the work plan ensured that vital information on the status of invasive animals was determined and that nationally agreed procedures for monitoring and reporting were developed and adopted.

The national assessment work plan addressed five priorities as determined by the Australian Government and VPC:

- to identify the information needs at regional, state, territory and national levels, and to develop and agree on national indicators for invasive animals
- to endorse national monitoring and reporting protocols and information access
- to collect and collate fundamental information to address the above needs

Protected areas are also affected by invasive animals, such as feral pigs, that damage wetlands and vegetation in the ACT (photo by Peter West)

- to develop standardised national products and report on invasive animals matters
- to establish data infrastructure and delivery, and a national information system.

The outcomes of the work plan include agreed procedures for monitoring and reporting on priority matters; a series of state, territory and national scale datasets and maps for 10 nationally significant invasive animal species; case studies demonstrating the types of impacts caused by invasive animals; and this Assessment as a benchmark for ongoing monitoring and reporting.

The National Land & Water Resources Audit

The Audit was established in 1997 to provide data, information and nation-wide assessments of Australia's land, water and biological resources to support sustainable development. It is an initiative of the Australian Government and published the first set of detailed assessment reports in 2002.

The Audit's aim is to provide a baseline to assess the effectiveness of land and water degradation policies and programs, and to improve Australian Government, state, territory and regional decision making on NRM. A key focus of the Audit involves the identification of NRM priorities (eg monitoring and evaluation coordination, condition and trend assessment processes), and the progressing of systems that enable the assessment of investments and information on the nation's natural resources. As part of its core activities, the Audit facilitates the process of developing a framework for the consistent collection, collation and analysis of natural resource (including invasive species) data and information across Australia.

The Audit (2003–2008) has six key areas of activity:

- developing a consistent national reporting mechanism for collating natural resource information collected under the National M&E Framework
- collating information to support the national State of the Environment reports
- developing nationally consistent, but regionally relevant, integrated resource condition reports
- facilitating reporting on the ongoing collection of natural resource information for key theme areas, including those related to the National M&E Framework
- reporting on national data and information management (in collaboration with ANZLIC — the Spatial Information Council)
- developing national assessments and supporting program evaluations.[3]

To facilitate the integrated delivery of NRM priority issues, the Australian Government, in association with state and territory governments, identified 56 regions covering all of Australia (Figure 1.2). An integrated NRM plan, developed within local communities, and supported by government and the best available science, has been developed for each region. These plans consider the environmental, social and economic impacts of NRM decisions on a regional basis, which will help improve the sustainable management of natural resources on a regional scale. In order to ensure desired outcomes, investment in NRM plans

[3] For further information see http://www.nlwra.gov.au

Figure 1.2 The 56 Natural Resource Management (NRM) regions of Australia

by governments and other organisations is based on the establishment of clear targets and appropriate monitoring.

Invasive Animals Cooperative Research Centre

The IA CRC was funded by the Australian Government in 2004 and builds on the strong foundation provided by the previous Pest Animal Control CRC. The Centre aims to counteract the impact of invasive animals through the development and application of new technologies and by integrating approaches across agencies and jurisdictions. It is the first time that research, industry, environmental, commercial and government agencies have worked together to create and apply solutions for invasive animal threats. A total of 41 organisations participate in the IA CRC. By combining national and international skills in science, management, commerce and industry, this unique partnership will deliver the means to combat existing high-profile invasive animal pests as well as those that have the potential to cause catastrophic impacts in the future.

The IA CRC aims to develop new tools and strategies to control invasive animals; develop new services to take more effective action against invasive animals; advance understanding of the nature and behaviour of Australia's invasive animals; and build greater capacity to anticipate, detect, prevent, limit or manage the impacts of existing or new invasive animals.

The IA CRC also strives to improve our collective capacity to prevent or detect invasive animal incursions and to help prevent damage from newly established or emerging pests. With this in mind, objectives that will be addressed through the national assessment work plan include:

- developing national survey and inventory procedures for monitoring and reporting invasive animals, and establishing national and local benchmarks for invasive animal impact, density and distribution
- developing information management procedures through a national information system containing distribution information
- reducing the risk of invasive animal impacts by forecasting and responding to potential, new, expanding and emerging invasive animal problems.

This will provide important information for all pest management agencies at national and regional levels and will build the capacity of agencies to prioritise resource allocation and to measure the success of control measures.[4]

Collaborating agencies

This Assessment was co-funded by the IA CRC and the Audit. Sponsor agencies included the Department of Agriculture, Fisheries and Forestry (DAFF) and the Department of the Environment, Water, Heritage and the Arts. VPC functioned as the national coordinating committee. The BRS, as part of DAFF, also provided guidance on national-scale issues.

For this national Assessment, all state and territory governments collaborated in the work plan to collect, collate and report detailed information on invasive animals and their impacts. The following agencies supplied comprehensive records to perform this assessment:

- NSW: Department of Primary Industries, and Department of Environment and Climate Change, and NRM representatives
- Qld: Department of Natural Resources and Water and NRM representatives

[4] For further information on IA CRC see http://www.invasiveanimals.com (Accessed 15 May 2008)

Feral pigs cause a range of adverse impacts and can act as vectors of exotic disease, such as foot-and-mouth disease if it were introduced to Australia (photo by NSW Department of Primary Industries)

- Victoria: Department of Sustainability and Environment, Department of Primary Industries, Parks Victoria, and NRM representatives
- Northern Territory: Natural Resources, Environment and the Arts
- WA: Department of Agriculture and Food, Department of Environment and Conservation, and NRM representatives
- South Australia: Animal and Plant Control Group of the Department of Water, Land and Biodiversity Conservation, Department of Environment and Heritage, and NRM representatives
- Tasmania: Department of Primary Industries and Water and NRM representatives
- Australian Capital Territory: Environment ACT
- Indigenous Land Corporation.

2 Monitoring and reporting

This chapter introduces the role of current frameworks for monitoring and reporting on natural resource management (NRM) priorities. This Assessment reports on two priority matters regarding invasive animals that shall form the basis of reporting under national monitoring and reporting frameworks. The following sections describe the methods that were developed and implemented for this Assessment to report on invasive animals in Australia.

Frameworks for monitoring, evaluation and reporting

The national, state and territory governments, along with community groups, industry and land managers have invested and continue to invest resources to address NRM issues across Australia. The most significant initiatives include the previous Natural Heritage Trust, the National Action Plan for Salinity and Water Quality, and the National Landcare Program. These programs are intended to support actions to achieve NRM outcomes. Lessons learnt from these initiatives include the need for program improvement, a focus on intermediate outcomes and the need for performance reports.

The Natural Resource Management Ministerial Council (NRMMC), which includes representatives of the Australian Government and all state and territory governments, was established to develop a coordinated approach to issues affecting NRM in Australia. In 2003, the NRMMC endorsed two national documents to assist with setting targets, monitoring, evaluation and reporting on NRM. They are the:

- National Framework for Natural Resource Management Standards and Targets (not described herein)
- National Natural Resource Management Monitoring and Evaluation Framework (National M&E Framework).

During 2007, work began on developing the National Natural Resource Management Monitoring, Evaluation, Reporting and Program Improvement (MERI) Framework to replace these two documents. It includes a framework strategy for evaluation of the Australian Government's NRM programs and is also intended to be useful for NRM programs funded through other sources.

Effective arrangements for monitoring, evaluation, reporting and program improvement are required to measure the level of impact, appropriateness, efficiency, effectiveness and legacy of investment initiatives. The MERI approach is based on continuous tracking and provides information to help steer the policy, program or project in the desired direction. The MERI Framework views continual learning and adapting in response to progressive monitoring and evaluation as a primary function of evaluation. The MERI cycle for planning, design and implementation of NRM policies, programs and projects is illustrated in Figure 2.1.

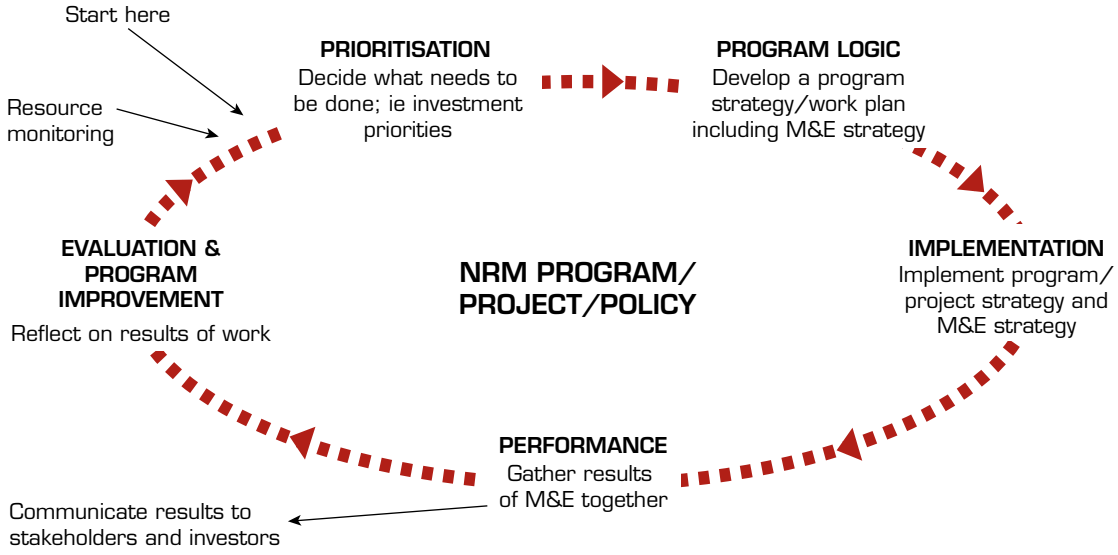
The current Assessment has been performed under the National M&E Framework and complements the MERI Framework.

National Natural Resource Management Monitoring and Evaluation Framework

The National M&E Framework was developed by the Australian and state and territory governments, and endorsed by the NRMMC in 2002–03. It assesses both the:

- health of Australia's land, water, vegetation and biological resources
- performance of programs, strategies and policies that provide national approaches to the conservation, sustainable use and management of these resources.

Figure 2.1 The monitoring, evaluation, reporting and program improvement cycle for natural resource management



M&E = monitoring and evaluation; NRM = natural resource management

Monitoring and evaluation activities need to focus on identifying the state of and trend in condition of natural resources and to assess the impact, appropriateness, effectiveness, and efficiency of investments. Assessment of information collated under the National M&E Framework will assist managers and the NRMMC to identify areas of concern and to better target the use of resources. Figure 2.2 presents a diagrammatic representation of the National M&E Framework.

The NRMMC agreed to a series of specific NRM topics (referred to as matters for target) for which regional targets are set under the National M&E Framework. For each matter for target identified, an overall resource condition indicator called an indicator heading has been developed.

The Invasive Species topic has two themes: Vertebrate Pests and Weeds. For Vertebrate Pests, the NRMMC set the following matter for target and indicator heading:

Matter for target
Ecologically significant invasive species

Indicator heading
Extent and impact of selected ecologically significant invasive vertebrate species.

The National Land & Water Resources Audit ('the Audit') is responsible for ongoing development of these indicators, as well as supporting the national collection and collation of data, and reporting against each indicator.

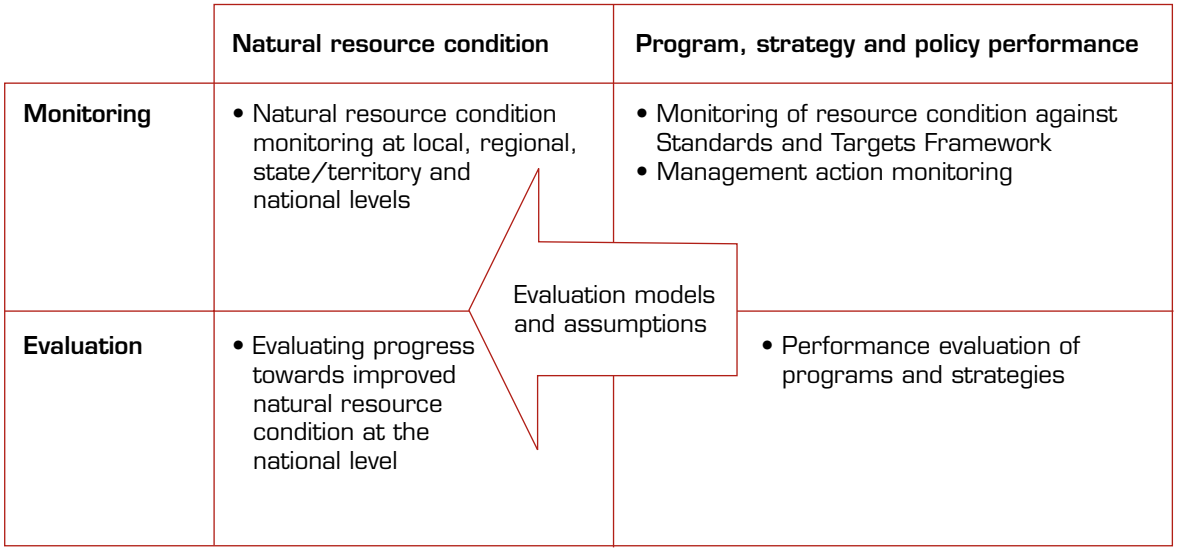
Such reporting will help to answer questions such as:

- What is the nature and extent of the issue?
- Is the existing or proposed intervention appropriate for the size of the issue?
- What types of intervention work best, are the most cost effective, and have the best transferability across regions?
- What is the impact of the policy or program investment — in the intermediate and long term?

Information needed on invasive animals

The development and adoption of consistent data attributes (such as occurrence, distribution, abundance and trend) for surveying and reporting invasive animal populations are important for developing standards and guidelines to manage information on invasive animals. Invasive animals are rarely confined by administrative or jurisdictional boundaries and are often highly mobile — giving them the capacity to respond to fluctuations in local conditions and the ability to spread into areas that

Figure 2.2 Diagrammatic representation of the National Natural Resource Management Monitoring and Evaluation Framework



are environmentally suitable. Uniform monitoring and reporting of invasive animals across Australia and consistent reporting processes will make it easier for stakeholders to assess the effectiveness of various management strategies and national investment programs.

On an Australia-wide basis, the fundamental questions for which consistent information is required to manage invasive animal species, develop policy and guide future investment activities are:

- What areas are affected and potentially affected by invasive animals?
- What are the impacts and potential impacts of invasive animals?

While it was beyond the scope of this Assessment, additional information is required on the following issues to improve the management of invasive animals in Australia:

- What management is being implemented and where is investment being allocated?
- What strategies are required to mitigate the impacts of invasive animals?

The effectiveness of management strategies and control activities can be measured in a number of ways. Information on the distribution, abundance and impacts of invasive animals is needed to identify where management and resources are required to implement strategies effectively.

Important wetlands like the Macquarie Marshes in NSW are damaged by feral pigs each year (photo by David Croft)

Indicators and information requirements

To manage invasive animals and their impacts effectively requires identifying information and products that are most useful in addressing management priorities. Monitoring, evaluating and reporting can provide meaningful information to target invasive animal management problems. In particular, national data on invasive animals are required to prioritise investment, measure the effectiveness of national funding programs, evaluate the effectiveness of management programs, and report the status of invasive animals against other natural resource themes.

In our review of previous monitoring and reporting initiatives for this Assessment, we found that a diverse range of methods has been applied by the relevant state and territory authorities to measure and report information on invasive animal populations. To improve management of invasive animals and evaluate the effectiveness of management interventions at a national scale, monitoring and reporting require:

- consistency across all state and territory jurisdictions
- uniformity in the scale of information being measured and reported within and across state and territory jurisdictions.

There is also a need to establish national trends in invasive animal populations and for information from the states and territories to be readily accessible through a centralised national database or information system.

To undertake a national assessment and improve the consistency of information across Australia for monitoring and reporting of invasive animals, the following actions were necessary:

- develop and adopt nationally agreed data standards for collection, collation and uniform reporting of information about invasive animals
- recommend data collection methods for local and regional areas using field manuals and monitoring techniques
- develop consistent data-collection methods at regional and state levels
- collect, collate and report information at regional and state levels using appropriate reporting tools and techniques
- report products at the state, territory and national levels.

The Australian Vertebrate Pests Committee (VPC) agreed to formalise two separate indicators under the indicator heading to address monitoring and reporting requirements. During 2006, VPC endorsed two national indicators for invasive animals to guide monitoring and reporting activities under the National M&E Framework.

1. Distribution and abundance of significant invasive vertebrate pests
2. Impacts of significant invasive vertebrate pests.

These indicators provide the basis against which fundamental information was collected and reported on for the Assessment. They improve the quality and consistency of reporting of the status of invasive animals and their impacts. The indicators complement each other by providing a combination of distribution and abundance information (measured on a broad scale) and impacts (measured on a localised scale).

VPC recommendations for fundamental data attributes

VPC recommended that the following fundamental data attributes would be needed to address collection of the respective indicators for invasive animals under the National M&E Framework:

- occurrence of the species
- density or relative abundance of the species
- distribution (spatial pattern) of the species
- trend in the abundance of populations
- quality of information and data collected
- impacts of invasive animals (measured in terms of environmental, economic and social impacts).

For the Assessment, VPC agreed to adopt a minimum reporting scale of a 0.5-degree grid (equivalent to about 50 km × 50 km) for information under the first indicator.

Although beyond the scope of the current Assessment, VPC also recommended that the following information would also be required to evaluate the effectiveness of investment, management strategies and policy throughout Australia:

- management activities, and response of populations to management intervention, such as control strategies
- number of new incursions and the scale of incursions.

Species for reporting

For the purposes of this Assessment and ongoing monitoring and reporting under the National M&E Framework, a list of established invasive animals of national significance was developed in consultation

with VPC (Table 2.1). The species list intends to reflect national, state and territory priorities for pest species management and will require ongoing or periodic review by VPC. The species list formed the basis for collection, collation and reporting under the national indicators for invasive animals.

It should be noted that species of significance vary by region and jurisdiction, and that the national priority species list reflects the priorities identified by VPC and the respective state and territory jurisdictions.

Table 2.1 Nationally significant invasive animals nominated by the Australian Vertebrate Pests Committee

Species	
Feral pigs	*Sus scrofa*
Feral goats	*Capra hircus*
Rabbits	*Oryctolagus cuniculus*
Foxes	*Vulpes vulpes*
Common carp	*Cyprinus carpio*
Cane toads	*Bufo marinus*
Common starlings	*Sturnus vulgaris*
Feral cats	*Felis catus*
Wild dogs and dingoes	*Canis lupus familiaris; Canis lupus dingo* and hybrids
Feral deer species	
Fallow	*Dama dama*
Red	*Cervus elaphus*
Sambar	*Cervus unicolour*
Rusa	*Cervus timorensis*
Hog	*Axis porcinus*
Chital	*Axis axis*

Monitoring protocols

Monitoring and reporting information to address the two national indicators for invasive animals under the National M&E Framework require agreed monitoring protocols. These provide a guide for collecting, collating and reporting information, and for promoting consistency and comparability.

A range of field-based techniques is available for monitoring invasive animals at the local and regional levels, including spotlighting, sight counts, and sand-pad monitoring. *Monitoring Techniques for Vertebrate Pests* presents the main techniques for monitoring invasive animals in Australia (Mitchell and Balogh 2007). Some are more suited to regional application than others, eg aerial surveys versus den counts. However, to apply these techniques for all invasive species at a state, territory or national scale is not practical or cost-effective. Hence, a combination of recommended local-scale field monitoring techniques and regional-, territory- and state-level approaches is required to achieve the best level of monitoring in a cost-effective way. By combining a variety of these monitoring approaches, these local- and regional-scale datasets can be used to develop state, territory and national information.

This Assessment developed two monitoring protocols to address the two indicators for invasive animals.

Indicator 1.
Monitoring protocol for the distribution and abundance of significant invasive vertebrate pests.

Indicator 2.
Monitoring protocol for the impacts of significant invasive vertebrate pests.

Distribution and abundance — Indicator 1

To develop the *Monitoring protocol for the distribution and abundance of significant invasive vertebrate pests*, we identified the following key issues for information collection, collation and reporting for invasive animals:

- There were no formally agreed consistent attributes for invasive animal monitoring.
- High-quality and meaningful data need to be collected at the local level to maintain accuracy in regional and state datasets.
- The methods described in *Monitoring Techniques for Vertebrate Pests* (Mitchell and Balogh 2007) can be used to collect data on invasive animal populations in a consistent way.

Spotlighting can be used to monitor fox numbers (photo by NSW Department of Primary Industries)

Therefore, to develop an appropriate indicator protocol, it was agreed that:

- Core data attributes are required for monitoring and reporting.
- Existing state and territory monitoring should be considered for the Assessment.
- Existing broad-scale monitoring should be used to provide distribution and abundance information.
- The recommended reporting scale should be reviewed after completion of the Assessment for its use in future assessments.
- Cross-theme information, such as soil type and vegetation data, should be used wherever relevant.

For the Assessment, we decided that the primary data for Indicator 1 should include the following five data attributes.

Occurrence
The presence status of a species within an area (ie present or absent)

Distribution
A measure of spatial pattern throughout an area (ie localised or widespread)

Abundance
A measure (in numbers or relative value) of density within a defined area (ie occasional, common or abundant)

Trend
A measure of change in animal abundance over time for the area in question (ie increasing, stable, decreasing or unknown)

Aerial surveys are one method used for monitoring feral goat populations (photo by NSW Department of Primary Industries)

Data quality
A measure of data quality associated with most of the information used to determine overall classification (ie low, medium or high).

VPC subsequently endorsed the *Monitoring protocol for the distribution and abundance of significant invasive vertebrate pests*, and an overview of the indicator protocol is presented in Appendix 1.

Impacts — Indicator 2

To develop the *Monitoring protocol for the impacts of significant invasive vertebrate pests*, we identified the following key issues for information collection, collation and reporting for invasive animals:

- There were no formally agreed monitoring framework or agreed methods for measuring and reporting the impacts of all invasive animals.
- Meaningful information on the impacts of invasive animals is required, but the techniques available are most suitable for collection of detailed impact information at the local level.

Therefore, to develop an appropriate indicator protocol, it was agreed that:

- Core data attributes for monitoring impacts should be identified.
- Existing local-scale monitoring programs can be used to report impacts.
- Case studies should be used to report key findings from monitoring programs.
- Effective tools need to be developed to monitor the impacts of invasive animals.

It was agreed that reporting of invasive animal impacts should use a series of case studies from established regional programs because impact reporting across large areas is often impractical. It was agreed that case studies should encompass local, regional, state, territory and national datasets where available. Many data attributes for impact reporting were nominated, and it was agreed that it should address a number of species and the various impact types associated with each species (see the guidelines for reporting invasive animal impacts in Appendix 2).

For this Assessment, VPC endorsed the *Monitoring protocol for the impacts of significant invasive vertebrate pests*, and an overview of the indicator protocol is presented in Appendix 2. It should be noted that VPC recommended further development of this indicator protocol for monitoring invasive animal impacts. Further research is required to develop techniques for impact monitoring across jurisdictions, and a framework is needed for reporting information at the state, territory and national scales.

Data collection and collation

This Assessment implemented the two agreed indicator protocols for monitoring and reporting information on invasive animals and their impacts. This section briefly describes the process followed to gather the required information.

Data sources

A range of information was gathered from the respective state and territory government agencies and relevant non-government organisations. Existing state-wide distribution and abundance survey data and impact information were sourced from the states and territories. Where feasible, state- and territory-wide information was either updated or collected to facilitate accurate reporting.

Data on occurrence, distribution and abundance

Following the methods defined by the recommended *Monitoring protocol for the distribution and abundance of significant invasive vertebrate pests* (see Appendix 1), we developed various datasets that had been collated from relevant sources. These collated datasets enabled us to report on the distribution and abundance of invasive animals throughout Australia in a consistent way.

Monitoring of pest impacts is also particularly important for determining when and where to undertake control (photo by Jonathan Lee)

Distribution and abundance information was compiled from various datasets (eg fauna atlas records), transect surveys (eg aerial survey and spotlight-count data), land manager surveys (eg questionnaires) and field-sampling programs across regional areas wherever available. These datasets were consolidated into a consistent value for occurrence, distribution, and abundance using a standardised approach to present the maps in this Assessment.

Where localised, regional and state datasets were available from relevant state sources, they were collated into a centralised database for this Assessment. Detailed datasets and information were obtained from:

- field-based ground and aerial surveys using rigorous scientific-sampling techniques
- control records and management-activity information
- various registers and wildlife atlas-style databases
- historical records, verified as current
- expert opinion and reviews from specialists in wildlife and pest management fields
- questionnaire surveys and reporting
- anecdotal reports and subjective accounts.

To present the data from the various sources at a national scale, the occurrence, distribution and abundance data were processed through five phases (see Table 2.2 for a summary of these phases and Figure 2.3 for a schematic representation of the data collection and collation process). These phases involved collecting and compiling local-scale data at state, territory and national levels into a consistent format (see Figure 2.3) based on indicator protocols (see

Appendixes 1 and 2). This Assessment also adopted a step-wise process to collate existing information on species extent, based on occurrence, distribution and abundance data (Figure 2.4).

Table 2.2 Phases of data compilation and reporting for occurrence, distribution and abundance data

Phases	
Phase 1 Occurrence	■ collection of species occurrence data from all available databases for the period 2000–2006 ■ preparation of state, territory and national occurrence maps
Phase 2 Abundance, distribution, data quality, and trend	■ collection of species distribution data from all available databases for the period 2000–2006 ■ interview-style consultation with relevant stakeholders[a] to gather institutional knowledge on abundance, distribution, data quality and trend
Phase 3 Draft state and territory mapping products	■ review of draft state and territory maps by experts from relevant agencies
Phase 4 Draft national mapping products	■ review of draft national maps by experts from relevant agencies to ensure comparability across jurisdictions
Phase 5 Final national mapping products	■ development of a series of national products ■ endorsement of the products by VPC

VPC = Australian Vertebrate Pests Committee

[a] Consultation with natural resource management regional groups, state government agencies and relevant authorities

We developed a geographic information system (GIS) data-capture routine to provide a step-wise approach for entering all available spatial data and to assign to it an appropriate distribution and abundance classification. The data-capture routine was designed for reporting on the five data attributes:

- occurrence (present, absent or unknown)
- distribution (localised or widespread)
- abundance (occasional, common or abundant)
- trend (increasing, decreasing, stable or unknown)
- data quality (high, medium, low or no data).

To address these five attributes, data were compiled from existing information sources wherever available. Existing state-wide datasets were available for New South Wales (NSW), Queensland (Qld) and Western Australia (WA) at the commencement of this Assessment. They were accessed and, where appropriate, updated during the course of the assessment (see Woolnough et al 2005, West and Saunders 2007). Partial datasets for South Australia (SA), Victoria (Vic) and the Australian Capital Territory (ACT) were also available but required updating. To report on the five attributes, datasets for Tasmania (Tas) and the Northern Territory (NT) were developed for this Assessment from existing databases.

Data were collated to varying scales ranging from 1:25 000 to a 1:50 000 scale. Fine-resolution datasets were collated in Vic, Tas, NSW, Qld and WA, and aggregated to the national 0.5-degree grid cell. Subsequently, information was aggregated and scaled up to the recommended national-reporting scale of 0.5 degrees (equivalent to 1:100 000) (see the section on data aggregation below).

Figure 2.3 Data compilation process of local and regional data to produce state, territory and national datasets

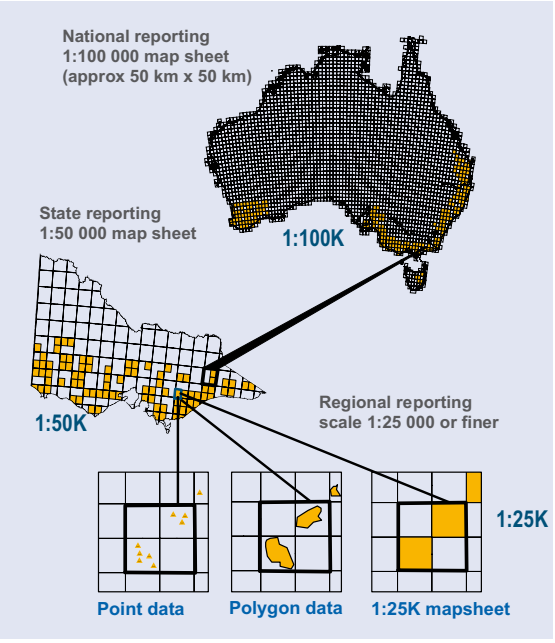


Figure 2.4 Step-wise data collection and collation process for occurrence, distribution and abundance data

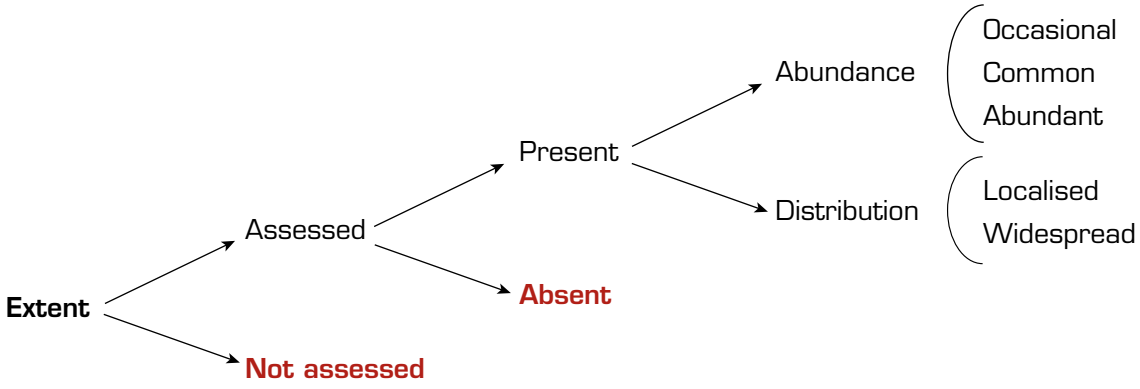


Table 2.3 shows the approximate resolution of the original data available in each state and territory. The finest resolution of available data in this table was 'property-scale' (for WA) and '5-km grid' (for NSW and the ACT). Appendix 3 presents a summary of the pest species data and information accessed to develop the respective state, territory and national distribution and abundance datasets.

Because the quality and accuracy of the various datasets varied, a data-quality value was assigned to each respective dataset. Expert groups were formed in each state and territory to review each dataset. Cross-border discrepancies were reviewed in each jurisdiction, particularly where precise estimates were lacking.

Data collection, collation and reporting from all states and territories were undertaken between June 2006 and April 2007.

Potential distribution predictive models

This Assessment used climate-matching (using 'CLIMATE' software) models based on the climatic conditions of a species' overseas range to predict its potential Australian distribution. The use of climate models to predict the potential distribution of an introduced animal species based on its current worldwide distribution is well established — although not without limitations. The use of habitat-suitability matching is still under development but may improve

Table 2.3 Approximate resolution of original state- and territory-based data collated to develop national datasets for the distribution and abundance of invasive animals

Jurisdiction	NSW	Qld	ACT	Vic	NT	WA	SA	Tas
Original data resolution	5-km grid [a]	17-km grid [b]	5-km grid [a]	1:25 000	1:100 000	Property scale and 10-km grid [c]	1:100 000	1:25 000

NSW = New South Wales; Qld = Queensland; ACT = Australian Capital Territory; Vic = Victoria; NT = Northern Territory; WA = Western Australia; SA = South Australia; Tas = Tasmania; km = kilometre

[a] See West and Saunders (2007)

[b] See Annual Pest Distribution Survey, Biosecurity Queensland[1]

[c] See Woolnough et al (2005)

It is important to recognise that, although the original method of data collection at the state and territory level may vary for some data available for this Assessment, a standardised method was initiated to derive consistent datasets for all species. In some cases, such as feral deer, a number of species are known to occur in the wild in Australia; however, because their management and control remains largely comparable between species, there was no need to treat them separately for this Assessment. The extent of all deer species allows decision makers to address their problems as a whole, and future assessments will identify whether treatment at individual species level is required.

[1] http://www.nrw.qld.gov.au/pests/maps/pest_distribution/annual_pest_dist_maps.html (Accessed 10 October 2007)

predictions of a species' potential range when combined with climate matching. Regardless, given the inherent limitations of both approaches, the generalist and adaptable nature of many pest species and interactions with other species, such maps should be used only as a broad indicator of potential distribution rather than an accurate prediction of ultimate range.

This Assessment uses climate matching to predict the potential distribution of those species that are thought to have the potential to spread beyond their current range in Australia. Species that have already spread to their climatic limits in Australia (namely rabbits, foxes, wild dogs and feral cats) are not presented in this Assessment. Predictive maps using climate matching are provided for feral pigs, feral goats, common carp, cane toads and common starlings. Predictive maps incorporating suitable-habitat information are also presented for all species except common carp. For feral goats, it was not possible to divide habitats by preference, so all habitats known to be used by the species were considered simultaneously.

CLIMATE software

The CLIMATE software package matches the climates (temperature and rainfall data) of selected regions around the world where a species is present, to the climate of other selected regions. The potential range of a species within the analysis site is produced as a series of maps. The desktop version of CLIMATE employed in this Assessment uses the statistical program 'R'. A Euclidean calculation was used to determine the closest matches between the input overseas data and the target site. The maps presented here use match classes that summarise the output as high, medium and low.

Land use

Land use data, captured at the catchment scale, were provided by the Bureau of Rural Sciences according to the Australian Land Use and Management (ALUM) Classification[5] (see also BRS 2006). The ALUM classification is a system for ordering land use information into categories such as cropping and nature reserves. The system provides a nationally consistent way to collect and present land use information for a wide range of users across Australia. The ALUM classification was completed in 2005 and is the Australian Spatial Data Infrastructure standard for land use datasets.

The classification has six primary levels of land use that are distinguished in order of generally increasing levels of intervention or potential impact on the natural landscape:

- Class 1 — Conservation and Natural Environments
- Class 2 — Production from Relatively Natural Environments
- Class 3 — Production from Dryland Agriculture and Plantations
- Class 4 — Production from Irrigated Agriculture and Plantations
- Class 5 — Intensive Uses
- Class 6 — Water.

Limitations of habitat matching using land use data

There are a number of limitations associated with using habitat matching as a predictor of suitable areas for pest species. These limitations are:

- Broad definitions for land use categories — broad categories in land use and variation within classes may lead to anomalous results (eg 'grasslands' may comprise alpine grasslands, as well as tall tropical grasses in northern Australia).
- Scale of data for analysis — the large reporting units used in this analysis would result in large within-cell variation in results.
- Species-specific requirements and temporal and spatial issues — this analysis does not consider specific requirements for species, such as feral pigs requiring access to perennial water.
- Matrix of habitats — most species require a number of suitable habitats in close proximity, and this method does not consider that species require multiple habitats or continuity of habitats to survive.
- Human activities and other factors — in addition to habitat and climate conditions, a wide range of factors limit a species' ability to survive and/or

[5] http://adl.brs.gov.au/mapserv/landuse/alum_classification.html (Accessed 15 May 2008)

Rabbits (*Oryctolagus cuniculus*) excavate large warrens for shelter and breeding, and are a major problem in agricultural landscapes (photo by NSW Department of Primary Industries)

spread, such as rivers, human activity, previous history and stochastic events such as fire.

- Catchment-scale land use data have been captured by jurisdictional agencies and as a result are a patchwork of different years.

Data on impacts

Following the methods defined by the recommended *Monitoring protocol for the impacts of significant invasive vertebrate pests* (see Appendix 2), we developed information from a number of different sources.

Invasive animals cause a diverse range of impacts, so measuring and reporting these across large areas can be particularly difficult. The impacts of invasive animals can also vary significantly between environments and jurisdictions; eg feral pigs can cause significant damage to crops in some areas and few problems in other areas. A further problem is that the impacts of invasive animals are not always easily discerned from the impacts of other land management activities such as land clearing, agriculture and the effects of climate change. As a result, measuring and reporting the impacts of invasive animals are usually conducted on a local scale or in unison with control programs and regional monitoring activities.

The VPC recommended the use of existing programs and monitoring activities wherever possible because of the lack of broad-scale impact monitoring and the lack of suitable techniques to monitor and report the impacts of invasive animals across all jurisdictions simultaneously.

Information on the impacts of invasive animal species was compiled from existing management programs and monitoring activities. A series of impact case studies was prepared to report the findings of each program, and a template for reporting impacts information was used to promote interpretability and consistency between programs. It should be noted that impact case studies were not available for all pest species of this Assessment.

The impact case studies reported information on five key program attributes:

- Project summary (pest species, program variables measured)
- Monitoring methods (techniques, analysis, methodology)
- Impact type (impact description)
- Current findings and results (quantified results)
- Key outcomes (implications of results).

The impact case studies provide a snapshot of information on the impacts of a small number of invasive animals in Australia. Each case study presents the current findings from each management and monitoring program, although the findings are not necessarily representative of the level of impacts throughout Australia.

In addition to information obtained from the impact case studies, a large volume of information is available on the impacts of invasive animals from important research throughout Australia that has been compiled over many years.[6]

VPC recommended impact case studies for this Assessment and noted the need for further development of impact monitoring and reporting mechanisms and development of an impact-monitoring framework to include case studies and other impact information throughout Australia to assess the effectiveness of investments and major funding initiatives. A commitment to monitoring and reporting by state and territory government agencies and NRM regional groups will make trend

[6] For more information on the impacts of invasive animals, see:
http://www.environment.gov.au/biodiversity/invasive/ferals (Accessed 15 May 2008)
http://www.daff.gov.au/brs/land/feral-animals (Accessed 15 May 2008)
http://www.feral.org.au (Accessed 15 May 2008)
http://www.invasiveanimals.com (Accessed 15 May 2008)

information more readily available for subsequent assessments. Ongoing monitoring and reporting activities will raise the level and availability of high-quality information for decision makers. Future assessments will enhance information availability.

Data aggregation and analysis

A series of data-aggregation rules was developed by the Cooperative Research Centre for Spatial Information and the Audit. Data-aggregation rules were prepared to aggregate the spatial data collated from all states and territories. The rules were developed to aggregate attribute data from 1:25 000 and 1:50 000 scales to 1:100 000. Based on the guidelines, a series of customised GIS routines was prepared to facilitate the aggregation. All data were aggregated to the national reporting scale of 0.5 degrees (equivalent to 1:100 000). A summary of the aggregation rules is contained in Appendix 4.

Data verification, integrity and implications

The datasets for nationally significant invasive animals used in this Assessment have been compiled from a large number of state and territory datasets that vary in their quality and reliability. Many forms of data and information have been used to generate consistent national datasets, including dedicated regional and state-wide assessments, intensive field-sampling activities, aerial surveys, baiting records, scientific surveys, anecdotal reports, perception-based reports and institutional knowledge, trapping data, and atlas records. As noted above, some data have been prepared from anecdotal reports. This variation in data quality has a number of implications for the interpretation of the national products. These issues need to be considered when interpreting the results.

Although the expert review panels in each state and territory verified the state-wide datasets by examining the data, and a number of datasets were derived from field-based techniques and aerial surveys, there are four additional data-integrity issues that need to be considered when interpreting state, territory and national data and products. These are:

The footprints and signs of animals can be used to monitor activity (photo by NSW Department of Primary Industries)

- Some data require further verification or cross-validation.
- Data vary in currency and were collected at the regional and state level between 2000 and 2006–07.
- Large areas contain qualitative information (eg institutional knowledge) that has not been derived from quantitative surveys.
- Where quantitative information is available (reported as 'data with expert opinion'), our national products can be applied with more certainty and confidence.

Every effort has been taken to collect, collate and compile all available information on invasive animals in each jurisdiction for national reporting. However, since the completion of data compilation, the project team has been notified of a few populations of pests that were inadvertently overlooked at the time of data compilation, such as feral deer known to occur on Cobourg Peninsula, NT.

3 Distribution and abundance of significant invasive vertebrate pests

This chapter summarises the main outcomes of the collection, collation and reporting of distribution and abundance information throughout Australia to report under the indicator for '*Distribution and abundance of significant invasive vertebrate pests*' (see Chapter 2).

The extent of significant invasive vertebrate pests

This Assessment addresses an important issue: the need for knowledge of the distribution and abundance of invasive pest species required to manage and mitigate their adverse impacts using available techniques and management strategies. Information on the distribution and abundance of pest species is required specifically to identify where resources are needed and to define the scale of the problem(s) associated with a pest species.

The extent of a species refers to its geographic range at a given point in time. Most of the information in this Assessment has been compiled from state- and territory-based management programs that have collected and collated data on the extent of invasive animal species before, or directly as part of, this Assessment. It provides baseline information on these species in each jurisdiction and, in some cases, has been developed over many years of management and monitoring, and includes reports from landholders and land managers.

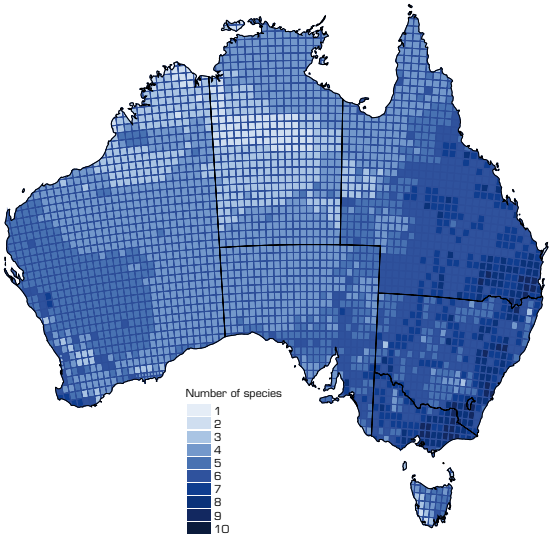
Occurrence of 10 nationally significant invasive animals

The 10 invasive animal species of national significance that were selected by the Australian Vertebrate Pests Committee (see Table 2.1 in Chapter 2) have collectively colonised all regions in Australia and many of the large coastal islands. There are no regions that are free of invasive animals, and the major concentrations occur in the eastern states. Figure 3.1 shows the occurrence of species of significance in Australia (as the sum of pest species present in each grid square). Their occurrence throughout Australia can be summarised in five ways:

- All areas of Australia contain at least one invasive animal species.
- The greatest diversity of invasive animal species occurs in eastern and southeastern Australia.
- Vast areas of inland Australia contain invasive animals.
- Many large islands contain invasive animals.
- The range of all species overlaps state and territory jurisdictional boundaries.

The following sections discuss the findings of this Assessment for the current distribution and abundance of the 10 nationally significant invasive animals. These results include occurrence, distribution and abundance data, trend in abundance, an assessment of the quality of the data used, and an estimate of the potential distribution of species (for those species that have not yet reached their potential extent).

Figure 3.1 Occurrence of 10 of Australia's nationally significant invasive animals



Feral pigs

Feral pigs (*Sus scrofa*) are introduced omnivores and a serious pest species in Australia. They are widely distributed throughout all states and territories, and are most abundant in eastern and northern Australia (Choquenot et al 1996). They also inhabit several coastal islands.

A number of characteristics have allowed feral pigs to successfully colonise Australia, such as their generalised diet and high fecundity. Even though populations are restricted largely to areas where there is permanent water, females can produce a large number of offspring per year, allowing populations to increase rapidly whenever conditions are favourable. Population density can reach 20 animals per square kilometre (Choquenot et al 1996).

Feral pigs are serious pests in Australia. They are responsible for an enormous amount of damage to environmental assets, agricultural production, primary industries and social values. An estimate of their total impacts (mainly associated with production loss) suggests the economic costs alone could be up to $106.5 million per year in Australia (McLeod 2004). They also pose a major threat to biodiversity. 'Predation, habitat degradation, competition and disease transmission by feral pigs,' is listed as a 'key threatening process' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act).

The following sections discuss the Assessment's findings on occurrence, distribution, abundance, data quality and trend for feral pigs.

Current occurrence, distribution and abundance

Presently, feral pigs inhabit an estimated 45% (ie 3.43 million square kilometres) of Australia. They occur in all states and territories, and on some large coastal islands (see Figure 3.2). In summary, the Assessment found that feral pigs:

- are most abundant in New South Wales (NSW) and Queensland (Qld) (see Figure 3.3)
- occur at low densities throughout parts of Western Australia (WA), South Australia (SA) and Victoria (Vic) (see Figure 3.3)
- are present in the southeast of Tasmania (Tas) and on Flinders Island

Feral pig (*Sus scrofa*) (photo by Brendan Cowled)

Figure 3.2 Feral pig occurrence throughout Australia

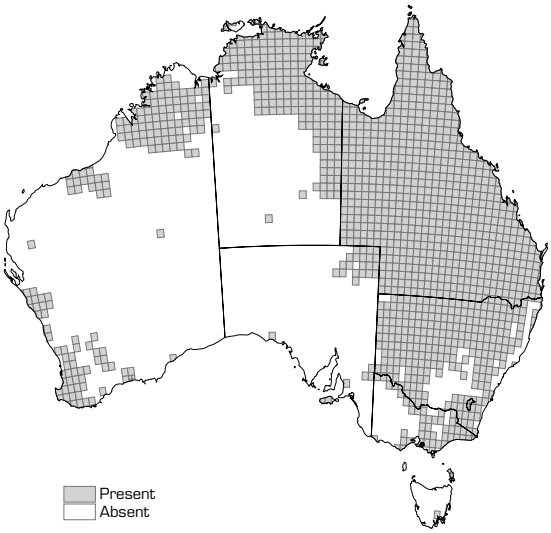
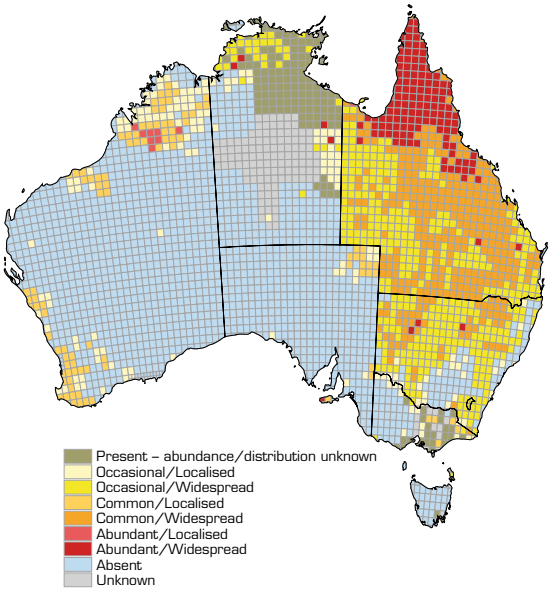


Figure 3.3 Occurrence, distribution and abundance of feral pigs throughout Australia



- occur throughout most of their range in Australia at 'occasional' and 'common' abundances (see Figure 3.4)
- are absent from 50% of the country and their occurrence is unknown in 5% (see Figure 3.5)
- are 'widespread' throughout NSW and Qld and are 'localised' throughout other states and territories (see Figure 3.6)
- are largely absent from Australia's arid and semiarid interior (apart from parts of far-western NSW and southwestern Qld) because of inadequate water resources and shelter (see Figure 3.6).

Figure 3.4 Feral pig abundance throughout Australia

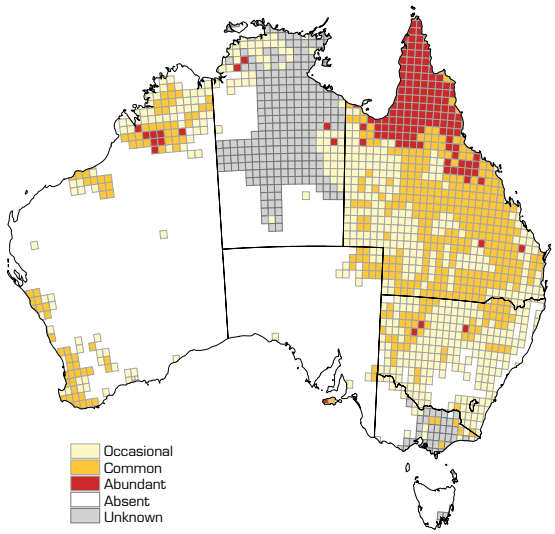


Figure 3.5 Percentage of reporting units occupied by feral pigs for each abundance class

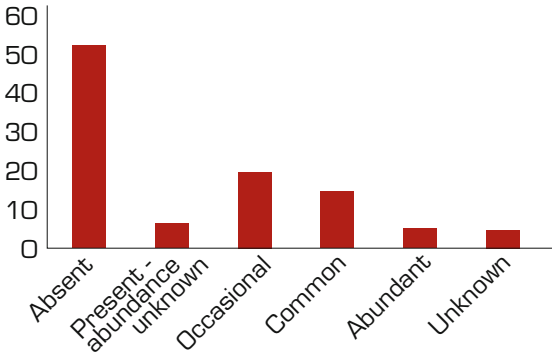
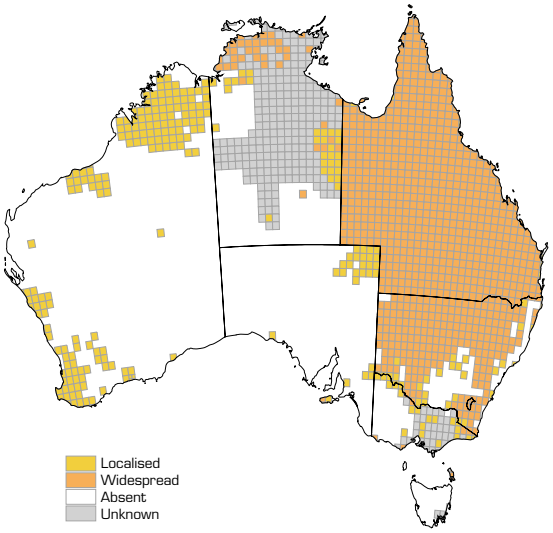


Figure 3.6 Feral pig distribution throughout Australia



Abundance trend and data quality

Figure 3.7 summarises the Assessment's findings on the trend in abundance of feral pigs throughout Australia (at the national scale). Information was only available for a few regions in the Northern Territory (NT) and SA, and was unavailable for most areas of the feral pig's current national range. In recent years, widespread drought may have reduced the overall abundance of feral pigs; however, this trend was not identified during this Assessment.

Information available for feral pigs varies in data quality throughout Australia. Figure 3.8 presents an overview of the quality of data used in this Assessment for each reporting unit. A number of areas, such as Qld, SA and the NT have high-quality data that are supported by expert opinion, while other areas have moderate levels of supporting information.

Potential distribution of feral pigs

The areas most suitable for feral pigs, based on their climate and habitat characteristics, are presented in Figure 3.9. At the scale of this Assessment, the climatic conditions appear to be suitable for feral pigs throughout all regions of Australia. This is not surprising given that they can occur in tropical, rangeland and alpine environments. However, other factors limit the spread and occurrence of feral pigs, particularly the availability of permanent water and shade.

Figure 3.7 Trend in the abundance of feral pigs throughout Australia

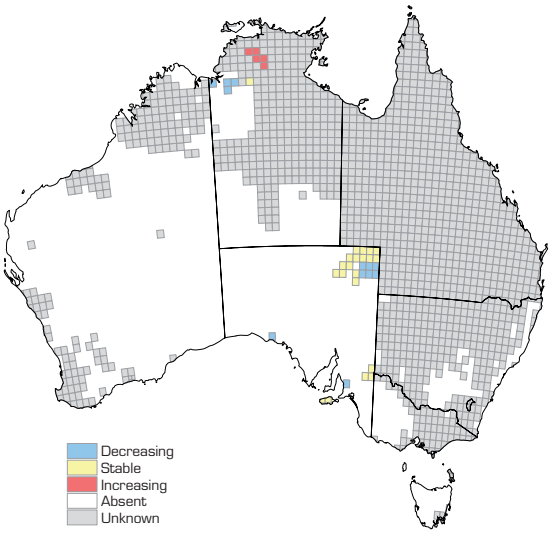
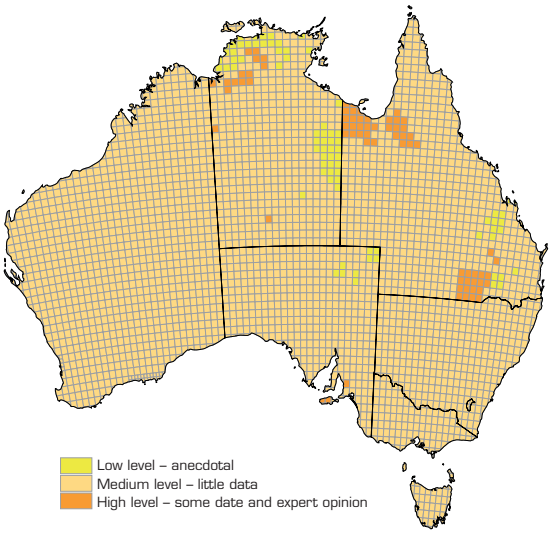
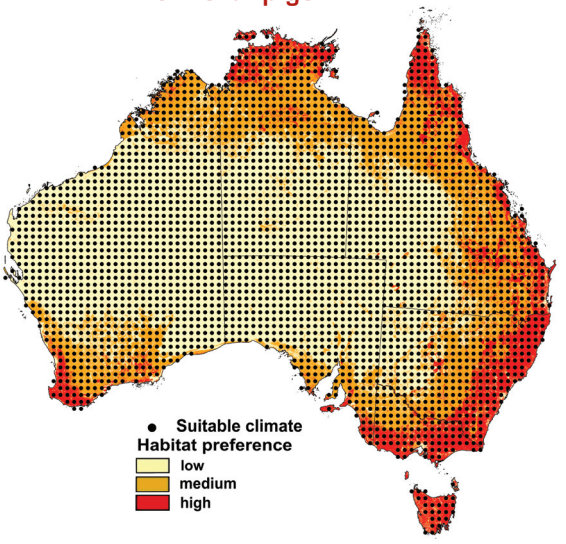


Figure 3.8 Data quality of information for feral pigs throughout Australia



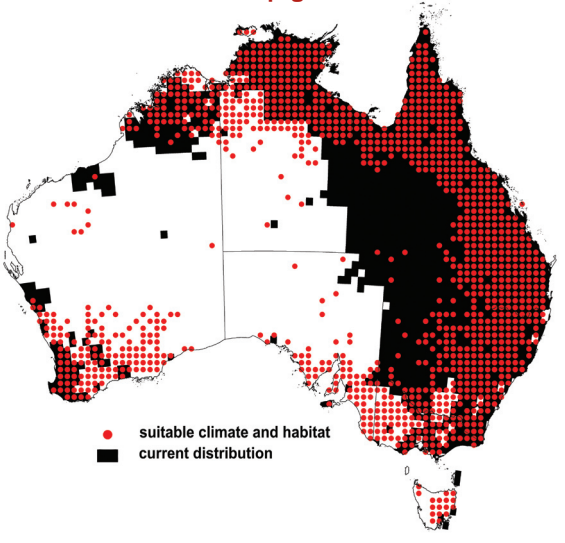
Feral pigs inhabit an estimated 45% of Australia. Comparison with suitable climate and habitat information shows many other areas where feral pigs are currently absent that are suitable for them in terms of their climate and habitat characteristics (see Figure 3.10). These areas occur in all states and territories except Qld. There are also areas where feral pigs are currently present that do not correspond with suitable climate and habitat. The primary reason for this disparity is that their distribution is regulated largely by accessibility to fresh water and adequate shelter, which are often controlled by human activities. In some cases, agricultural and land use practices throughout Australia inadvertently provide opportunities for feral pigs, allowing them to survive where climate and habitat are generally unsuitable. The provision of water for livestock (particularly in drier regions) is one example.

Figure 3.9 Suitable climate and habitat for feral pigs



Source: BRS, 2007

Figure 3.10 Suitable climate and habitat against the current extent of feral pigs



Source: BRS, 2007

Feral goats

Feral goats (*Capra hircus*) are introduced herbivores found in all states and territories of Australia and many large islands (Parkes et al 1996). Most populations have been established from escaped or released domestic animals and, more recently, from animals released to control weeds (McLeod 2004).

Feral goats are generalist herbivores that graze and browse a range of food types, including pastures, foliage, twigs, bark and fruit. They can withstand long periods of drought and can move over large distances between food and water resources. Females can breed twice per year, allowing populations to increase quickly when resources are abundant because breeding is dependent on food availability. Populations can reach very high densities, up to 98 animals per square kilometre (Fleming 2005).

The impacts of feral goats include losses to agricultural production, damage to the environment and impacts on society. The economic cost of feral goat impacts has been estimated at $7.7 million per year (McLeod 2004).

Feral goats are serious pests in Australia and can significantly alter vegetation communities. 'Competition and land degradation by feral goats' is listed as a 'key threatening process' under the EPBC Act. In recognition of this, the Commonwealth has published the *Threat Abatement Plan for Competition and Land Degradation by Unmanaged Goats*. This threat abatement plan is under review to identify management, research and other actions needed to ensure the long-term survival of native species and ecological communities affected by feral goats[7] (see also DEWHA 2008a).

The following sections discuss the Assessment's findings on occurrence, distribution, abundance, data quality and trend for feral goats.

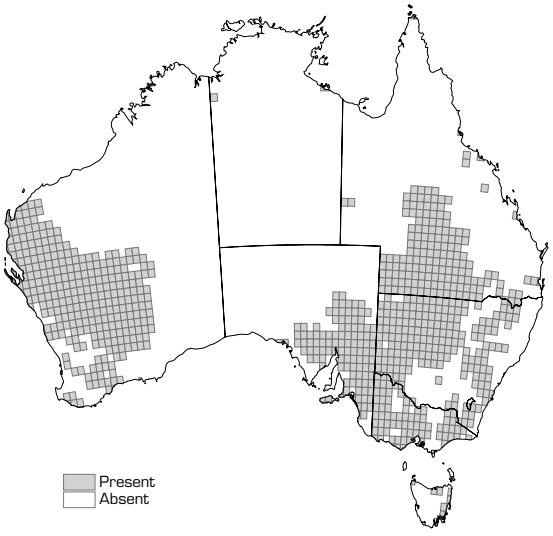
Current occurrence, distribution and abundance

Feral goats presently inhabit an estimated 28% (ie 2.13 million square kilometres) of Australia. They occur in all states and territories, and on some large coastal islands (Figure 3.11). In summary, the Assessment found that feral goats:

Feral goats (*Capra hircus*) (photo by Graham Johnson)

- are abundant across large areas of NSW, SA, Qld and WA, and occur in many remote and dry regions (see Figure 3.12)
- only exist in one location in the NT and are known to occur only in a few locations in Tas (see Figure 3.12)
- occur mainly at 'occasional' and 'common' abundances throughout their range, although the data available for their abundance in Vic and Tas are limited (see Figure 3.13)
- are absent from over 70% of Australia (see Figure 3.14)
- are mainly 'localised' in WA and are 'widespread' throughout the eastern and southern regions of Australia (see Figure 3.15).

Figure 3.11 Feral goat occurrence throughout Australia



[7] http://www.environment.gov.au/biodiversity/threatened/tap-drafts.html (Accessed 27 May 2008)

Figure 3.12 Occurrence, distribution and abundance of feral goats throughout Australia

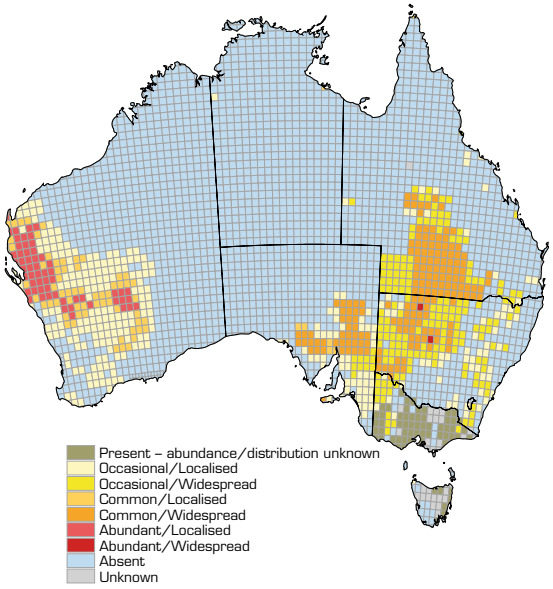
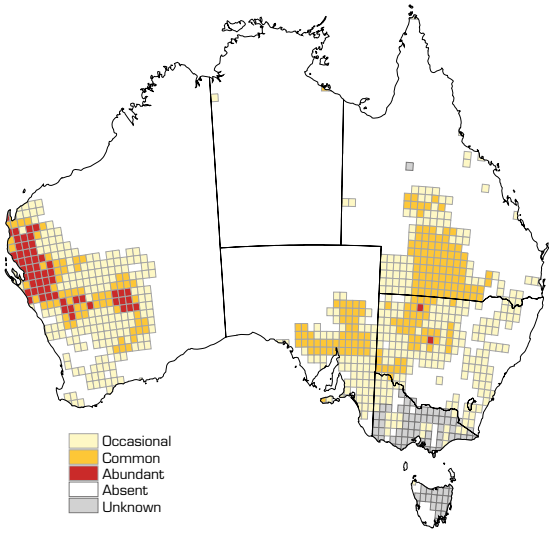


Figure 3.13 Feral goat abundance throughout Australia



Abundance trend and data quality

Figure 3.16 summarises the Assessment's findings on the trend in abundance of feral goats throughout Australia (at the national scale). Information about their trend in abundance was available only for SA. However, regional datasets on the trend in abundance exist in several states. In SA, feral goats are perceived to be predominantly stable throughout most their range and are decreasing in some areas including areas of the Flinders Ranges (Figure 3.16). Trend

Figure 3.14 Percentage of reporting units occupied by feral goats for each abundance class

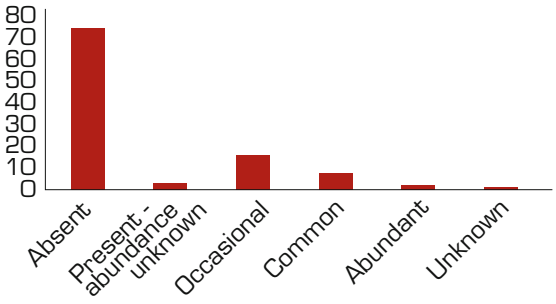


Figure 3.15 Feral goat distribution throughout Australia

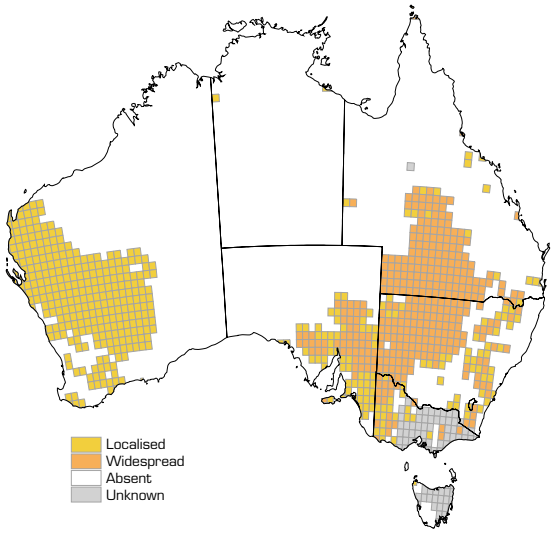


Figure 3.16 Trend in the abundance of feral goats throughout Australia

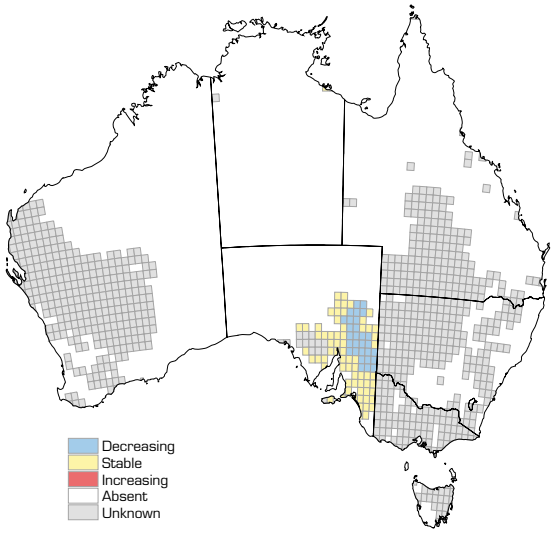


Figure 3.17 Data quality of information for feral goats throughout Australia

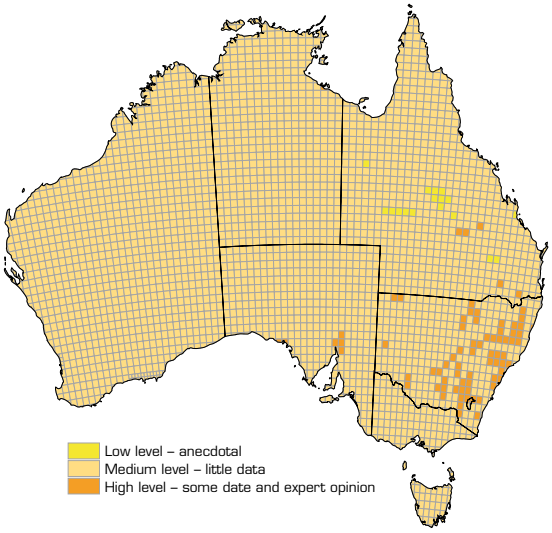
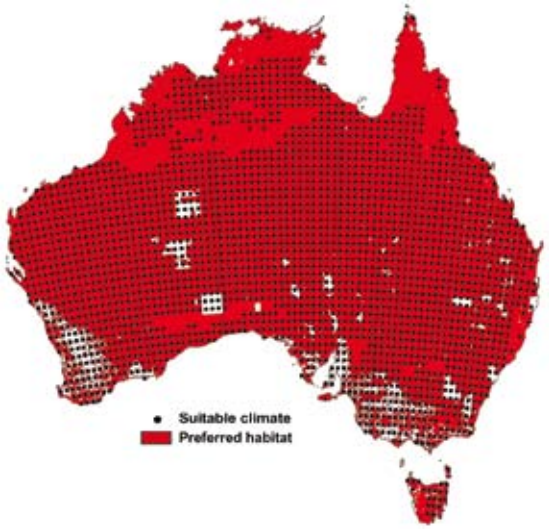
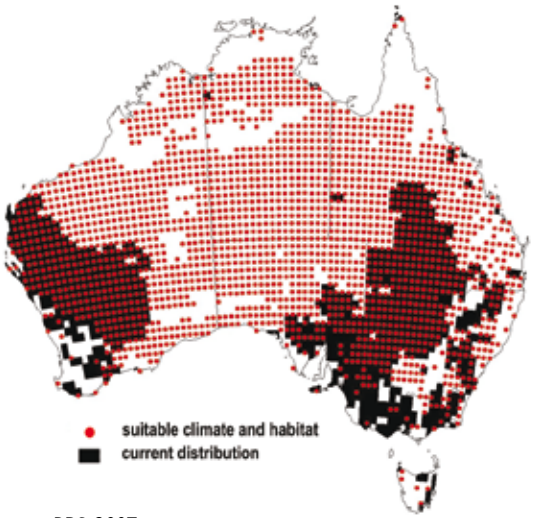


Figure 3.18 Predicted suitable climate and habitat for feral goats



Source: BRS, 2007

Figure 3.19 Predicted suitable climate and habitat against the current extent of feral goats



Source: BRS, 2007

information is largely unavailable for most regions of the country.

Figure 3.17 shows the quality level of the data used in this Assessment for each reporting unit in Australia. The quality of data for feral goats varies; a number of areas, such as NSW, Qld and SA, have high-quality data available that are supported by expert opinion, while most of the remainder of the country has moderate levels of supporting information.

Potential distribution of feral goats

The areas most suitable for feral goats, based on their climate and habitat characteristics, are presented in Figure 3.18. The climate-matching analysis suggests that a large proportion of Australia is suitable for feral goats and that they may potentially inhabit all jurisdictions. Because it was not possible to differentiate between preferred habitats according to high, medium and low suitability (as for other species), a single category for preferred habitat is presented (see Figure 3.18). This incorporates land use classes[8] (see also BRS 2006). When climate-matching analyses were incorporated with suitable habitats (as described in Figure 3.19), the analysis suggests that feral goats could occur in almost all areas of Australia. Predictions that they may survive in all areas are not surprising given that domestic goats have been bred selectively for thousands of years to survive in a range of environments and that feral goats in Australia are descendents of domestic goats gone wild.

Feral goats currently inhabit an estimated 28% of Australia. Analysis of the areas that combine high climate matches with suitable habitat suggests that feral goats could inhabit a much larger range in mainland Australia and Tas. However, climate and suitable habitat are not the only factors that determine the range. Other factors may include

8 http://adl.brs.gov.au/mapserv/landuse/alum_classification.html (Accessed 15 May 2008)

pasture and browse species, predators and human activity. For example, feral goats are preyed upon by wild dogs and dingoes, and their range is limited by agricultural development and practices. Further spatial analyses that consider these factors are required to improve the accuracy of predicted range information for feral goats in Australia.

Feral deer

Domestic deer were introduced to Australia during European settlement for a wide range of reasons, including farming, hunting and acclimatisation. Escaped or released deer have subsequently established wild populations and are becoming a nuisance in many regions. Currently six main species of feral deer, also referred to as wild deer, occur in the wild throughout Australia. These include: fallow deer (*Dama dama*), red deer (*Cervus elaphus*), sambar (*Cervus unicolour*), rusa (*Cervus timorensis*), chital (*Axis axis*) and hog deer (*Axis porcinus*) (see Chapter 1).

Feral deer are thought to be responsible for a wide range of economic, environmental and social impacts; however, the costs are largely unquantified. In New Zealand, feral deer cause severe damage to vegetation (Long 2003).

Feral deer are an emerging pest species that has the potential to become a serious pest in Australia. In some states and territories, their range has increased significantly in recent years and their impacts are more readily reported. While their ecological limits have not been determined, feral deer can potentially occupy a broad range of medium- to high-rainfall temperate areas of Australia and could subsequently expand to occupy this area. Feral deer are listed as a 'key threatening process' under some state legislation but have not been nominated under Commonwealth legislation.

The sections discuss the Assessment's finding on occurrence, distribution, abundance, data quality and trend for feral deer.

Current occurrence, distribution and abundance

Feral deer presently inhabit an estimated 8.8% (ie 670 000 square kilometres) of Australia and occur in all states and territories (Figures 3.20 and 3.21). In summary, this assessment found that feral deer:

Fallow deer (*Dama dama*) (photo by Brian Boyle)

Rusa deer (*Cervus timorensis*) (photo by Brian Boyle)

- are common and widespread in parts of Vic, Tas, Qld and SA, and are occasional throughout NSW and WA (see Figure 3.22)
- occur as small populations on Cobourg Peninsula and Groote Eylandt in the NT
- have predominantly 'occasional' and 'common' abundances throughout their range

Figure 3.20 Feral deer species occurrence throughout Australia

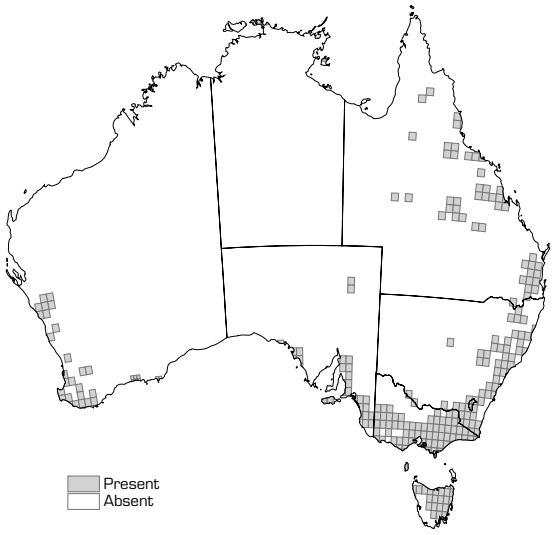


Figure 3.21 Occurrence, distribution and abundance of feral deer species throughout Australia

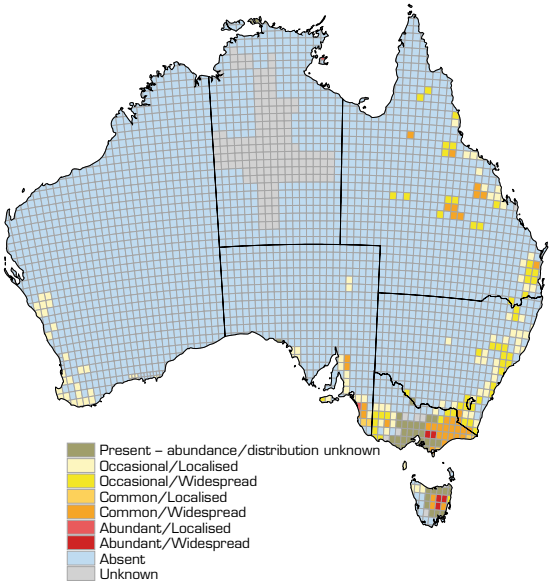
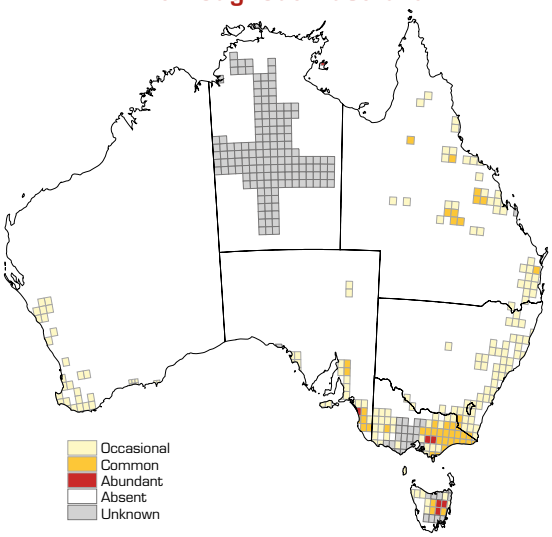


Figure 3.22 Feral deer species abundance throughout Australia



- are absent from the dry semiarid and arid regions where other pest species can survive (see Figure 3.22)
- are absent from over 80% of Australia under current climate conditions but are thought to be spreading (see Figure 3.23)
- are often reported as being 'widespread' within regional populations (see Figure 3.24)

Figure 3.23 Percentage of reporting units occupied by feral deer for each abundance class

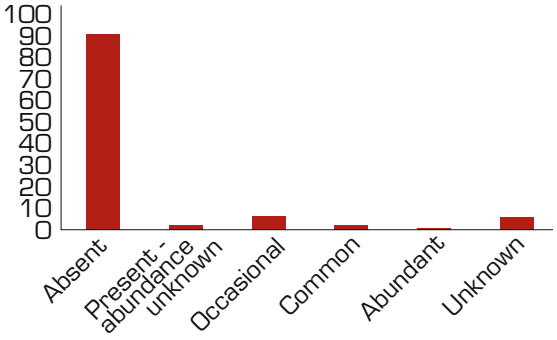
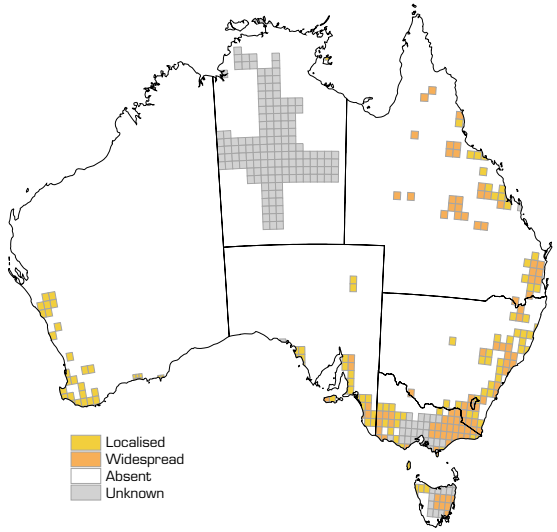


Figure 3.24 Feral deer species distribution throughout Australia



- also occur on some islands, such as Kangaroo Island in SA (see Figure 3.24).

Abundance trend and data quality

Figure 3.25 summarises the Assessment's findings on the trend in abundance of feral deer species throughout Australia (at the national scale). Information on their trend in abundance was only available for small areas of southeastern SA and the central plateau of Tas. In both cases, deer were reported to be increasing in many areas. Kangaroo Island reported a decreasing abundance (see Figure 3.25).

Trend information was largely unavailable for all other areas of the current national range, until follow-up assessments are performed.

Figure 3.25 Trend in the abundance of feral deer species throughout Australia

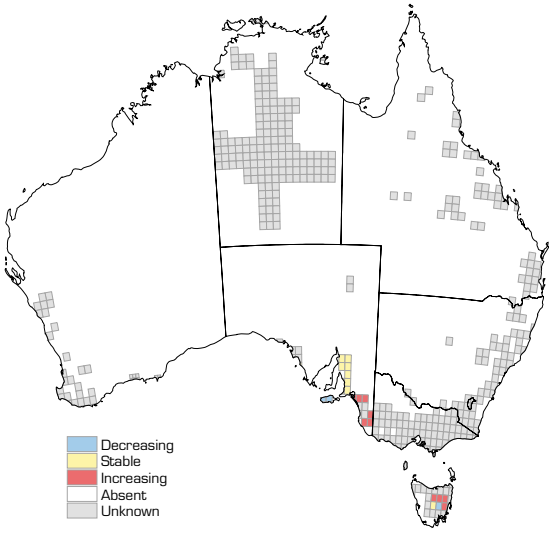


Figure 3.26 Data quality of information for feral deer species throughout Australia

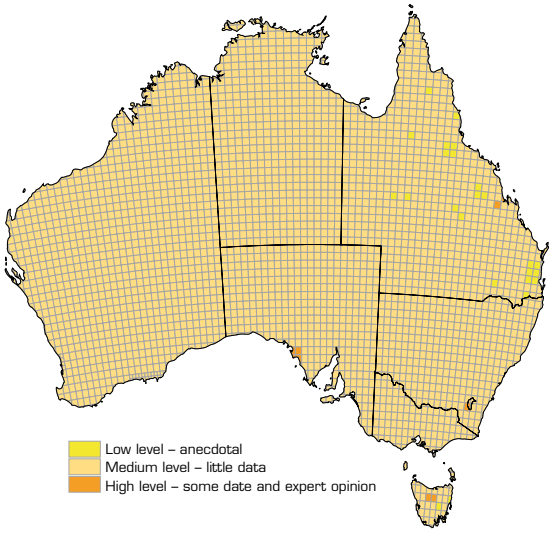


Figure 3.26 shows the quality of the data used in this Assessment for each reporting unit in Australia. The quality of data for feral deer varies; a small number of areas have high-quality data available that are supported by expert opinion (see Figure 3.26), while most of Australia has moderate levels of supporting information.

Potential distribution of feral deer species

The potential distribution of feral deer species was not assessed as part of this Assessment because there are numerous species of feral deer and because they are known to occupy different areas, ranging from northern Australia to the southern highlands. Information available for this Assessment reports all feral deer species simultaneously. Thus, predictions would overestimate the potential range of deer in Australia. Species-specific models would overcome this problem but were beyond the scope of this Assessment. Future analysis could either address a number of like species or provide individual species analyses.

Red deer (*Cervus elaphus*) are one of many species commonly occurring in the wild throughout Australia (photo by Peter West)

Rabbits

Rabbits (*Oryctolagus cuniculus*) were introduced in the mid to late 1800s and are presently found in all states and territories throughout Australia. They inhabit dry arid and semiarid landscapes through to alpine tundra (Williams et al 1995). Rabbit populations generally fluctuate in response to rainfall and pasture availability, and can increase rapidly when conditions become favourable. Populations can reach 300–400 per square kilometre (Williams et al 1995).

While rabbits have historically been considered an agricultural pest because they compete with livestock for pasture, they are also recognised as a major environmental pest due to their contribution to land degradation and damage to native vegetation (Williams et al 1995). The economic impact of rabbits in Australia has been conservatively estimated at over $100 million per year (McLeod 2004).

Rabbits are major pests in Australia and can seriously alter vegetation communities. 'Competition and land degradation by rabbits' is listed as a 'key threatening process' under the EPBC Act. The Australian Government is currently reviewing the *Threat Abatement Plan for Competition and Land Degradation by Rabbits* to mitigate the impacts of rabbits in Australia.[9] (See also DEWHA 2008b).

Rabbits have largely reached their ecological limits in Australia regarding range and overall distribution. The ongoing impact of rabbit haemorrhagic disease (RHD) and myxomatosis has reduced rabbit populations, but evidence suggests that rabbit numbers are recovering from post-RHD levels. Following the release of RHD virus in 1996, many studies reported recovery of native vegetation communities. In areas where additional control has been undertaken (using techniques such as warren destruction), native vegetation has increased significantly, for example in the Flinders Ranges of SA (see Chapter 4).

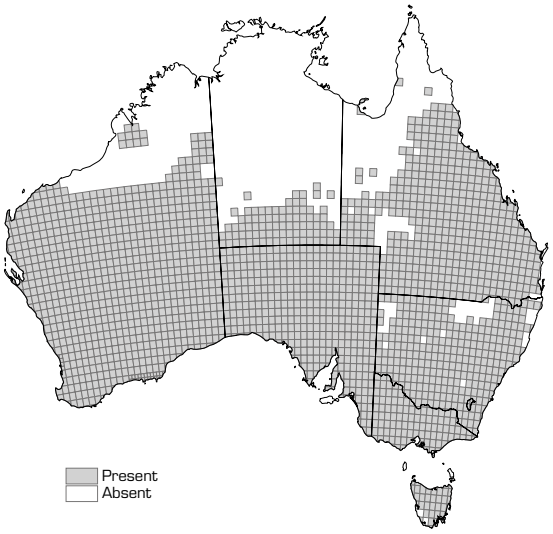
The following sections discuss the Assessment's findings on occurance, distribution, abundance, data quality and trend for rabbits.

Current occurrence, distribution and abundance

Rabbits presently inhabit an estimated 70% (ie 5.33 million square kilometres) of Australia. In summary, the Assessment found that rabbits:

Rabbit (*Oryctolagus cuniculus*) (photo by G Chapman CSIRO)

Figure 3.27 Rabbit occurrence throughout Australia



- occur in all states and territories (see Figure 3.27)
- are abundant across SA and WA, and parts of NSW, Qld, Vic, the NT and Tas (see Figure 3.28)
- occur in low abundance in a large proportion of WA, NSW, Qld and the NT (see Figure 3.29)
- are absent from large areas in northern Australia north of the Tropic of Capricorn (see Figure 3.29)
- occur mainly at the 'occasional' abundance level (see Figure 3.30)
- are 'widespread' throughout most their national range (see Figure 3.31).

[9] http://www.environment.gov.au/biodiversity/threatened/tap-drafts.html (Accessed 27 May 2008)

Figure 3.28 Occurrence, distribution and abundance of rabbits throughout Australia

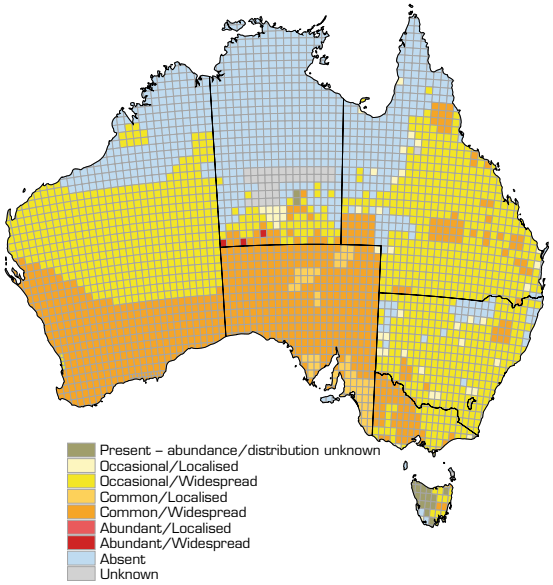


Figure 3.29 Rabbit abundance throughout Australia

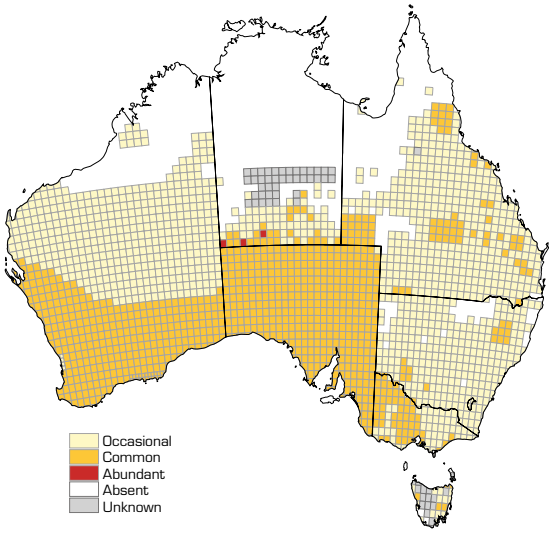


Figure 3.30 Percentage of reporting units occupied by rabbits for each abundance class

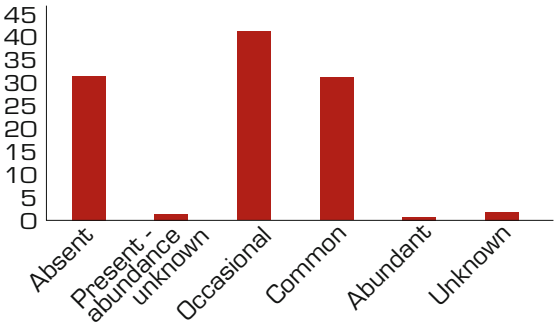
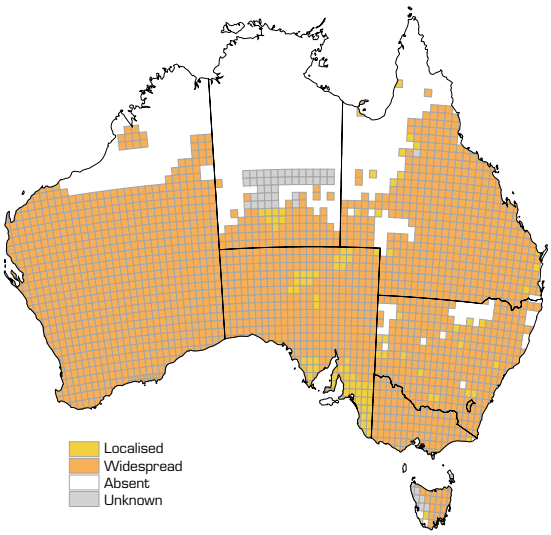


Figure 3.31 Rabbit distribution throughout Australia



Rabbits can build very large warrens with up to 150 active entrances (photo by CSIRO)

Abundance trend and data quality

Figure 3.32 summarises the Assessment's findings on the trend in the abundance of rabbits in Australia (at the national scale). Information about their trend in abundance is largely unavailable for the areas in which they occur. In SA and Tas, the trend is reported as stable. Increases in abundance were reported from the NT and SA. Trend information is largely unavailable for most of Australia.

Figure 3.33 shows the quality level of the data used in this Assessment for each reporting unit in Australia.

The quality of data for rabbits varies; a number of areas, such as Qld and the NT have high-quality data that are supported by expert opinion, while other areas have moderate levels of supporting information.

Potential distribution of rabbits

The potential distribution of rabbits was not examined as part of this Assessment because rabbits are believed to be at their geographic limit under current climatic conditions.

Figure 3.32 Trend in the abundance of rabbits throughout Australia

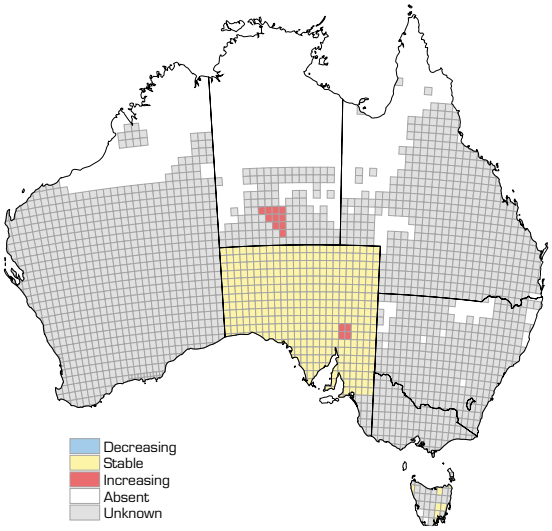
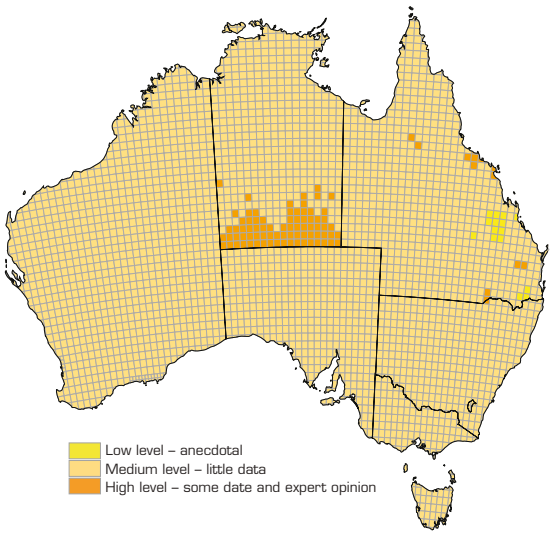


Figure 3.33 Data quality of information for rabbits throughout Australia



Foxes

Foxes (*Vulpes vulpes*) are an introduced predator that were initially brought to Australia for sport hunting and are now distributed widely throughout the southern half of the country, with the exception of some islands (Saunders et al 1995). Foxes are abundant in all states and territories except Tas, where only a few records are known. Foxes are predominantly 'occasional' to 'common' throughout their range. Their national distribution is similar to that of rabbits, but they are often found in low numbers where dingoes are prevalent (Saunders et al 1995). Population densities can reach 7.2 per square kilometre (Saunders et al 1995).

Foxes are opportunistic predators and scavengers, and are considered the greatest threat to the survival of native fauna (Saunders and McLeod 2007). They possess a number of attributes that allow them to occupy a wide range of habitats (Saunders et al 1995). Foxes are effective predators of native wildlife and vulnerable livestock. Their impacts are significant and the total cost is the highest of any pest species — an estimated $227.5 million per year (McLeod 2004). For this reason, 'Predation by the red fox' is listed as a 'key threatening process' under the EPBC Act and under NSW legislation. The Australian Government is currently reviewing the *Threat Abatement Plan for Predation by the European Red Fox* to mitigate the impacts of foxes in Australia[10] (see also DEWHA 2008c).

The following sections discuss the Assessment's findings on occurrence, distribution, abundance, data quality and trend for foxes.

Current occurrence, distribution and abundance

Foxes presently inhabit an estimated 76% (ie 5.79 million square kilometres) of Australia. In summary, the Assessment found that foxes:

- occur in all states and territories of Australia, after recently being discovered in Tas (see Figure 3.34)
- are most abundant in areas of SA and NSW (see Figure 3.35)
- are common throughout southern WA, inland Australia and Qld (see Figure 3.36)
- are absent from over 20% of Australia (see Figure 3.37)

10 http://www.environment.gov.au/biodiversity/threatened/tap-drafts.html (Accessed 27 May 2008)

Foxes (*Vulpes vulpes*) prey on a large variety of native animals (photo by Clive Marks)

Figure 3.34 Fox occurrence throughout Australia

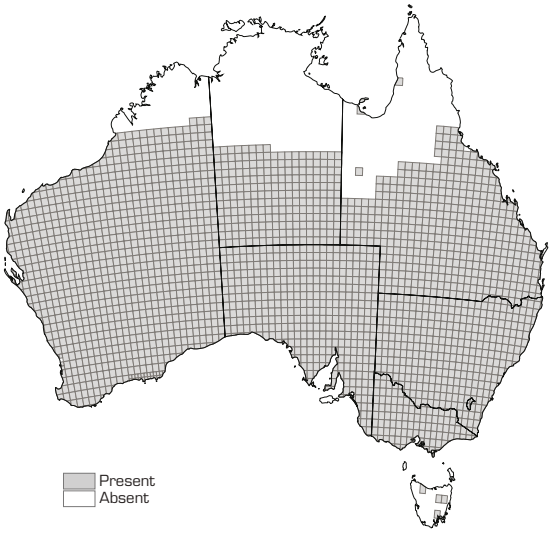
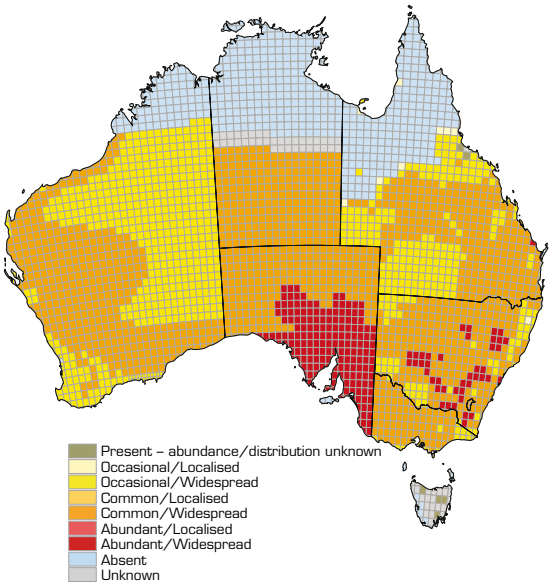


Figure 3.35 Occurrence, distribution and abundance of foxes throughout Australia



- are 'widespread' throughout almost their entire range (see Figure 3.38).

Abundance trend and data quality

Figure 3.39 summarises the Assessment's findings on the trend in abundance of foxes in Australia (at the national scale). Information on the trend in abundance is limited to SA and the NT. In these areas, their

Figure 3.36 Fox abundance throughout Australia

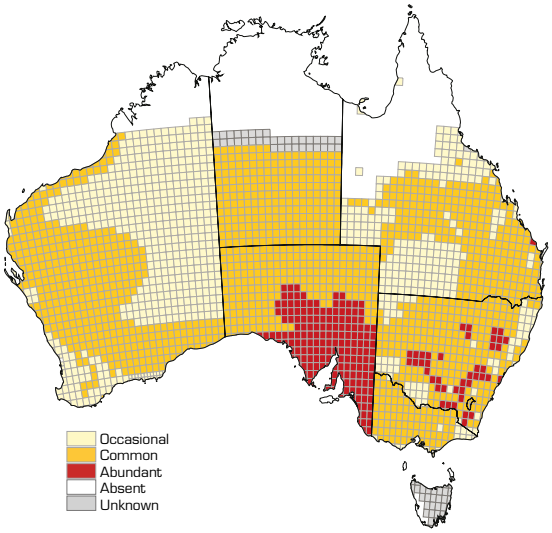
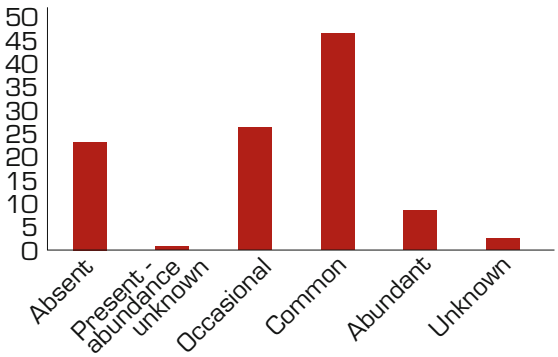


Figure 3.37 Percentage of reporting units occupied by foxes for each abundance class

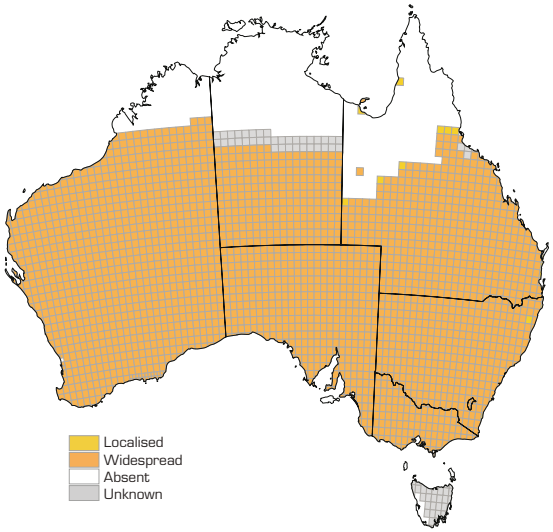


abundance is largely stable; however, they are reported to be increasing at their northern limit in the NT (Figure 3.39).

Trend information is largely unavailable for other areas of Australia. Where monitoring and reporting are undertaken, future assessments will reveal important trend information on fox abundance.

The trend in abundance of foxes may be influenced by the recovery of rabbit populations (as prey) following RHD because rabbits are thought to support foxes, especially during periods when other prey is less available. The ranges of foxes and rabbits are very similar.

Figure 3.38 Fox distribution throughout Australia



Controlling foxes prior to lambing can reduce predation of newborn lambs (photo by NSW Department of Primary Industries)

Figure 3.39 Trend in the abundance of foxes throughout Australia

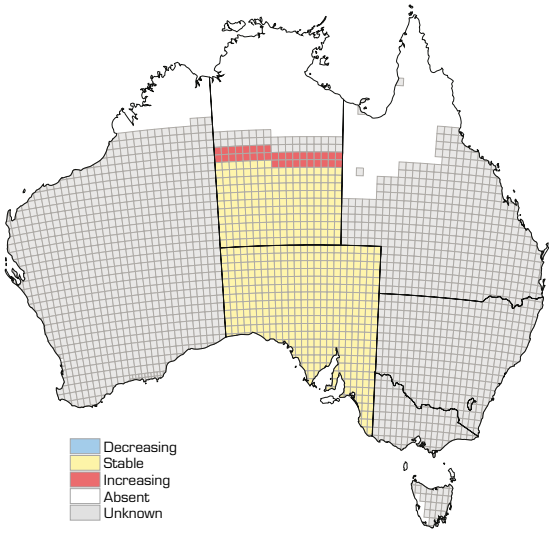


Figure 3.40 Data quality of information for foxes throughout Australia

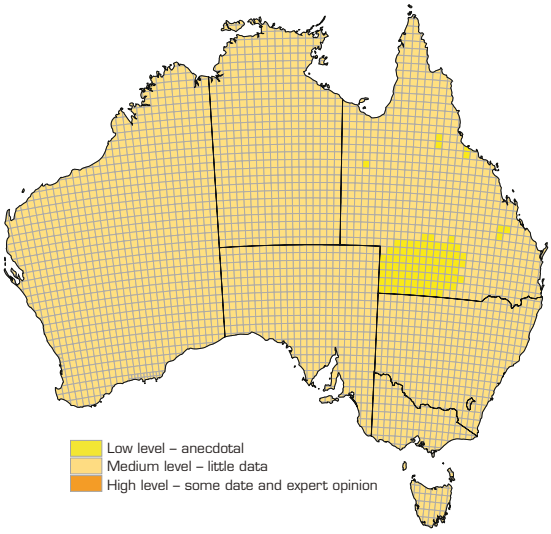


Figure 3.40 shows the quality of the data used in this Assessment for each reporting unit in Australia. The quality of the data for foxes varies; most of the country has moderate levels of supporting information, but abundance data are limited for Vic and parts of Tas.

Potential distribution of foxes

The potential distribution of foxes was not assessed as part of this Assessment because foxes are believed to be at their geographic limit under current climatic conditions.

Wild dogs

The wild dog population of Australia comprises all wild-living dogs and includes dingoes (*Canis lupus dingo*), feral dogs (*Canis lupus familiaris*) and their hybrids. They are distributed widely throughout the country and are pests in many agricultural areas. Dingoes are thought to be descendents of Asian wolves that were first introduced to Australia about 3500–4000 years ago (Corbett 1995). Feral dogs are descendents of European domestic dogs that were introduced over the past 200 years. Dingoes and feral dogs also hybridise, which is considered a threat to purebred dingoes of Australia.

Wild dogs (including dingoes) occupy a wide range of habitats and can produce large litters about once a year (Fleming et al 2001). The abundance of wild dogs is likely to have increased since European settlement throughout much of their range because of artificial water sources and food supplies. However, their abundance has been restricted by the dog-proof fence from many areas of sheep and livestock grazing in NSW, Qld and SA.

Wild dogs are considered pests primarily where they are responsible for predation and injury of livestock, and where they pose a risk to humans. An estimate of the annual economic loss in Australia due to wild dog impacts, which includes the costs associated with wild dog control, is about $66 million (McLeod 2004). Many Australians also consider dingoes a native species, which has resulted in controversy over their management.

The following sections discuss the Assessment's findings on occurrence, distribution, abundance, data quality and trend for wild dogs.

Current occurrence, distribution and abundance

Wild dogs presently inhabit an estimated 82.8% (ie 6.3 million square kilometres) of Australia. In summary, the Assessment found that wild dogs:

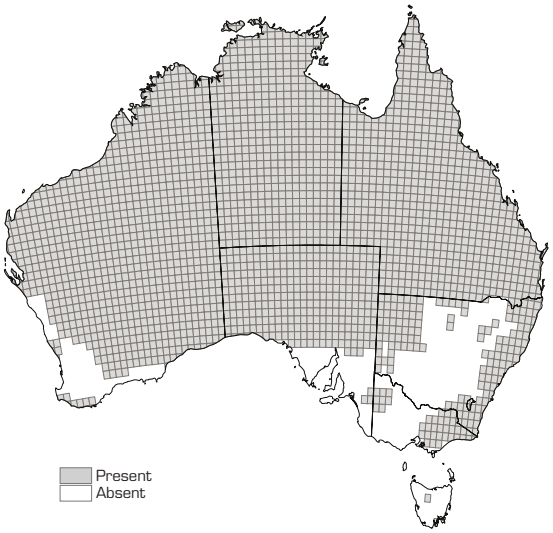
- are common in all states and territories of Australia except Tas, where only a few records were reported (see Figures 3.41 and 3.42)
- occur in high numbers in parts of WA, Qld, northern NSW and the NT (see Figure 3.42)
- have a low abundance in significant parts of WA, the NT, SA and NSW (see Figure 3.42)

Wild dog (*Canis* species) adjacent to the dog-proof fence (photo by Peter Fleming)

- are 'common' throughout most their range, but are absent from large regions in the south, equating to 16% of Australia (see Figures 3.43 and 3.44)
- are mainly 'widespread' throughout the eastern parts of their national range and are 'localised' throughout the western parts of their range (see Figure 3.45).

Wild dogs and dingoes are a significant top-order terrestrial predator, particularly in the rangelands and pastoral zone of Australia. The need for their

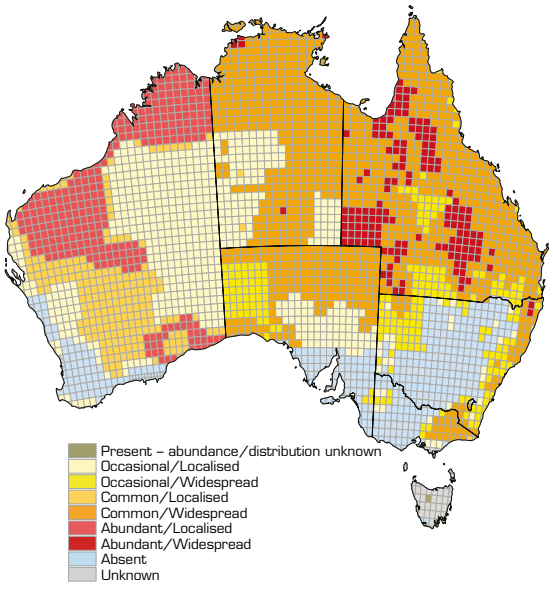
Figure 3.41 Wild dog occurrence throughout Australia



Wild dogs also keep the numbers of native herbivores such as kangaroos in check (photo by David Jenkins)

control is likely to be ongoing, and strategic management of their impacts is the best management approach. Where wild dogs and dingoes occur together, interbreeding threatens the genetics of dingoes.

Figure 3.42 Occurrence, distribution and abundance of wild dogs throughout Australia



Abundance trend and data quality

Figure 3.46 summarises the Assessment's findings on the trend in abundance of wild dogs in Australia (at the national scale). Their abundance trend is reported as being stable, where information is available. In the north of the NT, wild dogs are reported as increasing.

Figure 3.43 Wild dog abundance throughout Australia

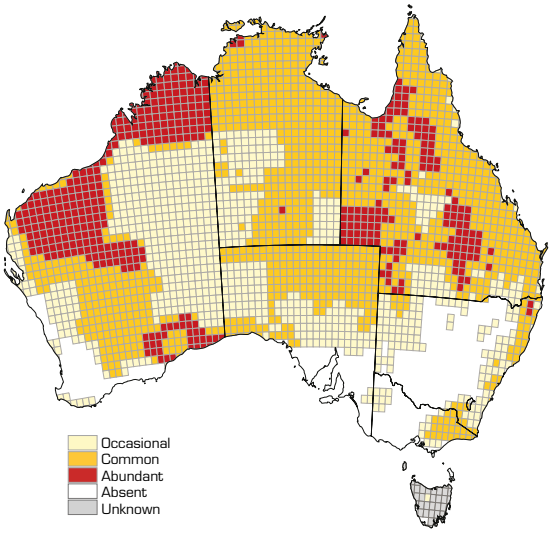


Figure 3.44 Percentage of reporting units occupied by wild dogs for each abundance class

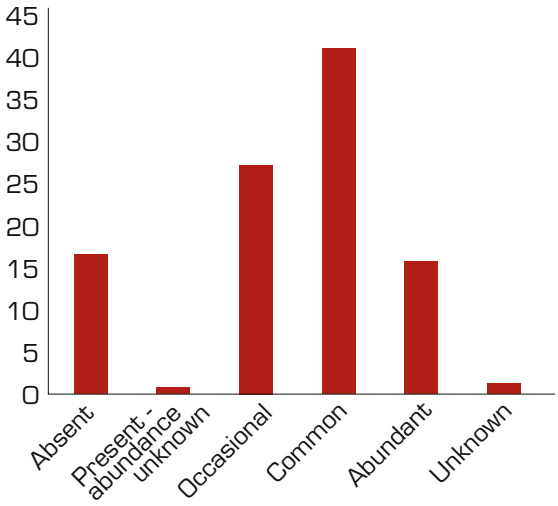


Figure 3.45 Wild dog distribution throughout Australia

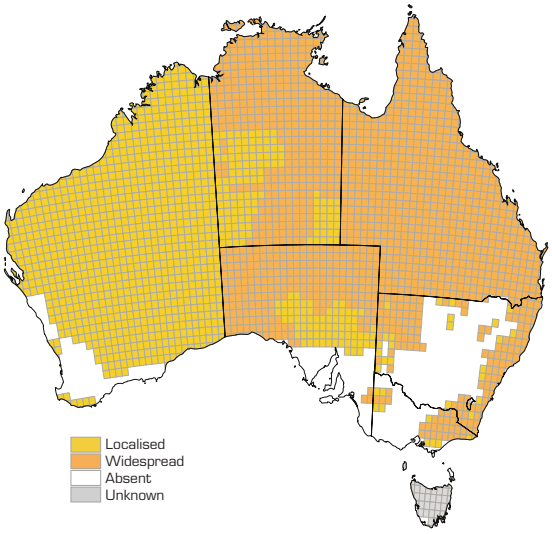


Figure 3.46 Trend in the abundance of wild dogs throughout Australia

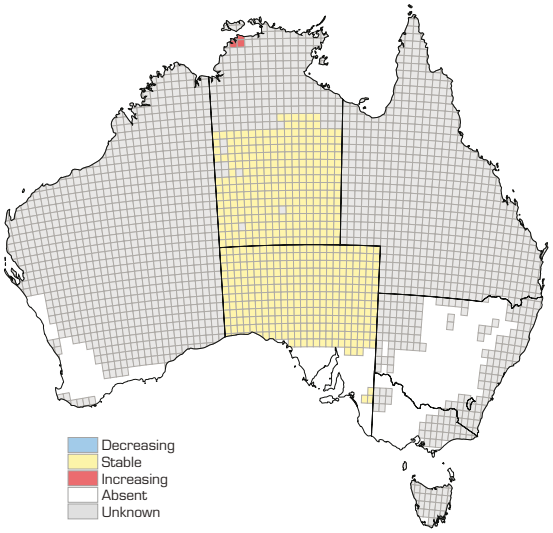
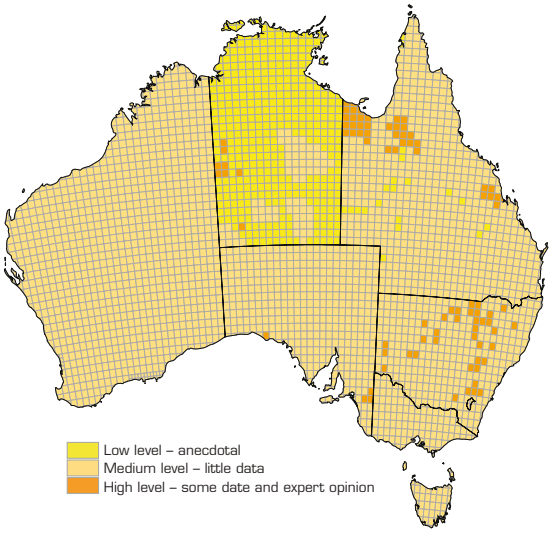


Figure 3.47 Data quality of information for wild dogs throughout Australia



Wild dogs are largely absent from areas north of the dog-proof fence in southern Australia, where they are reported as being stable. Information on the trend in abundance is limited throughout other states where wild dogs occur.

Figure 3.47 shows the quality level of the data used in this Assessment for each reporting unit in Australia. The quality of information for wild dogs ranges from high to low. A number of areas contain high-quality data that are supported by expert opinion, particularly in NSW, Qld, the NT and SA, while other areas of the country have moderate levels of supporting information.

Potential distribution of wild dogs

The potential distribution of wild dogs was not assessed as part of this Assessment because wild dogs are believed to be at their geographic limit under current climatic conditions.

Feral cats

Domestic cats (*Felis catus*) were introduced to Australia either before or during European settlement and have been released deliberately in many areas to control rabbits, mice and rats (McLeod 2004). Feral cat populations have now established in almost every significant habitat type throughout Australia, including subalpine areas, sandy deserts, forests and coastal dune systems. They also inhabit many islands, but have recently been eradicated from Macquarie Island.

There are about 18 million feral cats in the wild (McLeod 2004), and populations can reach as high as 57 per square kilometre (Dickman 1996). They are highly effective predators and are responsible for predation of a wide range of native species (Dickman 1996). 'Predation by feral cats' has been listed as a 'key threatening process' in NSW and Commonwealth legislation.

The environmental, economic and social impacts of feral cats are varied, and their environmental impact has been estimated to be $144 million per year (McLeod 2004). The costs of control have also been estimated in the order of $1 million per year (Bomford and Hart 2002, Reddiex et al 2006). The Australian Government is currently reviewing the *Threat Abatement Plan for Predation by Feral Cats* to mitigate the impacts of feral cats in Australia.[11] (See also DEWHA 2008d).

The following sections discuss the Assessment's findings on occurrence, distribution, abundance, data quality and trend for feral cats.

Current occurrence, distribution and abundance

Feral cats presently inhabit an estimated 99% (ie 7.54 million square kilometres) of Australia. In summary, the Assessment found that feral cats:

- occur in all states and territories of Australia (see Figure 3.48)
- are common throughout WA, the NT, Qld, SA and parts of NSW (see Figures 3.49)
- occur in SA and some parts of NSW and Qld in abundance (see Figure 3.50)

[11] http://www.environment.gov.au/biodiversity/threatened/tap-drafts.html (Accessed 27 May 2008)

Feral cats (*Felis catus*) are significant predators of native wildlife and have contributed to the failure of species reintroduction programs (photo by Robert Brandle)

- occur in 99% of reporting units in Australia and are only absent from some islands (see Figure 3.51)
- are mainly 'common' and 'widespread' throughout their range (see Figures 3.51 and 3.52).

Figure 3.48 Feral cat occurrence throughout Australia

Figure 3.49 Occurrence, distribution and abundance of feral cats throughout Australia

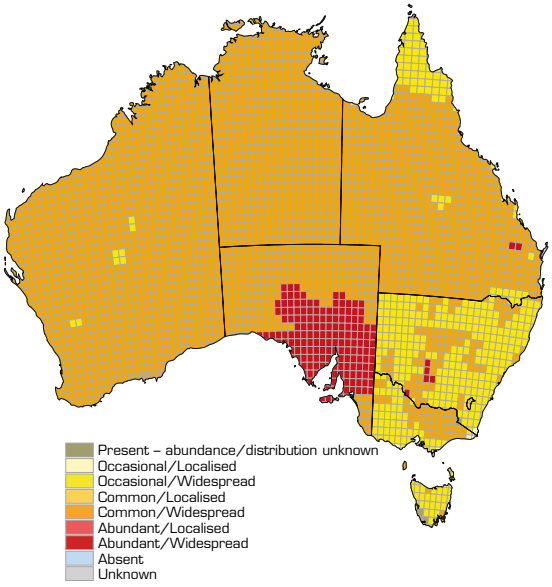
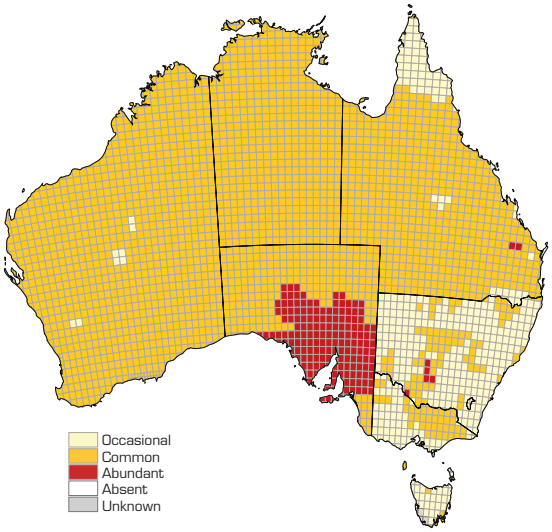


Figure 3.50 Feral cat abundance throughout Australia



Abundance trend and data quality

Figure 3.53 summarises the findings of this Assessment on the trend in the abundance of feral cats in Australia (at the national scale). Information on the trend in abundance reveals that feral cats are largely stable in SA and the NT (Figure 3.53). The trend in populations in Tas varies by region.

Figure 3.51 Percentage of reporting units occupied by feral cats for each abundance class

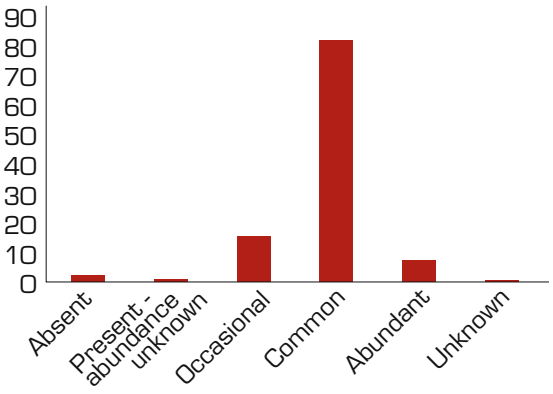
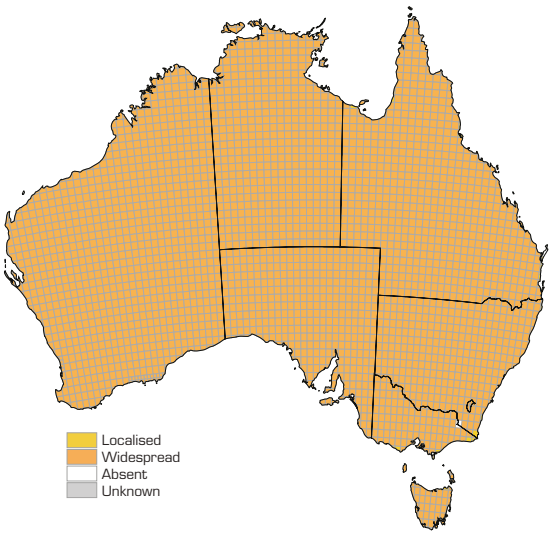


Figure 3.52 Feral cat distribution throughout Australia



Implementation of accurate monitoring techniques and ongoing monitoring and reporting, as well as future assessments, will reveal critical information on trend in the abundance of feral cats to address management and information needs.

Figure 3.54 shows the quality of the data used in this Assessment for each reporting unit in Australia. The quality of the data ranges from high to low. High-quality data supported by expert opinion are available in northern Qld, while other areas have moderate to low quality information. Ongoing monitoring and future assessments will improve the availability of high-quality information.

Figure 3.53 Trend in the abundance of feral cats throughout Australia

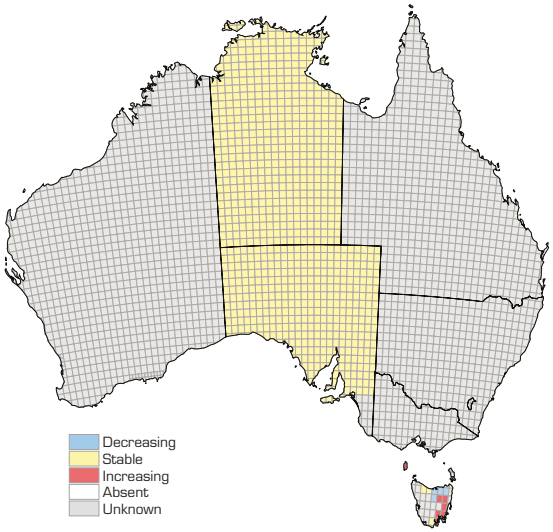
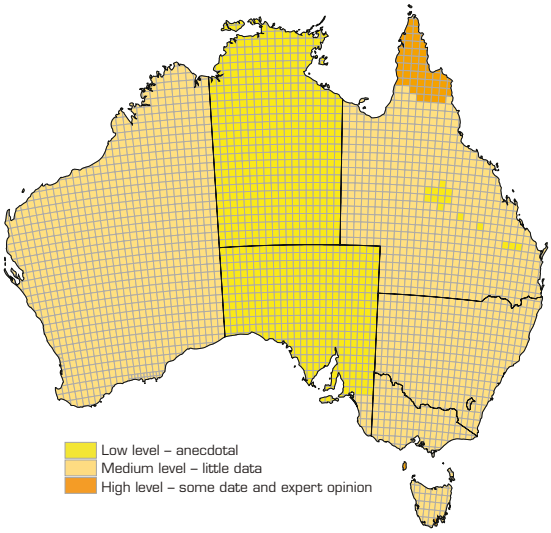


Figure 3.54 Data quality of information for feral cats throughout Australia



Feral cats (*Felis catus*) can survive in a wide range of habitats and have highly variable diets (photo by David Croft)

Potential distribution of feral cats

The potential distribution of feral cats was not assessed as part of this Assessment because feral cats occupy 99% of Australia and are absent only from some islands.

Common starlings

Common starlings (*Sturnus vulgaris*) were introduced to Australia by acclimatisation societies in the late 1850s and are now common throughout lowland suburban and cleared agricultural land in the southeast region of the continent. They have a broad diet and can survive in a wide range of habitats (Feare 1984).

Common starlings are able to breed very quickly and are recognised as a nationally significant pest species because of the damage they cause to horticulture industries, cropping, wine and rice production. Economic loss to horticulture industries from pest birds exceeds $290 million per year, and common starlings are one of the main species causing this damage (Tracey et al 2007). Potential cost impacts to horticultural crops alone, if starlings successfully colonise WA, have been estimated at $21 million per year (ACIL 2006). They are also considered an environmental pest because they compete with native birds for nesting hollows and can carry many parasites and diseases that can be transmitted to a number of animals.

Damage to wine grapes by common starlings (*Sturnus vulgaris*) can be substantial (photo by Ron Sinclair)

Common starlings (*Sturnus vulgaris*) often forage among domestic livestock (photo by Tina Bentz)

The following sections discuss the Assessment's findings on occurrence, distribution, abundance, data quality and trend for common starlings.

Current occurrence, distribution and abundance

Common starlings presently inhabit an estimated 21% (ie 1.6 million square kilometres) of Australia. In summary, the Assessment found that common starlings:

- are present throughout all states and territories of Australia, except the NT (see Figure 3.55)
- occur in SA and Vic in abundant populations, and are also common in Qld, NSW, Tas and the ACT (see Figures 3.56 and 3.57)
- occur in low numbers in WA and remote parts of SA (see Figure 3.57)
- are absent from 60% of Australia, and it is unknown whether they occur in 18% of the country (see Figure 3.58)
- are mainly 'widespread' throughout their range (see Figure 3.59).

Figure 3.55 Common starling occurrence throughout Australia

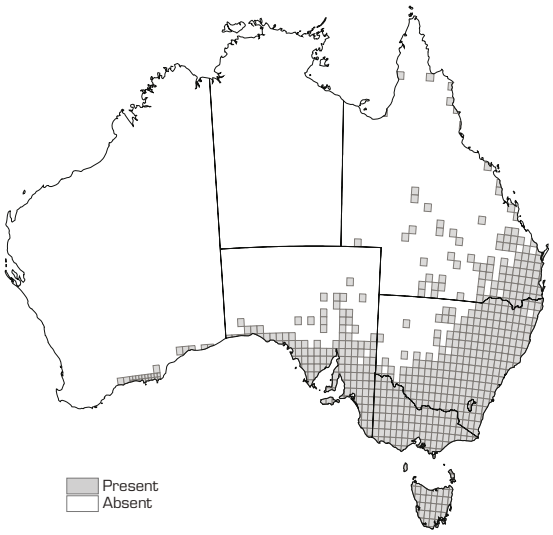


Figure 3.56 Occurrence, distribution and abundance of common starlings throughout Australia

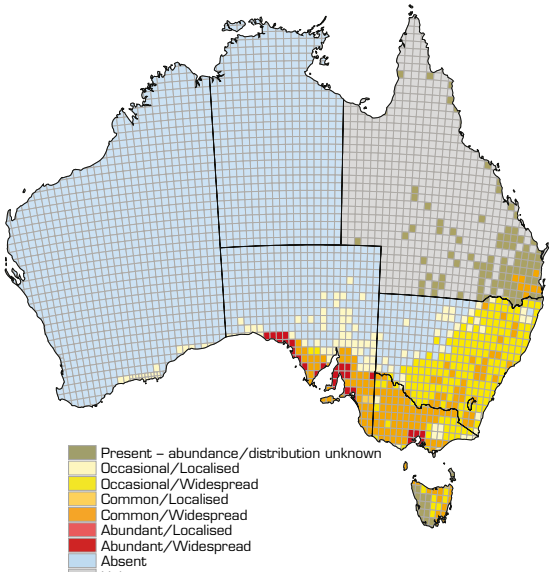


Figure 3.57 Common starling abundance throughout Australia

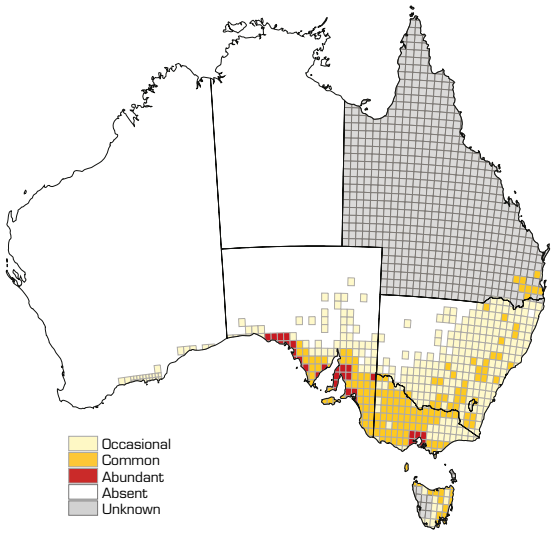


Figure 3.58 Percentage of reporting units occupied by common starlings for each abundance class

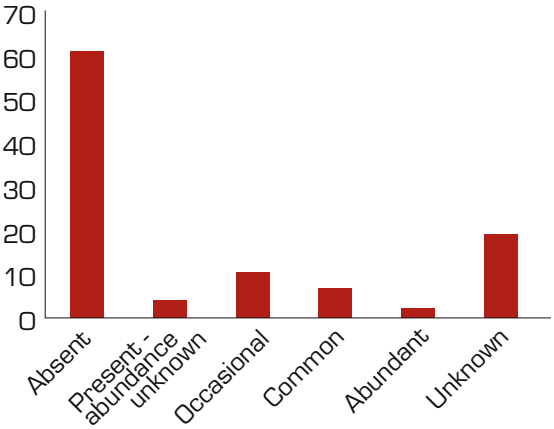


Figure 3.59 Common starling distribution throughout Australia

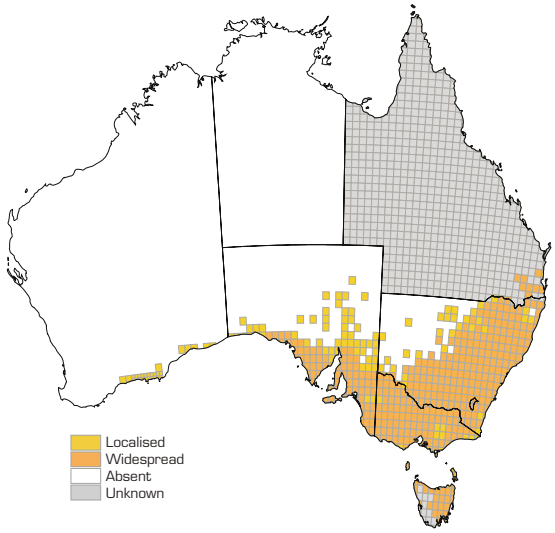
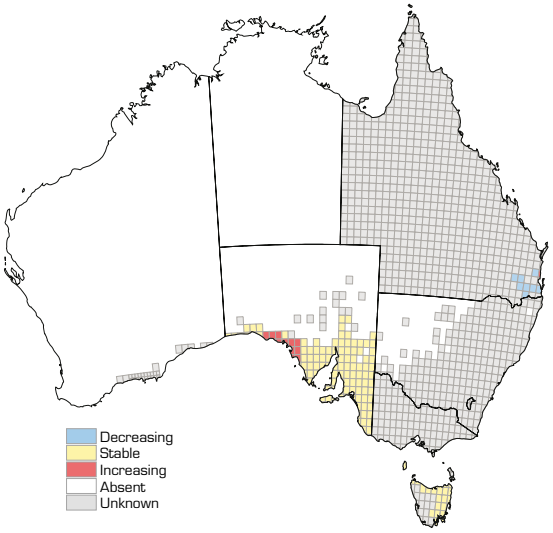


Figure 3.60 Trend in the abundance of common starlings throughout Australia



Abundance trend and data quality

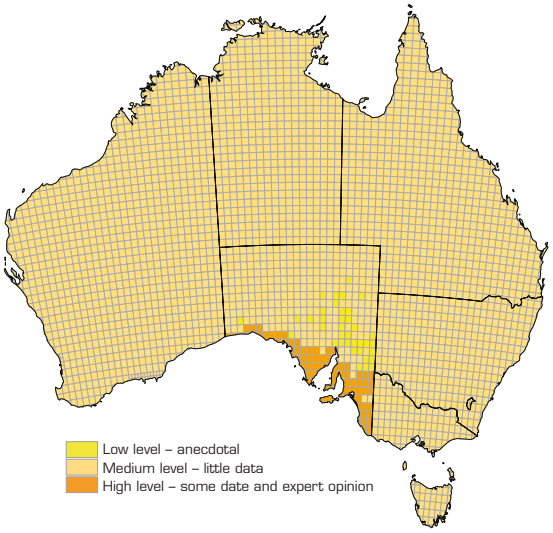
Figure 3.60 summarises the Assessment's findings on the trend in the abundance of common starlings in Australia (at the national scale). They were reported as increasing in the western areas of their range in SA and are stable elsewhere in the state. In Tas, their abundance was reported as being stable. The only region in Australia where common starlings were reported to be decreasing was southeastern Qld. All other areas of Australia lacked sufficient information of trend in abundance for this Assessment. Ongoing monitoring and reporting will provide trend information for future assessments.

Figure 3.61 shows the quality of the data used in this Assessment for each reporting unit in Australia. Information for common starlings ranges from high to low quality. Areas containing high-quality data that are supported by expert opinion occur mainly in SA, while other areas of the country have moderate levels of supporting information. However, high-quality regional datasets are available in many states and territories, and ongoing monitoring will improve the availability of high-quality information.

Potential distribution of common starlings

There are general limitations of climate matching and in particular habitat matching to predict a species' potential range. There are also additional issues with predicting the range of highly mobile species, such as birds. Many bird species exhibit

Figure 3.61 Data quality of information for common starlings throughout Australia



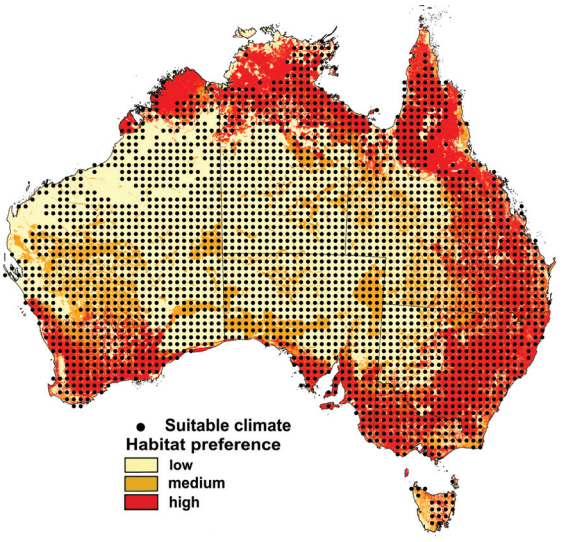
nomadic and migratory behaviour, and move around seasonally. As a result, their breeding season and non-breeding season habitat requirements may differ. This makes predicting their annual habitat requirements more complex and explains in part the apparent anomalous results below. Further analysis is required to develop improved predictive maps for common starlings.

Figure 3.62 shows the areas of Australia that are reported as the most suitable for common starlings

based on their climate (dots) and habitat characteristics (colour shading) according to initial modelling predictions. The predictions on suitable climate in this figure utilise the best available information at the present time and suggest that the climate throughout almost all areas of Australia is suitable for common starlings (represented by dot symbols in Figure 3.62). However, a range of other attributes influence where common starlings are likely to occur at different times of the year, including nest hollow opportunities and food resources. An initial compilation of expert opinion regarding suitable habitat for common starlings and use of this information in modelling indicates that the arid and semiarid interior of Australia are the least suitable (see habitat preference distribution in Figure 3.62).

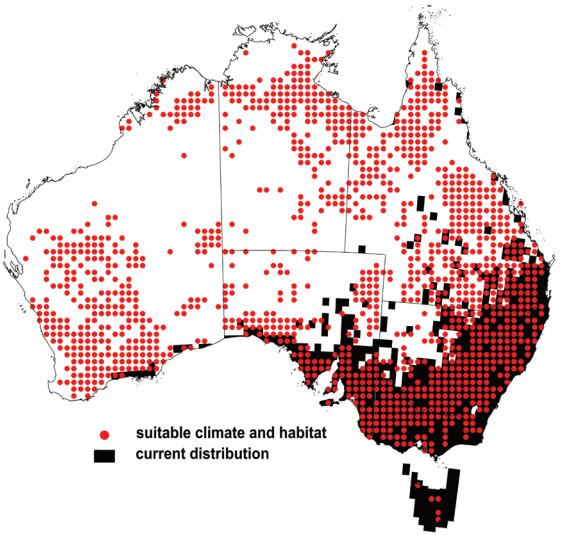
Common starlings presently occupy an estimated 21% (ie 1.6 million square kilometres) of Australia. When their present distribution is compared with suitable climatic areas and areas that contain suitable habitat, it appears that common starlings have the potential to occupy a significantly larger area than they do at present (see Figure 3.63). The predictions suggest that vast areas of the NT and WA are suitable for common starlings, and that they have the potential to spread further throughout SA, Qld and NSW. The modelling predictions suggest that most of Tas is unsuitable in regard to climate and habitat, and yet common starlings occur in all regions of the state. This disparity suggests that further analysis is required to improve modelling predictions.

Figure 3.62 Suitable climate and habitat for common starlings



Source: BRS, 2007

Figure 3.63 Suitable climate and habitat against the current extent of common starlings



Source: BRS, 2007

Common carp

Common carp (*Cyprinus carpio*) were introduced deliberately to Australia in a number of stages during early settlement. They are now widespread throughout the Murray-Darling Basin and major rivers of NSW (Lintermans 2007), with smaller populations found in WA and Tas (Koehn et al 2000). Common carp are a significant freshwater pest and are thought to cause a number of impacts including reduced water quality, altered fish species composition, bank erosion, turbidity and reduced aquatic plant growth (Koehn et al 2000). They can tolerate a range of environmental conditions, breed efficiently and survive in degraded habitats (Koehn et al 2000).

Common carp can reach very high densities, in some cases representing up to 90% of the fish biomass in lakes, rivers and streams (Lintermans 2007). They pose an economic threat by affecting industries that depend on pristine water quality and aquatic habitats, including agriculture, tourism and recreational fisheries. Common carp cause a number of environmental, economic and social impacts; the costs of which have been estimated at $15.8 million per year (McLeod 2004).

The following sections discuss the Assessment's findings on occurrences, distribution, abundance, data quality and trend for common carp.

Current occurrence, distribution and abundance

Common carp presently inhabit rivers and creeks throughout 11.5% (ie 860 000 square kilometres) of Australia. In summary, the Assessment found that common carp:

- inhabit most states and territories of Australia, except the NT (see Figure 3.64)
- occur mainly within the Murray-Darling Basin — Australia's largest freshwater river system (see Figure 3.64)
- are abundant in NSW and parts of SA (see Figure 3.65)
- are found in WA, Qld and Tas in isolated populations, while their abundance throughout most of Vic remains unknown (see Figure 3.66 and 3.67)

Common carp (*Cyprinus carpio*) (photo by John Gasparotto)

- have not been reported from approximately 86% of reporting units (see Figure 3.68)
- mainly occur in a 'localised' distribution throughout their range (see Figure 3.68).

Common carp have the potential to cause enormous damage to aquatic habitats and are associated with major costs to both public and private sectors (Koehn et al 2000). They are a nationally significant pest species and, although their environmental impacts are not well identified, they are thought to cause damage in wetlands, reduce water quality and adversely impact on native fish communities. However, because some impacts, presumed to be caused by common carp, can also be caused by other factors, impacts are particularly difficult to pinpoint. Ongoing monitoring and reporting activities, as well as critical research, are needed to identify the impacts that common carp may be having on the environment, economy and social values.

Figure 3.64 Common carp occurrence throughout Australia

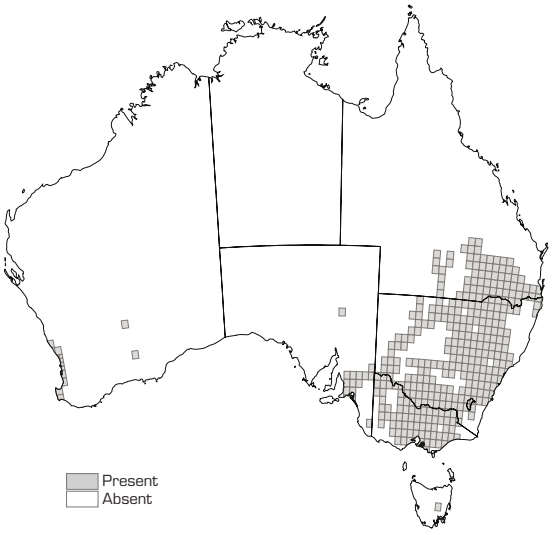


Figure 3.65 Occurrence, distribution and abundance of common carp throughout Australia

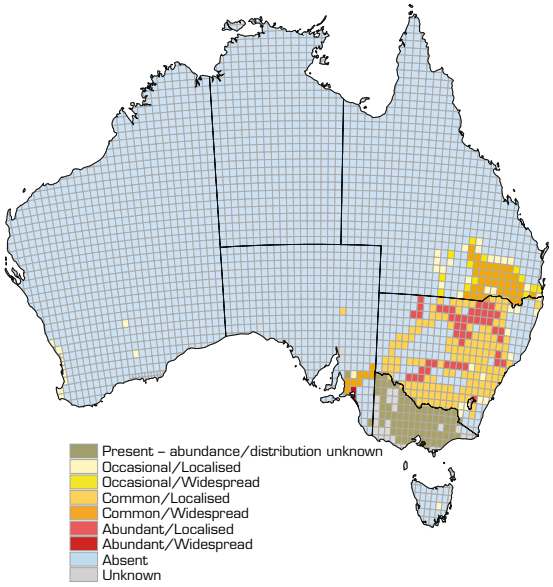
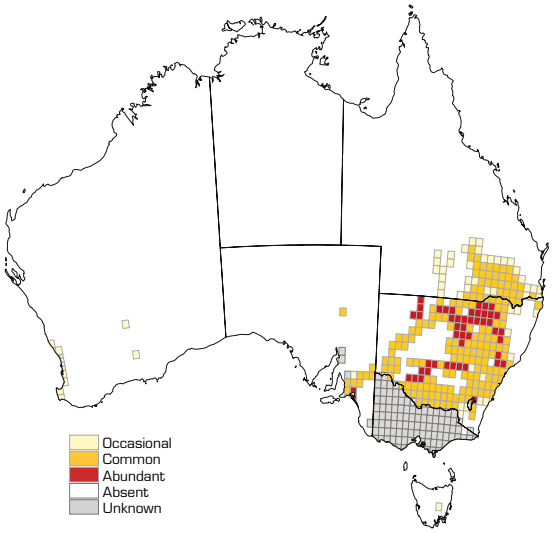


Figure 3.66 Common carp abundance throughout Australia



Abundance trend and data quality

No trend information was available for common carp throughout Australia (at the national scale) at the time of this Assessment (see Figure 3.69). Some states have detailed records of common carp biomass within selected rivers and will be able to provide trend information following monitoring in future follow-up assessments.

Figure 3.67 Percentage of reporting units occupied by common carp for each abundance class

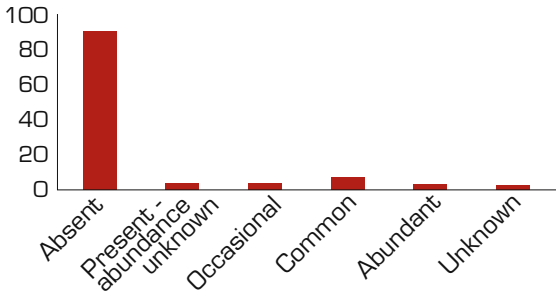


Figure 3.68 Common carp distribution throughout Australia

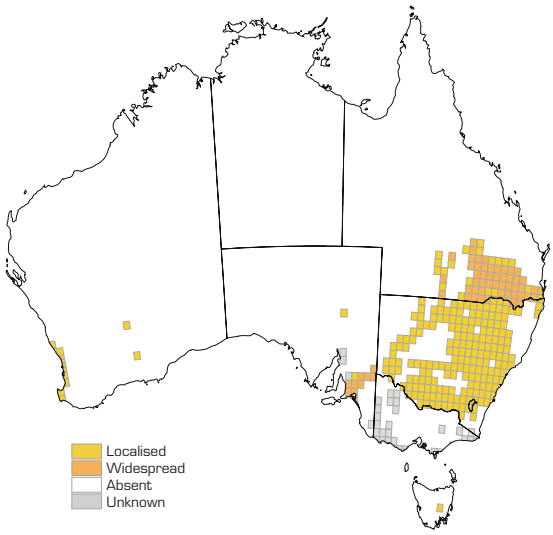
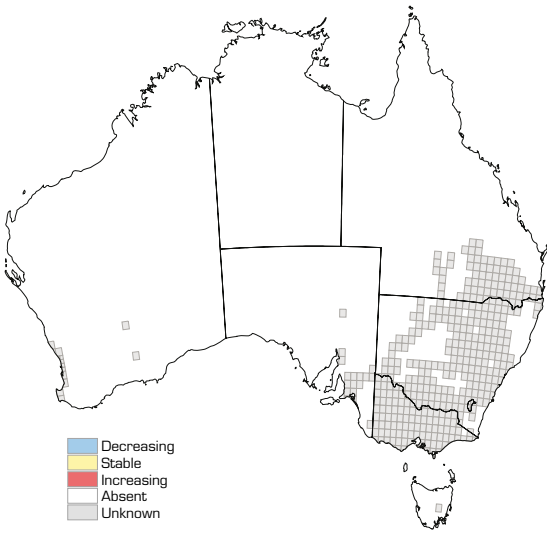


Figure 3.69 Trend in the abundance of common carp throughout Australia



Common carp are a major pest and have been implicated in causing irreversible damage to rivers in the Murray-Darling Basin. They can represent the majority of fish biomass in rivers (photo by Peter West)

Figure 3.70 shows the quality of the data used in this Assessment for each reporting unit in Australia. Information for common carp is mainly of moderate quality at this scale. Finer-scale data exist in most areas where common carp occur and are of high quality. Other areas of the country have moderate levels of supporting information or common carp are absent.

Potential distribution of common carp

The areas that are most suitable for common carp, based on the climate characteristics of their overseas and Australian distribution and their current known habitat, are presented in Figure 3.71. According to the climate matching, common carp may potentially occur within much of the southern half of the continent and parts of Tas. This prediction is very broad, and the actual potential distribution is dependent on the availability of suitable rivers, streams, dams and water bodies. Although this analysis did not consider the availability of perennial water, perennial rivers were overlaid on the potential climatic distribution to give a more realistic visual representation of the potential distribution of common carp, which is much narrower than the broad climatic range. The availability of perennial water would need to be considered further to make accurate predictions.

Common carp currently inhabit rivers and creeks throughout 11.5% of Australia and are largely restricted to the Murray-Darling Basin. They have been found in two lakes in Tas and in some areas in

Figure 3.70 Data quality of information for common carp throughout Australia

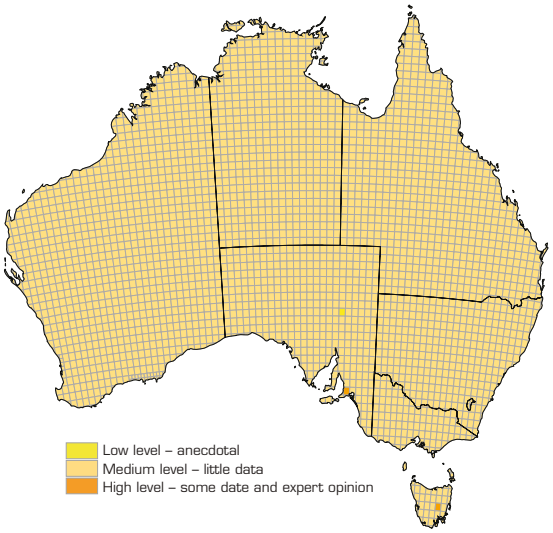
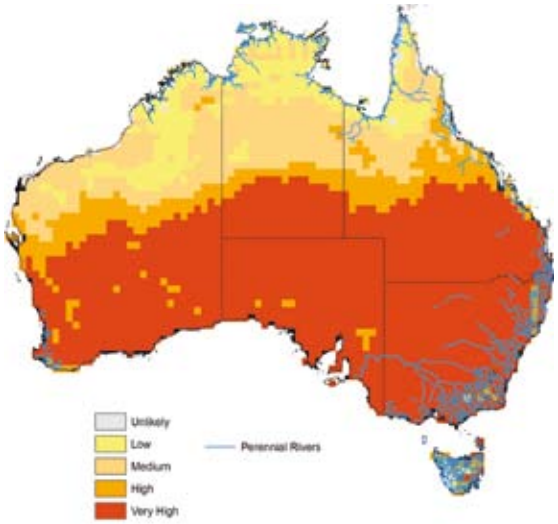


Figure 3.71 Predicted suitable climate for common carp with major rivers in Australia



Source: BRS, 2007

WA. Further analysis is required to prepare national predictions of the potential range of common carp that incorporate water quality attributes, as well as climate and habitat factors. As for most species, the potential range is also influenced by human activities and land management practices. These would also need to be considered in the analysis.

Cane toads

Cane toads (*Bufo marinus*) were introduced deliberately to Qld for insect control in sugar cane crops; however, they have since spread throughout Qld, northern NSW and the NT (Molloy and Henderson 2006). They are now are a significant introduced pest in Australia. Although the long-term impacts of cane toads are poorly understood, they are presumed to cause a range of adverse impacts primarily to native animals and wildlife. They are also considered a significant threat to domestic pets because they can release toxins from their skin (Doody et al 2006). A wide range of native species has been known to die following ingestion or part-ingestion of cane toads. They are also formidable predators of native fauna including insects, reptiles and other frogs, and may cause the displacement of native species. Cane toads are tolerant of a wide range of conditions and can produce spawn containing up to 35 000 eggs.

Cane toads continue to expand their range in Australia. In recent years, they have rapidly spread across the NT and now approach the WA border. Spread rates equate to about 27–50 kilometres per year, and single movements of several kilometres per night have been observed. At the current rate of spread, the cane toad invasion is likely to reach into WA between 2008 and 2010 (Peacock 2007). They have successfully colonised several large coastal islands in Qld and the NT, and have been found in densities up to 2000 per hectare in newly colonised areas (Molloy and Henderson 2006). Flooding events hasten the rate of spread of cane toads, and recent flooding in Qld and northern NSW is anticipated to spread cane toads into new areas. Community-based programs (such as Kimberley Toad Busters) that aim to limit their introduction to WA have been successful to date but will need to continue.

The following sections discuss the Assessment's findings on occurrence, distribution, abundance, data quality and trend for cane toads.

Current occurrence, distribution and abundance

Cane toads presently inhabit an estimated 20% (ie 1.52 million square kilometres) of Australia. In summary, this Assessment found that cane toads:

- occur in Qld, the NT and northern NSW (see Figure 3.72)

Cane toad (*Bufo marinus*) (photo by Kimberley Toad Busters)

- occur in a few locations on the central coast of NSW (see Figure 3.72)
- have spread rapidly across the NT in recent years and are approaching the WA border
- are reported as 'abundant' in Qld and 'common' throughout most of the remainder of their current range (see Figures 3.73 and 3.74)
- are absent from about 78% of Australia (see Figure 3.75)
- are 'widespread' throughout nearly their entire range (see Figure 3.76).

Figure 3.72 Cane toad occurrence throughout Australia

Figure 3.73 Occurrence, distribution and abundance of cane toads throughout Australia

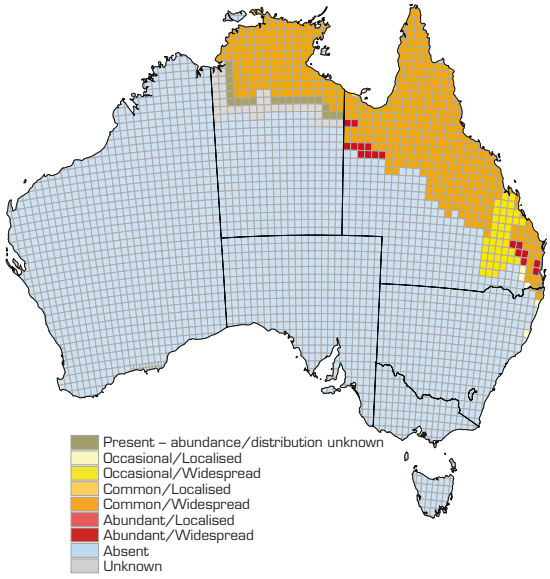
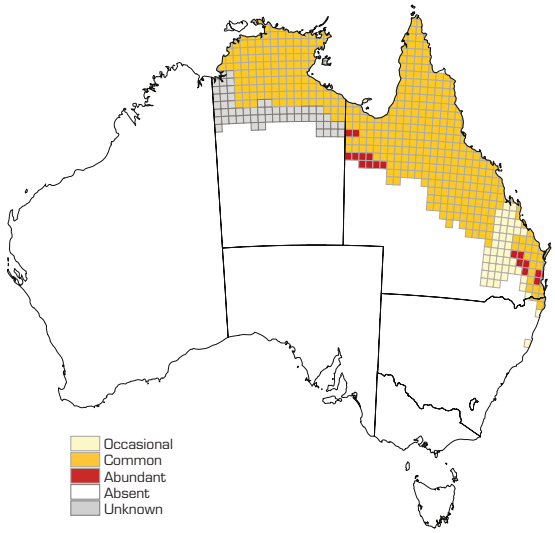


Figure 3.74 Cane toad abundance throughout Australia



Abundance trend and data quality

Figure 3.77 summarises the Assessment's finding on the trend in the abundance of cane toads in Australia (at the national scale). They are widespread throughout northern Australia; however, at the time of this Assessment, they were reported to have been increasing only in the NT (see Figure 3.77). More recent flooding in Qld and northern NSW is anticipated to cause further spread of the species.

Figure 3.75 Percentage of reporting units occupied by cane toads for each abundance class

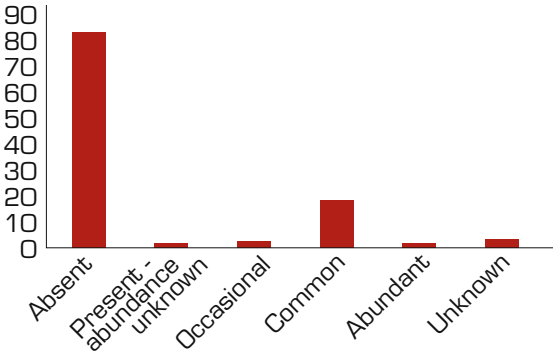
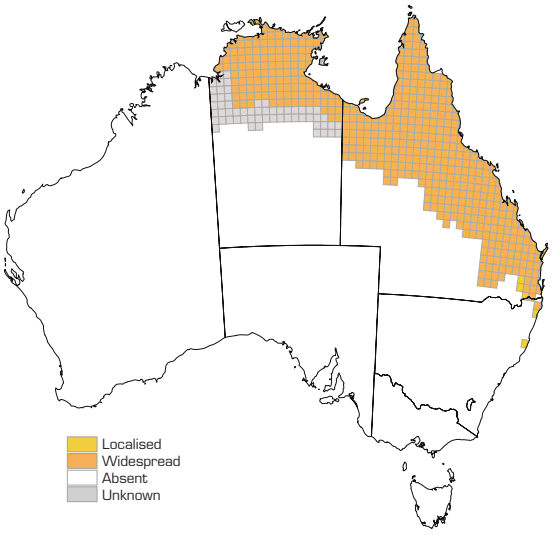


Figure 3.76 Cane toad distribution throughout Australia



In recent years, they have also spread rapidly across northern Australia from east to west at a rate of 27–50 kilometres per year.

Information on the trend in abundance of cane toads is largely unavailable for all other areas of the current national range at this scale until follow-up assessments are performed. Where independent information of the trend in abundance is available, appropriate data should be provided to relevant state government agencies to facilitate improved monitoring and reporting hereafter.

Figure 3.78 shows the quality of the data that were used in this Assessment for each reporting unit. Information for cane toads is of moderate quality throughout most of their range. High-quality data

A dead freshwater crocodile (*Crocodylus johnstoni*) at the Baines River, NT, after eating a cane toad (photo by Craig Mills)

Figure 3.77 Trend in the abundance of cane toads throughout Australia

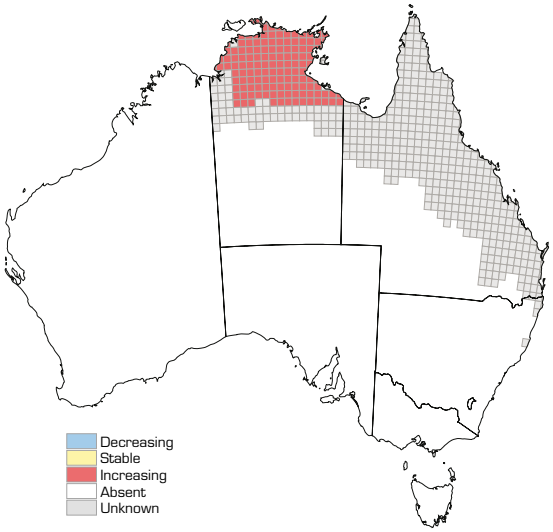
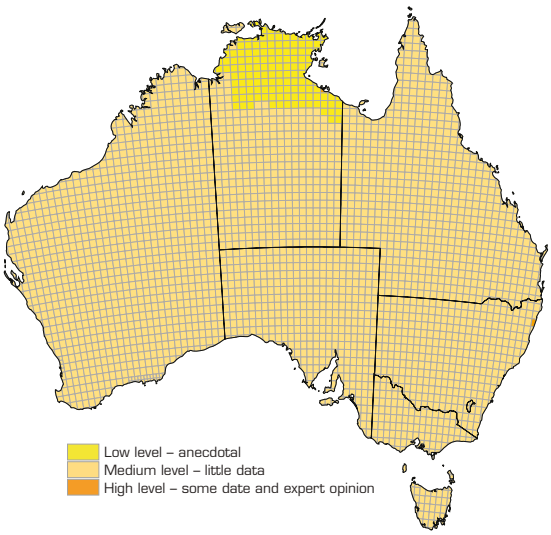


Figure 3.78 Data quality of information for cane toads throughout Australia



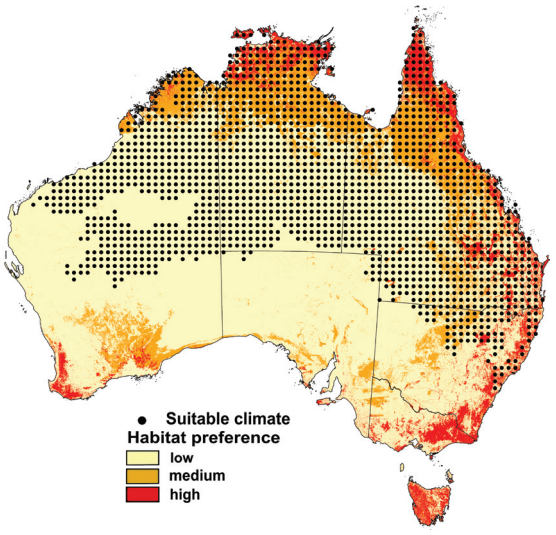
that are supported by expert opinion were reportedly only available in small areas of NSW, while other areas reported moderate to low levels of data quality at this reporting scale.

Potential distribution of cane toads

The native range of the cane toad is around the equator, and its dependence on water for breeding would suggest that predicting the potential distribution of cane toads should be reasonably straightforward. However, there is a range of factors that make predictions more complex, including:

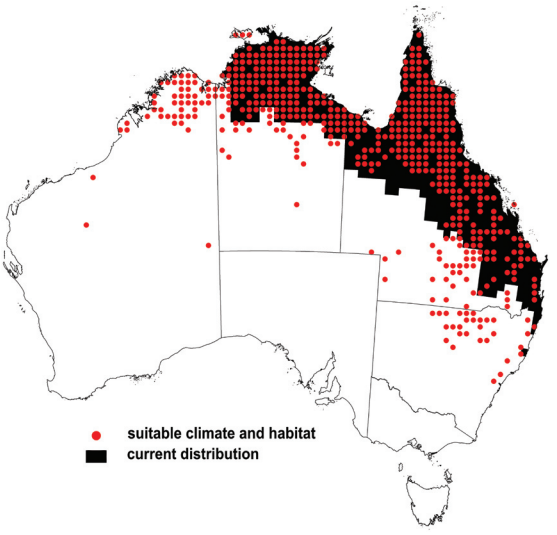
- the influence of human-modified habitat or water sources
- the large changes in water distribution and general habitat between wet and dry seasons in northern Australia

Figure 3.79 Suitable climate and habitat for cane toads



Source: BRS, 2007

Figure 3.80 Suitable climate and habitat against the current extent of cane toads



Source: BRS, 2007

- the adaptability of cane toads with their high generational turnover and reproductive capacity.

The predictive suitable climate and habitat maps in Figures 3.79 and 3.80 show a reasonably high concordance with the current distribution of cane toads. However, it is likely that the ability of cane toads to adapt will allow them to move to higher latitudes than currently observed in their worldwide distribution — particularly with the influence of climate change.

Figure 3.79 shows the areas of Australia that are reported as the most suitable for cane toads based on their climate and habitat characteristics according to modelling predictions. The initial modelling on suitable climate and habitat suggests that the climate throughout broad areas of northern Australia is suitable for cane toads (dot points in Figure 3.79). However, several other attributes influence where cane toads survive. An initial compilation of expert opinion suggests that suitable habitat occurs in northern Australia; along the east coast of Qld, NSW and Vic; areas in southern WA; and all regions of Tas (see habitat preference distribution in Figure 3.79).

The comparison of their present extent with the overlap between the climatically suitable areas and suitable habitat areas reveals that cane toads have nearly reached their geographic limits (see Figure 3.80). However, their geographic limits in Australia are likely to be influenced by other environmental factors, such as land use activities, water sources and irrigation practices.

Cane toads presently occupy an estimated 20% (ie 1.52 million square kilometres) of Australia. The modelling predictions suggest that most of Australia is unsuitable in regard to climate and habitat for cane toads, but that there are many regions within NSW, Qld and WA, and some regions in the NT where cane toads may potentially spread — particularly given recent increases in rainfall throughout many of these regions.

Other significant invasive animals

A number of additional introduced species in Australia were addressed as part of this Assessment. Table 3.1 summarises the occurrence of these species, which include established as well as new and emerging species that are known to occur throughout Australia. National occurrence, distribution and abundance data for these species were not complete at the time of this Assessment but should be incorporated in future assessments.

Feral donkeys (*Equus asinus*) are widespread in parts of the rangelands of WA, the NT and SA (Norris and Low 2005). They are well adapted to arid regions and compete with stock (Wilson et al 1992).

Feral horses (*Equus caballus*) are found in all states and territories except Tas but are most common in livestock (cattle) production areas of the NT and Qld (McLeod 2004). Scattered populations also occur in alpine and subalpine regions of eastern Australia (McLeod 2004). Feral horses contribute to land degradation through soil erosion and fouling of waterholes (Dobbie et al 1993).

Feral camels (*Camelus dromedarius*) occupy most of the desert and semidesert country in SA, the NT, Qld and WA. Camels cause damage through erosion, they suppress recruitment of some plant species and cause impacts to waterholes, which may be significant for native fauna and culturally important to Indigenous communities. Camels also damage rangeland infrastructure (Edwards et al 2004, Norris and Low 2005).

Water buffalo (*Bubalus bubalis*) were introduced to remote settlements in northern Australia in the 19th century. As feral populations became established, they destroyed wetlands and harboured livestock disease. The Brucellosis and Tuberculosis Eradication Campaign of the 1980s nearly eradicated the species from the wild, but their numbers have increased steadily in recent times.

Feral donkeys (*Equus asinus*) are emerging pests in arid Australia (photo by Brian Lukins)

Red-eared slider turtles (*Trachemys scripta elegans*) released illegally into rivers may be very difficult to control (photo by Jessica Gibson)

Table 3.1 Occurrence of other significant invasive pest species throughout the states and territories of Australia

Invasive pest species	NSW	ACT	Qld	Vic	NT	SA	WA	Tas
Feral camel	✔	✘	✔	✘	✔	✔	✔	✘
Feral horse	✔	✔	✔	✔	✔	✔	✔	✘
Feral donkey	✔	✘	✔	✘	✔	✔	✔	✘
Water buffalo	✘	✘	✘	✘	✔	✘	✘	✘
Banteng	✘	✘	✘	✘	✔	✘	✘	✘
Red-eared slider turtle	✔	✘	✔	✘	✘	✘	✘	✘

✔ = present; ✘ = absent

Inaccessible areas of arid Australia contain populations of feral camels, horses and donkeys (photo by Brian Lukins)

Banteng (*Bos javanicus*) is a type of feral cow that is largely restricted to the Cobourg Peninsula in the NT (Norris and Low 2005). They can cause substantial damage to dune systems and alter vegetation structure (Norris and Low 2005), but interestingly, are an endangered species in their native habitat of southeast Asia (Norris and Low 2005).

Red-eared slider turtles (*Trachemys scripta elegans*) are a serious pest in Qld and are known to occur in NSW (Table 3.1). There is a significant risk of slider turtles being introduced to inland rivers, but their impacts are largely unknown. Recent flooding events in Qld and NSW may lead to further dispersal of the species into new areas.

Summary of distribution and abundance information

Nationally significant invasive animals inhabit all areas of Australia. All species in this assessment inhabit multiple state and territory jurisdictions. All NRM regions contain a range of pest species. The highest concentrations of pest species occur in the eastern regions of Qld, NSW and Vic, where between seven and 10 nationally significant species are known to occur (see Figure 3.1). The smallest number of invasive animal species occur in the central areas of the NT.

The Australian continent covers 7.62 million square kilometres, and four nationally significant species, namely foxes, rabbits, wild dogs and feral cats, inhabit more than 70% of this area (see Table 3.2). Other species, including feral pigs and feral goats, occupy very large ranges and their impacts to primary production and the environment are known to be substantial. Species such as cane toads and common starlings are rapidly expanding their ranges and have the potential to occupy much larger areas throughout Australia unless adequate containment strategies are developed.

The species with the largest national geographic ranges are well established and have the capacity to survive and persist in a wide range of habitats and climatic regions. Of the 10 species assessed as part of this Assessment, the species that occupy the largest areas include:

- feral cats, which inhabit 99% (ie 7.54 million square kilometres) of Australia
- foxes, rabbits and wild dogs, each of which inhabits 70% (ie 5.33 million square kilometres) or more of the continent.

Given these figures, there is little doubt that any control programs to address the problems caused by these species will require significant large-scale planning, coordination and resources across many state and territory jurisdictions. Equivalent coordination, planning and resources can also be justified at the regional level because invasive animal populations have the capacity to recolonise areas after initial control activities take place. To address this issue, follow-up control needs to be considered in funding programs and operational budgets.

Table 3.2 Proportion of Australia occupied by invasive animal species

Species	Region of Australia that is occupied (in percentage)	Equivalent land area (in million square kilometres)
Feral cats	99	7.54
Wild dogs	82.8	6.30
Foxes	76	5.79
Rabbits	70	5.33
Feral pigs	45	3.43
Feral goats	28	2.13
Common starlings	21	1.60
Cane toads	20	1.52
Common carp	11.3	0.86
Feral deer	8.8	0.67

Further research is required to develop control techniques and management strategies to ensure any such initiatives are cost effective and deliver desired outcomes at a national scale.

Conclusions

Some important conclusions can be drawn from the results of this Assessment.

Pests are increasing in distribution and abundance despite control programs.

Invasive animals are a national issue because they inhabit all jurisdictions and NRM regions, and they are abundant and widespread throughout Australia. They have significant impacts costing Australia at least one billion dollars per year.

Available population trend data on abundance reveal that, although control programs are being undertaken, some established species such as foxes and rabbits are still increasing in abundance in a number of regions. Other species, such as common starlings, feral deer and cane toads are spreading into new areas and require immediate attention to prevent further colonisation.

Need for a national response

A national response is required to address the spread of most pests, in particular cane toads. In recent years, cane toads have colonised large areas of northern Australia and are encroaching on the WA border. They have been recorded spreading up to 50 kilometres per year. A coordinated campaign between state and territory governments and the Australian Government is required to minimise further invasion by cane toads and control them in areas they have recently colonised. Community-based control campaigns, such as Kimberley Toad Busters, are vital in preventing further invasion and should be adequately supported by relevant governments. Apart from hand collection of live animals, practical, safe and effective control options are lacking and are required urgently. Control programs need to be ongoing to be effective in the long term.

Importance of modelling, monitoring and control

Where pest populations have been reduced in recent years, either from drought or national control initiatives, follow-up monitoring and control are essential to reduce recolonisation and population recovery.

Modelling predictions reported in this Assessment suggest that many species are still capable of invading new areas of Australia. Management authorities need to be vigilant to reduce the likelihood of species expanding further because once an invasive animal becomes well established, it is extremely difficult and often prohibitively expensive to eradicate.

Ongoing monitoring and reporting will provide improved information on the distribution, abundance and trend in invasive animal populations in the jurisdictions of Australia.

Need for more information

A commitment is required by state and territory governments and the Australian Government to ongoing and improved monitoring of invasive animals (and their impacts) to raise the quality of national information and datasets. Most information about the established and nationally relevant species described in this Assessment is of medium to low quality. Most information was obtained from expert opinion from local specialists who provided general knowledge based on observations and sources such as control activities; some scientific data were obtained from field sampling, but in other cases, anecdotal information only was available. For those species that are new and emerging (ie that we still may be able to eradicate), very little information is available from most jurisdictions.

4 Impacts of significant invasive vertebrate pests

This chapter summarises the main outcomes of the collection, collation and reporting of impacts information throughout Australia to report under the indicator, '*Impacts of significant invasive vertebrate pests*' (see Chapter 2). Information has been compiled from management programs that directly or indirectly monitor and report the impacts of invasive animals on environmental, economic and social values.

The economic, environmental and social impacts of invasive animals in Australia have been estimated at one billion dollars per year (McLeod 2004, Tracey et al 2007). However, this is considered a conservative estimate and there are many gaps in our knowledge on impacts. The cumulative effects of invasive species are particularly difficult to measure and report; thus, the real impact cost of invasive pest animals is likely to exceed this value.

Invasive animals are known to threaten many of Australia's Matters of National Environmental Significance, including Threatened Species and Ecological Communities, and Listed Migratory Species (eg little terns), Marine Species and Environments (eg grey-headed albatross on Macquarie Island), and Wetlands of International Importance (eg Macquarie Marshes Ramsar wetland in NSW). They are listed in the top three greatest threats to threatened species and ecosystems, riparian environments and important wetlands of Australia (Tait 2005), and are a major threat in almost all World Heritage Areas in Australia.

These threats range from cane toads in Kakadu, rabbits on Macquarie Island to feral pigs in the wet tropics. Their significance is duly reflected in the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act), where invasive animals represent 7 (41%) of the 17 listed 'key threatening processes' for nationally listed threatened biodiversity.

Foxes prey on the nests of many freshwater turtles, such as the eastern long-necked turtle (*Chelodina longicollis*) at Jervis Bay (photo by Paul Meek)

Measuring and monitoring impacts

Measuring and reporting the impacts of pests usually require detailed sampling of a number of attributes. The types of impacts caused by invasive animals include: damage to water quality and runoff, changes to soil structure and erosion, alteration of plant species composition and biomass, damage to crops and production systems, changes in animal populations and production, spread of human and livestock disease, change in ecosystem structure, and species extinction (Hone 1994).

At present, many invasive animals are listed under state and Commonwealth threatened species legislation as 'key threatening processes' because of their impacts on environmental and biodiversity values. Some species are also recognised as a serious threat for exotic disease maintenance and transmission; for example, if diseases such as foot-and-mouth disease were introduced to Australia.

Rabbit warrens encourage weeds and soil erosion (photo by NSW Department of Primary Industries)

Measurements of impacts often involve direct counts of damage, indirect assessments such as questionnaire surveys, extrapolations from experiments to field conditions, and modelling predictions. Other techniques can be applied to measure the impacts of pests in the field. These range from visual scoring of crop damage to monitoring prey populations before and after pest-control activities.

The impacts of invasive animals are widespread, varied and significant throughout Australia. Many of the impacts are poorly quantified and poorly presented for decision making at the various levels of management. Improved information regarding the impacts of pests is required to allow decision makers to manage pests effectively. Information on pest impacts is particularly important at the local scale to decide how much control to implement to reach a desired goal and to decide what level of impact by a pest is considered 'acceptable'.

How does monitoring help in the management of invasive animals?

Monitoring is an essential part of invasive animal management and can include simultaneous monitoring of pest numbers and pest impacts.

Monitoring the impacts of a pest is fundamental to:

- identify priorities for immediate and future management (eg planning and resource allocation)
- evaluate previous management activities (eg the response of pests to control)
- improve understanding and knowledge (eg the relationship between pest numbers and their impacts)
- raise awareness and provide education on current and potential problems, as well as opportunities for prevention and control.

Case studies of impacts

This Assessment has addressed the issue of reporting the impacts of invasive animals by selecting a series of projects that have measured impacts directly using field-sampling techniques.

The following is a set of observations from research and management projects that provide information on the impacts of invasive animals in Australia.

The protocol for measuring the '*Impacts of significant invasive vertebrate pests*' is under development by the Australian Vertebrate Pests Committee (VPC). The finalised protocol is anticipated to recommend techniques for consistent monitoring of the impacts of invasive animals, to provide consistency in data collection and reporting Australia-wide. Until such time as a protocol is developed and endorsed by VPC and adopted, VPC has agreed that the most effective way to report the impacts of invasive animals is by using a series of selected studies that present information about the impacts of pests in Australia. Referred to hereafter as case studies, this approach was chosen because there is presently no single agreed consistent method for measuring and reporting all the different types of impacts associated with invasive animals. They vary between species and different assets (environmental, economic and social). Damage also typically varies between locations and at different times or seasons (Hone 2007).

The current Assessment uses these case studies to monitor the trends in impacts over time and in future assessments. In most instances, the case studies have been sourced from management and monitoring programs that have a range of objectives,

including the control of pests, but these programs can be used simultaneously to report the impacts of pests. Measuring and reporting impacts is generally resource demanding, and varies by species, region and the type of impact, eg damage to wine grapes by common starlings.

The case studies have been selected to report the impacts of invasive animals from a range of species and various impact types and locations, and these case studies use existing pest management programs wherever available.

The following two objectives were addressed for impact reporting through case studies:

- to present an overview of impacts of significant invasive vertebrate pests throughout the regions of Australia across social, economic and environmental themes
- to provide examples of monitoring the impacts of pest species over time to report the effectiveness of various management programs.

The case studies present a series of research findings that identify and report the impacts of various invasive animals in Australia. Ideally, a number of species, impact types and locations should be used to report the impact of all pest species throughout Australia (ie to present an overview of impacts). Because the case studies are also aimed at reporting the impacts of pest species over time and into the future, the chosen studies were selected for their capacity to be included in future assessments. Consequently, some of the case studies cannot present many results in this Assessment, but their results are expected to be included in future assessments.

The following section contains the case studies that were reported from national, state and territory governments to summarise the impacts of invasive animals from the relevant monitoring and management programs for this Assessment. The reporting format of the case studies has followed the guidelines for invasive animal impact case studies (see Appendix 2) wherever suitable. Where this format was unsuitable, an alternative format has been applied.

Case study 1
The threat posed by invasive animals to biodiversity in New South Wales

Adapted from Coutts-Smith, AJ, Mahon PS, Letnic M and Downey PO (2007). *The Threat Posed by Pest Animals to Biodiversity in New South Wales*, Invasive Animals Cooperative Research Centre, Canberra.

In New South Wales (NSW), invasive animals pose a risk to 388 threatened species and communities — representing 40% of threatened biodiversity. They comprise 154 plant species, 186 animal species, 17 threatened populations of plants or animals, and 31 endangered ecological communities.

A further examination of each of these groups, as well as the categories of threat (ie endangered and vulnerable), is presented below.

Endangered and vulnerable species

Threatened species in NSW are categorised according to the degree to which they are threatened, using the internationally accepted World Conservation Union Red List classifications of 'endangered' or 'vulnerable'.[12] Invasive animals pose a threat to 38% of all native species listed as endangered and to 42% of species listed as vulnerable in NSW (Coutts-Smith et al 2007). This equates to 26% and 27% of endangered and vulnerable plant species, respectively, and to 77% and 62% of endangered and vulnerable animal species, respectively.

Most of the invasive animal species that pose a threat to biodiversity in NSW can be classified into one of three broad groups: terrestrial predators, terrestrial herbivores, or fish (including all the aquatic alien species). Examination of these major groups of invasive animals revealed that introduced herbivores threaten the highest percentage of species, at 63%, followed by predators at 44%, fish at 7%, and remaining invasive animals at 5% (see Table 4.1). Introduced herbivores pose the main invasive animal threat to endangered and vulnerable plant species, as well as plant populations and ecological communities. Introduced predators pose the main threat to endangered and vulnerable animal species, as well as animal populations (see Table 4.1).

[12] http://www.iucnredlist.org (Accessed 15 May 2008)

Threatened plant and threatened animal species

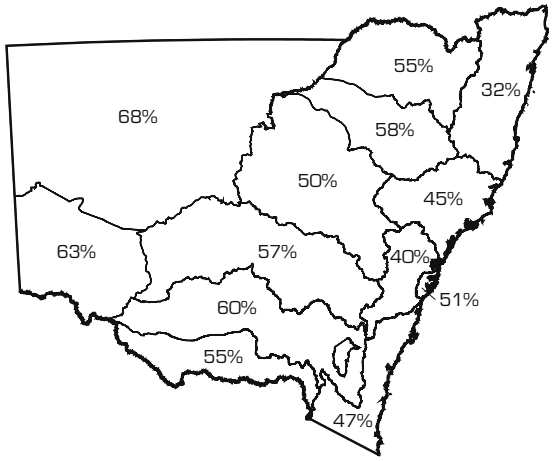
Of the 5248 vascular plant species that occur in NSW, 578 are listed as threatened. Of these, 154 are at risk from invasive animals (see Table 4.2). These figures include algae, aquatic plants and fungi, for which accurate numbers are not available. Dicotyledons are the most frequently identified group of plants at risk, with 122 species threatened by invasive animals. However, as a proportion, monocotyledons are the most at risk with 35% of all threatened monocotyledons at risk from invasive animals (see Table 4.2).

Of the 938 native animals that occur in NSW, 276 are listed as threatened. Of these species, 186 are at risk from invasive animals. This includes 15 threatened fish and invertebrate species at risk from invasive animals, for which accurate numbers are not available (see Table 4.2). Invasive animals pose a threat to two-thirds of the animal species and to 83% of the animal populations listed as threatened in NSW (see Table 4.2). Birds were identified most frequently as being at risk, with 74 species threatened by invasive animals. However, as a proportion, reptiles are the most at risk with 93% of all threatened reptiles at risk from invasive animals (see Table 4.2).

Threatened plant and animal populations and ecological communities

Invasive animals pose a threat to 83% of the endangered animal populations (see Table 4.2). The types of animal populations at risk include mammals, frogs, fish and birds. In contrast, invasive animals pose

Figure 4.1 Percentage of threatened species in each natural resource management region at risk from invasive animals in NSW



Native animals such as the shingleback skink (*Trachydosaurus rugosus*) are vulnerable to predation by foxes and feral cats (photo by Lee Webley)

Table 4.1 Number of threatened species at risk from the major invasive animal groups in NSW

Groups of invasive animals	Number of threatened species at risk							Total number and percentage of threatened species at risk	
	Endangered species		Vulnerable species		Populations		Ecological communities		
	Plant	Animal	Plant	Animal	Plant	Animal		Number	%
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	5	4	2	10	0	1	0	20	5
Total	92	76	62	110	2	15	31	388	100

Note: Total values are not cumulative as many threatened species are threatened by more than one group of pest animals.

Table 4.2 The threat posed by invasive animals to specific groups of threatened species in NSW

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

nr = not recorded; na = not applicable

[a] excludes four species for which threats could not be determined, and includes algae, aquatic plants and fungi for which accurate numbers are not available

[b] includes fish and invertebrates, for which accurate numbers are not available

Note: 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.

a threat to only 11% of threatened plant populations (see Table 4.2). Invasive animals also pose a threat to 31 endangered ecological communities (as defined by the *Threatened Species Act*[13] and the EPBC Act), or 38% of all endangered ecological communities in NSW.

Natural resource management regions of New South Wales

All of the 13 natural resource management regions in NSW contain significant proportions of threatened species at risk from invasive animals, ranging from 32% in the Northern Rivers Catchment Management Authority (CMA) to 68% in the Western CMA (see Figure 4.1).

Further information

Coutts-Smith AJ, Mahon PS, Letnic M and Downey PO (2007). *The Threat Posed by Pest Animals to Biodiversity in New South Wales*. Invasive Animals Cooperative Research Centre, Canberra.

[13] ecological community means an assemblage of species occupying a particular area

Case study 2
National valuation of invasive animal impacts — Counting the costs assessment

Adapted from McLeod R (2004). *Counting the Cost: Impact of Invasive Animals in Australia 2004*. Cooperative Research Centre for Pest Animal Control, Canberra.

The economic, environmental and social impact of 11 invasive animal species on Australian agricultural industries and the environment were estimated in a desktop review. The review provided a 'triple-bottom-line' national perspective on the impacts of invasive animals. Species were selected on the basis of relevance to current and potential research activities, and in consultation with research specialists. Cost estimates include pest control and production-loss estimates per year. The environmental impacts of three species were assessed where some data were available. Environmental impact data were lacking for all other species.

The cost of the impact of the 11 species subject to assessment totalled $720 million per year (see Table 4.3). Foxes, feral cats, rabbits and feral pigs were estimated to account for 82% of losses, of which loss in agricultural productivity accounts for about half of the total costs estimated. Independent research on the impacts of pest birds (Tracey et al 2007) indicates that the overall impacts of invasive animals cost over $1 billion per year in Australia.

The costs included in the economic impact assessment were:

- costs to control invasive animals including baiting, fencing and shooting, and research associated with improved management of the specific species
- production losses (estimated for sheep, cattle and cropping industries), including: predation on young stock, crop damage and competition for feed
- public sector research and management costs.

The cost assessments included in the environmental impacts were typically based on an invasive animal's impact on biodiversity. Where possible, impacts were quantified in cost terms, although it should be noted

Table 4.3 Economic, environmental and social costs of impact of pest species (in order of cost) per year

Triple-bottom-line impacts							
	Total	Economic		Environmental		Social	
	Cost ($m)	Qualitative impact	Cost ($m)	Qualitative impact	Cost ($m)	Qualitative impact	Cost ($m)
Fox	227.5	**	37.5	**	190.0	*	nq
Feral cat	146.0	*	2.0	**	144.0	*	nq
Rabbit	113.1	**	113.1	*	nq	*	nq
Feral pig	106.5	**	106.5	*	nq	*	nq
Wild dog	66.3	**	66.3	*	nq	*	nq
Mouse	35.6	**	35.6	*	nq	**	nq
Common carp	15.8	*	4.0	**	11.8	*	nq
Feral goat	7.7	*	7.7	*	nq	*	nq
Cane toad	0.5	*	0.5	*	nq	*	nq
Wild horse	0.5	*	0.5	*	nq	*	nq
Camel	0.2	*	0.2	*	nq	*	nq
Total	719.7		373.9		345.8		

$m = $ million; ** = larger impact; * = smaller impact; nq = not quantified

The size of a feral pig's home range is determined largely by food availability (photo by Steve Lapidge)

that accurate information relating to ecological cause-and-effect relationships, along with the communities' valuations of species preservation, are not readily available. Environmental valuations were undertaken for feral cat, fox and common carp impacts because data were available for these species.

Many gaps exist in our knowledge of the major environmental and social impacts of invasive animals. These impacts are shown in Table 4.3 for each species in qualitative terms, and where quantitative impact information was readily available it was included.

Further information

McLeod R (2004). *Counting the Cost: Impact of Invasive Animals in Australia 2004*. Cooperative Research Centre for Pest Animal Control, Canberra.

Invasive Animals Cooperative Research Centre[14]

[14] http://www.invasiveanimals.com (Accessed 15 May 2008)

Case study 3
Impacts of invasive animals on national environmental assets and biodiversity

The Department of the Environment, Water, Heritage and the Arts (DEWHA) maintains spatial and other information on Matters of National Environmental Significance that are protected under the EPBC Act. These matters include Listed Threatened Species and Communities, Migratory Species, Wetlands of International Significance, and World Heritage Areas and National Heritage Sites. In this analysis, the Matters of National Environmental Significance are referred to as 'environmental assets'.

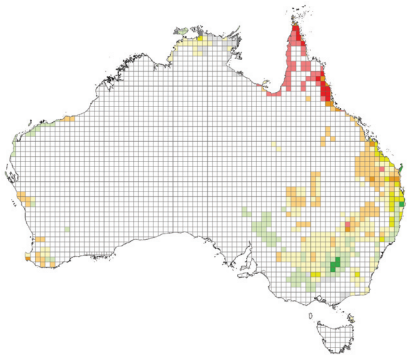
Information available from DEWHA includes distribution maps of each asset, as well as a database that summarises the environmental assets and threats that relate to them. The threats are those explicitly listed in threat abatement plans, recovery plans, management plans, species profiles, listing and conservation advice, and other references. The threats include invasive animals.

DEWHA has developed tools to count the number of environmental assets that are affected by a given threat (eg an invasive animal species) in an area, say a grid cell. From this, continental-scale density maps were compiled of the number of environmental assets affected by that given threat.

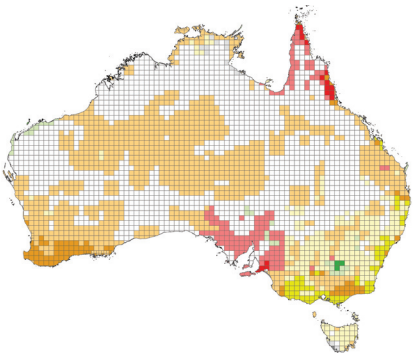
In this illustrative analysis, the asset–threat density maps have been integrated with the distribution and abundance maps for feral pigs, feral goats, rabbits, feral cats and foxes compiled for the current assessment (see Chapter 3). Figure 4.2 shows the number of environmental assets that are identified as being affected by the respective invasive animal species per grid-square area. The areas in red denote high pest abundance coinciding with environmental assets, orange denotes medium pest abundance with environmental assets, and yellow denotes low pest abundance in areas with environmental assets. The green areas indicate that potentially sensitive assets occur where the pest is not yet present, representing priorities for monitoring and opportunities for early eradication should the pest colonise. In the case of

Figure 4.2 Abundance of invasive animals and the density of affected environmental assets for (a) feral pigs, (b) feral goats, (c) rabbits, (d) feral cats and (e) foxes

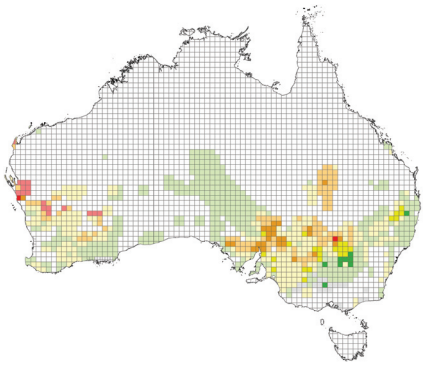
a) Feral pigs and affected environmental assets



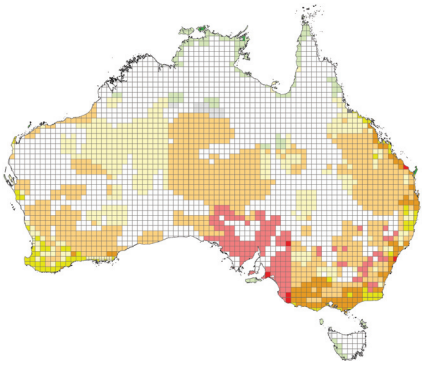
d) Feral cats and affected environmental assets



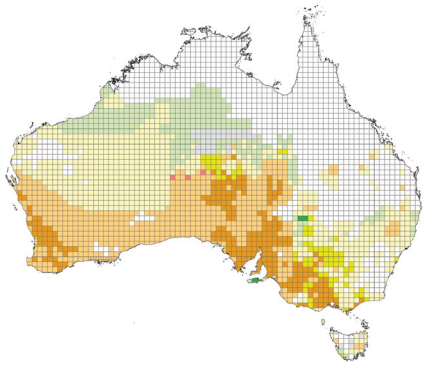
b) Feral goats and affected environmental assets



e) Foxes and affected environmental assets



c) Rabbits and affected environmental assets



Pest Abundance	*Number of Affected Assets* 3+	1 - 2
Abundant		
Common		
Occasional		
Absent		
Unknown		

No colour indicates areas with no affected assets, although the pest animal may or may not occur

Source: DEWHA, 2007

the red fox, the whole of Tasmania should be regarded as a 'green area' because of the potential impact of foxes on susceptible species in Tasmania not covered by this analysis. Only five species were addressed for this analysis.

The compiled data allow for additional analyses to be undertaken, for example to:

- provide lists of the particular assets affected in different areas of a pest range
- produce maps of classes of assets affected by a pest (eg wetlands, critically endangered species, mammals or orchids).

Such analyses have obvious value in assessing assets, threats and priorities for action at a range of spatial scales, and can provide information that can feed into development and application of threat abatement plans and other planning documents.

Further information

Department of the Environment, Water, Heritage and the Arts[15]

[15] http://www.environment.gov.au (Accessed 15 May 2008)

Case study 4
Monitoring feral pig predation on nesting threatened sea turtles in Cape York, north Queensland

Project title
Feral pig predation on sea turtle nests in north Queensland

Lead agency
Cape York Peninsula Development Association Incorporated, in conjunction with the Department of Natural Resources and Water (now Biosecurity Queensland, Department of Primary Industries and Fisheries) and the Natural Heritage Trust

Species
Feral pig (*Sus scrofa*)

Location

The study was conducted during summer of 2006–07 at four monitoring sites in north Queensland: three located along the western edge of Cape York and one site on Prince of Wales Island.

Monitoring

Turtle nests were identified during beach surveys (see Figure 4.3), and the following parameters were recorded:

- the number of turtle nests disturbed by predators
- the level of predation on turtle nests
- the likely predator species recorded during the specified monitoring period.

Impact type

Predation rates at the four sites were calculated from a simple estimate of the percentage of nests disturbed by feral pigs. Threatened sea turtles are valued by Indigenous groups and tourists, and their decline could have a range of social impacts and ecosystem effects.

Current findings

The study found that:

- Feral pigs prey on up to 70% of sea turtle nests in far-north Queensland.
- An average of 35% of sea turtle nests were destroyed by feral pigs and wild dogs.
- Predation rates can reach 100% of nests.
- Feral pig control can reduce predation levels on threatened sea turtle nests.

The results are summarised in Table 4.4.

A continuing high level of predation from feral pigs on turtle nests in the region was observed. Further monitoring is expected to provide long-term impact data.

Further information

Biosecurity Queensland, Department of Primary Industries and Fisheries[16]

Figure 4.3 Monitoring sea turtle nest predation in north Queensland

Photo supplied by Biosecurity Queensland.

[16] http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/4790_ENA_HTML.htm (Accessed 15 May 2008)

Table 4.4 Predation rates on sea turtle nests by feral pigs and wild dogs at four sites in far-north Queensland

Sites	Number of nests monitored	Monitoring period (weeks)	Predation rate (%) (number of nests destroyed)	Major predator
Napranum	197	14	65% (128)	Feral pigs
Mapoon	669	15	16% (107)	Wild dogs
Injinoo	210	13	70% (147)	Feral pigs
Prince of Wales Island	15	9	20% (3)	Feral pigs

Case study 5
Monitoring feral pig damage to banana and sugar cane production in north Queensland

Project title
Monitoring the economic cost of feral pigs to agricultural industries in the wet tropics of Queensland

Lead agency
Department of Natural Resources and Water (now Biosecurity Queensland, Department of Primary Industries and Fisheries)

Species
Feral pigs (*Sus scrofa*)

Location

The study site was the wet tropics of north Qld, particularly the coastal strip and associated highlands near Innisfail.

Monitoring

The following parameters were monitored:

- the economic damage caused by feral pigs to sugar cane and banana farms; determined from interviews with land holders and farm inspections between 2000 and 2002
- feral pig control costs
- lost production (and costs)
- an index of pig activity; used as a surrogate for density.

Impact type

Feral pigs cause much damage to sugar cane and bananas in Qld (see Figure 4.4). An estimate of the level of damage (in terms of on-farm costs) was supplied by landholders. Damage to crops was also measured during farm inspections in fixed 10 m × 2 m plots. The relationship between the estimates of damage (including control costs and lost production) and pig activity (presence or absence of any pig sign, ie tracks, scats or traces) was combined separately for either banana or cane farms at each survey period and assessed.

Current findings

Although information collected is largely specific to the wet tropics region, the study found that:

- Feral pigs caused, on average, direct economic damage of $1800 per banana farm per year and $5350 per cane farm per year.
- Feral pigs caused damage to 16 150 tonnes of sugar cane (valued at over $377 000) or 5.65% of the sugar crop.
- There was no significant relationship between pig activity and the economic damage they caused for either banana or sugar cane farms.
- The total costs of feral pig damage and costs of control averaged $4100 per year for each banana farm and $10 600 per year for each cane farm.

Further information

Mitchell JL and Dorney W (2002). *Monitoring Systems for Feral Pigs*. Report to the National Feral Animal Control Program, Bureau of Rural Sciences, Canberra.

Biosecurity Queensland, Department of Primary Industries and Fisheries[17]

[17] http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/4790_ENA_HTML.htm (Accessed 15 May 2008)

Figure 4.4 Feral pig sow destroyed after damaging sugar cane crops

Photo by Ben Allen

Case study 6
Monitoring rabbit impacts on native vegetation and regeneration in the Flinders Ranges, South Australia

Project title
Operation Bounceback from the Flinders Ranges and surrounding regions: Impacts of rabbits on native vegetation in the Flinders Ranges

Lead agency
Department of Environment and Heritage South Australia, and the Animal and Plant Control Group of Department of Water Land and Biodiversity South Australia

Species
Rabbits (*Oryctolagus cuniculus*)

Location

Operation Bounceback is an ecosystem recovery project operating in the Vulkathunha-Gammon Ranges National Park, Flinders Ranges National Park and adjoining sheep stations.

Monitoring and outcomes

The project involved measuring vegetation response to the following experimental treatments:

- fenced vegetation enclosures
- broad-scale rabbit control.

There were five separate monitoring sites, all located within the broad study area of Operation Bounceback.

Site 1 Mulga exclosures at Arcoona Creek catchment, Vulkathunha-Gammon Ranges National Park

The number of mulga seedlings (*Acacia aneura*) that germinate after heavy summer rainfall events was measured under rabbit control treatments.

Despite substantial reductions in rabbit densities following the introduction of biocontrol agents, rabbit grazing is still preventing recruitment of mulga and the species is declining. Rabbits have caused 40% mortality in six months (see Figure 4.5).

Site 2 Spidery wattle exclosures at Balcanoona Creek catchment, Vulkathunha-Gammon Ranges National Park

The spidery wattle (*Acacia araneosa*) is an endemic plant in South Australia that is listed as 'vulnerable' under the EPBC Act and as 'endangered' under South Australian legislation.

The number of spidery wattle that grew beyond seedling size was measured under rabbit control treatments.

Rabbit and feral goat exclusion significantly enhanced recruitment of spidery wattle and resulted in the establishment of a mixed age-class population within the exclosures; plant numbers have increased by 94% where rabbits and goats have been excluded.

Site 3 Gum Creek Acacia victoriae *shrubland rabbit-control experiment, Flinders Ranges National Park*

The number of perennial plants in quadrats and species composition was measured under rabbit-control treatments.

Rabbit control enhanced recruitment of moderately palatable perennial plants and reduced the weediness of annual vegetation, despite substantially increased compensatory grazing by other herbivores.

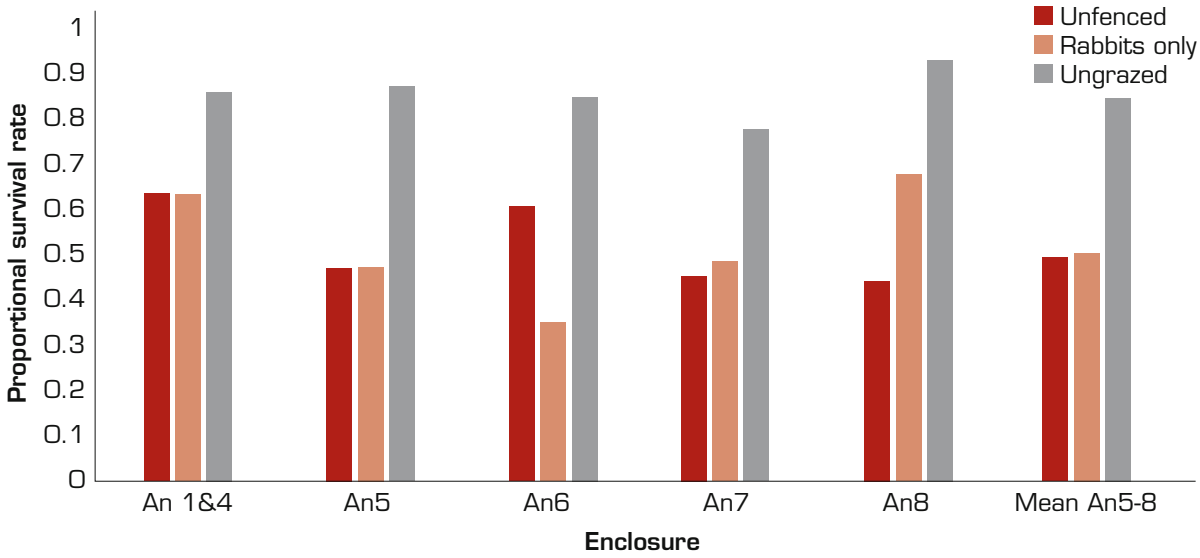
Site 4 Chenopod shrubland and grassland exclosures, Flinders Ranges National Park

Plant biomass and the number of perennial plants were recorded in vegetation exclosures to measure the grazing pressure of rabbits.

Control of rabbits and native herbivores enhanced biomass of short-lived chenopods and native grasses, and reduced weediness.

These data indicate that grazing by rabbits and other herbivores limits shrub recruitment and reduces the biomass of palatable species in native pastures.

Figure 4.5 Proportional survival of mulga (*Acacia aneura*) seedlings in the six months following germination in 1997 in five sets of enclosures (An1&4, An5, An6, An7, and An8) in the Vulkathunha-Gammon Ranges National Park, South Australia. Unfenced areas are grazed by rabbits, feral goats and euros.



Site 5 Land condition assessment and vegetation monitoring points in Vulkathunha-Gammon Ranges National Park and Flinders Ranges National Park

A land condition index was used to assess the land and vegetation condition based on vegetation community type, species composition and abundance, and level of grazing impact.

Overgrazing by rabbits and other herbivores reduced the general land condition, as measured by the proportions of palatable and unpalatable species in recognised vegetation associations. Photo monitoring points were also established to assess the change in vegetation over time (see Figure 4.6).

Land condition in both national parks was estimated to be poor because of historical overgrazing by livestock and the subsequent arrival of rabbits.

Current findings

The entire floristic integrity of arid-zone Acacia shrublands, survival of their dependent fauna and stability of the pastoral industries they sustain are all threatened by ongoing rabbit grazing. These studies indicate that the process of degradation is reversible for moderately palatable species. Monitoring within each of the individual monitoring programs will be ongoing.

Further information

Operation Bounceback, South Australian Department of Environment and Heritage[18]

Figure 4.6 Photo monitoring points to assess impacts to vegetation by grazing rabbits (1992 and 2007)

1992 (photo by Greg Mutze)

2007 (photo by Greg Mutze)

[18] http://www.environment.sa.gov.au/biodiversity/bounceback_project.html (Accessed 15 May 2008)

Case study 7
Monitoring predation impacts of foxes on native wildlife at Southern Ark Program, Victoria

Project title
Southern Ark

Lead agency
Victorian Government, Department of Sustainability and Environment

Species
Foxes (*Vulpes vulpes*)

Location

Far-east Gippsland, Victoria (see Figure 4.7)

Foxes pose a serious threat to native animals (photo by Sam Vine)

Figure 4.7 Location of Southern Ark area of operation

Monitoring

Parameters measured included changes in the distribution of small- to medium-sized native mammals under various fox-control treatments (monitoring involved a conditional case–control design).

Species monitored were:

- native animals: long-nosed potoroo (*Potorous tridactylus*), southern brown bandicoot (*Isoodon obesulus*), long-nosed bandicoot (*Perameles nasuta*), brush-tailed possum (*Trichosurus vulpecula*), and other small mammals
- foxes (*Vulpes vulpes*).

Impact type

Foxes are known to have a profound impact on small- to medium-sized mammals. Some of these mammals are threatened species. A reduction in fox populations following control was assumed to decrease predation rates and allow an increase in numbers and expansion of the spatial range of small mammals. The level of impact by foxes on native mammals was thought to be significant.

Current findings

Fox predation impacts on native wildlife are known to be significant, and small- to medium-sized mammals (35–5000 grams) (also referred to as 'critical weight range mammals') are particularly susceptible to extinction risk from fox predation.

Preliminary results indicated marginal increases in the populations of long-nosed potoroo and southern brown bandicoots at one location following fox control.

The impact of fox populations on the distribution and abundance of small mammals could not be determined fully at this early stage in the Southern Ark program. However, ongoing monitoring is expected to produce significant information regarding trends and impacts for future assessments.

Further information

Department of Sustainability and Environment's Southern Ark Program[19]

[19] http://www.dse.vic.gov.au (follow Plants & Animals link) (Accessed 15 May 2008)

Case study 8
Monitoring predation impacts by foxes on threatened shorebirds in New South Wales

Project title
NSW Fox Threat Abatement Plan — threatened shorebird program

Lead agency
Department and Environment and Climate Change, NSW

Species
Foxes (*Vulpes vulpes*)

Location

This project monitored many of the 25 major breeding sites for threatened shorebirds (little terns, pied oystercatchers, hooded plovers and beach stone-curlews) along the NSW coastline (see Figure 4.8). Intensive broad-area (across-tenure) fox control was undertaken, wherever feasible, at sites over six breeding seasons 2001–02 to 2006–07. The allocation of sites to treatment was non-random.

Monitoring and analysis

Shorebirds were observed directly at least weekly. The date of first nesting, number of adult breeding pairs, number of nests (distinguishing between clutches), number of eggs, number of chicks and the number of young fledged were recorded throughout the season. Causes of egg and chick mortality were recorded opportunistically. Breeding success at each site was calculated as the number of young fledged divided by the number of breeding pairs. Breeding success for the period 2001–02 to 2006–07 was compared between treatments (with and without fox control) and between years.

Figure 4.8 Monitoring sites for threatened shorebirds in NSW

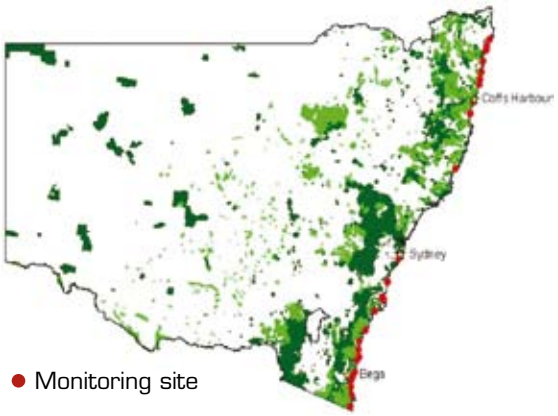
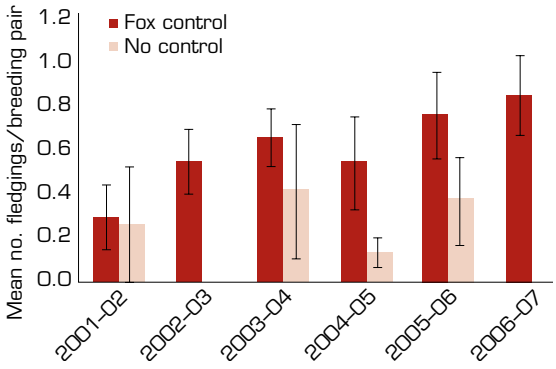


Figure 4.9 Breeding success of little terns at sites with and without fox control



Impact type

Fox predation on eggs and chicks can reduce breeding success and hence the recruitment of all four species of threatened shorebirds dramatically. Foxes have been reported to cause 100% mortality in eggs and chicks at individual sites.

Current findings

Breeding success of threatened shorebirds, especially little terns, was significantly greater at sites with fox control (see Figure 4.9). Nevertheless, fox predation remained a common source of mortality at all sites, suggesting there is potential to improve control programs. Measuring the effects on adult numbers is complicated by the ability of birds to move between sites. However, the number of little terns appears to be increasing across NSW. Monitoring is ongoing.

Further information

NSW Department of Environment and Climate Change[20]

[20] http://www.environment.nsw.gov.au (Accessed 15 May 2008)

Case study 9
Monitoring introduced predator impacts on native fauna in the Jarrah Forest bioregion, southwest Western Australia

Project title
Introduced and native predator interactions in the northern jarrah forest

Lead agency
Western Australian Department of Environment and Conservation and the Invasive Animals Cooperative Research Centre

Species
Foxes (*Vulpes vulpes*) and feral cats (*Felis catus*)

Location
The study site is the northern jarrah forest of southwest Western Australia (WA) (see Figure 4.10).

Monitoring

Monitoring in baited and unbaited regions encompassed:

- fox and feral cat density monitoring (through molecular techniques based on identification of individuals from hair and scats, and indexes of abundance or density from active and passive sand plots)
- trapping and radio telemetry spotlighting of chuditch, two species of varanids, the southwest carpet python and the common brush-tailed possum (to derive density estimates and habitat use)
- wire cage and Elliott and pitfall trapping techniques (to monitor prey availability)
- scat analysis (to determine whether diet reflected prey availability).

Impact types

Foxes are known to prey upon a suite of native species.

Foxes occupy a wide range of environments, including open woodlands (photo by Steve Lapidge)

Current findings and implications

This study found that:

- The impacts of foxes were mitigated by the control activities. However, potential indirect effects, including increased predation by previously subordinate predators (mesopredator release), have not yet been quantified fully.
- Conventional reporting on the extent of area subject to fox and feral cat control (ie the number of hectares baited) was insufficient to assess the effectiveness of control strategies.
- Standard techniques of monitoring passive sand plots to derive indexes of fox and feral cat activity did not reflect the long-term effectiveness of the baiting strategies.

Future monitoring

The effectiveness of future fox baiting in the northern jarrah forest will be assessed by quantifying fox and feral cat densities, determining if there are indirect effects from mesopredator release and monitoring the long-term biodiversity outcomes (eg a sustained increase in the abundance of native species).

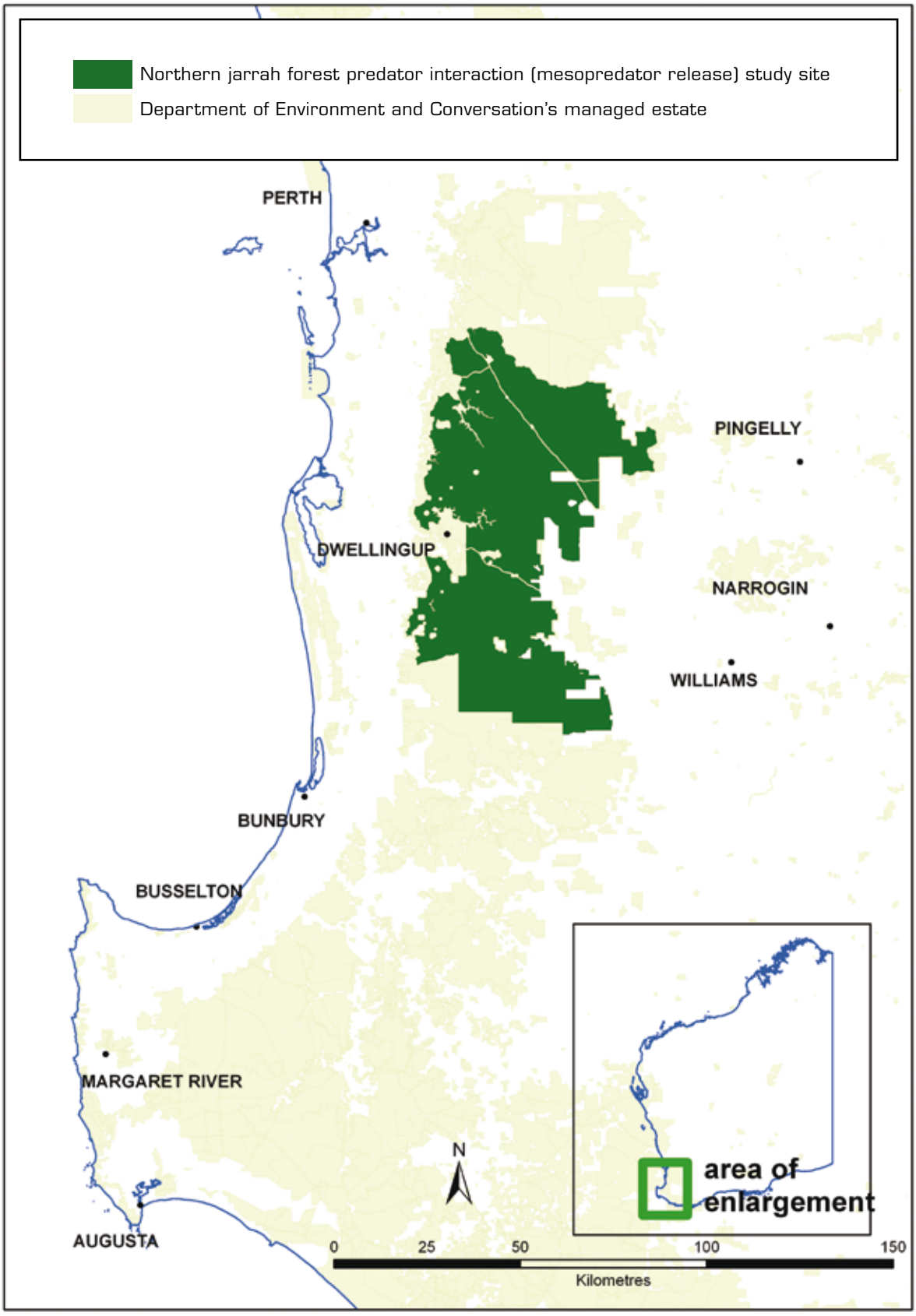
Further information

WA Department of the Environment and Conservation[21]

Invasive Animals Cooperative Research Centre[22]

[21] http://www.dec.wa.gov.au (Accessed 15 May 2008)
[22] http://www.invasiveanimals.com (Accessed 15 May 2008)

Figure 4.10 Location of the northern jarrah forest in the WA Department of Environment and Conservation's managed estate



Source: WA Department of Environment and Conservation

Use of information about the impacts of invasive animals

Nationally significant invasive animals inhabit all areas of Australia and their impacts are significant. In total, invasive animals cause at least one billion dollars damage each year to the economy, environmental assets and society (McLeod 2004, Tracey et al 2007).

This Assessment presents some of the impacts of invasive animals through case studies from management and monitoring programs around Australia. This chapter is not intended to provide a comprehensive overview of invasive animal impacts. The case studies reported herein present a snapshot of impacts information from various areas and programs that may be used to monitor the impacts of invasive animals over time. When considered in conjunction with information on the distribution and abundance of invasive animals, these case studies provide a reference point to help define the problem(s) caused by invasive animals throughout Australia.

The case studies should be used in conjunction with existing information on the impacts of invasive animals that has been determined over many decades of research and monitoring in Australia. A wide range of scientific research is available and can be periodically reviewed to provide an overview when needed, and to track changes in the level of information and knowledge on impacts throughout Australia.

Impacts information is crucial to the management of invasive pest animals. It is required to determine management priorities, identify the level of control needed to reach goals, and evaluate previous management programs, and is fundamental for maximising the cost-effectiveness of control activities. Resources for undertaking control programs are not limitless, and there is an inherent need to allocate resources where they will achieve the most cost-effective solutions.

In most instances, measuring the precise impacts of species is particularly difficult and requires experimental procedures and sampling designs to overcome confounding factors. The case studies reported herein provide a snapshot from a small set of monitoring programs, and ongoing monitoring of impacts through case studies is required to reveal longer-term impacts of pests in Australia.

Summary of current impacts information

The case studies selected for this Assessment reveal that invasive animals cause a wide range of ecological and economic impacts in Australia. The following list summarises current knowledge about the impacts of invasive animals from these nine case studies:

- Invasive animals cost over $1 billion per year through economic, environmental and social damage. The main culprits are foxes, pest birds, feral cats, rabbits and feral pigs.
- Invasive animals threaten 40% of threatened biodiversity in NSW, represented by 388 species, as well as 83% of endangered animals populations and 38% of endangered ecological communities.
- All natural resource management regions contain threatened species at risk by invasive animals (eg 68% in western NSW).
- There is significant overlap between invasive animal populations and environmental assets of national importance in all state and territories of Australia.
- Feral pigs are known to cause substantial production losses to sugar cane and bananas in north Qld, costing hundreds of thousands of dollars to the industries.
- Feral pigs also prey on up to 70% of sea turtle nests in north Qld.
- Rabbits significantly affect native vegetation, particularly regeneration. They prevent recruitment of native mulga, threatened Acacias and chenopod shrublands, and contribute to poor land condition in South Australia.
- Foxes are significant predators of a wide range of native fauna in Australia, such as potoroos and bandicoots in Victoria, chuditch in WA, and threatened shorebirds such as pied oyster catchers and little terns in NSW.

Improving monitoring and reporting of impacts

Ways to improve the monitoring and reporting of invasive animal impacts to provide more detailed assessment of pest impacts in Australia include:

- increasing investment in key research to identify the impacts of invasive animals to ensure that the impacts are addressed in broader management programs
- improving tools and techniques to monitor impacts across a range of management levels, including regional, state and territory levels
- strengthening linkages with research and monitoring programs such as Cooperative Research Centres, industry groups and national control programs (such as the National Feral Animal Control Program) to assess the social, environmental and economic impacts of invasive animals
- looking closely at a range of species and a variety of impact types; social, environmental and economic
- supporting natural resource management regional groups in monitoring and reporting activities to address key information gaps regarding impacts information for invasive animals

Cane toads (*Bufo marinus*) were introduced to control cane beetles, but have spread throughout northern Australia (photo by Liz Poon, CSIRO)

- increasing monitoring of impacts where investment programs and control activities are occurring, and ensuring that monitoring and reporting of pest impacts are prerequisites for funding of control programs.

Lack of information on the impacts of fish, birds and amphibians

At the time of this Assessment, there were no suitable studies supplied from state and territory government agencies on the impacts of birds, fish and amphibians that could be included in this section. For future assessments, we make the following recommendations.

- To prepare a case study to identify the impacts from pest birds, use the existing 'national list of 20 pest birds in horticulture' from Tracey et al (2007) *Managing Bird Damage to Fruit and Other Horticultural Crops*. This list includes common starlings, house sparrow, European blackbird, and urban pest species such as pigeons and Indian mynas.
- There are presently 34 established alien fish species in Australia (West et al 2007). To prepare a case study to identify the impacts of pest fish, relevant state and territory fisheries departments and research organisations, such as the Invasive Animals Cooperative Research Centre, should be consulted to select suitable existing programs where the impacts of pest fish can be identified and reported.
- The impacts of cane toads in Australia are presently being investigated by numerous authorities and research specialists. To prepare a case study on cane toad impacts, relevant state and territory departments and research organisations, such as the Invasive Animals Cooperative Research Centre and The University of Sydney, should be consulted to select suitable existing programs where the impacts of cane toads can be identified and reported.

5 Investment in the management and control of invasive animals

Where is funding going and what benefits does it provide?

Evaluating the effectiveness of management decisions, control options and investment is essential. To assess the effectiveness of investments on invasive animal populations and the adverse impacts they cause, information is needed on where investments are being allocated, what control and management activities are being undertaken, which activities are successful and why, and what levels of damage are being caused by invasive animals. This information is also necessary to determine which management strategies may need to be implemented in the future to reduce the impacts of pests on the economy, environment and society.

This chapter identifies sources of information about investment and where investment is allocated. The information can be compared with the national abundance and impacts data available in this Assessment (and from other initiatives) to identify the outcomes of major investments. This can serve to identify investment priorities, and where to target investments in future activities.

Australian Bureau of Statistics surveys

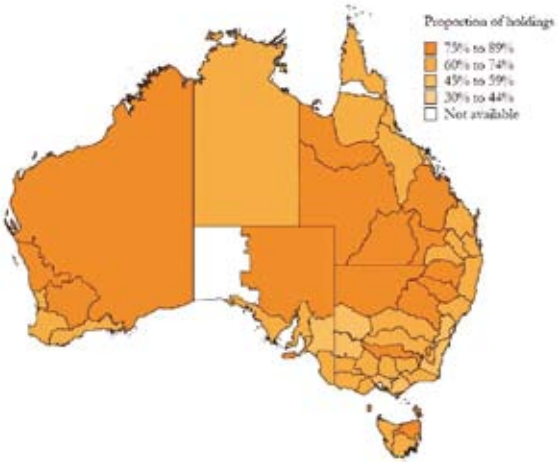
National information on the costs of control of invasive animals may be obtained from the Australian Bureau of Statistics (ABS) biennial survey on 'Natural Resource Management activities and issues on Australian farms'. This survey commenced in 2004–05 and collects information on natural resource management (NRM) issues (including invasive animals and their management) from 130 000 agricultural establishments throughout Australia. It has gathered information on pest species, control activities, costs of pest management by landholders, pest animal impacts, and the proportion of land impacted. This information can be reported at state and NRM-regional levels for comparison with the extent and impact data available within this Assessment (see Figure 5.1). The next biennial survey is scheduled for reporting during 2008.

Previous natural resource management programs and future Caring for our Country initiatives

Although the new NRM initiative Caring for our Country program is scheduled to take effect from July 2008, information on investments in research and control should also be available from previous NRM programs. Previous Australian Government NRM programs have helped restore and conserve Australia's environment and natural resources by funding thousands of community group projects. These have involved important on-ground environmental activities and control of invasive animals to protect environmental assets.

Other initiatives, such as the National Feral Animal Control Program (NFACP), have funded vital research and control projects for invasive animals in Australia. Each year, NFACP funds projects that aim to develop improved approaches to controlling the impacts

Figure 5.1 Proportion of landholdings reporting invasive animal-related issues



Source: Modified from ABS (2006)

of invasive animals, improving the effectiveness of control techniques, and producing guidelines for managing nationally significant invasive animals.

Many of these projects and programs show where investment (through control) is allocated. Comparison of these information types with the national distribution, abundance and impacts information from this Assessment may reveal whether funding is targeting the correct areas, identify priorities for future funding and determine whether outcomes from funding are being reached on a national scale

Areas of active management

It is equally important to identify areas of active management to allow the outcomes of management strategies to be assessed against investment and management action targets. Information on where control is being carried out can be used to evaluate the effectiveness of major investment programs. This information can be compared with that on the extent and impact of pest species to identify strategies and resources required to manage these pests.

A number of authorities are responsible for the management and control of pest species in Australia. To evaluate major investments and programs, and to provide a representative picture of management activities, information on the areas of active management would need to be collated from many authorities at local, regional, state, territory and national levels. The main authorities undertaking control include government agencies and regional authorities, community groups and landholders. Information on the area of active management and the management options that are selected is also important for planning the allocation of resources for future management activities.

Options available for managing invasive animals include local eradication, no management, crisis management, one-off management, sustained management and targeted management (Braysher 1993). Additional information that would be important to collate in this process includes:

- where pests have been locally eradicated
- the area of control
- the levels of control
- the intensity and frequency of control activities
- the assets being protected.

Pest impacts and environmental assets

To assess how well the investments and control programs are performing, it is essential to collect and report information on the impacts of invasive pest species. Examining information on environmental, economic and social assets is also important to determine whether resources and investment are being allocated to the most important areas.

Identifying where investment is being allocated, and determining its effectiveness in reducing the impacts of invasive animals on assets requires three types of information:

- investment in control activities — available through government NRM programs (eg the Caring for our Country program)
- impacts on assets — available from ABS landholder surveys or other sources
- the area of active management — available from relevant government and non-government authorities at all levels.

The current Assessment provides a valuable tool for evaluating NRM programs and future Caring for our Country programs, and can be used to identify priorities for future investment, control activities and research. Future assessments are expected to build on the information reported in this Assessment, which will provide better information on invasive animals distribution, abundance and impacts that can be used to evaluate various investments and funding programs.

It is anticipated that the next national assessment on invasive animals will also report on five key areas to allow the effectiveness of investment strategies to be assessed. These are:

- national, state and territory investments in invasive animal control
- the areas of active invasive animal management (and associated activities)
- control costs (incorporating annual control costs by regions)
- environmental, economic and social assets being protected
- impacts of invasive animals on respective assets.

6 Building on national compilations in future assessments

This section briefly summarises a series of recommended improvements to national compilations of information about invasive animal distribution, abundance and impacts for monitoring and reporting under the National Monitoring and Evaluation Framework (National M&E Framework) described in Chapter 2. These recommendations form the basis of our recommendations for a national information system for invasive animals presented in Chapter 7 and for future directions presented in Chapter 8.

Building on existing information

Previous surveys and national assessments have provided information on the distribution and density of a number of invasive animals throughout Australia (Wilson et al 1992; NLWRA 2001, 2002). A number of other significant surveys and assessments of invasive animals have been coordinated through state and territory government initiatives. This Assessment builds on those national, state and territory achievements by capturing detailed information for a broad range of established invasive animals of national significance.

At the time of this Assessment, each state and territory jurisdiction maintained an independent database or series of information datasets on invasive animals that were used for state-level management activities. National information presented in this Assessment has been consolidated from these existing state- and territory-based datasets on the distribution, abundance and impacts of invasive animals. During this Assessment, the states and territories identified a need for further development and improvement of their datasets to provide better information at the national level. We recommend a framework of regular national assessments to support this process.

Future assessments

For future assessments and to build on the achievements of this Assessment, we present five key recommendations to improve the data available for monitoring and reporting of nationally significant invasive animals in Australia.

1. Consider and adopt (where feasible) monitoring techniques for vertebrate pests (see Mitchell and Balogh 2007) at regional and state or territory levels.
2. Adopt flexible and practical national monitoring protocols (see Chapter 2) at regional and state or territory levels.
3. Include emerging pest species within management programs as well as monitoring and reporting activities.
4. Develop ongoing data management procedures regarding invasive animal species for state or territory and national authorities.
5. Manage national data within a national information system for invasive animal species, or a complementary system.

The collection, collation and reporting of key matters for target for invasive animals provides a platform for ongoing improvements in the monitoring, evaluation and reporting of invasive animals. This Assessment provides, for the first time, national information on nationally significant invasive animals using a consistent method as a benchmark for ongoing monitoring and evaluation. Implementation of national monitoring protocols and consistent use of monitoring manuals hereafter will provide three key outcomes:

1. fundamental information for ongoing monitoring, evaluation and reporting requirements
2. more comprehensive and comparable information on invasive animals for future assessments

3. meaningful information on trends in pest populations and their impacts to evaluate the success or otherwise of investment programs, policy and management programs throughout Australia.

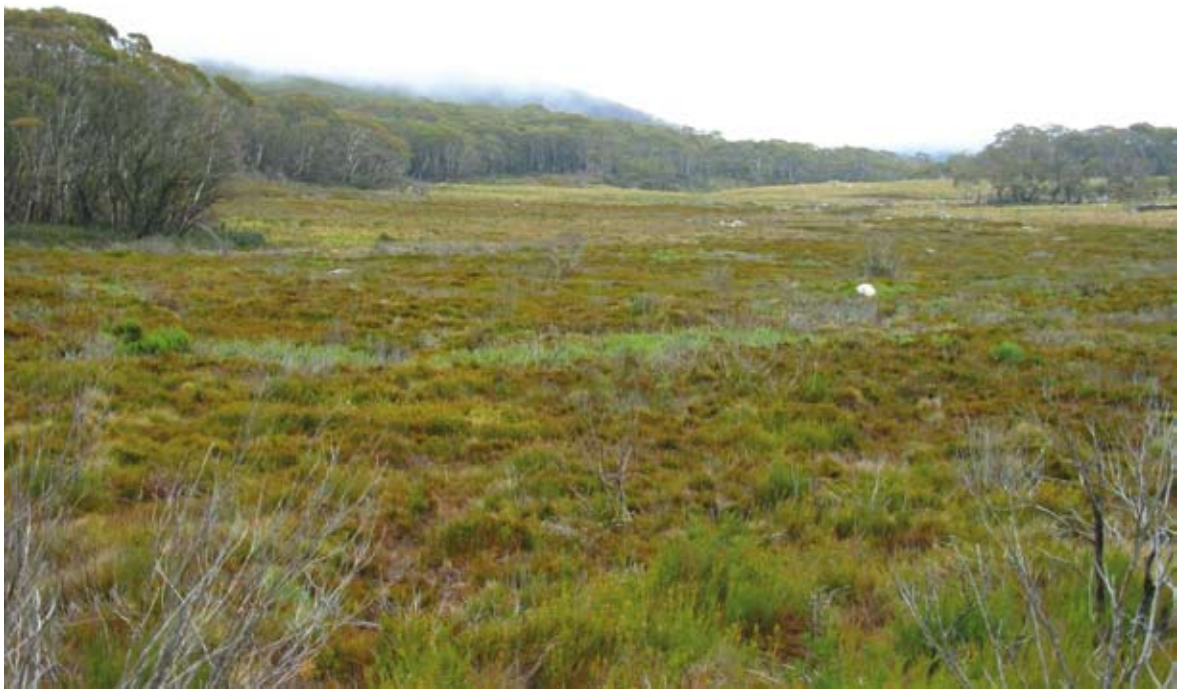
Requirements for future monitoring and reporting

This Assessment identified a number of specific requirements for monitoring and reporting of information on the distribution and abundance of invasive animals for the National M&E Framework. These requirements include the need for methods and procedures to:

- compile and aggregate relevant fine-scale datasets within a centralised database that maintains the integrity of state- and territory-based data and associated attribute fields
- formalise data access and establish exchange agreements for accessing state and territory datasets for national compilations
- address jurisdictional border discrepancies and resolve conflicting data
- develop products for review (and endorsement) by respective authorities
- verify qualitative information through ground-truthing surveys, and for reporting the level of accuracy and precision of collected data.

Increased and continued use of field-based techniques for monitoring invasive animals, as defined by monitoring technique manuals (see Mitchell and Balogh 2007) and the adoption of the national monitoring protocol (see Chapter 2), will significantly improve the quality and reliability of future national datasets. Future assessments will provide data of higher quality and allow trends in populations throughout Australia to be reported more accurately.

A commitment to providing adequate resources to monitor and report invasive animals and their impacts ensures a capacity to report fundamental information on invasive animals to address key matters for target under the National M&E Framework.



Invasive pest species can damage Matters of National Environmental Significance such as Ginini Flats Ramsar wetland, ACT (photo by Peter West)

7 Information management and a national information system

This section briefly describes the importance of national information management for invasive animals, as well as the information systems available for ongoing information management and reporting.

A number of systems have been developed, or are under development, by governments to manage information and to deliver information products to decision makers. Two existing systems that could be considered for the delivery of products and data regarding invasive animals include the Australian Natural Resources Atlas and Australia's Resources Online (ARO). The third option under consideration is the development of a national information system for invasive species. These options are briefly described below.

The Australian Natural Resources Atlas and associated Data Library

The Australian Natural Resources Atlas[23] provides information to aid decision making across all aspects of natural resource management. It covers the broad topics of water, land, agriculture, people and ecosystems. The atlas presents information nationally, by state or territory and by region, and also by information topic. Users of the atlas can prepare a map (using the Map Maker facility) or search hundreds of reports (using the Data Library facility). The atlas also provides access to various 'theme reports' (accessed through the link 'Natural resource topics' on the Atlas website). This service may provide some of the functional requirements for reporting national invasive species information to a range of decision makers within state and national governments. However, this system may not have the capacity to collect, collate, manage or update complex state-administered datasets for invasive species.

Australia's Resources Online

The ARO[24] reporting mechanism is being developed as part of the Australian Natural Resource Atlas. Where possible it will use interoperable systems. This would provide access to currently available natural resource data compiled from distributed data sources, which are managed by the respective custodians of the data. ARO will also provide information on resource condition and trend at the national, state and, where possible, regional scales, as well as links to information on project- or output-level reporting systems. ARO aims to strengthen the links between monitoring and reporting activities. This service may also perform functions required for collection of relevant information about invasive species and delivery of various products to end-users, although it may not have the capacity to address requirements stipulated by the National Monitoring and Evaluation Framework (National M&E Framework), or all the needs of state, territory and national governments for monitoring and reporting of invasive animals.

A national information system for invasive species

The third option for information management is the development of an invasive species-specific national information system, or the development of an invasive species component of an existing national information system.

This Assessment has produced the first nationally consistent dataset of significant invasive animals in Australia. The state and territory jurisdictions and regions that have contributed to the Assessment have expressed significant interest in maintaining and updating the dataset at regular intervals through further national assessments. There is a need to expand the list of species assessed to accommodate those relevant

23 http://www.anra.gov.au (Accessed 15 May 2008)

24 http://www.anra.gov.au/aro/index.html (Accessed 15 May 2008)

specifically to states and territories, as well as emerging species that may present significant problems in the future. A national information system could address these needs, as well as the requirements to monitor and report under the National M&E Framework.

This Assessment coincided with unanimous agreement by relevant authorities at national, state or territory, and regional levels of the need for a national invasive species information system.

The national coordinating committees for invasive animals and weeds — the Australian Vertebrate Pests Committee and the Australian Weeds Committee collectively recommended that:

- It is a priority to develop or adopt an information system for invasive species information management.
- A national information system will allow improved coordination and reporting on invasive animal issues and trends, which are required to implement the Australian Pest Animal Strategy.
- A detailed assessment is required regarding the suitability of existing systems (and those under development) to manage invasive species information.

Urgent need for a national information system

There are four fundamental reasons why a national invasive species information system is imperative for invasive animal management in Australia.

1. There is a critical need for consistency in the way information is collected and reported for delivery of meaningful state, territory and national products for decision makers and policy development.
2. There is an urgent need for a platform for monitoring and reporting information on invasive species matters under the National M&E Framework. Each state and territory has committed to reporting on invasive animal matters for target. A national information system could address these and many additional needs nominated by relevant authorities (eg the need for information on emerging species, areas of investment, control activities, impacts on assets, and areas of active management).
3. State, territory and national information requires validation to support decision-making. A national information system could supply a platform for inclusion of detailed survey information and better use of information from the present and future assessments.
4. Existing protocols and monitoring practices are likely to evolve over time to incorporate better techniques and procedures developed through research and operational activities. A national information system is required to manage, maintain and update invasive animals datasets to ensure that the most up-to-date information is available for decision makers and reporting.

Key issues

The key issues regarding state and territory data and information management that need to be addressed in the development of a national information system are:

- Jurisdictions presently use different information systems for monitoring and reporting on invasive pests.
- Datasets often reside within several agencies within jurisdictions, requiring data to be consolidated from several state or territory agencies.
- Consolidation of information into a central location was feasible for this Assessment; however, there are currently few mechanisms in place for generating state- and territory-wide datasets as part of normal state or territory activities.

Chapter 8 discusses the way forward for the development and adoption of a national information system for invasive animals in Australia.

8 Future directions

This section briefly describes the priorities and future directions for monitoring, evaluating and reporting of nationally significant invasive animals in Australia.

This Assessment provides, for the first time, national information on significant invasive animals in Australia and serves as a benchmark for ongoing monitoring and evaluation. It also provides information that can be used broadly as a measure of the success, or otherwise, of management policy and programs in place throughout Australia.

The indicator protocols (see Chapter 2) developed during the course of this Assessment provide guidance for state, territory and regional groups for monitoring and reporting under the National Monitoring and Evaluation Framework (National M&E Framework). Implementation of these national protocols will provide more comprehensive information on invasive animal distribution and abundance, as well as additional information on trend in invasive animal abundance and the quality of the available information about pest species. When compared with the current Assessment, future assessments will show accurate trends in pest populations and their impacts.

Species of national significance

To assess the effectiveness of management strategies and investment in invasive animal management (using distribution, abundance and impacts information) requires monitoring of a consistent list of species throughout all jurisdictions. The Australian Vertebrate Pests Committee (VPC) recommended 10 species as 'species of national significance' for monitoring and reporting activities at the state, territory and national levels under the National M&E Framework. The list was based on current state, territory and national priorities.

VPC is presently developing criteria for nominating established invasive animals of national significance, which may be used to guide ongoing monitoring and reporting activities. The proposed list is based on priorities, as well as legislation, management and policy. It is important that the species selected for monitoring and reporting represent state, territory and national priorities (as recommended by VPC and relevant Australian Government authorities).

During this Assessment, we identified a number of ways to improve the list of species recommended for monitoring and reporting under the National M&E Framework. These recommendations were:

- include emerging as well as established species in monitoring and reporting activities
- include additional pest fish species (also referred to as alien fish) in the list because pest fish present a significant threat to the environment and fishery industries
- include additional pest birds in the list because pest birds cause significant impacts on agricultural production and the environment
- ensure that the final list represents those species where the success of management can be measured and determined.

Involving stakeholders

The current Assessment engaged relevant groups from local government, regional bodies, state and territory governments, and the Australian Government to collate detailed data and information on invasive animals. Further engagement of natural resource management (NRM) regional groups is required to incorporate detailed local- and regional-level information, and to ensure an enduring system is in place to monitor and report on invasive animals in Australia. Adequate resources are required for NRM regional bodies to develop and implement invasive animal management and monitoring strategies to facilitate these tasks.

Where appropriate, additional stakeholders or groups (such as community groups and non-government organisations) were involved and may be able to provide additional information in the future on the extent and impacts of invasive animals.

Monitoring protocols

Monitoring and reporting activities under the National M&E Framework are guided by nationally agreed indicators for significant invasive animals, using accompanying monitoring protocols. The protocols are intended to form the basis for monitoring within regional areas, under the guidance of state or territory authorities. Two monitoring protocols were prepared under the guidance of VPC for the following two national indicators for significant invasive vertebrate pests.

1. Distribution and abundance of significant invasive vertebrate pests
2. Impacts of significant invasive vertebrate pests.

The protocol for distribution and abundance was endorsed by VPC and the Audit Advisory Council, and formed the basis of this Assessment (see Chapter 2 and Appendix 1).

The protocol for impacts (see Chapter 2 and Appendix 2) recommends the use of case studies to demonstrate, monitor and report invasive animal impacts, and also forms the basis of reporting for this Assessment. However, it was further recommended that the impacts protocol requires refinement for reporting meaningful information about invasive animal impacts that can reflect management and investment outcomes.

During this Assessment, we identified a number of recommendations for implementing the two monitoring protocols for invasive animals. We specifically recommend the:

- adoption of field-based monitoring technique manuals (such as Mitchell and Balogh 2007) at local and regional levels to maintain accurate information in national datasets
- validation of qualitative and anecdotal information contained in this Assessment through field-based verification surveys
- implementation of national monitoring protocols in an ongoing capacity to provide more detailed information on invasive animal populations, trends over time, and detailed impacts information required to assess the effectiveness of management and investments
- review of the reporting scale at which monitoring and reporting is undertaken, with the purpose of providing more detailed information for reporting changes in populations in response to management actions
- refinement of the indicator monitoring protocols if emerging species, alien fish species or pest bird species are included under the invasive animals indicator
- development of an impact monitoring framework to complement the existing impact monitoring protocol that can be used for monitoring and reporting the impacts of invasive animals, that can
  - facilitate ongoing and consistent monitoring of impacts information Australia-wide
  - evaluate the effectiveness of management and investment
  - prioritise management resources to where they are most needed
  - increase the effectiveness of best-practice control strategies
  - increase awareness of research requirements including innovative techniques
  - improve the knowledge and education of the impacts of invasive animals in Australia.

A trial phase to test how well the current indicators and monitoring protocols address the goals of the National M&E Framework will be important and should investigate their ability to:

- assess the status of invasive animals and their impacts in Australia
- monitor the success of management and investments using tangible means.

Roles and responsibilities

This Assessment developed and implemented consistent monitoring protocols to report national information on significant invasive vertebrate pests. To ensure an enduring process of monitoring, reporting, evaluation and program improvement, the ongoing roles and responsibilities of relevant regional, state and national authorities must be clarified. Methods for monitoring invasive animals and delivering information about their impacts to decision makers must be timely, accurate and precise.

Ongoing and reliable monitoring, reporting and information management rely on:

- agreement by relevant authorities on the fundamental information required to manage invasive vertebrate pests and their impacts
- agreement by authorities on who should be responsible for the required monitoring and reporting tasks at all levels

- agreement on data management, intellectual property and infrastructure
- institutional arrangements and data-sharing agreements
- funding and investment of ongoing monitoring and reporting activities.

A commitment is required through government NRM programs, such as the new Caring for our Country initiative, to funding of essential monitoring, evaluating, reporting, and program-improvement activities at state, territory and national levels to address the increasing problems caused by invasive animals in Australia.

Future assessments

The current Assessment should be used as one of many mechanisms to evaluate investment programs, NRM initiatives and future Caring for our Country programs. This Assessment may also be used, with appropriate supporting information, to identify priorities for future investment, control activities, management planning and research.

During the Assessment, state and territory jurisdictions and regions recommended the regular updating of information and datasets on invasive animals to maintain their usefulness to management authorities. Although ongoing monitoring and reporting activities are needed to maintain the underpinning information, a process of consolidating data into state and national formats should be developed through ongoing assessments.

Future assessments should be undertaken as recommended by the relevant national coordinating committee, being VPC. As a guide, we recommend that the next assessment should be undertaken within two to four years and that the indicators and monitoring protocols should be reviewed for their capacity to:

- assess the status of invasive animals and their impacts in Australia
- evaluate the effectiveness of management and investments over time.

It is anticipated that future assessments will build on the achievements of the current Assessment and, with the adoption of relevant monitoring protocols, will provide more detailed and increasingly valuable information on invasive animals and their impacts in Australia.

Future assessments should provide information on:

- the rate of spread at the invasion front for a number of species
- the spread of emerging species across various jurisdictions
- fluctuations in the distribution and abundance of established species
- trends in the populations of invasive animals in response to control programs.

These aspects are imperative to identify whether management actions and investments are having the desired effect on invasive animal populations and their associated impacts.

Additional information

During this Assessment, the states, territories and regions recommended that it should be a priority to maintain the invasive animal distribution and abundance datasets. A number of additional information types were identified that should be collected to determine the effectiveness of various investments and management programs, and there is a clear need to identify which authorities have the capacity to report on these matters. Specific information requirements for future assessments include:

1. **Updated information** — information is needed on the distribution, abundance and impacts of invasive animals for comparison with the current Assessment.
2. **Assets** — information on economic, social and environmental assets is required to assess whether investment is mitigating the impacts of invasive animals and to identify whether investment is targeting the best areas. Information on environmental assets can potentially be sourced from state, territory and national governments.
3. **Investment** — it is critical to determine whether allocated investment is targeting the best areas and whether it is having a positive outcome. Information on investments (including costs of control activities) could be identified from various sources, including government NRM programs (eg future Caring for our Country programs).
4. **Impacts** — information on the impacts of invasive animals and the effectiveness of control programs is critical to identifying whether investment is having the desired effect. The development of an impact-

monitoring framework is recommended to facilitate consistent reporting. Detailed information on the impacts of invasive animals can be obtained from research and monitoring programs. Reports of impacts from landholders can also be obtained from the Australian Bureau of Statistics' biennial surveys.

5. **Area of active management** — management authorities require information on management actions, control and associated activities to make informed decisions and to measure the effectiveness of investments in reducing invasive animal populations and their impacts. Active management information can be collated from the relevant authorities at all levels.
6. **Occurrence of new and emerging species** — to assess the effectiveness of management and investment on established species, information is required on their occurrence, distribution and abundance. However, for emerging species, and those still colonising new areas, occurrence information alone is sufficient as a measure of the effectiveness of management programs, strategies and investment.

A national invasive species information system

Agreement was reached during the course of this Assessment on the need for a national information system for invasive species in Australia to address future national reporting.

It is important to identify a clear strategy for the development (and adoption) of a national system for managing invasive species information, and it is equally important to identify ways to improve the collection, collation and reporting on an invasive animal's distribution, abundance and impacts information, and the communication of this information to decision makers. Any future national information system must address these needs as relevant to the states, territories and the Australian Government.

A national information system may provide a means for consolidating all state and territory data for ongoing access and use. However, a national information system for invasive animals also needs to:

- have an enduring capacity and allow for ongoing reporting requirements
- have an ability to consolidate all relevant state, territory and national datasets to report national information
- address current and future state, territory and national management and reporting needs, particularly National M&E Framework issues
- address data-access arrangements between the states and territories and the Australian Government for monitoring, evaluation and reporting activities.

The National Land & Water Resources Audit, the Australian Weeds Committee (AWC) and VPC should continue to work towards developing an information system for invasive species in Australia. The national biosecurity program — Biosecurity, Surveillance, Incident Response and Tracing (BioSIRT) — is currently under review for its suitability for ongoing monitoring and reporting of invasive species.

Appendix 1 Protocol for monitoring distribution and abundance

Monitoring Protocol — Distribution and abundance (*abbreviated version*)

Matter for target
Ecologically significant invasive species

Indicator heading
Extent and impact of selected ecologically significant vertebrate invasive species

Indicator
Distribution and abundance of significant invasive vertebrate pests

This protocol presents the recommended monitoring method for collecting, collating and reporting information on the distribution and abundance of significant invasive vertebrate pests at national, state or territory and regional levels. It is to be used in conjunction with the indicator protocol for *Impacts of Significant Invasive Vertebrate Pests*.

Methodology

Monitoring should be undertaken using the techniques appropriate for local-scale monitoring and developed into state-scale datasets using the following procedure. It should be applied to develop data at a minimum scale of 0.5-degree reporting units (equivalent to 1:100 000). Monitoring should be coordinated annually for new incursions of species (at a resolution of at least 1:25 000), two to three years for emergent species, and four to five years for established species. Data-aggregation procedures are needed to convert state data for national reporting. A series of national, state or territory and regional distribution and abundance maps will be produced from the data to reveal trends throughout Australia.

This methodology has been modified from the Queensland Government Department of Natural Resources and Water Annual Pest Distribution Survey, and New South Wales Department of Primary Industries state-wide survey methodology.

Step 1 Species occurrence

This criterion has the highest level of accuracy.

The occurrence of a pest should be recorded as:

- *present* — species exists in the defined area
- *absent* — species does not exist in the defined area
- *unknown* — it is not known (or participants are unsure) whether the species exists.

Step 2 Distribution — spatial pattern

When the presence is confirmed, the distribution of the species (incursion or spread of a species) within the defined area can to be recorded as:

- *localised* — species occurs in a clumped pattern and occupies less than 50% of a cell
- *widespread* — species occurs in most areas and occupies greater than 50% of a cell.

Distribution provides a useful indication of the size of infestations; however, its accuracy is influenced by the survey participant's varying perception of populations and the difficulty of assessing large areas of land. This criterion has a lower level of accuracy than 'occurrence'.

Step 3 Abundance — relative numbers

Abundance refers to the relative density of a species within an area and can be described as:

- *occasional or low* — animals spaced at wide intervals, or few or no sightings and/or little active evidence (eg very infrequent observations or little evidence of animals and tracks, scats and other traces)

- *common or medium* — a middle measure between occasional and abundant, or some animals seen at almost any time and/or much sign of activity (eg frequent observations or some evidence of animals and tracks, scats and other traces)
- *abundant or high* — infestations that have reached their full potential and provide little opportunity for additional animals to survive in that area, or many animals seen at any time and much sign of activity (eg very frequent observations or much evidence of animals and tracks, scats and other traces).

Abundance is particularly difficult to estimate because the participant's perception of abundance levels can vary with species; species detection varies between habitat types; and some habitats support higher concentrations of species, depending on environmental conditions.

Step 4 Trend

Trend refers to the change in animal abundance over time using anecdotal information where trends cannot be obtained and is recorded as:

- *increasing* — populations have increased in abundance over the previous five years
- *stable* — populations have remained stable in abundance over the previous five years
- *decreasing* — populations have decreased in abundance over the previous five years
- *unknown* — no information available.

Trend is particularly useful for measuring a change in populations over time, but this criterion only has a moderate level of accuracy.

Step 5 Data quality

Data quality and reliability should be reported using the following classification:

- *no data* — no information about data quality
- *low* — anecdotal information from ad hoc sources and incidental reports; no reliable expert knowledge or survey data; equates to 'low level' or 'anecdotal'
- *medium* — expert opinion from local specialists providing general knowledge based on observations and other sources, such as control activities; equates to 'little data'
- *high* — scientific data from recognised field-sampling protocols, field surveys, systematic sampling or formal assessment; equates to 'some data and expert opinion'.

Data quality is particularly useful for verifying the accuracy of information for interpretation and analysis.

Appendix 2 Protocol for monitoring impacts

Monitoring Protocol — Impacts (*abbreviated version*)

Matter for target
Ecologically significant invasive species

Indicator heading
Extent and impact of selected ecologically significant vertebrate invasive species

Indicator
Impacts of significant invasive vertebrate pests

This document presents the recommended monitoring protocol for collecting, collating and reporting information on the impacts of significant invasive vertebrate pests at the national, state or territory and regional levels. This protocol is to be used in conjunction with the indicator protocol for *Distribution and Abundance of Significant Invasive Vertebrate Pests*.

'Impacts' are any detrimental consequence of invasive animals on environmental, economic and social values, assets and services in a defined area. Information on impacts is required to assess the effectiveness of management strategies and control programs.

This indicator protocol recommends collecting accurate and detailed information on the impacts (social, environmental and/or economic) of pest species at selected areas to present valuable information for decision makers at all levels. Where broad-scale information on the impacts of invasive animals is not easily obtainable or is cost prohibitive, monitoring should be undertaken at selected areas and reported through case studies to supply information on pest impacts. Reporting should be undertaken from a series of studies using comparable techniques across species, impact types and regions. A series of techniques for monitoring the impacts of invasive animals can be found in Mitchell and Balogh (2007).

Guidelines for invasive animal impact case studies

1. **Project summary** — includes project name, definition of the problem, pest species, pest abundance, location, management program, lead agency or agencies, project duration, monitoring variables, and a site description.
2. **Monitoring methods** — includes a description of the monitoring objectives and variables measured (eg measurements of impact); a description of survey techniques; a statement about sampling and experimental design (sample size; frequency; replicates; transects and design); control activities associated with monitoring; and any data calculations and analysis performed to deduce results.
3. **Results** — includes a summary of the results of the monitoring regarding the impacts of invasive animals on economic, social and/or environmental assets (including figures, tables and images as necessary). This section should address the main impacts identified; the level of impact (quantitative or qualitative damage such as loss of production, species/habitats/ecosystem services affected, social costs, and any relevant information); a description of the impacts relative to animal density; and a description of potential impacts.
4. **Outcomes** — describes the outcomes in regard to management, trends regarding previous monitoring, and implications for industries and environments. A link should be provided to relevant publications, reports, websites and other studies.

Appendix 3 Summary of pest species data

	NSW	Qld	ACT	Vic	Tas	SA	NT	WA
Feral pigs	NSW Pest Animal Survey 2004–2006; expert knowledge	APDS 2006; expert knowledge	NSW Pest Animal Survey 2004–2006; expert knowledge	Atlas; State of Parks reports; expert knowledge	NVA; wildlife surveys; regional workshops; expert knowledge	Regional animal control boards; expert knowledge; previous survey maps	NT aerial surveys; expert knowledge	Pest Animal Survey; regional workshops; expert knowledge
Feral goats	NSW Pest Animal Survey 2004–2006; expert knowledge	APDS 2006; expert knowledge	NSW Pest Animal Survey 2004–2006; expert knowledge	Atlas; State of Parks reports; expert knowledge	NVA, wildlife surveys; regional workshops; expert knowledge	Regional animal control boards; expert knowledge; previous survey maps	NT aerial surveys; expert knowledge	Pest Animal Survey; regional workshops; expert knowledge
Feral deer	NSW Pest Animal Survey 2004-2006; expert knowledge	APDS 2006; expert knowledge	NSW Pest Animal Survey 2004–2006; expert knowledge	Atlas; State of Parks reports; expert knowledge	Aerial and spotlight surveys; regional workshops; expert knowledge	Regional animal control boards; expert knowledge; previous survey maps	na	Pest Animal Survey; regional workshops; expert knowledge
Rabbits	NSW Pest Animal Survey 2004–2006; expert knowledge	APDS 2006; expert knowledge	NSW Pest Animal Survey 2004–2006	Atlas; IPMS; State of Parks reports; expert knowledge; control records	NVA; annual spotlight surveys; regional workshops; expert knowledge	Regional animal control boards; expert knowledge; previous survey maps	Expert knowledge	Pest Animal Survey; regional workshops; expert knowledge
Feral cats	NSW Pest Animal Survey 2004–2006; expert knowledge	APDS 2006; expert knowledge	NSW Pest Animal Survey 2004–2006; expert knowledge	Atlas; State of Parks reports; expert knowledge	NVA; annual spotlight surveys; regional workshops; expert knowledge	Regional animal control boards; expert knowledge; previous survey maps	Expert knowledge	Expert knowledge
Wild dogs	NSW Pest Animal Survey 2004–2006; expert knowledge	APDS 2006; expert knowledge	NSW Pest Animal Survey 2004-2006; expert knowledge	Atlas; PAIS; State of Parks reports; expert knowledge	NVA; regional workshops; expert knowledge	Regional animal control boards; expert knowledge; previous survey maps	Expert knowledge	Pest Animal Survey; regional workshops; expert knowledge

	NSW	Qld	ACT	Vic	Tas	SA	NT	WA
Foxes	NSW Pest Animal Survey 2004–2006; expert knowledge	APDS 2006; expert knowledge	NSW Pest Animal Survey 2004-2006; expert knowledge	Atlas; IPMS; State of Parks reports; expert knowledge; control records	Fox database; expert knowledge.	Regional animal control boards; expert knowledge; previous survey maps	Expert knowledge	Pest Animal Survey; regional workshops; expert knowledge
Cane toads	NSW Pest Animal Survey 2004–2006; NSW DECC survey; Frog Rescue Service; expert knowledge	Qld cane toad database	na	na	na	na	Cane toad database; expert knowledge	na
Common starlings	NSW Pest Animal Survey 2004–2006; Birds Australia surveys/ database	Birds Australia surveys/ database	NSW Pest Animal Survey 2004–2006; Birds Australia surveys/ database	Atlas; State of Parks reports; expert knowledge	NVA; regional workshops; expert knowledge	Birds Australia surveys; expert knowledge; SA Ornith-ologists Association	Birds Australia surveys; expert knowledge	Field surveys; expert knowledge
Common carp	NSW Pest Animal Survey 2004–2006; NSW DPI database; expert knowledge	Fisheries database	NSW Pest Animal Survey 2004-2006; NSW DPI database; expert knowledge	Atlas; State of Parks reports; expert knowledge; Fisheries data	Inland Fisheries Service database; expert knowledge	SARDI database; expert knowledge	na	Department of Fisheries database

NSW = New South Wales; Qld = Queensland; ACT = Australian Capital Territory; Vic = Victoria; Tas = Tasmania; SA = South Australia; NT = Northern Territory; WA = Western Australia

APDS = Annual Pest Distribution Survey; Atlas = Atlas of Victorian Wildlife Records; DECC = Department of Environment and Climate Change; DPI = Department of Primary Industries; IPMS = Integrated Pest Management System; na = not applicable; NVA = Natural Values Atlas; PAIS = Pest Animal Information System; SARDI = South Australian Research and Development Institute

Appendix 4 National guidelines for data aggregation

National guidelines for data aggregation (*abbreviated version*)

Introduction

The development of national datasets for mapping the extent, abundance and distribution of invasive species using a 0.5-degree tile (standard 1:100 000 map sheets) has been endorsed by the Australian Weeds Committee and the Australian Vertebrate Pests Committee. This supports the National Land & Water Resources Audit's role to coordinate the collation of data against resource-condition indicators and develop nationally linked information systems.

A number of jurisdictions produce invasive-species data that are stored as point, line, polygon and raster data at various scales (eg 0.125 degrees or 1:25 000 and 0.5 degrees or 1:50 000) as part of routine monitoring and reporting activities. Thus, these data need to be aggregated or generalised for national reporting based on 1:100 000 map sheets while maintaining their thematic characteristics and integrity. To ensure consistency, national guidelines have been developed to outline rules for the aggregation of tiled data.

This paper identifies the agreed rules used to aggregate invasive species data for national reporting. Although there is no perfect solution to data aggregation, these rules are considered to be workable.

Definitions

Occurrence relates to the 'presence' status of a particular species within an area — whether it is present, absent or unknown (ie no data available or the area has not been assessed). When additional information is available, the 'presence' class of occurrence can be described further in terms of distribution and abundance (see below). For example, occurrence information based on presence or absence is used to determine the extent of a weed in a tiled reporting framework.

Distribution relates to the spatial pattern or dispersion of species over an area (eg widespread or localised, unknown or nil within a given area).

Abundance relates to the number of individuals of a species. In a quantitative situation it might be a count (eg 100) or range (eg 100–150), whereas in a subjective situation, it might be high, medium or low.

Density is a measure of abundance per unit area. In a quantitative situation, it might be 100 per square kilometre or 100–150 per square kilometre. However, in a subjective situation, and for the purposes of reporting state or territory and national data in map format, it could be represented as a combination of abundance and distribution (eg abundant and widespread, or occasional and localised).

Trend is defined as the change in occurrence, distribution, abundance or data quality over time. Trend is classified as increasing, stable, decreasing or unknown.

Data aggregation rules

Aggregation rules have been generated for:

- **Occurrence** — present, absent or unknown
- **Distribution** — localised, widespread, unknown or nil
- **Abundance** — occasional, common, abundant, unknown or nil
- **Data quality** — high, medium, low or unknown
- **Trend** — increasing, stable, decreasing or unknown.

Assumptions

Point, line, polygon or raster data are compiled in a fine map sheet grid (eg 1:25 000 or 1:50 000) that then requires aggregation for reporting at 1:100 000. Data will be aggregated directly from the finest input grid directly to the 1:100 000 grid and not through a stepped process such as 1:25 000 through 1:50 000 through to 1:100 000.

Occurrence (present, absent or unknown)

- Present — species occurs in the tile
- Absent — species does not occur in the tile
- Unknown — status is unknown.

Source data	Aggregated value
Present for **any** tile	Present
Absent for **all** tiles	Absent
Any combination of absent/unknown	Unknown

Distribution (localised, widespread, unknown or nil)

Distribution within the aggregated tile is based on Occurrence records of source tiles:

- Localised — individuals are located within less than half the area
- Widespread — individuals are dispersed over more than half the area
- Unknown — distribution is not known
- Nil — species does not occur.

Aggregation rules for distribution need to be undertaken in numerical order.

Distribution number 1 (Dbn1) — more than 25% of source tiles are Occurrence: Unknown and aggregated tile is Distribution: Unknown

Dbn2 — if all of the known remaining tiles are Occurrence: Absent, the aggregated tile is Distribution: Nil

If rules Dbn1 or Dbn2 are not met, then the following rules apply if there is at least one Occurrence: Present recorded (Present comes from Occurrence data).

Dbn3 — if less than 25% of source tiles are Occurrence: Present, the aggregated tile is Distribution: Localised

Dbn4 — if greater than or equal to 25% of source tiles are Occurrence: Present, then

(a) if the greatest distance between Occurrence: Present in both x and y directions is greater than 50% of the total distance of x and the total distance of y, then the aggregated tile is Distribution: Widespread

(b) if the greatest distance between Occurrence: Present in either the x or y direction is less than or equal to 50% of the total distance of x or y, then the aggregated tile is Distribution: Localised.

Data quality aggregation

Data quality classes are based on the National Land & Water Resources Audit report classes:

- **3** — based on reliable data
- **2** — little measured data
- **1** — derived without investigation through expert opinion
- **0** — no data available.

Data quality is aggregated by calculating the average of the source tiles. If the average is less than a source data class, it is assigned to the lower class.

Trend aggregation

- Increasing — an increasing number of individuals
- Stable — the number of individuals remains steady
- Decreasing — a declining number of individuals
- Unknown — the trend is not known.

Trend is aggregated by calculating the average of the source tiles, where increasing = 3, stable = 2 and decreasing = 1. Where the average calculation is between two trend categories, it can be assigned to the higher class. Note that this will result in an overestimate.

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Glossary

Abundance
A measure (in numbers or relative value) of density in a defined area.

Acclimatisation societies
Societies created in order to enrich the fauna of a region with animals and plants from around the world.

Alien species
Belonging to a foreign country; animals that have been intentionally or accidentally introduced as a result of human activities.

Biocontrol
Control of pests by disrupting their ecological status through the use of organisms that are natural predators, parasites or pathogens.

Biodiversity
Variability among living organisms from all sources (including terrestrial, marine, and other ecosystems and ecological complexes of which they are part), which includes diversity with species and between species and diversity of ecosystems (Beeton et al 2006).

Caring for our Country
Australian Government natural resource management initiative, commencing July 2008.

Critically endangered
As defined in and listed under the EPBC Act, a native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.

Distribution
A measure of spatial pattern or dispersion throughout a defined area.

Ecological community
An assemblage of species occupying a particular area.

Emerging species
Any newly established vertebrate species whose distribution, abundance and impacts are likely to be significant.

Endangered species
As defined in and listed under the EPBC Act, a native species is eligible to be included in the endangered category at a particular time if, at the time, (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.

Eradication
Application of measures to eliminate a species from a defined area.

Established population
A population that is self-sustaining through reproduction or immigration and has survived in a location for a period of time.

Exclosure
Area fenced to keep unwanted animals out.

Exotic species
A species that originates from a foreign country; an imported species that only occurs in captivity.

Feral species
Species of an introduced animal with an established self-sustaining population in the wild.

Hybrid
A crossbreeding between related species or subspecies.

Impact of pest species
An adverse consequence of a pest species, often classed as social, environmental, or economic.

Introduced species
A non-native species that was intentionally or unintentionally brought into an area by humans.

Invasive species
A species occurring as a result of human activities beyond its acceptable normal distribution and which threatens valuable environmental, agricultural and personal resources by the damage it causes (Beeton et al 2006).

Key threatening process
A process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.

Matters of national environmental significance
Matters of national environmental significance include internationally important wetlands, nationally listed threatened species and ecological communities, listed migratory species, the Commonwealth marine environment, world heritage properties, national heritage places, and protection of the environment from the impact of nuclear actions.

Occurrence
Presence of a species within a defined area.

Pest animal or species
Any native, or introduced, wild or feral non-native species of animal that is currently troublesome locally, or over a wide area, to one or more persons, either by being a health hazard, a general nuisance, or by destroying food, fibre, or natural resources (Koehler 1964).

Regions, bioregions and subregions
There are 56 regions to facilitate the integrated delivery of natural resource management priority issues. The Interim Biogeographic Regionalisation for Australia also defines 85 bioregions and 404 subregions for assessing the status of native ecosystems, use in monitoring and evaluation, and assessing current natural resource management initiatives.

Threat abatement plan
Plan providing for the research, management and any other actions necessary to reduce the impact of a listed 'key threatening process' on a threatened species or ecological community.

Threatened species
A species listed under the EPBC Act as critically endangered; endangered; vulnerable; or conservation dependent.

Vulnerable
As defined in and listed under the EPBC Act, a native species is eligible to be included in the vulnerable category at a particular time if, at that time (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.

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