Counting the Cost: Impact of Invasive Animals in Australia, 2004

Pest Animal Control CRC

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Editor – Andrew Norris

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Pest Animal Control CRC

CRC AUSTRALIA

FOREWORD

Every Australian knows that invasive animals cause economic and environmental problems. We are taught at school that rabbits were "the grey blanket" over the country after the second world war and that one of the great achievements of the CSIRO was to deliver an (almost) knockout blow to the pest. Indeed myxomatosis may well be the best known animal disease amongst Australians.

In my role leading the Pest Animal Control Cooperative Research Centre, I often refer to the three "C's" meaning cats, cane toads and carp. The mere mention of these seem to ignite strong passion in many people, making me believe that the social impact of invasive animals has received little attention. When I take someone into our Centre's animal house, I can tell immediately if they've lived through a mouse plague by the shudder that the smell brings on. Wool producers tell heart wrenching stories about dog and fox attacks.

But while most people acknowledge the impact of invasive animals, to date we've had relatively little information on the overall impact on our economy, our environment and our society. This report, *Counting the Cost: Impact of invasive animals in Australia 2004,* is intended to give us a starting point for documenting the impact of invasive animals and its results are quite staggering: at least a $700 million annual impact on Australia.

It is important to point out several things about the report:

1. ***It is not exhaustive***. Dr. McLeod was commissioned only to bring together existing information and compile it in a consistent manner;
2. ***It is conservative.*** An important term of reference to Dr. McLeod was that he must use the lowest figure whenever a range estimate was provided in a cited report. We believe it is important to look at the impact of invasive animals, but not overstate or exaggerate the problem; and
3. ***It is transparent.*** All methodology is included in the report to enable others to build on it or too argue whether an impact is under or overstated.

The report therefore provides us with a springboard for looking at investments into invasive animal management. It does not stand alone, but adds substantially to our ability to prioritise research, control and prevention strategies and to explain to the Australian public the ongoing impact of invasive animals. This report is also useful in identifying knowledge gaps in the ability to quantify invasive animal damage, most markedly in the areas of counting the environmental and social costs.

Finally, I would like to thank the large number of people that have made comments on the report during its development. We have had the report extensively examined prior to publication and are grateful to those that provided additional papers, unpublished data and comments from the general to the specific.

Dr. Tony Peacock

CEO, Pest Animal Control CRC

eSYS DEVELOPMENT (www.esys.com.au) AND DR ROSS MCLEOD

The consulting firm eSYS Development Pty Limited was commissioned by the Pest Animal CRC to supply Dr Ross McLeod (rmcleod@esys.com.au) as the pest impact costing specialist. Dr McLeod is a project economist and financial analyst with 10 years experience designing, costing, implementing, evaluating and reviewing environmental, health and agricultural projects throughout 15 countries in Africa and Asia, and also Australia. With a Doctorate of Philosophy, his focus is on the union of science and economics. Today this is primarily associated with strategic and business planning, along with facilitating public-private partnership development to maximise the returns from publicly financed science and infrastructure development.

He has been responsible for the management of, and has participated in, numerous projects. Examples of which include, assessing the economic and ecological impact of selected environmental project design options on World Heritage – Great Barrier Reef hard coral communities, development of business plans for the commercialisation of animal health vaccines in southern and eastern Africa, feasibility of an environmental trust fund for Lake Victoria, Kenya to promote sustainable resource use, financial assessment of program development options for the Expanded Program of Child Immunisation in Pakistan and economic appraisal of product development opportunities for the Australian wine industry.

He is fully conversant with the techniques required to economically assess biologically-related projects and currently evaluates approximately 200+ projects per year for organisations such as Australian Wool Innovation, Grape and Wine R&D Corporation, Australian Pork Limited, Fisheries R&D Corporation, Forest and Wood Products R&D Corporation, Sugar R&D Corporation, Bureau of Sugar Experiment Stations, Australian Centre for International Agricultural Research and numerous CRCs.

In the field of pest and disease cost impact assessment he has undertaken and published several analyses. Examples include, the economic impact of parasites on the Australian sheep industry (International Journal for Parasitology), the economic impact of weeds, pests and diseases on the Australian sugar industry (Plant Protection Quarterly), and the economic impact of tick-borne diseases in cattle of Africa, Asia and Australia (Proceedings of The Association of Institutions for Tropical Veterinary Medicine).

EXECUTIVE SUMMARY

The economic, environmental and social impact of 11 major introduced vertebrate pests of Australian agricultural industries and the environment, are estimated in this desk-top review. This provides a ‘triple bottom line’ national perspective on vertebrate pest animal impact. Pests were selected on the basis of relevance to current and potential Pest Animal Control CRC research activities, and in consultation with centre staff. Annual cost values include control and production loss estimates. Many gaps exist in our knowledge of the major environmental and social impacts vertebrate pests have, therefore these impacts are discussed for each pest in qualitative terms. However, where quantitative impact information is readily available it is also included.

Table 1: Annual Impact of Pest Species (order of cost)

		Triple Bottom Line Impact					
	Total	**Economic**		**Environmental**		**Social**	
	$m	Impact	$m	Impact	$m	Impact	$m
Fox	227.5	◆	37.5	◆	190.0	♦	nq
Feral Cats	146.0	♦	2.0	◆	144.0	♦	nq
Rabbit	113.1	◆	113.1	♦	nq	♦	nq
Feral Pigs	106.5	◆	106.5	♦	nq	♦	nq
Dogs	66.3	◆	66.3	♦	nq	♦	nq
Mouse	35.6	◆	35.6	♦	nq	◆	nq
Carp	15.8	♦	4.0	◆	11.8	♦	nq
Feral Goats	7.7	♦	7.7	♦	nq	♦	nq
Cane Toads	0.5	♦	0.5	♦	nq	♦	nq
Wild Horses	0.5	♦	0.5	♦	nq	♦	nq
Camels	0.2	♦	0.2	♦	nq	♦	nq
Total	**719.7**		**373.9**		**345.8**		

nq = not quantified ◆ = bigger impact ♦ = smaller impact

Major control costs included in the economic impact assessment included baiting, fencing, shooting, and research associated with the improved management of the specific species. Production losses were estimated for sheep, cattle and cropping industries as a result of predation on young stock, crop damage and competition for feed. In addition to these agricultural losses, public sector research and management costs were included in the economic cost section.

Environmental impacts were typically based on the vertebrate pest’s impact on biodiversity. Where possible, these impacts have been quantified in cost terms, although it should be noted that accurate information relating to ecological cause and effect relationships, along with the communities’ valuation of species preservation are not readily available. Environmental valuations were undertaken for feral cat, fox and carp impacts, as data was in evidence for these species.

The cost impact of the 11 species subject to assessment totalled $720 million per year. Feral pigs, rabbits, foxes and feral cats were estimated to account for 83% of losses and agricultural productivity loss accounts for about half of total costs estimated.

Identified issues and recommendations

The main purpose of the consultancy was to estimate the social, economic and environmental impacts of major vertebrate pests. This is the first time 'triple bottom line' reporting, suggested in reports such as the Global Reporting Initiative's *Sustainability Reporting Guidelines* and Environment Australia's *Triple Bottom Line Reporting in Australia*, has been used to assess pest impact. In addition to summarizing the triple bottom line results, some points for future research have been outlined.

- Economic costs associated with competition by pests with sheep and cattle were the most straight forward impacts to derive, due to a large range of grazing experiments and previously conducted impact assessments. Economic impacts derived in this study are well below those previously calculated – largely due to contraction in the size of the national sheep flock and in the case of rabbits, the release of rabbit calicivirus (RHDV), which has decreased rabbit population pressures in many areas.
- Rabbits, foxes, feral pigs and feral cats were shown to inflict the greatest cost impact on the Australian economy. In the case of rabbits and pigs, the major component of the impact comes from reduced agricultural production, principally in the sheep and cattle industries. Given the heavy impact these pests impose on these industries, collaborative research projects should be sought with sheep and cattle producers, as they would be the major beneficiaries of such research.
- Feral cats and foxes were estimated to inflict large costs associated with predation of native fauna. In the absence of specific data specifying the Australian community's valuation of this impact, 'per bird killed' cost estimates were assumed for the analysis reported in Pimentel *et al*. (2000) and using analyses taken from the NSW EPA database. Given the large impact of this assumption, it is essential that survey work be conducted in Australia to determine community attitudes to the impact of fox and cat predation so more accurate of definition of loss can be determined.
- Social impacts were the most difficult impacts to estimate. The Global Reporting Initiative guidelines suggest that social performance measurement enjoys less consensus than environmental performance. Within this report, pest impacts on employment, health and indigenous peoples ways of life are documented in relevant sections. Only the costs of vehicle accidents associated with kangaroos are quantified, while the commercial use value of differing species are outlined.
- Although not regarded as a pest to the general Australia community, kangaroos inflict significant costs on grazing industries through pasture competition and damage of fences. These costs are substantial and comparable with other vertebrate species that inflict large losses within grazing industries. Given this large impact, along with traffic crash costs and substantial tourist and commercial resource value of kangaroos, it is desirable that the issue of population density management be assessed further and management tools devised to minimise costs and maximise the benefit of this national symbol.
- Despite inflicting a major impact, research into managing all of these pest species may not necessarily deliver the greatest benefit. Research projects need to be assessed in terms of their ability to reduce the overall cost of a pest species, along with risks of the investment generating an outcome. Benefit-cost analysis could be used to derive estimates of each projects expected economic pay off – as measured by a project's net present value (the difference between project benefits and costs) and benefit-cost ratio (the ratio of all project benefits to all project costs).

Dr Ross McLeod
eSYS Development

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OVERVIEW

- Economic, social and environmental impacts of 11 major vertebrate pest species are outlined in the report
- Cost impact is estimated on the basis of pest distribution, value of agricultural production and, where possible, social impact and biodiversity
- Research priorities for vertebrate pest management in Australia conclude the report

Background

Following the terms of reference from the Pest Animal Control Cooperative Research Centre (PAC CRC), this report has the following objectives:

- Review existing impacts of pest animals on Australia's environment, economy and society,
- Describe the possible impact of a new pest animal introduction; and
- Prioritise the 'top five' areas where R&D could make a difference to the 'triple bottom line'

As part of the consultancy, the analyst liaised with key organisations to determine impacts, identify key literature and set priorities for 11 major pest animal species being Fox, Pigs, Rabbit, Mice, Goats, Carp, Dogs, Cane Toad, Camels, Feral Cats and Wild Horses. In addition to these pest species, the Kangaroo has agricultural, environmental and social impacts that are both positive and negative. These impacts are explored in the last of the individual species chapters.

Triple Bottom Line Reporting

In addition to the reporting of financial and economic performance, there is demand for organisations to demonstrate accountability in the domains of social and environmental impact. The concept of 'triple bottom line' has emerged to encapsulate this form of reporting and incorporates the three elements of social, environmental and economic accountability. Key features of each of these elements are summarised below.

- Economic performance includes fiscal performance, relating to demand for products and services, community contributions and local procurement policies.
- Environmental performance includes impacts on air, water, land, natural resources, flora, and fauna made through processes, products or services.
- Social performance includes involvement in shaping local, national and international public policy, equality, treatment of minorities, employee issues and public concern.

Each of these elements of triple bottom line reporting are outlined throughout this report in relation to the impact of vertebrate pests in Australia. Individual chapters are presented for each species. A concluding chapter is included in the report, which presents the potential impacts of a new pest introduction, along with research priorities and future research requirements for existing vertebrate pest species.

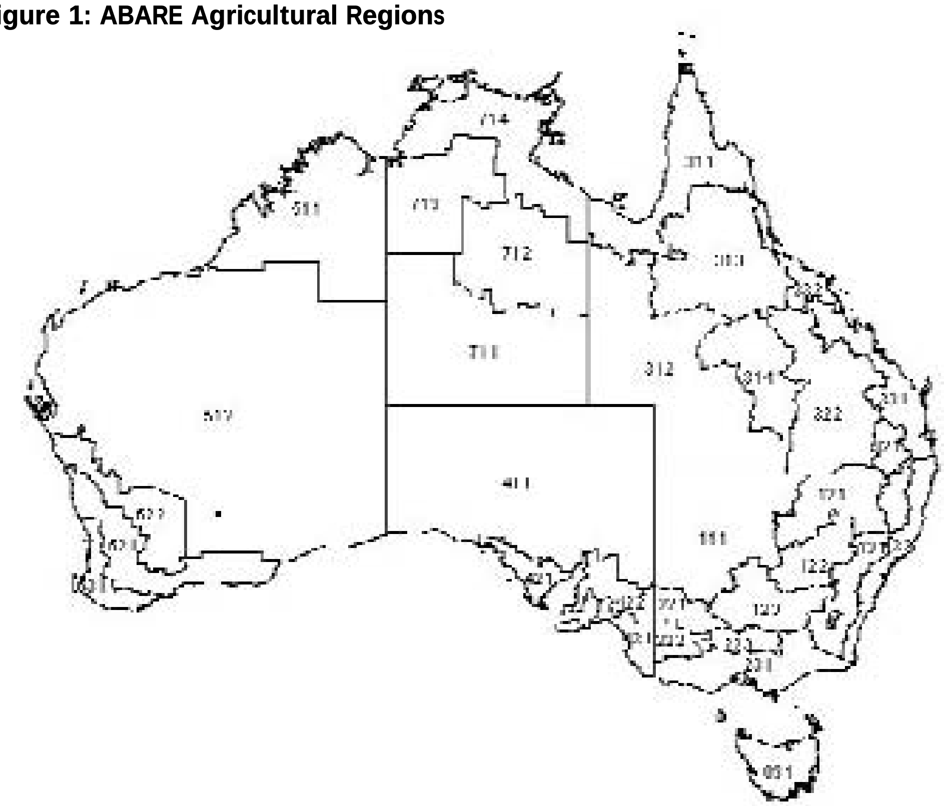
Economic Impact

Economic impact in the context of this report refers to the economic value of reduced agricultural productivity associated with each pest species. In order to estimate this impact the distribution of the pest is estimated, the value of agricultural production within the range of the pest identified and an assessment of the reduced value of production as result of the pest is calculated. Any research or management costs associated with the pest are also estimated. Each of these elements of the economic impact estimation procedure is provided in the following section.

Pest Distribution

Vertebrate pests vary in their abundance according to climatic conditions and the types of agro-production systems that prevail in different parts of Australia. The distributions of major pests are outlined in the literature and in Bureau of Rural Sciences distribution maps. This information is summarized for each pest and included towards the beginning of each chapter.

Figure 1: ABARE Agricultural Regions

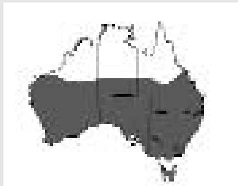


Box 1: Method for valuing pest economic impact

Pest Distribution

- Include data about densities of vertebrate species by ABARE region
- Bureau of Rural Sciences data and distribution maps utilised
- Scientific literature summarised in relation to distribution and potential for impact

Agricultural Production



- Include data about livestock numbers and areas cropped by ABARE region
- Gross margin data summarised for differing states and averages derived for Australia across sheep, cattle and broad acre industries

Valuation of Impact

- Pest distributions are superimposed over values of agricultural production in each region
- Estimates of reduced carrying capacities, yield losses and pest management costs
- Aggregate pest-related costs are calculated for each species
- Biodiversity impacts valued where possible
- Total cost (control and losses)

Agricultural Production

Agricultural production is most intensive in the higher rainfall, irrigated and more fertile parts of Australia. The numbers of sheep, cattle and cropped areas in each region provide a baseline from which to calculate cost impacts of pests. ABARE was sub-contracted to provide farm level data based on ABS and ABARE farm survey classification of agricultural production areas in Australia. These data sets are provided in the Appendix on a state by state and regional basis. The nature of regional breakdown used by ABARE is outlined in Figure 1. It is evident that the numbers of regions are greatest for NSW and Queensland, and there are fewer numbers of regions in arid areas of the continent. A number of pests, which include camels, rabbits and kangaroos, are more widespread in semi-arid and arid areas.

Representative gross margins for major sheep, cattle and broad acre production systems are also summarized in the Appendix. These budgets provide a basis from which to estimate the economic cost inflicted by vertebrate species, which reduce carrying capacity, and crop yields. Budgets are sourced from various state departments of agriculture and average enterprise profitabilities are estimated.

Valuation of Economic Impact

Regional pest abundance was superimposed over agricultural production in each region and economic losses calculated. Following Sloane *et al* (1988) analysis of vertebrate pest impact on the wool industry, pest abundance was defined in terms of spread within the specified region and also the estimated reduction in carrying capacity within affected areas. For the most part, production losses were estimated to be most severe in semi-arid areas where pests such as rabbits and kangaroos are likely to impose greater competitive pressure on grazing livestock. Within each chapter, losses are provided on a regional basis. Additionally, public sector research and management costs, along with private landholder control costs are also estimated and provided. Regional costs are aggregated to a national basis.

Environmental Impact

A range of environmental indicators has been highlighted for incorporation in triple bottom line reporting frameworks. Some of the key indicators outlined in Global Reporting Initiative (2002) and Environment Australia (2003) include description of major impacts on energy consumption, water quality, emissions, ozone depletion, land degradation and biodiversity in terrestrial, freshwater and marine environments. Vertebrate pests can cause land degradation, reduce water quality and decrease biodiversity.

Foxes and feral cats have had, and continue to have, an important impact on biodiversity. Correspondingly, the species listed under the *Environment Protection and Biodiversity Conservation Act 1999* for which vertebrate pests are a known or perceived threat, are outlined within each individual chapter of this impact assessment. Environment Australia (2003) noted that biodiversity within Australia provides a substantial contribution to the national economy, estimated to be in the vicinity of US$ 245 billion for terrestrial ecosystems and $US 640 billion for marine ecosystems. Given the substantial value of biodiversity, and consequent large potential cost threats vertebrate pests pose, environmental cost impacts have been quantified using environmental valuation techniques.

The community may gain value from biodiversity by being able to see birds of interest or catch desirable fish when using parks and waterways. Conversely, the absence of these species as a result of vertebrate pest predation imposes costs on the community as the amenity value of ecosystems is degraded. Biodiversity in these cases provides amenity value. The mere knowledge of species existing may also be of utility to people. This non-use value is commonly referred to as ‘existence value’. Survey-based techniques such as ‘contingent valuation’ are typically used to determine how much people value these use and non-use values. Within surveys respondents are provided with scenarios and asked to state their willingness to pay (WTP) (or less commonly their willingness to accept compensation) in dollars for a change in environmental conditions (See Jakobsson and Dragun, 1996 for discussion of methods).

Results from a range of surveys where people were asked to value ‘willingness to pay’ for ecosystems or for certain fauna species to be protected are presented in the following table – primarily using data from the ENVALUE database. These values are compared with valuation of vertebrate pest impacts. While there are limitations in transferring the results of a range of studies to derive a precise dollar value for impacts, it provides an indication of the likely magnitude of environmental values.

Table 2: Summary of Biodiversity Valuation Studies (Terrestrial)

Study	Comments
Loomis and White (1996) – rare and endangered species in the USA	Each household willing to pay $A 25.19 lump sum to protect species. Total willingness to pay across all Australian households[a] = $A 181 m per year
Hampicke *et al.* (1991) in Jakobsson and Dragun (1996), preserving endangered species in West Germany	Each household willing to pay $A 162-219 per year to preserve endangered species
Jakobsson (1994) in Jakobsson and Dragun (1996), preserving endangered species in West Germany	Each Victorian household willing to pay $A 118 per year to preserve all endangered species in Australia. Total willingness to pay across all Australian households[a] = $A 850 m per year
Jakobsson and Dragun (2001), value of endangered possum (Leadbeaters possum) in Victoria	Each Victorian household willing to pay $A 29 per year to preserve endangered possum species in Australia. Total willingness to pay across all Australian households[a] = $A 209 m per year
Rolfe *et al.* (2000) – avoid loss of endangered species because of tree clearing in Queensland	Each household would be willing to pay $A 11 per year to protect endangered species. Total willingness to pay across all Australian households[a] = $A 79 m per year
Rolfe *et al*. (2000) – avoid loss of endangered species because of tree clearing in Queensland	Each household would be willing to pay $A 1.69 per year to avoid 1% loss of non-threatened species. Total willingness to pay across all Australian households[a] = $A 12 m per year
Centre for International Economics (2001) – quoted study by van Beuren and Bennett to protect habitat in ACT	Each household would be willing to pay $A 24 per year to protect habitat of uncommon species in ACT
Bennett (1984)	Each household would be willing to pay $A 78 per year to protect Nadgee Nature Reserve
Lockwood and Tracey (1993)	Each household would be willing to pay $A 21 over 5 years for the heritage of the Bogong highlands
Pimentel *et al*. (2000) value of bird predation by pests	A cost per bird killed of $US 30 was used as a proxy. A bird watcher spends $0.4 per bird observed (USFWS, 1988), a hunter spends $216 per bird shot (USFWS 1988) and an ornithologist spends $800 per bird reared for release. Value of bird predation by Australian feral cats estimated to be $US 4.3 billion

(a): Assume 7.2 million households in Australia (Number at June 30, 2000 – ABS 2002)

A major impact of vertebrate predation is the potential extinction of fauna and flora species. Surveyed Australian households expressed a 'willingness to pay' to protect endangered species to be in the order of $11–118 per household per year. If this willingness was projected across all Australian households, then a maximum aggregate willingness to pay for species preservation of $79–850 million per year would be evident. The extinction pressure of vertebrate pests on endangered species, relative to other pressures such as land clearing and inter-species competition, needs to be ascertained in order to determine the social cost impact of vertebrate pests. The exact nature of these ecological relationships are currently unknown. Aside from endangered species preservation, it is evident that households were willing to pay $1.69 per household per year to prevent a 1% reduction in an uncommon species. Aggregated over 7.2 million households this amounts to $12 million per year.

Vertebrate predation leads to the reduction of uncommon and endangered species. Correspondingly, the value of damage, in terms of decreased biodiversity, could be a maximum of $12-850 million per year – depending on predatory pressure exerted by specific vertebrate species. These maximum cost estimates are significantly less than the value Pimental *et al.* (2000) derived for the value of bird predation by feral cats in Australia of $US 4.3 billion per annum. In light of this difference, a conservative estimate of $A 1 per bird killed by a vertebrate pest is included in the biodiversity impact valuation.

In the absence of survey data directly relating to the value of reduced vertebrate pest pressure, it is impossible to provide a precise estimate of native fauna value. The preservation of terrestrial biodiversity by the community is not valued to be zero. When valuing damage to a wetland in South Australia using survey-based techniques Bennett *et al.* (1997) noted the economic estimate of damage: "is an order of magnitude estimate only. It should not be employed as the value of the damage avoided. Rather, it should be used as an indicator of the strength of community preferences for protection".

There is a range of wetland and aquatic ecosystem habitat valuation studies documented on the NSW EPA (2004) ENVALUE database and also in the literature. A number of these are summarised in Table 3 and used to estimate the value of adverse impacts on water quality and inland recreational fishing by carp.

Table 3: Summary of Biodiversity Valuation Studies (Aquatic)

Study	Comments
Loomis (1987) in Young (1991) protection of Mono Lake's ecosystem	Each household would be willing to pay $A 29 per year to preserve wetlands in current state
Water Research Centre Flood Hazard Centre (1989)	Each UK household would be willing to pay $A 21 per year to improve water quality and fishing
Mitchell and Carson (1981)	Each household would be willing to pay $A 82 per year to improve water quality and fishing in the USA
Van Bueren *et al*. (1993)	Found that West Australian recreational anglers were willing to pay $5.5 per additional salmon caught
Burns *et al.* (1997)	Noted that south Australian recreational anglers were willing to pay $0.72 per additional whiting caught
Possingham *et al*. (2002) – protect freshwater ecosystems	WTP for improvements as 8c/household for swimming and fishing for every 10 kilometres of degraded waterway that is restored ($259,200/10 km for all Australian households willing to pay). $390m over river system in study

Assumes 2.5 million regular recreational fishers in Australia and 25% fish freshwaters (0.6 million). ABS (2002) estimate over 5 million people take part in recreational fishing.

The range of studies included in Table 3, demonstrate the wide range of biodiversity values. Valuation studies do, however, indicate that people are willing to pay for enhanced water and fishing quality. Recreational anglers in South Australia and Western Australia indicated a willingness to pay for additional fish. Such responses suggest that water and fishing quality have significant social value and should be considered in addition to many of the agricultural productivity cost estimates included in this report. Specific assumptions relating to carp impacts on water quality and recreational fishing quality are outlined in the carp section.

Social Impact

Social impact is perhaps the most difficult element of the 'triple bottom line' framework to define and to quantify. A range of social indicators were prescribed by the Global Reporting Initiative (2002) for company reporting and included the description of a workforce by region, net employment creation, injuries, workforce diversity and education, human rights and indigenous rights. In the context of this report the impact of vertebrate pests on employment prospects within rural and regional Australia, impact of pests on traffic accidents and possible impact of some pest species on indigenous Australia are outlined. These impacts may not all be negative. In the case of foxes, camels, kangaroos and rabbits, commercial resource use values of each species may lead to increased employment opportunities within regional abattoirs or harvesting enterprises. These benefits are relatively minor in comparison to cost pest impacts in most cases. Benefits are not deducted from cost impacts as data is not available for all species. Benefits associated with hunting, for example, or national symbol value in the case of the kangaroo, are difficult to estimate.

Structure of Report

The social, economic and environmental impact of 11 major vertebrate pest species are initially described within chapters for each pest species. Following these impact assessments, results are consolidated in the final section of the report. Research priorities are described given the magnitude of impacts estimated in the proceeding analysis and a new pest introduction scenario is simulated and costed to gain an appreciation for possible impact. A great deal of data relating to agricultural production and enterprise profitability has been assembled to estimate pest impact. These data sets are presented in the appendices so baseline data underpinning calculations are readily apparent.

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EUROPEAN MOUSE (*Mus domesticus*)

- Between 100,000 and 500,000 hectares of grain crops are subject to mouse infestation each year
- The 1993 mouse plague in southern Australia resulted in costs in the order of $65 million
- On an annual basis, mice inflict $35.6 million in control and production loss costs
- Mice spread disease and have a large social stigma

History

The introduced house mouse most probably came to Australia with the First Fleet. Closely associated with human activity, mice are now found throughout the country, especially in agricultural and urban areas. Normally population levels are relatively low. However, when conditions are favourable mice numbers can increase exponentially to plague proportions and they become a serious pest. Similar plagues are uncommon in other countries, even though mice are found worldwide.

The earliest reported mouse plague in Australia was in 1917 on the Darling Downs in Queensland and they have been occurring, with increasing frequency, ever since. Mouse plagues are most commonly observed within cereal grain producing areas of Queensland, NSW and southern Australia (Hone 1980, Mutze 1989, Plomley 1972, Redhead *et al*. 1985). Rainfall is the primary environmental cause of a mouse plague. (Hone 1980, Mutze 1989, Newsome 1969, Redhead *et al.* 1985). As a result of changes in farming practices such as the adoption of stubble retention, continuous cropping and widespread usage of minimum tillage the frequency of mouse plagues was increasing, although, recent drought years have resulted in reduced mouse population pressures. Somewhere in the order of between 100,000 and 500,000 hectares of grain crops are subject to mouse infestation each year (McLeod and Arthur, 2002).

Distribution

Figure 2: Mouse Plague Areas

House mice occur throughout the Australian continent. They live in a broad variety of habitats including agricultural regions, arid environments and urban areas. Mouse populations are usually relatively low and increase exponentially to plague proportions only in the grain growing regions of Australia when conditions are favourable. Periodic outbreaks in desert regions after rainfall or temperate regions after wildfires may also occur. Mice have prospered in grain growing regions of Australia largely through a lack of competition from native species.

Economic Impact

House mice cause damage to crops and stored grain, disrupt intensive livestock production and require considerable public and private monies for targeted control. During an outbreak, population densities of 1000 mice per hectare can be attained. Feeding mice damage grain, fodder, horticultural crops, buildings, farm equipment, electrical wiring, stored wool, retard the performance of poultry and pigs, along with spreading disease (Caughley *et al.* 1994). Of the various sectors impacted by a plague, grain producers suffered the most severe damage and control costs. Costs in this sector, along with other sector costs and research and management costs are outlined in this section.

Table 4: Annual Cost Impact of House Mouse

Cost Component	Control $A million	Loss $A million	Total $A million
Agricultural Production [a]			
Cropping Industries	-	22.79	22.79
Other farming	-	0.32	0.32
Management Cost [b]	10.00	-	10.00
Research Cost [c]	2.50	-	2.50
TOTAL COST	12.50	23.11	35.61

(a): Assumes plague (of 1993 order – $57 m production loss) is assumed to occur every 10 years in each of the four key mouse-prone production region. Other farm costs taken from Bomford and Hart (2002)

(b): Costs taken from Bomford and Hart (2002)

(c): Costs taken from Bomford and Hart (2002)

Grain farm production losses

Mouse plagues are sporadic – largely resulting from seasonal factors. Consequently, it is difficult to forecast the annual production loss attributable to this pest. As previously noted, extended cropping seasons, stubble retention, minimum tillage, direct drilling and conservation cropping have become widely adopted by farmers and provide favourable refuges for developing mice populations. Conversely, seasonal conditions over the last few years have not favoured mice plague development, and the frequency of plagues appears to have declined.

In the case of the 1993 southern Australia plague, approximately 450 thousand hectares of cereal, legume and oilseed crops were affected (Caughley *et al*. 1994). In response to the plague, state governments approved widespread strychnine baiting. The use of baiting to control mice has been shown to be cost-effective. For example, Brown *et al*. (1997) demonstrated that farmers in the Mallee would need to prevent losses of between 0.13 and 0.19 t/ha in cereal crops to cover the costs of mouse control. This figure represents between 8 – 12% of average yields. Economic analysis of control by Ashton *et al.* (1993) noted that in-crop baiting would decrease damage, however, biocontrol is potentially the most feasible option.

Despite the use of baiting in the 1993 plague, $58.9 million in losses were realised (Caughley *et al*. 1994). Given that a plague (of 1993 order) is assumed to occur every 10 years in each of the four key mouse-prone production regions, the annual cost of rodents to grain farmers – in any one year – is estimated to be $24.4 million. Of this total cost, $22.79 million is estimated to be production losses.

Other farms

Mice invade intensive farming enterprises such as poultry housing and piggeries causing damage to infrastructure, spoiling feed and, in some cases, causing damage to animals (Caughley *et al*. 1994). In addition to intensive farming, the grazing industry is impacted through mice consuming pastures, destroying feed grain and damaging stored hay. Similarly to grain producers, farm equipment and buildings are damaged as a result of a plague. During the 1993 plague of southern Australia, losses within piggeries and poultry farms were quantified as part of a phone survey. Most notably, mortality rates were higher among new born pigs, stress of weaners decreased growth rates and white muscle disease was found in carcasses. Within egg production enterprises, the laying rate decreased by up to 20%. Based on information from the phone survey, the mouse plague inflicted losses of $0.8 million, which included $0.03 million for baits (Caughley *et al*. 1994). Given that a plague (of 1993 order) is assumed to occur every 10 years in each of the four key mouse-prone production region, the annual cost of mice to other farmers – in any one year – is estimated to be $0.32 million.

House Mouse Management Costs

In addition to farming communities, house mice are pests within urban areas. A broad range of activities may be impacted including retail businesses, community services and households. Shops selling food are at high risk from suffering losses, while hotels and motels – which require high standards of cleanliness – also are affected. Schools, hospitals, telecommunications and grain storage facilities are damaged as a result of mouse population outbreaks (Caughley *et al*. 1994). In addition to baiting, a number of other management techniques can be used to reduce population pressure. Brown *et al*. (1997) noted that the removal of rubbish, mouse-proofing of grain storage facilities, grazing livestock on stubble, removal of weeds and optimisation of machinery harvesting configurations to minimise spillage during harvest, can be pursued. These authors further note that there has been limited habitat modification research (Newsome 1969, Mutze 1991, Kay *et al*. 1994, Twigg and Kay 1994, Saunders and Korn 1984, Chambers *et al*. 1996). Bomford and Hart (2002) estimated that the total expenditure on mouse control by public and private bodies was in the order of $10 million per year and $2.5 million on research targeting this species.

Environmental Impact

In the past strong poisons were used to kill mice, which would have had non-target species ramifications or possibly impacted upon natural predators of mice such as owls and other predatory birds. No information was found regarding the impacts of house mice on native flora and fauna, although some interaction is expected.

Social Impact

In terms of social impact, mice spread disease to humans, but most of all the build up of mice populations has negative affects on the community as many people regard mice as unpleasant animals and feeding mice destroy household goods.

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EUROPEAN RABBITS (*Oryctolagus cuniculus*)

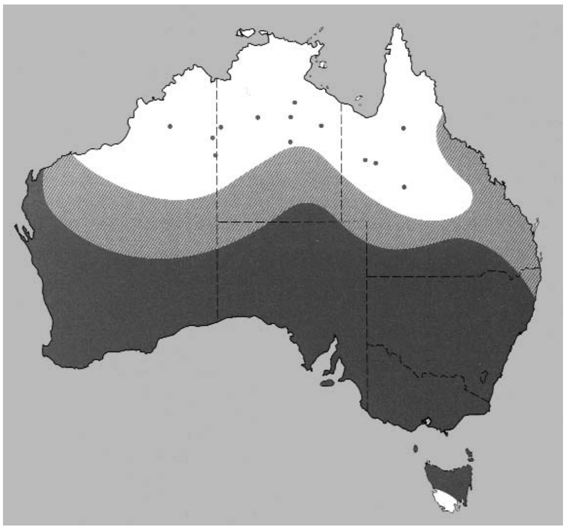
- Rabbits are widespread throughout Australia and are estimated to cost sheep, cropping and cattle farmers approximately $113.11 million each year
- Rabbits compete with native wildlife and livestock for food, and in some cases, are destroying native plants
- Native fauna, such as the Bilby, has been displaced following the spread of the rabbit.
- Biological control agents such as myxomatosis and rabbit calicivirus (RHDV) will not suppress populations indefinitely

History

The rabbit originated in Spain and southern France and domesticated rabbits arrived in Australia with the first fleet. The first feral populations were in south-eastern Tasmania where they numbered in the thousands on some estates by 1827. Thomas Austin, a member of the Victorian Acclimatisation Society, released 24 rabbits he had brought from England onto his property near Geelong for sport hunting on Christmas Day, 1859. By 1886 rabbits had spread north as far as the Queensland – New South Wales border and by 1900 they had reached Western Australia and the Northern Territory.

The rate of spread of the rabbit in Australia was the fastest of any colonising mammal anywhere in the world and was aided by the presence of burrows of native species and modifications to the natural environment made for farming. Rabbits are now one of the most widely distributed and abundant mammals in Australia. Since the introduction of RHDV, rabbit numbers have been reduced in arid areas, although the biological agent is not as effective in more humid, higher rainfall areas.

Figure 3: Rabbit Distribution (Courtesy BRS)



Dark shading represents areas of widespread and common abundance, whereas light shading denotes areas of scattered populations

Distribution

Since introduction in the 1860s, the rabbit has spread throughout Australia and is found almost everywhere south of the tropics. They have a more fragmented distribution north of the Tropic of Capricorn. Rabbit numbers were reduced by 95% – 100% in most of the south of Australia after myxomatosis was successfully introduced in 1950 (Williams *et al.* 1995). This form of control was most successful in areas where mosquitoes, by which the disease was transmitted between rabbits, were abundant.

Post myxomatosis average density of rabbits was estimated to be between 5% and 25% of the pre-myxomatosis levels, depending on climatic conditions (Myers 1962). Despite this, and the successful release of rabbit calicivirus (RHDV), today rabbits remain one of the most widespread and numerous animals in Australia.

Economic Impact

Prior to the release of RHDV, rabbit-related production losses in the Australian wool industry were estimated to be $130 million per annum (Sloane *et al*. 1988). Vere *et al*. (2004) estimated the cost of rabbits to temperate region wool producers in the absence of RHDV to be between $40–73 million per year. Estimates by ACIL (1996) suggest that annual losses were in the order of $600 million. Of this total cost, $300 million was associated with wool production, $70 million for sheep-meat, $150 million for cattle and $80 million for crops.

Since the release of RHDV these costs have declined (Saunders *et al*. 2002), most notably in arid areas. Simulation studies have suggested reduced costs in the order of 25%, 5% and 2.5% in the pastoral, wheat-sheep and high rainfall zones (Vere *et al* 2004). Revised costs, which include a reduction in sheep flock size and value of wool production, along with reduced rabbit competition as a result of RHDV are provided in Table 5.

Table 5: Annual Cost Impact of Rabbits

Cost Component	Control $A million	Loss $A million	Total $A million
Agricultural Production [a]			
Sheep Production Loss	-	35.40	35.40
Cattle Production Loss	-	34.39	34.39
Cropping Industries	-	18.33	18.33
Management Cost [b]	20.00	-	20.00
Research Cost [c]	5.00	-	5.00
TOTAL COST	25.00	88.11	113.11

(a): Agricultural production losses are included in this cost component. The gross margin per sheep or head of cattle sold is multiplied by the numbers in each region and the estimated reduced carrying capacity estimates. ABARE (2003) farm level statistic have been utilised to calculated production loss values

(b): Management cost taken from Bomford and Hart (2002)

(c): Research cost taken from Bomford and Hart (2002)

Livestock enterprises

Competition by rabbits results in the carrying of less livestock, lower wool production per animal, reduced lambing percentages, lessoned wool quality and higher stock mortality during periods of feed scarcity – such as during droughts. The impacts of rabbits are reviewed in papers such as Fleming *et al.* (2002) and Croft *et al*. (2002). Australian sheep numbers have been declining over the last 35 years, largely in response to the declining real price received for greasy wool. Numbers of sheep shorn by region, gross margin per sheep shorn and reduced carrying capacity as a result of rabbit pressures, were combined to estimate the aggregate production loss cost of rabbits on the sheep industry. It is evident that the overall cost is much less than those estimated by Sloane *et al*. (1988) in the late 1980s. This reduction can be explained by the large reduction in the national flock size and RHDV introduction.

In addition, rabbits decrease the carrying capacity of beef farms. The number of cattle sold in each region, gross margins for typical beef enterprises and reduced carrying capacity as a result of rabbit competition are presented in the following table. Cropping yield reductions as a result of rabbit damage were also estimated and are similar to those reported by ACIL (1996).

Table 6: Rabbit Agricultural Productivity Cost

Regions [a]	Area Affected (%)[b]	Production Loss (%)[c]	Sheep Grazing ($m)	Cattle Grazing ($m)	Crops ($m)	Total Loss ($m)
Arid	100	3	4.06	1.22	0.33	5.61
Sheep-Pastoral	100	3	31.33	33.17	18.00	82.50
Total			35.40	34.39	18.33	88.11

(a): See ABARE (2003) for regional definitions. Numbers of livestock, cropping areas and gross margin estimates are outlined in the Appendix. Arid regions includes areas 111, 411, while sheep pastoral includes 121, 122, 123, 221, 322, 421, 422, 512 and 531

(b): Estimated that 100% of specified regions are in some way impacted

(c): Competition between sheep and rabbits is likely to be most intensive in arid areas. Production loss estimates for each region are taken from Sloane *et al*. (1988), but reduced due to RHDV introduction. In the past rabbit densities were higher in arid areas (Wilson *et al*. 1992). Since RHDV introduction, Neave (1999) found higher rabbit densities in higher rainfall areas. For purposes of the analysis, similar production losses for each climatic zone are included. A crop yield loss of 0.5% is also included.

Cropping

Rabbits will feed on emerging crops. Losses of up to 100% in yield have been recorded on the fringes of paddocks in Western Australia. It has been suggested that, prior to RHDV, rabbits inflicted $6.5 million worth of production losses on South Australian producers alone (Henzell 1989).

Rabbit Management Costs

A significant amount of resources are also consumed in rabbit control. 1080 is the most commonly used toxin to control rabbits. 1080 is an effective and cheap toxin in areas where there are no major non-target concerns. Drawbacks of the product include the potential development of bait aversion by rabbits as a result of sustained baiting programs, the development of resistance to the toxin (there is some evidence from WA that this is occurring), the potential for rabbit populations to build-up rapidly following the cessation of a baiting program and the potential for non-target kill. Domestic pets can be killed in bating programs causing grief to domestic animal owners. The cost of 1080 has been estimated to be $0.15/kg of bait, with bait, such as oats, being approximately $250/t.

Application costs are a major component of the costs of baiting programs, as labour is consumed applying the poison to bait and during bait deployment. It was estimated that the Victorian Department of Conservation and Natural Resources spends more than $4 million per annum on rabbit control, although labour is likely to be the major component of this cost. It is estimated that the 1080 market for rabbit control currently is in the order of $1 million per annum (value of end product), although the use of 1080 has declined since the introduction of RHDV.

There are a number of indirect costs of rabbits which include disease transmission and degradation of rangelands leading to higher soilage of wool. William *et al.* (1994) noted that rabbit control costs in private forests can be as high as $80 per hectare during periods when trees are vulnerable to rabbit damage. Management costs are included in this assessment following Bomford and Hart (2002).

Environmental Impact

Rabbits compete with native wildlife for pastures, and in some cases are destroying native plants (Croft *et al.* 2002). In addition, overgrazing by rabbits removes plant cover and contributes to soil erosion. Native fauna, such as the Bilby, has been displaced following the spread of the rabbit. Rabbits are implicated in the local extinction of some native species through competition for food and burrows. They have major impacts on the regeneration of native vegetation, particularly in the rangelands. Vegetation losses caused by rabbits can lead to severe erosion of Australia's relatively infertile soils and reduce biodiversity (Eldridge 2000). In addition to having direct effects on native mammal species through competition, rabbits also contribute to the impact feral foxes have on native prey by maintaining higher densities of this predator. Key fauna and flora currently threatened (listed in threat abatement plan) are listed in Table 7.

Table 7: Flora and Fauna Species by threatened Rabbits

	Known Threat	Perceived Threat
Fauna	■ *Pterodroma leucoptera leucoptera*, Gould's Petrel ■ *Macrotis lagotis*, Greater Bilby	■ *Philoria frosti,* Baw Baw Frog ■ *Geopsittacus occidentalis,* Night Parrot ■ *Leipoa ocellata,* Malleefowl ■ *Neophema chrysogaster,* Orange-bellied Parrot ■ *Bettongia lesueur*, Burrowing Bettong ■ *Burramys parvus*, Mountain Pygmy-possum ■ *Dasycercus cristicauda*, Mulgara ■ *Dasyurus geoffroii,* Western Quoll ■ *Onychogalea fraenata*, Bridled Nailtail Wallaby ■ *Petrogale penicillata*, Brush-tailed Rock-wallaby

Table 7: Flora and Fauna Species by threatened Rabbits (continued)

	Known Threat	Perceived Threat
Flora	■ *Acacia insolita subsp. recurva* ■ *Caladenia amoena* ■ *Caladenia bryceana bryceana* ■ *Caladenia busselliana* ■ *Caladenia elegans* ■ *Caladenia gladiolata* ■ *Caladenia hastata* ■ *Caladenia viridescens* ■ *Conostylis micrantha* ■ *Cynanchum elegans* ■ *Darwinia carnea* ■ *Grevillea maccutcheonii* ■ *Hemiandra gardneri* ■ *Hemiandra rutilans* ■ *Pterostylis sp. Northampton* ■ *Thesium australe* ■ *Verticordia fimbrilepis*	■ *Acacia cretacea* ■ *Acacia rhamphophylla* ■ *Banksia cuneata* ■ *Caladenia caudata* ■ *Caladenia rigida* ■ *Daviesia bursarioides* ■ *Eremophila nivea* ■ *Eremophila viscida* ■ *Eucalyptus rhodantha* ■ *Grevillea scapigera* ■ *Prostanthera eurybioides* ■ *Pterostylis gibbosa* ■ *Tetratheca deltoidea*

Social Impact

The harvesting of rabbits and the rabbit skin industry have positive regional employment impacts. Since the release of RHDV the value of this industry has declined dramatically. ACIL (1996) estimated the value of wild rabbit skin and meat industries to be $10.1 million per year, while the sports-shooters and ammunition industry turnover was in the order of $36 million per year. There are a number of indirect costs of rabbits, including disease transmission. Rabbits host tapeworms (*Taenia pisiformis* and *T. serialis*) and liver fluke (*F. hepatica*). Williams *et al*. (1995) noted that rabbits could also increase the prevalence of hydatids (*Echinococcus granulosus*), paovirus, toxo plasmosis, distemper, brucellosois, coccidian and leptospirosis.

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EUROPEAN FOX (*Vulpes vulpes*)

- Foxes are distributed throughout Australia in a similar fashion to the rabbit
- The total annual cost of foxes is estimated to be $227.5 million
- The sheep industry suffers economic loss through fox predation, while public sector expenditure is related to fox control and research

History

The fox occurs naturally only in the northern hemisphere and was introduced into southern Victoria in the 1871 for recreational hunting. Colonisation was rapid and closely linked to the spread of the rabbit. By 1893 foxes were reported in New South Wales; in 1901 in South Australia; in 1907 in Queensland; and in 1912 in Western Australia. Today the fox is one of the most widely spread feral animals in Australia.

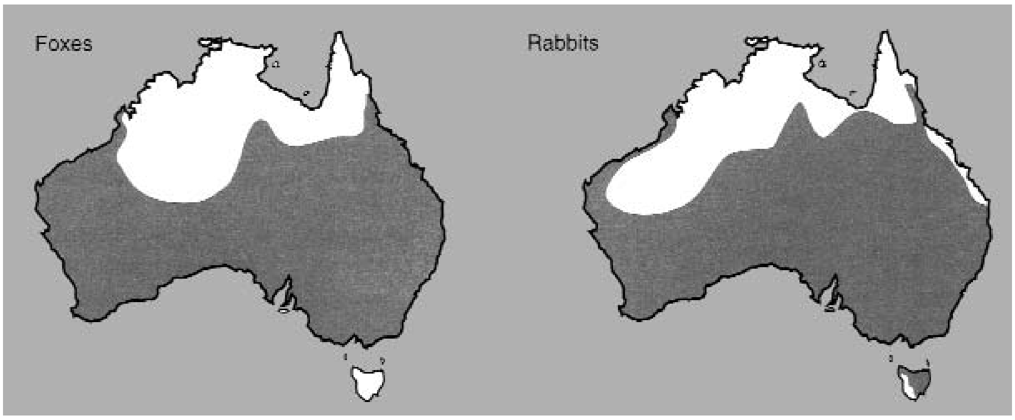
Foxes were deliberately introduced into Tasmania in 2001 with sightings increasing since that time. A fox carcass was found on a road at Burnie in October 2003. Efforts are being made to eradicate the fox before they establish in Tasmania.

Distribution

The fox is distributed throughout southern Australia, except on Kangaroo and other islands. Until recently, Tasmania has been free of foxes, however several individuals were maliciously introduced there in 2000, and sightings have been increasing since.

The distribution of foxes in mainland Australia is highly similar to that of the rabbit. They are found in diverse habitats including urban, arid and alpine areas. Fox distribution in some areas may be affected by the presence of dingoes, dingo fences and climate (Saunders *et al*. 1995)

Figure 4: Fox Distribution (Courtesy BRS)



Relative distribution of foxes and rabbits in Australia highlighted by shading

Economic Impact

Agricultural, environmental, management and research costs associated with foxes are provided in the following table. It is evident that the sheep industry suffers economic loss through fox predation, while public sector expenditure is related to fox control and research.

Table 8: Annual Cost Impact of Foxes

Cost Component	**Control $A million**	**Loss $A million**	**Total $A million**
Agricultural Production [a]			
Sheep Production Loss	-	17.50	17.50
Environmental Impact Cost	-	190.00	190.00
Management Cost [b]	16.00	-	16.00
Research Cost [c]	4.00	-	4.00
TOTAL COST	20.00	207.50	227.50

(a): Key loss is lamb predation. ABARE (2003) estimate 35 million lambs marked per year. Assumed 2% of all lambs marked are taken by foxes at a cost of $25 per head. See Saunders *et al.* (1997) for background of lamb predation.
(b): Management cost taken from Bomford and Hart (2002). Fox control expenditure in Tasmania of $9 million per year is also included (Tasmanian Dept. of Primary Industries, Water and Environment estimate)
(c): Research cost taken from Bomford and Hart (2002)

Sheep industry

Studies quantifying the impact of foxes on lamb production have produced variable results, with reports of foxes taking up to 30% of lambs in some areas (Lugton 1993) At present, there are 35 million lambs in Australia, with lambing losses being the main impact foxes have on the sheep industry. Significant amounts of resources are committed to fox control. Farmers most commonly shoot foxes and/or implement baiting programs. These are likely to remain the most effective short-term treatments to protect farms from lambing losses. Baiting can be difficult in rough terrain, particularly in the east where aerial distribution is largely avoided.

Fox Management Costs

Annually, over $16 million are spent managing the impacts of foxes in Australia. A further $4 million are devoted to research into fox control and the development of new management tools and strategies.

Environmental Impact

Australia accounts for about one third of the world's mammal species that have become extinct in modern times (Groombridge 1993). The fox is threatening the survival of many Australian mammals and birds (Saunders *et al*. 1994). Most commentators agree that the introduction of exotic predators, such as the European Red Fox (*Vulpes vulpes*), has contributed to the decline of many species of reptiles, mammals and birds in Australia. Following the methodology in Pimentel *et al*. (2000), the impact of fox predation on the bird population in Australia is valued. The assumptions used to quantify this impact are summarised in Table 9 and described in the subsequent text.

Table 9: Summary of Fox Biodiversity Impact Assumptions (Fox)

Assumptions and value	**Source**
Fox range – 3.6 million km^2	From distribution maps, foxes appear to be dispersed across about half of Australia (see maps in Saunders *et al.* 1994)
Fox density – 2 per km^2. Derived from Coman *et al* 1991 for temperate grazing (3.9), Thompson and Fleming 1994 for temperate grazing (4.6-7.2), Newsome and Catling 1992 for dry sclerophyll forest (0.2), Newsome and Catling 1992 for semi arid grazing (2.0), Marlow 1992 for arid grazing (0.9), and as high as (0-12) for urban outlined in Saunders *et al.* 1994	Densities vary widely across Australia from 15 per km^2 in urban areas, to averages of about 1–5 in dry sclerophyll and temperate grazing areas and 0.1 in tundra. An average of 2 km^2 is used in the study
Total Australian fox population – 7.2 million	Derived from density and range assumptions
Food requirement for foxes per day – 372 g / fox/ day or 136 kg per fox / year	Saunders *et al*. (1993) constructed a generalised model to estimate the daily energy expenditure, excluding direct costs of reproduction, for urban foxes
Live bird off-take by foxes per year – 9.5 million kg	Assumes 1% of feed requirement met by live birds (see diet studies by Coman 1973, Croft and Hone 1978).
Number of birds equivalent – 190 million per year	Assumes each native bird weighs somewhere around 50 g
Value of bird predation – $A 190 million per year	Each bird valued at $1 – derived from Pimentel *et al.* (2000) method

It is difficult to ascertain the current number of foxes in Australia as the range and density of foxes in the various agro-ecological zones of Australia fluctuate considerably. Saunders *et al.* (1994) noted that estimates of fox densities vary from as high as fifteen adults per km^2 in urban areas of Britain (Harris and Rayner 1986, Harris and Smith 1987) to as low as 0.1 adults per km^2 in tundra and boreal forest (Voigt 1987). In this assessment it is assumed that about half of Australia supports fox populations, at an average density of 2 foxed per km^2. Given these assumptions the total Australian fox populations is calculated to be about 7.2 million.

The extent of predation is similarly difficult to determine. There has been a range of fox dietary studies to determine the eating habits of this species. Saunders *et al.* (1994) indicated that two of the most comprehensive were by Coman (1973) and Croft and Hone (1978), in Victoria and New South Wales respectively. Examination of the gut content of foxes found the most common items to be sheep, rabbits and house mice. These items accounted for about 70% by volume, while other macropods represented 2% and birds 6% by volume.

Gut content studies give no real indication of the quantum of feed intake by foxes over any period of time. To determine overall feed requirement, Saunders *et al*. (1993) developed a generalised model to calculate daily energy expenditure. Based on yearly averages, an adult male required 2001 kJ per day or the equivalent of 372 grams of wild bird. If it is assumed that 1% of the 372 g per day feed intake is birds, then foxes account for about 9.5 million kg per year of live bird predation. Converting this volume of off-take by an average bird weight of 50 g, foxes are estimated to account for 190 million fatalities per year. This off-take is converted to a cost value by assuming each bird is valued by the community at $1 and the total value of fox predation is $190 million per year.

Saunders *et al*. (1994) concluded, "while diet studies indicate the range of prey consumed by foxes, diet studies alone are not a reliable indication of the extent of damage caused by foxes. Some endangered native species may occur only rarely in the diet, but foxes may be having a significant impact on their populations. Conversely, other species that occur consistently in fox diet maybe in sufficient numbers that they can tolerate long-term fox predation without any resulting decline in population densities. The damage that fox predation causes to native fauna can only be quantified by scientifically designed and replicated studies where fox predation is reduced and the response of the prey is monitored". With this issue in mind, the range of fauna current at risk from extinction due to fox predation is detailed in the following table from the national abatement plan.

Table 10: Summary of Fauna Species threatened by Foxes

Known Threat	Perceived Threat
■ *Leipoa ocellata*, Malleefowl ■ *Sterna albifrons*, Little Tern ■ *Dasyurus geoffroii*, Western Quoll ■ *Lagorchestes hirsutus*, Rufous Hare-wallaby ■ *Macrotis lagotis*, Greater Bilby ■ *Myrmecobius fasciatus*, Numbat ■ *Perameles gunnii,* Eastern Barred Bandicoot ■ *Petrogale lateralis*, Black-footed Rock-wallaby ■ *Potorous longipes*, Long-footed Potoroo ■ *Caretta caretta*, Loggerhead Turtle ■ *Chelonia mydas*, Green Turtle	■ *Philoria frosti,* Baw Baw Frog ■ *Geopsittacus occidentalis*, Night Parrot ■ *Neophema chrysogaster*, Orange-bellied Parrot ■ *Pezoporus wallicus flaviventris*, Western Ground Parrot ■ *Stipiturus malachurus intermedius*, Mount Lofty Southern Emu-wren ■ *Turnix melanogaster*, Black-breasted Button-quail ■ *Pseudomys fieldi*, Djoongari ■ *Bettongia lesueur*, Burrowing Bettong ■ *Sminthopsis douglasi,* Julia Creek Dunnart ■ *Bettongia tropica*, Northern Bettong ■ *Burramys parvus*, Mountain Pygmy-possum ■ *Dasycercus cristicauda*, Mulgara ■ *Dasyuroides byrnei,* Kowari

Table 10: Summary of Fauna Species threatened by Foxes (continued)

Known Threat	Perceived Threat
	■ *Leporillus conditor,* Greater Stick-nest Rat ■ *Onychogalea fraenata*, Bridled Nailtail Wallaby ■ *Parantechinus apicalis,* Dibbler ■ *Petrogale penicillata*, Brush-tailed Rock-wallaby ■ *Potorous tridactylus gilberti,* Gilbert's Potoroo ■ *Pseudomys oralis*, Hastings River Mouse ■ *Zyzomys pedunculatus,* Central Rock-rat ■ *Delma impar,* Striped Legless Lizard ■ *Dermochelys coriacea*, Leathery Turtle ■ *Pseudemydura umbrina*, Western Swamp Tortoise

Social Impact

Australia has been one of the world's most productive exporters of fox pelts, with the industry being worth around $8 million in 1984 (Saunders *et al*. 1994). Demand fluctuates widely and prices have fallen a great deal over the last 20 years. The commercial harvest for fox pelts in Australia occurs during autumn and winter in the south-east of the continent. It is estimated that about 60 per cent of fox pelts supplied to the trade comes from New South Wales, 30 per cent from Victoria and the remainder from South Australia (Saunders *et al*. 1994). Most foxes are killed using rifles and spotlights. Despite a considerable harvest rate in some years, there is no evidence that this rate of removal had a significant impact upon the level of damage caused by foxes (Saunders *et al.* 1994).

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FERAL PIGS (*Sus scrofa*)

- Feral pig (*Sus scrofa*) populations in Australia originated from released or escaped domestic stocks and now inhabit 38% of the mainland
- Pigs inflict losses through livestock predation, crop damage, and native vegetation destruction, and are also vectors of disease
- Feral pigs are currently inflicting $107 million in control and production loss costs per year.
- The introduction of Foot and Mouth disease and potential for pigs to harbour the disease would result in far higher economic costs.

History

The feral pig (*Sus scrofa*) population in Australia originated from released or escaped domestic stocks that were introduced with European settlement. Pigs in Australia were originally of the Berkshire and Tamworth breeds. These were later modified by cross breeding with breeds from China, India, Timor and other parts of Europe. In the 19th century, problems with stray and feral pigs became apparent in areas surrounding settled regions.

Feral pigs have colonised many parts of the Northern Territory, Queensland, New South Wales, and other states and territories, restricted mainly to watercourses and their associated floodplains in inland or seasonally dry areas of Australia. In eastern Australia and south-west Western Australia, populations are still spreading, often through deliberate or accidental releases.

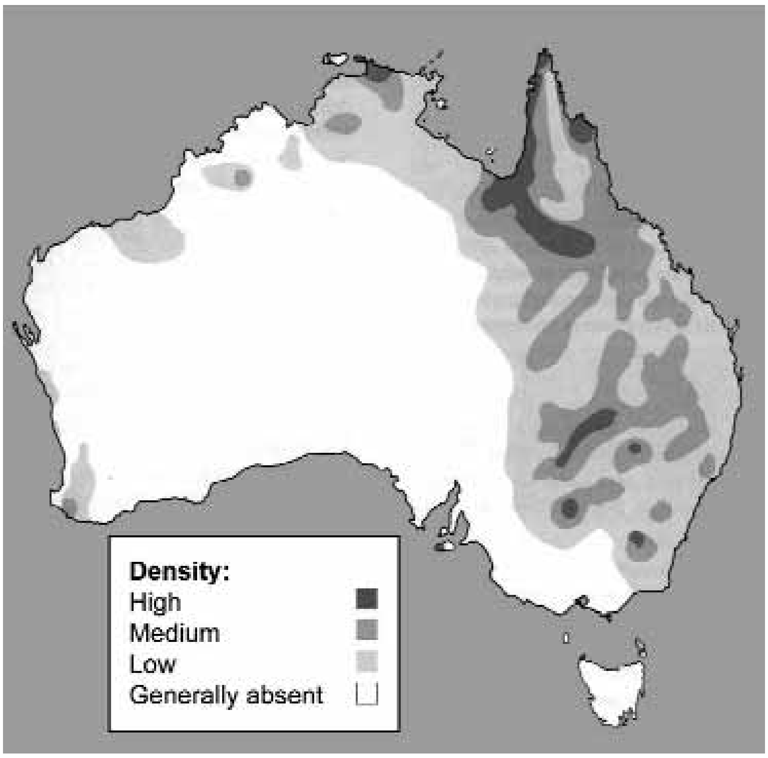

Figure 5: Distribution of Feral Pigs (Courtesy BRS)

Distribution

Feral pigs are established in around 38 percent of the continent and estimates of their numbers in Australia range from 3.5 to 23.5 million (Hone, 1990). The problem is concentrated mostly in Queensland, NSW, the ACT and the Northern Territory, with more isolated population pockets across the other States and offshore areas, such as Flinders and Kangaroo Island (Choquenot *et al* 1996). Because of their low heat tolerance, feral pigs abundance is highest in wetlands, floodplains and watercourses, where population densities may reach 10 to 20 per kilometre, or higher. Their distribution and abundance can vary markedly from year to year according to environmental conditions. Their dependence on drinking water and vegetation for shelter means seasonal factors have significant influences over the number and distribution of the feral pig population (Wilson *et al.* 1992). Despite this, it may be pertinent to note that feral pigs' generally sedentary nature has slowed their spread outside their existing territories (Caley 1993). The distribution of feral pigs in Australia is outlined in the following figure provided by BRS.

Economic Impact

The economic impact of the feral pig problem stems from the direct damages caused to agriculture and farming, environmental degradation and the response and control costs associated with these problems. At the same time, sizeable game meat and recreational hunting industries have developed around feral pigs, and it is thought these activities may play important pest control roles.

Table 11: Annual Cost Impact of Feral Pigs

Cost Component	Control $A million	Loss $A million	Total $A million
Agricultural Production [a]		100.00	100.00
Management Cost [b]	5.00	-	5.00
Research Cost [c]	1.50	-	1.50
TOTAL COST	6.50	100.00	106.50

(a): Agricultural production losses are outlined in Bomford and Hart (2002)
(b): Outlined in Bomford and Hart (2002)
(c): Outlined in Bomford and Hart (2002)

Agricultural Production Impact

Feral pigs inflict direct losses on the agricultural sector through predation of newborn animals, reduce grain and cane yields by devouring and destroying crops, compete with livestock for pasture land, and damage infrastructure such as fences. The damage bill caused to agricultural production is conservatively estimated to be at least $100 million per annum.

Sheep farming and wool industries in parts of Australia are threatened by feral pig predation of young lambs. In semi-arid rangelands where the problem is considered most serious, predation rates have been estimated to be as high as 35 percent (Plant *et al*. 1978, Pavlov *et al*. 1981). Because the extent of the problem is dependent on seasonal variation in feral pig densities, investment in control may be adjusted according to these seasonal factors.

Feral pigs are a threat to a variety of crop production because they have a highly adaptable omnivorous diet. An estimate from 1979-80 suggested damage to grain crop alone stood at $41.4 million (Tisdell 1982). For mainstream crops such as wheat, the damage in NSW was estimated to be a 3 percent loss in production. Pig rummaging and feeding also threaten the sugarcane industry. Although the loss in 1982 was estimated to be only around 0.1 to 0.15 percent of Queensland's production, it nevertheless amounts to 20,000 tonnes (Tisdell 1982). A 1993 study puts the loss at 25,000 tonnes worth around $625, 000 (McIlroy *et al.*1993).

Feral Pig Management Costs

There are few recent estimates of the magnitude of spending relating to controlling the feral pig problem. Bomford and Hart (2002) estimated that landholders and the government spend $5 million per annum on pig control, while $1.5 million is spent on research.

Environmental Impact

Feral pigs, due to their fecundity and omnivorous habits, are commonly regarded as a serious environmental threat. However, there have been few studies that quantify the extent of the damage caused. Although not considered a substantial predator, feral pigs affect the survival of native fauna by causing damage to their habitat and through feed competition. Native vegetation is also affected by trampling damage and the spread of rootrot fungus (*Phytophthora cinnamomi*) and dieback disease. Despite feral pigs' apparent destructive potential, the actual impacts are often unknown because of intervention of other relevant factors. For instance, although feral pigs are known to feed on seeds of native fruits and plants, little is known about whether this causes material physical damage to the seedlings (McIlroy *et al*. 1993). Similarly, the negative impact feral pigs have on native insects such as earthworms is not altogether clear given the existence of conflicting experimental evidence (Pav Ecol 1992, Mitchell 1993). Feral pigs are also threatening some species of native fauna and flora. Key species currently threatened (listed in threat abatement plan) are listed in Table 12.

Table 12: Flora and Fauna Species threatened by Feral Pigs

	Known Threat	Perceived Threat
Fauna	■ *Zyzomys palatalis Carpentarian*, Rock-rat ■ *Casuarius casuarius johnsonii,* Southern Cassowary ■ *Dasyornis brachypterus*, Eastern Bristlebird ■ *Geocrinia alba*, White-bellied Frog, Creek Frog ■ *Geocrinia vitellina*, Orange-bellied Frog ■ *Mixophyes fleayi*, Fleay's Frog ■ *Mixophyes iteratus*, Southern Barred Frog ■ *Rheobatrachus silus*, Gastric-brooding Frog ■ *Caretta caretta,* Loggerhead Turtle ■ *Eretmochelys imbricate*, Hawksbill Turtle ■ *Natator depressus*, Flatback Turtle ■ *Scaturiginichthys vermeilipinnis,* Red-finned Blue-eye	■ *Lasiorhinus krefftii*, Northern Hairy-nosed Wombat ■ *Potorous longipes*, Long-footed Potoroo ■ *Bettongia tropica*, Northern Bettong ■ *Turnix melanogaster*, Black-breasted Button-quail ■ *Litoria lorica*, Armoured Mistfrog ■ *Litoria nannotis*, Waterfall Frog, ■ *Litoria nyakalensis,* Mountian Mistfrog ■ *Litoria rheocola*, Common Mistfrog ■ *Nyctimystes dayi*, Lace-eyed Tree Frog ■ *Spicospina flammocaerulea*, Sunset Frog ■ *Taudactylus acutirostris*, Sharp-snouted Day Frog ■ *Pseudophryne corroboree*, Southern Corroboree Frog ■ *Engaeus martigener,* Furneaux burrowing crayfish

Table 12: Flora and Fauna Species threatened by Feral Pigs (continued)

	Known Threat	Perceived Threat
Flora	■ *Ballantinia antipoda*, Southern Shepherd's Purse ■ *Calonemorchis elegans*, Elegant Spider Orchid ■ *Caladenia winfieldii* Majestic Spider Orchid ■ *Phaius australis* Lesser Swamp-orchid ■ *Phaius tancarvilleae* Swamp Lily, Greater Swamp-orchid ■ *Thelymitra manginii,* Cinnamon Sun Orchid ■ *Cynanchum elegans*, White-flowered Wax plant ■ *Ptychosperma bleeseri* Palm	■ *Cullen parvum*, Small Scurf-pea

Social Impact

Bomford and Hart (2002) noted that feral pigs can act as vectors for a number of wildlife diseases that affect both livestock and humans. Of particular concern, pigs can transmit leptospirosis, brucellosis, melioidosis, tuberculosis, porcine parvovirus, sparganosis and other arbovirus. Feral pigs can also transmit and act as reservoirs for exotic diseases such as Foot and Mouth Disease and Japanese encephalitis.

Commercial Use Value

Feral pigs in Australia provide valuable meat export potential, because of their biological similarities with European wild boars (Choquenot *et al* 1996). Export of this game meat, predominantly to Europe, generates around $10 to 20 million annually (Ramsay 1994). Recreational hunting is also regarded as having considerable commercial value and plays an important role in controlling feral pig numbers. It was estimated in 1982 there are 100,000 recreational hunters spending $45 million annually on hunting and related activities (Tisdell 1982). The same study suggests amateur hunting may reduce the feral pig population by 7.5 percent a year and deliver over $3.5 million in savings to landowners affected by feral pigs. As with other species, the net benefit of the game meat production is included as a commercial resource use value in the costing.

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CARP (*Cyprinus carpio*)

- Carp, *Cyprinus carpio*, were introduced to Australia's waters on a widespread basis in 1964
- Carp are now the most abundant large freshwater fish in the Murray-Darling Basin
- The species is estimated to generate an annual cost of $15.8 million per year through degradation and management costs
- The relationship between native fish species decline and carp abundance is not clear

History

Carp (*Cyprinus carpio*) originated in central Asia and spread throughout Asia and Europe as an ornamental and aquaculture species. Carp were released into the wild in Australia on a number of occasions in the 1800s and 1900s but did not become widespread until a release of 'Boolara' strain carp from a fish farm in the Murray River near Mildura in 1964. The spread of carp throughout the Murray-Darling Basin coincided with widespread flooding in the early 1970s, but carp were also introduced to new localities, possibly through their use as bait.

Introduced carp are now the most abundant large freshwater fish in the Murray-Darling Basin and are the dominant species in many fish communities in south-eastern Australia.

Distribution

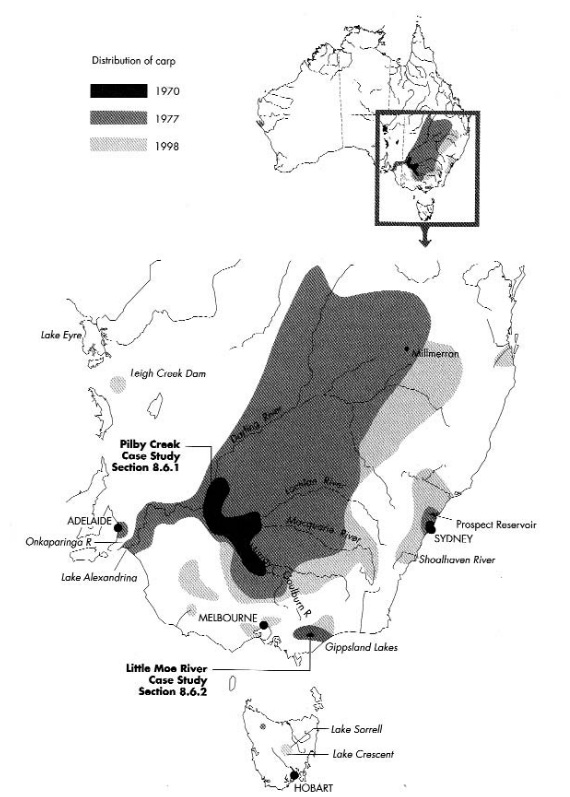

Figure 6: Distribution of Carp (Courtesy BRS)

Carp, are found in all Australian states and is the dominant species of the Murray-Darling Basin. Carp are commonly found to be from 50 g to 5 kg in weight and can tolerate a range of water temperatures, salinity levels and polluted water.
A survey of fish abundance in Australian rivers by Driver (2003) found that inland rivers had higher carp densities than coastal rivers. Carp were found in all inland sites below an altitude of 500 m above sea level. Higher carp densities were associated with riverine systems exhibiting human impacts, most notably, the effects of dams and agriculture. Alteration of flows and water temperatures, physical barriers to fish migration, carp spawning habitat created in artificial lakes and agricultural effects on water quality were all linked to higher carp biomass densities (Driver 2003).

Economic Impact

Carp can increase water turbidity and damage aquatic plants through their feeding behaviour, degrading aquatic systems and therefore detrimentally affecting values of wetlands. These costs, along with carp management and research costs are outlined in the following table. It should be noted that there exists a lack of quantitative data on the impacts carp have on the environment. Confounding factors, such as removal of riparian vegetation, watercourse alteration, and stock access to waterways, make it difficult to quantitatively assess carp damage. It is estimated that this species generates an annual cost impact of more than $15.8 million per year.

Table 13: Annual Cost Impact of Carp

Cost Component	Control $A million	Loss $A million	Total $A million
Management of carp [b]	2.00	-	2.00
Research Cost [c]	2.00	-	2.00
Environmental Impact [a]	-	11.80	11.80
TOTAL COST	4.00	11.80	15.80

(a): Annual cost to community estimated in this assessment
(b): Control costs for carp taken from Bomford and Hart (2002) and $1 million per year from the Tasmanian government for Crescent Lake
(c): Public sector research costs for carp taken from Bomford and Hart (2002) and new projects.

Carp Management Costs

Bomford and Hart (2002) indicated that $2 million per year is spent by the public sector on carp management. Somewhere in the order of $2 million was spent on research. Farmers also complain about damage done to irrigation canals and water losses due to the digging behaviour of carp. It is difficult to quantify these losses, but they may have some significance at a national level.

Environmental Impact

Carp generate environmental impact through causing increased water turbidity, reducing the abundance of invertebrates and aquatic plants and possibly displacing other fish species. Each of these elements are discussed in this section.

Environmental impacts generally result from the bottom-feeding behaviour of carp. Sediment in inhaled and sifted through the gill rakers in an activity known as 'mumbling' and can increase turbidity, release sediment nutrients and destroy aquatic plants. In relation to generic water quality issues in Australia, Possingham *et al*. (2002) noted the annual cost of water turbidity to be $24 million and the cost of sedimentation to be $4 million per annum. If carp contributed to 10% of this cost, then the impact of carp-related sedimentation and heightened water turbidity would be about $2.8 million per year.

The impacts of carp on native fish populations are not readily apparent (Harris, 1994). Carp may make aquatic habitat less suitable for native fish breeding and survival, and provide competition for resources. The greatest impact of carp is on the abundance of invertebrates and aquatic plants, which form the basis of native fish diets. There is some anecdotal evidence of competition. For example, a recent fish survey found that there was an average of only 2.6 native fish species per site in the Murray region, compared with 4.6 species in the Darling sites. Carp were the main alien species contributing to the changes in the proportional abundance of native species. Native species whose abundances were most reduced by river regulation were western carp gudgeons, bony herring, and striped gudgeons (Driver 2003). The range of freshwater fish species, which are currently in danger, are outlined in Table 14. The contribution carp is possibly making toward the extinction of these species does cause social cost.

Table 14: Current Threatened Freshwater Fish Species

Genus, Species	Common Name	Listed
Maccullochella macquariensis	Trout Cod	16 Jul 00
Macquaria australasica	Macquarie Perch	16 Jul 00
Nannoperca oxleyana	Oxleyan Pygmy Perch	16 Jul 00

In some parts of Australia fishing has been banned as a result of carp presence. Lake Cresent (Tasmania), for example, which had 1,559 full season anglers who exclusively fished this area, was closed until the current brown trout season. Aside from directly affecting the well being of these fisherman, possible decreased expenditure by these people would have affected support industries. Each freshwater angler is estimated to spend around $535 on the sport (Henry and Lyle 2003).

Households surveyed in America and Australia have indicated a willingness to pay for the restoration of wetlands and anglers were found to be willing to pay for prized species. These values were presented in the introductory section where ‘willingness to pay’ was as high as $80 per household per year in the USA. For the purposes of valuing biodiversity in this report, it is assumed that each household would be ‘willing to pay’ $50 per year for improved fishing quality.

Households with fishers are most likely to benefit from being able to catch prized native species. The size of the recreational fishing sector in Australia is substantial. ABS (2002) estimated some 5 million Australians fishers, although participation rates vary considerable. Only limited numbers of these fishers would use inland waters where carp are present. A survey of fishing in NSW indicated that there were an estimated 998,501 recreational fishers in 2001. Recreational fishing activity was greatest in estuarine waters (47% of total events). Fishing in coastal waters (28% of events), freshwater rivers (15% of events) and lakes and dams (10% of events) followed in importance (NSW Fisheries 2002)

Given that somewhere in the order of 25% of fishers surveyed utilised inland waters, and many of the 5 million fishers in Australia would be irregular, it is estimated that there are around 0.6 million Australians who have regular contact with inland waters where carp could possibly be a problem. Aggregating the ‘willingness to pay’ for improved fishing quality of $50 per household over 0.6 million fishers, the aggregate cost of decreased fishing quality is estimated to be $30 million per year. This cost is derived on the basis, that in the absence of carp, fishers would have satisfactory water quality and greater abundance of native fish. If carp were contributing to a 30% decline in prized fish species, then a social cost of $9 million per year could be attributed to the impact of carp on recreational fisheries.

Only one carp study in Gippsland has pulled together the various costs associated with carp. The study by the Gippsland Lakes and Catchment Action Group (1996) estimated the annual cost of carp on the native commercial fishery, losses to recreational fishing, impact on tourism and local commerce to be $35 million per year, although, the method for estimating these losses was not explained (Koehn *et al*. 2000). Aggregating the turbidity and decline in recreational fisher value estimated in this analysis, generates an annual cost of $11.8 million per year.

Social Impact

The commercial harvesting of carp provides employment opportunities in rural and regional Australia. For example, K and C Fisheries, the largest carp producer in Australia, processed 900 tonnes of carp in 1999. The retail prices for whole carp can reach $7 per kilogram, however, much of the commercial catch is used for low-value products such as fertiliser (15 cents per kilogram) and crayfish bait (50 cents per kilogram). There are 70 licensed carp fishermen in Australia and the total gross value of the industry in 2002 was $A 1.7 million (Bell 2003). There are a number of costs associated with carp production including harvesting costs: licences, nets, labour, vehicles, boats, issuance, QAP factors; storage costs: refrigeration plant and running costs, factory approved by govt/AQIS, QAP factors; marketing costs: transport, commission, handling unknown factors, chemical analysis; and packaging costs: cardboard boxes, plastic crates, ice slurry, plastic bags/liners, pallets (Bells 2003).

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FERAL GOATS (*Capra hircus*)

- Australia has an estimated 2.6 million feral goats, distributed in all states and territories
- Feral goats compete with sheep and cattle for fodder and cause $4 million per annum in production loss costs
- The mustering and sale of feral goats generates $6 million per annum in farm-gate revenue, but costs $2 million in mustering expenses

History

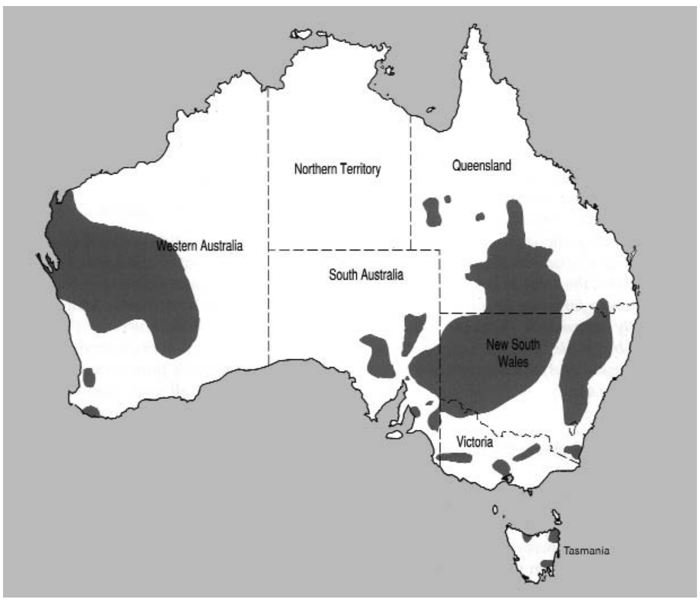
Goats first arrived in Australia with the first European settlers. Subsequent introductions were also made for a variety of reasons. During the 19th Century, goats were set free on islands and the mainland by mariners as an emergency food source. Cashmere and angora goats were imported during the mid 1800s to establish a goat fibre industry. Settlers, railway construction gangs, and miners also transported goats around Australia as a supply of milk and meat.

Feral goat populations established from escaped, abandoned or released domestic animals. More recently, feral goat populations have established from goats used to control weeds in inland New South Wales and Queensland.

Distribution

Feral goats occur in all states and territories of Australia, as well as on several offshore islands. The main concentrations are in New South Wales, southern Queensland, central eastern South Australia and Western Australia where land adapted for sheep farming also provides good goat habitat. Australia has an estimated 2.6 million feral goats.

Figure 7: Distribution of Feral Goats (Courtesy BRS)



Dark shades represent areas of highest density

In 1993 there were about 2.6 million feral goats in Australia but this number has fluctuated widely under the influence of extended dry periods and the effectiveness of management programs (Parkes *et al.* 1996).

Economic Impact

Australia's feral goats occupy about 1.21 million square kilometres, mostly in the semi-arid and arid lands used for pastoral farming of sheep. Bomford and Hart (2002) cited studies suggesting that feral goats inflict production losses in the order of $20 million per year, while Sloane *et al.* (1988) estimated that feral goats cost the Australian wool industry $3 million per year in production loss costs. In this analysis it is estimated that the cattle and sheep industry suffer production losses from feral goat competition in the order of $4 million per annum.

Table 15: Annual Cost Impact of Feral Goats

Cost Component	Control $A million	Loss $A million	Total $A million
Agricultural Production [a]			
Sheep Production Loss	-	1.85	1.85
Cattle Production Loss	-	2.39	2.39
Management Cost [b]	2.00	-	2.00
Research Cost [c]	1.50	-	1.50
TOTAL COST	3.50	4.23	7.74

(a): Agricultural production losses are included in this cost component. The gross margin per sheep or head of cattle sold is multiplied by the numbers in each region and the estimated reduced carrying capacity estimates. ABARE (2003) farm level statistic have been utilised to calculated production loss values
(b): Management cost taken from Bomford and Hart (2002)
(c): Research cost taken from Bomford and Hart (2002)

Feral Goat Management Costs

Bomford and Hart (2002) calculated that governments spend a total of $2 million per year on feral goats control and $1.5 million on research.

Impact on grazing industries

Feral goats compete with sheep in semi-arid areas for feed. The extent of this overlap varies between habitats. Assumptions relating to the impact of feral goats across differing production regions used in this cost assessment are provided in the following table, using assumptions outlined in Sloane *et al*. (1988).

Table 16: Goat Agricultural Productivity Costs

Regions [a]	Area Affected (%)[b]	Production Loss (%)[c]	Sheep Grazing ($m)	Cattle Grazing ($m)	Crops ($m)	Total Loss ($m)
Semi Arid	100	1	1.85	2.39	-	4.23
Total			1.85	2.39	-	4.23

(a): See ABARE (2003) for regional definitions. Numbers of livestock, cropping areas and gross margin estimates are outlined in the Appendix. Semi-arid regions defined by Sloane *et al*. (1988) include areas 312, 111, 411 and 512
(b): Estimated that 100% of specified regions are in some way impacted. See Appendix for regional data
(c): Competition with goats is likely to be most intensive in arid areas. Production loss estimates for each region are taken from Sloane *et al*. (1988)

In the case of Henzell's (1989) analysis, each feral goat was estimated to cost the sheep industry $8.15 per head, or a total of about $18 million per year. This estimate included the potential sale of wild goats. As previously noted, Sloane *et al* (1988) estimated a production loss cost of $3 million per year in the wool industry.

Environmental Impact

Feral goats damage vegetation, soils, and native fauna in the large areas of pastoral land that are overgrazed (Environment Australia 1999). Feral goats contribute to land degradation through damaging soil structure and exposing it to erosion (Braysher 1993). They deplete the soil's protective cover of vegetation and break-up the soil crust with their hooves (Braysher 1993). In the Endangered Species Protection Act 1992, the Commonwealth Government has listed 'competition and land degradation by feral goats' as a 'Key Threatening Process' to the survival of native species. Table 17 summarises flora and fauna under threat as a result of feral goats.

Table 17: Flora and Fauna Species threatened by Feral Goats

	Known Threat	Perceived Threat
Fauna	■ *Leipoa ocellata* Malleefowl	■ *Petrogale lateralis* Black-footed Rock-wallaby ■ *Petrogale penicillata* Brush-tailed Rock-wallaby ■ Petrogale xanthopus Yellow-footed Rock-Wallaby
Flora	■ *Acacia araneosa* ■ *Acacia barattensis* ■ *Cynanchum elegans* ■ *Drakonorchis drakeoides* ■ *Eriocaulon carsonii* ■ *Grevillea beadleana* ■ *Grevillea iaspicula* ■ *Westringia crassifolia*	■ Brachyscome muelleri

Social Impact

Feral goats are a commercial resource, providing employment in rural and regional Australia. About one million goats are mustered each year, mainly for abattoir slaughter (Parkes *et al*, 1996). The gross value to feral goat exporters in 1993 was $29 million. Farmers captured about $6 million annually from feral goat sales, of which about $2 million is spent on mustering costs (Braysher 1993).

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DOGS (*Canis lupus familiaris*) AND DINGOES (*Canis lupus dingo*)

- Wild dog population of Australia comprises of native dingoes (*Canis lupus dingo*) and feral dogs introduced since European settlement (*C. l. familiaris*)
- Wild dogs cause substantial losses in the agricultural and grazing sectors through predation of young and adult livestock. Production losses are valued at $48.3 million per year
- Considerable resources are spent maintaining a dingo fence – estimated to cost $10 million per annum.

History

The wild dog population of Australia comprises of native dingoes (*Canis lupus dingo*) and feral dogs introduced since European settlement (*C. l. familiaris*), and hybrids of the two sub-species. Both dingoes and dogs are derived from wolves (*Canis lupus*). Dingoes were brought to Australia approximately 4000 years ago by the Aboriginal people, who used them for food, companions, hunting-aids and bed-warmers. The dingo never reached Tasmania. Domestic dogs were brought into Australia by Europeans in 1788 and abandonment, neglect, loss or deliberate release has seen the continued establishment of wild populations since.

Dingoes and other wild dogs are widely distributed throughout the country and are present in most environments. Hybridisation between the subspecies over that time has resulted in a lesser proportion of pure dingoes, especially in south-eastern Australia.

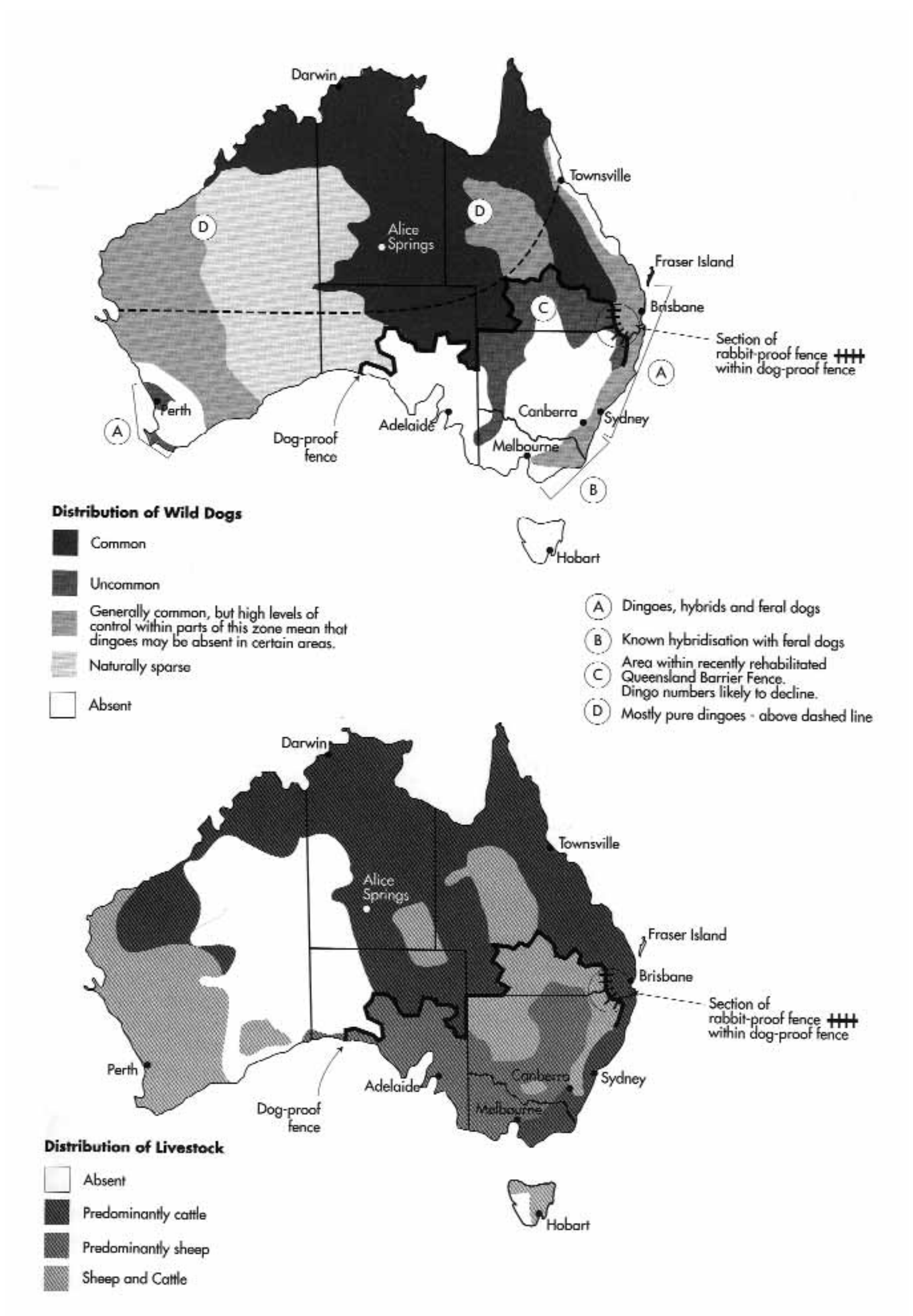
Despite their perceived threats to the livestock industry, there are growing efforts to preserve the population of pure dingoes. Pure dingoes, smaller in size than their feral dogs counterpart, are coming under threat because of their slower breeding patterns and through hybridisation. Under State and Territory legislations, dingoes are in fact conserved and protected as a native species in areas where they pose no threats to livestock. Some research suggests at current rate of hybridisation, pure dingoes may become extinct by 2100 (Fleming *et al*. 2001).

Distribution

Prior to European settlement, dingoes occurred throughout the mainland. Human control since then has effectively shaped the geographic distribution and concentration of wild dogs. Population management programs, including erection of barrier fences, mean they are largely excluded from agricultural regions in South-eastern Australia and areas surrounding Perth. Whilst pure dingoes populate throughout the mainland, hybrid and wild-living domestic breeds dominate in the coastal regions (Fleming *et al*. 2001).

Wild dogs' elusive and nocturnal habits make it difficult to precisely estimate the size of wild dog populations. Instead, researchers seek to identify the change in the population density and prevalence through measuring frequency of visits to bait stations and aerial sightings. Estimates of population density in New South Wales, for example, range from 0.1 to 0.3 wild dogs per square kilometre (Fleming *et al*. 2001)

Figure 8: Distribution of Wild Dogs (Courtesy BRS)



Economic Impact

Wild dogs cause substantial losses in the agricultural and grazing sectors, even though cattle and other livestock may constitute only a small proportion of wild dogs' diet.

Table 18: Annual Cost Impact of Wild Dogs

Cost Component	Control $A million	Loss $A million	Total $A million
Agricultural Production [a]			
Sheep Production Loss a	-	15.90	15.90
Cattle Production Loss b	-	32.40	32.40
Management Cost [b]	6.50	-	6.50
Fencing cost [c]	10.00	-	10.00
Research Cost [d]	1.50	-	1.50
TOTAL COST	18.00	48.30	66.30

(a): Assumed 0.5% of all sheep (71.2 million) are taken by dogs at a cost of $30 per head. Range of studies in Fleming *et al* (2001) by NERDA (1966), Schaefer (1981), Fleming and Korn (1989) and Fleming (Unpublished) indicate dog predation losses of 0.8-1.33%. Conservative loss estimate included for all of Australia. In total, ABARE (2003) estimate 5.4 million sheep deaths in 2003. Given the assumptions used in this analysis, dogs account for 16% of deaths.

(b): Calves are most susceptible to dog predation (Fleming *et al*. 2001). Eldridge and Bryan (1995) estimated between 1.6-7.1% of calves in the Northern Territory subject to dog predation. For the whole of Australia it is assumed that 1% of calves are killed by dogs. Using a per head value of $540 (Eldridge and Bryan, 1995) and about 6 million calves in Australia (ABS, 2003), a total calf cost of $32.4 million per year is estimated.

(c): Management cost for government and landholders, along with fence costs taken from Bomford and Hart (2002)

(d): Research cost taken from Bomford and Hart (2002)

Livestock Losses

Agricultural losses are derived from attacks and harassment of livestock, costs associated with control programs and decisions to leave empty vulnerable areas that would otherwise be suitable for grazing. For example, it is common for farmers to reduce their sheep holdings or substitute them for cattle because of vulnerabilities to wild dog attacks (Backholer 1986). Even with active management programs in place, surveys suggest wild dogs cause approximately one percent loss in sheep numbers (Fleming *et al*. 2001). A 1995 study even suggests cattle predation by wild dogs costs each Northern Territory pastoral property an average of $89,000 p.a. (Eldridge and Bryan 1995).

Wild Dog Management Costs

Around $16.5 million per year is spent by the public sector on extensive wild dog population management programs, including $10 million building and maintaining barrier fencing. A further $1.5 million dollars is invested in research.

Environmental Impact

There appears to be no firm consensus view on the biodiversity and environmental impact of wild dogs. Unlike other introduced species of wild animals, dingoes have been integrated into established predator-prey relationships and may play a constructive ecological role of regulating the population of certain native faunas. The controlling influence of wild dogs on marsupials and emus numbers is demonstrated by the difference in their prevalence across the two sides of the barrier fencing (Pople *et al*. 2000). Nevertheless, predation by wild dogs is believed to pose threats to remnant populations of endangered fauna, but likely to have only limited effect on more established species (Robertshaw and Harden 1989).

The negative impact wild dogs have on native fauna may also be countered by their effects on other introduced species of predators; in particular foxes, feral cats and feral pigs. Some have argued the removal of wild dogs will increase the fox population size (Denny 1992, Burbidge and McKenzie 1989), although there is little general evidence supporting this proposition. Instead, experience from the 1960 to 70's suggests the presence of wild dogs contributed to the demise of foxes and feral cats during drought periods. This is due to the latter species being starved of their usual diet of small marsupials and rats, whilst wild dogs monopolise the available cattle and kangaroo carcasses.

Apart from predation on native species, wild dogs may also be valuable in controlling the population of introduced pest species. There have been a number of studies confirming wild dogs' effectiveness in eliminating significant numbers of wild goats, rabbits and rodents (Corbett and Newsome 1987). The impact on smaller pests such as rats is especially pronounced during drought periods as wild dogs switch their diets away from larger mammals.

Social Impact

Unlike some other species of wild animals, there are few established avenues of exploiting wild dogs as a commercial resource. Trade in skins and pelts are heavily restricted under State and Territory legislation whilst the Commonwealth prohibits export of wildlife products. Instead, dingoes may be of indirect value to the tourism industry both as a native wildlife symbol and targets of recreational hunters. Moreover, there are some moves by certain breeding societies to treat and trade dingoes as pets. Dingoes' potential status as domestic pets have been recognised under NSW legislation. These developments add to the commonly held belief that dingoes carry intrinsic iconic value that is not susceptible to monetary measurements.

The 'Fraser Island' Dingo is believed to be the purest strain of dingo in Australia. They have become accustomed to the presence of locals and tourists on this sand island. In recent years dingoes have attacked a German tourist and a young boy was attacked and killed in April 2001. The two dingoes responsible were promptly killed, but tourism may have suffered as a result of these attacks. Dogs also vector rabies, and therefore, have public health impacts.

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FERAL CAMELS (*Camelus dromedaries*)

- There are approximately 200 000 camels in Australia – with 100 000 being in Western Australia
- Most beef cattle producers in Central Australia regard camels as a pest species, principally because bull camels damage fences during the rutting season and compete with livestock for forage
- Approximately 49 tonnes of camel meat with an average wholesale value of $250 000 is processed annually for the export market

History

Of the world's 19 million camels (FAO 1998), the majority are found in the tropics and there are significant numbers in sub-Saharan Africa. The Arabian camel (Dromedary) has one–hump and is generally found in Pakistan, India, North Africa, the Middle East and some parts of Australia and Russia.

Camels were first introduced into Australia in the 1840's to assist in the exploration of inland Australia. Between 1840 and 1907, between 10,000 and 20,000 camels were imported from India with an estimated 50-65% landed in South Australia. It is not know when the first feral population established but some escaped during the Burke and Wills expedition in 1860. The feral animal population increased substantially after the 1920's when trucks became the widespread form of transport.

Distribution

Australia may now have the largest wild population of camels. They occupy most of Australia's desert country including the Great Sandy, Gibson, Great Victoria and Simpson deserts, as well as much of the semi-desert lands. There were approximately 200 000 camels in Australia in 1993 and the population of is expanding rapidly (McCloy and Rowe 2000). In 2003 the Australian feral camel population was estimated to be in the order of 300,000. Short *et al*. (1988) estimate the camel now ranges across 2.8 million km2, or 37% of the Australian mainland.

Camels in Australia are of the Dromedary (one–hump) species. Camels range in pastoral land in arid and semi-arid Australia, with pastoral areas dominated by Acacia trees and shrubs are particularly well suited to camel grazing.

Economic Impact

In times of scare forage camels are likely to compete for herbage with sheep and cattle. This competition inflicts a cost of Australian grazing industries. The species, does however, have commercial use value. An industry for meat production from central Australian camels began in the early 1990's. Within the Northern Territory, minimal pastoral activity is observed in areas habited by feral camels (Edwards *et al*. 2001).

Table 19: Annual Cost Impact of Camels

Cost Component	Control $A million	Loss $A million	Total $A million
Agricultural Production [a]			
Sheep Production Loss	-	0.05	0.05
Cattle Production Loss	-	0.16	0.16
Management Cost [b]	-	-	-
Research Cost [c]	-	-	-
SUB TOTAL	-	0.21	0.21

(a): See ABARE (2003) for regional definitions. Numbers of livestock, cropping areas and gross margin estimates are outlined in the Appendix. Regions includes 511, 711 and 411
(b): Management cost assumed to be insignificant
(c): Research cost assumed to be insignificant

Competition with Grazing Industries

Research in Central Australia (Dörges and Heucke 1995) has shown that camels and cattle have differing dietary preferences. Camels spend up to 97% of their grazing time feeding on shrubs and forbs. Grasses were only of importance after rain before forbs became available. Because camels and cattle have different dietary preferences, co-grazing them under careful management is a possibility. Indeed, evidence from pastoralists with camels on their stations suggests that cattle perform better under drought conditions when grazed in paddocks with camels, whilst there is no difference in cattle performance under good seasonal conditions. This is thought to be possibly due to a combination of rumen microbe transfer (Miller *et al.* 1996).

Table 20: Camel Agricultural Productivity Costs

Regions [a]	Area Affected (%)[b]	Production Loss (%)[c]	Sheep Grazing ($m)	Cattle Grazing ($m)	Crops ($m)	Total Loss ($m)
Semi Arid	5	1	0.05	0.16	-	0.21
Total			0.05	0.16	-	0.21

(a): See ABARE (2003) for regional definitions. Numbers of livestock, cropping areas and gross margin estimates are outlined in the Appendix. Semi-arid regions defined by Sloane *et al.* (1988) include areas 312, 111, 411 and 512
(b): Estimated that 100% of specified regions are in some way impacted
(c): Competition with camels is likely to be most intensive in arid areas.

There are some dietary overlaps between cattle and camels for preferred tree, shrub and herbage species and for grass at certain times (Dörges and Heucke 1995). To account for this overlap, a minor reduction in cattle and sheep carrying capacity has been included in the costing analysis. The assumptions used are provided in the table above. Aggregate production losses are minor, and the possibility for enhancing production also exists.

Camel Management Costs

No information on the costs of camel management and research were found when compiling this report.

Commercial Resource

The Australian camel industry has live export markets to Brunei and Malaysia. The Central Australian Camel Industry Association (CACIA) conducts camel slaughtering and camel meat marketing. It has been slaughtering around 300 camels per year since 1995, which represents approximately 49 tonnes of camel meat with an average wholesale value of $250 000.

Environmental Impact

Bomford and Hart (2002) indicated that browsing by camels may deplete shelter and refuge availability for desert mammals. Camel grazing can also have deleterious effects on native vegetation, particularly some rare and threatened species (Dörges and Heucke 1995).

Social Impact

The industry provides employment for small numbers of people in remote parts of WA, NT and SA, as cattle station employees trap and shoot camels. Limited numbers are also involved in meat processing and exporting.

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CANE TOADS (*Bufo marinus*)

- Cane toads were introduced from Hawaii to Australia in 1935, to control scarab beetles that are pests of sugar cane
- Range from Kakadu National Park in the Northern Territory through to the New South Wales coast as far south as Yamba
- The main controls on the spread of Cane Toads in southern Australia are quarantine checks and public awareness and response
- A decline in quoll numbers and native frogs in areas where large numbers of cane toads are found has been recorded.
- All stages of the Cane Toad's life-cycle are poisonous

History

The cane toad has a natural range in Central and tropical South America. 101 cane toads from Hawaii were deliberately released at Gordonvale, Queensland in 1935 by the Australian Bureau of Sugar Experimental Stations as a biological control for French's Cane Beetle and the Greyback Cane Beetle, which are major pests of sugar cane.

Distribution

Figure 9: Distribution of Cane Toads

(Source: Sutherst *et al.* 1995, Van Dam *et al.* 2002)

The natural range of Cane Toads extends from the southern United States to tropical South America. They were deliberately introduced from Hawaii to Australia in 1935. Since then, the cane toads have spread rapidly – south into New South Wales, with one isolated community in Port Macquarie, and west into the Northern Territory. In March 2001 they reached the wetlands of heritage-listed Kakadu National Park. The species is observed in the eastern and northern parts of Queensland and through to Kakadu National Park in the Northern Territory. Within New South Wales, they occur on the coast as far south as Yamba. A lack of natural predators and favourable environmental conditions, have aided the cane toad in its colonisation in Australia. The toad is predicted to increase its geographic range throughout coastal and near-coastal regions of northern Australia to encompass an area of approximately 2 million km^2 (Sutherst *et al*. 1995).

Economic Impact

Cane toads have no direct impact on agriculture, but a considerable amount of resources are targeted at finding biological controls. Scientists at CSIRO research bio control methods, while staff at the University of Adelaide have isolated a sex pheromone that may be of value. Current cost impacts of the toad are outlined below.

Table 21: Annual Cost Impact of Cane Toads

Cost Component	Control $A million	Loss $A million	Total $A million
Research Cost [a]	0.50	-	0.50
TOTAL COST	0.50	-	0.50

(a): Research cost taken from Bomford and Hart (2002)

Cane Toad Management Costs

The main controls on the spread of Cane Toads in southern Australia are quarantine checks and public awareness and response. Research into cane toads costs around $0.5 million every year, however no estimates of the costs of management were found.

Environmental Impact

Australian native fauna that have been killed by cane toads include Goannas, Freshwater Crocodiles, Tiger Snakes, Red-bellied Black Snakes, Death Adders, Dingoes and Northern Quolls. There is some evidence of the environmental impacts of cane toads. Populations of Northern Quoll, *D. hallucatus*, have seriously declined in Queensland following colonisation by cane toads (Burnett 1997). These quoll populations have not recovered in the past 10 years, therefore cane toads impact on quolls is likely to be a long-term phenomena (Burnett 1997, in Glanznig, 2003).

Social Impact

All stages of the cane toad's life-cycle are poisonous. The venom produced by the parotoid glands acts principally on the heart. No humans have died in Australia from Cane Toad poisoning. Cane Toads are also poisonous to pets and in Hawaii up to 50 dogs a year have died after mouthing Cane Toads. The introduction of cane toads into traditional Aboriginal areas, such as Kakadu, may result in the decline in dingo, snake and crocodile numbers – threatening the nomadic hunter and gatherer lifestyle.

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WILD HORSES (*Equus caballus*)

- Australia has an estimated 300,000 feral horses, mainly in central and northern Australia
- Feral horses have limited impact on agricultural industries
- The brumby is a symbol of Australian identity
- Public concerns over humane measures of control have arisen

History

Horses were introduced in Australia with European settlement. Over time, animals escaped and were released and were first recognised as pests in Australia in the 1860's.

Distribution

In 1992 feral horse numbers in Australia were estimated at 300,000. Most feral horses occur in the extensive cattle production areas of the Northern Territory and Queensland, as well as in some areas of Western Australia and South Australia. Smaller, scattered populations occur in alpine and sub-alpine regions of eastern Australia in New South Wales and Victoria.

Density of feral horses can vary greatly and is dependent on factors such as management programs, climate, and incidence of bush fires.

Economic Impact

Research costs are the major cost associated with this species. Key economic impacts include:

Table 22: Annual Cost Impact of Wild Horses

Cost Component	Control $A million	Loss $A million	Total $A million
Research Cost [a]	0.50	-	0.50
TOTAL COST	0.50	-	0.50

(a): Research cost consultant estimate based on those for other species in Bomford and Hart (2002)

Wild Horse Management Costs

There are a range of control methods which include (English 2000):

- Immobilisation using drugs delivered by dart rifle – suitable only for small groups that can be closely approached, and not without risk to the horses.
- Mustering and trapping – feasible under some circumstances but not without animal welfare concerns, especially in the transport of the animals after capture.
- Ground shooting – appropriate in open country, but very difficult in rough terrain, especially in following up wounded horses.

- Shooting from helicopters – considered by the Senate Standing Committee on Agriculture (Model Code of Practice for the destruction or capture, handling and marketing of feral livestock animals 1991) to be the only practical method for quick, large-scale and humane culling of large animals in inaccessible locations.

Although these management processes are well documented, no current estimates of annual expenditure on wild horse management were found.

Environmental Impact

Scientists have found that feral horses can damage native environments by increasing soil erosion, killing vegetation, disturbing the soil and destroying native plants along frequently used routes, trampling and fouling waterholes, collapsing wildlife burrows, spreading weeds through their dung and hair, and competing with native animals for food and shelter (Berman and Jarman 1988, Dyring 1990).

Social Impact

Wild horses are regarded as a national symbol by many Australians and the subject of bush folk lore. Inhumane management of wild horses has received wide media attention in Australia. Habitation of wild horses in the highland areas of the NSW and Victorian border regions may be a source of eco tourism and employment of people in these regional areas.

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FERAL CATS (*Felis catus*)

- There are approximately 21 million feral and domestic cats in Australia
- Feral cat predation has a major impact on native fauna abundance
- 19 species of endangered mammals are under threat from feral cats
- Feral and domestic cats are estimated to inflict $144 million in losses mainly through bird predation each year
- Cats are carriers of toxoplasmosis.

History

Cats have long been associated with humans and have been distributed throughout most of the available habitats in the world, including many uninhabited islands. European settlers first brought them to Australia during the 18th century. However, cats may have arrived earlier via the trading routes from south-east Asia, shipwrecks or visits by European ships, especially on Australia's west coast.

In addition to the escape of domestic cats into the wild, cats were deliberately released in Australia during the 19th century, in a misguided attempt to control rabbits, rats and mice. Feral cats were established in the wild by the 1850s and are now widespread throughout Australia, ranging from the tropics to southern oceanic islands such as Macquarie Island from where they were recently eradicated.

Distribution

Figure 10: Range of Feral Cats

Feral cats are widely distributed across mainland Australia, Tasmania and on many offshore islands. They can survive in dry conditions because they are predominantly nocturnal and can utilise the moisture from their diet. Pimentel *et al*. (2001) indicated that there are approximately 3 million pet cats and 18 million feral cats in Australia. The distribution across Australia is outlined in the Figure 10.

Economic Impact

Cats do not impose an economic cost on agriculture, but resources are targeted at controlling cat numbers and the pursuit of cat-related research. These costs are provided in the following table.

Table 23: Annual Cost Impact of Feral Cats

Cost Component	Control $A million	Loss $A million	Total $A million
Management Cost [a]	1.00	-	1.00
Research Cost [b]	1.00	-	1.00
Environmental Cost [c]	-	144.00	144.00
SUB TOTAL	2.00	144.00	146.00

(a): Taken from Bomford and Hart (2002)
(b): Taken from Bomford and Hart (2002)
(c): Assumes 18 million cats, kill eight birds per year valued at $1 per bird (derived from Pimentel *et al.* 2000)

Feral Cat Management Costs

Bomford and Hart (2002) estimated that $1 million is spent by the public sector each year to control cats. Feral cats have been eradicated from a number of offshore islands using conventional control techniques, but control is labour intensive, as feral cats can be quite trap shy, do not take baits readily and generally avoid human contact, making them difficult to shoot. Barrier fencing has proved to be the most effective current control technique for feral cats (Coman and McCutchan 1994). Unfortunately, the high cost of fencing makes this technique useful only for small areas of land.

Recreational shooters kill feral cats, however the magnitude of the impact on feral cat or prey populations is unknown. (Biodiversity Group 1999). Baiting is usually the cheapest and most effective broadscale technique but is much less effective than techniques for baiting dogs and foxes (Short *et al.* 1997). Baiting feral cats is difficult as they are often found in low densities, can have large home ranges, are disinclined to feed on carrion except during drought or during food shortages, and are naturally wary.

Exclusion fences are a possible way of minimising predation on threatened species of native animals. There is private expenditure on exclusion in Australia (for example, Australian Wildlife Conservancy), which helps to reduce fox, cat and dig predation. The cost of fencing maybe as high as $18,000-55,000 per km. Correspondingly, a review of fence designs (Coman and McCutchan 1994) outlined the need for a comprehensive evaluation of the cost-effectiveness of different fence designs (Biodiversity Group 1999).

Environmental Impact

Feral cats generally eat small mammals, but can also eat birds, reptiles and insects. In pastoral regions in Australia, young rabbits make up the majority of their diet. Determining the impact of feral cats on native wildlife on the Australian mainland is more difficult. It is complicated by other factors such as introduced herbivores like rabbits competing with native animals for food and shelter, and habitat loss caused by clearing, grazing animals and urban development.

When valuing the impact of feral cats in the USA, Pimentel *et al.* (2000) estimated the cost of each bird taken by a cat. A cost per bird killed of $US 30 was used as a proxy because each bird watcher spends $0.4 per bird observed (USFWS, 1988), a hunter spends $216 per bird shot (USFWS 1988) and an ornithologist spends $800 per bird reared for release. Australians would also place a value on each bird eaten by a feral cat, but this value is possibly only likely to become significant when species are threatened or feral cat populations reduce the probability of bird watchers seeing certain species. Surveys outlined in the overview indicated a willingness to pay for biodiversity conservation and, correspondingly, a value of $1 per bird killed is included in the cost impact. Corresponding with the Pimentel *et al*. (2000) analysis, it is estimated that each cat kills eight birds per year.

Like foxes, the environmental impact inflicted by feral cats could be far more acute than a calculation of bird predation when threats to endangered species are factored into the calculation. To provide an indication of the range of species threatened by cats, Table 24 is provided, which outlines key mammal, reptile and bird species that are threatened (from the national abatement plan) by feral cats.

Table 24: Fauna Species Threatened by Feral Cats

Known Threat	Perceived Threat
■ *Cyanoramphus novaezelandiae cookie*, Norfolk Island Parrot ■ *Sterna albifrons*, Little Tern ■ *Lagorchestes hirsutus*, Rufous Hare-wallaby ■ *Leporillus conditor*, Greater Stick-nest Rat ■ *Macrotis lagotis*, Greater Bilby ■ *Myrmecobius fasciatus,* Numbat ■ *Perameles gunnii*, Eastern Barred Bandicoot	■ *Litoria aurea*, Green and Golden Bell Frog ■ *Philoria frosti*, Baw Baw Frog ■ *Geopsittacus occidentalis*, Night Parrot ■ *Lathamus discolour*, Swift Parrot ■ *Leipoa ocellata*, Malleefowl ■ *Neophema chrysogaster,* Orange-bellied Parrot ■ *Ninox novaeseelandiae undulate,* Norfolk Island Boobook Owl ■ *Pezoporus wallicus flaviventris*, Western Ground Parrot ■ *Stipiturus malachurus intermedius,* Mount Lofty Southern Emu-wren ■ *Turnix melanogaster*, Black-breasted Button-quail ■ *Bettongia lesueur*, Burrowing Bettong ■ *Dasyurus maculatus gracilis* ■ *Isoodon auratus,* Golden Bandicoot ■ *Petaurus gracilis*, Mahogany Glider ■ *Burramys parvus*, Mountain Pygmy-possum ■ *Crocidura tenuata var. trichura,* Christmas Island Shrew ■ *Dasyuroides byrnei,* Kowari ■ *Lasiorhinus krefftii,* Northern Hairy-nosed Wombat ■ *Onychogalea fraenata*, Bridled Nailtail Wallaby ■ *Parantechinus apicalis,* Dibbler ■ *Petrogale lateralis,* Black-footed Rock-wallaby ■ *Petrogale penicillata,* Brush-tailed Rock-wallaby

Table 24: Fauna Species Threatened by Feral Cats (Continued)

Known Threat	Perceived Threat
	■ *Petrogale Persephone*, Proserpine Rock-wallaby ■ *Potorous longipes*, Long-footed Potoroo ■ *Potorous tridactylus gilberti,* Gilbert's Potoroo ■ *Pseudomys fieldi,* Djoongari ■ *Pseudomys oralis*, Hastings River Mouse ■ *Zyzomys pedunculatus,* Central Rock-rat ■ Delma impar ■ Striped Legless Lizard

Social Impact

Feral cats vector diseases including toxoplasmosis and sarcosporidiosis. These diseases can be transmitted to native animals, domestic livestock and humans. In people, toxoplasmosis can also cause debilitation, miscarriage in pregnant women and congenital birth defects. If rabies were to be accidentally introduced into Australia the potential for feral cats to act as carriers would be high.

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KANGAROO

- The kangaroo has substantial tourism, commercial resource use and national identity value, along with inflicting costs on rural industries and motorists
- Reduced livestock carrying capacity, fence maintenance, traffic accidents and crop damage estimated to be $76 million per year
- Commercial use of kangaroo skins and meat generates annual revenue of $200 million per year
- Some kangaroo species may have increased in number as a result of changed land use – displacing other native species

History

There are 48 species of kangaroo found in Australia. The most abundant species include red and grey kangaroos (*Macorpus rufus, M. giganteus* and *M. fuliginosus*) and Euros and Wallaroos (*Macorpus robustus*). These species are common in sheep and cattle grazing areas and are commercially harvested.

Whether the native kangaroo is indeed a pest or not is a hotly debated topic. Within grazing areas kangaroos compete with sheep and cattle for forage and damage crops and fences (Gibson and Young 1987, Sloane *et al*. 1988). Given the need to manage rangelands sustainably, Kangaroo Management Plans were introduced on a state-by-state basis to regulate the commercial harvesting of these species.

Distribution

Eastern grey kangaroos are found down the east coast where annual rainfall is greater than 250 mm (Caughley *et al.* 1987). This distribution includes all of Queensland (except western Cape York), New South Wales, Victoria and north-eastern Tasmania. The western grey kangaroo occurs across the south of the continent, with a distribution extending northwards through western New South Wales and into a small area of southern central Queensland (Pople and Grigg 1999). The highest densities of this species are in central NSW around Cobar and Hillston.

In 2002 it was estimated that there were 58.6 million kangaroos of commercially harvested species. The highest densities were within the sheep pastoral zone, where approximately 15% of the national flock are found. Densities of red kangaroos are lower outside the 'Dingo fence' because of the presence of dingoes. Red kangaroos occur across the continent west of the Great Dividing Range, but excluding Cape York, Arnhem Land, the Kimberley region, the south-west corner and Tasmania (Pople and Grigg 1999).

Economic Impact

Kangaroos compete with sheep and cattle for fodder inflicting a cost on these industries. These economic impacts are described in the following section.

Table 25: Annual Cost Impact of Kangaroo

Cost Component	Control $A million	Loss $A million	Total $A million
Agricultural Production [a]			
Sheep Production Loss	-	7.46	7.46
Cattle Production Loss	-	8.12	8.12
Cropping Industries	-	11.90	11.90
Fencing Cost [b]	16.70	-	16.70
Traffic Accident Cost [c]	-	30.00	30.00
Research Cost [d]	2.00	-	2.00
TOTAL COST	18.70	57.48	76.18

(a): Agricultural production losses are included in this cost component. The gross margin per sheep or head of cattle sold is multiplied by the numbers in each region and the estimated reduced carrying capacity estimates. ABARE (2003) farm level statistic have been utilised to calculated production loss values

(b): An average fence damage cost of $0.2 per head shorn or head of cattle sold is used to calculated additional fencing costs imposed by this species. This estimate is a consultant estimate derived from Gibson and Young (1987)

(c): Assumed 5,000 kangaroo-related accidents pear year nationally at a cost of $6,000 per accident.

(d): Consultant estimate assuming there are 10 full time scientists involved in kangaroo research, at a cost of $0.2 m per scientist per year (includes support staff and other overheads)

Competition with Sheep and Cattle

Competition with grazing sheep and cattle is a large cost associated with the kangaroo. A previously conducted cost assessment and survey of vertebrate pest impacts in the sheep industry (Sloane *et al*. 1988) estimated kangaroos to be by far the biggest constraint on production on the wool industry. Of the $303.5 million per year vertebrate pest cost impact, kangaroos were calculated to inflict $200 million, followed by rabbits $94.5 million and thirdly feral pigs $2.8 million.

Given the large perceived impact of kangaroos on these industries a great deal of research by ecologists has examined the nature of kangaroo diets (e.g. Griffiths and Barker 1966, Wilson 1991, Dawson and Ellis 1994). Results of dietary overlap studies do not point to as acute competition as previous surveys and costings suggest. Correspondingly, reduced carrying capacity estimates, as a result of kangaroo pressure, are used in this costing analysis compared to those previous used in cost assessments.

Table 26: Kangaroo Agricultural Productivity Costs

Regions [a]	Area Affected (%)[b]	Production Loss (%)[c]	Sheep Grazing ($m)	Cattle Grazing ($m)	Crops ($m)	Total Loss ($m)
Arid	100	1.0	1.21	1.62	0.77	3.60
Sheep-Pastoral	100	0.5	6.24	6.50	11.13	23.88
Total			**7.46**	**8.12**	**11.90**	**27.48**

(a): See ABARE (2003) for regional definitions. Numbers of livestock, cropping areas and gross margin estimates are outlined in the Appendix. Arid regions includes areas 111, 312, 411, 512, 511, 711 while pastoral includes 121, 122, 123, 221, 222, 313, 314, 421, 422, 522, 712, 713.

(b): Estimated that 100% of specified regions are in some way impacted

(c): Competition between sheep and kangaroos is likely to be most intensive in arid areas, therefore 1% reduced carrying capacity is assumed for these regions. A lower impact of 0.5% is assumed for pastoral regions. Crop yields in broad-acre cropping areas are assumed to be reduced by 0.2%.

There is limited evidence of competition above the very low pasture biomass of 50-60 g/m^2, whereas the presence of kangaroos reduced the liveweight of sheep at pastures below that threshold. An investigation by Wilson (1991) on the Darling River suggested direct competition between sheep and kangaroos. To reflect the possibility of greater competition under lower fodder biomass, the reduction in carrying capacity is estimated to be greater in the arid regions. These various assumptions are provided in the table above, along with the costs of repairing fences as a result of perceived kangaroo damage, taken from farmer surveys in Gibson and Young (1987).

Kangaroo Management Costs

Each year around $2 million is spent on research into kangaroo management, however no estimate of the total cost of managing kangaroos was found.

Environmental Impact

The kangaroo could threaten rare species in the absence of commercial culling. Since establishment of the pastoral zone with European settlement, the numbers of major species have increased. Trials have suggested that an uncontrolled kangaroo populations threaten a huge range of biodiversity (Caughley *et al*. 1987). This has been observed during research at Hattah-Kulkyne National Park where monitoring following commercial harvesting observed increased abundance of 20 rare or threatened plant species in culled areas when compared with unculled areas (Pople and Grigg 1999).

Social Impact

In addition to commercial usage value for meat and skins, the kangaroo has national tourism value, but does cause traffic accidents. These social values are outlined, with accident cost being quantified and included in the cost assessment.

National Tourist Symbol

It is very difficult to value kangaroos' contribution to Australia's tourism industry. However, the value would be very high. The economic value of inbound tourism to Australia was $16.1 billion in 1996 (14.5% of export earnings, Marsupial CRC 2000). Of these tourists, 22% were thought to travel to Australia because of unique wildlife and 11% indicated they would not visit this country without it. Thus, wildlife contributes between $1.8 and $3.5 billion of inbound tourist expenditure, which amounts to employment for between 14,700 and 29,500 people (Marsupial CRC 2000).

Kangaroo Industry

The use of kangaroos for skins and meat for pet food has been the focus of the commercial use of kangaroos (Corrigan 1988). Kangaroos are commercially culled under approved management initiated since the 1970s. More than half of the kangaroos shot commercially in Australia each year are used for their hides only, so meat production could be increased without more kangaroos being killed (Pople and Grigg 1999). In the event that all meat was used Switala (1995) estimated the availability of 55,000 tonnes of meat. Using a price of $3–6 per kilogram, Switala (1995) calculated that this potential tonnage represented a meat industry with a potential value of $171–341 million. At present, the kangaroo industry generates annual revenue of $200 million and employs some 4,000 people, primarily in remote and regional areas (equivalent to 6-7,000 jobs in cities). (Marsupial CRC 2000)

Road Accidents

Kangaroos are a leading cause of animal-related traffic accidents and resulting repair, injury and absence from work related costs for those involved with incidents. There is limited information relating to the magnitude of kangaroo accident costs. The RACV in Victoria, receives about 1,000 claims/year and $2 million in claims due to accidents involving motor vehicles and animals.

National road accident databases (see Australian Transport Safety Bureau (2000), Bureau of Transport Economics (2000)) recorded 1392 crashes over an eight-year period resulting in hospitalisation after animals were hit. Nationally, this represents 1.0% of all hospitalisation crashes in this time period.

The NRMA. reported 11,000 claims nationally for animal-related accidents over the last 12 months (NRMA 2003). Kangaroos, dogs and cows were the species involved in most incidents. Traffic accidents can entail a wide range of costs which include vehicle repair, legal costs, medical expenses, insurance costs and long term care, lost labour for carers and travel delay costs in the cases of serious accidents. The cost per crash was estimated by the Bureau of Transport Economics (2000) to vary from $1.65 million in the case of a fatality to $5,808 for a minor incident. Given the low number of animal-related accidents causing serious injury, an average per incident cost of $6,000 was assumed and 5,000 kangaroo-related accidents were estimated to occur per year in the costing assessment. The aggregate cost of this item was estimated to be $30 million per year.

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CONCLUSIONS

- The total annual cost of the 11 species included in the cost assessment was $720 million per year
- Of this total, foxes, rabbits, feral pigs and feral cats accounted for 83% of all costs
- An introduction of an exotic pest, such as the Stoat *Mustela erminea* could generates economic losses of $39 million per year
- Costs alone do not justify research expenditure. Investment needs to assessed in the context of it's ability to reduce pest impact.

Summary of Results

Annual cost values include control and production loss estimates. Major environmental and social impacts are discussed for each pest in qualitative and quantitative terms were possible based on international literature and were quantified for feral cats and carp. The aggregate annual cost impacts for each species are provided in the following table.

Table 27: Annual Impact of Pest Species (order of cost)

		Triple Bottom Line Impact					
	Total	Economic		Environmental		Social	
	$m	Impact	$m	Impact	$m	Impact	$m
Fox	227.5	◆ (bigger)	37.5	◆ (bigger)	190.0	◆	nq
Feral Cats	146.0	◆	2.0	◆ (bigger)	144.0	◆	nq
Rabbit	113.1	◆ (bigger)	113.1	◆	nq	◆	nq
Feral Pigs	106.5	◆ (bigger)	106.5	◆	nq	◆	nq
Dogs	66.3	◆ (bigger)	66.3	◆	nq	◆	nq
Mouse	35.6	◆ (bigger)	35.6	◆	nq	◆ (bigger)	nq
Carp	15.8	◆	4	◆ (bigger)	11.8	◆	nq
Feral Goats	7.7	◆	7.7	◆	nq	◆	nq
Cane Toads	0.5	◆	0.5	◆	nq	◆	nq
Wild Horses	0.5	◆	0.5	◆	nq	◆	nq
Camels	0.3	◆	0.3	◆	nq	◆	nq
Total	**719.7**		**373.9**		**345.8**		

nq = not quantified ◆ = bigger impact ◆ = smaller impact

The total cost of species included in the analysis totalled $720 million per year.

Of the economic impact, feral pigs, rabbits, kangaroos and feral cats were estimated to account for 83% of losses. In the case of estimating the impact of vertebrate pests on the sheep industry, Sloane *et al.* (1988) found that rabbits and kangaroos accounted for the bulk of production losses. Agricultural production loss costs accounted for about half of the losses valued in this assessment.

Potential Impact of New Introduction

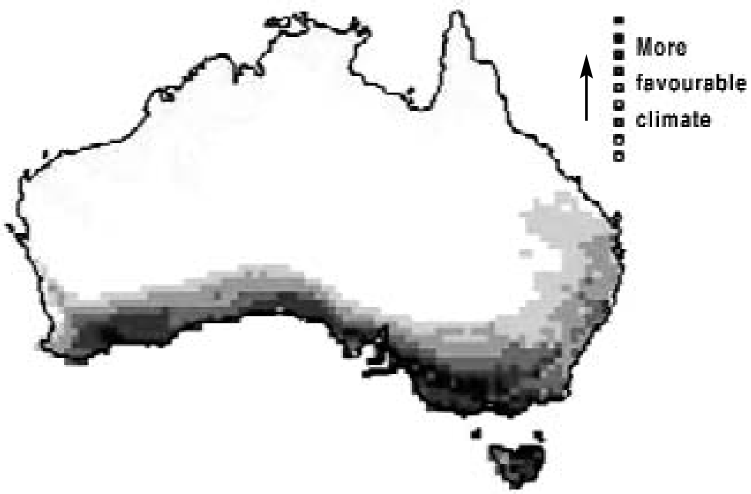
In total, 25 exotic mammals, 20 birds, one amphibian and four reptiles have become established in Australia. Bomford (2003) noted that there a number of factors influencing whether an exotic vertebrate species will become established in Australia. Factors include likelihood of escape or wilful release and whether the species will establish wild populations, whether the vertebrate is a pest elsewhere and the match of Australian and native climates. A vertebrate species that could become established and generate large economic and environmental impact is the Stoat. The potential economic impacts of such an introduction are outlined in the remainder of this section.

Potential Impact of Stoats

Stoats (*Mustela erminea*) are widely distributed in the northern hemisphere and have been introduced into New Zealand. Stoats are native to Great Britain but they come into conflict with man because they are predators of both native and introduced game birds. Stoats inhabit a range of ecotypes governed by the availability of prey. Murphy and King (2004) noted that stoats can be observed from beach to remote mountain country within New Zealand and in forest types including dune land, tussock, grassland and farm lands. The CLIMATE program was used to match the suitability of Australian rangelands with those where stoats are found overseas. Background relating to the software program is provided in Pheloung (1996)

Darker dots represent the most favourable climate types within Australia for stoats. In the figure it is evident that southern Australia is most suitable for stoat development. Given that stoats originated in Great Britain it is not surprising that these areas are most favourable. In terms of climatic suitability, stoats could occupy somewhere in the order of about 30% of the Australian land mass.

Figure 11: Climatic Suitability for Stoats (Courtesy BRS)



The density of stoats varies according to agro-ecology and primarily the availability of prey. Murphy and King (2004) summarised a range of stoat density studies conducted in New Zealand. Densities varied from 2-10 stoats per km^2 but it was noted that densities are difficult to determine as this analysis involves labour-intensive live trapping, sample area definition and a range of assumptions regarding immigration, emigration and catch ability of different species. If the lower bound of density were to be observed in Australia, the total stoat population could be in the order of 4.2 million stoats at saturation of maximum range.

Stoats are opportunist predators. In Britain stoat diet consists principally of rabbits, small rodents and birds. In New Zealand stoats prey mainly on birds, rats (*Rattus* spp.), feral house mice (*Mus musculus*), rabbits and invertebrates, but diet varies greatly according to the habitat they occupy. The average daily meat intake of stoats and a percentage contribution of live birds to the stoat diet in Australia is provided in the table to estimate the off-take of Australian birds as a result of stoat introduction

Assumptions and value	**Source**
Potential range – 2.1 million km^2	From climatic mapping using CLIMATE program (see Pheloung 1996)
Stoat density – 2 per km^2	Derived from a range of studies in New Zealand cited in Murphy and King (2004). Basse *et al.* (1999) suggested the normal range of stoat densities to be 2-10 km^2 in New Zealand
Total Australian potential stoat population – 4.2 million	Derived from density and range assumptions
Food requirement for stoat per day – 50-90 g meat/stoat/day or 22 kg/year	Captive stoats are maintained on this intake per day (Murphy and King 2004)
Live bird off-take by stoats per year – 1.84 million kg	Assumes 2% of feed requirement met by live birds (Consultant estimate).
Number of birds equivalent – 37 million per year	Assumes each native bird weighs somewhere around 50 g
Value of bird predation – $A 37 million per year	Each bird valued at $1 – derived from Pimentel *et al.* (2000) method and studies in Chapter 1

Table 28: Summary of Stoat Biodiversity Impact Assumptions

Based on yearly averages, an adult male requires about 60 g of meat per day. If it is assumed that 2% of per day stoat feed intake is birds, then stoats could account for about 1840 tonnes per year of live bird predation. Converting this volume of off-take by an average bird weight of 50 g, stoats are estimated to account for 37 million bird fatalities per year. This number of birds is converted to a cost value by assuming each bid is valued by the community at $1 and the total value of stoat-bird predation is $37 million per year

Cost Component	**Control $A million**	**Loss $A million**	**Total $A million**
Environmental Cost [a]	-	37.00	37.00
Management Cost [b]	1.00	-	1.00
Research Cost [c]	1.00	-	1.00
SUB TOTAL	2.00	37.00	39.00

Table 29: Potential Annual Impact of Stoats

(a): Assumptions above

(b): Consultant estimate.
(c): Consultant estimate

Vertebrate Pest Management Research

A range of potential R&D directions are currently, and could in the future, be pursued to reduce the economic, social and environmental costs of major vertebrate pests in Australia. These areas are summarised in the following table.

Area	**R&D Direction**
Bait and Toxin Development (canids, pigs, feral cats, pest birds)	New toxins; bait formulation; effectiveness and delivery
Biocontrol	Biocides (rabbits, carp); anti-viral vaccines; fertility control (large herbivores, feral cats)
Virally Vectored Immuno-contraception	product delivery; product safety; VVIC in rats; species-specificity
Ecological Solutions	Interactions between predators and prey; interactions between habitat disturbance and predation; density surveys; evaluating alternative management strategies; evaluating the threat posed by exotic fish species; population dynamics analysis; adaptive management practices
Other Products	Molecular genetic tools; attractants
Economic Assessments	Biodiversity & social costs; commercial harvesting (kangaroos, camels); economics management
Detection and Prevention	Response Strategies; Decision Analysis; disease detection; ethical issues of using GMOs to manage invasive animals

Table 30: Summary of Key Areas for Future Pest R&D

In the field of pest impact assessment, there are also a number of priorities. For example, this study was commissioned to focus on 12 vertebrate species. There are a number of other species which cause impact and include (Bomford, personal communications):

- Pest birds – at least 70 native and nine exotic bird species cause agricultural damage or cause other problems such as damage to aquaculture and fisheries or posing a risk to aircraft (Bomford 1992, 2003, Bomford and Sinclair 2002).
- Rodents – The introduced black rat (*Rattus rattus*) and at least four native species are considered crop pests (Caughley *et al*. 1998). The introduced brown rat (*R. norvegicus*) is not usually considered a significant pest.
- Deer – six species of deer have established exotic populations (Wilson *et al*. 1992). So far they are only minor agricultural pests but their range and abundance is increasing (Moriaty pers. comm.). Deer are also susceptible to a range of livestock diseases.
- Finfish – ten introduced fish species are considered pests and at least 13 additional species have the potential to become future pests (Bomford and Hart 2002).

To estimate the complete cost of vertebrate pests in Australia, impact assessment for each of these species need to be conducted.

Setting Research Priorities

The mere existence of a large social, economic and/or environmental impact does not automatically mean research designed to alleviate the cost imposed by a particular species should be pursued. Research should be assessed in the context of its propensity to reduce the burden of the pest and in terms of the size of the investment. Cost-benefit analysis is a process that compares the benefits against the costs of undertaking research and development projects and can be used to set priorities. The estimation of project benefits is the most critical component of cost-benefit analysis.

The size of the pest impact needs to be considered, scope for the research product to reduce the pest impact assessed, potential industry adoption estimated, and the probability of the project generating tangible industry benefits assessed. Initially, the target segment of the industry relevant to the research technology needs to be defined. Key factors in the production system relevant to the success of research delivery and adoption need to be determined using survey techniques, consultation with industry participants, historical data, and documentation of previous research successes. PAC CRC needs to consider using this approach, on a portfolio basis, to set R&D priorities.

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APPENDICES – APPENDIX A: GROSS MARGINS

A range of gross margin studies are used to estimate the economic impact of vertebrate pest species. Average per hectare or per head of livestock estimates are used to generate national economic costs.

Broad acre Crops

The gross margin for wheat and barley in NSW and Queensland are demonstrated in the following table. It is evident that fertiliser is the major production cost, while insecticides are not generally used. With the adoption of minimum production systems, herbicides have become a higher cost over the last 20 years. The profitability of production is largely driven by the yield and price received by farmers.

Table 31: Gross Margin Budgets for Wheat and Barley

	NSW Dry-land Wheat (long fallow)	**NSW Dry-land Wheat (short fallow)**	**QLD Dry-land Wheat**	**QLD Dry-land Barley**
Income ($/ha)	612.50	437.50	692.00	554.00
Farm price ($/t)	175.00	175.00	289.5	210.00
Yield (t/ha)	@3.5 t/ha	@2.5 t/ha	@2.5 t/ha	@2.8 t/ha
Cultivation ($/ha)	6.19	12.38	20.00	13.50
Sowing ($/ha)	56.77	56.77	24.04	30.58
Fertiliser ($/ha)	103.24	88.75	52.71	52.71
Herbicide ($/ha)	53.31	31.12	21.25	30.18
Insecticide ($/ha)	0.00	0.00	0.00	0.00
Harvesting ($/ha)	54.22	38.72	45.00	45.00
Levies ($/ha)	6.22	4.44	7.10	5.68
Insurance ($/ha)	12.56	8.97	0.00	0.00
Gross Margin ($/ha)	**320.00**	**196.36**	**522.00**	**382.00**

Source: NSW Agriculture, 2003 and QDPI (2002)

Sheep

Sheep are grazed across all states of Australia except in the Northern Territory where only a small number are raised. Sheep production systems vary from specialist wool production enterprises using merino sheep, through to fat lamb production employing European breeds. A reduction in the carrying capacity of agricultural lands as a result of competition pressure by vertebrate pests has differing economic impacts on each of these enterprise types. A range of sheep enterprise gross margin budgets are outlined in the following table to illustrate the range of these values. Average values used in the impact analysis are also derived from the table.

Table 32: Gross Margin Budgets for Sheep

	NSW Merino Wether (21 micron)	NSW Merino Ewe (21 micron)	NSW First Cross	WA Self-replace (high rainfall)	WA Self-replace (low rainfall)
Gross Margin ($/enterprise unit)	20,321	47,844	71,918	67,540	73,236
Number of Sheep Shorn	980	1,397	1,421	4,380	4,271
Gross Margin ($/per sheep shorn)	20.74	34.24	50.61	15.42	17.14

Source: NSW Agriculture (2003) and WA Agriculture (2003)

It is evident that there is a wide range of gross margins across enterprise types and states. Much of the variation is associated with the improvement in pastures and. For the purposes of the costing a conservative estimate of $20 per sheep shorn is used to estimate the economic impacts of reduced carrying capacity due to the variation in enterprise profitability and impact of changes in livestock capital associated with changes in stocking rate.

Cattle

Cattle production systems vary from intensive production in high rainfall areas of southern Australia through to the production of heavier export cattle in northern areas. The gross margin per animal sold varies according to the intensity of production. A range of cattle enterprise gross margin budgets are outlined in the following table to illustrate the range of these values. Average values used in the impact analysis are also derived from the table.

Table 33: Gross Margin Budgets for Cattle

	NSW Jap Ox Grassfed	NSW Young Cattle	NSW Yearling	WA Self-replace Yearling
Gross Margin ($/enterprise unit)	57,670	48,294	47,024	31,161
Number of Cattle Sold	83	79	83	127
Gross Margin ($/per head sold)	694.82	611.32	566.55	245.36

Source: NSW Agriculture (2003) and WA Agriculture (2003)

For the purposes of the costing a conservative estimate of $400 per head sold is used to estimate the economic impacts of reduced carrying capacity. A conservative estimate is used due to the variation in enterprise profitability and impact of changes in livestock capital with varying livestock densities.

References

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WA Agriculture (2003) Gross Margins Guide 2003 Western Australia, from website

APPENDIX B: BROAD ACRE LIVESTOCK AND CROP STATISTICS

Sheep, cattle and broad acre cropping data are sourced from ABARE (2003) to provide a baseline from which to estimate the economic impact of key pests. Within each of the individual species analysis, pest density maps are laid over agricultural production intensity in each region to determine the economic losses imposed by the respective species. Data for 2002 are outlined in this Appendix so the reader can review loss calculations.

Table 34: Regional Agricultural Statistics NSW (2002)

Region	111	121	122	123	131	132
Sheep at 30 June	3,351,130	4,527,817	8,794,673	10,416,286	11,525,927	235,499
Sheep sold	1,043,389	1,943,823	4,619,468	5,643,128	3,787,126	23,395
Sheep shorn	3,511,574	4,689,146	9,833,406	12,284,876	11,925,240	250,062
Beef cattle at 30 June	130,754	1,186,097	536,603	785,679	1,872,664	429,501
Beef cattle sold	41,006	462,638	317,255	468,768	680,807	194,374
Barley area sown	27,038	176,977	147,166	280,423	7,357	2,151
Wheat area sown	171,425	992,521	989,699	823,562	35,334	934
Wheat area harvested	131,357	977,578	989,001	792,287	35,334	934
Barley area harvested	27,038	174,291	145,949	264,819	7,357	2,151
Barley production	59,304	491,373	326,345	475,715	20,124	5,274
Wheat production	171,441	2,483,194	2,372,637	2,021,561	124,473	1,954

Table 35: Regional Agricultural Statistics Victoria (2002)

Region	221	222	223	231
Sheep at 30 June	1,291,951	2,859,212	4,184,035	13,234,389
Sheep sold	1,005,378	1,622,974	2,521,718	4,436,756
Sheep shorn	1,203,735	3,311,806	4,327,524	15,363,350
Beef cattle at 30 June	70,988	215,030	203,212	1,609,097
Beef cattle sold	33,963	81,763	136,209	564,946
Barley area sown	318,031	274,583	63,418	58,593
Wheat area sown	563,274	266,360	166,583	112,027
Wheat area harvested	563,274	266,284	166,583	109,983
Barley area harvested	318,031	274,583	63,418	58,162
Barley production	540,513	809,156	171,907	224,349
Wheat production	1,098,483	838,789	486,789	381,627

Table 36: Regional Agricultural Statistics Queensland (2002)

Region	311	312	313	314	321	322	331
Sheep at 30 June	77,384	2,208,156	295,182	2,146,457	729,362	2,884,512	-
Sheep sold	31,869	783,412	107,698	442,238	345,520	789,086	-
Sheep shorn	72,476	2,557,419	423,927	2,477,132	848,926	2,926,502	-
Beef cattle at 30 June	805,709	1,092,310	1,943,820	1,062,905	559,695	3,104,713	1,427,838
Beef cattle sold	174,005	363,860	491,944	337,850	428,291	1,110,705	516,443
Barley area sown	-	-	-	-	63,535	60,214	721
Wheat area sown	-	-	-	-	35,552	380,437	10,415
Wheat area harvested	-	-	-	-	35,552	304,143	10,415
Barley area harvested	-	-	-	-	63,147	52,427	721
Barley production	-	-	-	-	130,711	76,925	1,634
Wheat production	-	-	-	-	60,159	528,590	12,127

Table 37: Regional Agricultural Statistics South Australia (2002)

Region	411	421	422	431
Sheep at 30 June	1,592,796	2,800,733	3,681,968	5,377,444
Sheep sold	269,863	641,715	2,037,009	2,253,406
Sheep shorn	1,569,444	2,655,585	4,044,044	5,325,399
Beef cattle at 30 June	226,223	68,023	113,097	703,079
Beef cattle sold	60,278	34,045	39,864	233,888
Barley area sown	10,554	250,986	674,959	109,734
Wheat area sown	102,562	791,056	917,406	89,462
Wheat area harvested	102,562	791,056	917,350	89,462
Barley area harvested	10,554	250,986	674,959	101,706
Barley production	28,934	530,511	1,750,255	241,752
Wheat production	284,526	1,633,315	2,605,777	330,104

Table 38: Regional Agricultural Statistics Western Australia (2002)

Region	511	512	521	522	531
Sheep at 30 June	-	1,318,746	14,895,140	3,972,014	2,362,548
Sheep sold	-	404,152	5,730,590	1,639,761	758,797
Sheep shorn	-	1,586,931	16,156,457	4,255,024	2,597,809
Beef cattle at 30 June	474,067	471,793	407,767	32,196	454,310
Beef cattle sold	99,682	131,436	148,996	1,540	199,696
Barley area sown	-	-	699,056	475,389	10,213
Wheat area sown	-	6,083	2,083,588	2,125,285	16,398
Wheat area harvested	-	6,083	2,074,179	2,106,773	16,398
Barley area harvested	-	-	697,518	475,389	10,213
Barley production	-	-	1,585,625	1,004,604	32,374
Wheat production	-	2,896	4,235,289	3,488,564	53,831

Table 39: Regional Agricultural Statistics Tasmania and NT (2002)

Region	631	711	712	713	714
Sheep at 30 June	2,921,752	-	-	-	-
Sheep sold	708,069	-	-	-	-
Sheep shorn	2,922,284	-	-	-	-
Beef cattle at 30 June	226,095	328,278	600,463	743,079	152,172
Beef cattle sold	112,982	78,842	84,177	177,042	34,965
Barley area sown	5,538	-	-	-	-
Wheat area sown	2,343	-	-	-	-
Wheat area harvested	2,343	-	-	-	-
Barley area harvested	5,454	-	-	-	-
Barley production	21,146	-	-	-	-
Wheat production	9,725	-	-	-	-

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