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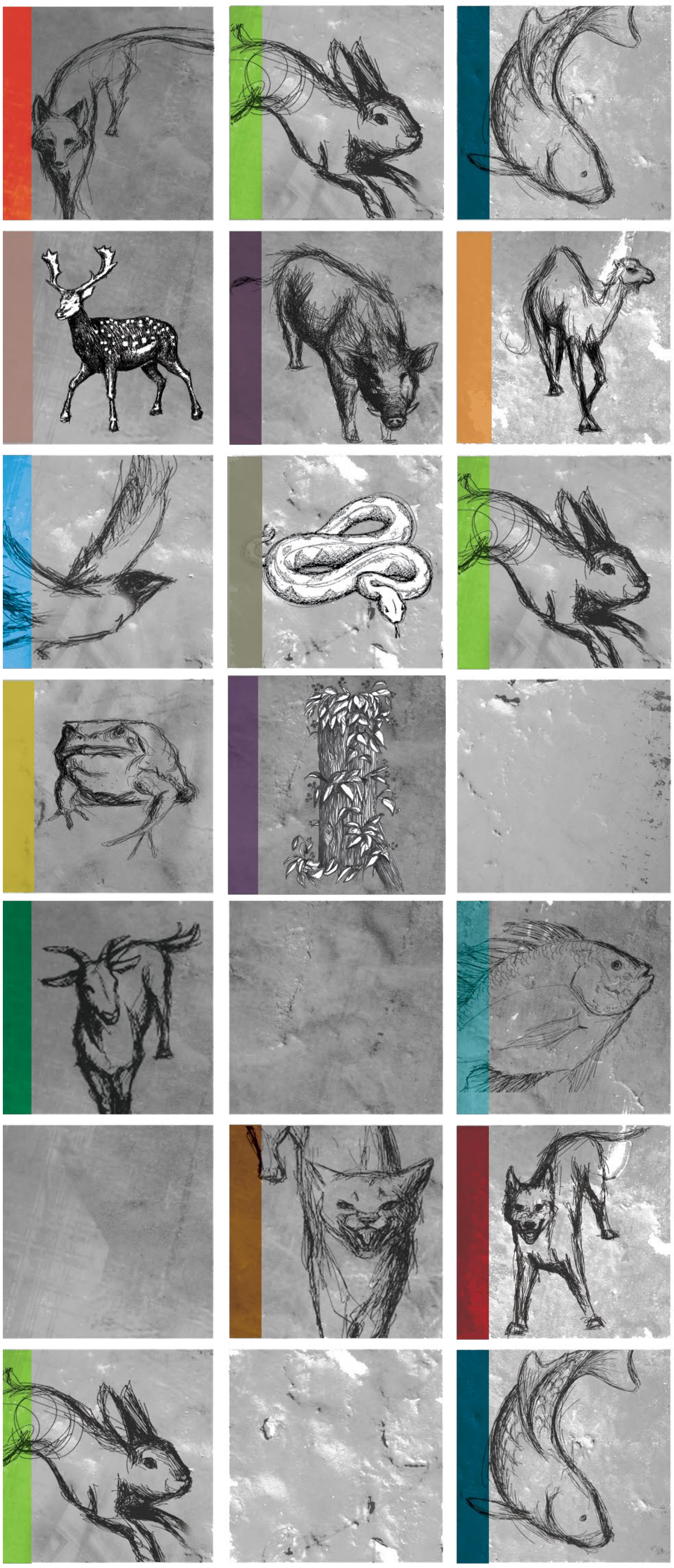

Cost of Pest Animals in NSW and Australia, 2013-14

eSYS Development Pty Ltd

NSW Government
Natural Resources Commission

Centre for Invasive Species Solutions

Cost of Pest Animals in NSW and Australia, 2013-14

Report by eSYS Development Pty Ltd, 2016

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1. Summary

A number of studies have estimated the economic impact of pest animals. McLeod (2004) calculated nationwide annual losses for agricultural industries of $336 million in 2004. This was subsequently updated by Gong et al (2009) who estimated the production loss costs of foxes, rabbits, wild dogs and feral pigs to be $285 million. The inclusion of damage by native and introduced birds by Gong et al (2009) resulted in an estimated Australian pest animal production loss valuation of around $600 million per year.

Prices for agricultural products have changed since the last major report on impact was released in 2009, as has the distribution and production losses inflicted by major pest animals. This study provides an update of the NSW and Australia-wide annual production loss costs and expenditures by governments and landholders on pest animal management for 2013-14. Foxes, wild dogs, feral pigs, introduced birds (starlings), rabbits, goats and pest fish (carp) are included in the report. Losses for carp are estimated for a lowered value of recreational fishing quality, whereas production losses for other pests are valued as net losses in output borne by wool, sheep-meat, beef, viticulture and broad acre cropping enterprises in NSW and across Australia. The impacts of feral deer are discussed in the final chapter of the report, however, impacts are not quantified in economic terms.

Many of the assumptions used in this update are derived from the Gong et al (2009) study, however, price and production data are sourced from the Australian Bureau of Statistics (ABS) for 2013-14. Data used to calculate impacts are included in sections for each of the pests included in the study. High, average and low impact scenarios are provided for guidance as to the likely range of pest animal cost impacts.

Method

The cost impact of pest animals is calculated by adding together production losses and expenditures on management at the farm and government levels. Production loss valuation is the most difficult component of impact to estimate due to the vast range of agro-climates and industries across which pest damages are observed. Calculation involves estimation of the distribution and abundance of a pest, the degree productivity in differing agricultural enterprises is hindered and the value of any declines in output or product quality. Output can be valued using fixed prices, or assumptions can be made using economic modelling to capture any changes in prices following pest animals impacting supply or demand conditions of a market. This latter approach is referred to as the ‘economic surplus’ method and was adopted by Gong et al (2009). Production losses are valued using both fixed price and economic surplus methods in this study.

Key losses include reduced wool and meat production as a result of grazing competition with rabbits and goats, predation by wild dogs, foxes and feral pigs, crop damage by feral pigs and introduced bird damage on viticulture. The value of recreational fishing in the Murray Darling Basin is calculated as the major cost inflicted by carp using ‘willingness to pay’ survey results and numbers of fishers active in this region. Annual losses are estimated for wool, sheep-meat, beef and grain industries for the 2013-14 year, along with data on the expenditures by governments and farmers. All values are in 2013-14 $ terms, as well as impacts being made as relevant as possible to the 2013-14 year in terms of livestock numbers.

Value of Production Losses by Pest Animals

Net annual losses in production due to pest animals in NSW and Australia are included in Table 1 for low, average and high impact scenarios. An average production loss cost of $151.5 million is estimated for NSW across seven pest species. It is difficult to compare these aggregate losses with those of other studies as different pests have been included.

It is evident that production losses associated with rabbits have the largest average cost impacts for both NSW and Australia. Wild dogs, foxes, introduced birds and pigs cause moderate impacts.

In the case of goats there is a considerable commercial harvesting industry, particularly in western NSW. Consequently, production loss costs are likely to be offset by the net value of the feral goat harvesting industry. Carp impose cost through the displacement of native fish species in recreational fisheries. This cost is estimated to be around $9 million per year in NSW. Unlike other species included in the report this economic cost does not relate to production losses, rather, loss of fishing quality.

Table 1: Annual Economic Impact by Pest Animals for NSW and Australia, 2013-14 $ terms

Scenario	Low		Average		High	
	NSW	Australia	NSW	Australia	NSW	Australia
Production Loss Cost	$m	$m	$m	$m	$m	$m
Rabbits	21.01	108.31	42.03	216.63	48.08	250.57
Goats	3.76	5.30	4.74	6.79	5.92	8.48
Pigs	11.98	12.73	13.49	14.40	14.73	15.64
Fox	10.24	26.74	11.66	28.40	14.35	34.59
Dogs	17.16	64.39	17.16	89.33	21.98	111.21
Introduced Birds	8.44	48.98	11.82	68.57	25.32	146.93
Carp	4.36	11.18	8.72	22.36	17.44	44.72
Subtotal Production Losses	**76.94**	**277.63**	**109.61**	**446.46**	**147.82**	**612.13**
Subtotal Management	37.74	138.58	41.86	150.11	62.62	185.18
Total	**114.68**	**416.21**	**151.47**	**596.57**	**210.44**	**797.32**

Impacts on Agriculture and Fishing

Production loss costs for each industry are outlined in Table 2. Beef and wool production are the most severely impacted industries in NSW, with annual production losses around $30-35 million per year in each of these industries. In total, all industries are calculated to suffer losses of $110 million across the state. There is a high degree of uncertainty around this estimate. A range of annual losses from $77 to $148 million are included for NSW, as pest numbers and distribution vary with seasons, as does the severity of production losses on affected agricultural enterprises. Variations in pest animal distribution and production loss assumptions have a more substantial impact on production loss estimates when compared to the two economic approaches used to valuing losses. The variation in the value of losses calculated using fixed price and economic surplus approaches was not as substantial.around this estimate. A range of annual losses from $77 to $148 million are included for NSW, as pest numbers and distribution vary with seasons, as does the severity of production losses on affected agricultural enterprises. Variations in pest animal distribution and production loss assumptions have a more substantial impact on production loss estimates when compared to the two economic approaches used to valuing losses. The variation in the value of losses calculated using fixed price and economic

Table 2: Annual Economic Impact by Industry for NSW and Australia, 2013-14

Scenario	Low		Mean		High	
	NSW	Australia	NSW	Australia	NSW	Australia
Cost by Industry	$m	$m	$m	$m	$m	$m
Agricultural Production						
Wool Production Loss	26.36	62.99	35.15	94.45	37.05	98.06
Sheep-meat Production Loss	15.27	36.04	18.50	50.46	24.32	60.67
Beef Production Loss	17.98	113.52	29.37	204.03	31.58	221.22
Broad acre Cropping Industries	4.54	4.93	6.05	6.60	12.11	40.54
Viticulture	8.44	48.98	11.82	68.57	25.32	146.93
Recreational Fishing	4.36	11.18	8.72	22.36	17.44	44.72
Subtotal Production Losses	**76.94**	**277.63**	**109.61**	**446.46**	**147.82**	**612.13**
Vertebrate Pest Management						
Broad acre & Livestock Farm control	12.38	34.59	16.51	46.13	20.63	57.66
Viticulture Farm control	5.00	19.67	5.00	19.67	5.00	19.67
Commonwealth Expenditure	-	14.74	-	14.74	-	14.74
State and Territory Expenditure	20.36	69.58	20.36	69.58	36.99	93.11
Subtotal Management	**37.74**	**138.58**	**41.86**	**150.11**	**62.62**	**185.18**
Total	**114.68**	**416.21**	**151.47**	**596.57**	**210.44**	**797.32**

Expenditure on Pest Management

Broad acre (cereal cropping and livestock) farm expenditures on pest management were derived from the ABS (2008) survey of landholder natural resource management practices. The survey found some $768 million was spent over 0.15 million Australian farms in 2006-07 on pest management. Gong et al (2009) disaggregated this cost as it included management of native animals and birds, feral and domestic animals, and insects; along with fixed and variable components. The authors estimated an average cost of $325 per farm, with low and high estimates of $250 and $400 respectively. In the current study, these costs are increased by inflation to a 2013-14 estimate of $400 pest animal expenditure for an average farm, $500 for a high cost and $300 for low expenditure farm.

The numbers of NSW and Australian cereal and livestock businesses in 2014 outlined by ABS (2013) are multiplied by these per farm pest expenditure estimates to derive an estimate of total farm expenditure. Expenditures are not attributed to individual species using this approach. Total broad acre pest animal farm costs are estimated to be $17 million in NSW and $46 million nationally. In addition to broad acre industries, losses are estimated for introduced birds in viticulture. Control costs per hectare are taken from the Gong et al (2009) and indexed to 2013-14, then multiplied by the areas planted to viticulture in this year. Using this approach around $5 million is estimated to be spent on introduced bird control in viticulture industries of NSW in 2013-14 and $20 million nationally.

Government pest animal spending for 2013-14 has been sourced for NSW, South Australian and Western Australia. Commonwealth and other state estimates are derived from the Gong et al (2009) expenditures for 2008, but indexed to 2013-14 using inflation. These estimates are included in the Appendix.

Discussion

Pest animals are estimated to impose an overall average cost of $152 million on NSW agricultural industries and recreational fisheries in 2013-14. Production loss costs make up most of these impacts, particularly losses to the grazing industries from rabbits, wild dogs and viticulture damage caused by birds. Quantified economic losses are generally higher than those estimated in the Gong et al (2009) report. Assumptions in relation to calculating dog losses, changes in prices and volumes of livestock and crop products and increased pig prevalence underpin much of the observed variation

Photo: European rabbit by Kevin Solomon

Acronyms

ABARES	Australian Bureau of Agriculture and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
BRS	Bureau of Rural Sciences
BAS	Businesses Activity Statement
CPI	Consumer Price Index
CSIRO	Commonwealth Scientific and Research Organisation
DPI&F	Department of Primary Industries and Fisheries Queensland
DSE	Dry Sheep Equivalent
EVAO	Estimated Value of Agricultural Operations
GVP	Gross Value of Production
IA CRC	Invasive Animals Cooperative Research Centre
LVP	Local Value of Production
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
NSW DPI	New South Wales Department of Primary Industries
RHD	Rabbit Haemorrhagic Disease
RLBP	NSW Rural Lands Protection Board
SIP	Stocked Impoundment Permit

2. Introduction

- Economic impacts of seven pest animal species in NSW and Australia are outlined in the report. They include rabbits, introduced birds (starlings), foxes, wild dogs, feral pigs, carp and feral goats. An overview of feral deer impacts is also provided, however, no annual economic estimate of damage is quantified due to limited data.
- Impacts include farm and government control expenditures and production loss costs. Farm survey data are used to estimate control costs across all pests in broad acre and viticulture industries; and control cost is not attributed to individual species.
- Production losses are estimated on the basis of the proportion of affected industries being subject to no, medium and high pest densities.
- Losses in agricultural production are valued a fixed price approach. Sensitivity analysis is included for high and low pest impact scenarios, and in the case of rabbits 'economic surplus' modelling, is included in a sensitivity scenario to capture market impacts of pest costs on the supply of agricultural commodities.

2.1. Background

The Natural Resources Commission is conducting a review of pest animal management in NSW. As part of the review, economic analysis is required to determine the cost impact of pest animals in NSW to identify any trends in prevalence and production impacts. Specific objectives of the analysis include:

- Draw on the economic welfare approach adopted by Gong et al (2009) to develop a regional model to estimate pest-related production loss cost estimates;
- Review existing impacts and trends of pest animals on Australia's environment, economy and society;
- Calculate the direct and indirect costs of birds, goats, fish, fox, pigs, rabbit and dogs - including descriptions of confidence in estimates; and
- Undertake cost sensitivity analysis to highlight robustness of results to key assumptions

These costs do not include quantified economic losses from other species (e.g deer, tilapia, native animals) and, except for carp, environmental or social costs.

2.2. Organisation of the Report

These impacts are explored in a series of chapters arranged by species. Each chapter begins with an overview of the pest, a summary of pest distribution, then estimation of economic impacts. Production loss values for the wool, sheep-meat, beef, cereal crop or horticultural industries are outlined in the economic impact sections of each chapter. Pest animal management costs and environmental impacts are described in the concluding sections of each chapter.

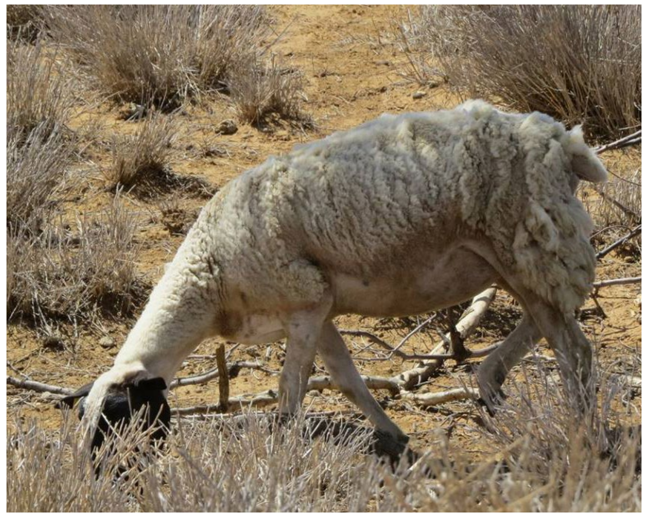


Photo: Feral goat by Rebbekah Hearn

Economic Impact

Gong et al (2009) noted that the economic costs associated with pest animals include both direct production losses and the expenditures associated with management, administration, and research. In order to calculate losses, the proportion of an industry impacted by a pest and the production loss within this segment of the industry needs to be determined. This is not straightforward. Pests are spread across much of Australia, with much of their impact being undocumented and varying with seasons. In order to quantify losses in a transparent and systematic fashion Gong et al (2009) outlined the proportion of beef, sheep-meat, wool and cropping industries in zero, low, medium and high impact pest areas, then calculated production losses for each of these segments. The same approach is adopted in this study, except pest densities are described as being zero (not significant enough to cause production losses)[1] medium and high. The proportion of industry production and estimated production loss assumptions associated with each of these calculations are detailed in each pest animal species chapter.

2.3. Agricultural Production Losses

Pest Distribution

Pest distribution maps developed by NSW DPI (West and Saunders 2003, 2007) and a peer review process involving researchers (Glen Saunders, Peter Fleming and Peter West) were used to estimate the proportion of industries in each state subject to pest impacts in the Gong et al (2009) study. These estimates have been largely used in this analysis. Some small changes have been made in light of changes in prevalence over the last 7 years. They include increases in feral pig area affected as a result of the ending of the droughts at the time of the 2009 study, increased wild dog prevalence in selected states and decreased Rabbit Haemorrhagic Disease (RHD) efficacy leading to increases in rabbit numbers.

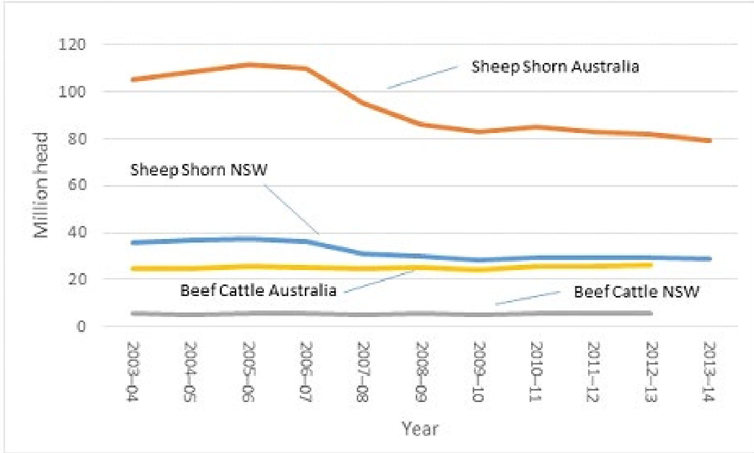
Production Losses in Pest Affected Areas

The key production losses from pest animals within livestock industries are that of predation and grazing pressure. These losses were summarised by Gong et al (2009) using a range of studies to estimate the decreased production from wild dog predation (Fleming et al 2002), and predation of lambs by foxes (Saunders and McLeod 2007) and feral pigs (Choquenot et al 1996). Mortality losses from these and other studies outlined in each chapter are used to estimate the cost of predation from these pests in the current costing study.

The impact of grazing pressure by rabbits and goats is less clear. A diversity of opinion is reflected in the literature provided in the chapters for these two pests. Gong et al (2009) used the studies by Croft et al (2002), Fleming et al (2002) and Williams et al (1995) to conclude the main impact of rabbits is to decrease sale weight of calves and lambs, and reduce the amount of wool produced per sheep. This key impact is retained in this study, with assumptions about the magnitude of losses in low and high rabbit and goat areas being provided in the respective chapters for these pests.

A major influence on the impact of pest animals is the size of the industry and price received for commodities produced in the industries they affect. The large economics impacts of rabbits on the wool industry estimated by ACIL (1996) of $300 million occurred when the national flock was more than double what it is today. Reduced losses estimated in subsequent studies (Sloane et al 1988, McLeod 2004) are not simply due to the release of RHD. Since the Gong et al (2009) study the size of the national flock has stabilised and the beef herd has moderately increased, although much has been outside of NSW.

ABS (2015) livestock and cropping data for the 2013-14 financial year is included for this cost analysis Similarly, the value of viticulture and crop production for this year was included to estimate bird and feral pig losses in 2013-14 (See Appendix 1). This year was selected as the base year for calculation as it reflected the most up-to-date production and price information. The year is not selected as a representative year for pest impacts.



Valuing Production Losses

Losses in production are valued using enterprise gross margins and prices for relevant commodities. New South Wales Department of Primary Industries (NSW DPI)[2] gross margins for wool, sheep-meet, beef and cropping were used. The net value of losses in sheep and cattle through predation and reduced wool and meat production as a result of grazing pressure were valued using price data in these budgets. Assumptions are provided in tables which accompany the impact assessment for each pest species.

Losses can be valued using a fixed price or economic surplus approach. Using a fixed price approach, the loss in production is valued using constant pricing. Pests may have an impact on the price paid for commodities where they have a large influence on supply. An example is the introduction of biological agents to control rabbits. Cooke et al (2013) cite the study by Waithman which assessed wool and livestock production within NSW before and after the introduction of myxomatosis. It showed that greasy wool production increased by 26 per cent, and sheep and lambs slaughtering increased by 21-25 per cent following introduction of the agent. In this case increases in wool and meat supply may be large enough to decrease the price received for these products. A fixed price approach may overstate the benefit for producers as the consumer receives benefit from reduced product prices. Gong et al (2009) attempted to capture these price impacts using an economic surplus approach. The approach is summarised in Table 3 below.

[1] For example, rabbits in black soil plains of the Riverina. They are present, but in insufficient numbers to cause significant production losses.

[2] http://www.dpi.nsw.gov.au

Table 3: Economic Surplus Approach

Gong et al (2009) noted that the supply of an agricultural commodity is reduced from what it otherwise would be due to the impact of a pest. The responsiveness of market prices to this supply change is quantified in the slopes of supply and demand functions known as elasticities. Consumer and producer impacts are calculated using ‘surpluses’ which reflect modelled changes in prices and quantities following reductions in supply as a result of a pest. Background information about the calculation method is outlined in Alston et al (1995).

Economic surplus modelling has generally been used in Australia to estimate the benefits from research (Edwards and Freebairn 1982), particularly where benefits are being calculated for export industries that have an impact on world prices. In these cases, the benefits from research that improves the productivity of an Australian industry can be passed to overseas consumers through reduced international pricing and use of a fixed price approach overstates benefits captured by Australia.

Use of a fixed price approach for pest animals may overstate costs for Australia as the impacts of less supply are felt in overseas markets as well as nationally. Gong et al (2009) found overseas net impacts to be marginal. Less than 5 percent of overall pest animal costs were appeared to be felt outside of Australia. However, in the current 2013-2014 update, the economic surplus approach is used in a sensitivity analysis to estimate production loss impacts for rabbits using the DREAM model developed by Wood et al (2001). This was to determine whether the Gong et al findings on the distribution of benefits still applied and whether there were any differences in economic impact estimates for the two methods in the case of rabbit impacts.

2.4. Aggregate NSW and National Losses

The proportion of the wool, sheep-meat, beef and cropping industries in zero, low and high pest impact areas, production loss estimate in each of the segments and value of agricultural production data are combined to estimate NSW and Australian pest animal production losses. This is undertaken for fixed price estimates of average, low and high production losses. Key parameters are included in Appendix 1.

Photo: Feral cat by Brett Krause

2.5. Government Control Costs

Gong et al (2009) estimated national farm level management costs by multiplying an average estimate of pest animal control expenditure per farm by the number of grazing and cropping farms. ABS had undertaken a survey of farm expenditure on pest management during 2006-07 over 150,403 Australian farms.

Using these results Gong et al (2009) assumed a range of $250-400 per farm pest animal expenditure with an average of $325 per farm. This estimate is inflated to 2013-14 terms using the changes in Consumer Price Index (CPI) outlined in ABARES (2014) for 2005-06 and 2013-2014. The number of farms are multiplied by $400 per farm (average), $500 (high) and $300 (low) to calculate pest animal control costs. Some livestock and broad acre businesses may have joint crop and livestock activities.

The total number of livestock and broad acre crop farms are multiplied by 80 percent to account for this possible overlap when estimating numbers of farms. Farm numbers and estimated expenditures are outlined in Table 4. These costs are not attributed to individual pest species throughout the report and are reported as overall farm level feral pest management costs in Tables 1 and 2.

Table 4: Farm Level Pest Animal Control Expenditure, 2013-14

	Unit	NSW	Australia Total
Number of Businesses[3]			
Livestock (Sheep and beef)	Number	41,513	111,307
Broad acre crops	Number	10,070	32,837
Farmer Pest Management Costs			
Mean Vertebrate Pest Control	$m	15.5	46.1
High Scenario	$m	19.3	57.7
Low Scenario	$m	11.6	34.6

2.6. Government Control Costs

The public sector directs resources to pest animal research and management at the Commonwealth and state levels. Commonwealth spending includes the Invasive Animals CRC, Murray-Darling Basin Authority (MDBA) and departmental spending. State governments also provide resources to control pest animals. NSW, South Australian, West Australian and Northern Territory spending estimates were provided for 2013-14. Commonwealth and other state estimates are derived from the Gong et al (2009) expenditures for 2008, but indexed up to 2013-14 using CPI inflation indices. These estimates are included in the Appendix.

Photo: Feral goats by Daryl Panther

3 Taken from ABS (2015). 7121.0 - Agricultural Commodities, Australia, 2013-14. An agricultural business operation with value of $5,000 was included following ABS’ Estimated Value of Agricultural Operations (EVAO) or declared in Businesses Activity Statement (BAS).

3. European Rabbits

Key findings:

- Rabbits are estimated to inflict production loss costs on wool, sheep-meat and beef industries in NSW of $42 million per year
- Biological control agents such as myxomatosis and rabbit haemorrhagic disease (RHD) have decreased rabbit populations but populations are increasing again due to disease resistance
- A revised national cost estimate of $216 million reflects increased livestock prices and greater rabbit abundance. In 2009 rabbits were estimated to cost these industries $206 million

3.1. Overview

Rabbits were released into Australia in 1859 and have subsequently expanded their range to more than 70% of the landmass. The Invasive Animals CRC (2012) has noted competition and land degradation causes overgrazing of native and sown pastures, loss of plant biodiversity, decreased crop yields, reduced livestock carrying capacity and increased erosion. Department of Primary Industries and Fisheries Queensland (DPI&F) (2008) highlight that rabbits eat around 15% of their body weight per day, compared to sheep and cattle which consume 3% of their body weight over the same period.

The cost of this damage varies by rural enterprise. DPI&F (2008) estimated that the rabbits cost the wool industry $1.7 per rabbit/year, $2.2 per rabbit/year for store cattle and up to $6.3 per rabbit for irrigated lucerne. At the national level, rabbits have been calculated to cost broad acre crop and livestock producers more than $200 million per year (Gong et al 2009, McLeod 2004). These costs would be much greater without myxomatosis and rabbit haemorrhagic disease (RHD) being introduced into Australia.

Since the introduction of RHD in the mid-1990s rabbit numbers have been reduced. Surveys of abundance showed densities decreased by around two-thirds in low rainfall areas, but only by a quarter in wetter climates (Cox et al 2013). It has been estimated that biological control agents have resulted in rabbit abundance being about 15% of the potential population size in Australia (Cooke et al. 2013).

Since Gong et al (2009) estimated national rabbit cost impacts, the efficacy of RHD is thought to have diminished in some areas, as rabbit populations develop resistance, the size of the national sheep flock has decreased and prices for livestock products have increased. Consequently, costs of rabbit-related production losses have changed. Significant amounts of resources are also consumed in rabbit control programs – which include the use of poisons, warren ripping and fumigation at the farm level and to a lesser extent by government agencies. These costs require updating.

Photo: European rabbit by Chris Lane

3.1. Rabbit Temporal Abundance

Rabbits are abundant in most regions of Australia south of the tropics (Williams et al. 1995). The introduction of biological control agents (myxomatosis in the early 1950s and RHD in 1995) have greatly reduced rabbit numbers in these areas, decreasing economic costs of the pest.

Prior to RHD, ACIL (1996) calculated annual losses of $600 million, half of which was associated with the wool industry, and the remainder borne by meat producers and cropping enterprises. Since RHD these costs have declined (Cooke et al 2013). Modelling suggests reduced costs of the order of 25%, 5% and 2.5% in the pastoral, wheat-sheep and high rainfall zones have been achieved (Vere et al 2004). Losses were estimated to be $130 million per annum across the national wool industry (Sloane, Cook and King 1988) in the late 1990s, while Vere et al (2004) estimated a cost of $14 million per year at a density of 4 rabbits per hectare up to $39 million at a density of 10 per hectare within temperate production regions.

Photo: European rabbit by Chris Lane

The timing of these economic impact studies, along with the size of the national sheep flock and rabbit abundance at a site in the arid pastoral area of north-eastern South Australia, (Cooke et al, 2013) is mapped in the following figure.

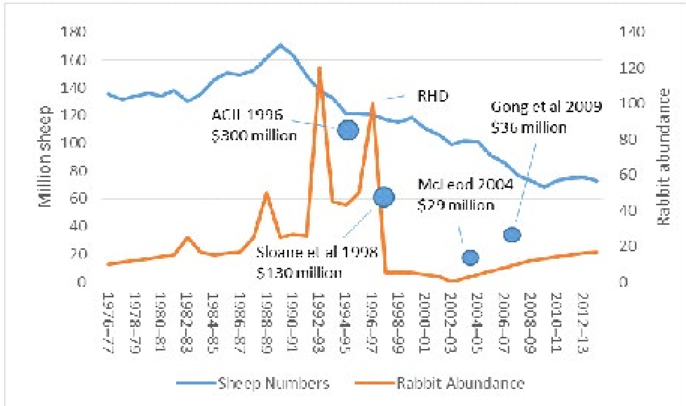


Figure 2: Rabbit Abundance, National Sheep Numbers and Cost Impacts.
Source: Cooke et al (2013), ABS (2015), selected cost studies

It is evident that rabbit abundance increased as myxomatosis became less effective, then a high level of control was attained following the introduction of RHD. Since this introduction rabbit-related wool production losses have been estimated to be below $50 million per year (Gong et al 2009, McLeod 2004). Population control appears to be waning again as rabbits become resistant to RHD. Revised costs, which include a reduction in national sheep flock size and value of wool production, are provided in the next section.

3.3. Economic Impact
Impact on Livestock Enterprises

Gong et al (2009) note that grazing competition by rabbits leads to reduced carrying capacity of farm land - resulting in less livestock, lower wool production per animal, reduced lambing percentage, lessoned wool quality, reduced sale weights and higher stock mortality. A range of studies have been undertaken to estimate rabbit-related production losses.

Cooke et al (2013) cite the study by Waithman which assessed wool and livestock production within NSW before and after the introduction of myxomatosis. It showed that greasy wool production increased by 26 per cent, and sheep and lambs slaughtering increased by 25 per cent and 21 per cent following introduction of the agent. The production increase per animal was estimated to be marginal. Wool per sheep shorn sheared increased by 4 per cent and lambing rates by 1 per cent. Increased carrying capacity from reduced rabbit grazing pressure was highlighted as the key production benefit. Williams et al (1995) estimated that 16 rabbits/ha are equivalent to one Dry Sheep Equivalent (DSE).

ACIL (1996) estimated the potential increase in sheep production in high rabbit density areas was between 30 and 40%, while cattle production could increase by 20 to 30% in the absence of rabbits. The key impact included in the Gong et al (2009) economic impact study was reduced sale weight of calves and lambs, and reduced amounts of wool produced per animal following the studies of Croft et al (2002), Fleming et al (2002) and Williams et al (1995).

These studies found that sheep raised in Central NSW with no grazing pressure from rabbits had a 7.23 kg greater average live weight after three years (compared with those raised with rabbits) and also produced 21% more greasy wool per head per year. These production impacts are included in the following table for sheep in no, medium and high rabbit impact areas. Reduced wool production of 3 and 15% were included for medium and high impact areas.

The proportion of the flock in each state estimated to be raised in no, medium and high rabbit impact areas are also outlined in the Table 5. The assumptions are derived from Gong et al (2009). Wool production by state (See Appendix), net margin per kg greasy wool and reduced production as a result of rabbit pressures were combined to estimate aggregate production loss cost impact of rabbits on the sheep industry.

Photo: European rabbit by Rick Nash

Table 5: Rabbit Production Loss Assumptions by Industry and State

Rabbits		NSW	VIC	QLD	SA	WA
Wool Production						
% production area no impact	%	70	70	60	60	60
% production area medium impact	%	23	23	30	30	30
% production area high impact	%	7	7	10	10	10
% total production loss[4]	%	1.74	1.74	2.40	2.40	2.40
Wool production loss [5]	kt	2.75	1.55	0.34	1.58	2.18
Value of wool production loss[6]	$m	12.84	9.27	1.73	8.24	12.70
Loss as proportion of LVP[7]	%	1.65	1.65	2.28	2.28	2.28
Sheep-meat Production						
% production area no impact	%	70	70	60	60	60
% production area medium impact	%	23	23	30	30	30
% production area high impact	%	7	7	10	10	10
% total production loss	%	1.67	1.67	2.30	2.30	2.30
Sheep-meat production loss[8]	t	1.84	3.46	0.21	1.91	1.15
Value of sheep-meat loss[9]	$m	6.98	13.14	0.79	7.25	4.37
Loss as proportion of LVP[10]	%	1.59	1.59	2.19	2.19	2.19
Beef Production						
% production area no impact	%	70	70	60	60	60
% production area medium impact	%	23	23	30	30	30
% production area high impact	%	7	7	10	10	10
% total production loss	%	1.67	1.67	2.30	2.30	2.30
Beef production loss	t	8.67	7.53	26.84	2.69	2.44
Value of beef production loss	$m	22.20	20.80	77.05	7.92	11.35
Loss as proportion of LVP	%	1.59	1.59	2.19	2.19	2.19
Total value of production losses	**$m**	**42.03**	**43.21**	**79.56**	**23.41**	**28.41**

[4] The percentage total production loss in NSW is estimated by multiplying the proportion of production in no impact (0% loss), plus medium density rabbit production (25%) multiplied by 3% and high density loss of 15% by the 7% of production in these areas. The weighted loss is estimated to be 1.74%. This calculation is conducted for each state and added to calculate the national total.

[5] Total production including wool on skins in Table 21 is multiplied by this proportion to determine production loss. In the case of NSW 158 kt is multiplied by 1.74% to generate a loss of 2.75 Kt. This loss is added for each state to generate a national total.
The percentage volume of lost production is multiplied by the ABS local value of wool production. To account for taxes and miscellaneous marketing costs a simplifying assumption of 95% of the value of local production of livestock products are estimated to represent net production losses. For NSW, a loss of 1.74% multiplied by 95% times the local value of wool production of $777 million equals $12.84 million per annum. This loss is added for each state to generate a national total

[6] LVP is the Local Value of Production. For NSW, a loss of $12.84 million represents 1.65% of gross value of production. ABS define LVP as the value at the place of production, including indirect taxes. The local value of production is calculated by subtracting total marketing costs from gross value of production (GVP). Marketing includes items such as freight, cost of containers, commission, insurance, storage, and other logistics.

[7] A similar weighted average loss is estimated for beef and sheep-meat producers. Lamb production in NSW of 110 Kt (Table 21) is multiplied by 1.67% to estimate tonnes of production loss. Losses are estimated for lamb production as this was noted by Gong et el (2009) as a key production impact.

[8] The value of lamb production is multiplied by 95% and the weighted loss estimate to generate the value of production losses. For NSW, $440 million of local lamp production value is multiplied by 1.67% and 95%. This generates a loss of $6.98 million for the state. State totals are added to generate a national production loss.

[9] LVP is the local value of lamb production in each state outlined in Table 21.

In addition, rabbits decrease the production of beef farms. Cooke et al (2013) cite the study by Waithman which found beef cattle numbers in NSW increased by 10 per cent following myxomatosis and the number of cattle slaughtered increased by 26 per cent. More conservative estimates of rabbit impacts on cattle slaughter weights were derived from Gong et al (2009). It is estimated that live weights are decreased by 3 and 14 percent in low-medium and high rabbit impact areas. The number of cattle raised in no, medium and high impact areas and reduced beef production as a result of rabbit competition are presented in Table 5.

National Production Losses

Aggregate NSW and Australian production losses for rabbits are reported for wool, sheep-meat and beef production in Table 6. The calculation assumes a fixed product price and, following Gong et al (2009) cropping losses are not included. The overall production loss cost for NSW is $42 million and nationally $217 million in 2013-14. This impact is slightly above that of Gong et al (2009) where rabbits were calculated to have a national production loss cost impact of $206 million.

Table 6: Annual Production Loss Impact of Rabbits, 2013-14

Cost Component	NSW	Other States and Territories	Australia
	$million	$million	$million
Agricultural Production [a]			
Wool Production Loss	12.84	31.94	44.78
Sheep-meat Production Loss	6.98	25.55	32.53
Beef Production Loss	22.20	117.11	139.31
Subtotal	**42.03**	**174.60**	**216.63**

Rabbits can cause production losses in cereal crop production enterprises. These losses were not included in the Gong et al (2009) study and have not been included in Table 6 of the current cost impact assessment. Surveys of state agency perceptions of pest animals in the 2000s undertaken by West and Saunders (West and Saunders, 2007) asked rangers to rank the impacts of rabbits. In neither did rangers

Photo: European rabbit by C Cameron

Sensitivity Analysis

The foregoing average cost estimates are based on a large number of assumptions for which there are limited data. Low and higher impact scenarios are included to gauge how estimates of production loss costs vary with changes in key assumptions.

Low Scenario – Reduced Livestock Production Loss Estimates

McLeod (2004) estimated rabbit-related production losses of 3-5 per cent in arid areas and 2-3 percent in the sheep wheat zone. The upper range for production loss estimates are lower than those used per cent were included for wool producers in high rabbit density areas. This is a result of different agro-climatic groupings being used to estimate losses. There is considerable uncertainty around the magnitude of rabbit-related impacts. Production loss estimate assumptions are halved for both low and high impact rabbit areas to gauge the impact of changes on cost impact estimates. It is evident that production loss estimates fall considerably under this assumption (Table 7).

Table 7: Average, Low, High and Economic Surplus Rabbit Production Loss Scenarios

Cost Component	NSW	Other States and Territories	Australia
	$ million	$ million	$ million
Average			
Wool Production Loss	12.84	31.94	44.78
Sheep-meat Production Loss	6.98	25.55	32.53
Beef Production Loss	22.20	117.11	139.31
Rabbit Production Loss	**42.03**	**174.60**	**216.63**
Low Scenario			
Wool Production Loss	6.42	15.97	22.39
Sheep-meat Production Loss	3.49	12.77	16.26
Beef Production Loss	11.10	58.56	69.66
Rabbit Production Loss	**21.01**	**87.30**	**108.31**
High Scenario			
Wool Production Loss	12.84	31.94	44.78
Sheep-meat Production Loss	6.98	25.55	32.53
Beef Production Loss	22.20	117.11	139.31
Broad acre Cropping Industries	6.05	27.89	33.94
Rabbit Production Loss	**48.08**	**202.49**	**250.57**
Economic Surplus			
Producer Surplus	19.42	192.09	211.51
Consumer Surplus	0.91	1.80	2.71
Rabbit Production Loss	**20.33**	**193.88**	**214.21**

High Scenario - Inclusion of Cropping

Inclusion of cropping yield reductions of 1 percent (McLeod, 2004) in rabbit affected areas increases total damage by $34 million per year.

Economic Surplus Approach

The above estimates, along with those of Sloane et al. (1988), McLeod (2004) and ACIL (1996) assume fixed values for production and prices when calculating aggregate losses. Gong et al (2009) and Tisdell (1982) include scope for prices to react to changes in production levels as a result of pest constraints being removed. This approach uses an equilibrium displacement model of the Australian wool, beef and sheep-meat sectors. The same framework is used in this sensitivity analysis and conducted in the DREAM model for production loss costs only. Model assumptions are outlined in the Appendix. As found in the Gong et al (2009) study, the current study confirmed that most production loss costs of rabbits are borne by Australian producers because of the price elasticities and levels of domestic versus overseas consumption for beef, wool and lamb assumptions included in the model. The rest of the world is only impacted by Australian rabbits to a very limited degree. Also, as shown in Table 7 similar economic losses are evident for the fixed cost and economic surplus approaches.

3.4. Rabbit Management

Rabbit control includes baiting, shooting, fumigation, trapping and the ripping of warrens (Williams et al 1995). Cooke et al (2013) noted that after RHD many landholders ceased to control rabbits. The poison 1080 is relatively low cost, estimated to be $2.41/kg of bait (Saunders et al 2002), however unlike biological agents can kill non target species. Labour costs are a major component of control costs. Expenditure on fumigation is limited because of high labour costs, and contract costs for warren ripping are A$10 per warren. It has been estimated that around A$20 million is spent per year on rabbit control (Bomford and Hart 2002, Gong et al 2009). Farm or government management costs are not attributed to individual pest species in this report.

3.5. Environmental Impact

Rabbit populations can impair efforts to regenerate native flora, and overgrazing makes soils prone to wind and water erosion (IA CRC, 2012). They also are a source of nutrition for feral foxes and sustain populations of this pest which preys on threatened native fauna.

Photo: European fox by James Doumtsis

4. European Fox

Key Findings:

- Foxes are most abundant in southern Australia. Previous costing studies have estimated the value of sheep predation to be in the order of $18-40 million per year
- Variation in reported rates of fox predation underpin the range in values of economic impact studies. Rates of between 1-5 percent of stock have been suggested.
- Based on a predation rate of 3 percent of young sheep in high fox density areas, a national cost of $28 million is estimated.
- NSW wool producers are calculated to suffer the most substantial fox-related economic production losses at $12 million in 2013-14.

Photo: European fox by Danny McCreadie

4.1. Overview

Gong et al (2009) calculated foxes cost the wool industry $19 million per year and sheep-meat producers $5 million. Foxes are most abundant in southern Australia, with NSW and Victoria estimated to bear most of the national cost. Of the national total, NSW wool producers were estimated to account for $7 million, or more than a third of all production loss costs.

Cost estimates in the Gong et al (2009) study are similar to those estimated by McLeod (2004 where the cost was driven by the assumption that predation accounted for 2% of an annual turnover of 35 million lambs valued at $25 per head - yielding a total loss of $18 million. Losses in the Gong et al (2009) and McLeod (2004) studies were less than the fox-related costs estimated by Bomford and Hart (2002) who estimated that 5% of all viable lambs were subject to fox predation, resulting in an annual production loss cost of $40 million. Costs are updated in this chapter based on 2013-14 ABS flock size and livestock price data.

4.2. Fox Distribution

The fox is primarily found south of the wet tropics in Australia and reflects rabbit distribution to a large degree. A survey of fox distribution across NSW Rural Land Protection Board (RLPB) districts observed the pest in 98% of the state (West and Saunders 2003). Foxes were found in high density in 21% of all surveyed districts, 66% of districts reported medium density and 11% low density. A small proportion of NSW was found to be fox free. The area, accounting for 2% of the state's land mass, included Grafton and north-western areas. High density areas included Cobar, Hillston, Hay, Narrandera, Coonamble, Tamworth, Mudgee-Merriwa, Central Tablelands, Young, Gundagai, Hume, Cooma and Bombala RLPB Districts (West and Saunders 2003).

The above proportions of NSW affected by foxes differ to those reported by Gong et al (2009). These authors indicated 60 percent of the sheep rearing areas of the state had zero percentage fox density, while high density areas covered 10 percent of the state. This difference may reflect differing definitions about density and associated impact. Foxes may be present (eg. non zero density), but not have significant impacts on livestock productivity.

4.3. Economic Impact

Agricultural Production Impact

Saunders et al (2010) indicate the economic impact of fox predation is unclear. The authors cite predation losses of 1-30%, with differences in animal husbandry such as flock size and timing of lambing being key factors determining the magnitude of losses (Lugton, 1993). It was suggested that high fox predation losses can also be governed by factors such as the proportion of twins and mothering ability of ewes (Coman, 1985). These factors underpin large variations in recorded fox-related mortality.

Linton (2002), for example, conducted a survey about fox control in South Australia and recorded farmers with low lamb marking percentages (50-80%) having large benefits from group fox control with a reduced mortality of 35%, while those with high lamb marking percentages achieved gains of less than 10 per cent. Dennis (1969) surveyed more than four thousand dead lambs in Western Australia and concluded only 3% would have survived in the absence of predation. McFarlane (1964) found only 10 percent of mutilated lamb carcasses actually suffered mortality due to attack.

Correspondingly, estimates of actual rates of lamb predation vary. Some 0.8% of lambs in south-eastern Australia were estimated to the subject of predation by foxes (Greentree et al., 2000) and as high as 30% of lambs in western NSW (Lugton, 1993). McLeod et al. (2010) found that when fox control was implemented under optimum (best practice) conditions, lamb survival could be improved by up to 20%. When calculating the benefits of fox control,

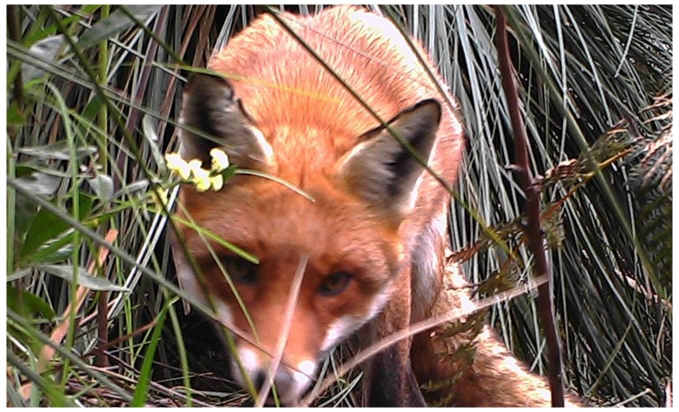


Photo: European fox by Kim Thompson

Jones et al (2006) increased lambing percentages between 1 and 5%.

In the current costing study, it is assumed that 3 percent of young stock (lambs, relative lambs marked) in high fox density areas are subject to fox predation and 1 percent of adult stock (relative to end of year stock numbers) are killed by foxes. These estimates of mortality are multiplied by the cost of replacements to calculate the value of lost production in Table 8.

Photo: European fox by Rob Brewster

Table 8: Fox Production Loss Assumptions

Fox		NSW	VIC	QLD	SA	WA
Wool Production						
% production area no impact	%	60	60	60	60	60
% production area medium impact	%	30	35	35	35	35
% production area high impact	%	10	5	5	5	5
Medium impact young stock loss (1%)[11]	M	0.02	0.01	0.00	0.01	0.01
Medium impact adult stock loss (1%)[12]	M	0.05	0.03	0.01	0.02	0.03
High impact young stock loss (3%)[13]	M	0.02	0.00	0.00	0.00	0.01
High impact adult stock loss (1%)	M	0.02	0.00	0.00	0.00	0.00
Medium impact young stock loss ($30 per head)	$m	0.47	0.24	0.04	0.23	0.40
Medium impact adult stock loss ($100 per head)	$m	4.50	2.82	0.62	2.05	3.09
High impact young stock loss ($30 per head)	$m	0.47	0.10	0.02	0.10	0.17
High impact adult stock loss ($100 per head)	$m	1.50	0.40	0.09	0.29	0.44
Value of mortality	$m	6.95	3.56	0.76	2.68	4.10
Loss as proportion of LVP[14]	%	0.73	0.52	0.80	0.60	0.60
Sheep-meat Production						
% production area no impact	%	60	60	60	60	60
% production area medium impact	%	30	35	35	35	35
% production area high impact	%	10	5	5	5	5
Medium impact young stock loss (1%)[15]	m	0.02	0.02	0.00	0.01	0.01
Medium impact adult stock loss (1%)[16]	m	0.01	0.01	0.00	0.00	0.00
High impact young stock loss (3%)	m	0.02	0.01	0.00	0.00	0.00
High impact adult stock loss (1%)	m	0.02	0.00	0.00	0.00	0.00
Medium impact young stock loss ($50 per head)	$m	1.01	0.81	0.04	0.46	0.40
Medium impact adult stock loss ($100 per head)	$m	1.15	0.96	0.08	0.49	0.47
High impact young stock loss ($50 per head)	$m	1.01	0.35	0.02	0.20	0.17
High impact adult stock loss ($100 per head)	$m	1.54	0.42	0.07	0.30	0.40
NV of sheep-meat mortality loss	$m	4.71	2.54	0.20	1.45	1.44

[11] For NSW 30% of merino lambs marked are assumed to be in medium impact fox areas. These 5.26 million young sheep are subject to 1% predation, resulting in 0.02 million fatalities due to foxes. This number is multiplied by $30 per head to generate young stock losses in medium fox impact areas.

[12] Adult stock in the wool industry refers to all adult merino sheep. It is noted that these livestock have both wool and meat purposes and less ewes in recent years are being used for breeding merino lambs (http://www.thesheepsite.com/articles/14/change-in-australian-sheep-flock/). This assumption is likely to result in the relative share of mortality losses between sheep-meat and wool industries to be underestimated.

[13] Some 10% of merino lambs marked are estimated to occur in high density areas. Assuming 3% are subject to predation, total mortalities of 0.02 million are estimated for NSW.

[14] LVP is Local Value of Production. The total cost of fox-related mortality in the wool industry is divided by the local value of wool production in Table 21 to provide an indication of relative losses to overall value of wool production.

[15] Lamb production losses for the sheep-meat sector are calculated as a proportion of 'Lambs marked other' in Table 21. The proportion of 'Lambs marked other'' estimated to be in medium and high fox density areas is multiplied by the estimated fox-related mortality rates as a proportion of 'Lambs marked other'.

[16] Adult sheep-meat stock are 'Cross bred adult ewes' in Table 21.

[17] Sheep meat LVP is the estimated local value of lamb production in Table 21. Lamb production would include merino lambs. The proportion is therefore indicative of the value of mortality losses of 'Lambs marked other' and 'Cross bred adult ewes' relative to the local value of lamb production. Attributing mortality losses to sheep-meat and wool production is confounded by the dual purpose of these livestock.

National Production Losses

The overall national production loss cost of foxes is estimated to be $28 million, with NSW sheep producers estimated to suffer production losses of $12 million. There is considerable uncertainty surrounding the magnitude of production losses. Sensitivity analyses are conducted to determine the robustness of results to key assumption. They are included in Table 10 as high and low cost impact scenarios.

Low Scenario – Less livestock in medium and high density areas

The proportion of the sheep flock raised in fox-affected areas varies by state. In NSW it was assumed that 30 per cent of the flock is raised in medium impact areas, while 10 percent are raised in high fox density areas. There is a degree of uncertainty about these assumptions. The proportions of the flock in NSW medium and high impact areas are reduced by half in this scenario. Fox production losses in NSW fall to $5.8 million per year under this assumption.

Table 9: Annual Production Loss Impact of Foxes, 2013-14

Cost Component	NSW	Other States and Territories	Australia
	$million	$million	$million
Agricultural Production			
Wool Production Loss	6.95	11.10	18.05
Sheep-meat Production Loss	4.71	5.63	10.34
Fox Production Loss	**11.66**	**16.73**	**28.40**

Photo: European fox by Casey McCallum

Photo: European fox by Chris Cox

Table 10: Average, Low and High Production Loss Scenarios

Cost Component	NSW	Other States and Territories	Australia
	$ million	$ million	$ million
Average			
Wool Production Loss	6.95	11.10	18.05
Sheep-meat Production Loss	4.71	5.63	10.34
Fox Production Loss	**11.66**	**16.73**	**28.40**
Low Scenario			
Wool Production Loss	3.48	11.10	14.58
Sheep-meat Production Loss	2.35	5.63	7.99
Fox Production Loss	**5.83**	**16.73**	**22.56**
High Scenario			
Wool Production Loss	7.90	12.39	20.29
Sheep-meat Production Loss	6.74	8.08	14.81
Fox Production Loss	**14.64**	**20.46**	**35.10**

4.4. Fox Management Costs

With the number of fox baits per year in NSW being estimated to be 2 million (Saunders and McLeod 2007), fox control by NSW farmers was estimated to be $7.3 million per year. State government agencies contribute a similar amount to that of landholders of $7 million per annum (Gong et al. 2009). Control costs are not specified for individual pests in this report, however foxes are likely to account for a significant proportion of the $46 million estimated to be spent by broad acre farmers and livestock producers on vertebrate pests.

4.5. Environmental Impact

Foxes have positive and negative environmental impacts. Saunders et al (2010) noted their role in containing medium to low density rabbit populations. On the other hand, they have been implicated in the predation of 84 species listed (28 a high risk because of foxes) as threatened in schedules of the EPBC Act 1999 (Newsome et al. 1997).

Photo: European fox by Lee Allen

5. Wild Dogs

Key Findings:

- Wild dog production losses have increased since 2009, due to increased dog predation being reported in Queensland, the Northern Territory and Western Australia
- National production losses are valued at $89 million per year, with Queensland beef producers bearing most impact. Losses for these producers are estimated to be $45 million, or half of all losses in 2013-14.
- Losses in NSW are estimated to be $17 million, with 67 percent being borne by sheep producers. Losses are relatively low in south eastern Australian due to the adoption of fencing and other management strategies.

Photo: Wild dog by Leo Berzins

5.1. Overview

Wild dogs (*Canis familiaris*) include dingoes, feral dogs, and their cross breeds. They are found across Queensland, the Northern Territory, Western Australia and South Australia, with scattered populations in New South Wales and Victoria (Fleming et al. 2014, Wicks et al 2014). West and Saunders (2006) reported that wild dogs are absent from 70% of NSW. However, during between 2002 and 2005 densities were perceived to have been increasing in some areas (West and Saunders, 2006).

Where present, wild dogs cause mortality in sheep and cattle populations through predation. Aside from this impact, the existence of wild dogs influences the decision making of landholders to not stock sheep and goats, which causes economic impacts in times of relatively high wool and sheep-meat prices. This is identified as an issue in the western Division of NSW and dogs are implicated in the contraction of the harvested goat industry in Western Australia (Bell, 2015). Gong et al (2009) estimated that the production impacts of wild dogs on young cattle and sheep in high density areas was around 10 percent. Approximately 5 percent of Queensland, Western Australia and Northern Territory beef production was deemed to occur in these regions.

Estimates of dog-related production losses vary from $41 million (McLeod 2004) across Australia to state estimates of $67 million in Queensland (Hewitt, 2009). The National Wild Dog Action Plan (2014) includes a range of estimates from $48 to $60 million annually. Gong et al (2009) estimated wild dog production losses were greatest for the beef industry, particularly in Queensland. Overall national economic costs for the beef industry were calculated to be $27 million, with Queensland bearing $20 million, or 73% of total national annual economic costs of $49 million for wild dogs.

5.2. Wild Dog Distribution

Wicks et al (2014) noted that dogs are spread across Queensland, the Northern Territory and much of Western Australia and South Australia, and regionally across New South Wales and Victoria. The dog barrier fence and other management programs have largely restricted wild dog populations to areas outside of south-eastern Australia.

Estimating wild dog densities is problematic due to their nocturnal and evasive nature. They are most active during the few hours of darkness around dawn and dusk and occur naturally at relatively low densities - so the likelihood of property owners and others seeing them is low. Estimating density requires a great deal of effort and a structured sampling framework like a network of remote cameras. The numbers within the fenced area have been increasing, particularly in Queensland, where cluster fences are being constructed and more are planned to manage dogs within targeted areas of land with like-minded property owners who wish to run wool or meat sheep and have enterprise choice. Sheep are more reliable during dry times in the Mitchell grass areas of Queensland, when cattle can have limited income potential.

A recent national survey of 525 farmers from statistical local areas known to contain wild dogs by Wicks et al (2014), found 66 per cent of farmers reporting wild dog problems on their property and around half reported wild dogs reduced lambing and/or calving rates. The surveyed number of farms was estimated to account for 17 per cent of total Australian farms in these industries (Binks et al 2015). Results of the survey are reported in the following table. It is evident that the proportion of landholders reporting wild dog problems was highest in Queensland, Western Australia and the Northern Territory. Half of the surveyed land holders in Queensland and Western Australia reported the problem as being severe.

Survey participants were asked whether impacts had increased, decreased or remained constant. Around half of the interviewees (45 per cent) reported impacts had become more severe, while 38 per cent said they had remained the same and 11 per cent said were reduced. The problem appears to have become more severe in Queensland and Western Australia. Bell (2015) reported that wild dogs have multiplied and spread throughout the West Australian rangelands when examining their impact on goat production.

Binks et al (2015) compared farmer wild dog perceptions in 2010 and 2014 and concluded severity ratings were broadly similar, although a slightly greater proportion rated severity as moderate rather than minor. A smaller proportion of landholders thought the problem on their property had become more severe in 2014 when compared to 2010. This response varied by state. Respondents in Queensland and the Northern Territory were more likely to report an increase in severity.

Table 11: Landholder Wild Dog Perceptions by State

Percent of respondents (%)	NSW	Vic.	Qld	SA	WA	NT	Aust.
Landholders aware of wild dog problems	68	52	95	44	92	94	72
Landholders reporting wild dog problems	69	52	72	44	73	83	66
Landholders reporting severe dog problems	22	37	51	23	52	31	34
Landholders reporting increasing problems	36	36	62	15	62	54	45
Landholders reporting management action	86	91	93	86	94	93	90

5.3. Economic Impact

Agricultural Production Impact

The key impact of wild dogs on livestock production is that of predation. Fleming et al. (2001) noted that surveys indicate wild dogs cause a one percentage loss in sheep numbers with management programs in place. Ecker et al (2015) indicated that financial impacts differed depending on the severity of wild dog attacks and the proportion of sheep operations compared with cattle in the region.

The survey by Binks et al (2015) also reflected variability in annual losses. Sheep losses per wild dog affected property averaged eight per cent (relative to current stock) with higher rates in Queensland and Victoria, and lower rates in South Australia (SA) and NSW. Cattle losses averaged two per cent per property nationally, with higher rates in SA and the NT. Young sheep and cattle are particularly vulnerable. Of the national loss of stock to wild dog predation, 66 per cent of all sheep killed and 91 per cent of all cattle killed were aged less than 12 months.

Mortality rates of 10 percent in young sheep and cattle are included in high wild dog density areas in Table 12. The proportion of sheep and cattle in no, medium and high wild dog impact areas is estimated in the table largely using proportions derived from Gong et al (2009) study. There is considerable uncertainty about the proportion of state herds and flocks subject to dog predation. For example, 80 percent of the Queensland wool and 90 percent of the sheep-meat industries were estimated by Gong et al (2009) to be in zero dog density areas. Hewitt (2009) on the other hand surveyed 109 sheep and goat producers in 2008/09 and estimated 91 percent of the state's flock was subject to dog predation. A high production loss cost of $17 million per year was estimated for Queensland sheep producing areas as part of this study.

Table 12: Wild Dog Production Loss Assumptions by Industry and State

Dogs	Region	NSW	VIC	QLD	SA	WA	NT
Wool Production							
% production area no impact	%	85	95	78	85	78	-
% production area medium impact	%	15	5	15	15	18	-
% production area high impact	%	-	-	7	-	4	-
Medium impact young stock loss (4%)[18]	m	0.03	0.00	0.00	0.01	0.03	-
Medium impact adult stock loss (3%)	m	0.07	0.01	0.01	0.03	0.05	-
High impact young stock loss (10%)	m	-	-	0.00	-	0.02	-
High impact adult stock loss (7%)	m	-	-	0.01	-	0.02	-
Med impact young stock loss ($30 per head)	$m	0.95	0.13	0.06	0.40	0.81	-
Med impact adult stock loss ($100 per head)	$m	6.76	1.21	0.80	2.64	4.77	-
High impact young stock loss ($30 per head)	$m	-	-	0.07	-	0.45	-
High impact adult stock loss ($100 per head)	$m	-	-	0.87	-	2.47	-
Value of mortality	$m	7.70	1.34	1.81	3.04	8.51	-
Loss as proportion of LVP[19]	%	0.99	0.24	2.38	0.84	1.53	-
Sheep-meat Production							
% production area no impact	%	85	98	90	100	98	-
% production area low impact	%	15	2	10	-	2	-
% production area high impact	%	-	-	-	-	-	-
Medium impact young stock loss (4%)[20]	m	0.04	0.00	0.00	-	0.00	-
Medium impact adult stock loss (3%)	m	0.02	0.00	0.00	-	0.00	-
High impact young stock loss (10%)	m	-	-	-	-	-	-
High impact adult stock loss (7%)	m	-	-	-	-	-	-
Med impact young stock loss ($50 per head)	$m	2.03	0.19	0.05	-	0.09	-
Med impact adult stock loss ($100 per head)	$m	1.72	0.16	0.07	-	0.08	-
High impact young stock loss ($50 per head)[21]	$m	-	-	-	-	-	-
High impact adult stock loss ($100 per head)	$m	-	-	-	-	-	-
Value of sheep-meat mortality loss	$m	3.75	0.35	0.11	-	0.17	-
Loss as proportion of LVP	%	0.85	0.04	0.32	-	0.09	-
Beef Production							
% production area no impact	%	85	95	80	95	80	80
% production area low impact	%	15	5	13	5	13	15
% production area high impact	%	-	-	7	-	7	5
Medium impact young stock loss (2%)	m	0.00	0.00	0.01	0.00	0.00	0.00
Medium impact adult stock loss (1%)	m	0.01	0.00	0.01	0.00	0.00	0.00
High impact young stock loss (10%)[22]	m	-	-	0.02	-	0.00	0.00
High impact adult stock loss (5%)	m	-	-	0.04	-	0.01	0.00
Med impact young stock loss ($450 per head)	$m	1.85	0.33	2.92	0.15	0.62	0.48
Med impact adult stock loss ($650 per head)	$m	3.86	0.55	8.67	0.26	1.22	1.76
High impact young stock loss ($450 per head)	$m	-	-	7.85	-	1.67	0.80
High impact adult stock loss ($650 per head)	$m	-	-	23.35	-	3.28	2.94
Value of beef mortality loss	$m	5.70	0.88	42.79	0.40	6.79	5.98
Loss as proportion of LVP	%	0.41	0.07	1.21	0.11	1.31	1.43

[18] http://www.abc.net.au/news/2015-12-04/wild-dog-cost-recalculated-as-new-bait-set-for-release/7000418

[19] Assumed mortality is applied to the proportion of each states flock or herd in medium and high dog density areas. For NSW, 5.26 million merino lambs are marked. Around 15% of these are in medium density areas where a 4 percent mortality loss is assumed. Combining the proportions and numbers of merinos marked generates a mortality loss of 0.03 million sheep.

[20] LVP is gross value of production. Total mortality for wool sheep producers in each state is divided by the value of wool production in each state. For example, in NSW, $7.7 million is divided by $777 million in Table 21 to generate a percentage loss of production of 0.99%.

[21] A similar process to that in wool is used to estimate sheep-meat dog related production losses. Total mortality of $3.75 million in NSW is divided by the value of lamb production of $440 million to generate a 0.85% proportional loss.

[22] No sheep-meat production is assumed to occur in high dog density areas. This assumption is taken from Table 3.7 of Gong et al (2009).

[23] No beef production in NSW and Victoria and South Australia is assumed to occur in high density dog impact areas. This assumption is taken from Table 3.7 of Gong et al (2009).

Sheep Losses

Gong et al (2009) estimated that production losses to be similar for young cattle and sheep across all dog densities. Adult sheep where estimated to have higher production losses than adult cattle in high densities areas only. For example, a production loss of 5% was assumed for adult cattle and 10% for adult merino and crossbred sheep in these areas. As noted, the recent ABARES survey of dog-affected properties by Binks et al (2015) found sheep losses averaged eight per cent (relative to current stock) and cattle losses averaged two per cent per property nationally, with young stock being particularly vulnerable. To reflect these findings, the production loss estimates of Gong et al (2009) are adjusted so sheep have higher assumed mortality losses. It is estimated that adult sheep have mortalities losses of between 3-7% in medium and high dog density areas, and young stock (sheep less than one year) between 4-10% mortality losses relative to current stock.

Cattle losses

A survey of approximately 67% of cattle graziers in the Northern Territory in 1995 estimated annual calf losses attributable to predation by wild dogs to between 1.6% and 7.1% (Eldridge and Bryan 1995). Losses to wild dog amongst Queensland cattle producers are also high. Calf losses of 30% have been reported under certain circumstances, with predation losses of between 0–29.4% per annum (Fleming et al 2011, Rural Management Partners 2003).

Hewitt (2009) estimated cattle production losses of $23 million across Queensland in 2008/09 using a survey of 191 farmers across the state. The state-wide loss of calves was estimated to be 2.72 percent. When valued at $150 per calf, state-wide losses were estimated to be $23 million per year. The author noted that if a value for weaners was used to estimate young stock losses, as opposed to a calf cost, production loss costs for the beef industry would be at least two times higher.

Fleming et al (2011) noted that despite losses of calves to predation by free-ranging dogs being observed in a variety of Australian production systems, predation losses are undetectable in most years (Eldridge et al. 2002). Average losses of 5 percent of adult cattle and 10 percent of young stock in high density wild dog areas are included in the above table. A rate of 2 percent for young cattle and 1 percent of adult cattle (relative to current) stock is included for medium dog density impacted areas.

In addition to predation, Binks et al (2015) reported reductions in lambing or calving rates was reported by around 42 per cent of surveyed landholders in wild dog affected areas in 2014. Approximately 10 per cent of landholders reported they had either left, or were thinking of leaving the wool industry, because of the presence of wild dogs. These costs are not included in the analysis, so estimates can be viewed as conservative.

National Production Losses

The overall national production loss cost of wild dogs is estimated to be $89 million, with Queensland beef producers bearing much of the impact. NSW sheep producers are estimated to suffer production losses of $11.5 million. The overall cost to the state is calculated to be $17.2 million, or around 21 percent of nationwide costs.

Table 13: Annual Production Loss Impact of Wild Dogs, 2013-14

Cost Component	NSW	Other States and Territories	Australia
	$ million	$ million	$ million
Agricultural Production			
Wool Production Loss	7.70	14.70	22.40
Sheep-meat Production Loss	3.75	0.63	4.38
Beef Production Loss	5.70	56.84	62.54
Wild Dog Production Losses	**17.16**	**72.18**	**89.33**

Photo: Wild dog by K Foster

Photo: Wild dog by Tweed Shire Council

Low Scenario – Less livestock in high density areas

The proportion of the national sheep flock and beef herd being raised in wild dog affected areas varies with seasonal conditions and surveys provide a broad indication about how widespread wild dog predation is perceived. The proportion assumed in the current study is similar to that included by Gong et al (2009), but high impact areas are slightly increased due to recent surveys. When proportion of livestock in high impact areas is decreased by 50 percent the national wild dog production loss cost decreases to $64 million per year.

High Scenario - Inclusion of Higher Stock Prices

The cost of mortality is estimated by assuming a cost impact equivalent to replacement value of the affected stock class. For juveniles, the costs of merino sheep lambs are $30 per head, sheep-meat lambs $50 and calves $450 per head. It is difficult to determine precise values for replacements as trade in new born sheep and cattle is limited. Gross margins sourced from NSW Agriculture include 4 month wether replacements valued at $40 per head, marketed cross bred lambs attaining $123-136 per head at sale (10 months), inland weaner cattle of $368 per head and vealers of $516-601 per head. The gross margins were developed between 2012 for cattle and October 2015 for crossbred ewe production. A higher cost of replacement scenario is included, where young stock prices are doubled. The overall production loss costs of wild dogs increase to $111 million per year.

Table 14: Average, Low and High Wild Dog Production Loss Scenarios

Cost Component	NSW	Other States and Territories	Australia
	$ million	$ million	$ million
Average			
Wool Production Loss	7.70	14.70	22.40
Sheep-meat Production Loss	3.75	0.63	4.38
Beef Production Loss	5.70	56.84	62.54
Wild Dog Production Loss	**17.16**	**72.18**	**89.33**
Low Scenario			
Wool Production Loss	7.70	10.14	17.85
Sheep-meat Production Loss	3.75	0.63	4.38
Beef Production Loss	5.70	36.46	42.16
Wild Dog Production Loss[23]	**17.16**	**47.23**	**64.39**
High Scenario			
Wool Production Loss	8.65	16.63	25.28
Sheep-meat Production Loss	5.78	0.96	6.73
Beef Production Loss	7.55	71.65	79.20
Wild Dog Production Loss	**21.98**	**89.24**	**111.21**

24 The low and average scenarios are the same for NSW as no cattle or sheep are assumed to be raised in high density dog impact areas. This assumption is taken from Table 3.7 of Gong et al (2009)

5.4. Wild Dog Management

Binks et al (2015) found 88 per cent of surveyed landholders in wild dog affected areas and 45 per cent with no fox or dog problems reported undertaking some form of management. Shooting, baiting and trapping were the most common wild dog/fox control methods used by landholders. Farmers in Queensland, WA and NSW used trapping and baiting to a greater extent than other states, whereas fencing and use of guard animals were most prevalent in Victoria. The survey found farmers in wild dog affected areas are spending 26 days and $7,197 a year on wild dog management. Wicks et al (2014) indicated that variations in wild dog management across states were in part due to differences in state legislation and the definitions between 'wild dogs' and 'dingoes', along with different responsibilities for their management.

5.5. Environmental Impact

Aside from mortality-related production losses Wicks et al (2014) indicated wild dogs spread diseases such as the hydatid tapeworm, Echinococcus granulosus (Lightfoot 2010) and the protozoan parasite Neospora caninum, which may cause bovine abortion (NSW Agriculture 2004). The impact of wild dogs on biodiversity is complex. They help modulate marsupial and emu populations, their removal may lead to increases in fox populations (Denny, 1992, Burbidge and McKenzie, 1989) and pests such as wild goats, rabbits and rodents (Corbett and Newsome, 1987), but they also threaten endangered fauna (Robertshaw and Harden, 1989, Allen and Fleming 2012). Predation by wild dogs was outlined as a threat to 36 species listed in the NSW Threatened Species Conservation Act 1995 (Coutts-Smith et al 2007). Allen et al (2012) found that dingoes are as much a threat to native fauna as foxes and feral cats.

6. Feral Pigs

Key Findings:

- Feral pigs inhabit nearly half of the Australian land mass with NSW and Queensland experiencing the largest populations and production losses
- Nationally feral pigs are calculated to have inflicted $14.4 million in production loss costs per year in 2013-14, which is above the 2009 estimate of $10 million
- Australia-wide losses are estimated to be $5 million for wool producers, $3 million for sheep-meat farmers and $7 million for broad acre wheat and barley producers
- The production loss cost to NSW is estimated at $13.5 million in 2013-14, which is more than 90 percent of the national total

6.1. Overview

Feral pigs are found across 45 percent of Australia (West 2008, Choquenot et al. 1996), causing damage to crops and inflicting costs on livestock producers through the predation of young animals. A range of economic impact studies have valued national pig impacts on agricultural enterprises (Gong et al. 2009, Choquenot et al. 1996).

Feral pig-related production losses were estimated to be around $6 million per year in the Australian grains industry by Gong et al (2009), followed by sheep-meat ($1 million) and lost wool production of $2.3 million. NSW and Queensland were calculated to bear the bulk of production losses. Pigs are also considered a major risk factor in the potential spread of exotic diseases and are the subject of substantial control efforts which were estimated to cost more than $6 million per year in management and research by Bomford and Hart (2002).

6.2. Feral Pig Distribution

The number of wild pigs in Australia have been estimated to range from 3.5 to 23.5 million (Hone 1990) and populations cover nearly half of the country (West, 2008). They are thought to be most dense in Queensland, NSW and the Northern Territory, although scattered populations are found in other areas. They mostly reside near water sources where densities as high as 50 per square kilometre have been recorded (Giles 1980). However, as of 1996, such extreme densities are no longer observed (Choquenot et al. 1996). Densities of feral pigs are highly variable over time, particularly along river systems and marshlands in western NSW.

Gong et al (2009) estimated the states of NSW and Queensland to have low to high density feral pig areas impacting upon the wool, sheep-meat and grains industries. Around 1-2 percent of NSW was estimated to be highly impacted. A larger proportion of 9 percent of the states sheep flock was estimated to be raised in low-medium impact areas. The total cost of feral pigs to NSW wool producers was $2.28 million and to sheep-meat producers $0.94 million (Gong et al 2009).

Photo: Feral pig by Michelle Drew

6.3. Economic Impact
Agricultural Production Impact

Lambs are subject to predation by feral pigs and they also reduce grain yields by destroying crops. Assumptions about the proportion of grain crops in NSW and Queensland subject to feral pig losses, along with those for wool and sheep-meat industries are outlined in the following table (Table 15). The assumptions are largely based on those used by Gong et al (2009). Losses are valued using NSW gross margins and value of production data for 2013-14 produced by the ABS.

Photo: Feral pig by Rebbekah Hearn

Table 15: Feral Pig Production Loss Assumptions

Pigs	Unit	NSW	QLD
Wool Production			
% production area no impact	%	80	85
% production area medium impact	%	15	15
% production area high impact	%	5	0
Medium impact young stock loss (2%)	m	0.02[24]	0.00
Medium impact adult stock loss (1%)	m	0.02[25]	0.00
High impact young stock loss (5%)	m	0.01	-
High impact adult stock loss (2%)	m	0.02	-
Medium impact young stock loss ($30 per head)[26]	$m	0.47	0.03
Medium impact adult stock loss ($100 per head)	$m	2.25	0.27
High impact young stock loss ($30 per head)	$m	0.39	-
High impact adult stock loss ($100 per head)	$m	1.50	-
Value of mortality	$m	4.62	0.30
Loss as proportion of LVP[27]	%	0.59	0.39
Sheep-meat Production			
% production area no impact	%	80	85
% production area medium impact	%	15	15
% production area high impact	%	5	-
Medium impact young stock loss (2%)[28]	m	0.02	0.00
Medium impact adult stock loss (1%)	m	0.01	0.00
High impact young stock loss (5%)	m	0.02	-
High impact adult stock loss (2%)	m	0.00	-
Medium impact young stock loss ($50 per head)	$m	1.01	0.04
Medium impact adult stock loss ($100 per head)	$m	0.57	0.03
High impact young stock loss ($50 per head)	$m	0.85	-
High impact adult stock loss ($100 per head)	$m	0.38	-
Value of sheep-meat mortality loss	$m	2.81	0.07
Loss as proportion of LVP	%	0.64	0.19
Broad acre Cropping Industries			
% production area no impact	%	80	90
% production area medium impact (@1%)	%	15	7
% production area high impact (@3%)	%	5	3
% total production loss	%	0.30	0.16
Crop production loss[29]	mt	0.02	0.00
Value of crop production loss[30]	$m	6.05	0.54
Loss as proportion of LVP	%	0.29	0.16
Total value of production losses	**$m**	**13.49**	**0.91**

[25] Medium impact young stock loss for the NSW wool industry is estimated as 2% (mortality) multiplied by 15%of the flock in medium impact areas times 5.26 million merino lambs marked. A similar process is used for high density impact estimation.
[26] Medium impact adult sheep loss for the NSW wool industry is estimated as 1% (mortality) multiplied by 15%of the flock in medium impact areas times 15.02 million adult merinos. A similar process is used for high density impact estimation
[27] The number of estimated mortalities are multiplied by $30 per head for young stock and $100 for adult stock. Total young merino losses in medium impact areas are 0.02 million multiplied by $30, which equals $0.5

Bengsen et al. (2014) modelled feral pig grazing competition in semi-arid floodplains and showed they had impact on pastures at densities of up to 7 pig's km2 (Choquenot 1996). Gentle et al (2015) indicated the scope for damage to pastures is less clear. The key impact on livestock producers is estimated to be predation of young stock, rather than grazing pressure.

There is limited data on rates of predation. Choquenot et al (1996) plotted predation as a function of pig density, with rates of 5 percent at 1 pig per square km, up to 20 percent at 6 pigs per square km. Densities in NSW have been estimated at 2 per square km (Saunders and McLeod, 1999), therefore predation rates of 5 percent of marked lambs were included for sheep producers in high density feral pig areas. Lower estimates outlined in the above table are included for adult sheep.

Feral pigs damage cereal and tropical crops. Losses in sorghum spp. and maize crops in the Northern Territory ranged between 7 and 50% (Caley, 1993, sugarcane yields were reduced by 6% and bananas by 1% in north Queensland (Mitchell and Dorney 2002). Losses in 1982 were estimated to be around 0.1 to 0.15 percent of total Queensland production (Tisdell, 1982).

Stomach contents of pigs were examined by Gentle et al (2015) in the Queensland Murray-Darling Basin. Crop residues were found 9 percent more frequently than non-crop plants. Tisdell (1982) estimated production losses of 3% in wheat, 5% sorghum, 1% barley and 3% in maize when calculating economic impacts of feral pigs. For crops such as wheat and barley, the damage in NSW and Queensland was estimated to be 1 percent in medium impact and 3 percent in high impact areas. These losses are estimated in the above table and valued using NSW gross margins.

National Production Losses

The economic impact of the feral pig problem stems from the direct damage caused to agriculture and farming, environmental degradation and the response and control costs associated with these problems. These costs are estimated in Table 16. They are most likely an underestimate as it is known that feral pigs also impose damage and economic loss to other rural industries such as sugarcane, bananas, macadamia and other horticultural industries. These are not included in the losses summarised in Table 16. Recreational hunting industries target feral pigs which generate economic benefits, and also help control the pest.

Photo: Feral pig by Weldon Thompson

Photo: Feral pig by Leigh Deutscher

[28] LVP is gross value of production.
[29] Medium impact sheep meat young stock losses are estimated by multiplying the proportion of the sheep meat in these areas by the assumed mortality losses. For NSW, this is 15% times 2% by 6.76 million lambs marked 'other' in Table 21.
[30] Tonnes of lost production are estimated by adding wheat and barley production then multiplying by the weighted production loss. For NSW, 0.3% loss is applied to 6.6 mt of wheat and 1.49 mt of barley resulting in a loss of 0.02 mt.
[31] The local value of wheat and barley production in Table 21 is multiplied by 97% (to account for any taxes or levies) and the weighted loss. For NSW, 0.3% is multiplied by $2 billion in wheat and barley production.

Table 16: Annual Feral Pig Production Losses, 2013-14

Cost Component	NSW	Other States and Territories	Australia
	$million	$million	$million
Agricultural Production			
Wool Production Loss	4.62	0.30	4.92
Sheep-meat Production Loss	2.81	0.07	2.88
Broad acre Cropping Industries	6.05	0.54	6.60
Feral pig production losses	**13.49**	**0.91**	**14.40**

Sensitivity Analysis

Cost estimates are based on a large number of assumptions for which there is limited data. Low and higher impact scenarios are included to gauge how costs estimates vary with changes in key assumptions.

Low Scenario – Lower crop yield decreases

High density feral pig production losses for crop yields were included at 3 percent. There is a high degree of uncertainty about their magnitude. In the low impact scenario, they are reduced to 1.5 percent. The value of national crop production losses then falls to $4.5 million per year.

Table 17: Average, Low and High Feral Pig Production Loss Scenarios

Cost Component	NSW	Other States and Territories	Australia
	$ million	$ million	$ million
Average			
Wool Production Loss	4.62	0.30	4.92
Sheep-meat Production Loss	2.81	0.07	2.88
Broad acre Cropping Industries	6.05	0.54	6.60
Feral Pig Production Loss	**13.49**	**0.91**	**14.40**
Low Scenario			
Wool Production Loss	4.62	0.30	4.92
Sheep-meat Production Loss	2.81	0.07	2.88
Broad acre Cropping Industries	4.54	0.39	4.93
Feral Pig Production Loss	**11.98**	**0.76**	**12.73**
High Scenario			
Wool Production Loss	5.02	0.30	5.31
Sheep-meat Production Loss	3.66	0.07	3.73
Broad acre Cropping Industries	6.05	0.54	6.60
Feral Pig Production Loss	**14.73**	**0.91**	**15.64**

High Scenario - Inclusion of Higher Stock Losses

High density feral pig production losses of 9 percent were included for wool and sheep-meat producers in the Gong et al (2009) study. This is more than the base assumptions of 5 percent mortality for high pig impacts on young stock in this study. If the mortality rate is doubled in high density areas by 50%, then production losses increase to $15.6 million per year for Australia.

6.4. Management Costs

Trapping is the most widely used practice for managing wild pigs. (Reddiex et al. 2006, West and Saunders 2007). The poison 1080 (sodium fluoroacetate) is most frequently used in bait. McGaw and Mitchell (1998) estimated that government and private feral pig control expenditure in Queensland was $1.1 million in 1984. Mitchell and Dorney (2002) surveyed 19 cane and 11 banana farms in North Queensland and found trapping and dogging the most common control methods, costing as much as $100 thousand for each cane farm and $27 thousand for banana farms.

Bomford and Hart (2002) calculated that $5 million per annum is spent on pig control by the private and public sectors. A range of projects are supported by the Australian Government Department of Agriculture and Water Resources (and its predecessors), under their Australian Pest Animal Management Strategy. Projects included $2.6 million in the Kakadu National Park Feral Animal Management Strategy. The Invasive Animal Cooperative Research Centre (IACRC) have had a number feral pig R&D projects including the development of PIGOUT® and HOG-GONE® baits.

Feral pig meat has commercial value. Ramsay (1994) estimated wild pig meat export to be between $10-20 million per year, although there is considerable variation in the export volumes. Recreational hunting has economic value, with Tisdell (1982) estimating there were around hundred thousand recreational hunters in the early 1980s spending $45 million per year (Tisdell, 1982). These benefits are not included in the cost analysis. Feral pig management costs are included in the overall management costs of vertebrate pests outlined in the introductory chapter.

6.5. Environmental Impact

Feral pigs host the bacteria Leptospira spp. and Brucella spp which cause infertility in livestock and humans. They also can transmit exotic diseases, such as the foot and mouth disease (FMD) virus. Mitchell (2010) stated the environmental impacts of feral pigs have not been studied intensively. Maps have been developed to better understand the potential impact of feral pigs which are considered a pest of 152 nationally listed threatened species.

Photo: Feral pig by Leigh Deutscher

7. Pest Fish (Carp)

Key Findings:

- Current carp control strategies have largely been ineffective and abundance has increased fourfold within the Murray-Darling Basin over the last decade
- The species could become more prolific with planned delivery of water onto floodplain habitats
- An annual economic cost of $22 million per year is estimated through reduced recreational fishing quality
- Carp also impact on 11 threatened fish species (IA CRC, 2015)

Photo: Carp by Stuart Mitchell

7.1. Overview

Lintermans (2004) indicated that around 34 alien fish species have been introduced into Australian freshwaters, principally from the aquarium or ornamental fish industry. Fulton and Hall (2014) indicated these introductions are one of eight key threats to native fish, with carp and tilapia being two of eleven exotic species established in Australia. The spotted tilapia (Tilapia mariae) is not in NSW, however, the Mozambique tilapia (Oreochromis mossambicus) are abundant on the Gold Coast in Queensland and established on the north coast of NSW in late 2014.

Common carp, Cyprinus carpio, became widespread following release of the 'Boolara' strain in Victoria during the 1960s. McLeod (2004) estimated the annual economic impact of carp on recreational fisheries to be $25 million. Current carp control strategies have largely been ineffective and abundance has increased fourfold within the Murray-Darling Basin over the last decade (IA CRC 2015). The Native Fish Strategy of 2004 indicates effective control at the 'landscape' scale is required to sustainably manage this pest species.

7.2. Carp Distribution

Carp can tolerate a range of water temperatures and salinity levels and are found in all Australian states. They are the dominant species of the Murray-Darling Basin (MDB) following flooding in the 1970s. Collins (2014) indicated that carp numbers throughout the MBD have adversely affected native fish populations, with half of the native fish species in the river system listed as vulnerable or threatened with extinction (MDBA, 2013).

Zampatti and Bice (2015) indicated this pest fish species could become more prolific with planned delivery of water onto floodplain habitats as an objective of environmental flow delivery programs. Krug and Walker (2014) cite recent research that carp numbers are increasing since floods in 2011 and their range has increased to coastal catchments of the New South Wales north coast. They are widespread in the MDB and continue to expand their distribution into upland areas.

7.3. Economic Impact

Fulton and Hall (2014) noted that carp feeding leads to a suspension of sediment - increasing water turbidity and damaging aquatic plants - although the authors stress that claims about impacts are difficult to confirm due to limited information on waterway health prior to carp becoming established. The authors concluded that where the species accounts for more than 80% of total fish biomass they would have a significant environmental impact. They make the habitat less suitable for native fish breeding and survival, compete for food resources, are a vector for at least 2 fish parasites, feed on native fish eggs and also consume the eggs and tadpoles of native frogs (Fulton and Hall, 2014).

A decline in the number of native fish stocks has a social cost. McLeod (2004) cited a range of households surveyed in America and Australia which indicated a willingness to pay for the restoration of wetlands. On average, each household was willing to pay around $30-80 per year and it was estimated that each fisher would be ‘willing to pay’ $40 per year for improved fishing quality in Australia. More recent studies have been conducted in Australia. Zander et al (2010) used choice modelling in a survey of 708 urban Australians to assess the economic value of ecosystem services provided by tropical rivers.[32] Respondents were willing to pay $52 for an increase from “3-star” to “4-star” fishing quality (Zander et al 2010).

Gregg and Rolfe (2013) undertook an economic assessment of the value of recreational angling at Queensland dams involved in the Stocked Impoundment Permit (SIP) Scheme using onsite surveys involving 804 anglers and an online survey of 219 anglers purchasing a SIP licences. Using the travel cost method anglers were found to value each fishing day at $184. The most important factor governing dam travel was found to be the state of campsites and ablutions, then perceived fishing quality. Yamazaki et al (2011) used a double-bounded dichotomous-choice contingent valuation method for valuing recreational fishing in Tasmania and found the number of fish caught from the inshore saltwater fishery did not significantly affect mean willingness to pay.

No survey or modelling studies were recovered which outlined the cost of decreased fishing quality. In the absence of data, it is assumed that a reduction is fishing quality is equivalent to the willingness to pay for a one-star change in fishing quality of $52 per fisher found by Zander et al (2010). Ernst and Young (2011) estimated the number of recreational fishers in the Murray-Darling Basin and their contribution to the economy. Fishers were estimated to contribute $1.3 billion and generate approximately 10,950 jobs per year. The total number of fishers was estimated to be 0.43 million, with 39 percent being in NSW and 27 percent in Victoria. This number would likely increase with any carp biomass decline (and replacement by native fish) in the future. The 2011 estimate of fishers is less than that estimated by McLeod (2004) of 0.6 million Australians who were considered to have regular contact with inland waters where carp could possibly be a problem.

IA CRC (2012) stressed that ‘putting a realistic value on environmental impact and loss of biodiversity is virtually impossible, as ‘the environment’ is not normally bought or sold’. While it is extremely difficult to value biodiversity, recreational fishers would likely value an improvement in the native catch. Multiplying a ‘willingness to pay’ for improved fishing quality of $52 per household over 0.43 million fishers generates a national cost of decreased fishing quality due to carp of $22 million per year. Using the Ernst and Young (2011) estimate, 39 percent, or $9 million of the cost, is assumed attributable to the NSW proportion of total recreational fishers in the MDB.

The estimated cost of carp of $22 million on recreational fishing quality is equivalent to around 10 percent of the annual cost of elevated river turbidity, eutrophication and sedimentation calculated by Possingham et al (2002). IA CRC (2012) noted that ‘if carp were not present, it is unknown how native fish species numbers might increase (Gehrke et al 2010) and then how much of that increase in native fish would be transferred to angler catches.’

There is a high degree of uncertainty about the financial order of willingness to pay. Correspondingly, a lower cost scenario of 50% of the willingness to pay ($26 per fisher) is also included as a more conservative estimate of carp impact. Under this assumption the national cost of decreased recreational fishing quality as a result of carp is $11 million per annum. Ernst and Young (2011) found the annual spending of recreational fishers in the MDB to be $3,144 per fisher per year. An estimate of willingness to pay of $52 is equivalent to 1 percent of this direct fishing expenditure per annum. If willingness to pay was doubled, the annual cost of decreased fishing quality ($104 per fisher) as a result of carp in the MBD would be $45 million per year.

7.4. Carp Management

Fulton and Hall (2014) noted that state authorities undertake limited direct control of carp. Both Queensland and New South Wales have implemented carp control plans across small to medium scales, but only for limited periods of time. In contrast, Tasmania has implemented an intensive carp control plan in Lakes Crescent and Sorrell on an ongoing basis since 1995, with carp successfully contained to these two lakes and subsequently eradicated from Lake Crescent.[33]

Carp induced sedimentation may also require water to be treated to meet standards required for agriculture and potable water and irrigation corporations need to de-silt their channel infrastructure. These costs are likely to be significant and should be quantified as part of on-going research. Harvesting of carp has a commercial value, which offsets some of the above economic costs to some degree.

Photo: Carp by Marc Ainsworth

8. Feral Goats

Key Findings:

- Australia has an estimated 3 million feral goats, distributed in most states and territories
- Feral goat numbers have been increasing in NSW, but decreasing in most other states. NSW accounts for around 70 per cent of the national feral goat population
- Feral goats compete with sheep and cattle for forage and cause $7 million per annum in production loss costs
- Around 2.13 million goats were slaughtered in 2014, 90% of which were from rangelands. The economic value of this production is considerably more than the losses associated with grazing competition

[32] Fitzroy River (catchment 96,000 km2) in Western Australia, Daly River (53,000 km2) in the Northern Territory and Mitchell River (73,000 km2) in Queensland

[33] http://www.pestsmart.org.au/wp-content/uploads/2012/06/Diggle2011_TasCarpManual.pdf

8.1. Overview

Feral goats were estimated to inflict annual economics costs of $7.7 million in 2003 (McLeod 2004), largely from production losses derived from pasture competition with sheep and cattle. Of the total economic costs, sheep and cattle production losses were estimated to be $4.23 million and control costs of $3.15 million. Kimball and Chuk (2011) cite the impact study conducted by Henzell (1989) in the 1980s which estimated feral goats caused net losses of $25 million per year. These costs included reduced stock production, the exotic disease threat and government control expenditures. These losses are offset by the commercial value of feral goat harvesting. Forsyth and Parkes (2004) estimated an annual off-take of approximately 1 million goats and suggested feral goats generate net benefits for the economy as production loss costs are less than the value of feral goat harvesting. These losses and benefits are estimated in this chapter.

8.2. Feral Goat Distribution

Feral goats are found across Australia, with large populations in western New South Wales, southern Queensland, central eastern South Australia and in Western Australia. Kimball and Chuk (2011) noted that the population is dominated by Angora, Cashmere, Anglo-Nubian, British Alpine, Saanen and Toggenburg breeds.

Pople and Froese (2012) report that feral goat populations have been estimated over 30 years as part of aerial surveys for kangaroo management. The size of the feral goat population increased from 1.4 million in 1997 to 4.1 million in 2008, then experienced a decrease in 2010 to 3.3 million. Goat numbers have been increasing in NSW with an estimated population size of 2.95 million in 2011 (Pople and Froese, 2012).

NSW feral goat populations have increased despite droughts in the 2000s and the state now accounts for around 70% of the national population. Kimball and Chuk (2011) cite West and Saunders (2007) who examined survey data; and concluded goats inhabit 38% of New South Wales. This estimate is used to calculated the proportion of the sheep industry raised in feral goat affected areas.

There was an increase in feral goat numbers in Queensland up until 2005, particularly in the mulga areas, then decreases across the state were observed. Numbers have also been decreasing in Western Australia. They have been most pronounced in the Murchison and Gascoyne regions. These trends are provided in Figure 3. The significant increase in NSW feral goat numbers and declines in most other states are readily apparent.

8.3. Economic Impact

Impact on Livestock Enterprises

Sloane et al (1988) calculated that feral goats cost the national wool industry $3 million per year in production loss costs. They compete for feed resources with sheep and cattle in semi-arid areas. Pople and Froese (2012) indicated that using a linear relationship between goat density and grazing pressure is an oversimplification, as determining the grazing impacts of domestic and native herbivores is very difficult. Kimball and Chuk (2011) indicated that goats are mainly at low and medium densities across NSW, but there are some high-density populations in the north-west and in the Northern, Central and Southern Slopes regions.

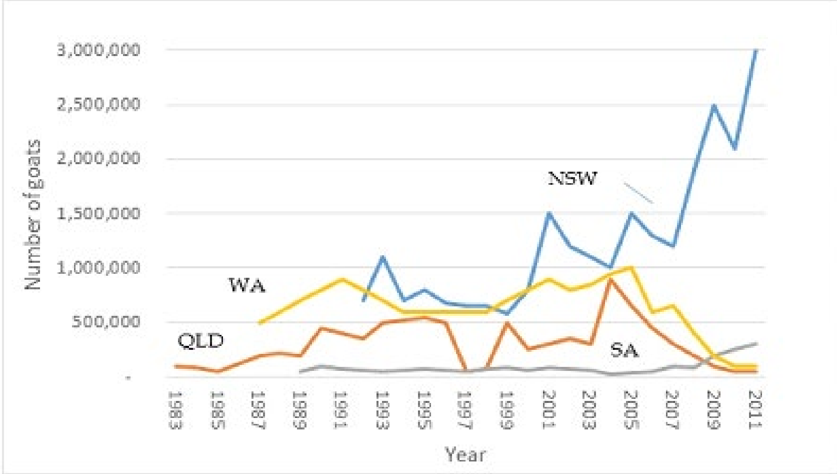


Figure 3: Estimated Feral Goat Numbers, by State, 1983-2011
Source: Pople and Froese (2012), p. 28.

Parkes et al. (1996) calculated that feral goats at densities of 2-5 per square kilometre consume between 0.73 and 1.83 tonnes of dry matter per square kilometre respectively, or up to 0.93% of the total biomass. This is far less than rabbits which consume 10 tonnes per square kilometre at average densities (Newsome 1993), or around 10% and 25% of the food eaten by large herbivores (Parkes et al. 1996). Grazing studies conducted in Queensland by Thompson et al. (2002) found feral goats accounted for 3-30 per cent of grazing pressure; kangaroos 16–36 percent; and livestock 37–72 percent.

Economic analysis of feral goat enterprises in western NSW by Khairo et al. (2011) included the assumption that livestock carrying capacities increased at the rate of 0.4 sheep DSE for each goat removed, however, noted that goats prefer not to graze with sheep and tend to avoid areas where sheep are stocked. Economic modelling for Broken Hill assumed the sold weight of sheep and cattle and wool cut per head would be slightly higher if the harvesting of feral goats was not undertaken.

Assumptions relating to the impact of feral goats across differing states used in this cost assessment are provided in Table 18. The assumptions on reduced production are conservative given grazing studies and economic analysis studies cited above did not find large production decreases from feral goat grazing competition. Only limited sheep-meat losses are estimated as prime lamb production is limited in arid areas.

Photo: Feral goats by Michael Perkins

Table 18: Feral Goat Production Loss Assumptions

Goats		NSW	QLD	SA	WA
Wool Production					
% production area no impact	%	62	95	95	80
% production area medium impact (@1%)	%	35	5	5	20
% production area high impact (@2%)	%	3	-	-	-
% total production loss	%	0.41	0.05	0.05	0.20
Wool production loss	kt	0.53	0.01	0.03	0.15
Value of wool production loss	$m	3.03	0.04	0.17	1.06
Loss as proportion of Gross Value Production	%	0.39	0.05	0.05	0.19
Sheep-Meat Production					
% production area no impact	%	95	99	99	98
% production area medium impact (@1%)	%	4	1	1	2
% production area high impact (@2%)	%	1	-	-	-
% total production loss	%	0.06	0.01	0.01	0.02
Sheep-meat production loss	kt	0.07	0.00	0.01	0.01
Value of sheep meat production loss	$m	0.25	0.00	0.03	0.04
Loss as proportion of Gross Value Production[33]	%	0.06	0.01	0.01	0.02
Beef Production					
% production area no impact	%	62	95	95	80
% production area medium impact (@0.25%)	%	35	5	5	20
% production area high impact (@0.75%)	%	3	-	-	-
% total production loss	%	0.11	0.01	0.01	0.05
Beef production loss	t	0.571	0.146	0.015	0.053
NV of beef production loss	$m	1.46	0.42	0.04	0.25
Loss as proportion of Gross Value Production	%	0.10	0.01	0.01	0.05
Total value of production losses	$m	4.74	0.46	0.25	1.34

Photo: Feral goats by Jason Wishart

[34] The value of sheep meat production loss of $0.25 million in NSW is divided by the value of lamb production ($ 440 million) in Table 21 to estimate cross bred sheep meat production losses.

In addition to production losses, Parkes et al. (1996) indicated that diseases such as yersiniosis, leptospirosis, Johne's disease and bovine tuberculosis have the potential to be vectored by goats, although they are not common. Kimball and Chuk (2011) concluded that it is unlikely that parasites and diseases have any major impact on the density or distribution of unmanaged goats, in part due to the aridity of the production areas where they are commonly observed.

National Production Losses

Aggregate NSW and Australian production losses for feral goats are reported for wool and beef production in Table 19. The overall production loss cost for NSW is $4.74 million and nationally $6.79 million in 2013-14.

Table 19: Annual Production Losses of Feral Goats, 2013-14

Cost Component	NSW	Other States and Territories	Australia
	$million	$million	$million
Agricultural Production			
Wool Production Loss	3.03	1.27	4.29
Sheep-meat Production Loss	0.25	0.07	0.32
Beef Production Loss	1.46	0.71	2.17
Feral Goat Production Losses	4.74	2.05	6.79

Sensitivity Analysis

As well as an average estimate of production loss, cost estimates are included for low and high cost scenarios. Resulting estimates are reported in Table 20. As goat meat production and price data is limited and volumes are volatile, no economic surplus scenario is included.

Low Scenario – Reduced Feral Goat Impacted Areas

West and Saunders (2007) examined survey data and concluded goats inhabit 38% of New South Wales. This estimate is used to calculate the proportion of the sheep industry raised in feral goat affected areas across Australia. There is some uncertainty around the magnitude of the estimate. If only 75% of the area is included in the average scenario, then production loss costs would decline to $5.3 million per annum as shown in Table 20.

Table 20: Average, Low and High Feral Goat Production Loss Scenarios

Cost Component	NSW	Other States and Territories	Australia
	$ million	$ million	$ million
Average			
Wool Production Loss	3.03	1.27	4.29
Sheep-meat Production Loss	0.25	0.07	0.32
Beef Production Loss	1.46	0.71	2.17
Feral Goat Production Loss	**4.74**	**2.05**	**6.79**
Low Scenario			
Wool Production Loss	2.38	0.95	3.33
Sheep-meat Production Loss	0.21	0.05	0.26
Beef Production Loss	1.17	0.53	1.70
Feral Goat Production Loss	**3.76**	**1.54**	**5.30**
High Scenario			
Wool Production Loss	3.78	1.58	5.37
Sheep-meat Production Loss	0.31	0.09	0.40
Beef Production Loss	1.83	0.89	2.71
Feral Goat Production Loss	**5.92**	**2.56**	**8.48**

High Scenario – Higher Production Losses

Production losses were limited to between 1-2 percent for sheep and 0.25-0.75 percent for cattle in goat-affected areas. If higher production losses (25% more than assumed for the average scenario) were included for wool, beef and sheep-meat producers, then costs would increase to around $8.5 million per annum.

8.4. Feral Goat Management

Management includes shooting and mustering. The sale of mustered animals leads to significant commercial value. Khairo et al. (2011) developed farm models for the Bourke, Cobar and Broken Hill district; and estimated the value of opportunistic harvesting of feral goats. They found the ‘operation to be profitable for landholders in all districts and could be improved by additional capital investment aimed at maximising feral goat turnoff’. The numbers of harvested feral goats vary according to price and seasonal conditions. At the time of the McLeod (2004) impact study around one million goats were mustered each year, mainly for abattoir slaughter.

Pople and Froese (2012) indicated that most harvested goats are processed at abattoirs, however, a regular supply of marketable goats is a key constraint to an abattoirs’ profitability (Toseland 1993). Kimball and Chuk (2011) estimated Australia-wide feral goat slaughter has increased from 0.5 million in 1988 to 1.4 million in 2010. MLA (2015) noted that some 90 percent of production is derived from rangeland goats sourced from semi-arid western regions of the eastern states. In 2014 goat slaughter reached 2.13 million head (MLA, 2015). The commercial value of this harvest reduces the economic cost of production losses relating to feral goats.

8.5. Environmental Impact

Feral goats can overgraze native vegetation causing accelerated rates of erosion and land degradation. Kimball and Chuk (2011) noted there are ‘no documented examples of goats on mainland Australia severely damaging large areas in the absence of significant populations of other herbivores’. The Endangered Species Protection Act 1992, identify feral goats as a threat to (94 identified in NSW) native species.

9. Feral Deer

Key Findings:

- Feral deer are found in pockets across Australia. 218 deer herds were estimated across the country in 2002, numbering 0.2 million animals. Nearly half are in NSW.
- Although the economic impacts of deer are reviewed in this chapter, there is no annual economic loss or management costs estimated for NSW or Australia
- There is limited information about the impacts of wild deer, although they are implicated in the spread of livestock disease; compete for pasture; inflict crop damage and damage motor vehicles.
- They can trample and over graze protected flora. Studies in the Royal National Park in New South Wales documented overgrazing, browsing, trampling, ring-barking, antler rubbing and dispersal of weeds.

9.1. Overview

Moriaty (2004) reported 218 deer herds across Australia in 2002, numbering 0.2 million animals. Many were derived from long standing acclimatisation herds, although releases since the 1990s have led to increases in the overall size of the national herd. Around half the herds in 2002 were found in NSW, a quarter from Victoria, and smaller numbers in Queensland, South Australia and other states and territories (Moriarty 2004). West and

Photo: Feral deer by Ayden Doumtsis

Saunders (2007) indicated that six species of wild deer including fallow (Dama dama), red (Cervus elaphus), sambar (Cervus unicolour), rusa (Cervus timorensis), chital (Axis axis) and hog (Axis porcinus) are observed in NSW.

Herd size dynamics differ across states. Numbers of Sambar deer have risen dramatically in Victoria. Less than 10 thousand were thought to reside in the state in 1995, which has increased to around 70 thousand in 2002 (Moriaty, 2004). Surveys of government land managers in NSW by West and Saunders (2007) suggest that deer numbers in the state are also increasing. Deer presence was reported from 30 new areas across the state between 2002-2005. They are noted as being the least studied mammal species in Australia, with only two papers published in peer-reviewed scientific journals during the 20th century.

9.1. Overview continued

Herd size dynamics differ across states. Numbers of Sambar deer have risen dramatically in Victoria. Less than 10 thousand were thought to reside in the state in 1995, which has increased to around 70 thousand in 2002 (Moriaty, 2004). Surveys of government land managers in NSW by West and Saunders (2007) suggest that deer numbers in the state are also increasing. Deer presence was reported from 30 new areas across the state between 2002-2005. They are noted as being the least studied mammal species in Australia, with only two papers published in peer-reviewed scientific journals during the 20th century.[35]

9.2. Feral Deer Distribution

Wild deer species were estimated to reside across 40,700 km2 of NSW, or 5% of the total state's land mass in 2002 (West and Saunders 2003). They are mainly found in the Coast and Tablelands Divisions of NSW, and are less frequently observed across the Slopes and Western Division. Notably, they occur in many conservation reserves and bioclimatic modelling suggests wild deer could increase their range (NSW Department of Environment, 2010). West and Saunders (2007) report that increases in their range, abundance and associated impacts were evident throughout NSW (more than any other pest species).

The distribution and population growth of wild deer in other parts of Australia is mixed. In South Australia fallow deer (Dama dama) is the key wild species in the south east, mid north and Mt Lofty Ranges. Wild deer occur in forested and woodland areas in the eastern parts of Victoria, and in parts of western Victoria (Wright et al 2005). Chital, red and fallow deer were established in Queensland by Acclimatisation Societies and number in the tens of thousands (Pople et al. 2005).

Photo: Feral deer by Leigh Swan

Photo: Feral deer by Randall O'brien

[35] https://theconversation.com/the-protected-pest-deer-in-australia-11452

9.3. Economic Impact

West and Saunders (2007) indicated that there is limited information about the long term impacts of wild deer, although they are implicated in the spread of livestock disease; compete for pasture; damage crops and motor vehicles. The authors surveyed Rural Lands Protection Boards officers across the state to gauge perceptions about wild deer damage in 2004/05 and found regional differences. The spread of weeds was thought to be the biggest impact in the Central Slopes Division, and least cited issue within Western Division.

Deer-related vehicle accidents were the highest rated issue in the North Coast Division, and least rated in the Northern Tablelands. Fence damage, crop damage and spread of livestock disease were nominated across all regions as key pest impacts. A survey of 270 landholders in South Australia by the Department of Water, Land and Biodiversity Conservation found 60 percent of farmers with wild deer problems thought potential disease carriage and risks to vehicles were the main impacts (McLeod, 2005).

Agricultural Production Impact

FJensz and Finley (2013) concluded that it is probably only high density wild deer populations that impact forestry and agriculture. At high numbers they compete with livestock for feed and damage young plantings or prevent regeneration. ABC Rural cited examples from the New South Wales far south coast with farmers noting they "don't make hay anymore, now I buy in $10,000 to $12,000-worth a year and that's what the deer are doing to me, they're eating me out."[36] A southern NSW beef producer running 400 head of cattle indicated "at least 100 deer were regularly on their property. They said a conservative estimate put the cost of deer in grazing pressure alone at $20,000 per year".[37]

Competition is limited in many areas as high deer density is not frequently observed. West and Saunders (2007) survey respondents indicated wild deer were most commonly observed in groups of between 3 and 10 individuals or as solitary animals.[38] When reflecting on trends between 2002 and 2004/5 surveys, the authors concluded impacts related to competition for pasture and damage to crops and fences have increased. This was thought to be a result of the drought.

Lindeman and Forsyth (2008) assessed agricultural impacts of deer in Victoria. They examined the reasons why an Authority to Control Wildlife permit had been obtained to shoot wild deer and also telephoned 48 Victorian landholders with permits listing deer species in mid-2007. The most frequent reasons for issuing permits were eating trees, damaging fences and eating pasture. Other reasons included eating fruit crops and vegetables, trampling crops and fouling of pasture crops or water. Estimates of agricultural financial losses by 15 contacted landholders ranged from $200 to $20 000 and averaged $4600.

The authors undertook a series of field visits to examine deer impacts. No direct competition for cattle pastures in Gippsland could be attributed to sambar deer, with the farmer considering wombats and kangaroos as more serious competitors. The authors concluded that orchard and plantation impacts are more important than competition for pasture. Establishing competition impacts in Queensland has also been difficult. Dryden (2005) noted there is overlap in the diets of deer and cattle in Queensland, however, forage species selection differs, especially in winter. Deer may contribute to the spread of weeds. (Wright et al, in McLeod, 2005).

[36] ABC Rural (2015) Feral deer destroying pastures on New South Wales south coast, 28 Aug 2015, at http://www.abc.net.au/news/2015-08-28/feral-deer-destroying-pastures-on-nsw-south-coast/6732498

[37] http://www.theland.com.au/story/3370754/feral-deer-policy-gaps/

[38] During 2004/05 a short mail-out questionnaire was distributed to Rural Lands Protection Boards to obtain information on the impacts, control and management of pests of which 48 responses were received. It contained some outcomes from the 2002 survey for 2002 and 2004 comparisons.

Traffic and Train Impacts

Rowden et al (2008) reported that many thousands of collisions occur between motor vehicles and animals each year across Australia, resulting in repair costs to property, injury, and loss of animal life. Vehicle accidents as a result of deer have been estimated to cause between 750 to 3,200 human injuries in England per annum (Wilson 2003).

Attewell and Glase (2000) indicated there is limited information of animal-related accidents in Australia, in part due to many incidents being unreported. Between 2001 and 2005 there were 11 fatal crashes, 1399 injury crashes, and 2532 non-casualty crashes attributed to swerving to avoid an animal in NSW. Nearly half involved kangaroos and wallabies and a third livestock. NSW Transport (2011) provided more recent animal crash data for 2011. In this year there were 67 crashes for 'other animals' as the object hit in first impact and 248 crashes for kangaroo/wallabies. Some 903 crashes were a result of swerving to avoid an animal.

Costs include damage to vehicles, treatment of injuries and any loss of production as a result of morbidity and mortality. Ramp and Roger (2008) cite National Roads and Motorists' Association estimates that vehicle damage from collisions cost an average of $3,000 per incident across all animals in Australia (NRMA 2003). Similar costs were recorded for deer related crashes in the USA. Vehicle insurance data across the United States indicated the 2006-2007 average vehicle repair cost was about US$2,850 for deer (Huijser et al 2009), or around $4,000 Australian dollars.

Deer also impact rail transport. The cost of animals on rail tracks in the UK was around £4.9m in 2012/13 (Rail Safety and Standards Board, 2014). The costs include damages to equipment, delays and compensation payments from a total of 346 crashes with animals over that year. Feral deer accounted for 211 of 346 crashes (61 per cent). This amounts to around $30,000 Australian dollars per crash.

9.4. Management Costs

McLeod (2005) indicated that current management of wild deer across Australia varies by state due to legislation. West and Saunders (2007) reported that ground shooting represented 90 per cent of control efforts across NSW in 2004. The Northern Illawarra Wild Deer Management Program (NIWDMP) undertakes landholder surveys to ascertain deer impacts on residential landholdings and rural landholdings. Surveys (350 surveys) are conducted yearly and residential surveys are conducted every 2 years (4000+ surveys). Residential surveys in 2012 and 2014 found approximate value of damage to properties of $0.6 million and repairs of $0.2 million for these periods (Michael Knez, pers comm, January 2016. These farm level control costs are not included in Tables 1 and 2.

A survey of landholders in Victoria found most (74%) farmers incurred no cost for deer control as recreational deer hunters do not require fees for services. The Australian Deer Association wild deer has a commercial value. For example, Dryden (2005) noted there are 15 commercial safari hunters in southern Queensland which generate financial benefits. A survey was undertaken across Victoria by RMCG, EconSearch and DBM Consultants (2014) in 2013 to calculate hunter expenditure. The survey estimated annual 2013 Direct Gross State Product impacts of game hunting by game-licence holders to be $118 million, with flow-on benefits of $177 million. Other wild deer management approaches include exclusion fencing, which incur direct costs to landholders and other agencies.

[34] https://theconversation.com/the-protected-pest-deer-in-australia-11452

9.5. Environmental Impact

West and Saunders (2005) noted that wild deer are often perceived as posing a serious threat to exotic disease carriage. Jesser (2005) noted their current or potential role in carriage of Cattle tick (Boophilus microplus), Screw-worm fly (Chrysomyia bezziana), Leptospirosis (Leptospira spp.) Surra (Trypanosoma evansi), Johne's disease (Mycobacterium avium paratuberculosis), Brucellosis (Brucella abortus), Ovine Johne's disease (OJD), Bovine Johne's disease (BJD), Bovine tuberculosis (Mycobacterium bovis), Yersinia (Yersinia pseudotuberculosis), Tissue worm (Elaphostrongylus cervi), Malignant catarrhal fever (MCF), (Gamma herpesvirinae) and Louping ill. English (2005, in McLeod 2005) concluded that wild deer would 'pose a relatively small risk in the event of an exotic disease outbreak, compared to pest species like feral pigs and goats'. Others, such as the CSIRO report on Australia's Biosecurity Future, found increasing deer numbers would increase the risk of foot and mouth and blue-tongue outbreaks.[39]

Wild deer can trample and over graze protected flora. Jesser (2005) noted studies outlining the impact of rusa deer in Royal National Park in New South Wales which documented overgrazing, browsing, trampling, ring-barking, antler rubbing, and spread of weeds (Clarke, et al. 2000). The Department of Environment NSW[40] noted areas of the park with high deer density have 30-70% fewer plant species than those areas with limited deer grazing (NPWS 2002).

Queensland has also been difficult. Dryden (2005) noted there is overlap in the diets of deer and cattle in Queensland, however, forage species selection differs, especially in winter. Deer may contribute to the spread of weeds. (Wright et al, in McLeod, 2005).

Photo: Feral deer by Ayden Doumtsis

Photo: Feral deer by Francesca Bowman

Photo: Feral deer by Daryl Panther

[39] http://www.weeklytimesnow.com.au/news/politics/nsw-government-pressured-to-declare-wild-deer-a-pest-species/story-fnkerdda-1227198189773
[40] http://www.environment.nsw.gov.au/determinations/FeralDeerKtp.htm

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Appendix

Appendix 1: Industry Data and Estimates, 2013-2014

Table 21: Industry Data and Estimates, 2013-2014

State		NSW	VIC	Queensland	SA	WA	Tasmania	NT	Total
Number of Businesses[40]									
Livestock (Sheep and beef)	Number	41,513	25,590	19,664	10,538	9,596	4,163	243	**111,307**
Broad acre crops	Number	10,070	6,409	6,409	4,766	4,551	632	-	**32,837**
Broad acre Pest Management Costs[41]									
Number of farms	Number	41,266	25,599	20,858	12,243	11,318	3,836	194	**115,315**
Mean (@$400 per farm) Management	$m	16.5	10.2	8.3	4.9	4.5	1.5	0.1	**46.1**
High (@$500 per farm) Management	$m	20.6	12.8	10.4	6.1	5.7	1.9	0.1	**57.7**
Low (@$300 per farm) Management	$m	12.4	7.7	6.3	3.7	3.4	1.2	0.1	**34.6**
Sheep numbers at 30 June 2014	million	26.71	15.37	2.34	10.97	14.41	2.78	-	**72.57**
Adult sheep	million	18.84	10.79	2.00	7.27	10.19	2.03	-	**51.12**
Merino adult sheep	million	15.02	8.06	1.78	5.86	8.84	1.54	-	**41.10**
Breeding adult ewes	million	15.35	8.48	1.35	5.98	7.95	1.52	-	**40.63**
Cross bred adult ewes	million	3.82	2.73	0.22	1.41	1.35	0.49	-	**10.02**
Sheep <1 year	million	7.88	4.57	0.34	3.71	4.22	0.75	-	**21.46**
Lambs marked merino	million	5.26	2.24	0.34	2.22	3.77	0.54		**14.37**
Lambs marked other	million	6.76	4.63	0.24	2.64	2.27	0.75		**17.29**

Table (cont)

[40] Taken from ABS (2015). 7121.0 - Agricultural Commodities, Australia, 2013-14. An agricultural business operation with value of $5,000 was included following ABS' Estimated Value of Agricultural Operations (EVAO) or declared in Businesses Activity Statement (BAS).

[41] The number of farms are multiplied by $400 per farm (average), $500 (high) and $300 (low) to calculate pest animal control costs. Some livestock and broad acre businesses may have joint crop and livestock activities. For example, of the livestock industries (Sheep farming specialised, Beef cattle farming plus beef cattle feedlots, Sheep-beef cattle farming and Grain-sheep or grain-beef cattle farming) included in ABS (2013) 7106.0 - Australian Farming in Brief, 2013, mixed farming accounts for nearly 20 percent of businesses. The total number of livestock and broad acre crop farms are multiplied by 80 percent to account for this possible overlap when estimating numbers of farms.

State		NSW	VIC	QLD	SA	WA	Tas	NT	Total
Sheep slaughtered	million	7.34	13.50	0.99	5.17	3.95	1.01	-	31.96
Mutton production	kt	57	79	12	39	36	5	-	228
Lambs slaughtered[42]	million	5.26	10.58	0.44	3.89	2.55	0.82		23.54
Lamb production[43]	kt	110	207	9	83	50	15	-	474
Value of lamb meat production	$m	440.00	828.00	36.00	332.00	200.00	60.00	-	1,896.00
Value of sheep meat production[44]	$m	580.90	848.73	53.08	441.67	371.19	73.30	-	2,368.87
Sheep shorn[45]	million	28.80	18.10	2.90	10.90	15.80	2.60	-	79.10
Shorn greasy wool production	kt	128.40	72.30	11.10	53.30	73.60	10.50	-	349.20
Value of wool production[46]	$m	776.98	560.87	75.89	361.49	556.92		-	2,332.15
Adjusted for skins	kt	158.00	89.00	14.00	66.00	91.00	13.00		431.00
Value of wool production	$m	956.10	690.42	95.72	447.62	688.58	-	-	2,878.44
Beef cattle at 30 June	million	5.33	2.43	12.76	1.11	1.97	0.53	2.16	26.29
Cattle < 1 year	million	1.37	0.73	2.49	0.32	0.53	0.15	0.35	5.95
Beef meat production	kt	519.00	451.00	1,167.00	117.00	106.00	-	-	2,360.00
Value of beef production	$m	1,399.38	1,311.09	3,526.16	362.40	519.27	182.86	418.90	7,720.06
Barley hectares	million	0.72	0.92	0.11	0.81	1.26	-	-	3.81
Barley production	mt	1.49	2.04	0.18	1.89	3.56	-	-	9.15
Value of Barley production	$m	368.88	468.97	43.90	432.98	925.53	6.49	-	2,246.75
Wheat hectares	million	3.27	1.54	0.76	1.93	5.11	-	-	12.60
Wheat production	mt	6.60	3.40	1.04	4.25	9.98	-	-	25.26
Value of wheat production	$m	1,711.3	1,018.4	305.3	1,308.0	3,057.2	11.1	-	7,411.32

[42] Taken from ABS (2015). 7218.0.55.001 Livestock and Meat, Australia for 2013-14 (July-June).
[43] Taken from ABS. (2015). 7218.0.55.001 Livestock and Meat, Australia. Table 11. Tonnes are carcass weight and exclude offal.
[44] Taken from ABS (2015). Value of Agricultural Commodities Produced, Australia, 2013-14. Lamb value estimated using assumption of 400c/kg cwt.
[45] ABARES; Australian Bureau of Statistics, Livestock Products, Australia, cat. no. 7215.0, Canberra; Australian Wool Innovation Wool Production Forecasting Committee; Australian Wool Testing Authority, Key Test Data Summary, Melbourne
[46] Taken from ABS (2015). Value of Agricultural Commodities Produced, Australia, 2013-14. Local value is used. ABS defines this as the value at the place of production, including indirect taxes. The local value of a commodity is calculated by subtracting total marketing costs from gross value. Marketing includes freight, cost of containers, commission, insurance, storage, handling and other charges necessarily incurred by the producer in delivering commodities to the market place.

Appendix 2: Government Pest Animal Management Expenditure

Average state expenditure equals the low expenditure scenario for all states, except for NSW, South Australia and Western Australia as industry expenditures are removed from low and average to avoid any double counting of these costs with farm level costs. Explanations are included in the footnotes.

Table 22: State and Commonwealth Pest Animal Management Expenditure, 2013-14

		NSW[47]	VIC[48]	QLD	SA[49]	WA[50]	Tasmania	NT[51]	Total
State Expenditure									
Average	$m	20.36	15.66	8.60	2.79	12.16	9.88	0.13	**69.58**
High Scenario	$m	36.99	15.66	8.60	3.60	18.26	9.88	0.13	**93.11**
Low Scenario	$m	20.36	15.66	8.60	2.79	12.16	9.88	0.13	**69.58**
Commonwealth Expenditure									
Average	$m								**14.74**
High Scenario	$m								**14.74**
Low Scenario	$m								**14.74**

[47] NSW expenditures are from G. Saunders for 2014/15. Rural development corporation and CRC commonwealth funds are excluded. LLS expenditures is excluded in the mean and low scenarios, as some resources could overlap with farm level spending. Average farm pest expenditure outlined in Gong et al (2009) included "fixed costs of management", which may include levies and rates. Local land services expenditures are included in the high expenditure scenario.
[48] Victorian, Queensland, Tasmanian and Commonwealth spending is taken from Gong et al (2009) but indexed to 2013/14 using CPI
[49] South Australian expenditure was provided by John Virtue (13 December 2015). They are an amalgam of state-level unit in PIRSA and information provided from regions within the Department of Environment, Water & Natural Resources (DEWNR). They are unpublished and were compiled to inform the annual budget estimates process of parliament. Estimates include state spending on rabbits, fox, deer, and wild dogs.
[50] Western Australian estimates were provided by Viv Read (2 Dec 2015) and Malcolm Kennedy (8 December 2015). State level costs included in the average and low scenarios include $5.86 million for wild dogs and the DAFWA 2013/14 Invasive Species CF budget of $6.3 million. Industry funds of $6.1 million included in the high cost scenario.
[51] NT estimates for 2013-14 were provided by Glen Edwards (8 Jan 2016) and largely comprise wild dog control.

Appendix 3: Introduced Birds (Starlings in Viticulture)

Introduced bird control costs are based on the Tracey et al (2007) survey of production loss estimates included in Gong et al (2009) study, but adjusted for inflation and the inclusion of introduced bird species only.[52] Tracey and Saunders (2003) indicated the starling (*Sturnus vulgaris*) causes most damage to the wine grape industry. Around Orange in NSW the species is perceived to cause 80-90% of all bird damage. Some unprotected crops in a survey of 30 local producers were thought to suffer yield reductions of 45 percent due to bird damage, however, an average total loss of 9.4 percent was found across all producers included the survey. Production loss costs are outlined in the table below. They are derived from surveys included in Tracey et al (2007), where birds were estimated to inflict losses of 7 percent of viticulture production.

Table 23: Annual Introduced Bird Production Loss and Farm Control Expenditures, 2013-14

Introduced Birds	Unit	NSW	VIC	QLD	SA	WA	Tas	Total
Horticultural areas								
Viticulture	m ha	0.04	0.03	0.00	0.07	0.01	0.00	**0.15**
Horticultural LVP								
Viticulture	$m	168.80	294.60	49.70	351.30	103.60	11.50	**979.5**
Horticultural Production Losses								
% production viticulture	%	7	7	7	7	7	7	7
NV Production Losses								
Viticulture	$m	11.82	20.62	3.48	24.59	7.25	0.81	**68.6**
Total NV of production losses	**$m**	**11.82**	**20.62**	**3.48**	**24.59**	**7.25**	**0.81**	**68.6**
Control Costs								
Viticulture	$m	5.00	4.26	0.05	8.90	1.33	0.14	**19.7**
Total Control Costs	**$m**	**5.00**	**4.26**	**0.05**	**8.90**	**1.33**	**0.14**	**19.7**
Total Control and Losses	**$m**	**16.81**	**24.88**	**3.53**	**33.49**	**8.58**	**0.94**	**88.2**

[52] Native species such as Sulphur crested cockatoos (Cacatua galerita), galahs (Elophus [Cacatua] roseicapilla), little corellas (Cacatua sanguinea) and longbilled corellas (Cacatua tenuirostris) cause the bulk of damage to the nut industry. Stone fruits, such as cherries, are also impacted by native birds such as rosellas (Sinclair and Bird, 1987) and pome fruits losses are largely caused by parrots (Platycercus spp. and Polytelis spp.) (Tracey et al 2007).

Given high production losses were outlined in Tracey and Saunders (2003) a high loss scenario of 15 percent is included in addition to the mean estimates in the cost results summary table provided in the discussion section at the start of the report (Table 1). It is not clear from the summary of the survey in Tracey et al (2007) whether the losses are total or net. A low production loss cost scenario of 5 percent is also included in Table 1 to accommodate this uncertainty. About $5 million is estimated to be spent on introduced bird control in viticulture industries of NSW in 2013-14 and $20 million nationally. This estimate is derived from the Gong et al (2007) control cost of $110 per hectare for viticulture, adjusted for inflation. A total of $135 per hectare is estimated for introduced bird control in 2013-14.

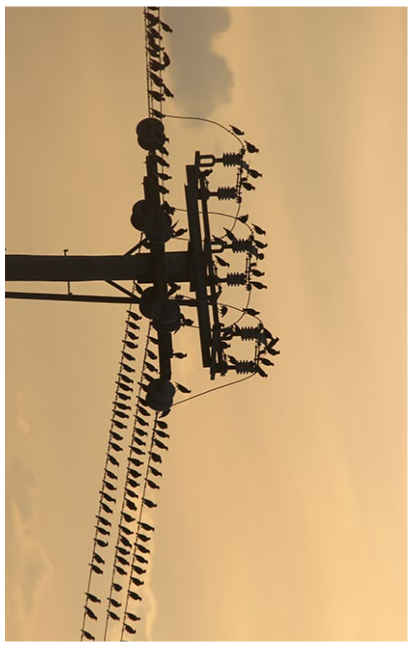


Photo: Peter Tremain

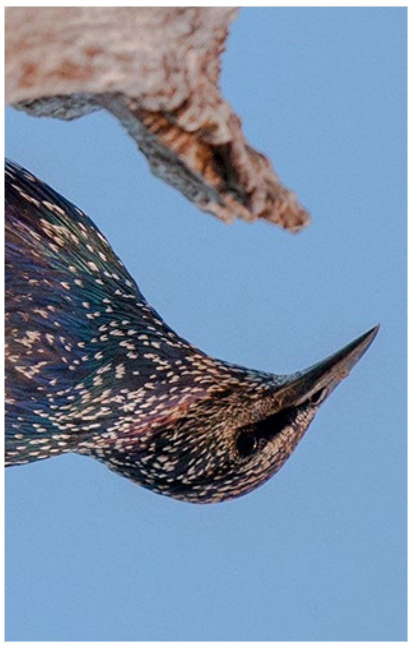


Photo: Michael Perkins

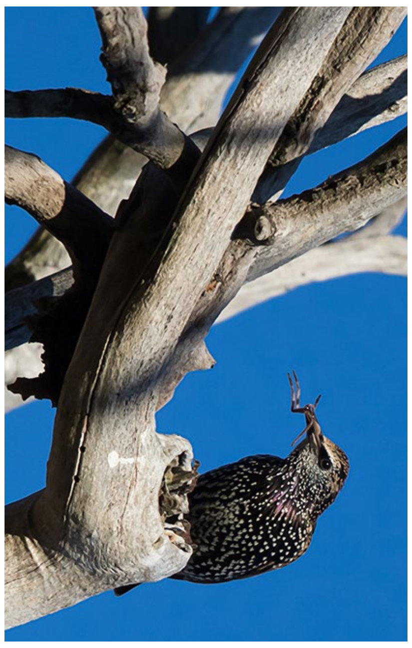


Photo: Danny McCreadie

Appendix 4: Economic Surplus Estimates

Table 24: Beef Industry Data for Economic Surplus Modelling

	Price	Links	Production	Consumption	Supply Elasticity	Demand Elasticity	k-rabbit[53]
	$/t	Index	kt [54]	kt	E	N	%
NSW	2,696	0.8	519	255	1.0	-0.3	1.59%
Queensland	3,022	0.8	1,167	152	1.0	-0.3	2.18%
Victoria	2,907	0.8	451	188	1.0	-0.3	1.59%
Tasmania	2,907	0.8	63	16	1.0	-0.3	-
South Australia	3,097	0.8	117	54	1.0	-0.3	2.19%
West Australia	4,899	0.8	106	83	1.0	-0.3	2.18%
NT	4,899	0.8	-	8	1.0	-0.3	-
Rest of World	5,000	0.5	57,323	58,990	1.0	-4.0	-
Total			59,746	59,746			

[53] k is the % supply shift for rabbits on wool, sheep-meat and beef supply.
[54] Australian beef production of 2,422 kt for 2013-14 from ABS (7218.0.55.001 Livestock and Meat, Australia - excludes calves). Apparent consumption is divided amongst states on basis of populations. World production of 59,746 taken from ABARE Commodity Statistics. Price Index taken from Gong et al (2009). An averaged supply elasticity of 1.0 for Australia and 1.0 for Rest of World derived from Gong et al (2009). Demand elasticities of -0.3 for Australia and -4.0 (average Japan, Korea, US and ROW) also taken from Gong et al (2009). Unit prices for each state estimated by dividing ABS local value by kt. (ABS, Value of Agricultural Commodities Produced, Australia, 2013-14). Rest of World assumed to be at a similar proportional premium to that in Gong et al (2009).

Table 25: Wool Industry Data for Economic Surplus Modelling

	Price[55]	Links[56]	Production[57][58]	Consumption[59]	Supply Elasticity	Demand Elasticity	k-rabbit
	$/t	Index	kt	kt	E	N	%
NSW	4,918	0.8	158	0.5	0.8	-0.5	2.09%
Queensland	5,421	0.8	14	0.5	0.5	-0.5	2.88%
Victoria	6,302	0.8	89	0.5	0.5	-0.5	2.09%
Tasmania	na	0.8	13	0.5	0.5	-0.5	-
South Australia	5,477	0.8	66	0.5	0.5	-0.5	2.88%
West Australia	6,120	0.8	91	0.5	0.5	-0.5	2.88%
Rest of World	5,411	0.8	1,687	2,115	0.7	-0.5	-
Total			2,118	2,118			

[55] Unit prices for each state estimated by dividing ABS local value by kt. (ABS, Value of Agricultural Commodities Produced, Australia, 2013-14) by shorn and on-skin greasy production. Rest of World price is assumed to be at a similar proportional premium to that in Gong et al (2009).
[56] Price links and supply elasticities for wool taken from Gong et al (2009). Demand elasticities for wool by Australian states taken from Gong et al (2009) and Rest of World a middle of the range estimate of -0.5 derived from EU, NZ, USA, China and ROW. Supply elasticities averaged at 0.8 across Australia.
[57] Global wool production of 2,118 kt taken from ABARE Commodity statistics for 2012-13.
[58] ABARE Commodity Statistics 2013-14 production in Australian shorn wool production (431 kt) includes shorn and on-skin production. 428 Kt is estimated to be exported
[59] Australian wool exports, by destination, recorded trade basis for 2013-14 of 428 kt taken from ABARE Commodity Statistics. 3Kt of domestic consumption distributed equally amongst states.

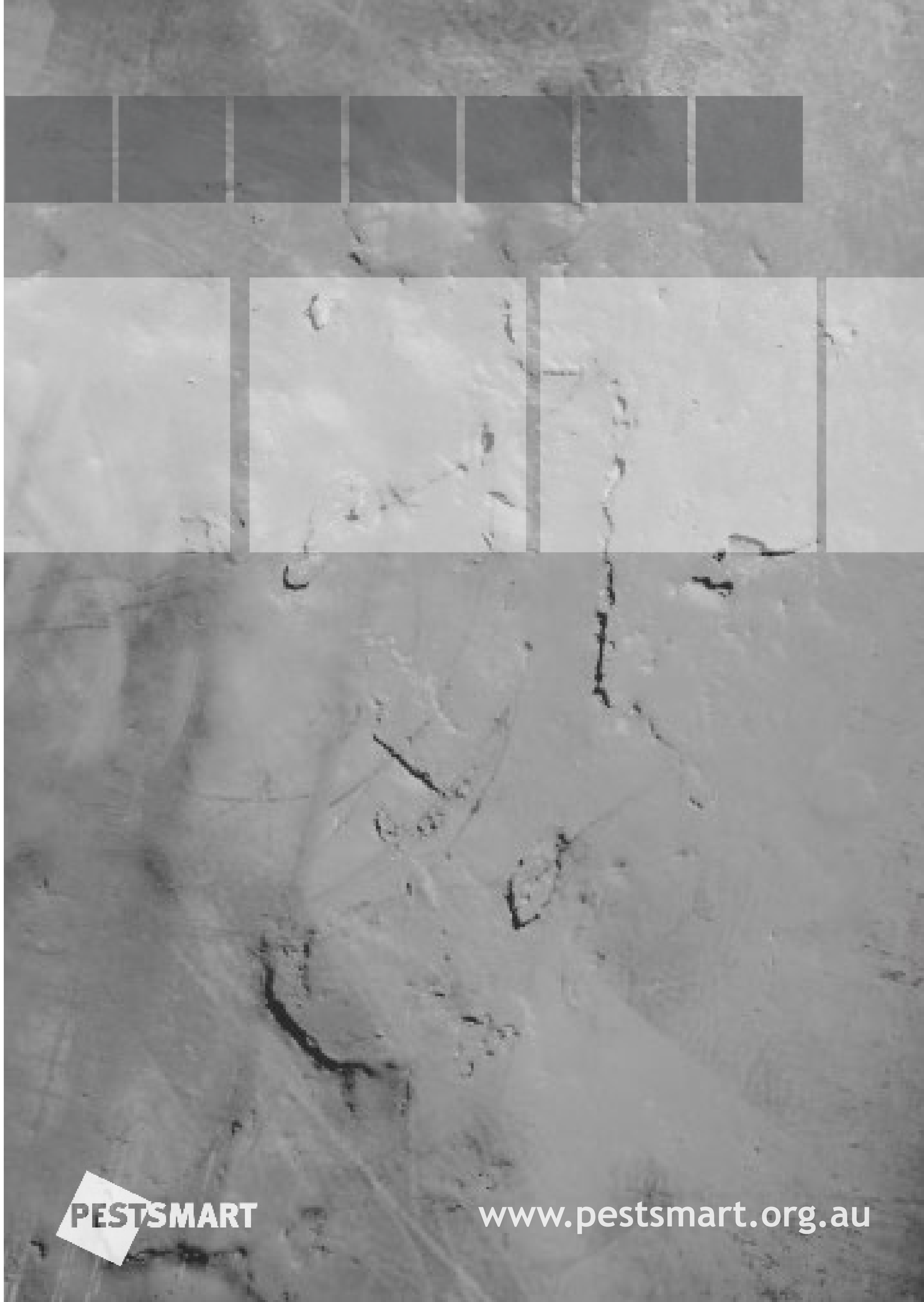
Table 26: Sheep-Meat Industry Data for Economic Surplus Modelling

	Price	Links[60]	Production[61]	Consumption[62]	Supply Elasticity	Demand Elasticity	k-rabbit
	$/t [63]	Index	kt	kt	E	N	%
NSW	4,000	0.8	110	78.0	1.4	-0.7	1.13%
Queensland	4,000	0.8	9	47.0	1.4	-0.7	1.55%
Victoria	4,000	0.8	207	58.0	1.4	-0.7	1.13%
Tasmania	4,000	0.8	15	5.0	1.4	-0.7	-
South Australia	4,000	0.8	83	17.0	1.4	-0.7	1.55%
West Australia	4,000	0.8	50	28.0	1.4	-0.7	1.55%
Rest of World[64]	4,000	0.8	5,451	5,692	0.4	-0.3	-
Total			5,925	5,925			

[60] Price links and supply elasticities for wool taken from Gong et al (2009). Rest of world is a middle of range estimate for listed countries. Demand elasticities for sheep meat by Australian states taken from Gong et al (2009) and Rest of World a middle of the range estimate of -0.3 derived from listed countries.
[61] Australian state carcass weight production taken from ABS 7218.0.55.001 - Livestock and Meat, Australia for 2013-14.
[62] State consumption of lamb assumed 9.9 kg per person per year apparent consumption multiplied by state populations. From ABARE 2015, Summary of Australian statistics for meat.
[63] Derived from ABARE (2015) Australian saleyard prices of livestock for lamb in 2013. Rest of World price is assumed to be at a similar proportional premium to that in Gong et al (2009).
[64] MLA reported that Australia produced approximately 8% of the world's lamb and mutton supply in 2013 (FAO).

Table 27: Annual Rabbit Producer and Consumer Surplus Costs, 2013-14

	Australia ($ millions)				NSW ($ millions)			
	Wool	Sheep-meat	Beef	Total	Wool	Sheep-meat	Beef	Total
Producer Surplus	51.31	20.10	140.10	211.51	14.28	4.87	0.27	19.42
Consumer Surplus	0.04	1.89	0.78	2.71	0.01	0.60	0.30	0.91
Total	51.35	21.98	140.88	214.21	14.29	5.47	0.57	20.33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