Australian Government
Department of Agriculture
ABARES

An integrated assessment of the impact of wild dogs in Australia

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Research by the Australian Bureau of Agricultural and Resource Economics and Sciences

Research report no. 14.4
April 2014

This publication (and any material sourced from it) should be attributed as: Wicks, S, Mazur K, Please P, Ecker S & Buetre B, 2014, An integrated assessment of the impact of wild dogs in Australia, ABARES Research report no. 14.4, Canberra, April. CC BY 3.0.

Cataloguing data
Wicks, S, Mazur K, Please P, Ecker S & Buetre B, 2014, An integrated assessment of the impact of wild dogs in Australia, ABARES Research report no. 14.4, Canberra, April.

ISSN: 1447-8358
ISBN: 978-1-74323-180-7
ABARES project: 43176

Internet
An integrated assessment of the impact of wild dogs in Australia is available at:
http://www.daff.gov.au/ABARES/Pages/publications.

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Acknowledgements
The authors thank Lisa Elliston, Sandra Parsons, Bertie Hennecke, Peter Fleming, Darryl Mayberry, Ben Allen, Lee Allen, Meat and Livestock Australia National Livestock Reporting Services (NLRS) – Robert Millner and Matt Groth, Greg Mifsud, Andrew Woolnough, Andrew Crocos, Allen Robley, Peter Bird and all focus group participants. This project was supported through the Australian Pest Animal Research Program.

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Summary

Wild dogs are a significant pest animal in Australia. They are widespread in Queensland, the Northern Territory and much of Western Australia and South Australia, as well as being present in parts of New South Wales and Victoria. Wild dogs are known to have a significant detrimental effect on the agricultural sector (market impacts), but they also cause non-market impacts in terms of adverse social impacts and environmental damage. These impacts are described in more detail below.

In general, wild dogs are considered pest animals because of their attacks on livestock and are subject to control. Their legal status varies across the states and territories, with the dingo regarded as a regulated native species under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*. Most states and territories have a wild dog management strategy, either as a stand-alone strategy or as part of a broader vertebrate pest strategy. These strategies are based on both the individual state legislation and a national approach, aligning to the Australian Pest Animal Strategy over time.

Management of wild dogs is mostly conducted by landholders, who bear the cost of production losses from wild dog attacks. In some areas wild dog control is undertaken by the relevant state government or is financially supported by local government.

Improved wild dog management is a challenge because of the nature of the problem. It requires coordinated action by all landholders. No individual landholder can capture the full benefits of wild dog control if their neighbours are not taking similar action. The management of wild dogs is further complicated by different types of landholders with different objectives. Private landholders are generally seeking to run profitable farm businesses, while governments managing public land including national parks or state forests have other goals. Where private landholders share boundaries with public lands the management of wild dogs can be particularly difficult, with the public land becoming a home and potential 'refuge' for wild dogs.

The challenge facing government is to implement policies and programs that support coordinated wild dog management in order to ensure the benefits of control are fully realised, but to do this in a way that does not take over, or crowd out, the private investments that individual landholders have an incentive to make in wild dog control.

Integrated assessment of wild dog management

The evidence presented in this report indicates that there are positive net economic returns to wild dog management for the three case study regions under most assumptions about the rate of growth in attack rates. In addition to significant economic benefits of wild dog control, there are also significant non-market benefits associated with wild dog management. It is likely that private landholders are not taking these non-market benefits into consideration when deciding how much to invest in wild dog control. However, in the absence of a coordinated approach to wild dog management, there is likely to be significant under-investment by private landholders to control wild dogs.

Estimated market impacts of wild dogs on sheep and beef producers in Australia: Results from three case studies

Where wild dogs are present in Australia, sheep and cattle are vulnerable to wild dog attacks. These attacks can cause not only the death of lambs and calves but also severe injuries to

juvenile and adult sheep and cattle. In a national survey an estimated 66 per cent of landholders reported wild dog problems on their property in the 12 months prior to the survey, and around 55 per cent of landholders reported that the presence of wild dogs had reduced lambing and/or calving rates. In this study, on average, each landholder reporting attacks on their property suffered livestock losses of around 100 animals a year, with a further 65 to 70 animals injured. In response to wild dog problems, landholders reported changing the livestock composition of their farming enterprise and taking active management such as baiting, shooting, trapping and exclusion fencing.

The economic cost of these problems was not estimated explicitly in this study. Instead, the economic costs over 20 years were estimated under a plausible range of growth rates for wild dog attacks in the absence of management. It was estimated that, the economic cost over 20 years in Eastern Victoria, one of the three case study areas considered in this study, would range between $1.8 million and $31.6 million, in net present value terms, if wild dog attacks were to grow between 2 and 20 per cent a year respectively in the case study area in the absence of wild dog control. The case study region of Eastern Victoria represents only around 13 per cent of the state's landmass and 1.7 per cent and 10.8 per cent of the states sheep and cattle population. For the South Australian Arid Lands, another case study area, the economic cost was estimated to range between $1.4 million and $34 million over 20 years, in net present value terms, depending on the assumed rates of growth in wild dog attacks in the absence of management. This case study area represents about 33 per cent of the landmass of the state of South Australia but 10.4 per cent of the cattle population of the state. For South Western Queensland, the third case study area that represents around 19 per cent of the landmass of Queensland and 22.6 per cent and 3.6 per cent of the state's sheep and cattle population, respectively, the corresponding estimates were $2.4 million and $54 million. These results are based on livestock losses and the subsequent impact on the size of livestock herds and flocks over time.

Where information was available on the costs of wild dog control in the three case study regions, these were estimated and compared with the estimated benefits. In the majority of cases, the investment being made in wild dog controls generated significant benefits. The only exception was in South Western Queensland, where the estimated control costs outweighed the estimated benefits unless the rate of attack was 10 per cent or higher in the absence of control.

Estimated non-market impacts of wild dogs in Australia

The above results take into consideration only the adverse market impacts of wild dogs associated with livestock losses and injuries. Inclusion of the estimated non-market benefits of wild dog control was found to refine the 'market' assessment in all three case study regions under the assumed scenarios.

A choice modelling survey with respondents randomly selected within Victoria, Queensland and South Australia was used to estimate the willingness of individuals to pay for the management of wild dogs in order to reduce social and environmental impact in the three case study areas. The resulting estimated non-market benefits of the management of wild dogs were all positive and significant. Respondents in Victoria, Queensland and South Australia reported being willing to pay $0.035, $ 0.01 and $0.41 respectively to reduce the adverse impacts of wild dogs on householders. They also reported being willing to pay $3.98, $3.63 and $5.67 respectively to reduce the adverse impacts of wild dogs on native species. However, respondents in Victoria and Queensland reported being willing to pay $1.44 and $0.11 respectively to protect public areas from the adverse effects of wild dogs whilst respondents in South Australia were not willing to pay to protect public areas from the adverse effects of wild dogs.

The incorporation of these non-market impacts strengthened the estimated net social benefits of wild dog control in each of the three case study regions.

Despite a widespread perception of the adverse impact of wild dogs on the environment and a reported willingness of the community to pay to reduce these impacts on native species and public lands, the effect of wild dogs on Australia's environmental assets is uncertain. There is some evidence that wild dogs are an 'apex predator' and have a positive impact by reducing the density of other feral animal populations. There is also a view that wild dogs have a negative impact through the reduction of native species populations. This was explored for the South Australian Arid Lands case study to investigate the conditions under which wild dogs limit kangaroo numbers and reduce competition for pasture for livestock. Realistic scenarios were identified where it is not economic for landholders to implement wild dog controls because of the corresponding increase in kangaroos competing with livestock for pasture.

Psychological stress caused by wild dogs

An estimated 35 per cent of landholders nationally reported that the presence of wild dogs left them feeling angry, while an estimated 21 per cent reported feelings of distress and anger. These issues were explored further through a series of semi-structured interviews with landholders in each of the case study regions. Some participants reported being constantly alert to the problem of wild dogs and one participant reported feeling like a failure because of an inability to control the problem adequately.

A quantitative survey—the Impact of Event Scale–Revised survey—was undertaken with 39 participants in the case-study regions who had been directly affected by wild dogs. The 22-item scale measured traumatic stress associated with wild dogs and found that these participants reported similar or higher levels of stress to people who had experienced other types of trauma. Psychological intrusiveness was a particular characteristic of the study, with potential implications for support and treatment.

Implications for wild dog management

This study highlights at least three key factors to improve the management of wild dogs in Australia.

- First, there are likely to be benefits associated with government or industry bodies providing a coordination role. Securing cooperation of all landholders, including private and government—the so called 'nil tenure' approach, is central to the effective management of wild dogs.

- Second, the psychological stress suffered by individuals with direct experience of wild dogs is significant and comparable to that suffered by individuals experiencing other traumatic events. There may be a role for governments to monitor the extent of this stress and ensure adequate support is available to those who require it.

- Third, there may also be a role for governments to invest directly in wild dog management to capture the non-market benefits identified in this study. The magnitude of that investment is not known. The benefit–cost analyses show that there are positive returns to current investments. There are likely to be benefits to additional investment, but the level of investment that generates the greatest market and non-market returns cannot be determined using a benefit–cost analysis approach and requires further research.

1 Introduction

Wild dogs are one of the pest animals established in Australia that have had a significant detrimental impact on Australia's economy, environment and communities. Previous studies on the impact of pest animals have estimated the economic impact of wild dog populations in Australia (Gong et al. 2009; McLeod 2004). While the social impacts of wild dogs on agriculture in Australia have long been acknowledged (Sykes 1982), prior to the recent surge of interest in this topic, there had been little systematic research into the social impacts of wild dogs and of invasive animals in general (Fitzgerald & Wilkinson 2007). More recently, a number of social science and social impact studies concerning wild dogs have been undertaken (Fenton 2009; Fitzgerald & Wilkinson 2009; Lightfoot 2010; Russell 2006). No previous studies have attempted to comprehensively estimate the market and non-market environmental and social impacts of wild dogs in Australia.

This paper evaluates the economic, environmental and social impacts of wild dogs in Australia and assesses the costs and benefits of investing in wild dog management to prioritise future investments. It uses a cost–benefit analysis framework applied to three case study regions. The work was funded by the Australian Pest Animal Research Program and contributes to the following program objectives:

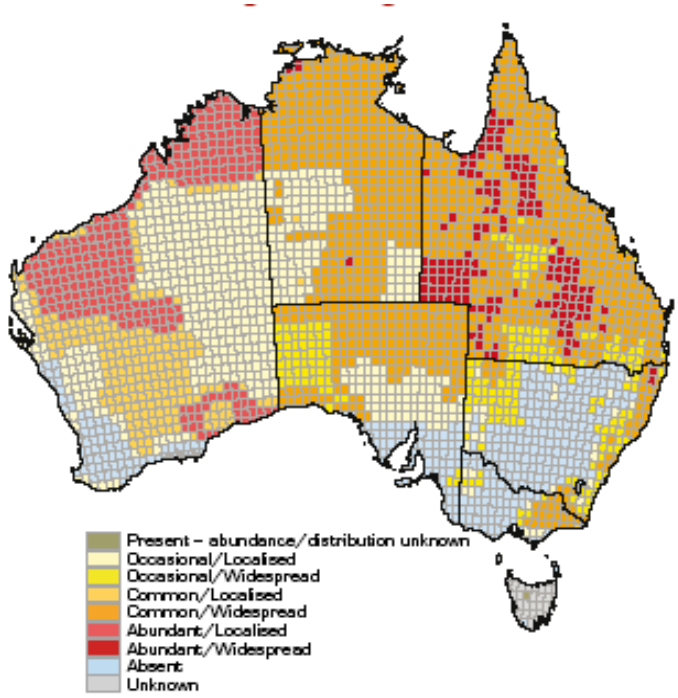
- to develop integrated, strategic approaches to manage the impacts of nationally significant pest animals on agriculture
- to quantify the benefits of pest animal management.

This report is structured as follows. Chapter 2 provides some background to the issue of wild dogs in Australia. Chapter 3 describes the range of methodologies used to assess and quantify the social, economic and environmental impacts of wild dogs in Australia. Australians' perceptions and attitudes to wild dogs are explored in Chapter 4. An assessment of the social, economic and environmental impacts of wild dogs—including quantification of the benefits of management—is presented in Chapters 5, 6 and 7. Chapter 8 presents a quantitative approach to measuring traumatic stress of people arising from wild dog attacks. The report concludes with a discussion of the implications for wild dog management.

2 Wild dogs in Australia

Wild dogs—including dingoes (*Canis lupus dingo*), feral domestic dogs (*Canis lupus familiaris*) and hybrids of the two—are considered one of the most significant pest animals problems affecting Australian agriculture, and in particular sheep and cattle producers. Wild dogs are widespread in Queensland, the Northern Territory and much of Western Australia and South Australia (Map 1). They are also present in parts of New South Wales and Victoria.

Map 1 Distribution and abundance of wild dogs in Australia



Source: NLWRA and Invasive Animals Cooperative Research Centre (2008).

Economic, environmental and social impacts of wild dogs

Where wild dogs are present in Australia, sheep and cattle are vulnerable to wild dog attacks. Wild dog attacks cause not only the death of lambs and calves but can also cause severe injuries to juvenile and adult sheep and cattle. The increased stress imposed on livestock through attacks can result in mismothering by sheep, reduced weight gain, poor wool growth and low-quality meat (Mitchell & Balogh 2007).

Wild dogs are also implicated in the spread of diseases to livestock. Wild dogs can carry the hydatid tapeworm, *Echinococcus granulosus*, which can be transmitted to both livestock and humans (Allen 2008; Lightfoot 2010). Wild dogs have also been identified as host animals of the protozoan parasite *Neospora caninum*, which may cause bovine abortion (NSW Agriculture 2004; Rural Management Partners 2004; Walker 2004, cited in Hewitt 2009).

Wild dogs not only have a significant detrimental impact on Australian agriculture, they have a social impact on landholders and those living in rural communities. They are also perceived to have an adverse impact on the natural environment.

The social impacts of wild dogs on agriculture in Australia have long been acknowledged (Sykes 1982). The impacts of wild dogs on society relate to the danger they impose to the health and safety of the community. This includes the psychological impact—such as stress, anxiety and depression—on individuals affected by dog attacks on their livestock, the spread of disease and the threat of physical attacks (Lightfoot 2010). People also feel concern for the potential environmental damage that wild dogs cause.

The effect of wild dogs on Australia's environmental assets is uncertain. There is some evidence that wild dogs are an 'apex predator' and have a positive impact by reducing the density of other feral animal populations such as rabbits, goats, pigs, cats and foxes, thereby protecting some smaller native species (Glen et al. 2007; Johnson 2007; Queensland Rural Lands Protection Board 2002). However, there is also a view that wild dogs have a negative impact through the reduction of native species populations (Fleming et al. 2001; Lightfoot 2010; McLeod 2004).

Current management of wild dogs

The management of wild dogs in Australia varies between the states and territories, largely due to differences in state legislation and the definitions and distinctions between 'wild dogs' and 'dingoes'. The legal status of dingoes and other wild dogs also varies within some states and territories. However, most legislation specifies that management of wild dogs is the responsibility of the landowner.

Wild dogs are seen as pest animals because of their attacks on livestock. However, the dingo is regarded as a regulated native species under the *Environment Protection and Biodiversity Conservation Act 1999*. In general, wild dogs are considered pest animals and are subject to control.

Most states and territories have a wild dog management strategy, either as a stand-alone strategy or as part of a broader vertebrate pest strategy. These strategies are based on both the individual state legislation and a national approach, aligning to the Australian Pest Animal Strategy over time.

In the absence of a coordinated approach to wild dog management, there is likely to be significant under-investment to control the pest animal. The benefits to an individual landholder of controlling wild dogs on his or her property are influenced by the efforts of neighbouring landholders to also control wild dogs. If neighbouring landholders make little or no effort, then the benefits to an individual landholder are greatly reduced. Securing cooperation of all landholders, including private and government—the so-called 'nil tenure' approach, underpins effective management of wild dogs.

Management of wild dogs is mostly conducted by landholders, who bear the cost of production losses from wild dog attacks. In some areas wild dog control is undertaken by the state government or is financially supported by local government (for example, see Tully et al. 2011).

A variety of methods are used in Australia to control wild dog populations. Techniques include exclusion fencing, guardian animals, shooting, trapping and poisoning. The choice of control technique is largely dependent on the technique's effectiveness in different environments (Southwell et al. 2013), as well as jurisdictional legislation.

Lethal baiting is considered to be one of the most cost-effective control methods available (Sharp 2012a). Ground baiting allows baits to be placed where they are most likely to be found by wild dogs, while minimising the chance of their uptake by non-target animals. Aerial baiting is

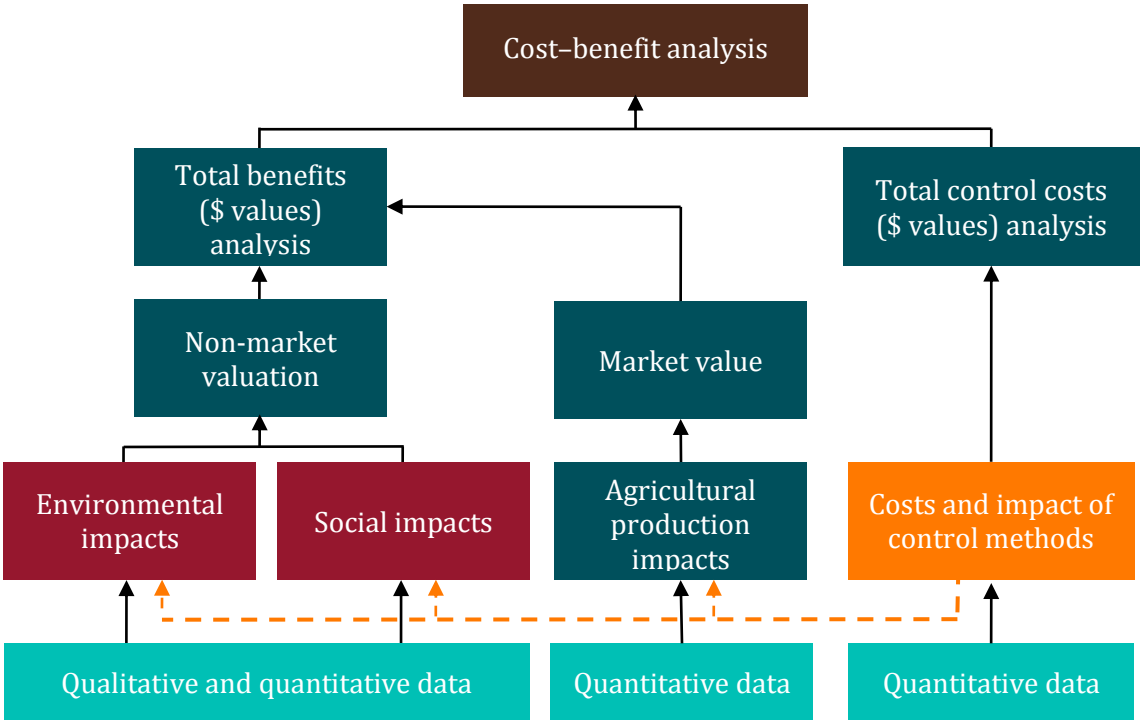
often used where the terrain makes ground baiting impossible or impractical (Sharp 2012b). The use of exclusion fencing is only relatively minor in comparison to the use of other management techniques (Southwell et al. 2013).

Gong and colleagues (2009) estimated that expenditure on management, administration and research on vertebrate pests in 2007–08, including but not limited to wild dogs, was around $122.7 million, split among the Commonwealth ($12.6 million), states and territories ($75.5 million) and landholders ($34.6 million). It was not possible to separate the wild dog component of this expenditure.

3 Integrated assessment methodology

An integrated approach has been adopted to quantify the economic, environmental and social costs and benefits of wild dog management. A combination of modelling and survey techniques was used to quantify the impact of wild dogs in Australia. Figure 1 provides an overview of the integrated approach to the analysis.

Figure 1 Assessing economic, environmental and social impacts of wild dogs



This approach integrates the economic impacts of wild dogs on Australian agriculture with non-market environmental and social impacts into a holistic assessment of the impact of wild dogs. This enables a more accurate estimation of the return to the entire Australian community of investments to control wild dogs.

A case-study approach was used to explore the impacts of wild dogs and associated management. Three case study regions were assessed, within Victoria, South Australia and Queensland. These areas were selected for several reasons. First, all case study areas are inhabited by wild dogs. Second, in these areas wild dogs affect the state of ecosystems, the profitability of livestock enterprises, and people living in the surrounding communities. Third, each case study area represents a different type of livestock production system.

Estimating market impacts

The market impacts of wild dogs are assessed through the estimation of the benefits from wild dog controls and the associated costs of those controls.

To estimate the benefits, two scenarios are examined: a baseline scenario where wild dog control measures are implemented, resulting in fewer livestock losses; and a no control scenario. The estimated benefits are the value of livestock losses avoided from wild dog controls, calculated as the difference between net revenues from livestock production in the baseline and

in the no control scenario. Given uncertainty about the growth in the wild dog population and associated impacts in the absence of controls, a series of no control scenarios are modelled to investigate the sensitivity of the estimates to assumptions about the rate of growth in livestock attack rates.

Costs are the expenditures in managing wild dogs, estimated using data on current control programs. Both benefits and costs are projected over a period of 20 years and discounted at a rate of 7 per cent.

A bioeconomic livestock model was developed to estimate the net revenue from livestock production activities, with and without wild dog controls. The model is dynamic and decisions in one period affect returns to production in future periods. It includes a net revenue function, livestock growth equations and damage functions. Net revenue is estimated as the difference between revenues and costs valuing the returns to land, labour and capital. Revenue is estimated as the returns from livestock slaughtered—meat production—plus the returns from wool production for sheep. Two categories of costs are included in the estimation of net revenue: maintenance costs and slaughter costs. Livestock growth equations keep track of births, deaths and slaughter numbers within the herd each year. Damage functions estimate the effect of wild dog attacks on livestock numbers in each scenario. The model is based on one previously developed by ABARES to estimate the cost of a foot and mouth disease outbreak in Australia (Cao et al. 2002). Separate models are developed for cattle and sheep production and applied to the three case study regions: Eastern Victoria, the South Australian Arid Lands and South Western Queensland. For further detail on the modelling refer Appendix A.

Assessing non-market impacts

The non-market impacts of wild dogs have been assessed using a variety of techniques. A national survey of landholders about wild dog and fox management in 2010 provided some information about how landholders feel about the presence of wild dogs in their area. A participatory approach to identifying the social impacts of wild dogs was also employed in the three case study regions. An Impacts of Event Scale survey was used to assess the psychological stress on individuals known to have been directly affected by wild dogs. This approach was adopted to address some of the gaps in knowledge—putting a significant focus on personal, psychological, emotional and stress impacts and attempting to quantify the stress impacts to provide hard data for key decision makers. A choice modelling survey was also used to estimate the willingness of individuals to pay to manage wild dogs in order to reduce social and environmental impacts. Each of these techniques is described briefly below.

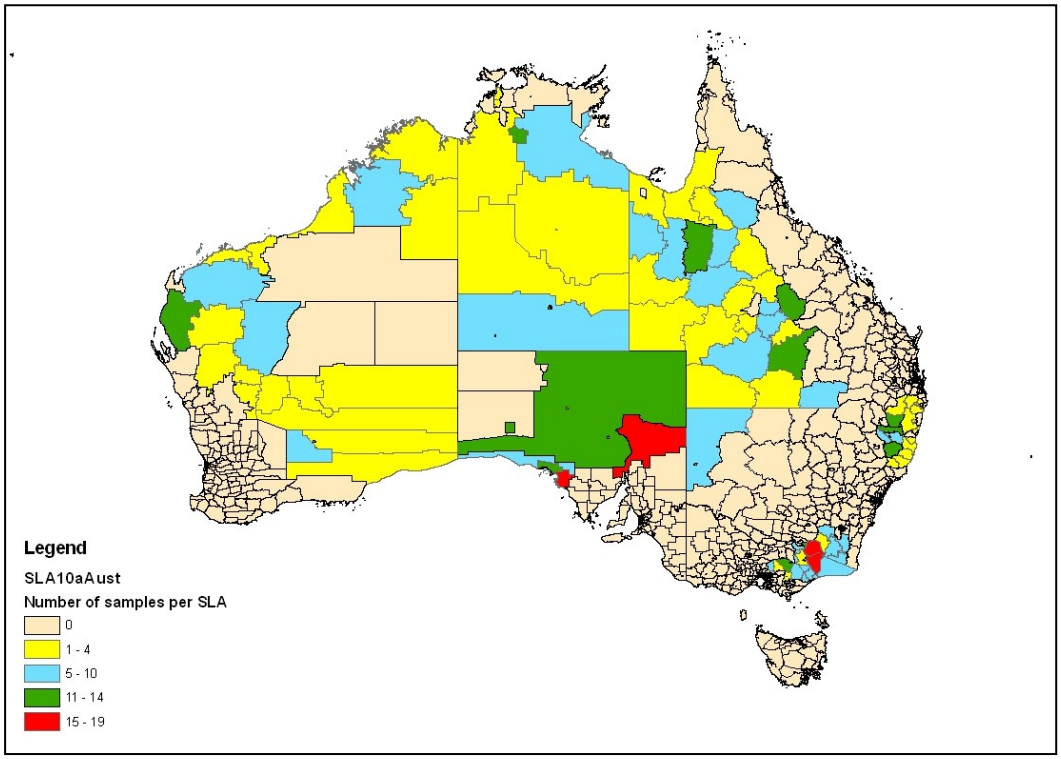
National survey of social impacts of wild dogs

In 2010, ABARES undertook a national survey for the project 'Understanding the drivers of barriers to participation in wild canid management in Australia: Implications for the adoption of a new toxin, para-aminopropiophenone' (Southwell et al. 2013). The survey focused on better understanding current attitudes to wild dog and fox management from a broader national perspective and across state boundaries; it also measured financial, environmental and social impacts.

Relevant questions from this national survey provide insights into the proportion of farmers with fears for the safety of their family or workers, and those reporting feeling very distressed, anxious and angry as a result of wild dogs.

A total of 525 private land managers were surveyed by telephone. Respondents were randomly selected from a database of property owners obtained from the Australian Bureau of Statistics within statistical local areas known to contain wild canids. All the mainland states and territories in Australia were surveyed, with the exception of the Australian Capital Territory. Landholders in Tasmania were excluded from the survey. Map 2 highlights the number of respondents per statistical local area that participated in the survey.

Map 2 Number of respondents per statistical local area that participated in the 2010 ABARES survey of wild dog and fox management



Participatory approach in case study regions

A participatory approach to identifying the social impacts of wild dogs involved face-to-face, in-depth, semi-structured interviews (with some telephone interviews) and informal focus groups in the three case study areas: Eastern Victoria, South Australian Arid Lands and South Western Queensland. Forty-seven people were interviewed in total across the three regions, including landholders, community members, some government agency staff and other key stakeholders.

The aim was to identify the main social and psychological impacts of the wild dog problem from the perspective of landholders and other key stakeholders. Key questions guiding the interview process included:

- What are the main characteristics of the wild dog attack event(s)?
- What were/are the impacts of the wild dog attack event(s)?
- Do you have any wild dog management? What type?
- In your view, what constitutes effective management?

- What support would assist you with the social-psychological impacts of the wild dog attack event(s)?
- Do you have any key messages to send to government?

The textural data acquired from the interviews and focus groups were analysed for key themes with the assistance of NVivo software (QSR International), a text analysis tool. The findings provide a broad context for the impacts on individuals, businesses and communities reflecting the situation at the time of the study in the three case study regions.

The social impacts were subsequently validated by land managers, experts on wild dog management and other stakeholders. For further detail on this participatory approach, refer Appendix B.

Impact of Event Scale survey to assess psychological stress

This inquiry into social impacts also considered the psychological impacts of wild dogs amongst a sample of individuals known to have been directly affected by wild dogs.

A quantitative survey was undertaken with 39 participants in the case study areas to assess the level of traumatic stress they experienced as a result of attacks. This 'Impact of Event Scale–Revised survey' contained a 22-item scale which measures traumatic stress associated with a critical incident or event in terms of intrusive thoughts, avoidance thoughts and thoughts associated with hyperarousal. The response format asks people to answer using a five-point (0 to 4) scale where 0 equates to 'not at all' and 4 to 'extreme impact'.

The findings were compared with the findings from other studies using this survey tool. The other studies examined traumatic response to events that include motor vehicle accidents, war service in Vietnam veterans, and life threatening events such as a sudden cardiac arrest or an acute myocardial infarction. For further detail on this survey, refer Appendix C.

Choice modelling approach to value non-market impacts

A choice modelling approach was used to estimate the value of the social and environmental benefits associated with wild dog management in the three case study areas. Respondents were asked to trade off the environmental, economic and social attributes of alternative wild dog management scenarios to estimate the relative values of each attribute. Specifically, respondents were surveyed to determine their willingness to pay over a 10-year period to protect households, native species and public areas from the negative impact of wild dogs.

The web-based choice modelling survey was conducted in early 2012. The respondents were randomly selected within Victoria, South Australia and Queensland. In total, 1817 responses were collected from six split samples. Two samples for each state were selected to distinguish between the rural and urban population. In addition to questions designed to elicit respondents' willingness to pay for wild dog management to protect households, native species and public areas, other questions were asked—about awareness of wild dog issues and socio-demographic information—to understand better the views of the general community.

The choice modelling framework is consistent with the principles of cost–benefit analysis and can be directly incorporated into the assessment of the market impacts of wild dogs, allowing for a more complete comparison of the benefits and costs of management options. For more information about the choice modelling survey and methodology, refer Appendix D.

4 Awareness and attitudes to wild dogs in Australia

The attitudinal questions asked as part of the choice modelling survey provide insights into the perceptions of both rural and urban Australians about the impact of wild dogs. The national survey of landholders also provided information regarding landholders' awareness, attitudes and experiences with wild dogs in Australia. Selected results from these surveys are presented in this chapter.

Awareness of wild dog problems

An estimated 72 per cent of landholders nationally reported they were aware of wild dog attacks occurring in their area (Table 1). The majority of landholders reported they were aware of these attacks through the media, although a significant proportion also reported observing attacks on their own property. Landholders in close proximity to a national park or state forest were more likely to report being aware of wild dog attacks in their area.

Table 1 Selected results of national survey of landholders (per cent)

	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 with wild dog problems:							
– reported the problem as severe	22	37	51	23	52	31	34
– reported the problem getting worse	36	36	62	15	62	54	45
– reported undertaking management action	86	91	93	86	94	93	90
– reported wild dog management as effective	39	29	71	63	28	16	47

An estimated 54 per cent of people in rural areas of Victoria, South Australia and Queensland who responded to the choice modelling survey reported that wild dogs were a problem in their state (Table 2). Rural-based survey respondents in Queensland were more likely to report that wild dogs were a problem than their counterparts in Victoria and South Australia.

In contrast, an estimated 41 per cent of people in urban areas of Victoria, South Australia and Queensland who responded to the choice modelling survey reported that wild dogs were a problem in their state (Table 2). Urban-based survey respondents in Queensland were more likely to report that wild dogs were a problem than their counterparts in Victoria and South Australia.

Table 2 Responses to attitudinal questions from the choice modelling survey, average by responding group (per cent)

	Victoria		South Australia		Queensland	
	Urban	Rural	Urban	Rural	Urban	Rural
Wild dogs are a problem in my state	38	49	35	50	50	61
Wild dogs pose a significant risk of attacks to farm livestock	64	72	65	73	65	76
Wild dogs pose a risk of attacks on humans	41	41	31	39	51	57
Wild dogs pose a risk of attacks to pets	58	62	51	58	62	66
Wild dogs can significantly contribute to some native species becoming endangered	62	67	61	68	67	73
Wild dogs limit the spread of feral animal populations	42	36	44	44	42	43
Wild dogs maintain balance among wildlife species	20	12	18	16	19	17
Dingoes maintain balance among wildlife species	39	32	40	40	41	48

Perceived and reported impact on farm businesses

More than 60 per cent of both urban and rural respondents to the choice modelling survey in Victoria, South Australia and Queensland reported that wild dogs pose a significant risk of attack to farm livestock in their state (Table 2).

An estimated 66 per cent of landholders reported wild dog problems on their property in the 12 months prior to the survey being conducted. A higher proportion of landholders reported wild dog problems on their property in the Northern Territory (83 per cent), Queensland (72 per cent) and Western Australia (73 per cent). Of those reporting wild dog problems on their property in the 12 months prior to the survey, an estimated 34 per cent said the problem was severe. More than half the landholders in Western Australia reporting problems with wild dogs indicated the problem was severe. In contrast, around half of landholders in New South Wales reported their problems with wild dogs as minor.

Around 55 per cent of landholders reported that the presence of wild dogs in their area had reduced lambing and/or calving rates. In Queensland and Western Australia, more than two-thirds of landholders reported a reduction in lambing and/or calving rates as a result of wild dogs. An estimated 17 per cent of landholders nationally reported changing their livestock composition or that they had left the industry. In Queensland, 25 per cent of landholders reported changing their livestock composition or leaving the industry.

On average, landholders reporting wild dog attacks on their property reported livestock losses of approximately 65, with approximately a further 72 injured. In all states the reported number of sheep killed per farm was greater than the number of cattle killed. In the Northern Territory the losses were all cattle, reflecting the lack of sheep in this jurisdiction. The states reporting the greatest number of sheep losses were Western Australia, South Australia and Queensland.

On average, around 45 per cent of landholders with wild dog problems reported that the problem was becoming more severe. An estimated 38 per cent reported it stayed the same, and 11 per cent reported it was less severe. Landholders in Western Australia, Queensland and the Northern Territory were more likely to report an increase in severity, while landholders in South Australia were more likely to report that the problem had stayed the same or become less severe.

Landholders' awareness of wild dog attacks in their area, and their experiences of wild dog problems on their property, were higher for those in close proximity to a national park or state

forest. Landholders in these areas were almost twice as likely to report a severe problem with wild dogs (64 per cent as against 34 per cent), and were slightly more likely to report the problem as becoming more severe.

Perceived and reported impact on individuals

An estimated 43 per cent of respondents to the choice modelling survey reported that wild dogs pose a risk of attacks on humans (Table 2). Respondents in Queensland were more likely to report this than those in South Australia. In Victoria there was no difference in this view between rural and urban-based survey respondents. In contrast, rural-based respondents in Queensland and South Australia were more likely to report that wild dogs pose a risk of attacks on humans, compared with their urban-based counterparts.

A consistently higher proportion of respondents to the choice modelling survey, almost 60 per cent, reported that wild dogs pose a risk of attacks to pets in their state (Table 2). There were no significant differences in the responses of rural and urban-based survey respondents.

Around 35 per cent of landholders reported that the presence of wild dogs in their area had left them feeling angry, with around 21 per cent reporting feelings of distress and anxiety.

Perceived impact on the environment

Around 60 per cent of respondents to the choice modelling survey reported that wild dogs can significantly contribute to some native species becoming endangered in their state (Table 2). There was little reported difference in the views of respondents in different states or between the rural and urban-based respondents.

An estimated 42 per cent of respondents reported that wild dogs limit the spread of feral animal populations, such as rabbits and foxes (Table 2). The views of urban and rural-based respondents did not differ significantly. These views were also reasonably consistent among respondents in Victoria, South Australia and Queensland.

Around 17 per cent of respondents reported that wild dogs maintain balance among wildlife species in their state (Table 2). Again, there were few differences in the views of respondents in different states or between rural and urban-based respondents.

A higher proportion of respondents, around 40 per cent, reported that dingoes maintain balance among wildlife species in their state (Table 2). Respondents in Queensland, particularly rural-based respondents, were more likely to report this view than those in Victoria and South Australia.

Management of wild dogs

An estimated 22 per cent of landholders reporting problems with wild dogs on their property had made changes to the livestock composition of their farming enterprise as a result of wild dog attacks.

An estimated 90 per cent of landholders reporting problems with wild dogs on their property undertook active management of wild dogs. Actions taken by landholders included aerial and ground baiting, shooting, trapping and exclusion fencing. Shooting and ground baiting were the most common forms of wild dog management undertaken by farmers, although aerial baiting was reported by a significant proportion of landholders in Western Australia and Queensland. Trapping was also reported by almost half of all landholders with wild dog problems in South Australia and Western Australia.

Landholders with wild dog problems on their property also reported on government initiatives to manage wild dogs in their area, with ground baiting being the most common management technique. Again, aerial bating was reported as a relatively more common management technique by landholders in Queensland and Western Australia.

Landholders with wild dog problems on their property reported a number of coordinated wild dog management actions in their area. These included coordinated ground and aerial baiting as well as shooting.

At the national level, an estimated 47per cent of landholders with a wild dog problem on their property believed that management actions undertaken in their area were effective (Table 1). Landholders in Queensland and South Australia were considerably more likely to report that wild dog management actions in their area were effective (around two-thirds). In contrast, just 16 per cent of landholders in the Northern Territory with a wild dog problem on their property reported that management was effective in their area (Table 1).

An estimated 87 per cent of landholders with a wild dog problem nationally reported that more management on public land would improve the overall management of wild dogs in their area. More than two-thirds of landholders with a wild dog problem reported that more effective baiting programs and more government support to apply different technologies would improve management. An estimated 36 per cent of landholders with a wild dog problem reported that greater accessibility to baits would improve management in their area. Around 40 per cent of landholders with a wild dog problem reported that relaxed legislation on trapping would improve management in their area, although responses varied significantly by state. In Victoria, 83 per cent of landholders with a wild dog problem on their property reported that relaxed legislation on trapping would improve management.

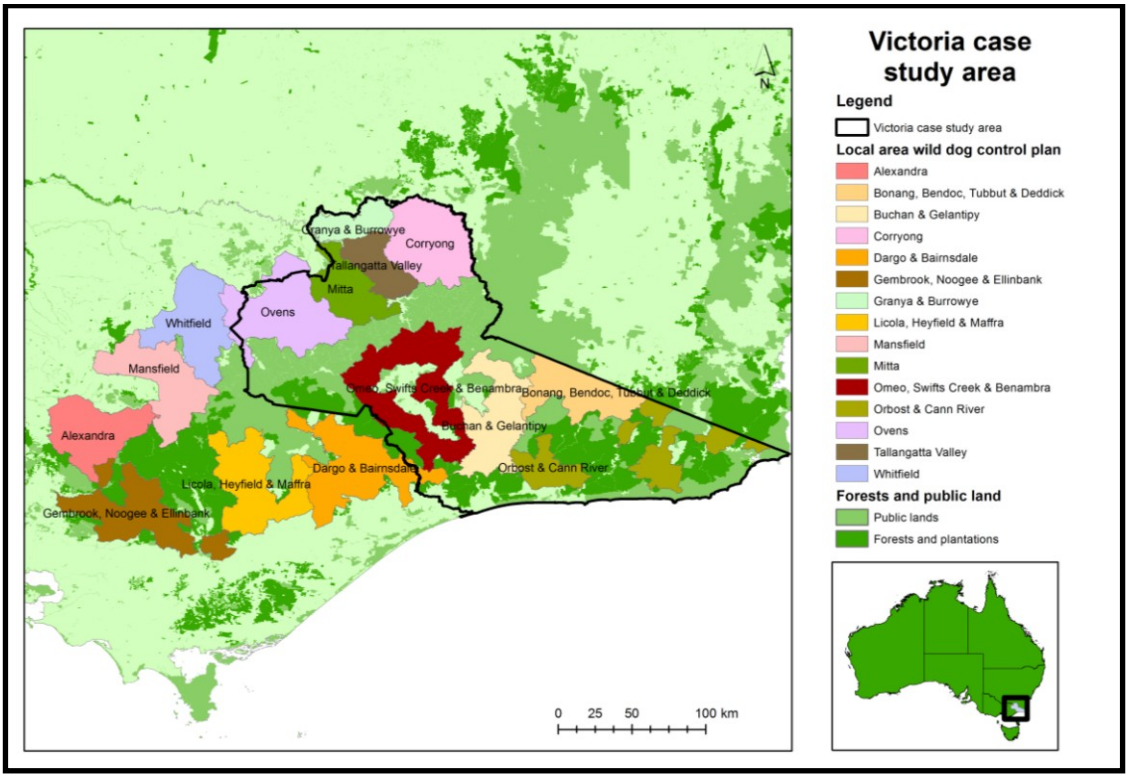
5 Eastern Victoria

Case study region

The Victorian case study area includes the town of Orbost and the statistical local area of Balonne within East Gippsland Shire and a number of statistical local areas in north-east Victoria, including East and West Alpine Shire, Towong Shire, Falls Creek Alpine Resort and Mount Hotham Alpine Resort (Map 3)

The area covers 30 000 square kilometres and the major population centres include Shepparton–Mooroopna, Wangaratta, Wodonga, Moe–Yallourn, Morwell and Traralgon. In 2009, the total population of this area was approximately 358 000 (ABS 2010).

Map 3 Eastern Victoria case study region



There are a number of different land uses including agriculture, state and national parks and forestry. Nature conservation covers an estimated 46 per cent of the area. Map 3 depicts the complex integration of public and private land, which increases the difficulties of managing wild dogs in this area. Further, the rugged landscape limits accessibility and provides wild dogs access to public lands where they are afforded protection. Wild dogs are generally found in and near forested areas of the north-east and Gippsland regions, and some areas of the north-west.

Production characteristics

Livestock production in this area consists of both cattle and sheep (Allen et al. 1998; Lightfoot 2010). In 2011 there were an estimated 264 000 sheep and 260 000 cattle in the case study area (Table 3). The Victorian breeding herd consists of 37 per cent Merino ewes, with the remainder used in cross breeding activities to produce slaughter lambs (Barker 2011). The gross value of production of wool in the region was $18.8 million in 2010–11, and sheep meat was valued at

$9.7 million. The gross value of beef production in the region was much higher, at around $96.9 million.

Table 3 Livestock numbers and gross value of production, Eastern Victoria (2010–11 dollars)

Statistical local area	Sheep (including lambs)				Meat cattle
	Sheep numbers	GVP of sheep slaughtered ($)	GVP of wool ($)	Cattle numbers	GVP of cattle slaughtered ($)
Alpine East	1 091	47 330	2 743 310	18 975	8 774 451
Alpine West	1 932	55 258	2 171 603	18 153	6 780 008
East Gippsland – SW	51 853	2 764 988	4 487 416	58 633	22 306 742
East Gippsland – Balonne	141 890	3 915 833	2 688 248	42 484	15 265 686
Towong Part A	27 081	1 000 708	1 694 512	24 751	9 222 990
Towong Part B	40 282	1 872 072	5 046 211	94 795	34 539 825
Total	**264 129**	**9 656 189**	**18 831 300**	**257 791**	**96 889 702**

Source: Australian Bureau of Statistics, Agricultural commodities cat. no. 7121.0 and Value of agricultural commodities.

Management of wild dogs

In Victoria wild dogs are declared 'established pest animals' under the *Catchment and Land Protection Act 1994*. All landowners—including state, local government and private landowners—have responsibility under the Act to take all reasonable steps to prevent the spread of, and as far as possible eradicate, established pest animals (VIC DEPI 2013).

It was reported that wild dog management in Eastern Victoria has a long history that goes back more than 75 years to the Chestnut Wild Dog Destruction League in the north-east of the state. Twenty years ago the first wild dog community meeting was held at Swifts Creek, located on the Great Alpine Road between Omeo and Ensay in East Gippsland, to encourage the state government to respond on wild dog management.

The Victorian Government has responsibility as a public land manager to manage wild dogs on its land. This role is largely undertaken by the Victorian Department of Environment and Primary Industries.

The Victorian Government has a Wild Dog Control Program, with community representation to government provided through a Wild Dog Management Committee. Wild Dog Controllers undertake the on-ground work. When field work for this study was undertaken the Victorian Department of Environment and Primary Industries was reportedly focusing its management program on protecting livestock by working in the buffer zone between public and private land.

At the time of undertaking the field work, there were representatives to the Wild Dog Management Groups in the north-east and in East Gippsland, appointed by the Victorian Minister for Agriculture, to liaise between the community and government on wild dog management. At the time of writing this report, the organisation has slightly changed. There were mixed opinions from participants about the effectiveness of the Wild Dog Management Groups. Their terms of reference did not include control over the on-ground action which led to criticism—particularly in relation to effective on-ground action. Some participants saw the groups as providing useful local area representation, while others were not sure the government was 'listening to them' as it was perceived that the wild dog problem was not improving.

The Victorian Government has 24 Wild Dog Controllers—most commonly referred to as 'doggers'—who undertake the on-ground work for wild dog control. In Gippsland, one of these positions focuses on baiting activities. Some participants had issues with the 'doggers', highlighting that they tend to be of variable quality. It was reported that some were excellent and responsive while others did not communicate well or respond to landholders' needs. This was very frustrating for the landholders, and one landholder said that complaints tended not to be reported because landholders think nothing will happen. In terms of indicators of success for the effectiveness of the wild dog program, complaints were not considered to be useful. It was suggested that a better indicator would be to account for the number of sheep restocked to previously excluded area(s) or to use the number of attack free days.

It was reported that the wild dog control culture in Victoria has been undergoing radical change over the last few years, with an increasing emphasis on getting communities and government staff to work together on the issue. The state government is making efforts to give more control to the communities, providing them with opportunities to learn new skills in the area of wild dog control. One indicator of this change was the government's move to change the title of one of their trapper positions from 'dogger' to 'community baiting officer'. As with many changes, some people were 'for it' and some 'against'.

The character of the natural environment in Eastern Victoria and how it affects the wild dog issue

The public–private land interface is a key issue in Eastern Victoria in relation to the wild dog problem. The rugged, high-relief landscape with large tracts of forested public land alongside the less densely vegetated agricultural land means that it is a very different type of environment from the flatter, more open country of South Western Queensland or the South Australian Arid Lands. These features of the Eastern Victorian landscape mean that the salient wild dog issues are slightly different from those found in the other case study regions.

This type of terrain and associated ecosystems were thought to lead to some particular wild dog issues and impacts:

- public land as home and 'refuge' for wild dogs
- wild dog impacts on native fauna
- impacts of fires on natural ecosystems and flow-on effects to wild dog behaviour
- other issues, for example, concern about the safety of visitors to national parks, blackberry infestations, cross-breeding of different kinds of dogs
- large areas of plantation and absentee landowners generally equating to less wild dog control by the land managers.

As well, the different state government legislation and policies in the case study areas also affect the issue.

Market impacts

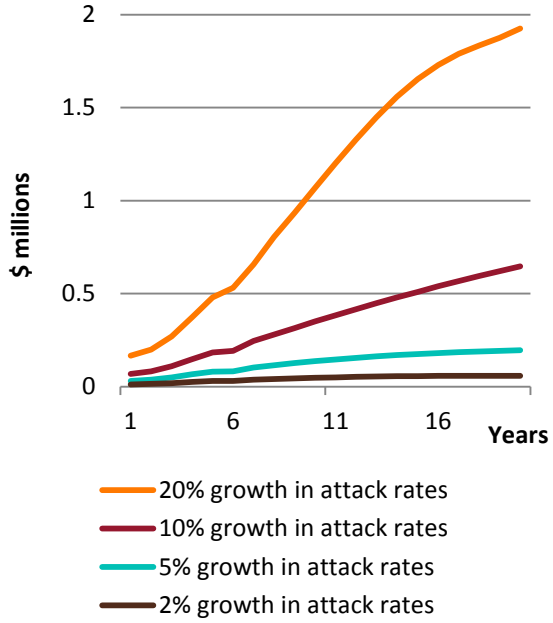
The market impacts of wild dogs and the potential benefits of wild dog control are estimated by comparing the economic costs and benefits under scenarios with and without control. Given uncertainty about the likely increase in wild dog attack rates in the absence of control, several scenarios are presented.

Revenues and benefits

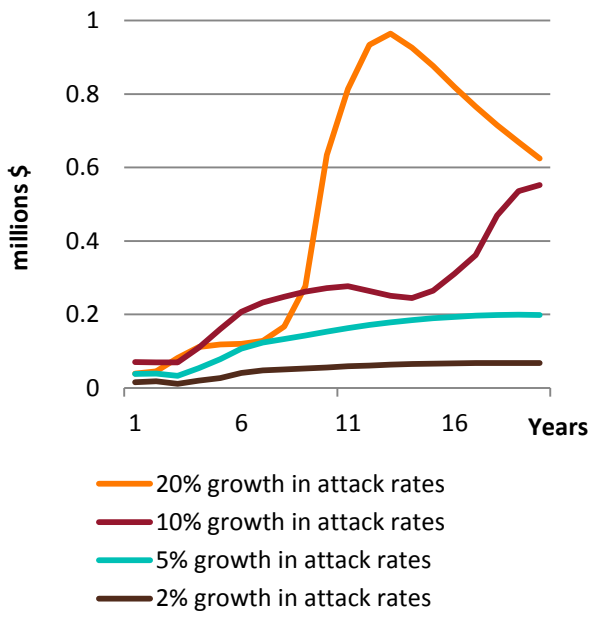
Annual estimates of discounted benefits—for each rate of growth in livestock deaths—are presented in Figure 2(a) and 2(b) for cattle and sheep respectively. The discounted benefits are represented by the curves in Figure 2 and the areas under these curves are the present value of benefits. The sharp downward slope of the discounted net benefits commencing in year 14 results from discounting of constant net benefits (in nominal terms) from year 14 onwards. For a 20 per cent growth in livestock deaths the present value of benefits to cattle producers from wild dog control measures in Eastern Victoria are approximately $31.7 million over 20 years (Table 4).

Figure 2 Benefits of wild dog control for cattle and sheep industries, Eastern Victoria

(a) Discounted net benefits from wild dog controls for the cattle industry, for calf death rates



(b) Discounted net benefits from wild dog controls for the sheep industry, for sheep death rates



Cost–benefit analysis measures

The present values of benefits from control measures for Eastern Victoria are presented in Table 4 and increase with the growth in wild dog attack rates.

Estimates of the cost of wild dog controls for Eastern Victoria are currently unavailable. As a result, a threshold analysis approach has been used. Under the threshold approach, wild dog control programs will break even if the present values of costs and benefits (Table 4) over the 20-year period are equal. For example, if the growth in attack rates is 10 per cent, the present value of wild dog control costs across 20 years must not exceed $12.42 million for this investment to be economically feasible.

Table 4 Cost–benefit analysis measures for Eastern Victoria, by growth in livestock deaths over 20 years (2009–10 dollars)

	Increase in livestock deaths			
	2%	**5%**	**10%**	**20%**
Present value of benefits – cattle ($'000)	857	2 582	7 181	21 830
Present value of benefits – sheep ($'000)	996	2 778	5 234	9 833
Total present value of benefits ($'000)	1 853	5 360	12 416	31 662
Present value of costs of control program ($)	na	na	na	na

Note: na = not available.

Sensitivity of results to choice of discount rate

These results are based on an assumed discount rate of 7 per cent, as recommended by the Department of Finance and Deregulation. The sensitivity of these findings to the choice of discount rate was assessed by assuming a discount rate of 5 per cent and 10 per cent. The effect of the sensitivity analysis focused on the present value of the benefits as the costs of wild dog control were not available. A higher discount rate reduces the present value of the benefits, while a lower discount rate increases the present value of the benefits. The results of this analysis are presented in Appendix E. Overall, the impact of the sensitivity analysis on the results is not large.

Non-market impacts

The non-market impacts of wild dogs in Eastern Victoria were assessed in several ways. The social impacts of wild dogs, as reported through semi-structured interviews, were qualitatively assessed and are presented below. The non-market impacts were also quantified through a choice modelling study. These results are also presented in this section.

Qualitative assessment of social impacts

Public land as home and 'refuge' for wild dogs and wild dog impacts on native fauna

It is considered to be common knowledge in this part of Victoria that the wild dogs live, take refuge and breed in the vast tracts of public land in north-east Victoria and East Gippsland. Because of the wild dogs' close connection with public land there was also a substantial amount of information being reported from the participants about the impacts of the wild dogs on native fauna. One participant reported that two weeks earlier he found dog scat at Falls Creek that was full of possum fur.

> ... impact on agricultural production is one thing, but the impact on biodiversity is the bigger issue. It is massive. We have people with their heads in the sand, not appreciating that. The hybrid dog is different to dingoes. They are not dingoes. (key stakeholder in wild dog management)

The impact of wild dog attacks on native fauna is an issue that concerns many of the landholders living close to public land. But it is not only the public land that the dogs inhabit—they are also in forested areas and private bush blocks. One landholder reported that over the past two decades the dogs have been getting more used to living closer to landholders.

Many of the landholders were also very aware that the public is more likely to provide support on wild dog management in relation to the safety of native fauna than in relation to the safety of agricultural livestock such as sheep and cattle.

Key stakeholders reported seeing evidence of wild dogs killing red back wallabies, black wallabies, koalas, goannas, emus and possums, with wombats, wallabies, kangaroos and

echidnas being a main component of their main diet. One participant commented that a lot of dog faeces seem to have wombat hair in them.

Fire impact on natural ecosystem and flow on to wild dog behaviour

Several participants reported that wild dog problems had been much worse since the 2003 fires in the eastern Victorian high country and associated farm land. The fires changed the local vegetation and hence the ecosystem. Prior to these major fires there was a substantial network of tracks for wildlife. This network was wiped out overnight and it is believed that the wildlife and local ecosystem have not yet recovered.

The understanding is that, because the fires 'opened up the country', native wildlife (particularly kangaroos) left the bush for the farms to obtain food. The wild dogs then followed to the farms. Since that time the bush has developed very thick undergrowth that is not as suitable for some of the native animals (for example, wallabies), but suitable for wild dogs. It was acknowledged that the decade of drought had also contributed to native animals looking for food on private land, but the impact of the fires was very significant.

Since the fires two invasive species have been observed to have increased in population in the bush/high country: dogs and deer. The deer population 'has just exploded'. With the opening up of the bush and the changes in the landscape, it appears that the dogs have become more dispersed and developed new behaviour patterns. It is reported that this has made it more difficult for the trappers who need to learn these new patterns of dog behaviour. The increase in the number of feral deer has also had an impact on the wild dog population as it is believed that deer are a new link in the food chain for wild dogs. It is considered that wild dogs now have access to feed on deer carcasses and the occasional brumby carcass. The availability of the deer carcasses is thought to be contributing to the good health and survival of wild dog pups. Their high rate of survival is an observed trend that emerged several decades ago.

The fires also burned down some fences, giving the dogs greater access to private land. One participant reported shooting and trapping 50 dogs in a three-month period since the fires, with no apparent decline in the rate of dog attacks.

There is a sense that there is no official understanding or acknowledgement of the fires as a contributing issue to the wild dog problem.

The impact of the fires has emphasised the need for integrated management of fencing (for wild dog management) at the interface of public and private land and access to public land for fire management. Evidence from cameras placed on a dog fence has shown that the fences keep out not only the dogs, but also many kangaroos and other native as well as feral animals. This is of great benefit to the landholder. The challenge is to keep the fences maintained as many of the animals can damage them.

Other issues

A key issue raised, in connection with visitors to the public lands, was a concern that they may become the target of attacks as a result of the increasingly aggressive behaviour observed in the wild dog population. There have been some dog attacks and threats of attacks on landholders; however, these landholders are competent with guns and know how to deal with the situation. But they are very aware that many tourists are not equipped or skilled in this way and could end up being a target for a dog, or pack of dogs, attack. National survey data indicates concern amongst some of the farmers for family and worker safety. Although the percentages were low, the fact that some people are were concerned about the human safety aspect of the wild dog issue in Victoria—be it family, farmers or visitors—makes this an issue worth noting.

On a different subject, effective management of wild dogs can have beneficial flow-on effects for weed management. A couple of landholders commented that land stocked with sheep provided an effective control of blackberries because the sheep would eat them. For one landholder, since they removed the sheep due to the wild dog problem, the blackberries have 'taken over'. They now have to pay an extra $5000 per annum to spray the blackberries.

Another concern was around the management (or lack) of domestic dogs and their contribution to the wild dog problem. Increased cross-breeding of domestic dogs with dingoes/wild dogs is considered to be contributing to the increased aggressive behaviour of the wild dog population.

Quantitative assessment of non-market impacts

The estimated non-market benefits of the management of wild dogs in Victoria were positive and significant. Respondents in Victoria reported being willing to pay $3.98 a year (for 10 years) per household to protect one native species from becoming threatened as a result of wild dog attacks in the Eastern Victoria case study region (Table 5). Victorian respondents also reported being willing to pay $1.44 per household a year to protect 1000 square kilometres of public area from the adverse effects of wild dogs, and $0.035 per household a year to protect one household in the case study region. These values were significantly different from the values reported by respondents in other states (and summarised in the following two chapters of this report).

Table 5 Victorian households' annual willingness to pay (for 10 years) to ameliorate the adverse impacts of wild dogs in Eastern Victoria

	Annual marginal values per household
Households protected (per household)	$0.035** (0.004~0.066)
Native species protected (per species)	$3.977*** (2.910~.5.028)
Public area protected (per 1000 km^2)	$1.436*** (0.001~0.002)

Note: Significance levels indicated by: * 0.1, **0.05, ***0.01; 95 per cent confidence interval in brackets calculated using the bootstrapping procedure from Krinsky and Robb (1986).

Given considerable uncertainty about the rate of growth in wild dog attacks in the absence of controls, the non-market benefits of control have been estimated for four scenarios (Table 6). These scenarios were developed using a logarithmic damage curve that assumed the impact of wild dogs on non-market goods would be similar to the assumed percentage change in calf deaths used to estimate the market impacts.

As the long-term (10 and 20 years) non-market impacts of wild dogs are difficult to predict, the estimates (Table 6) are hypothetical. These estimates were used only as an example to estimate the potential total net benefits of the management of wild dogs in the case study area. Therefore, it is estimated that, with controls, 25 households in Eastern Victoria are protected from the adverse impacts of wild dogs over 10 years if the rate of growth in wild dog attacks is 2 per cent in the absence of control. In contrast, it is estimated that controls protect 579 households in Eastern Victoria from the adverse impacts of wild dogs if the rate of growth in wild dog attacks is 10 per cent in the absence of control. It is estimated that the number of households, native species and public areas protected in Eastern Victoria increases when a 20-year period is considered, noting considerable uncertainty over a longer time horizon.

Table 6 Assumed non-market benefits from the management of wild dogs for the different scenarios of wild dog attacks in Eastern Victoria

Scenario	2%	5%	10%	20%
10 years				
Number of households protected	25	86	209	579
Number of native species protected	0	1	3	8
Public area protected (1000 km^2)	0	1	2	6
20 years				
Number of households protected	86	209	497	805
Number of native species protected	1	3	7	11
Public area protected (1000 km^2)	1	2	6	9

Aggregate non-market values were calculated using the marginal values reported in Table 5, the number of non-market goods protected reported in Table 6 and the estimated population. Estimated non-market values for 10- and 20-year periods, in present value terms using a 7 per cent discount rate, are reported in Table 7.

Table 7 Total non-market benefits from management of wild dogs, Eastern Victoria ($'000)

Scenario		**2%**		**5%**		**10%**		**20%**
10 years								
Households protected		4 431		15 507		37 661		104 121
CI	479	8 273	1 675	28 954	4 068	70 317	11 247	194 405
Native species protected		0		20 345		61 036		162 764
CI	0	0	14 885	25 716	44 656	77 149	119 084	205 730
Public area protected		2 011		7 040		17 097		47 269
CI	745	3 244	2 607	11 354	6 332	27 573	17 507	76 232
Total benefits		**6 442**		**42 893**		**115 794**		**314 154**
CI	1 224	11 516	19 168	66 024	55 057	175 039	147 838	476 368
20 years upper bound								
Households protected		23 391		56 806		134 774		218 312
CI	2 527	43 673	6 136	106 062	14 558	251 638	23 581	407 612
Native species protected		30 688		92 064		214 816		337 569
CI	22 452	38 789	67 357	116 368	157 167	271 524	246 977	426 681
Public area protected		10 619		25 789		61 185		99 109
CI	3 933	17 125	9 552	41 590	22 662	98 674	36 708	159 836
Total benefits		**64 697**		**174 658**		**410 775**		**654 990**
CI	28 912	99 587	83 045	264 020	194 387	621 837	307 266	994 129
20 years lower bound								
Households protected		15 507		37 661		89 352		144 736
CI	1 675	28 954	4 068	70 317	9 651	166 830	15 634	270 237
Native species protected		20 345		61 036		142 418		223 800
CI	14 885	25 716	44 656	77 149	104 198	180 014	163 740	282 879
Public area protected		7 040		17 097		40 564		65 707
CI	2 607	11 354	6 332	27 573	15 024	65 419	24 337	105 968
Total benefits		**42 893**		**155 794**		**272 334**		**434 243**
CI	19 168	66 024	55 057	175 039	128 874	412 263	203 710	659 084

Note: CI = confidence interval.

Respondents to the choice modelling questionnaire were asked their willingness to pay over 10 years to protect households, native species and public areas from the impact of wild dogs. To extend this analysis to a 20-year period for consistency with the market impacts, an assumption needed to be made regarding the willingness of those respondents to pay for an additional 10 years. In the absence of other information, an upper and lower bound are presented in Table 7 for the 20-year scenario. The upper bound represents the non-market benefits assuming that respondents were willing to continue to pay the same amount per household per year for the full 20 years. The lower bound represents the non-market benefits assuming that respondents were

not willing to spend any more to protect households, native species and public areas from wild dogs between years 10 and 20.

The total non-market benefits from the management of wild dogs in Eastern Victoria over 10 years were estimated to range between $6.4 million and $314 million depending on the assumed rate of growth in wild dog attacks in the absence of control. When the rate of growth in wild dog attacks was assumed to be 2 per cent in the absence of control, the non-market benefits were dominated by those associated with the protection of households. As the assumed rate of growth in wild dog attacks increases, the non-market benefits associated with the protection of native species became relatively more important.

The non-market benefits in Eastern Victoria over 20 years were estimated to range between $43 million and $655 million depending on the assumed rate of growth in wild dog attacks in the absence of control and the assumption regarding respondents' willingness to pay to protect households, native species and public areas between years 10 and 20. The protection of native species made the greatest contribution to the total non-market benefits over a 20-year period regardless of these assumptions.

The total non-market benefits in Eastern Victoria were the highest of all the case studies, driven mostly by the larger population/number of households and native species within the region. It should be noted that there is considerable uncertainty regarding the number of non-market goods adversely affected by wild dogs and that, with improved information, the marginal non-market values reported in Table 5 could be used to derive revised estimates.

Integrated assessment

The total net benefits of the management of wild dogs in Eastern Victoria were estimated by combining the market and non-market benefits and costs over a 20-year period (Table 8). The non-market benefits were larger than the market benefits of wild dog control. As mentioned previously, in the absence of data on control costs, a threshold analysis approach is used for this case study region. The results indicate that if attack rates grow at 2 per cent a year in the absence of control then investments in wild dog controls in Eastern Victoria in the range $44.7 million to $66.5 million over 20 years will generate positive returns, depending on the assumed willingness of respondents to pay to protect households, native species and public areas between years 10 and 20. If the rate of wild dog attacks grows faster than this, then greater investments in wild dog control will generate positive returns.

Table 8 Net benefits of the management of wild dog programs in Eastern Victoria over 20 years

Variable (upper bound estimate)			**Growth in attack rates**	
Scenarios	**2%**	**5%**	**10%**	**20%**
Present value of market benefits ($'000)	1 853	5 360	12 416	31 662
Present value of costs of control program ($'000)	na	na	na	na
Net present market value ($'000)	1 853	5 360	12 416	31 662
Present non-market value ($'000)	64 697	174 658	410 775	654 990
Present value of total net benefits ($'000)	66 550	180 018	423 191	686 652
Variable (lower bound estimate)			**Growth in attack rates**	
Scenarios	**2%**	**5%**	**10%**	**20%**
Present value of market benefits ($'000)	1 853	5 360	12 416	31 662
Present value of costs of control program ($'000)	na	na	na	na
Net present market value ($'000)	1 853	5 360	12 416	31 662
Present non-market value ($'000)	42 893	115 794	272 334	434 243
Present value of total net benefits ($'000)	44 746	121 154	284 750	465 905

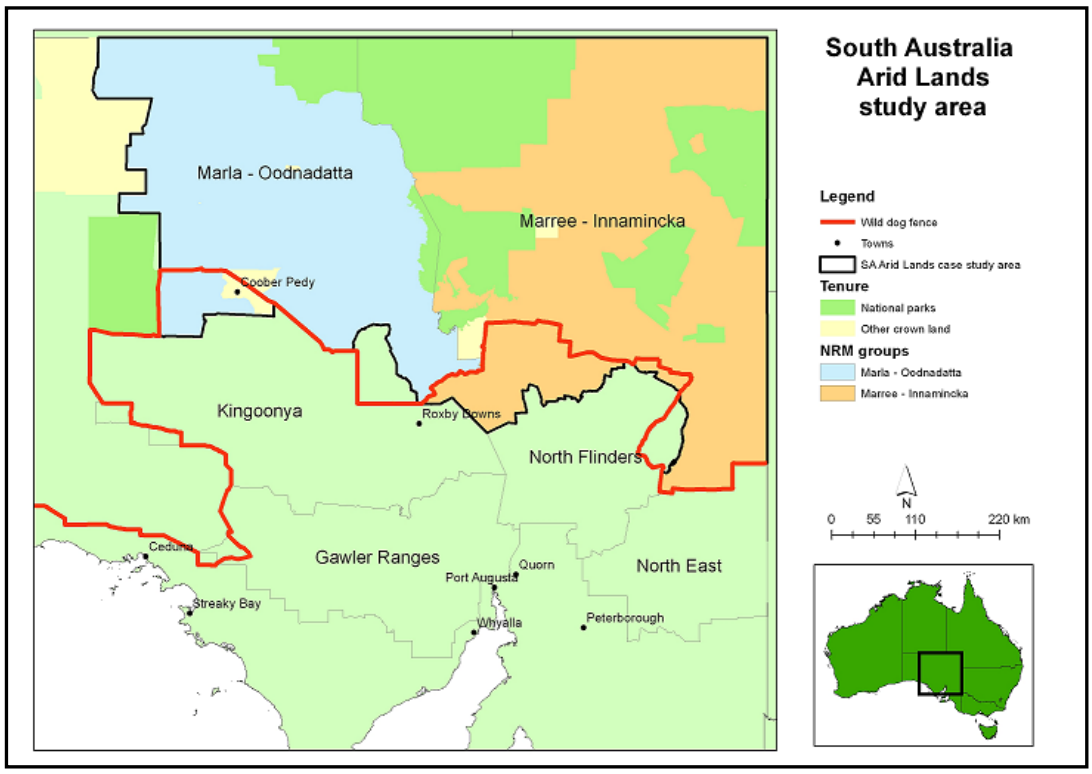
Note: Values in 2011–12 dollars; na = not available.

6 South Australian Arid Lands

Case study region

The South Australian Arid Lands case study area comprises two natural resource management groups: Marla–Oodnadatta and Marree–Innamincka. These groups are located in the northern arid zone of South Australia (Map 4) and cover an area of 320 000 square kilometres with a population of 1500.

Map 4 South Australian Arid Lands case study region



Production characteristics

Cattle production is the primary agricultural enterprise in this area, with 38 properties on 23 million hectares stocking an average of 114 500 head of cattle each year between 1999–2000 and 2007–08 (C Turner, Department of Environment and Natural Resources' Pastoral Board, pers. comm. 16 May 2011). Approximately 70 per cent of the study area is used for grazing, with nature conservation covering approximately 20 per cent.

Wild dog management

In South Australia, the term 'dingo' is used for both wild dogs and dingoes. The government policy objective on the management of dingo populations is to protect the livestock industry to the degree necessary to ensure its economic survival, while at the same time recognising that continued survival of the dingo as a wildlife species is ensured (Biosecurity SA 2011).

The *Natural Resources Management Act 2004* has the broad objective of protecting agriculture, the environment and the public from the impact of pest animals and plants. Under the Act, dingoes (including dingo crosses) are declared pests south of the South Australian Dog Fence.

Management of dingoes in South Australia is the responsibility of landholders, with assistance from Biosecurity SA, Local Dog Fence Boards, and the Natural Resource Management Boards.

All landholders south of the dog fence must destroy dingoes on their properties. Additionally, under the *Dog Fence Act 1946,* landholders must take all reasonable steps to destroy all wild dogs (dingoes) in the vicinity of the dog fence (Biosecurity SA 2011).

North of the South Australian Dog Fence, the dingo is 'a legitimate wildlife species', although unprotected. Dingoes are controlled in the cattle zone here when they pose a risk to calves. They are also controlled in a 35-kilometre buffer zone immediately north of the dog fence.

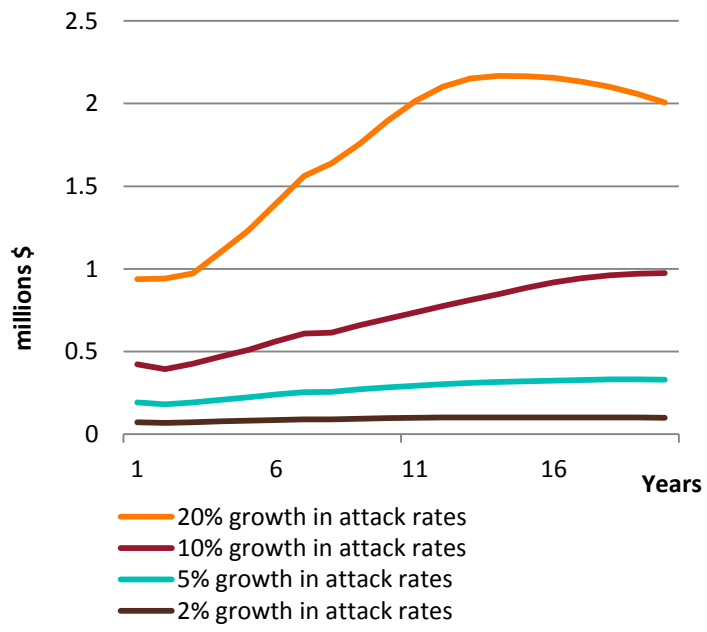
Ground baiting is the primary wild dog control measure used to reduce calf losses in this area (Allen 2012). Other control measures, such as shooting, are sometimes used but have a negligible effect in the control of wild dogs (Allen 2012). There are no private wild dog fences on any of the properties in this case study area. The purpose of the dog fence (Map 4), which runs roughly along the south of the case study area, is to protect livestock enterprises south of the fence (Yelland 2001).

Market impacts

Revenues and benefits

Annual estimates of discounted benefits—for each rate of growth in livestock deaths—are presented in Figure 3. The discounted benefits are represented by the curves in Figure 3 and the area under these curves is the present value of benefits. The downward slope of the discounted net benefits commencing in year 14 results from discounting of constant net benefits (in nominal terms) from year 14 onwards. For a 20 per cent growth in calf deaths the present value of benefits to cattle producers from wild dog control measures in the South Australian Arid Lands is approximately $34 million over 20 years (Table 9).

Figure 3 Benefits of wild dog control for the beef industry in the South Australian Arid Lands - *Discounted net benefits from wild dog controls for the cattle industry, for calf death rates*



Cost–benefit analysis measures

The present values of benefits from wild dog controls for South Australian Arid Lands are presented in Table 9. Note that these values increase with the growth in wild dog attack rates.

The present value of costs is the sum of discounted average annual cost estimated over a 20-year period. The average annual costs of wild dog management were estimated from the annual costs of past and current control programs in the area. The present value of costs for the South Australian Arid Lands is estimated at approximately $432 000 in 2009–10 dollars (Table 9). For simplicity, it is assumed that the present values of costs are constant across all rates of growth in calf deaths.

In the South Australian Arid Lands, expected returns from a dollar invested in wild dog controls, as estimated by the benefit–cost ratio, range from 4.25 to 80 for the four ascending rates of growth of wild dog attacks (Table 9). The corresponding estimated net present value of benefits ranges from $1.4 million to $34 million. Threshold probabilities estimate the perceived probability at which the benefits of wild dog control are equal to the cost of control measures (Table 9). For example, for a 5 per cent increase in calf deaths, if the perceived probability of successful control is greater than 8 per cent, the expected benefits of the control programs are estimated to be greater than the expected costs of the control program.

Table 9 Cost–benefit analysis measures for the South Australian Arid Lands, by growth in calf deaths over 20 years (2009–10 dollars)

	Increase in calf deaths			
	2%	**5%**	**10%**	**20%**
Present value of benefits – cattle ($'000)	1 836	5 484	14 181	34 478
Present value of costs of control program ($'000)	432	432	432	432
Benefit–cost ratio	4.25	12.69	32.81	79.78
Net present value ($'000)	1 403	5 051	13 749	34 046
Threshold probability (%)	23.54	7.88	3.05	1.25

Sensitivity of results to choice of discount rate

The sensitivity of these results to the choice of discount rate was assessed by assuming a 5 per cent and a 10 per cent discount rate. These results are presented in Appendix E. An increase in the discount rate lowers the net present value and the benefit–cost ratios presented above. Similarly, a decrease in the discount rate increases the benefit–cost ratios and net present values. Importantly, all cost–benefit analysis measures for the South Australian case-study region remain positive regardless of the choice of discount rates assessed.

Box 1 Wild dog management and its impact on kangaroo competition for grazing vegetation, South Australian Arid Lands

In the South Australian Arid Lands, kangaroos compete with cattle for grazing vegetation, reducing the land's carrying capacity (Coulson & Eldridge 2010; Jonzen et al. 2005). Consequently, successful control of wild dogs may inadvertently lead to larger populations of kangaroos.

To investigate this interaction, the potential revenue losses that beef producers may incur have been estimated for varying levels of kangaroo competition. The level of competition varies from year to year depending on the quantity and quality of pasture available. For example, kangaroos and cattle are expected to compete more strongly in dry times when vegetation is scarce. But following good rainfall and an associated flush of vegetation, there is plenty of food for both cattle and kangaroos. Wild dog controls are therefore likely to affect competition between cattle and kangaroos for grazing vegetation.

The annual cost of kangaroo competition has been estimated as the revenues that may have been generated from pasture consumed by kangaroos rather than cattle. This is based on the assumption that kangaroos are not a source of revenue for the producer. For more detail on how this was estimated, refer Appendix A. Given variability in both the net value of a cow and the level of competition for grazing vegetation over time, a range of estimated costs for kangaroo competition are presented as a matrix of values in Table 10. Where the net value of a cow is $300 and kangaroos are competing with cattle 50 per cent of the time, the annual cost of kangaroo competition is estimated to cost all graziers in the case study area, on average, $1.7 million a year.

Table 10 Annual cost of kangaroo competition, South Australian Arid Lands ($m, valued in 2009–10 dollars)

Net value of a calf-producing cow ($ per head) a	Competition for grazing vegetation: between kangaroos and cattle									
	100%	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
500	5.65	5.09	4.52	3.96	3.39	2.83	2.26	1.70	1.13	0.57
450	5.09	4.58	4.07	3.56	3.05	2.54	2.03	1.53	1.02	0.51
400	4.52	4.07	3.62	3.16	2.71	2.26	1.81	1.36	0.90	0.45
350	3.96	3.56	3.16	2.77	2.37	1.98	1.58	1.19	0.79	0.40
300	3.39	3.05	2.71	2.37	2.03	1.70	1.36	1.02	0.68	0.34
250	2.83	2.54	2.26	1.98	1.70	1.41	1.13	0.85	0.57	0.28
200	2.26	2.03	1.81	1.58	1.36	1.13	0.90	0.68	0.45	0.23
150	1.70	1.53	1.36	1.19	1.02	0.85	0.68	0.51	0.34	0.17
100	1.13	1.02	0.90	0.79	0.68	0.57	0.45	0.34	0.23	0.11
50	0.57	0.51	0.45	0.40	0.34	0.28	0.23	0.17	0.11	0.06

Note: **a** ABARES annual Australian Agricultural and Grazing Industry Survey.

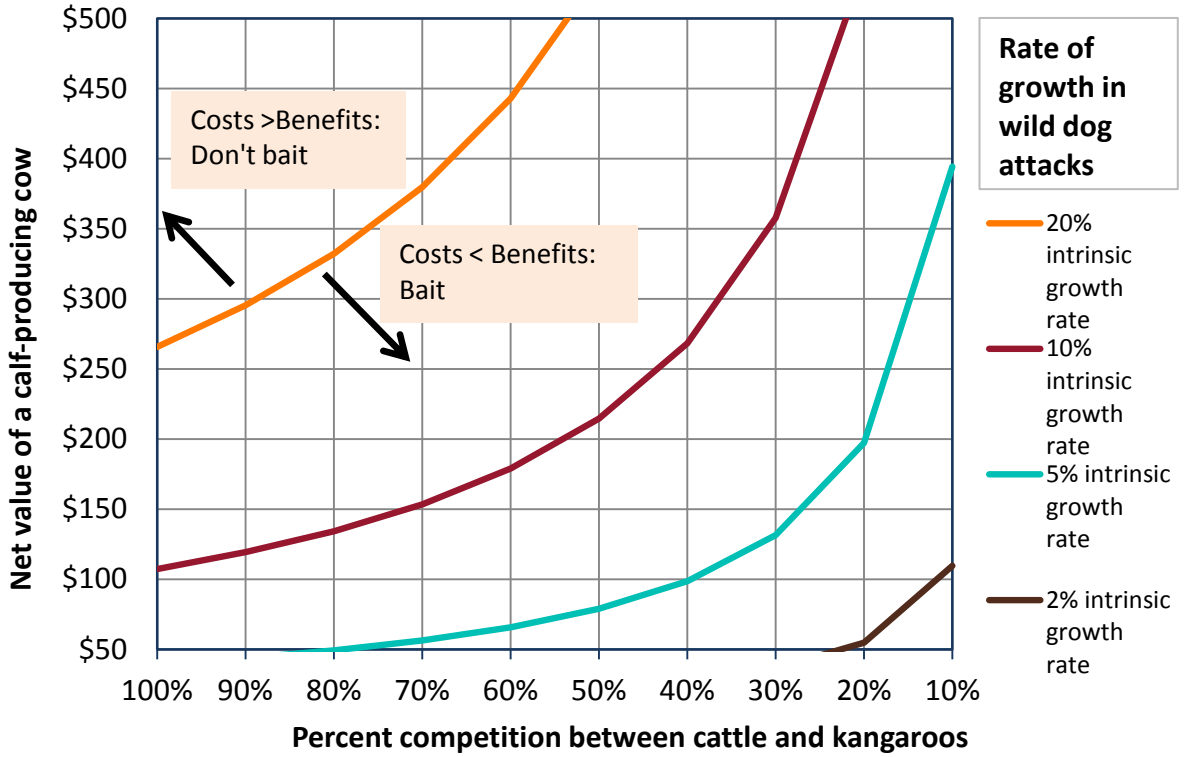
Breakeven curves for South Australian Arid Lands wild dog control programs

Breakeven curves, loci, for when the present value of the benefits from reduced calf losses and the present value of costs from increased kangaroo competition are equal, are presented in Figure 4. Four curves are presented, one for each rate of growth in calf deaths. The area left of a breakeven curve represents cases where the cost from increased kangaroo competition for grazing vegetation outweighs the benefits from wild dog controls. The converse is true for areas to the right of these curves.

Wild dog attacks on calves and calf deaths are expected to increase in drought times when the availability of wildlife prey is reduced. At these times, attack rates can increase rapidly to the point where more than 30 per cent of calves may be killed by wild dogs (Allen 2010b). At the same time, competition between kangaroos and cows for the limited available forage is high. This situation is depicted in Figure 4 by a growth in calf deaths of 20 per cent—the orange breakeven curve—and competition of 80 per cent or higher.

For this example, assume that the competition levels are exactly 80 per cent and the value of a calf-producing cow is $300. In this situation, the 20 per cent breakeven curve shows that there are benefits from implementing wild dog controls. However, one unintended consequence from wild dog controls is the reduction in predation on kangaroos, which may increase the competition for grazing vegetation. If the competition levels increase to 90 per cent, Figure 4 shows that the investment in wild dog management will result in a long-term loss to the graziers, assuming the grazier values a calf-producing cow remains at $300. If, however, the net value of a calf-producing cow were lower at $250 in this example, the present value of costs from kangaroo competition would be less than the present value of the benefits from reduced calf deaths. That is, controlling wild dogs in these times is likely to provide net benefits to beef producers.

Figure 4 Breakeven curves for wild dog baiting programs, South Australian Arid Lands



With more favourable rainfall conditions, calf deaths from wild dog attacks are expected to decrease on account of increased wildlife prey availability. During these times, the growth rate in calf deaths may be represented by a 2 per cent growth in calf deaths—the brown breakeven curve in Figure 4. This figure shows that for most combinations of the percentage of competition and the net value of a calf-producing cow, the costs of kangaroo competition will outweigh the benefits of control measures; in the area above the brown curve. So it is not in a beef producer's interests to implement control measures. Controlling wild dogs in more favourable conditions is unlikely to return a benefit to beef producers. It is only when the net value of a calf-producing cow is small (around $50 per head) and competition is less than 20 per cent, that the cost of grazing vegetation lost to kangaroos is smaller than the benefits from reducing calf deaths.

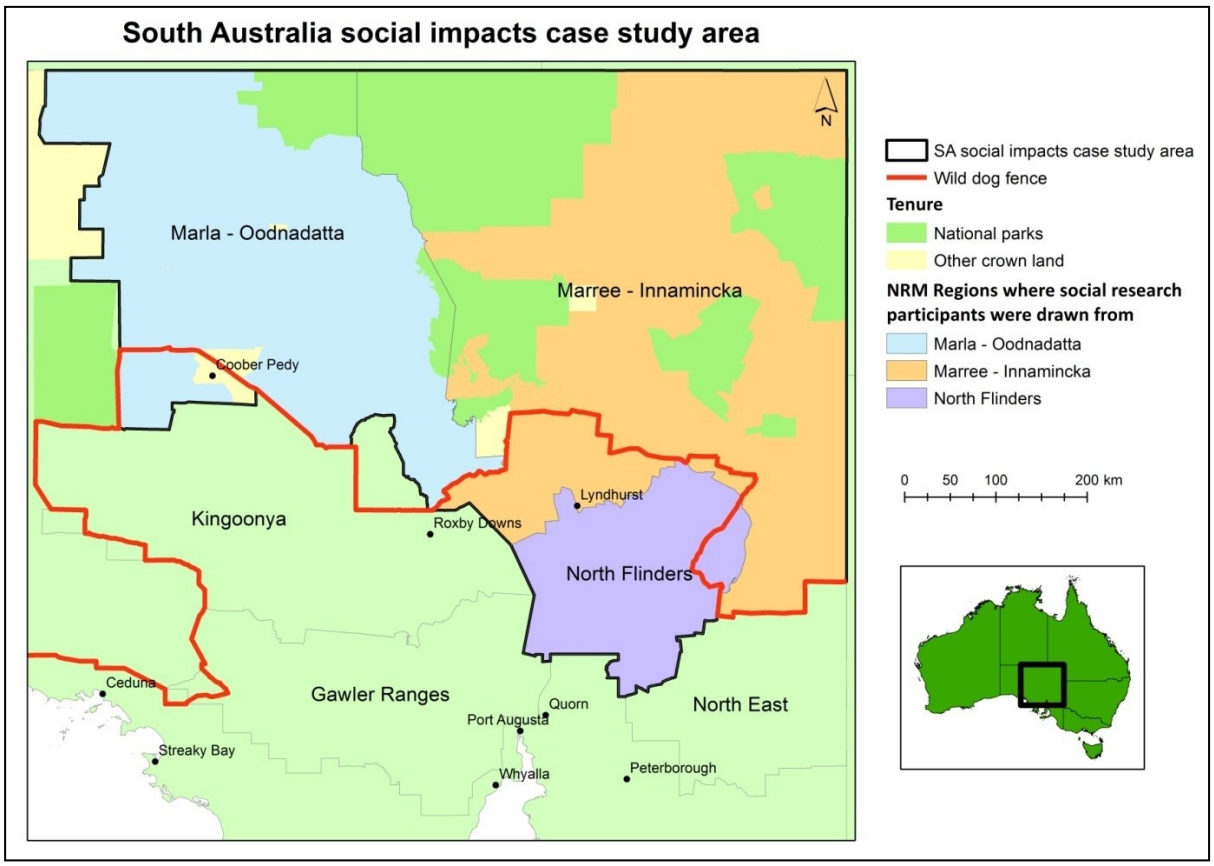
This analysis shows that the net returns to beef production from wild dog management are influenced by the net value of a calf-producing cow, the degree of kangaroo competition for grazing vegetation, and the growth in calf death rates. Changes in these factors will occur over time, resulting in adjustments to beef producers' decisions to manage wild dogs. Such adjustments may be considered by reference to Figure 4. For example, if rainfall occurs during a drought resulting in improved environmental conditions, this will translate into a move from the orange breakeven curve to the brown breakeven curve. As discussed, there is less opportunity for a beef producer to obtain positive net returns from implementing wild dog controls when located on the brown breakeven curve.

Non-market impacts

The non-market impacts of wild dogs in the South Australian Arid Lands were assessed in several ways. The social impacts of wild dogs, as reported through semi-structured interviews, were qualitatively assessed and are presented below. For the social impact assessment only, this

case study area was extended southwards to include the natural resource management group North Flinders, which is largely located south of the dog fence (Map 5). North Flinders has properties with sheep, and property owners were known to experience social impacts differently to those with cattle properties in the Marla–Oodnadatta and Marree–Innamincka area. Land managers from the North Flinders and the Marree–Innamincka areas were interviewed or attended a focus group to identify key themes and concerns relating to wild dog management. This included representatives from sheep and cattle stations and also Indigenous land managers.

Map 5 South Australian Arid Lands qualitative social impacts case study area



The non-market impacts were also quantified through a choice modelling study. These results are also presented in this section.

Qualitative assessment of social impacts

Threats to livelihood

Graziers in the case study area south of the dog fence said they had been dealing with wild dogs for up to 40 years, with the impact fluctuating over time, such as a reported increase around 2006–09. Graziers said that wild dog damage to sheep flocks was significantly lowering lambing percentages, although they were hesitant to provide a quantitative estimate of this because of all of the other factors that can impact on lambing percentages. One participant said that in 2008 their lambing percentage was just 3 per cent, in comparison to the expected 80–90 per cent, which they assumed was largely related to wild dogs. Financial impacts were not just associated with stock losses but also related to costs and time spent in managing the dog problem. Fuel costs were highlighted, with graziers travelling large distances to manage the situation.

The geographical character of the country south of the dog fence, as well as other factors including cost, precludes the option of diversifying into cattle for many graziers. These sheep graziers have no option but to work to protect their current livelihood. Participants noted that those who were able to move into cattle were happier and certainly less stressed by wild dog attacks.

Participants also noted that the role of pastoralists in natural resource management was threatened by dingo problems because this could drive them away from farming, leaving the country untended.

On a contrasting note, one pastoralist said that they would rather farm north of the dog fence because the dingoes keep down the number of feral animals, particularly rabbits, meaning that the country is in better condition.

Perception that sheep farmers are on their own when it comes to dog control

Participants at the focus group estimated that more than half of the landholders in the case study area do not have sheep. These areas include cattle properties, national parks and Indigenous-owned land. There was a perception among sheep farmers that these other landholders are not interested in the wild dog problem. Compounding this is that many landholders are absentee or part-time. In addition, where 20 years ago there may have been six or seven people staffing the properties and up to two of them may have been dedicated to managing the dingo situation, now there is 'skeleton staff'. The depopulation of the area over the last 20 years was also seen as a contributing issue for dog control. One participant referred to there being as few people in the region as there had been in 1860. Cattle farmers who had experienced the problem before they transitioned from sheep to cattle were seen as allies in that they continued some wild dog control. However, the fact that these cattle farmers had exhausted their resources and given up sheep farming meant that their energy for ongoing wild dog management may be limited.

> ... X (who has since transitioned to cattle) was ... the first ... sheep person inside the fence ... in South Australia to really bring it to the government's attention, the problem of dingoes in the sheep country and then go out of sheep. And he put his baits and everything out, but he says if he hears a dingo howling now, he puts his deaf ear up.

Stock losses due to wild dogs were seen as compounding issues for the sheep industry in the case study area. There was a sense that the survival of this industry was under threat. Some participants communicated a fear of being forgotten, both as remote residents and as food producers contributing to long term food security, which was interrelated with their sense of inadequate support for wild dog control.

> ... It's a tricky one and we all wonder if the government actually wants something at all. They make it that hard for us in every way. And they'd be far happier and we often hear it, if say all this country was closed down. They wouldn't have to administer it the same. That doesn't do anything good for the food production does it?

Dog behaviour and its impact on wild dog management

North of the dog fence, dogs were thought to be mostly dingo. Graziers north of the fence noted that not all the dogs are a problem—it might be only one in eight or ten that might attack stock.

The erratic nature of the attacks and not knowing when an attack might happen were a source of stress. One participant from south of the dog fence said that while there might be two attacks over a six-week period, the chasing of the stock was constant.

Participants were adamant there was no threat of attack on humans, with no reports of people being bitten or physically confronted by dogs. There was, however, a sense that the dogs had figured out strategies for avoiding capture. Focus group participants located south of the dog fence, where trapping is allowed, reported incidents when dogs had defecated or destroyed traps without taking the baits, sometimes only minutes after they had been laid, giving the impression that the dogs were watching.

> ... they've got a way of living in the wild and yeah, they know how to outsmart you. We've gone every year hunting them and living with them and working with them and you keep on learning more. A lot of times after you've been looking for them, you'll go back a couple of days later, and they've followed (your) tracks. And some of them, you'll put a bait out and they'll come and cock their leg on that. I've come along and I've actually seen the piddle still dripping off the ... bait.

Some participants noted that wild dog control may be detrimentally affecting pack structure—for example, by removing older dogs from the pack leaving younger (teenager) dogs that may be more likely to kill for fun. A participant representing Indigenous-owned lands commented that, in contrast to feral dogs, dingoes have a strong pack structure and upsetting this can cause further problems.

> ... They've got a real system. A real fair-dinkum system. They got a family and that system is very organised ... when you kill members of their family and when these guys come in and try and upset the family structure, that's when the trouble starts.

They also noted that dingoes can be timid and take only what they need to live. It was also commented that dingoes have a place in the ecology and that their other food sources, such as kangaroo and dunnart, have been reduced by foxes and cats.

Several participants noted that the behaviour of dogs was different south and north of the dog fence, with those in the south being more 'shy' and elusive. This is presumably because they are hunted more strongly south of the dog fence and learn the dangers of human interaction more so than those located north of the fence. Focus group participants shared the opinion that the dogs were heading south, through the frequent gaps in the fence,, into the declared pest zone.

Wild dog impacts on individuals and families

The intrusiveness of the wild dog issue for graziers located south of the dog fence was evident. Participants told how they were constantly alert to the problem of wild dogs and spent large amounts of time chasing dogs. One participant called this a 'system of vigilance'. They described a cycle of seeing, chasing and hunting individual dogs which would keep them up early and home late until that particular dog was eliminated. This behaviour was compelled by the belief that once a dog had been spotted, and an attempt made to kill it, the dog becomes 'shy' and disappears. Hence, graziers believed they needed to hunt down the dog on first sighting, as this may be the only chance they have. At times this led to injuries or damage to property.

> It doesn't matter what fence gets in the way. What gutter gets in the way. Doesn't matter how much you smash your vehicle up, you get that dog. Straight through fences, straight through them ... because that's how important it is, getting that dog.

Graziers described spending large amounts of time on purposeful hunting and trapping, but also responding to chance sightings. This sense of needing to be constantly alert meant that graziers were vigilant all the time. Holidays and relaxation were compromised. Impacts on family life were also noted with partnerships and parenting often competing for time with long hours of wild dog control.

> Your family quality too—you get home, and you've been chasing dogs all day and your kids are there and they're sort of asking you this, asking you … You're tired and grumpy. They say things to you and you snap at them. And it's hard on everybody.

Sheep graziers were also spending significant time attending meetings and planning forums and/or lobbying in relation to wild dog management. One participant estimated that this amounted to more than 16 days a year away from home.

Lives are impacted in a myriad of ways. Concerns were expressed over handling poisons and foul meat, although this has improved with better poison management over time. A number of graziers mentioned that they cannot have working dogs or let pet dogs out of the home yard for fear of their taking a bait. Neighbours will often prevent baiting close to their boundaries to protect their pets.

Wild dog issues also impact on people's lives through emotional and psychological stress factors, as discussed earlier in this report. One participant reported feeling like a failure because of the inability to adequately control the dingoes. Participants also noted that counselling and other emotional support was not what was needed—what was needed was management of the wild dog problem.

Box 2 Effective wild dog management: perceptions of landholders

Participants communicated that, in this case study area, there is an artificially increased number of dingoes because they feed on livestock and that they need to be controlled. Graziers trap, shoot and bait and use 'every other means you can think of too'. Many of the graziers participating in the study said they want all wild dogs out of the declared pest zone south of the South Australian Dog Fence. They considered the intention of the legislation, to keep dingoes out of this area, as a pragmatic goal, despite the difficulty in actually achieving this.

> ... there are three different Acts that cover it. (In) ... South Australia and the pastoral country, once you're inside the dog fence, they're a notified pest. And everybody who ever holds that land is required under the two or three different laws to destroy them.

Opinions on effective management varied. Baiting was an area of discussion. Aerial baiting is not allowed north of the dog fence. One participant said that they use only 'shoot on sight' because they questioned the effectiveness of baiting. This participant had relied on research that showed that shooting could keep numbers down and said that he had a lack of evidence about the effectiveness of baiting. Other comments from graziers were that 'ill-informed people are scared of baits'. It was reported that with baiting, the ground baiting approach is a much more effective use of money than aerial baiting – which also happens to be illegal. Focus-group participants did not support a bounty system; they said it encouraged rorting of the system.

Management was often pre-emptive, attempting to eliminate a dog or dogs before they started killing. Signs towards this included seeing dog tracks around the stock and also having a radar for 'anything out of the normal' such as stock being stirred up and restless. The presence of eagles, who form a 'partnership' with the dogs, could also indicate there was carrion around and a dog might be killing in the vicinity.

Participants mentioned issues about policing of wild dog management, suggesting that someone needs to take this role and enforce management of wild dogs. Participants said that national parks are not patrolled in the same way as pastoral properties. One of the immediate actions participants located south of the dog fence suggested was to ensure that the pastoral board use their powers more, to enforce the legislation. They communicated that the legislation was adequate and rather it was the enforcement that was lacking. Landholders north of the dog fence

are not subject to this legislation.

Maintaining the dog fence was seen as an important contribution towards management. Participants commented that there were few resources targeted at this relative to other states, but they perceived that the patrolling and repairing of the fence were generally effective.

Quantitative assessment of non-market impacts

Two of the three estimated non-market impacts of wild dogs in the South Australian Arid Lands were positive and significant. Householders in South Australia reported being willing to pay $5.67 per household a year (for 10 years) to protect one native species from becoming threatened as a result of wild dog attacks in the South Australian Arid Lands (Table 11). South Australian householders also reported being willing to pay $0.41 per household a year to protect one household from the adverse affects of wild dog attacks in the case study region. In contrast, respondents were not willing to pay for the protection of public areas in the South Australian Arid Lands from the impact of wild dogs.

Table 11 South Australian householders' willingness to pay (for 10 years) to ameliorate the adverse impacts of wild dogs in the South Australian Arid Lands

	Annual marginal values per household
Households protected (per household)	$0.406*** (0.113~0.681)
Native species protected (per species)	$5.666*** (4.295~7.197)
Public area protected (per 1000 km^2)	$0.181 (–0.925~0.448)

Note: Significance levels indicated by: * 0.1, **0.05, ***0.01; 95 per cent confidence interval in brackets calculated using the bootstrapping procedure from Krinsky and Robb (1986).

The non-market benefits associated with the management of wild dogs are estimated for four scenarios regarding the rate of growth in wild dog attacks in the absence of control (Table 12). As the long-term (10 and 20 years) non-market impacts of wild dogs are difficult to predict, the estimates (Table 12) are hypothetical. These estimates were used only as an example to estimate the potential total net benefits of the management of wild dogs in the case study area. It is estimated that, with controls, one household in the South Australian Arid Lands is protected from the adverse impacts of wild dogs over 10 years if the rate of growth in wild dog attacks is 2 per cent in the absence of control. It is estimated that controls protect 32 households in the South Australian Arid Lands from the adverse impacts of wild dogs over 10 years if the growth rate of wild dog attacks is 10 per cent in the absence of control. Over a 20-year period the number of households protected in the region as a result of control ranges between five and 45. Similarly, the area of public land in the South Australian Arid Lands protected from the adverse impacts of wild dogs is estimated to vary between 1000 and 19 000 square kilometres depending on the assumption made about the rate of growth in attack rates in the absence of control.

Table 12 Assumed non-market benefits from the management of wild dogs for the different scenarios of wild dog attacks in the South Australian Arid Lands

Scenarios	2%	5%	10%	20%
10 years				
Number of households protected	1	5	12	32
Number of native species protected	0	1	2	7
Public area protected (1000 km^2)	1	3	7	19
20 years				
Number of households protected	5	12	28	45
Number of native species protected	1	2	6	9
Public area protected (1000 km^2)	3	7	17	27

Aggregate non-market values were calculated using the marginal values reported in Table 11, the number of non-market goods protected reported in Table 12 and the estimated population. Estimated non-market values for 10- and 20-year periods, in present value terms using a 7 per cent discount rate, are reported in Table 13.

Table 13 Total non-market benefits from management of wild dogs, South Australian Arid Lands ($'000)

Scenario		2%		5%		10%		20%
10 years								
Households protected		905		3 166		7 689		21 259
CI	252	1 518	883	5 314	2 146	12 906	5 932	35 681
Native species		0		9 225		18 450		64 575
CI	0	0	6 994	11 719	13 988	23 438	48 958	82 032
Public areas		0		0		0		0
CI	0	0	0	0	0	0	0	0
Total benefits		**905**		**12 391**		**26 139**		**85 834**
CI	252	1 518	7 877	17 033	16 133	36 344	54 890	117 713
20 years upper bound								
Households protected		4 776		11 598		27 517		44 574
CI	1 333	8 016	3 236	19 467	7 678	46 185	12 438	74 813
Native species		13 915		27 829		83 487		125 231
CI	10 549	17 676	21 099	35 352	63 296	106 056	94 944	159 085
Public areas		0		0		0		0
CI	0	0	0	0	0	0	0	0
Total benefits		**18 690**		**39 427**		**111 004**		**169 804**
CI	11 882	25 692	24 335	54 819	70 974	152 242	107 381	233 897
20 years lower bound								
Households protected		3 166		7 689		18 243		29 551
CI	883	5 314	2 146	12 906	5 091	30 620	8 246	49 599
Native species		9 225		18 450		55 350		83 025
CI	6 994	11 718	13 988	23 438	41 964	70 313	62 945	105 469
Public areas		0		0		0		0
CI	0	0	0	0	0	0	0	0
Total benefits		**12 391**		**26 139**		**73 593**		**112 576**
CI	7 877	17 033	16 133	36 344	47 054	100 933	71 191	155 068

Note: CI = confidence intervals.

Respondents to the choice modelling questionnaire were asked their willingness to pay over 10 years to protect non-market goods from the impact of wild dogs. The upper and lower bound estimates presented in Table 13 represent the range of plausible estimates of respondents' willingness to pay over a 20-year period. The upper bound is based on the assumption that respondents are willing to continue to pay to protect non-market goods from wild dogs between years 10 and 20. The lower bound is based on the assumption that respondents are not willing to continue to pay beyond year 10.

The total non-market benefits from the management of wild dogs in the South Australian Arid Lands over 10 years were estimated to range between $0.9 million and $85.8 million depending

on the assumed rate of growth in wild dog attacks in the absence of control. When the rate of growth in wild dog attacks was assumed to be 2 per cent in the absence of control, the non-market benefits were dominated by those associated with the protection of households. As the assumed rate of growth in wild dog attacks increases, the non-market benefits associated with the protection of public areas in the South Australian Arid Lands became relatively more important.

The non-market benefits in the South Australian Arid Lands over 20 years were estimated to range between $12.4 million and $170 million depending on the assumed rate of growth in wild dog attacks in the absence of control and the assumption regarding respondents' willingness to pay to protect non-market goods between years 10 and 20. When the rate of growth in wild dog attacks was assumed to be 2 per cent in the absence of control, the protection of native species made the greatest contribution to the total non-market benefits. As the assumed rate of growth in wild dog attacks increases, the non-market benefits associated with the protection of public areas became relatively more important.

The total non-market benefits in the South Australian Arid Lands were the lowest of all the case studies, driven mostly by the smaller population and number of households and native species within the region. It should be noted that there is considerable uncertainty regarding the number of non-market goods adversely affected by wild dogs and that, with improved information, the marginal non-market values reported in Table 11 could be used to derive revised estimates.

Integrated assessment

The total net benefits of the management of wild dogs in the South Australian Arid Lands were estimated by combining the market and non-market benefits and costs over a 20-year period (Table 14). As for Eastern Victoria, the non-market benefits in South Australia were larger than the market benefits. The results indicate that, if attack rates grow at 2 per cent a year in the absence of control, then the present value of the net benefits of wild dog control is in the range $13.8 million to $20.1 million over 20 years. If the rate of wild dog attacks increases at a faster rate than this in the absence of control, then the present value of the estimated net benefits of wild dog control increase to somewhere between $147 million and $204 million over 20 years.

Table 14 Net benefits from the management of wild dog programs in the South Australian Arid Lands over 20 years

Variable (upper bound estimate)			**Growth in attack rates**	
Scenario	**2%**	**5%**	**10%**	**20%**
Present value of market benefits ($'000)	1 836	5 484	14 181	34 478
Present value of costs of control program ($'000)	432	432	432	432
Net present market value ($'000)	1 404	5 052	13 749	34 046
Present non-market value ($'000)	18 690	39 427	111 004	169 804
Present value of total net benefits ($'000)	20 094	44 479	124 753	203 850
Variable (lower bound estimate)			**Growth in attack rates**	
Scenario	**2%**	**5%**	**10%**	**20%**
Present value of market benefits ($'000)	1 836	5 484	14 181	34 478
Present value of costs of control program ($'000)	432	432	432	432
Net present market value ($'000)	1 404	5 052	13 749	34 046
Present non-market value ($'000)	12 391	26 139	73 593	112 576
Present value of total net benefits ($'000)	13 795	31 191	87 342	146 622

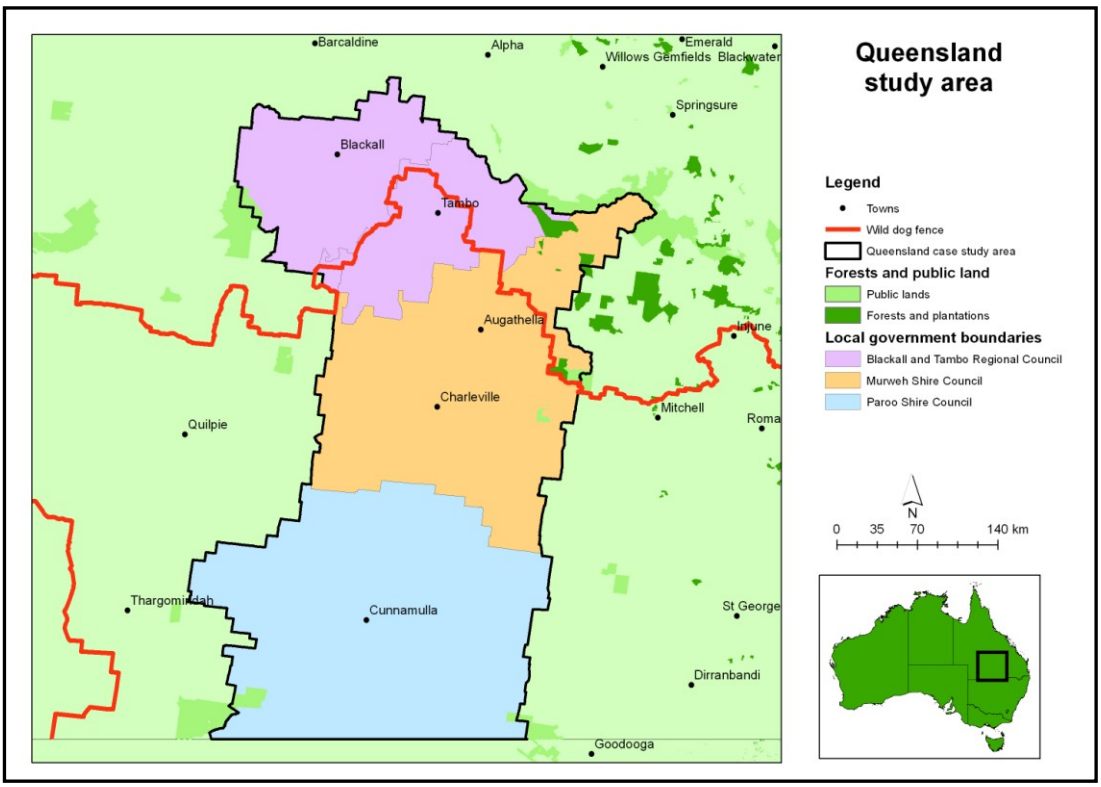
Note: Values in 2011–12 dollars.

7 South Western Queensland

Case study region

The Queensland case study consists of three local government areas: Paroo Shire, Murweh Shire and Blackall–Tambo Regional Council (Map 6). The area covers 320 000 square kilometres and population centres include the towns of Cunnamulla, Morven, Charleville, Tambo and Blackall. In 2009–10, the approximate population of this area was 8900 (ABS 2010).

Map 6 South Western Queensland case study region



Production characteristics

The area contains both cattle and sheep. In 2005–06, there were approximately 825 000 sheep and 457 000 cattle in the case study region, grazing on 3.5 million hectares. Grazing accounted for approximately 98 per cent of the land use in the study area. The gross value of production for these livestock industries was estimated at $168 million per year (Table 15).

Table 15 Livestock numbers and gross value of production, South Western Queensland (2009–10 dollars)

Statistical local area name	Sheep numbers	Sheep (including lambs) GVP of sheep slaughtered ($)	Sheep (including lambs) GVP of wool ($)	Cattle numbers	Meat cattle GVP of cattle slaughtered ($)
Murweh	193 195	1 776 545	1 015 680	198 374	60 728 158
Paroo	368 216	6 150 565	927 912	56 338	19 968 266
Blackall	145 100	1 741 012	518 897	99 219	41 185 566
Tambo	118 768	2 327 958	350 712	102 968	33 231 435
Total	**825 279**	**9 668 122**	**2 813 201**	**456 899**	**155 113 425**

Source: Australian Bureau of Statistics, Agricultural commodities cat. no. 7121.0 and Value of agricultural commodities produced cat. no. 7503.0, Canberra, 2005–06.

Wild dog management

In Queensland, wild dogs are declared as class 2 pest animals under state legislation—the *Land Protection [Pest and Stock Route Management] Act 2002*)—and land managers, private individuals, companies, and local and state government agencies have a legal responsibility to control wild dogs on their land. However, 'dingoes' are defined as native wildlife under the *Nature Conservation Act 1992* and, in accordance with other state legislation, are protected in national parks and state forests (Biosecurity Queensland 2011).

The 2011–16 Wild Dog Management Strategy (Biosecurity Queensland 2011) sets a framework for coordinating the actions of all stakeholders which will maximise the effective use of physical and economic resources used for wild dog management in Queensland. Under state legislation, local government has primary responsibility for wild dog control. The Queensland State Government does not fund wild dog control however it does fund management of the wild dog barrier fence, which divides the case-study area. The Wild Dog Management Strategy aims for zero tolerance of wild dogs inside (south of) the wild dog barrier fence. Outside (north) of the fence, the aim is to control wild dogs across all land tenures (Biosecurity Queensland 2011).

Wild dog control programs in the Queensland case study area are coordinated and implemented by the shire or statistical local area. Coordinated control measures used in this area include aerial and ground baiting, trapping, shooting and reliance on the wild dog barrier fence.

The bottom-up, community-based approach to wild dog management successfully developed in Paroo Shire has become the Queensland Government's preferred model for wild dog control (Tully et al. 2011).

Community-driven wild dog management

The wild dog problem was defined by one participant as a 'whole of community issue'—the wild dogs have an impact on communities and not just individuals. It was emphasised that there is a need to be proactive in admitting there is a problem and that it affects neighbours and the community.

This case-study area is characterised by very strong collective action by the local communities in wild dog management. This began in Paroo Shire (the southern shire in the case-study area), driven by a landholder named Peter Lucas (2012, pers. comm., 3 September). Its origins date back approximately 15 years and involved many early years engaging directly with other landholders, sharing wild dog experiences and how to address them.

The Paroo Shire model is essentially landholder-owned and community-driven, run by the volunteer effort of the local community. Shire funds are used to pay for baits and other on-ground methods of controlling wild dogs.

This model of wild dog management has been adopted to the north in Murweh Shire and, to a lesser extent, by Blackall–Tambo Shire. Some of the participants in this research emphasised the benefits of this community 'bottom-up' approach. Local syndicates have been established for active management of wild dogs. A next organisational layer, known as the Wild Dog Advisory Group, advises the local council and manages the shire funds.

Benefits to this approach were reported by research participants as including:

- greater ownership of the issue
- highly effective implementation due to the on-ground community network
- flexibility in management and communication due to the slightly informal structure of the model; using a combination of the internet and social gatherings.

A collective benefit reported is that fewer dogs travel south into the other shires such as Paroo Shire as the northern shires' wild dog programs become more effective. Essentially, collective action brings collective benefits.

Challenges associated with this model were reported as including:

- the amount of volunteer time put into wild dog control using this approach, including time to attend meetings and organise baiting programs. This is time away from family and from activities more directly related to agricultural productivity. There are instances where the whole family has been involved in baiting programs
- personal funds contributed to wild dog control—in addition to time contributed, landholders have at times paid directly for trappers and aerial baiting
- getting all landholders involved in any one region. Any property that does not have a landholder actively involved in wild dog management can become a 'haven' for the dogs. This issue relates particularly to cattle property owners and absentee landholders
- tensions between neighbours who are and who are not involved in program, as the success of this approach is known to be based on the principle of collective action—and not just individual action
- acquiring and maintaining shire funding to assist landholders in their program; in 2009 Murweh Shire provided a $600 000 grant over three years.

Market impacts

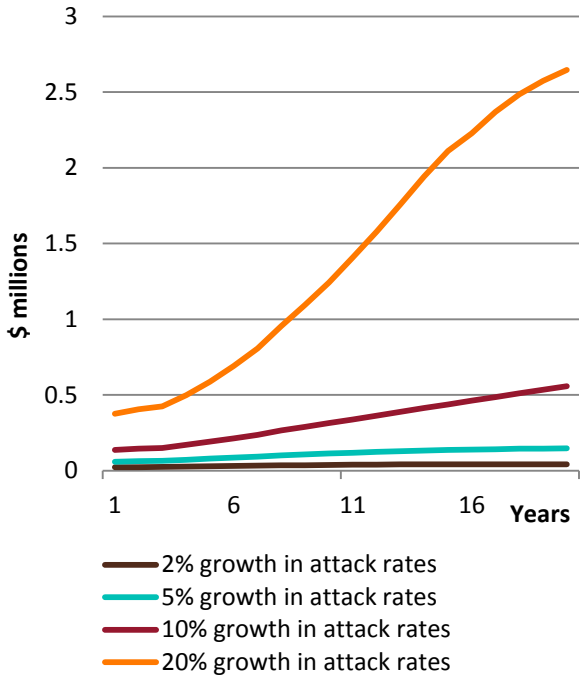
Revenues and benefits

Annual estimates of discounted benefits—for each rate of growth in livestock deaths—are presented in Figure 5(a) and Figure 5(b) for cattle and sheep respectively. The discounted benefits are represented by the curves in Figures 5(a) and 5(b) and the area under these curves is the present value of benefits. The sharp downward slope of the discounted net benefits commencing in year 17 results from discounting of constant net benefits (in nominal terms) from year 17 onwards. For a 20 per cent growth in livestock deaths the present value of benefits

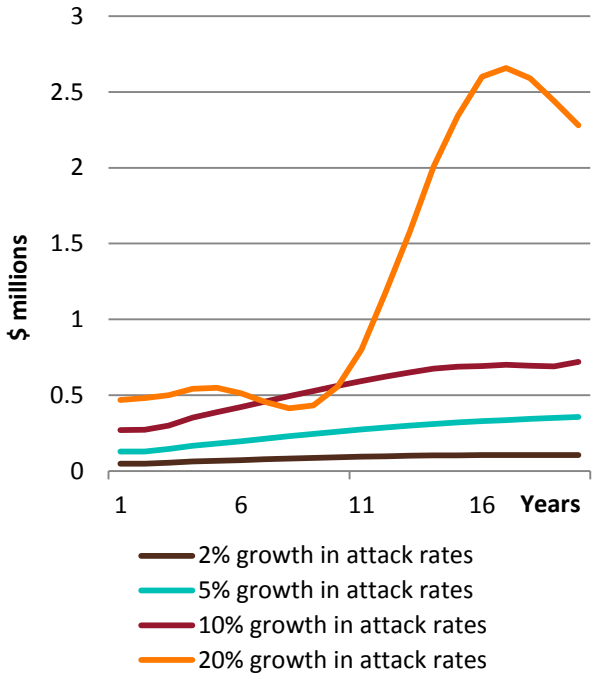
to cattle and sheep producers from wild dog control measures in South Western Queensland are approximately $53.5 million over 20 years (see Table 16).

Figure 5 Benefits of wild dog control for cattle and sheep industries, South Western Queensland

(a) Discounted net benefits from wild dog controls for the cattle industry, for calf death rates



(b) Discounted net benefits from wild dog controls for the sheep industry, for sheep death rates



Cost–benefit analysis measures

The present value of expected benefits from investment in wild dog controls in South Western Queensland is displayed in Table 16.

The present value of costs is the sum of discounted average annual cost estimated over a 20-year period. The average annual cost of wild dog management was estimated from the annual costs of past and current control programs in the area. These are valued at approximately $17 million for South Western Queensland in 2009–10 dollars (Table 16). It is assumed that the present values of costs are constant across all rates of growth in calf and lamb deaths.

The estimated returns, in net present value terms, from a dollar invested in wild dog controls for South Western Queensland rise from –$0.14 to $3.11 as the rate of livestock deaths increases in the absence of control (Table 16). For 2 and 5 per cent growth rates, the returns from wild dog controls are less than the cost of investments in controls. When attack rates are assumed to grow by 10 per cent or more in the absence of control, the benefits outweigh the costs and the benefit–cost ratio is greater than one.

When the growth in wild dog attack rates in the absence of control is assumed to be 10 per cent, the expected benefits of wild dog control only just outweigh the estimated costs of control. The effectiveness of that control must be very high, 99 per cent or greater, for this to generate net

economic returns. When the growth in wild dog attack rates in the absence of control is assumed to be 20 per cent, the expected benefits of wild dog control are considerably higher than the costs. This means that, even with uncertainty about the effectiveness of wild dog controls, it is still likely to be a cost-effective action.

Table 16 Cost–benefit analysis measures for South Western Queensland, by growth in livestock deaths over 20 years (2009–10 dollars)

	Increase in livestock deaths			
	2%	**5%**	**10%**	**20%**
Present value of benefits – cattle ($'000)	708	2 196	6 604	28 186
Present value of benefits – sheep ($'000)	1 715	5 093	10 769	25 383
Total present value of benefits ($'000)	2 422	7 289	17 373	53 569
Present value of costs of control program ($'000)	17 252	17 252	17 252	17 252
Benefit–cost ratio	0.14	0.42	1.01	3.11
Net present value ($'000)	–14 830	–9 964	120	36 317
Threshold probability (%)	na	na	99	32

Note: na = not applicable because the benefits do not outweigh the costs in this scenario.

Sensitivity of results to choice of discount rate

The sensitivity of these results to the choice of discount rate was assessed and is reported in detail in Appendix E. A lower discount rate increases the magnitude of the net present value and the benefit–cost ratio of wild dog management. Where the net present value is negative, a lower discount rate increases the negativity of this value. The results for a 7 per cent discount rate (see above), show that when the rate of wild dog attacks is assumed to grow at 10 per cent a year in the absence of control, the benefits of wild dog control are slightly larger than the costs. When the discount rate is 10 per cent, this no longer holds and the costs outweigh the benefits.

Non-market impacts

The non-market impacts of wild dogs in the Queensland case study region were assessed in several ways. The social impacts of wild dogs, as reported through semi-structured interviews, were qualitatively assessed and are presented below. The non-market impacts were also quantified through a choice modelling study. These results are also presented in this section.

Qualitative assessment of social impacts

Regional transition from sheep to cattle production

It was reported that the 'Morven–Augathella–Charleville triangle' used to be dominated by sheep production but that this pattern of agricultural activity has been changing since the early 1990s. The wild dog problem was considered by many to be a contributing factor to this shift – although the economic situation of the past couple of decades is known to be a major factor. This pattern has been repeated across many other regions of western Queensland.

Many participants commented on how the shift from sheep to cattle has had a major impact on the local rural towns. The key factor in this impact is that cattle production does not involve as many people or as much infrastructure as sheep production.

Evidence provided included:

- Charleville used to have nine shearing teams and now only has 'one and a half'.
- Augathella, which has shifted from sheep to cattle, used to have more than 30 people employed in the shearing industry. Landholders who still need shearers look to Charleville or further afield to find people with these skills.

- Tambo once had three shearing teams; now there are none. The shearing teams were made up of approximately 12 highly skilled shearers, 'pickerup', wool roller (skirts the wool and takes the edges off the fleece), wool classer and wool presser.

- It was commented that in Morven in the 1980s, the cricket team used to have many shearers and roustabouts but not anymore.

Overall there is a perception of a 'loss of sheep expertise' in the region. Impacts of this loss included:

- loss of cultural life in the towns, particularly at weekends. The shearing teams and their families used to contribute socially as well as economically to the local towns

- no-one with skills for the next generation to learn from

- higher costs for the skilled labour that remain in the area or are available due to a reduction in the economies of scale.

It is acknowledged that the decline in sheep farming over the past couple of decades has been strongly linked to the decline in wool prices. However, with the more recent rise in the price of sheep and lambs, many of the farmers do not want to shift back to sheep because of the wild dog issue. Many are deterred from returning to sheep farming because of the cost of investing once again in sheep farming infrastructure and the uncertainty whether the stock will survive and be economic in the face of wild dog attacks.

In Tambo it was reported that the land is more suitable for sheep production than cattle—it was suggested that there is three times greater net profit per acre for sheep than for cattle, and that this is also the case for other shires in the case study region.

One community representative said:

> If they are going to try to revive any sort of sheep business, they are going to have to bring the wild dogs under control.

A participant expressed the opinion that, whether the land is used for sheep or cattle, the land is more valuable without the associated wild dog issue.

Absentee landlords

The transition from sheep to cattle is also associated with an increasing number of absentee landlords. A cattle business can be managed at a distance. A research participant gave the example of an absentee landholder who bought a property in the area and stocked it with cattle. This landholder would travel from a New South Wales town to stay on the property for four to five days, twice a year. They were known not to spend any money locally. This owner was perceived to have no interest in wild dog management.

With the increasing number of absentee landlords comes an increase in the wild dog problem due to the landholders' limited presence and often limited interest in the issue. It has been reported that the dogs learn which properties have a limited human presence and wild dog management and use these properties as 'safe havens' to hide and breed.

Regional town decline

It was reported that Charleville's population in the 1950s and 1960s was much higher than it is today. According to the ABS Census statistics (Australian Bureau of Statistics, 1956; 1961; 2006) the population of the town of Charleville was 4517 in 1956; it rose to 5154 in 1961 and has been

steadily declining since then to 3276 in 2006. During its 'heyday', when sheep production was the dominant agricultural activity in the region, it was reported that Charleville used to have around 200 men employed just by the sheep industry. The direct economic flow-on benefits went to shopkeepers, service station owners and indirectly flowed on to every facet of the community. The observation was that this story repeats itself in other traditional sheep-producing regional centres in western Queensland.

The regional trend of a move away from sheep production towards cattle production is due to a combination of factors, of which the wild dog issue is one. A community representative provided a broader perspective on the issue. He spoke of the high wool price in the 1980s followed by the collapse in the early 1990s which led to trauma among sheep producers, who then shifted to cattle. This representative perceived the shift as a response to psychological trauma as well as to economic factors.

There was a call for Charleville Council to be more involved in wild dog management because of the impact on the number of sheep properties in the area and its flow-on impact on employment.

One participant observed that many facilities and services are being lost to Charleville—doctors, dentists, professionals, transport and political representation. They reported that more people are leaving the region due to social decline, evidenced by fewer children at schools, fewer subjects offered, and fewer medical facilities and specialists. As well, the observed trend is of more wives working off properties in the towns. In some cases the wives are locating themselves at quite a distance from their partners so that their children can have better opportunities.

Another observation made by a participant was that in the agricultural sector in western Queensland, there has been a significant decline in funding for research, development and extension. More than ten years ago the region was a significant central hub of science for the sheep and wool industries with the CSIRO and the Queensland Department of Primary Industries (now Queensland Department of Agriculture, Fisheries and Forestry) having a substantial presence in the region; approximately 40 staff provided good knowledge transfer and established productive relationships with producers. It was perceived that today, government agency presence is associated with legislation—national parks, animal welfare and vegetation management laws—and not animal production. The opinion is that this trend reflects a loss of sheep industry support in the area.

A community representative commented that the community is now struggling to work out how to keep people in the area.

Quantitative assessment of non-market impacts

The estimated non-market impacts of wild dogs in South Western Queensland were positive and significant. Consistent with the other case study regions, respondents were willing to pay most to protect native species in the region from becoming threatened. Householders in Queensland reported being willing to pay $3.63 per household a year (for 10 years) to protect one native species in South Western Queensland from becoming threatened as a result of wild dog attacks (Table 17). Queensland householders also reported being willing to pay $0.11 per household a year to protect 1000 square kilometres of public area in the case study region from the adverse impacts of wild dogs. This was similar to respondents in South Australia but considerably less than respondents in Victoria. Householders in Queensland were willing to pay $0.01 per household a year to protect one household in South Western Queensland from the impact of wild dogs. This is similar to respondents from Victoria but considerably less than respondents in South Australia.

Table 17 Queensland householders' willingness to pay (for 10 years) to ameliorate adverse impacts of wild dogs in South Western Queensland

	Annual marginal values per household
Households protected (per household)	$0.0105*** (0.003~0.018)
Native species protected (per species)	$3.633*** (2.180~5.201)
Public area protected (per 1000 km^2)	$0.114** (0.015~0.219)

Note: Significance levels indicated by: * 0.1, **0.05, ***0.01; 95 per cent confidence interval in brackets calculated using the bootstrapping procedure from Krinsky and Robb (1986).

The assumed number of households, the number of native species and the area of public land protected from the adverse impacts of wild dogs in South Western Queensland are reported in Table 18. As the long term (10 and 20 years) non-market impacts of wild dogs are difficult to predict, the estimates (Table 18) are hypothetical. These estimates were only used as an example to estimate the potential total net benefits of the management of wild dogs in the case study area. It is assumed that management of wild dogs protects between 52 and 1222 households in South Western Queensland from adverse impacts over 10 years, depending on the assumed growth in wild dog attacks in the absence of control. Similarly, the area of public land protected over a 10 year period in South Western Queensland as a result of wild dog controls was estimated to vary between 2000 and 58 000 square kilometres depending on the assumed growth in wild dog attacks in the absence of control. The number of households, native species and public areas protected in South Western Queensland increases when a 20 year time period is considered.

Table 18 Assumed non-market benefits from the management of wild dogs for the different scenarios of wild dog attacks, South Western Queensland

Scenarios	2%	5%	10%	20%
10 years				
Number of households protected	52	182	442	1 222
Number of native species protected	0	1	2	6
Public area protected (1000 km^2)	2	9	21	58
20 years				
Number of households protected	182	442	1 049	1 699
Number of native species protected	1	2	5	8
Public area protected (1000 km^2)	9	21	50	80

Aggregate non-market values were calculated using the marginal values reported in Table 17, the number of non-market goods protected reported in Table 18 and the estimated population. The non-market values for 10 and 20 year periods, in present value terms using a 7 per cent discount rate, are reported in Table 19.

Table 19 Total non-market benefits from the management of wild dogs, South Western Queensland ($'000)

Scenario		2%		5%		10%		20%
10 years								
Households protected		2 230		7 804		18 952		52 396
CI	619	3 798	2 165	13 294	5 258	32 285	14 537	89 259
Native species		0		14 785		29 570		88 709
CI	0	0	8 874	21 169	17 747	42 337	53 242	127 011
Public areas		1 140		3 992		9 694		26 801
CI	153	2 193	536	7 675	1 302	18 639	3 601	51 532
Total benefits		**3 370**		**26 580**		**58 215**		**167 906**
CI	772	5 991	11 575	42 137	24 308	93 262	71 380	267 803
20 years upper bound								
Households protected		11 771		28 586		67 821		109 859
CI	3 266	20 052	7 931	48 697	18 817	115 537	30 480	187 150
Native species		22 301		44 601		111 504		178 406
CI	13 385	31 930	26 769	63 859	66 923	159 648	107 077	255 437
Public areas		6 021		14 622		34 691		56 193
CI	809	11 577	1 964	28 115	4 661	66 703	7 550	108 048
Total benefits		**40 092**		**87 809**		**214 016**		**344 458**
CI	17 459	63 558	36 665	140 671	90 401	341 888	145 107	550 636
20 years lower bound								
Households protected		7 804		18 951		44 964		72 834
CI	2 165	13 294	5 258	32 285	12 475	76 598	20 208	124 076
Native species		14 785		29 570		73 924		118 279
CI	8 874	21 169	17 747	42 337	44 368	105 842	70 989	169 348
Public areas		3 992		9 694		22 999		37 255
CI	536	7 675	1 302	18 639	3 089	44 223	5 005	71 634
Total benefits		**26 580**		**58 215**		**141 887**		**228 368**
CI	11 575	42 137	24 308	93 261	59 933	226 664	96 202	365 058

Note: CI = confidence intervals.

Respondents to the choice modelling questionnaire were asked their willingness to pay over 10 years to protect non-market goods from the impact of wild dogs. The upper and lower bound estimates presented in Table 19 represent the range of plausible estimates of respondents' willingness to pay over a 20-year period. The upper bound is based on the assumption that respondents are willing to continue to pay to protect non-market goods from wild dogs between years 10 and 20. The lower bound is based on the assumption that respondents are not willing to continue to pay beyond year 10.

The total non-market benefits from the management of wild dogs in South Western Queensland over 10 years were estimated to range between $3.4 million and $168 million depending on the assumed rate of growth in wild dog attacks in the absence of control. When the rate of growth in wild dog attacks was assumed to be 2 per cent in the absence of control, the non-market benefits were dominated by those associated with the protection of households in South Western Queensland. As the assumed rate of growth in wild dog attacks increases, the non-market benefits associated with the protection of native species from becoming threatened became relatively more important.

The non-market benefits in South Western Queensland over 20 years were estimated to range between $27 million and $344 million depending on the assumed rate of growth in wild dog attacks in the absence of control and the assumption regarding respondents' willingness to pay to protect non-market goods between years 10 and 20. The protection of native species made the greatest contribution to the total non-market benefits over a 20-year period regardless of the assumption made about the rate of growth in wild dog attacks in the absence of control.

The total non-market benefits in South Western Queensland were higher than those reported for the South Australian Arid Lands but lower than those reported for Eastern Victoria. It should be noted that there is considerable uncertainty regarding the number of non-market goods adversely affected by wild dogs and that, with improved information, the marginal non-market values reported in Table 17 could be used to derive revised estimates.

Integrated assessment

The total net benefits of the management of wild dogs in South Western Queensland were estimated by combining the market and non-market benefits and costs over a 20-year period (Table 20).

Table 20 Net benefits from management of wild dogs in South Western Queensland over 20 years

Variable (upper bound estimate)			**Growth in attack rates**	
Scenario	**2%**	**5%**	**10%**	**20%**
Present value of market benefits ($'000)	2 422	7 289	17 373	53 569
Present value of costs of control program ($'000)	18 275	18 275	18 275	18 275
Net present market value ($'000)	–15 853	–10 986	–902	35 294
Present non-market value ($'000)	40 092	87 809	214 016	344 458
Present value of total net benefits ($'000)	24 239	76 823	213 114	379 752
Variable (lower bound estimate)			**Growth in attack rates**	
Scenario	**2%**	**5%**	**10%**	**20%**
Present value of market benefits ($'000)	2 422	7 289	17 373	53 569
Present value of costs of control program ($'000)	18 275	18 275	18 275	18 275
Net present market value ($'000)	–15 853	–10 986	–902	35 294
Present non-market value ($'000)	26 580	58 215	141 887	228 368
Present value of total net benefits ($'000)	10 727	47 229	140 985	263 662

Note: Values in 2011–12 dollars.

When only the market impacts were taken into consideration, the benefits of wild dog control in South Western Queensland exceeded the estimated costs only when it was assumed that wild dog attack rates would increase by more than 10 per cent a year in the absence of control. When

the non-market benefits are taken into consideration, the total market and non-market benefits of wild dog control in South Western Queensland exceed the costs even when the wild dog attack rates are assumed to increase by only 2 per cent a year in the absence of control. The results indicate that, if attack rates grow at 2 per cent a year in the absence of control, then the total net benefits of control range between $10.7 million and $24.2 million depending on the assumed willingness of respondents to pay to protect non-market goods between years 10 and 20. If attack rates grow at 20 per cent a year in the absence of control, then the estimated net benefits of control are in the order of $264 million and $380 million.

8 Measuring traumatic stress due to wild dog attacks

In addition to the qualitative assessment of the social impacts of wild dogs, this project endeavoured to obtain some quantitative measure of the adverse impact of wild dogs on people and communities. The psychological impacts of wild dogs were assessed through a sample of 39 participants who had been directly affected by wild dogs. Although these 39 participants were located across the three case-study regions, there was insufficient sample to analyse the results by region. They are presented in this chapter in aggregate.

Critical events

van der Kolk (1991) and van der Kolk and colleagues (1991) defined critical incidents as events that are 'sudden, terrifying experiences that explode one's sense of predictability of life'. Traditionally these events have been recognised as including earthquakes, explosions, fires or motor vehicle accidents, with the common outcomes being destruction of buildings, loss of records, injuries and loss of life. Notably the non-physical impact of these kinds of events on humans became most evident during and following the first and second world wars—commonly termed 'shell shock'.

Critical events involving suicide, death, threats of injury and child sexual abuse are now recognised as having impacts not only on the individuals directly involved but also on other individuals and whole communities (Poland 1993). The psychological consequences for individuals are now recognised and studied in terms of depression, post traumatic stress disorder (PTSD) and anxiety, as maladaptive side effects following such events. As early as 1991 (Home Office 1991), it was estimated that after a critical event, 40 to 70 per cent experience distress in the first months; 24 to 40 per cent experience distress after the first year; 15 to 20 per cent experience chronic levels of anxiety that remain high for longer than two years.

There are multiple ways to examine how critical events affect individuals. They include diagnostic interviews, observation, and use of screening devices including questionnaires. Brief questionnaires are commonly used as they do not require lengthy training or experience and are relatively brief. 'The Impact of Event Scale (IES) (Horowitz et al. 1979) is probably the most widely used self-report measure in the field of traumatic stress' (as cited in Creamer et al. 2003, p.1489). Together the 22 item scale measures traumatic stress associated with a critical incident or event based on three items, intrusiveness, avoidance and hyperarousal (Creamer et al., 2004).

The IES has been used as a measure of traumatic stress in Australia (Creamer et al. 2003). A considerable amount of data, using the IES and the IES–R (a revised version) has been collected over the last 20 years about multiple types of critical events. Table 21 highlights scores from several studies of different types of events and experiences.

Table 21 Overview of studies employing the Impact of Event Scale (IES) and Impact of Event Scale–Revised (IES–R) with different population groups*

Reference	Sample (n)	IES Total mean (SD)	Intrusion mean (SD) #	Avoidance mean (SD) #	Hyperarousal mean (SD) #
Creamer et al. 2003	Vietnam veterans in treatment for PTSD	2.64 (0.69)	2.72 (0.72)	2.30 (0.80)	2.99 (0.85)
	Vietnam veterans from the general community	1.82 (1.05)	1.75 (1.11)	1.59 (1.03)	2.21 (1.22)
Beck et al. 2008	Motor vehicle accident victims with PTSD	1.59 (0.90)	1.57 (0.99)	1.44 (0.90)	1.81 (1.07)
Baumert et al. 2004	Victims of heart attacks (multiple)	No total score given	4.0 (6.1)	3.9 (6.7)	4.2 (5.2)
	Victims of single heart attack event	No total score given	1.9 (2.9)	2.0 (4.4)	2.4 (3.0)
Butler et al. 2005	People whose partners have terminal breast cancer	1.67 (0.81)	2.09 (1.14)	1.31 (0.81)	IES scale
Chen et al. 2005	Taiwanese nurses under threat of SARS	1.19 (0.83)			Total only shown
Present study	Victoria (n=14)	2.13 (0.75)	2.55 (0.77	1.75 (0.94)	1.54 (0.62)
	Queensland (n=20)	1.65 (0.59)	2.11 (0.66)	1.22 (0.81)	1.19 (0.56)
	South Australia (n=5)	2.03 (0.54)	2.58 (0.65)	1.23 (0.76)	1.78 (0.58)
	Total (n=39)	1.87 (0.67)	2.33 (0.72)	1.41 (0.87)	1.39 (0.61)

Notes: *Including mean (SD) scores on dimensions of the scale. #Intrusion can be defined by items from the IES-R scale such as 'Any reminder brought back feelings about it' and 'I had dreams about it'. Avoidance can be understood by items such as 'I stayed away from reminders about it' and 'I tried not to talk about it'. Hyperarousal includes items such as 'I felt irritable and angry' and 'I was jumpy and easily startled'.

Impact of Events Scale–Revised (IES–R) survey results

Findings from the wild dogs study are shown in the final row in Table 21. The row highlights mean and standard deviation scores from the total sample and the three case study areas from the IES–R survey. Reliability statistics were run on the IES–R total and subscales and were found to be reliable with Cronbach alphas of .88 for the total scale, .77 for intrusion, .83 for avoidance and .71 for hyperarousal.

With the smaller numbers of respondents in the case-study areas, it is not possible to make comparisons between the areas; however, it is possible to compare the responses of the total sample of respondents to those of other studies listed in Table 21 using this measure.

The Impact of Event Scale (IES) (Horowitz et al. 1979) and the Impact of Event Scale–Revised (IES-R) (Creamer et al. 2003) is a widely used self report measure in the field of traumatic stress. Multiple events and circumstances have been examined using this scale for the degree of traumatic impact upon individuals. Such events include motor vehicle accidents, war service in Vietnam Veterans and life threatening events such as a sudden cardiac arrest. The comparison shown in Table 21 indicates a relative measure of stress and is not intended to imply that these different experiences are similar to each other. Whilst it is acknowledged that IES study results using different stressors are not directly comparable with each other, they provide some insight into levels and type of stress experienced by participants in the current study.

In terms of the intrusion scale, the mean score for the wild dogs study was above that of four other studies and lower than for two other studies: veterans with PTSD (Creamer et al. 2003) and multiple heart attack victims (Baumert et al. 2004). This suggests that wild dog events have a substantial intrusive impact on individuals. However, this was not the case with the avoidance and hyperarousal subscales, with only one study (partner with terminal breast cancer [Butler 2005]) with lower scores for avoidance, and none with lower scores on the hyperarousal scale.

Discussion

The survey using the IES–R provided a simple method, usable in association with semi-structured, field-based interviews, to acquire quantitative data to assess levels of stress associated with wild dog attacks. In summary, the findings, in comparison with other studies that have used the IES–R survey, indicate that the affected landholders' scores (on average) are similar to those of other populations experiencing trauma. However, it is important to note that the largest contributor to this is the level of intrusion associated with wild dog attacks. The findings indicate that psychological intrusiveness is experienced by many case-study participants dealing with the wild dog issue. This is perhaps explained by the nature of dog attacks in that they cannot easily be avoided and are regularly intrusive. This characteristic of intrusiveness was also clearly highlighted in the interviews reported in the case-study chapters.

The scores on the avoidance and hyperarousal levels were generally lower when compared to the other studies examined. This does not mean that avoidance and hyperarousal were not experienced by the farmers—just at lower levels than others experiencing trauma related events.

While there were too few respondents from South Australia to allow a statistical comparison of the case study areas in the different states, there was little difference among the regions across total and subscale scores. It should be noted that the level of intrusion was consistently higher across the states than many of the other studies, perhaps suggesting that intrusion is a consistent feature of wild dog attacks generally. This suggests a possible direction for treatment and/or support for affected farmers.

Managing intrusive thoughts and memories (for example, item 9 ‘Pictures about it popped into my mind’ on the IES–R) can involve several key issues. First, while the intrusions might be expressed in the way indicated by the scale item, often they are linked to associated places, sensations (for example, smells) or other related events. The intrusions can be best managed if the person experiencing them is aware of any associated triggers. Most importantly is that the person experiencing the intrusions does not interpret the memories in a destructive manner, and seeks medical or psychological treatment and support if this does occur.

9 Conclusions and implications for wild dog management

Wild dogs are a significant pest animal problem in Australia. Improved wild dog management is a challenge because of the nature of the problem. It requires coordinated action by all landholders. No individual landholder can capture the full benefits of wild dog control if their neighbours are not taking similar action. This reduction in the returns to landholders in investing in wild dog control leads to under-investment. This problem is not unique to wild dog management and also presents a challenge to the improved management of weeds and other invasive species and pest animals (Elliston & Beare 2005).

The management of wild dogs and other invasive and pest problems is also complicated by different types of landholders with different objectives. Private landholders are generally seeking to run profitable farm businesses, while governments managing public land including national parks or state forests have other goals. Where private landholders share boundaries with public lands the management of wild dogs can be particularly challenging.

Differences in the legal status of dingoes and wild dogs in some jurisdictions, and complexity about the interaction between wild dogs and other feral and native species, further complicate the management of wild dogs. While there is a view that wild dogs have a negative impact through the reduction of native species populations, there is also some evidence that wild dogs can have a positive impact by reducing the density of feral animal populations.

It is beyond the scope of this analysis to estimate the level of investment in wild dog management in Australia that generates the greatest net returns; however, given the requirement for coordinated action, it is likely that current levels of investment by private landholders are below the level that generates the highest returns. This report's assessment of the economic benefits and costs to sheep and beef producers of wild dog management across three case study regions suggests that there are significant benefits associated with the current levels of investment and there may be further benefits associated with increased investment.

The results of the non-market assessment suggest there are significant non-market benefits associated with wild dog management. Both urban and rural residents expressed positive willingness to pay to reduce the number of households, number of threatened native species and areas of public land adversely affected by wild dogs in Australia. The semi-structured interviews with landholders also show that the impacts of wild dogs go beyond damage caused to livestock and resulting losses in farm income; they also cause psychological stress.

The measures of traumatic stress, although applied to only a small sample size, indicate that landholders who have experienced wild dog attacks on their properties report significant levels of stress, not dissimilar to people who have been involved in motor vehicle accidents with post traumatic stress disorder, or people whose partners have been diagnosed with terminal breast cancer.

There is likely to be a role for governments in supporting coordinated action among landholders to improve wild dog management. To the extent that private landholders can be confident that similar actions are being taken on neighbouring land, they are likely to increase their investments to more optimal levels.

There may also be a role for governments in providing support to landholders reporting stress and anxiety as a result of their experiences with wild dogs. Monitoring these experiences and identifying trends in their occurrence is likely to be an important first step.

There may also be a role for governments to invest directly in wild dog management to achieve the estimated benefits. The magnitude of that investment is not known and would require further research that goes beyond the benefit–cost analysis presented in this report.

Appendix A: Bioeconomic livestock model

The dynamic bioeconomic livestock model includes revenue functions, livestock growth equations and damage functions.

Revenue functions

Revenue functions require data on the quantity of livestock produced by type and age cohort and the price of output, which is determined using a linear inverse demand function. The maximum age cohort varies depending on the type of livestock and whether it is breeding or non-breeding stock (Table A1).

Table A1 Miscellaneous livestock model parameters across the case study areas

Model parameter	Cattle in SA case study	Cattle in Qld case study	Sheep in Qld case study	Cattle in Vic. case study	Sheep in Vic. case study
Maximum age of breeding livestock	7 **a**	7 **a**	6 **b**	7 **a**	6 **b**
Maximum age of non-breeding livestock	6 **a**	6 **a**	4 **b**	3 **a**	4 **b**
Elasticity of meat demand **c**	-2.6	-5.1	-4.8	-5.7	-6.5

Source: **a** Thompson & Martin 2011, **b** Barrett 2003, **c** Griffith et al. 2001.

Cattle breeding herds contain a maximum of seven age cohorts for a maximum age of seven years. This ensures that the first age cohort contains livestock that are at most 12 months old, the second containing livestock that are between one and two years old, and so forth. The maximum age of non-breeding animals is lower than that for breeding animals.

The slope and the intercept parameters of the linear beef and sheep meat demand functions were estimated in the initial time period and are assumed constant for the remaining time horizon. This estimation required data on the price of meat, the weight per head of livestock by age cohort, the number of livestock slaughtered and the elasticity of demand for beef and sheep meat at saleyards. The National Livestock Reporting Service, Meat and Livestock Australia, provided annual data for the price of beef and sheep meat and livestock carcass weights. Average values for these parameters are presented in Tables A2 to A6. The average number of cattle slaughtered was estimated as a product of the average herd size by age cohort and proportion of beef cattle or sheep sold in each case study area—derived from ABARES annual Australian Agricultural and Grazing Industry Survey. The elasticity of meat demand (Table A1) is used to calibrate the model in the baseline scenario to the average herd size. The average herd size by age cohort is estimated from data on the number of livestock in the case study area and the herd composition (Barrett 2003; Thompson & Martin 2011).

Table A2 Starting values for the cattle model by age cohort (t=1), South Australian Arid Lands

Age cohort/category	Average herd size a no. of head	Price of beef b $/kg, in 2009–10 dollars	Carcass weight b kg/head	Cattle slaughtered no. of head
A. Calves	44 876	na	na	19 424
B. Breeding herd:				
1 - replacement heifers	8 352	1.79	365	3 615
2 - yr old cows	6 496	1.46	520	2 812
3 - yr old cows	6 496	1.46	520	2 812
4 - yr old cows	6 187	1.46	520	2 678
5 - yr old cows	6 187	1.46	520	2 678
6 - yr old cows	6 187	1.46	520	2 678
7 - yr old cows	7 424	1.44	450	3 213
C. Non-breeding herd:				
1 - yr old other cattle	6 496	2.02	240	2 812
2 - yr old other cattle	6 496	1.92	365	2 812
3 - yr old other cattle	6 496	1.88	550	2 812
4 - yr old other cattle	309	1.83	550	134
5 - yr old other cattle	309	1.78	550	134
6 - yr old other cattle	309	1.74	550	134

Source: **a** Total herd numbers from 1999 to 2000 provided by C Turner, Department of Environment and Natural Resources' Pastoral Board, pers. comm., 16 May 2011, and herd compositions specified by Thompson and Martin (2011); **b** Provided by National Livestock Reporting Service, Meat and Livestock Australia, 1999–2000 to 2009–10.

Table A3 Starting values for the cattle model by age cohort (t=1), South Western Queensland

Age cohort/category	Average herd size a no. of head	Price of beef b $/kg, in 2009–10 dollars	Carcass weight b kg/head	Cattle slaughtered no. of head
A. Calves:	112 041	Na	na	38 990
B. Breeding herd:				
1 - replacement heifers	42 700	1.79	350	14 860
2 - yr old cows	28 467	1.40	520	9 907
3 - yr old cows	28 467	1.40	520	9 907
4 - yr old cows	33 211	1.40	520	11 557
5 - yr old cows	33 211	1.40	520	11 557
6 - yr old cows	33 211	1.40	520	11 557
7 - yrs+ old cows	47 444	1.31	450	16 511
C. Non-breeding herd:				
1 - yr old other cattle	29 097	1.86	350	10 126
2 - yr old other cattle	29 097	1.79	550	10 126
3 - yr old other cattle	29 097	1.74	550	10 126
4 - yr old other cattle	2 771	1.70	550	964
5 - yr old other cattle	2 771	1.66	550	964
6 - yrs+ old other cattle	2 771	1.66	550	964

Source: **a** Total herd numbers estimated using statistical local area data for the 1996–97 and 2005–06 Census years from ABS, cat.no.7121.0, Agricultural commodities Australia and herd compositions specified by Thompson and Martin (2011); **b** Provided by National Livestock Reporting Service, Meat and Livestock Australia, 1999–2000 to 2009–10.

Table A4 Starting values for the cattle model by age cohort (t=1), Eastern Victoria

Age cohort/category	Average herd size a no. of head	Price of beef b $/kg, in 2009–10 dollars	Carcass weight b kg/head	Cattle slaughtered no. of head
A. Calves:	75 847	na	na	42 701
B. Breeding herd:				
1 - replacement heifers	24 378	1.76	350	13 725
2 - yr old cows	15 057	1.41	520	8 477
3 - yr old cows	15 057	1.41	520	8 477
4 - yr old cows	17 686	1.41	520	9 957
5 - yr old cows	17 686	1.41	520	9 957
6 - yr old cows	17 686	1.41	520	9 957
7 - yr old cows	23 422	1.31	450	13 186
C. Non-breeding herd:				
1 - yr old other cattle	11 019	1.88	350	6 204
2 - yr old other cattle	11 019	1.82	550	6 204
3 - yr old other cattle	11 019	1.77	550	6 204
4 - yr old other cattle	0	na	550	0
5 - yr old other cattle	0	na	550	0
6 - yr old other cattle	0	na	550	0

Source: **a** Total herd numbers estimated using statistical local area from the 2005–06 Census year and statistical division data between 2004–05 and 2009–10 from ABS, cat.no.7121.0, Agricultural Commodities Australia and herd compositions specified by Thompson and Martin (2011); **b** Provided by National Livestock Reporting Service, Meat and Livestock Australia, 1999–2000 to 2009–10.

Table A5 Starting values for the sheep model by age cohort (t=1), South Western Queensland

Age cohort/category	Average herd size a no. of head	Price of lamb b $/kg, in 2009–10 dollars	Carcass weight b kg/head	Sheep slaughtered no. of head
A. Lambs:	160361	na	na	44 260
B. Breeding herd:				
1 - yr olds hoggets (ewes)	82 574	1.43	22	22 790
2 - yr old ewes	84 389	1.69	25	23 291
3 - yr old ewes	96 186	1.69	28	26 547
4 - yr old ewes	63 519	1.64	28	17 531
5 - yr old ewes	63 519	1.43	21	17 531
6 – yrs+ ewes	63 519	1.40	20	17 531
C. Non-breeding herd:				
1 - yr olds hoggets (wethers)	43 919	1.69	27	12 121
2 - yr old wethers	38 063	1.69	30	10 505
3 - yr old wethers	60 315	1.69	30	16 647
4 - yr old wethers	21 276	1.64	30	5 872
5 - yr old wethers	21 276	1.60	27	5 872
6 - -yrs+ old wethers	21 276	1.56	25	5 872

Source: **a** Total herd numbers estimated using statistical local area from the 2005–06 Census year and statistical division data between 2002–03 and 2009–10 from ABS, cat.no.7121.0, Agricultural commodities Australia and herd compositions specified by Thompson and Martin (2011); **b** Provided by National Livestock Reporting Service, Meat and Livestock Australia, 2001–02 to 2008–09.

Table A6 Starting values for the sheep model by age cohort (t=1), Eastern Victoria

Age cohort/category	Average herd size a no. of head	Price of lamb b $/kg, in 2009–10 dollars	Carcass weight b kg/head	Sheep slaughtered no. of head
A. Lambs:	57 395	na	na	28 008
B. Breeding herd:				
1 - yr old hoggets (ewes)	16 179	2.49	22	7 895
2 - yr old ewes	21 365	1.84	25	10 426
3 - yr old ewes	23 232	1.84	28	11 337
4 - yr old ewes	15 661	1.79	28	7 642
5 - yr old ewes	15 661	1.93	21	7 642
6 – yrs+ ewes	14 935	1.88	20	7 288
C. Non-breeding herd:				
1 - yr old hoggets (wethers)	16 179	2.01	27	7 650
2 - yr old wethers	19 019	1.96	30	9 281
3 - yr old wethers	18 504	1.96	30	9 029
4 - yr old wethers	4 455	1.91	30	2 174
5 - yr old wethers	4 455	1.86	27	2 174
6 - -yrs+ old wethers	4 455	1.81	25	2 174

Source: **a** Total herd numbers estimated using statistical local area from the 2005–06 Census year and statistical division data between 2004–05 and 2009–10 from ABS, cat.no.7121.0, Agricultural commodities Australia and herd compositions specified by Thompson and Martin (2011); **b** Provided by National Livestock Reporting Service, Meat and Livestock Australia, 1999–2000 to 2008–09.

Wool demand functions were developed for the South Western Queensland and Eastern Victoria case study regions. Slope and intercept parameters for these functions were calculated from data on the quantity of wool produced per heat by age cohort, the average herd size, wool prices by age cohort and the elasticity of wool demand. The quantity of wool produced by age cohort (Table A7) was estimated using data on regional fleece weights for the average animal in the herd by case study area and accounts for the impact of age on yields using adjustment factors from Windsor and Young (2012). Wool prices by age cohort (Table A8) are estimated using the regional price of wool from the ABARES Australian Agricultural and Grazing Industry Survey, and prices by micron from the Australian Wool Exchange and Windsor and Young (2012) adjustment factors that quantify variability in fibre diameter across age cohorts. The elasticity of wool demand is used to calibrate the livestock model in the baseline scenario by assuming a highly elastic demand.

Table A7 Quantity of wool by age cohort per year a

	South Western Queensland b		Eastern Victoria c	
Age cohort	**Non-breeding herd and ewes not joined**	**Ewes joined**	**Non-breeding herd and ewes not joined**	**Ewes joined**
	kg/head	**kg/head**	**kg/head**	**kg/head**
1–2	2.55	2.55	2.40	2.40
2–3	2.83	2.55	2.66	2.40
3–4	2.76	2.48	2.60	2.33
4–5	2.71	2.42	2.54	2.28
5–6	2.69	2.41	2.53	2.26
6+	2.69	2.41	2.53	2.26

Source: **a** The table uses data on the average quantity of wool produced for the case study area and a conversion rate of 63 per cent from greasy to clean wool estimated from ABARES data and adjustment factors from Windsor and Young (2012); **b** It is assumed that the average fleece weight in South Western Queensland is 2.77 kilograms for a 3–4 year old wether; **c** The average fleece weight in Eastern Victoria is 2.66 kilograms for a 2–3 year old wether.

Table A8 Wool price by age cohort a

	South Western Queensland b		Eastern Victoria c	
Age cohort	**Non-breeding herd and ewes not joined**	**Ewes joined**	**Non-breeding herd and ewes not joined**	**Ewes joined**
	$/kg per head	**$/kg per head**	**$/kg per head**	**$/kg per head**
1–2	9.85	9.85	9.85	9.85
2–3	9.21	9.85	9.21	10.33
3–4	8.53	9.85	9.21	9.85
4–5	8.53	9.85	9.21	9.85
5–6	8.53	9.51	8.53	9.85
6+	8.53	9.51	8.53	9.85

Source: **a** This table uses regional data on the price of wool and a conversion rate of 63 per cent from greasy to clean wool estimated from ABARES data, prices by micron width from the Australian Wool Exchange and adjustment factors from Windsor and Young (2012) that account for the impact of age on price; **b** Regional wool prices were estimated at $9.04 per kilogram clean weight in South Western Queensland for a 3–4 year old wether; **c** Regional wool prices were estimated at $10.20 per kilogram clean weight in Eastern Victoria for a 2–3 year old wether (ABARES annual Australian Agricultural and Grazing Industry Survey).

Cost functions

Livestock production costs include the costs of maintenance and transport to saleyards or abattoirs. Maintenance costs are the on-farm costs to operate a grazing enterprise and are based on the operating costs of livestock producers as reported in ABARES annual Australian Agricultural and Grazing Industry Survey. Estimates of maintenance costs by age cohort for cattle and sheep production are in Tables A9 and A10. Transportation costs are estimated using data on the cost per head to move livestock and the distance travelled. Estimates of the transportation costs per head for the movement of livestock to saleyards or abattoirs where they are most likely to be sold are in Table A11.

Table A9 Annual cattle maintenance costs a

Age cohort	South Australian Arid Lands		South Western Queensland		Eastern Victoria	
	Breeding herd	Non-breeding herd	Breeding herd	Non-breeding herd	Breeding herd	Non-breeding herd
	$/head	$/head	$/head	$/head	$/head	$/head
1	88	88	104	104	184	184
2	138	130	164	155	289	273
3	138	130	164	155	289	273
4	138	130	164	155	289	273
5	138	130	164	155	289	273
6	138	130	164	155	289	273
7	138	113	164	134	289	236

Source: **a** Data on farm operating costs were obtained from ABARES annual Australian Agricultural and Grazing Industry Survey, from 1990–91 to 2009–10.

Table A10 Annual sheep maintenance costs a

Age cohort	South Western Queensland		Eastern Victoria	
	Breeding herd	Non-breeding herd	Breeding herd	Non-breeding herd
	$/head	$/head	$/head	$/head
1	27	22	40	33
2	30	25	44	37
3	30	28	44	41
4	30	28	44	41
5	27	21	40	31
6	25	20	37	30

Source: **a** Data on farm operating costs were obtained from ABARES annual Australian Agricultural and Grazing Industry Survey, from 1990–91 to 2009–10.

Table A11 Annual costs to transport slaughtered livestock a

Case study areas	Cattle	Sheep
	$/head	$/head
South Australian Arid Lands **b**	79.56	na
South Western Queensland **c**	47.9	12.91
Eastern Victoria **d**	4.80	8.71

Source: **a** The cost of transporting cattle was estimated by ABARES at $0.09 per head per kilometre and $0.015 per head per kilometre for sheep in 2009–10; **b** In the South Australian Arid Lands, cattle from Marla–Oodnadatta (north-west) are most likely sold at the SA Livestock Exchange or the Alice Springs saleyards and cattle from Marree–Innamincka are sent to the Roma saleyards (C Turner [Department of Environment and Natural Resources' Pastoral Board] pers. comm. 16 May 2011); **c** In South Western Queensland, cattle are most likely sent to the Dalby or Longreach saleyards and sheep most likely to be sold at the Wallangarra Meatworks or abattoirs near Brisbane (P Martin [ABARES] and R Millner [NLRA, MLA] pers. comm. 24 February 2012); **d** In Eastern Victoria, it is assumed that cattle from East Gippsland are sold at Bairnsdale saleyards and cattle from north-east Victoria are sent to Wodonga saleyards. Sheep from East Gippsland are sold in Shepparton or Melbourne saleyards and livestock from north-east Victoria are sent to the Shepparton or Wagga Wagga saleyards (P Martin [ABARES] and R Millner [National Livestock Reporting Service, Meat and Livestock Australia], pers. comm. 24 February 2012); na = not applicable.

Livestock growth equations

Livestock growth equations are a function of stock numbers in the previous period and so require starting values for the initial time period, along with parameters to estimate the change in stock numbers between time periods. Data on the average herd size—for sheep and cattle—are used as starting values for the initial herd size (Tables A2 to A6). The change in livestock numbers over time is based on rates of mating, branding, mortality and slaughter (Tables A12 and A13).

Table A12 Livestock mating and branding rates

Livestock enterprise	Case study areas		
	South Australian Arid Lands	South Western Queensland	Eastern Victoria
	%	%	%
Cattle			
– mating rate **a**	100	100	100
– branding rate **a**	79.2	74	89
Sheep			
– mating rate **a**	na	85.37	100
– branding rate **b**	na	75	98.4

Source: **a** ABARES data; **b** Curtis (2009).

Table A13 Livestock mortality rates

Livestock enterprise	Case study areas		
	South Australian Arid Lands	South Western Queensland	Eastern Victoria
	%	%	%
Cattle			
– Mortality rates for adult livestock:			
Breeding herd **a**	3.67	4.05	3.66
Non-breeding herd **a**	0.87	2.83	1.32
– Calf losses from wild dog attacks in the baseline scenario	8.8 **b**	0.5 **c**	0.98 **c**
– Calf losses from other factors	12 **b and a**	25.5 **a**	10.02 **a**
Sheep			
– Mortality rates for adult livestock:			
Breeding herd **a**	na	9.7	1.4
Non-breeding herd **a**	na	6.51	4.16
– Lamb losses from wild dog attacks in the baseline scenario **c**	na	14.2	11.41
– Ewe losses from wild dog attacks in the baseline scenario **c**	na	0.66	6.45
– Lamb losses due to other factors **a**	na	10.8	5.19

Source: **a** ABARES data; **b** Allen (2010b); **c** ABARES 2011 PAPP survey; **d** Curtis (2009).

The number of calves or lambs branded is a function of the number of lamb losses from wild dog attack and lamb deaths from factors other than wild dogs, such as pre-natal losses, birth injury, starvation or premature birth (Hatcher et al. 2010). Losses from wild dog attacks and from other factors increase the rate of decline of branding rates. Mortality rates include annual mortality rates for adult livestock, annual mortality rates from factors other than wild dogs and annual ewe, lamb and calf losses resulting from wild dog attacks.

Algebraic representation of the cattle model

The cattle livestock model maximises returns from slaughter activities. The objective function ($\prod$), displayed in equation (1), estimates the returns to cattle production over a given time horizon ($t \in [0, T]$).

$$\prod = \sum_{t=1}^{T} (1+r)^{-t} \left\{ \sum_{s} p_a^s(t) q_a^s(t) - \sum_{s} \sum_{a} transc \quad sl_a^s(t) - \sum_{s} \sum_{a} mc_a^s x_a^s(t) \right\} + \sum_{s} \sum_{a} (1+r)^{-T} \lambda_a^s(T) x_a^s(T) \tag{1}$$

Where:

t is the time period

r is the annual discount rate

s is the cattle type (c) or meat type (m)—where m includes young steers and young female cattle raised for slaughter from the non-breeding herd and c includes female cattle in the breeding herd

a is the age cohort of livestock in the herd

p_a^s is the price of beef of type s and age cohort a

q_a^s is the quantity of beef produced of type s and age cohort a

$transc$ is the cost per head to transport cattle from the farm gate to saleyards

sl_a^s is the number of cattle slaughtered of type s and age cohort a

mc_a^s is the annual maintenance costs per head of livestock of type s and age cohort a

x_a^s is the number of cattle in the herd of type s and age cohort a

$\lambda_a^s(T)$ is the value per head of livestock in the final time period (T) of type s and age cohort a.

In equation (1), returns are estimated as the sum of total revenues from beef produced minus the total slaughter and maintenance costs, discounted in each time period. Therefore, the objective function estimates the dollar returns to land, family labour and capital from beef-production activities. The last term of the objective function estimates the salvage value of the breeding herd in the final time period (t=T). This ensures the value of livestock in the final time period is non-zero and equals the value of the herd in the long-run steady state.

Price (p_a^s) is determined using a linear inverse demand curve (equation 2). Incorporation of a linear demand function in the model results in an objective function that has decreasing marginal returns; a feature which ensures an optimal solution is reached. As Australian beef producers are price takers, when using a downward sloping demand function it is expected that the price elasticity of demand will be relatively high.

$$p_a^s(t) = B_a^s - C_a^s q_a^s(t) \tag{2}$$

This function allows for annual price adjustments, depending on the quantity of beef produced (q_a^s). It is a linear function with positive intercept (B_s) and negative slope (C_s) parameters that are constant across time, but vary for type *s* and age cohort *a*. These parameters are estimated using an elasticity of demand and historical values for the price of livestock.

The remaining equations in this model are livestock growth equations and constraints.

Livestock growth equations estimate the annual livestock numbers in the herd of type *s* and age cohort *a*. These equations take into account the number of calves born, the number of livestock slaughtered and the number of livestock lost due to natural mortality. It is these equations that are adjusted to account for calf losses as a result of wild dog attacks.

Livestock growth equations to estimate the number of head in each age cohort are provided in equations (3) to (6). Beginning in equations (3) and (4) with functions for calves; livestock that are at most 12 months old.

Equation (3) estimates the number of calves diverted for non-breeding purposes (x_1^{m}) in the next period ($t+1$). This value is estimated as the number of male calves branded per year and female calves diverted for non-breeding purposes (xs). The number of male calves produced per year is estimated by the first term on the right-hand side of equation (3) and depends on the number of cows in the breeding herd (x_a^c) and the proportion of calves branded each year (α_a). A 50–50 split between male and female calves is assumed. The branding rate (α) is estimated for all joined livestock and is a function of the calf losses from wild dog attacks and other factors; resulting in $\alpha = 1 - \delta -$ other losses.

$$x_1^m(t+1) = \sum_{a=1}^{A_c} \alpha\, x_a^c(t)/2 + xs(t+1) \tag{3}$$

The number of breeding females of age 1 (x_1^c) in the next time period is estimated as the number of female calves produced less calf deaths from wild dog attacks (δ) and other factors and female calves diverted for slaughter (xs) in the current time period (equation (4)).

$$x_1^c(t+1) = \sum_{a=1}^{A_c} \alpha\, x_a^c(t)/2 - xs(t+1) \tag{4}$$

The number of cattle in the breeding and non-breeding herds for the remaining age cohorts is calculated using equations (5) and (6). Equation (5) estimates the number of cattle in age cohorts 2 through $A_s - 1$ for each time period. Cattle numbers in the current period are estimated as the number of livestock in the last time period (x_a^s) less losses due to natural mortality (μ_a^s) and the number of livestock slaughtered (sl_a^s) in the last time period. Equation (6) estimates the number of livestock in the maximum age cohort for the next time period. Equations defining changes in livestock numbers are identical for both the breeding and non-breeding herds.

$$x_{a+1}^s(t+1) = (1-\mu^s)x_a^s(t) - sl_a^s(t) \text{ for a} = 1,2,3,\ldots.\text{As} - 2 \text{ and} \tag{5}$$

$$x_{A_s}^s(t+1) = (1-\mu^s)x_{A_s-1}^s(t) - sl_{A_s-1}^s(t) + \left(1-\mu_{A_s}^s\right)x_{A_s}^s(t) - sl_{A_s}^s(t) \quad \text{for a} = \text{As} \tag{6}$$

The set of constraints appearing in equations (7) through (9) ensure the quantity of meat produced does not exceed the amount produced by the herd. These constraints restrict the

number of female calves transferred to the non-breeding herd, the total number of livestock slaughtered, the total quantity of meat sold in any year and the size of the breeding herd in each time period. Equation (10) ensures the annual grazing pressure does not exceed the land's carrying capacity.

In equation (7) the number of female calves transferred to the breeding herd must be fewer than or equal to the number of female calves born—estimated by the right-hand side of this equation—in each time period.

$$xs(t+1) \leq \sum_{a=1}^{A_c} \alpha\, x_a^c(t)/2 \tag{7}$$

For all age cohorts, equation (8) ensures the number of livestock slaughtered (sl_a^s) in any time period does not exceed the number of cattle produced in any time period.

$$sl_a^s(t) \leq (1-\mu^s)x_a^s(t) \tag{8}$$

Equation (9) restricts the total quantity of meat produced to less than the total quantity of beef supplied from breeding activities. Where w_a^s is the live carcass weight per head slaughtered by type s and age cohort a.

$$q_s(t) \leq \sum_{a=1}^{A_s} sl_a^s(t) w_a^s \tag{9}$$

Finally, equation (10) constrains the annual herd grazing pressure to no more than the carrying capacity of the land. Where β_a^s is the annual dry sheep equivalent by cattle type and age cohort and the CC is the carrying capacity.

$$\sum_s \sum_a \beta_a^s x_a^s(t) \leq CC \tag{10}$$

Algebraic representation of the sheep model

There are many similarities between the sheep and cattle livestock models. This section details the modifications to estimate the revenues from sheep enterprises.

A sheep livestock model has to maximise the returns from the production of sheep meat and wool across a given time horizon $(t \in [0,T])$. The current objective function in the cattle livestock model—equation (1)—will estimate the returns to sheep meat production, but modifications are required to quantify the revenues from wool production. Such modifications to estimate the returns to sheep production are incorporated in equation (11).

$$\Pi = \sum_{t=1}^{T}(1+r)^{-t}\left\{\left[\sum_s\sum_a p_a^s(t)q_a^s(t) + \sum_s\sum_a \mathrm{pw}_a^s(t)q\mathrm{w}_a^s(t)\right] - \sum_s\sum_a transc \quad sl_a^s(t) - \sum_s\sum_a mc_a^s x_a^s(t)\right\} + \sum_s\sum_a (1+r)^{-T}\lambda_a^s(T)x_a^s(T) \tag{11}$$

The majority of variables and parameters in equation (11) are also used in equation (1). Where this is the case definition for equation (11) is identical to those presented in the last section—

with the exception that they refer to sheep production. For example, $q_a^s(t)$ in the sheep livestock model is the total quantity of sheep meat produced from type s and age cohort a. Variables that are unique to the sheep livestock model include $\text{pw}_\text{a}^\text{s}$ the price of wool and qw_a^s is the quantity of wool produced by the flock.

In the sheep livestock model, demand curves are required for the price of sheep meat and the price of wool. The functional form of the demand curve for sheep meat is identical to that used in the cattle livestock model—see equation (2). The price of wool is determined using equation (12) below.

$$p\text{w}_a^s(t) = B\text{w}_a^s - C\text{w}_a^s q\text{w}_a^s(t) \qquad (12)$$

This function allows for annual price adjustments, depending on the quantity of wool produced $(q\text{w}_a^s)$. It is a linear function with positive intercept $(B\text{w}_a^s)$ and negative slope $(C\text{w}_a^s)$ parameters that are constant across time, but vary by type s and age cohort a. These parameters are estimated using an elasticity of demand and historical values for the price of wool.

The remaining equations in the cattle model include livestock growth equations—equations (3) through (6)—and a set of constraints equations (7) through equation (10) which are incorporated in the sheep model with no adjustments. However, parameters and variables in these equations are estimated for sheep production, instead of cattle. For example, livestock growth equations estimate the number of sheep in the following year, by age cohort in the breeding and non-breeding herd.

Estimating benefits from wild dog control programs

The effect of wild dog attacks on returns to livestock enterprises are estimated by incorporating a damage function in the livestock models. Damage functions estimate the proportion of livestock killed in each time period for each scenario. Functions are developed separately for the baseline scenario—with wild dog controls—and the no control scenario. Once incorporated in the livestock model, the models are optimised separately and the benefits are calculated as the difference in revenues between scenarios.

Assumptions on the impact of wild dogs on calves, ewes and lambs in the baseline scenario are presented in Table A13. In the baseline scenario, it is assumed the annual implementation of wild dog control programs will limit losses to these levels. For example, the annual baiting program in the South Australian Arid Lands, will limit calf deaths to 8.8 per cent (Allen 2010a). In sheep enterprises both ewes and lambs are affected. For example, in South Western Queensland the magnitude of these effects is 0.66 per cent and 14.2 per cent respectively (Table A13).

The no control scenario represents the case where no wild dog control measures are implemented. Separate logistic growth functions are used to estimate the proportion of calf, ewe and lamb deaths per year (Kompas & Che 2009). This function has the following form:

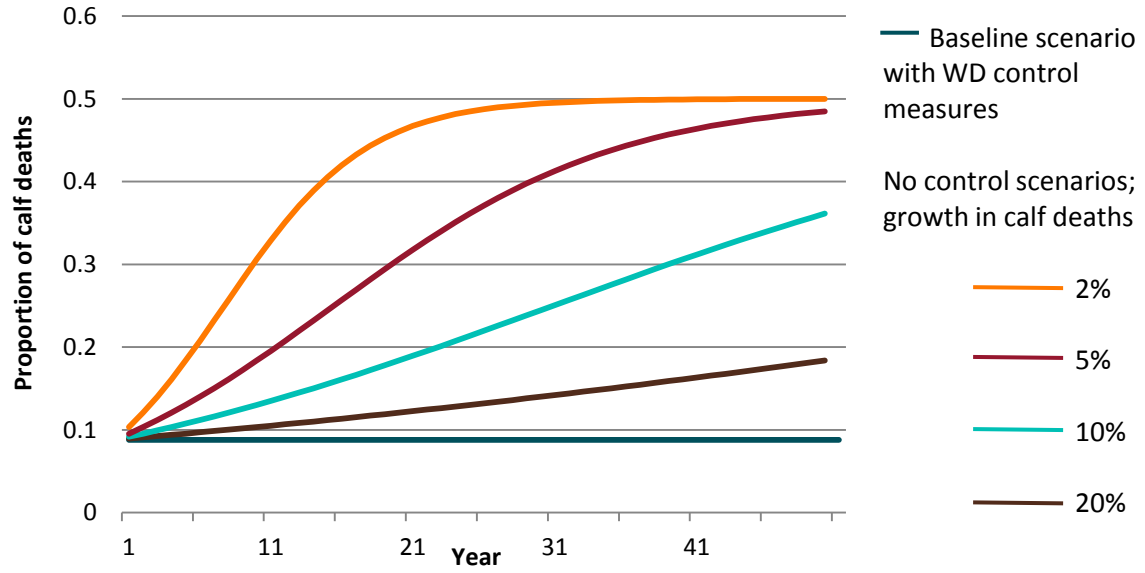
$$\delta_\text{a}(\text{t}) = \frac{\delta_\text{a}^\text{max}}{1+(\delta_\text{a}^\text{max}/\delta_0-1)\text{e}^{-\text{gt}}} \qquad (13)$$

where δ_a^{max} is the maximum losses, δ_0 is the initial losses and g is the intrinsic growth rate for losses. It is assumed that calf deaths will not exceed 50 per cent of calves born and lamb and ewe deaths can reach 100 per cent of the herd.

It should be noted that intrinsic growth rates are unknown and will change through time depending on production and environmental conditions. For example, in drought conditions the intrinsic growth rate is likely to be high as there is limited alternative prey for wild dogs, while in periods of favourable seasonal conditions the intrinsic growth rate is likely to be low. This uncertainty is captured by using a range of values for the no control scenario. The rate of growth in livestock deaths from wild dog attacks is assumed to take the values 2, 5, 10 and 20 per cent.

A graphical representation of these damage curves for the South Australian Arid Lands is presented in Figure A1. It shows that, if the wild dog population is left uncontrolled, the proportion of calves killed will continue to rise each time period. Damage functions that have higher growth rates reach the maximum damage level before those with lower rates.

Figure A1 Proportion of calf deaths from wild dog attacks, by scenario, South Australian Arid Lands



Estimating costs of wild dog control programs

The cost of wild dog control programs were estimated for control programs in each of the case study regions. Data for these estimations were collected from professionals in each region. The data collected are presented below and highlight the range of control measures implemented in each region.

South Australian Arid Lands

Ground baiting is the primary control measure used in this case study region to reduce the effects of wild dogs. Estimates of the average annual costs of the baiting program are presented in Table A14.

Table A14 Data to estimate annual baiting costs in the South Australian Arid Lands

Activity	Values	Data source
Total number of baits a	14 000 baits per year	P Bird at Biosecurity SA
Manufactured baits **b**		
– Material costs (DOGONE baits)	$1.62 per bait (in 2011 dollars)	Animal Control Technologies Australia, 22 August prices
– Freight costs	$25 per farm per year (in 2011 dollars)	Animal Control Technologies Australia, 22 August prices
Fresh baits **b**		
– Cost of meat	$0	P Bird [Biosecurity SA], pers. comm. 20 September 2011
– Cost of 1080 poison	0.33 cent per bait	P Bird [Biosecurity SA] pers. comm. 12 October 2011
– Number of labour days to prepare bait meat	12 hours per 1000 baits	P Bird [Biosecurity SA] pers. comm. 20 September 2011
– Distance travelled to procure fresh bait meat	50 kilometres per 1000 baits	P Bird [Biosecurity SA] pers. comm. 20 September 2011
Distribution costs:		
– Distance travelled	16 000 kilometres	P Bird at Biosecurity SA
– Number of labour hours	900 hours	P Bird at Biosecurity SA
– Wage rate for agriculture labour	$21.15 per hour	Fair Work Australia
– Wage rate for farm manager	$34.10 per hour	Fair Work Australia
– Vehicle costs per kilometre **c**	$0.93 per kilometre	Royal Automobile Club of Queensland

Note: **a** Application rates are provided for between 1989 and 1990 and these values are averaged to estimate an annual application rate; **b** Two types of baits are applied in the case study area: fresh baits poisoned with 1080 and manufactured baits. To estimate an average cost for the baiting program in the case study area, a 50–50 split between use of manufactured and fresh baits each year is assumed; **c** Includes cost of fuel, depreciation, wear and tear on vehicles for a four-wheel-drive Mitsubishi Triton, Nissan Navara, Toyota Hilux or Toyota Landcruiser ute.

The average annual baiting cost is estimated using data on the total quantity of baits applied in the case study area and the total cost per bait. The cost per bait comprises the cost of materials and the cost to distribute baits. The material cost for manufactured baits includes the cost of baits and the freight cost of delivering them. The material cost of fresh baits consists of the cost of poison and the cost of labour and transport to procure and prepare the bait. The cost of distributing baits consists of the cost of labour and vehicles used to distribute baits each year to the baiting areas. Data collected to estimate average annual distribution costs include: wage rates, vehicle costs—including fuel costs, depreciation and wear and tear for a four-wheel drive—and the distance travelled and labour hours to distribute baits each year. The average annual costs of the control program are estimated at approximately $38 000 a year (Table A14).

Eastern Victoria

Data on the cost of wild dog control programs for this case study area were unable to be obtained for this study.

South Western Queensland

Wild dog control programs in the South Western Queensland case study region use a range of control measures that, where possible, are implemented in a coordinated effort across the shire or region. Aerial and ground baiting activities are implemented by all three regions, with trapping undertaken in Murweh Shire and Paroo Shire and shooting in the Blackall–Tambo Region. Opportunistic shooting of wild dogs is undertaken throughout the regions by livestock managers. These costs are assumed to be negligible. Other costs of operating a wild dog control program that have been incorporated in this estimate include the cost of running wild dog committees, the cost of access to a wild dog facilitator, and the cost of maintaining the national wild dog fence.

Data to estimate the annual costs of these activities were collected using a survey developed by ABARES and provided to regional program managers. A breakdown of these costs is provided in Table A15. It is estimated that the current wild dog control program in South Western Queensland costs $1.5 million a year (in 2009–10 dollars).

Table A15 Average annual costs of wild dog control programs in South Western Queensland (2009–10 dollars)

Cost categories	Blackall–Tambo	Paroo	Murweh	Total costs
	$ per year	$ per year	$ per year	$ per year
A. Aerial baits				
– meat costs	24 525	32 009	17 000	73 535
– poison (1080) costs	136	178	94	409
– labour costs to prepare bait	17 343	2 030	1 692	21 065
– aircraft costs	4 761	12 172	16 693	33 626
Total cost of aerial baits	46 765	46 389	35 480	128 635
B. Ground baits				
– meat costs	9 750	1 725	28 001	39 476
– poison (1080) costs	54	10	156	219
– labour costs to prepare bait	20 727	169	1 692	22 588
– vehicle costs	1 515	268	4 352	6 135
Total cost of ground baits	32 046	2 172	34 200	68 418
C. Total trapping costs	0	10 847	549 127	559 975
D. Total shooting costs	129 090	207	na	129 296
E. Program costs				
– wild dog committee costs	219 834	1 104	na	220 938
– cost of wild dog facilitator	2 837	1 032	2 340	6 209
– national wild dog fence costs	408 495	na	na	408 495
Total program costs	631 166	2 136	2 340	635 642
Total cost control program	839 068	61 751	621 147	1 521 966

Source: **a** Approximately 526 kilometres of the national wild dog barrier fence passes through the South Western Queensland case study area at an estimated maintenance cost of $823 per kilometre, P Gray, Department of Fisheries and Forestry, pers. comm., 21 May 2012.

Cost of kangaroo competition in the South Australian Arid Lands

The annual cost of kangaroo competition—the value of grazing vegetation consumed by kangaroos—is estimated as revenue that may have been generated from cattle production in the absence of competition from kangaroos.

The potential revenue losses that beef producers may incur from varying levels of kangaroo competition are estimated by converting the current kangaroo densities in to cow equivalents and then estimating the potential revenue loss at varying levels of competition.

First, the estimation of cow-equivalent populations makes use of data on annual kangaroo densities, which were collected from 1995 to 2008 for Marla–Oodnadatta (DEH 2009). These

densities were converted to annual cow equivalents by assuming that there are 0.35 of dry sheep equivalents per kangaroo and 22 dry sheep equivalents for a 400 kilogram cow with a 7 to 10 month calf (McLaren 1997). In this way, current kangaroo densities are converted to calf-producing cow equivalents. Based on these conversion factors, average annual kangaroo densities in the case study area are estimated to have consumed vegetation equivalent to an average of 11 000 calf-producing cows per year, between 1995 and 2008.

Second, the average annual cow equivalent is multiplied by the net value of a calf-producing cow and the per cent competition for grazing vegetation to estimate the cost of kangaroo competition. Using Australian Agricultural and Grazing Industry Survey data it is estimated that the net value of a calf-producing cow varies between about $50 and $500 per head. It is assumed that the competition for grazing vegetation lies between 0 and 100 per cent depending on environmental conditions. A value of 10 indicates that kangaroos and cattle are competing for resources 10 per cent of the time and a value of 80 indicates they are competing 80 per cent of the time.

Appendix B: Participatory approach in case study regions

A participatory approach to identifying and assessing the social impacts of wild dogs was employed using face-to-face (and some telephone) in-depth semi-structured interviews and informal focus groups with key stakeholders and landholders in the three case study areas.

Selection of stakeholders and landholders to be involved in this study was made with the assistance of key stakeholders involved in the wild dog issue:

Greg Misfud (National)	Peter Lucas (Qld)
Duncan Jukes (Qld)	Andrew Martin (Qld)
Marilyn Clydesdale (Vic.)	Alan Brown (Vic.)
Vaughn Kingston (Vic.)	Heather Miller (SA)
Benjamin Allen (SA)	

The number of people interviewed/involved in focus groups in the three case study areas were:

Case study area	**Number of people**
South Western Queensland	22 people interviewed (included two informal focus groups)
Eastern Victoria	15 people interviewed
South Australian Arid Lands	10 people interviewed

Information sheets on the project were provided to participants. The interviews lasted approximately 40–90 minutes and the informal focus groups lasted between two and three hours. The interviews and focus groups were digitally recorded, transcribed by Smartdocs Ltd and thematically coded using NVivo8.

Appendix C: Impacts of Events Scale–Revised survey

The Impacts of Events Scale–Revised survey was used to provide a quantitative assessment of the level of stress of people known to have been directly affected by wild dogs. The survey contains a 22-item scale to measure traumatic stress associated with a critical incident or event, with participants asked to rate how much they were distressed or bothered by these items (listed below).

Item	Not at all	A little bit	Moder-ately	Quite a bit	Extrem-ely
1. Any reminder brought back feelings about it	0	1	2	3	4
2. I had trouble staying asleep	0	1	2	3	4
3. Other things kept making me think about it	0	1	2	3	4
4. I felt irritable and angry	0	1	2	3	4
5. I avoided letting myself get upset when I thought about it or was reminded of it	0	1	2	3	4
6. I thought about it when I didn't mean to	0	1	2	3	4
7. I felt as if it hadn't happened or wasn't real	0	1	2	3	4
8. I stayed away from reminders about it	0	1	2	3	4
9. Pictures about it popped into my mind	0	1	2	3	4
10. I was jumpy and easily startled	0	1	2	3	4
11. I tried not to think about it	0	1	2	3	4
12. I was aware that I still had a lot of feelings about it, but I didn't deal with them	0	1	2	3	4
13. My feelings about it were kind of numb	0	1	2	3	4
14. I found myself acting or feeling as though I was back at that time	0	1	2	3	4
15. I had trouble falling asleep	0	1	2	3	4
16. I had waves of strong feelings about it	0	1	2	3	4
17. I tried to remove it from my memory	0	1	2	3	4
18. I had trouble concentrating	0	1	2	3	4
19. Reminders of it caused me to have physical reactions, such as sweating, trouble breathing, nausea, or a pounding heart	0	1	2	3	4
20. I had dreams about it	0	1	2	3	4
21. I felt watchful or on-guard	0	1	2	3	4
22. I tried not to talk about it	0	1	2	3	4

Thirty-nine people undertook the survey (20 from South Western Queensland, 14 from Eastern Victoria and five from the South Australian Arid Lands). The participants were asked to undertake the survey as part of the interview and focus group process. The idea behind embedding the survey within the semi-structured interview and focus group process was to minimise disruption for the participants in undertaking the survey and to assess their psychological experiences of the wild dog issue while they were already engaged in talking about it.

Statistical analysis of this data was undertaken by Associate Professor Darryl Maybery of Monash University.

Appendix D: Choice modelling to estimate non-market impacts

Choice modelling, an advanced survey-based, non-market valuation technique, was used to value the social and environmental benefits of management of wild dogs in the three case study areas. Choice modelling is a cost-effective method to value use as well as non-use values for multiple environmental and social outcomes.

A robust and careful design process was employed to develop the questionnaire and survey. This involved a number of expert consultations (scientists, policy makers, regional and national wild dog facilitators, local specialists, and local communities) and an extensive literature review that provided information about the environmental and social impacts of wild dogs, the current strategies used for the management of wild dogs in the three case study areas, and potential outcomes of these controls. Six focus groups (two in each of the three states) were carried out in January 2012. A diversity of people in terms of age, gender, educational level and profession were involved to ensure an appropriate representation of the population. These specialists and focus groups were used to select the attributes for the development of the choice modelling questionnaire.

The final choice modelling questionnaire included a description of the case study area, the management of wild dog options, photos, maps, information about the issue, choice questions with presented scenarios (with and without control) and a number of questions about awareness of wild dog issues, socio-demographic questions and follow-up questions. In the final part of the questionnaire respondents were asked to choose their preferred option for wild dog management. An example of a choice set is presented in Figure D1. In order to construct the choice options including multiple attributes and multiple levels of these attributes an optimal orthogonal design was employed (Kanninen 2002).

Figure D1 Example of a choice set

OPTIONS	My household payment each year to 2022	Number of households negatively affected by wild dogs by 2022	Number of native species threatened by 2022	Public area negatively affected by wild dogs by 2022	Tick ONE
Option A (No control)	$0	2000 households negatively affected	13 species threatened	120 000 km2 negatively affected	☐
Option B (With control)	$50	1000 households negatively affected	7 species threatened	60 000 km2 negatively affected	☐
Option C (With control)	$20	200 households negatively affected	3 species threatened	90 000 km2 negatively affected	☐

The choice model used for the analysis was the conditional logit model. The conditional logit model provides the probability of an individual i choosing alternative j out of q in choice situation t. The conditional logit function is expressed as:

$$L_{\mathrm{ijt}}\left(\beta_{\mathrm{i}}\right)=\frac{\exp\left(\mu\beta_{i}\mathrm{x}_{\mathrm{ij}t}\right)}{\sum_{q=1}^{J}\exp\left(\mu\beta_{i}\mathrm{x}_{\mathrm{iqt}}\right)}$$

where μ is a scale parameter (usually normalised to one); x_{ijt} is a vector of observed variables; and βi is an unobserved coefficient vector for each individual i.

Two split samples for each state were selected to distinguish between the rural and urban population. However, the Poe and colleagues (1994) test indicated that there were no significant differences between the urban and rural sub-samples so the data were combined and separate estimates were calculated for Queensland, Victoria and South Australia.

The willingness to pay obtained from the three states represents an average annual household willingness to pay for protection of one native species from becoming threatened, one household and 1000 square kilometres of public area from the negative impacts of wild dogs in each of the case study areas. The willingness to pay values obtained from this study were aggregated to obtain Victorian, South Australian and Queensland communities' willingness to pay for the environmental and social goods affected by wild dogs. The total non-market value was estimated using households' annual willingness to pay for 10 years to protect households, native species from becoming threatened and public areas from the negative impacts of wild dogs in each of the

case study areas. The annual non-market values were discounted using a 7 per cent discount rate.

A logarithmic livestock damage function was applied to predict the potential long-term impacts of wild dogs on the environment and society.

The first step involved identification of a likely maximum number of households, number of native species and area of public land that can potentially be affected by wild dogs over 10- and 20-year time horizons. This information was obtained using expert opinion. The second step involved identification of the impacts under the current management scenario (baseline scenario used for the assessment of the market impacts). Under the current management scenario the impact of wild dogs on livestock was identified. Assuming a similar impact of wild dogs under the current management scenario on non-market goods, an average 6 per cent impact was chosen.

The difference between the maximum amount of non-market goods (native species protected from becoming threatened, households and public area protected from the negative impacts of wild dogs) that can be potentially affected over 10- and 20-year time horizons and the value of non-market goods affected under continuation of the current management scenario was identified for each case study region. This value was adjusted using a livestock logarithmic function to reflect the impact of wild dogs on non-market goods over 10- and 20-year time horizons under the four different scenarios (2, 5, 10 and 20 per cent growth in wild dog attacks in the absence of control). Table D1 presents the estimated potential environmental and social outcomes for different scenarios.

Table D1 Non-market benefits from the management of wild dogs after 10 and 20 years for four different scenarios about the growth in wild dog attacks in the absence of control

Case studies	Scenarios	2%	5%	10%	20%
10 years					
South Western Queensland	Number of households protected	52	182	442	1222
	Number of native species protected	0	1	2	6
	Public area protected (1000 km²)	2	9	21	58
Eastern Victoria	Number of households protected	25	86	209	579
	Number of native species protected	0	1	3	8
	Public area protected (1000 km²)	0	1	2	6
South Australian Arid Lands	Number of households protected	1	5	12	32
	Number of native species protected	0	1	2	7
	Public area protected (1000 km²)	1	3	7	19
20 years					
South Western Queensland	Number of households protected	182	442	1049	1699
	Number of native species protected	1	2	5	8
	Public area protected (1000 km²)	9	21	50	80
Eastern Victoria	Number of households protected	86	209	497	805
	Number of native species protected	1	3	7	11
	Public area protected (1000 km²)	1	2	6	9
South Australian Arid Lands	Number of households protected	5	12	28	45
	Number of native species protected	1	2	6	9
	Public area protected (1000 km²)	3	7	17	27

Note: The above predictions of different outcomes are only indicative for the purpose of this study.

The number of non-market goods (number of native species protected from becoming threatened, number of households and public area protected from wild dog impacts) presented in Table D1 were multiplied by households' willingness to pay over the 10- and 20-year period, discounted (7 per cent discount rate) and aggregated for the relevant population.

In the choice modelling survey, respondents were asked for their willingness to pay over 10 years. For the purpose of this study, the non-market values have been extrapolated to 20 years assuming that respondents would be willing to pay the same annual amount for an additional 10 years to continue obtaining the environmental and social benefits from the management of wild dogs. In reality, the annual payment over a longer period of time could be lower due to diminishing marginal utility.

The attitude and socio-demographic questions included:

- wild dogs are a problem in my state
- wild dogs pose a risk of attacks to on humans in my state
- wild dogs limit the spread of feral animal populations (for example, rabbits, foxes)
- dingoes are an important positive influence on tourism in my state
- dingoes maintain balance among wildlife species in my state

- wild dogs maintain balance among wildlife species in my state
- wild dogs pose a significant risk of attacks to farm livestock in my state
- wild dogs can significantly contribute to some native species becoming endangered in my state
- wild dogs pose a risk of attacks to pets in my state.

Appendix E: Sensitivity of economic analysis to choice of discount rate

The market impacts of wild dog control in the main report are present values over 20 years calculated using a 7 per cent discount rate. The sensitivity of the results to different discount rates is presented in this appendix.

Eastern Victoria

Table E1 Cost–benefit analysis measures for Eastern Victoria by growth in livestock deaths – for a 5 per cent discount rate

Variable (estimated across 20 years)	Increase in livestock deaths			
	2%	5%	10%	20%
Present value of benefits – cattle ($'000)	1 070	3 240	9 120	27 800
Present value of benefits – sheep ($'000)	1 250	3 490	6 630	12 600
Total present value of benefits ($'000)	2 310	6 730	15 700	40 400
Present value of costs of control program ($)	na	na	na	na

Note: All values estimated in 2009–10 dollars; na = not available.

Table E2 Cost–benefit analysis measures for Eastern Victoria by growth in livestock deaths, for a 10 per cent discount rate

Variable (estimated across 20 years)	Increase in livestock deaths			
	2%	5%	10%	20%
Present value of benefits – cattle ($)	630	1 880	5 140	15 500
Present value of benefits – sheep ($)	730	2 020	3 770	9 930
Total present value of benefits ($)	1 360	3 900	8 910	22 400
Present value of costs of control program ($)	na	na	na	na

Note: All values estimated in 2009–10 dollars; na = not available.

South Australian Arid Lands

Table E3 Cost–benefit analysis measures for the South Australian Arid Lands by growth in livestock deaths – for a 5 per cent discount rate

Variable (estimated across 20 years)	Increase in calf deaths			
	2%	5%	10%	20%
Present value of benefits – cattle ($'000)	2 235	6 728	17 572	42 542
Present value of costs of control program ($'000)	499	499	499	499
Benefit–cost ratio	4.48	13.49	35.22	85.28
Net present value ($'000)	1 736	6 229	17 074	42 043
Threshold probability (%)	22.32	7.41	2.84	1.17

Note: All values estimated in 2009–10 dollars.

Table E4 Cost–benefit analysis measures for the South Australian Arid Lands by growth in livestock deaths – for a 10 per cent discount rate

Variable (estimated across 20 years)	Increase in calf deaths			
	2%	5%	10%	20%
Present value of benefits – cattle ($'000)	1 404	4 146	10 561	25 808
Present value of costs of control program ($'000)	357	357	357	357
Benefit–cost ratio	3.93	11.61	29.58	72.28
Net present value ($'000)	1 047	4 3 789	10 204	25 451
Threshold probability	25.43	8.61	3.38	1.38

Note: All values estimated in 2009–10 dollars.

South Western Queensland

Table E5 Cost–benefit analysis measures for South Western Queensland by growth in livestock deaths – for a 5 per cent discount rate

Variable (estimated across 20 years)	Increase in livestock deaths			
	2%	5%	10%	20%
Present value of benefits – cattle ($'000)	869	2 719	8 301	35 962
Present value of benefits – sheep ($'000)	2 112	6 323	13 346	32 665
Total present value of benefits ($'000)	2 982	9 041	21 647	68 627
Present value of costs of control program ($'000)	19 915	19 915	19 915	19 915
Benefit–cost ratio	0.15	0.45	1.08	3.44
Net present value ($'000)	–16 934	–10 874	1 731	48 712
Threshold probability (%)	668	220	92	29

Note: All values estimated in 2009–10 dollars.

Table E6 Cost–benefit analysis measures for South Western Queensland by growth in livestock deaths – for a 10 per cent discount rate

Variable (estimated across 20 years)	Increase in livestock deaths			
	2%	5%	10%	20%
Present value of benefits – cattle ($'000)	534	2 637	4 810	20 037
Present value of benefits – sheep ($'000)	1 287	3 780	8 012	17 827
Total present value of benefits ($'000)	1 822	5 417	12 822	37 864
Present value of costs of control program ($'000)	14 253	14 253	14 253	14 253
Benefit–cost ratio	0.13	0.38	0.90	2.65
Net present value ($'000)	–12 431	–8 836	–1 431	23 611
Threshold probability	782	263	111	38

Note: All values estimated in 2009–10 dollars.

Appendix F: Review of previous studies on the social impacts of wild dogs

While the social impacts of wild dogs on agriculture in Australia have long been acknowledged (Sykes 1982), prior to the recent surge of interest in this topic there had been little systematic research into the social impacts of wild dogs and of invasive animals in general (Fitzgerald & Wilkinson 2007; Fitzgerald & Wilkinson 2009). More recently, social science and social impact studies concerning wild dogs have been undertaken (Fenton 2009; Fitzgerald & Wilkinson 2009; Lightfoot 2010; Russell 2006). These studies have generally had a regional or state focus and utilise different conceptual frameworks. Table F1 summarises the focus of these studies.

Table F1 Summary of key social science literature on impacts of wild dogs in Australia

Reference	Region	Topic
Russell (2006)	Tablelands of central NSW – case study of one property	Qualitative psychological/phenomenological study of wild dog impacts
Fitzgerald & Wilkinson (2009)	Upper Hunter Valley, NSW	Social impact assessment of invasive animals including wild dogs
Fenton (2009)	Western Queensland	Beliefs and attitudes influencing decision making of landholders to wild dog control
Lightfoot (2010)	Victoria	Social benefit–cost analysis of wild dogs included qualitative psychological assessment
Keen (Deakin University Honours project, 2011)	Victoria	Attitudes towards dingo vs wild dog management

Lightfoot's (2010) social benefit–cost analysis in Victoria found that the social impacts of wild dogs are complex and difficult to quantify. His assessment of the main categories of impacts included:

- personal health and safety issues
- flow-on effects of community-wide economic impacts
- animal welfare issues.

Fitzgerald and Wilkinson (2009) undertook an assessment of the social impact of invasive animals in Australia focusing on the Upper Hunter Valley in New South Wales. Wild dogs were one of the pests causing concern to landholders and natural resource managers in this region. They defined the social consequences to the main issues that they observed in relation to wild dogs in that region (Table F2).

Table F2 Key issues and social consequences of wild dogs

Main issues	Main social consequences
Prey on sheep and other farm animals	Reduced farm income
Induce fear and uncertainty among stock managers	Financial stress
Undermine sustainability of sheep farming	Additional farm work and expenditure
Responsibility for and cost of control are a source of social conflict	Psychological distress
	Loss of community cohesion
	Land use change

Note: Modified from Fitzgerald and Wilkinson (2009).

Three of the wild dog studies contained a significant element of studying or commenting on the psychological impacts on landholders of wild dog attacks on their livestock (Fitzgerald & Wilkinson 2009; Lightfoot 2010; Russell 2006).

The findings of Fitzgerald and Wilkinson (2009) included:

- significant emotional upset and frustration associated with wild dog or dingo attacks on farm stock
- a sense of psychological insecurity and uncertainty that farmers live with on a daily basis when wild dogs are present
- the experience of anxiety and uncertainty over the farmers' rights in relation to wild dog management.

Lightfoot (2010) reported that, despite the fact that psychological impacts vary considerably between among individuals, it was clear that for many, these impacts are significant. A key cause of distress was coping with livestock that have been killed or savaged. The Victorian farmers' stories had common themes of frustration, loss, grief, a sense of powerless, lack of control and helplessness which were indicators of the psychological pressure these farmers attribute to wild dog attacks. There was also increasing pressure to fence vast areas, spend more time staying out at night to protect stock, more time talking about the issue, and more time recording statistics and telephoning wild dog controllers to report attacks.

A key finding from Russell's (2006) study in New South Wales was that farmers described the dog attacks in such 'horrific terms and as highly sensual and perceptual events' that very few people would listen to them, including government and industry bureaucrats or other landholders. Related to this issue was that the emotional costs could not be quantified whereas financial ones could be (ibid.).

There are three issues that persist, to varying degrees, through these studies related to the:

- challenges of documenting and reporting on the ongoing, visceral and horrific stories of the impacts of wild dog attacks on stock so that those affected feel that they are being heard and represented in the reporting process
- challenge of finding a way to quantify the psychological distress (emotional cost) experienced by landholders coping with this issue
- challenge of communicating psychological and emotional impacts to others who are in key decision making positions and may be able to assist in some way.

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