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Returns on investment in wild dog management—beef production in the South Australian Arid Lands

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Abstract

Beef cattle producers in Australia have reported an increase in calf losses as a result of wild dog attacks in recent years. However, while control measures may reduce calf losses from wild dog attacks, they may also reduce attacks on kangaroos. Thus, wild dog control measures may inadvertently increase kangaroo competition with cattle for grazing vegetation, which is potentially costly for graziers. In this study the net returns to beef production from investments in wild dog controls in a case study area—omitting the social and environmental effect of wild dogs—is assessed. The case study area for this study includes the natural resource management district groups of Marla–Oodnadatta and Marree–Innamincka, in the South Australian Arid Lands. A bioeconomic livestock model is developed to estimate the benefits of South Australian wild dog control programs to reduce calf losses. A decision to control wild dogs will depend on the magnitude of the benefits of wild dog management relative to the costs of increased kangaroo competition for grazing vegetation. Results indicate that the decision to implement wild dog control—based solely on the net benefits from beef production—will vary with changes in the rate of increase in calf deaths, the extent of kangaroo competition for grazing vegetation and the net value of livestock.

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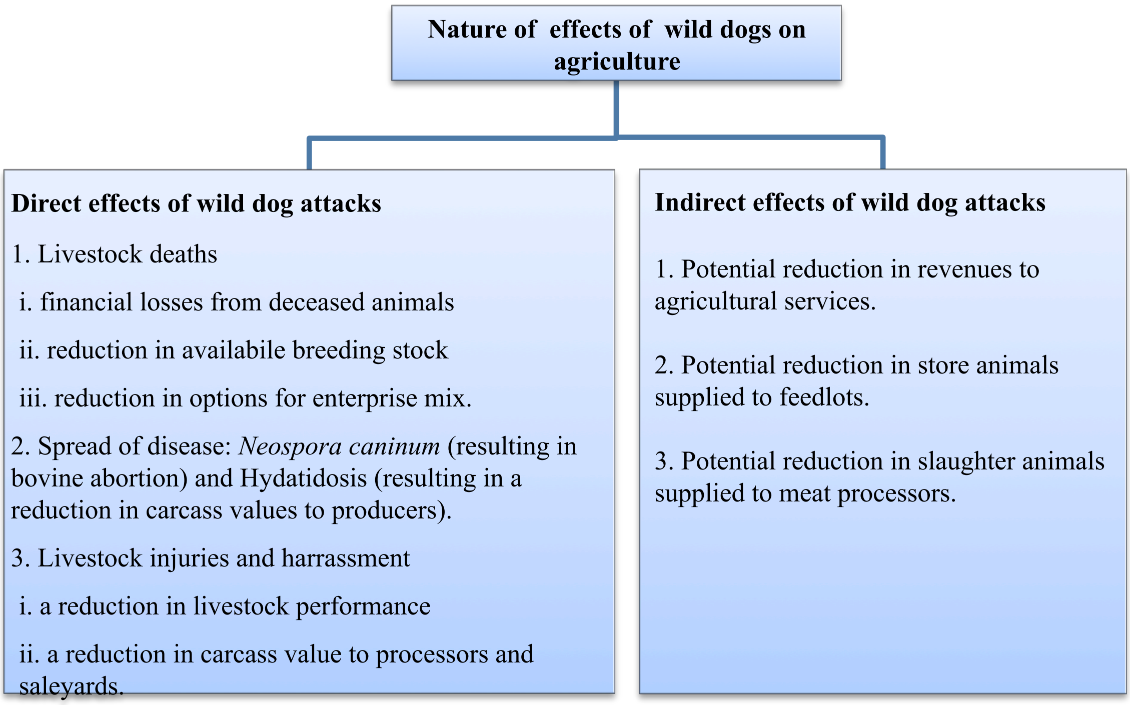
1 Introduction

In Australia, wild dogs, which include dingoes (*Canis lupus dingo*), feral domestic dogs (*Canis lupus familaris*) and hybrids of the two, are classified as a pest animal of national significance (Parliament of the Commonwealth of Australia 2005). These animals affect Australian grazing enterprises, people living in rural communities and the environment.

In some regions of Australia sheep and cattle are vulnerable to wild dog attacks. Wild dog attacks can not only cause the death of lambs, ewes and calves but can also injure rams, wethers and adult cattle. Figure 1 separates the direct affects on grazing enterprises from the indirect (or flow-on) effects to businesses that supply services to these enterprises. Two studies have estimated the cost of wild dog attacks on livestock production. McLeod (2004) estimated the value of sheep and cattle production losses at $15.9 million and $32.4 million per year, respectively (in 2004 dollars). More recently, Gong et al. (2009) estimated the annual total economic surplus losses for the sheep and beef industries at $21.9 million and $26.7 million, respectively (in 2008 dollars). While these studies show that wild dogs attack and kill a larger number of sheep than cattle (Allen & Sparkes 2001; Fleming et al. 2001), both studies indicate that revenue losses are greater for the cattle industry (Gong et al. 2009; McLeod 2004).

Figure 1 Effects of wild dog attacks on livestock enterprises



The major social impact of wild dog attacks on people living in rural communities relates to psychological stress that landholders experience as a result of the attacks on their livestock. Another significant issue involves the spread of particular diseases through the dogs to livestock and, in some cases, humans (Fitzgerald & Wilkinson 2009; Hewitt 2010; Lightfoot 2010).

The affect of wild dogs on the environment can be positive, negative or neutral depending on the context and perspective that are considered. Factors such as rainfall, habitat complexity and faunal diversity—that is, the strength of interactions between wild dogs as predators and their prey—has an influence (Fleming et al. 2011; Letnic et al. 2011). In the context of this paper only the interaction between wild dog and kangaroo populations is considered. Wild dogs prey on kangaroos and in some situations may reduce competition with cattle for grazing vegetation, which benefits beef producers.

The effective control of wild dogs is a complex process involving many participants, with potentially different incentives. Currently, regulations allocate responsibility for wild dog management to both private landholders and the state government. Regulations vary between states, but generally assign responsibility for controlling wild dog populations through land tenure; for example, graziers are responsible for wild dog populations on their land. State governments regulate control measures that landholders may implement and are also responsible for controlling wild dog populations on public lands (Fleming et al. 2001).

Selection of case study area

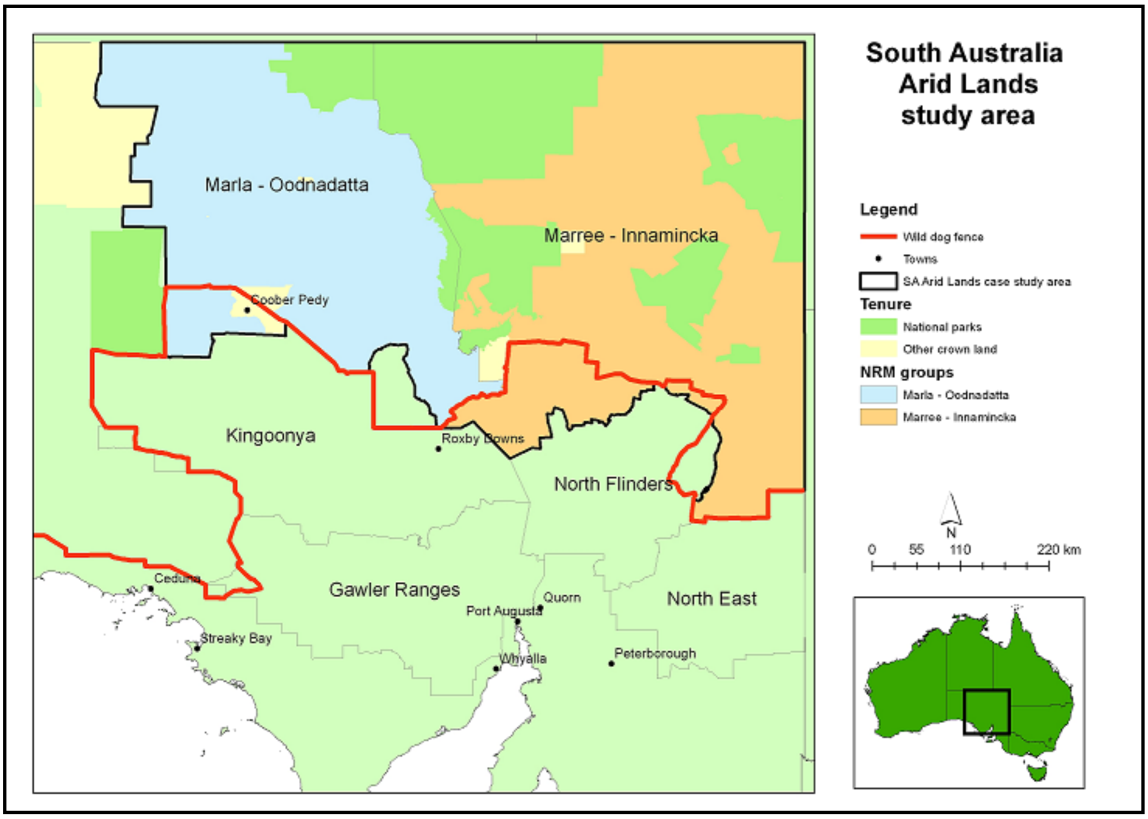
To date, three Australian studies have assessed the effectiveness of wild dog control measures to reduce calf losses in Australia: Allen (2010b) in northern South Australia; Allen (2005) in Queensland; and Eldridge et al. (2002) in the Northern Territory. These studies measured the magnitude of wild dog effects in paired areas (enclosed areas with and without control measures). Allen (2005) reported that the frequency and magnitude of calf losses to wild dogs was greater in areas where wild dogs were controlled, whereas Eldridge et al. (2002) reported no losses to wild dogs in either area. The rapid reinvasion of wild dogs into controlled areas and other factors relating to availability of preferred wildlife prey were believed responsible for these different results. In the northern South Australia study it was shown that control programs—in the form of ground baiting—reduced calf losses. Allen (2010b) was able to provide sufficient data to quantify the magnitude of effects (with and without control programs) for the present study.

The South Australian Arid Lands case study area consists of the two natural resource management groups of Marla–Oodnadatta and Marree–Innamincka. These areas are located in the northern arid zone of South Australia (Figure 2). Cattle production is the primary agricultural enterprise in the area, with 38 properties 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 2011, pers. comm. 16 May).

Ground baiting is the primary wild dog control measure used to reduce calf losses in this area (Allen 2012). Reduced calf losses allow producers to maintain a larger herd and hence, turn off more cattle for slaughter or to feedlots. However, while control measures reduce wild dog predation on livestock they may concurrently reduce predation on kangaroo populations. Larger kangaroo populations can increase competition between cattle and kangaroos for grazing vegetation, thereby reducing the land's commercial livestock carrying capacity and future returns from grazing activities (Coulson & Eldridge 2010; Jonzén et al. 2005).

This study examines the incentives that beef producers have, in a case study area, to undertake wild dog control measures; but considers only the effects on beef production. The benefits to beef producers from wild dog control programs were estimated and compared with estimates of the cost of increased kangaroo competition for grazing vegetation.

Figure 2 South Australian Arid Lands case study area



2 Method

This analysis comprises two components: estimation of the value of reduced calf losses from wild dog control and the associated costs of increased competition from kangaroos for available grazing vegetation. By comparing the costs of increased competition with the benefits of reduced calf losses, it is possible to assess the break-even points where the returns from investment in wild dog management outweigh the cost of increased kangaroo competition. Quantification of the effects of wild dogs on people in rural communities and the environment was not examined in this study.

In the first component, the value of reduced calf losses is reported using cost–benefit analysis measures, including Net Present Value; Benefits Cost Ratio; and the Threshold probability. Calculation of these measures requires estimation of the benefits and costs of wild dog control programs. Benefits were estimated using a bioeconomic livestock model and costs estimated using data on current control programs in the case study area.

The bioeconomic livestock model estimates the maximum revenue from slaughtering livestock produced in the South Australian Arid Lands. The model is dynamic and as such, decisions in one period affect returns to production in future periods. Livestock growth equations are used in the model to keep track of annual births, deaths and slaughter in the cattle herd. The benefits of the control program are estimated as the difference in revenues calculated for the baseline scenario relative to the no control scenario. The baseline scenario represents the situation where wild dog control measures are implemented, resulting in fewer calf losses. In the no control scenario, no control measures are implemented. Benefits are measured as the increased revenues from selling livestock that would have otherwise been killed by wild dogs and the value of a more productive breeding herd.

In the second component, the cost of increased competition between kangaroos and cattle is estimated numerically using data on kangaroo densities, degree of kangaroo competition and value of livestock.

Bioeconomic livestock model: concepts

The model is a dynamic bioeconomic livestock model that maximises returns to cattle production activities in the case study area. The dynamic feature of this model results in annual estimates of the number of head in each age cohort of the herd, number of calves produced, mortality rates, livestock slaughtered, volume of beef produced and revenue from slaughter activities. This model is based on a model developed by Cao et al. (2002) that estimates the cost of a foot-and-mouth disease outbreak in Australia.

The objective function (Π), displayed in equation (1), maximises the returns to cattle production over a given time horizon ($t \in [0, T]$).

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

Where:

t is the time period

r is the 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

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 this equation, 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 ($\mathrm{B_s}$) and negative slope ($\mathrm{C_s}$) 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 for each time period. 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 the 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 ($\mathrm{x_1^m}$) in the next period ($t+1$). This value is estimated as the number of male calves produced per year, net of livestock deaths from wild dog attacks (δ_a) and female calves diverted for slaughter (xs). Where the total number of calves produced depends on the number of cows in the breeding herd (x_a^c) and the proportion of calves branded per year (α_a). A 50–50 split between male and female calves is assumed.

$$x_1^m(t+1) = \sum_{a=1}^{A_c} \alpha_a \left(1 - \delta_a(t)\right) x_a^c(t)/2 + xs(t+1) \tag{3}$$

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_a) and female calves diverted for slaughter (xs) in the current time period (equation (4)).

$$x_1^c(t+1) = \sum_{a=1}^{A_c} \alpha_a \left(1 - \delta_a(t)\right) x_a^c(t)/2 - xs(t+1) \tag{4}$$

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 $A_s - 1$ (x_{a+1}^s for $a\epsilon[2, A_s - 1]$) for the next time period, 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 last cohort for the next time period. Equations defining changes in livestock numbers are identical for both the breeding and non-breeding herds.

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

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

The following set of constraints in equations (7) to (9) ensure the quantity of meat produced does not exceed the amount available from the herd. Constraints are placed on the number of female calves slaughtered, the total number of livestock slaughtered, the total quantity of meat sold in any time horizon and the size of the breeding herd in each time period. Equation (10) ensures the annual grazing pressure does not exceed the land carrying capacity.

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

$$xs(t+1) \leq \sum_{a=1}^{A_c} \alpha_a\left(1-\delta_a(t)\right) x_a^c(t)/2 \tag{7}$$

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

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

Equation (9) restricts the total quantity of meat produced to less than the total quantity of beef supplied by breeding activities. Where $\mathrm{w}_\mathrm{a}^\mathrm{s}$ is the sellable live carcass weight per head slaughtered by type s and age cohort.

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

Finally, equation (10) constrains the annual herd grazing pressure to no more than the carrying capacity of the land. Where $\beta_\mathrm{a}^\mathrm{s}$ is the annual dry sheep equivalent by cattle type and age cohort and the *CC* is the carrying capacity.

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

Bioeconomic livestock model: data and assumptions

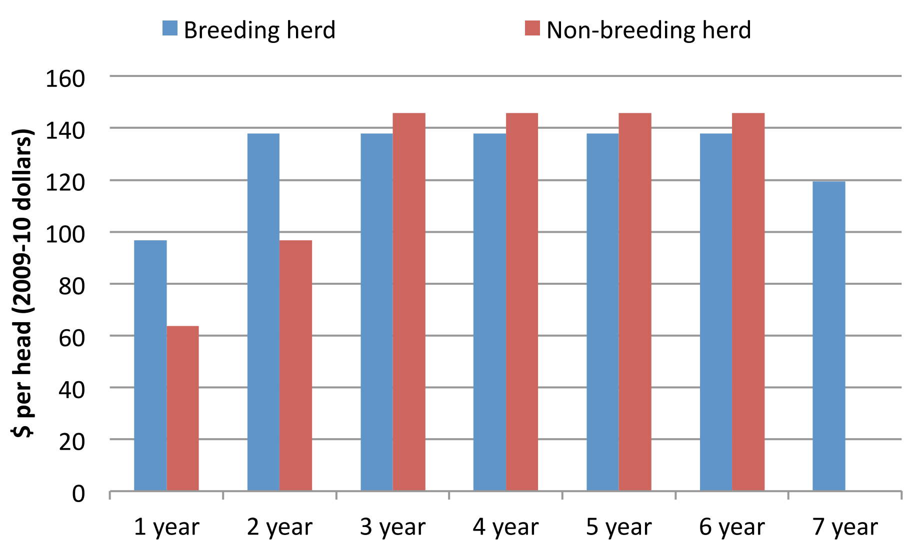
Where possible, all values and parameters used to develop the biological livestock model represent an average production environment for the South Australian Arid Lands case study area.

The model consists of breeding and non-breeding herds. Thompson and Martin (2011) estimate the maximum age of cattle in South Australian breeding and non-breeding herds to be 7 years and 6 years, respectively. Consequently, the livestock model contains seven age cohorts in the breeding herd; with the first age cohort containing livestock that are at most 12 months old, the second containing livestock that are between 1 and 2 years old, and so on, with each subsequent age cohort containing livestock that are an additional year older.

The slope and intercept parameters for the linear beef demand function are estimated using data on the price of meat, the weight per head of livestock by age cohort, the number of livestock slaughtered in the current decade and the elasticity of demand for beef at saleyards. The National Livestock Reporting Service, Meat and Livestock Australia, provided data for the price of beef and livestock carcass weights for 1999–2000 to 2009–10; average values for this period are presented in Table 1. The number of cattle slaughtered is estimated as a product of the average herd size and proportion of beef cattle sold in South Australia (Table 1). The proportion of beef cattle sold was derived from the ABARES annual Australian Agricultural and Grazing Industry Survey from 1990–91 to 2009–10 (P Martin [ABARES] pers. comm. 5 August 2011). A demand elasticity of approximately −3 is used to calibrate the model (Griffith et al. 2001).

As previously stated, costs of beef production include maintenance and transport costs. Maintenance costs are the on-farm costs to operate a cattle enterprise in the South Australian Arid Lands. Data on average farm management costs for 1990–91 to 2009–10 were derived from the Australian Agricultural and Grazing Industry Survey (P Martin [ABARES] pers. comm. 5 August 2011). These data were combined with information on livestock weight and number of head in each age cohort, to estimate the maintenance cost per head by age cohort. Parameters from these calculations—used in the livestock model—are presented in Figure 3.

Figure 3 Management costs per head by age cohort



Source: Australian Agricultural and Grazing Industry Survey

To estimate transport costs for cattle produced in the case study area, markets where cattle are most likely to be sold were identified. Cattle from Marla–Oodnadatta (North West) are more likely to be 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). It is estimated that the average cost to transport livestock to these saleyards is approximately $79.50 per head: using an average distance travelled of 880 kilometres and a price of $0.09 per head per kilometre (P Martin [ABARES] pers. comm. 11 August 2011).

Livestock growth equations are a function of stock numbers in the last period and require starting values for the initial time period, along with parameters to estimate the change stock number between time periods. Starting values for the initial herd size are derived using data on the size of the South Australia's cattle herds from 1999–2000 to 2007–08 (C Turner [Department of Environment and Natural Resources' Pastoral Board] pers. comm. 16 May 2011) and the beef herd composition in 2009–10 (Thompson & Martin 2011). It is assumed that the applied model will represent an average cattle production system for the South Australian Arid Lands. As such, starting values to define the age cohorts are estimated using the average herd size. Starting values used in the model are provided in Table 1.

The branding rate, $\propto_a$, is used to estimate the annual number of calves the breeding herd produced, including natural losses. A branding rate of 88 per cent is assumed, derived using Holroyd (1987). This value omits losses from wild dog attacks.

Mortality rates for livestock in age cohort 2 and above, μ_a^k, were estimated using data from the Australian Agricultural and Grazing Industry Survey (P Martin [ABARES] pers. comm. 11 August 2011). The values derived are approximately 3.69 per cent and 0.87 per cent for livestock in the breeding and non-breeding herd, respectively.

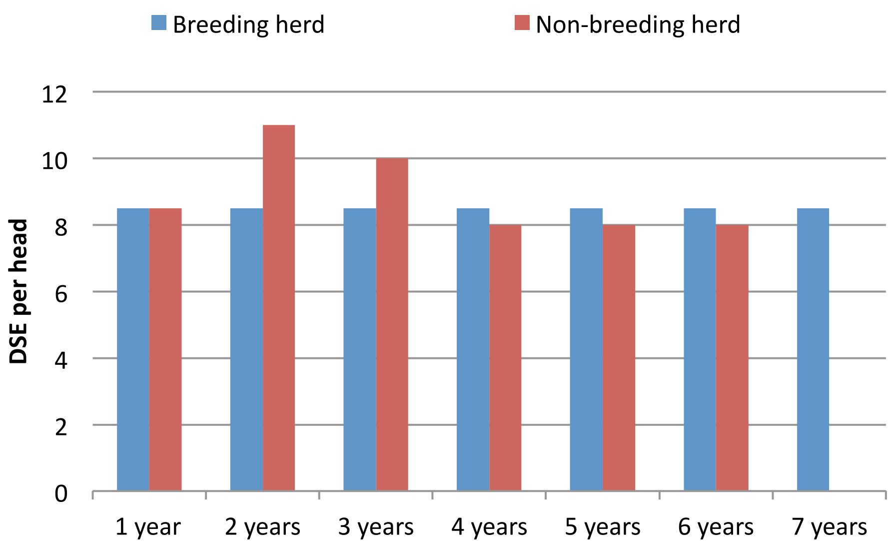
Table 1 Starting values for the cattle livestock model by age cohort (in t-=1)

Age cohort/category	Average herd size [a] (no. of head)	Price of beef [b] ($ per kilogram, valued in 2009–10 dollars)	Carcass weight [b] (kilograms per 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

Sources: **a** C Turner, Department of Environment and Natural Resources' Pastoral Board pers. comm., 16 May 2011 and Thompson & Martin 2011; **b** National Livestock Reporting Service Meat and Livestock Australia.

Parameters for defining the carrying capacity constraint include the dry sheep equivalents by cattle type and the maximum carrying capacity. Dry sheep equivalents by cattle type and age cohort are estimated from McLaren (1997) and values are presented in Figure 4. Additionally, when a cow has a calf at foot, an additional 3.25 dry sheep equivalents is added to the cow's total dry sheep equivalent (Figure 4). The maximum annual carrying capacity is estimated at 1.3 million dry sheep equivalents for the South Australia case study area (Thompson & Martin 2011; C Turner [Department of Environment and Natural Resources' Pastoral Board] pers. comm., 16 May 2011).

Figure 4 Dry sheep equivalents (dse) by age cohorts



Estimating benefits for the South Australian wild dog control program

The effect of wild dog attacks on returns to South Australian cattle enterprises are estimated by incorporating a damage function in the livestock model. Damage functions estimate the proportion of calves killed in each time period. 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 for each scenario and the benefits are estimated as the difference in the revenues from these results.

The baseline scenario represents the current control activities that are implemented to reduce calf losses from wild dog attacks in the case study area. Ground baiting is the primary control measure used in the South Australian Arid Lands. Other control measures, such as shooting, are sometimes used in this area 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 national wild dog fence does not benefit properties in the case study area, instead protecting livestock enterprises south of the fence (Yelland 2001). The location of the national wild dog fence relative to the South Australia case study areas is provided in Figure 2.

The effect of the annual baiting program, for the baseline scenario, is to keep calf deaths to 8.8 per cent (Allen 2010a). A graphical representation of this impact is provided in Figure 5.

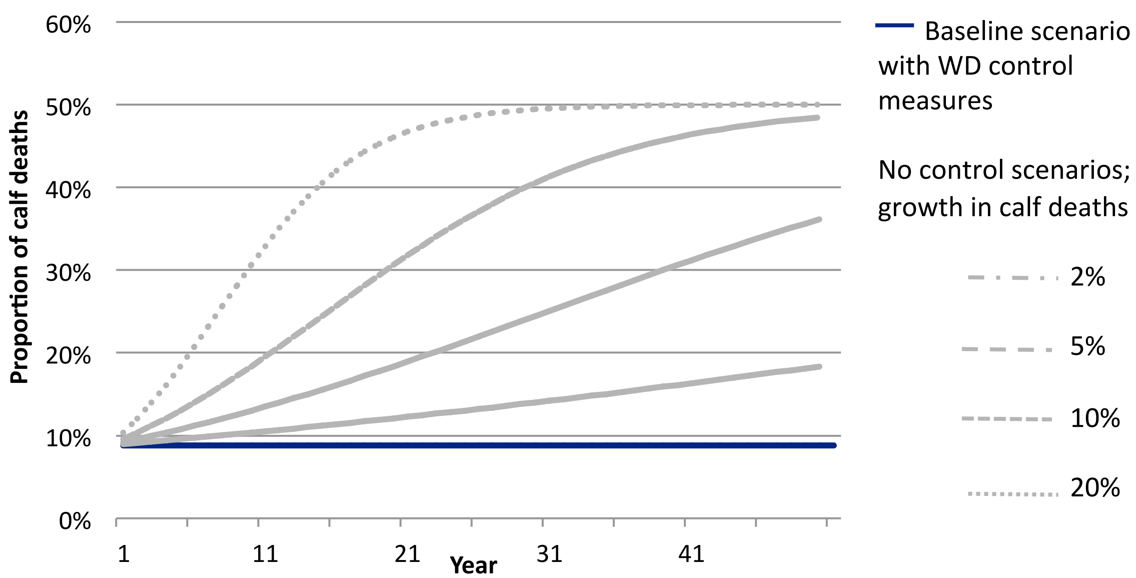
The no control scenario represents the case where no wild dog control measures are implemented. A logistic growth function is used to estimate the proportion of calf deaths per year (Kompas & Che 2009). This function has the following form:

$$\delta_a(t) = \frac{\delta_a^{max}}{1 + (\delta_a^{max}/\delta_0 - 1)e^{-gt}} \quad (11)$$

where δ_a^{max} is the maximum losses, δ_0 is the initial losses and g is the intrinsic growth rate for losses. For the case study area it is assumed that calf deaths will not exceed 50 per cent of calves born. The proportion of calves killed in the first time period is 8.8 per cent (Allen 2012) and intrinsic growth rates—the rate of growth in calf deaths from wild dog attacks— of 2 per cent; 5 per cent; 10 per cent and 20 per cent are used in the no control scenario.

It should be noted that definite intrinsic growth rates are unknown and are likely to change through time depending on production or 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 environmental conditions the intrinsic growth rate is more likely to be low. This uncertainty is captured by using a range of values for the no control scenario. A graphical representation of this damage curve is presented in Figure 5. This figure shows that if the wild dog population is left uncontrolled, the proportion of calves killed will continue to rise each time period in accordance with specifications of the damage function. Damage functions that have higher growth rates—such as 20 per cent—reach the maximum damage level before those with lower rates.

Figure 5 Proportion of calf deaths from wild dog attacks -by scenario



Cost of control programs

Ground baiting is the primary control measure used in the South Australia case study area to reduce the effects of wild dogs. Data and methodology to estimate the average annual costs of the baiting program are presented below.

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. Data on the number of baits dispersed annually, between 1989–90 and 2007–08, were obtained from P Bird at Biosecurity South Australia. It is estimated that on average 14 000 baits per year were applied; with a maximum annual application rate of 29 000 baits and a minimum of 890 (Allen 2012; Allen 2010a).

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.

The total baiting cost comprises the cost of materials and the cost to distribute baits. The material cost for manufactured baits, includes the price of purchasing 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.

Table 2 shows the values of parameters for estimating the average annual material costs of the baiting program in the case study area, from 1989 to 2008. The cost of distributing baits consists of the cost of labour and vehicles used to distribute baits each year. Data needed 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 required to distribute baits each year. Data for hourly wage rates and vehicle costs are provided in Table 2. The distance travelled and time spent to bait the whole case study area was estimated at, 16 000 kilometres and 900 hours for a manager and farm assistant, respectively (P Bird [Biosecurity South Australia] pers. comm. 12 October 2011). The average distribution costs for the annual baiting program in the case study area was estimated using data on the case study area baited each year (Allen 2010b). The average annual distribution costs are estimated at approximately $38 000 per year.

Table 2 Data to estimate the annual baiting costs

Activity	Values	Data source
Manufactured baits:		
– 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:		
– Cost of meat	$0	P Bird [Biosecurity South Australia], pers. comm. 20 September 2011
– Cost of 1080 poison	0.33 cent per bait	P Bird [Biosecurity South Australia] pers. comm. 12 October 2011
– Number of labour days to prepare bait meat	12 hours per 1000 baits	P Bird [Biosecurity South Australia] pers. comm. 20 September 2011
– Distance travelled to procure fresh bait meat	50 kilometres per 1000 baits	P Bird [Biosecurity South Australia] pers. comm. 20 September 2011
Labour costs:		
– 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 [a]	$ 0.93 per kilometre	Royal Automobile Club of Queensland

a Includes cost of fuel, depreciation, wear and tear on vehicles for a four-wheel-drive Mitsubishi Triton, Nissan Navara, Toyota Hilux or Toyota Land cruiser ute.

Cost of kangaroo competition

When kangaroos compete with cattle for grazing vegetation the land's carrying capacity is reduced (Coulson & Eldridge 2010; Jonzén et al. 2005). Consequently, a successful control of wild dogs may inadvertently lead to larger populations of kangaroos.

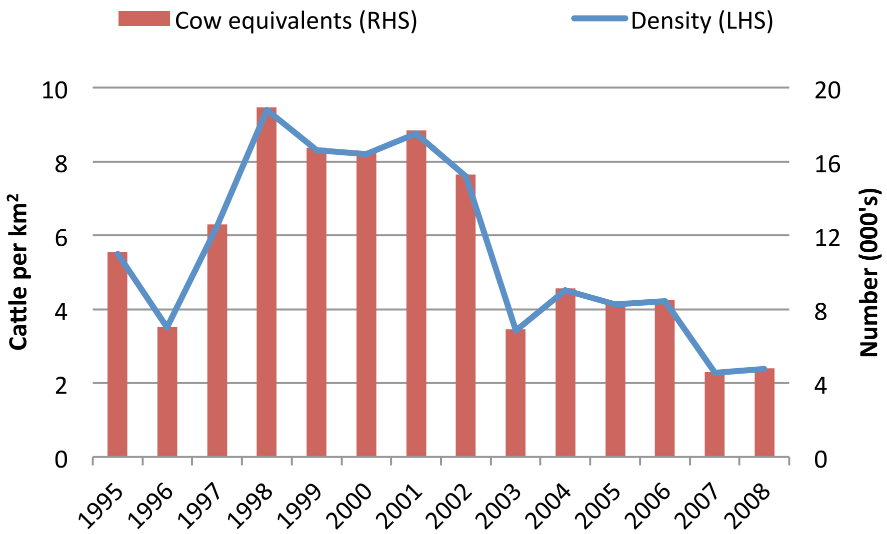
In this section the potential revenue losses that beef producers may incur, are estimated for varying levels of kangaroo competition. Competition occurs where kangaroos and cattle consume the same food resources in the same place at the same time (Caughley & Sinclair 1994). The level of competition varies from year to year depending on the quantity and quality of pasture availability. 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. In these circumstances it would be expected that kangaroo competition for grazing vegetation is lower. Therefore, depending on the seasonal conditions, wild dog controls can affect competition between cattle and kangaroos for grazing vegetation.

In this study, the annual cost of kangaroo competition is estimated as the revenues that may have been generated from pasture consumed by kangaroos, rather than cattle.

First, cow equivalent populations are estimated for kangaroo densities in the case study area. Estimates of annual kangaroo densities have been collected since 1995 for the Marla–Oodnadatta natural resource management groups and are presented in Figure 6 (DEH 2009). These densities are converted to cow equivalents measured in dry sheep equivalents using the standardised conversion tables in McLaren (1997). For these conversions it is assumed 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, that is 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 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. Also, competition for grazing vegetation lies between 0 and 100 per cent depending on environmental conditions. Where 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. These ranges allow for flexibility in the results so a range of scenarios may be considered.

Figure 6 Estimating cow equivalents for kangaroo populations



Source: DEH 2009

3 Results

The following three sections of results present estimates of the private benefits to graziers from reduced calf losses and the cost of increased competition for grazing vegetation from kangaroos. First, results are presented from the livestock model for the five scenarios used in this analysis, which includes a baseline scenario where wild dog controls are implemented and no control scenarios. The baseline scenario represents the current control activities used in the case study area where calf losses from wild dog attacks are maintained at 8.8 per cent. In the no control scenarios four different rates of increase in calf deaths are incorporated in the model: 2 per cent; 4 per cent; 10 per cent and 20 per cent. Results for an additional scenario are presented—for the case where wild dog attacks do not occur—as a reference point.

In the first section revenues from reduced calf deaths and the estimated cost of wild dog control programs are used to estimate the Net Present Value, Benefit Cost Ratio and the Threshold probability for the four rates of increase in calf deaths. The second section contains estimated costs of kangaroo competition. Both estimates are combined in the third section to assess the conditions under which the returns from investment in wild dog management outweigh the costs of increased grazing competition from kangaroos.

Livestock model output

Slaughter and herd numbers

Figures 7 and 8 display the optimal livestock numbers in the non-breeding and breeding herd, respectively. The annual slaughter numbers are presented in Figure 9. These results are presented on an annual basis, for each scenario and are needed to estimate the effect of wild dogs on beef production herds. Estimates of revenue used to address the first component of this study follow in the next section.

Figure 7 shows the number of livestock in the non-breeding herd over 20 years, for the six scenarios. In the baseline scenario a steady state of 43 500 head per year is reached for the non-breeding herd. In the no control scenarios, steady states are never achieved as the rate of calf deaths from wild dog attacks increases continuously throughout the time horizon. The effect of a 20 per cent growth in the rate of calf deaths relative to the baseline scenario in year 20, results in a 30 per cent reduction in the number of livestock in the non-breeding herd. This result estimates the maximum reduction in livestock numbers for the non-breeding herd, as a result of wild dog attacks for the 20-year time period.

Figure 7 Size of the non-breeding herd (over a 20-year time horizon), by scenario

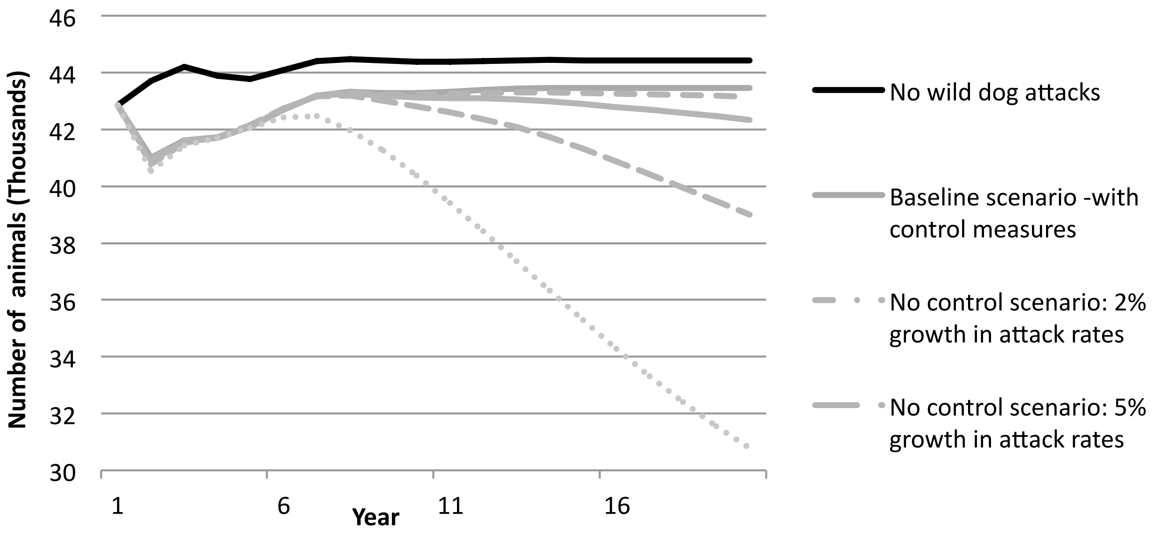
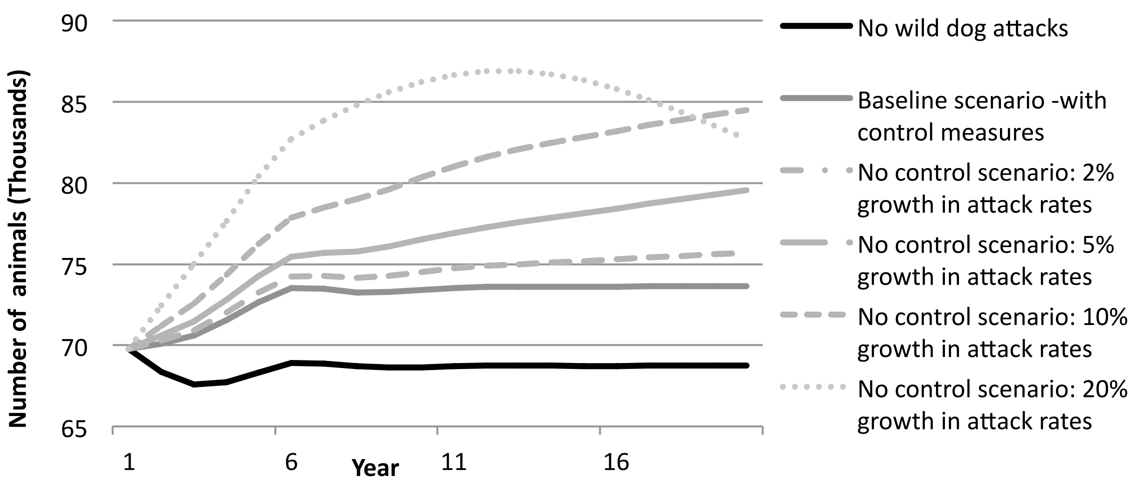


Figure 8 shows the number of livestock in the breeding herd, over 20 years, for the six scenarios. In the baseline scenario a steady state of 73 600 head per year is reached, for the breeding herd. In the no control scenarios, steady states are never achieved as the rate of calf deaths from wild dog attacks increases continuously throughout the time horizon. The bioeconomic livestock model allocates losses from wild dog attacks equally among calves entering the breeding herd and the non-breeding herd.

However, Figure 8 shows that as the rate of calf deaths increases the beef producers will retain more livestock in the breeding herd. The impact of a 20 per cent growth in the rate of calf deaths relative to the baseline scenario in year 20, results in a 12 per cent increase in the number of cows in the breeding herd. The results reflect revenue gains, in the no control scenario, from maintaining a larger breeding herd that makes up for revenue losses from wild dog attacks.

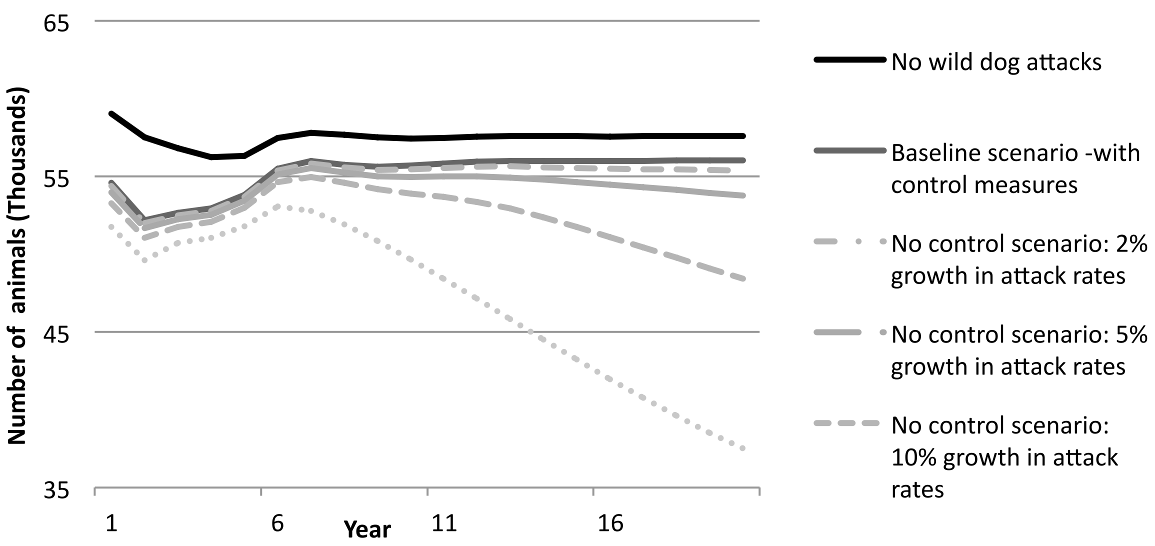
Figure 8 Size of the breeding herd (over a 20-year time horizon), by scenario



Results for the optimal number of livestock slaughtered from the herd are shown in Figure 9. In the baseline scenario, a steady state of about 56 000 head per year is reached. Slaughter numbers in the no control scenario decline with increases in the rate of calf deaths. For 20 per cent growth in the rate of calf deaths—in the no control scenario—livestock slaughter is estimated at about

37 500 head in year 20, relative to the baseline scenario. This represents a 33 per cent decline in the number of livestock slaughtered.

Figure 9 Total number of livestock slaughtered from the herd, by scenario



Revenues

Figure 10 shows the undiscounted revenues for the six scenarios. In the baseline scenario, undiscounted revenues reach a steady state of approximately $17 million per year. In the no control scenarios, revenue losses increase with the growth in calf deaths. By comparing the baseline scenario with the no control scenario for a 20 per cent growth in calf deaths, by year 20 undiscounted revenues have declined to $10.6 million; a 38 per cent reduction.

Estimates of the benefits of wild dog controls, for cost–benefit analysis measures, are calculated using these results. The benefits of wild dog controls are estimated for each rate of growth in calf deaths and are shown in Figure 11. Consider the scenario where there is a 20 per cent growth in calf deaths. Benefits from wild dog controls to minimise these affects are represented by the area between two curves—the undiscounted revenues for the baseline scenario and undiscounted revenues for the no control scenario assuming a 20 per cent growth in calf deaths. The sum of discounted benefits for this example is approximately $33.9 million over 20 years (Table 3). Estimates of the annual discounted benefits, of wild dog controls, for the four rates of growth in calf deaths relative to the baseline scenario, are shown in Figure 11.

Figure 10 Undiscounted revenues, by scenario

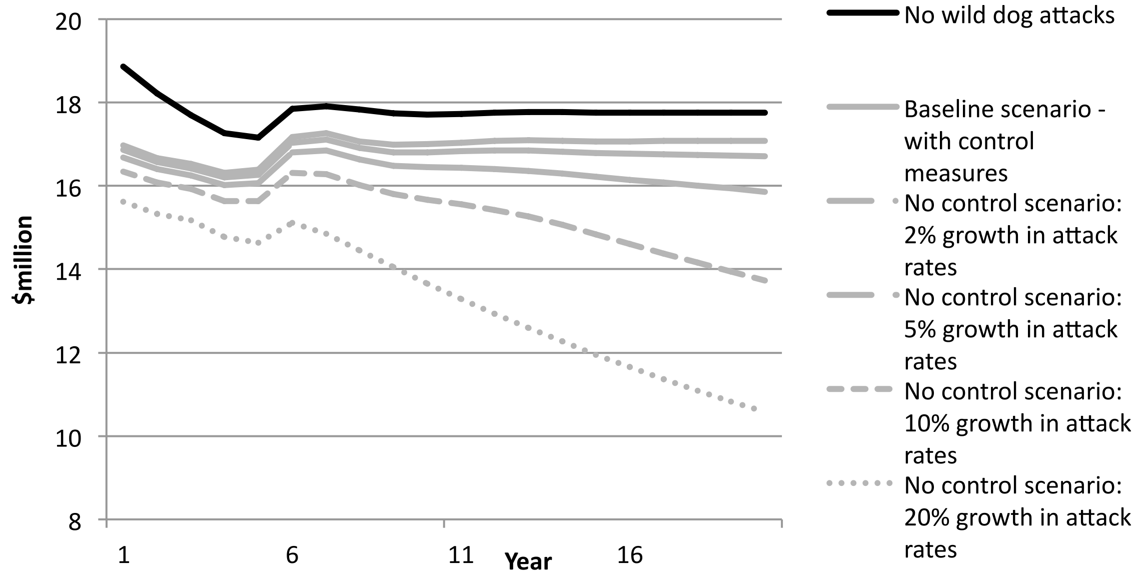
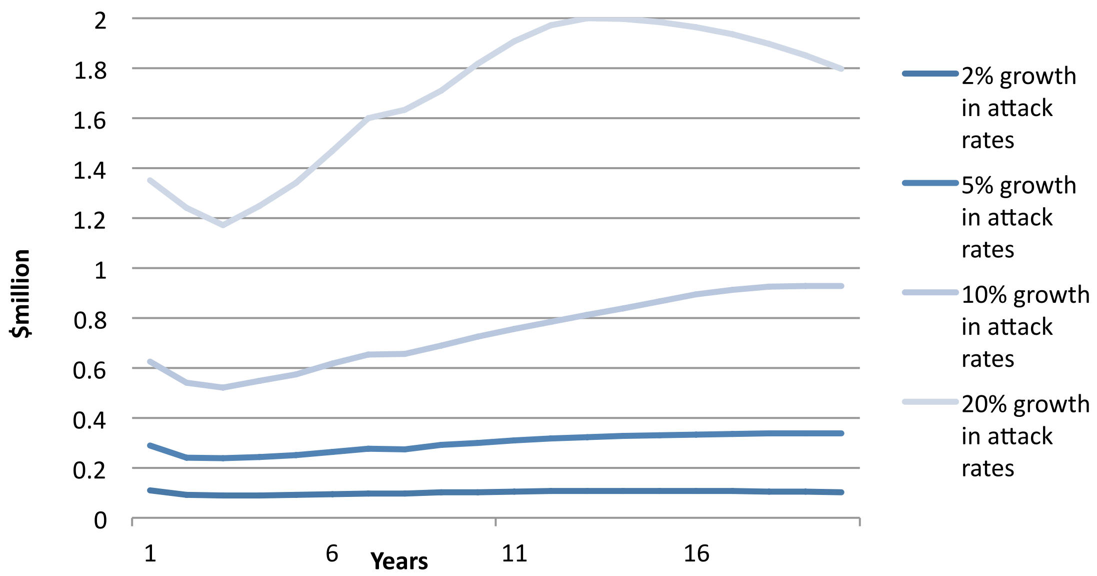


Figure 11 Discounted benefits from wild dog controls, by calf death rates



Cost–benefit analysis measures

This section contains estimates of the present value of benefits and the present value of costs that are required for estimating the cost–benefit analysis measures including Net Present Value, Benefit Cost Ratio and the Threshold probability.

The present value of benefits resulting from the wild dog control program in the South Australian Arid Lands, are presented in Table 3. Values are estimated for the four rates of growth in calf deaths over a 20-year time horizon.

It is assumed that the wild dog management program is implemented annually; at an average cost of $38 000 per year. Assuming that the present value of costs is constant across all rates of growth in calf deaths, the value of costs is around $432 000 over 20 years (Table 3).

Estimates of the Benefit–Cost Ratio, Net Present Value and Threshold probabilities are presented in Table 3. Both the Benefit–Cost Ratio and Net Present Value show that leaving aside the effect of increased kangaroo grazing competition, returns on a dollar investment in baiting measures by graziers to control calf deaths are positive. The benefits also increase for higher rates of growth in calf deaths.

Threshold probability estimates the perceived probability at which the benefits of wild dog control are equal to the cost of control measures (Table 3). For example, for a 5 per cent increase in calf deaths if the perceived probability of successful control is greater than 7.3 per cent, the expected benefits of the control programs are estimated to be greater than the expected costs of the control program.

Table 3 Cost–benefit analysis measures, by growth in calf deaths (in 2009–10 dollars)

Variable	Increase in calf deaths			
	2%	5%	10%	20%
Present value of benefits ($ across 20 years)	2 021 150	5 959 988	14 791 150	33 881 730
Present value of costs of control program ($ across 20 years)	432 161	432 161	432 161	432 161
Benefit–cost ratio	4.7	13.79	34.23	78.40
Net present value ($m)	1.6	5.5	14.36	33.45
Threshold probability	0.214	0.073	0.029	0.013

Cost of kangaroo competition for grazing vegetation

Estimates of the annual cost of kangaroo competition for grazing vegetation in the case study area are presented in Table 4. As both the net value of a cow and competition for grazing vegetation vary over time a range of estimated cost of kangaroo competition are presented as a matrix of values (Table 4). For example, 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 per year.

Table 4 Cost of kangaroo competition for case study area ($m, valued in 2009–10 dollars)

Net value of a calf-producing cow ($ per head)	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

Breakeven curves for wild dog control programs

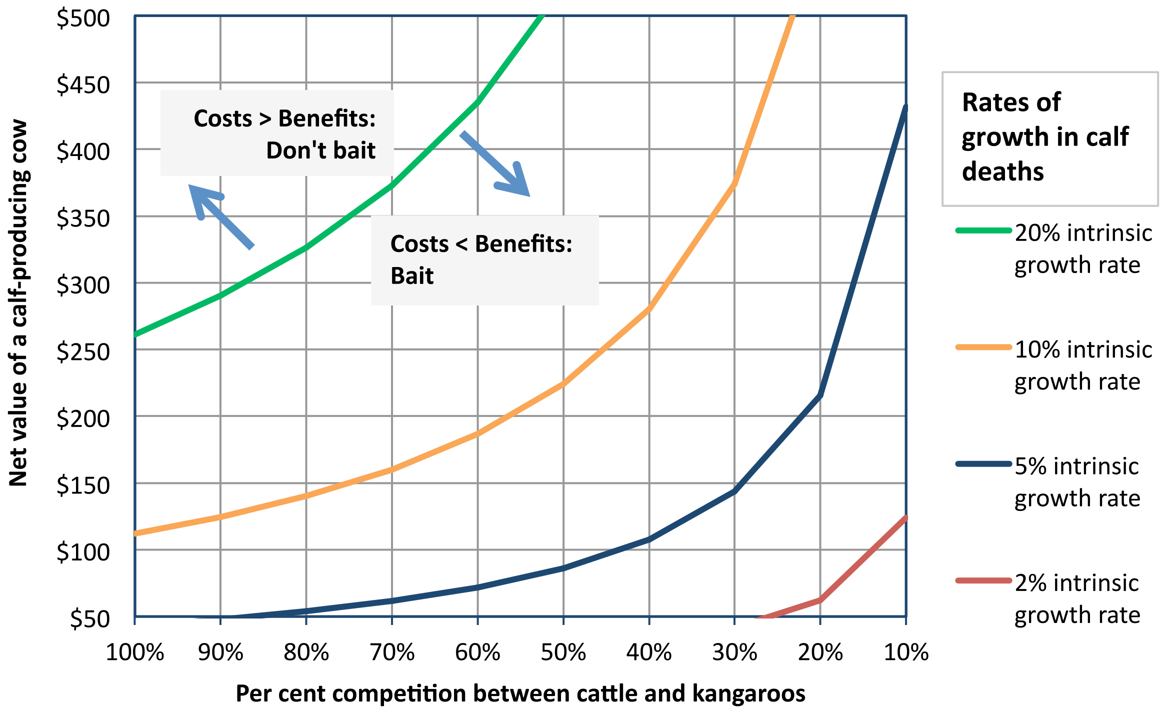
Breakeven curves, loci, for when the present value of the benefits from reduced calf losses and the present value of costs from increased kangaroo competition are equal, are presented in Figure 12. Four curves are presented, one for each rate of growth in calf deaths. The area left of a breakeven curve represents cases where the cost from increased kangaroo competition for grazing vegetation outweighs the benefits from wild dog controls. The converse is true 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, the attack rate can increase rapidly to the point where more than 30 per cent of calves can 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 12 by a growth in calf deaths of 20 per cent—the green breakeven curve—and competition of 80 per cent or higher. The results of this study show that if the net value of a calf-producing cow is $250 or less in this situation, the present value of the costs from kangaroo competition is 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.

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 2 per cent growth in calf deaths—the red breakeven curve in Figure 12. 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 red 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 study 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 12. For example, if rainfall occurs during a drought resulting in improved environmental conditions, this will translate into a move from the green breakeven curve to the red 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 red breakeven curve. Similarly, Figure 12 may be used under different conditions to assess adjustments in the decisions to manage wild dogs.

Figure 12 Breakeven curves for wild dog baiting programs



4 Conclusions

This study has examined beef producers' incentives to implement wild dog control measures in a case study area. These incentives were assessed by comparing the benefits of wild dog control programs to beef producers with the costs of kangaroo competition for grazing vegetation. The selected case study area consists of two natural resource management groups: Marla–Oodnadatta and Marree–Innamincka in the South Australian Arid Lands.

The benefits of wild dog control programs were assessed as the returns from reduced calf losses in the case study area less the cost of wild dog control programs. The benefits of reduced calf losses were estimated using cost–benefit analysis measures including the Net Present Value; Benefit Cost Ratio; and Threshold probability of success. In this study, a bioeconomic livestock model was developed to quantify the returns to beef production from investments in wild dog controls. The benefits of wild dog control measures are estimated for four different growth rates—2, 5, 10 and 20 per cent—in calf deaths in the event that control measures cease. These scenarios allow the potential effects of variability in environmental conditions to be considered. For example, in drought conditions it is likely that wild dog attacks on livestock and calf deaths will increase, a 20 per cent rate of growth in calf deaths was used to capture this scenario. A scenario where favourable rainfall conditions prevail was represented in the analysis, by a 2 per cent rate of growth in calf deaths.

Benefits estimated in this study value only the returns to the beef production enterprises in the South Australian Arid Lands and exclude an assessment of the social and environmental effects.

While wild dog control measures reduce dog predation on livestock, they also reduce predation on kangaroos and can increase competition between kangaroos and cattle for grazing vegetation. Competition occurs where kangaroos and cattle consume the same food resources in the same place at the same time. The level of competition varies from year to year depending on the quantity and quality of pasture availability. In this study, the costs of increased kangaroo competition were estimated using data on kangaroo densities in the case study area. Costs were estimated for varying levels of kangaroo competition and a range of net values for calf-producing cows in the case study area.

A decision to control wild dogs will depend on the trade-off between the benefits of wild dog management and the costs of increased kangaroo competition for grazing vegetation. This study shows that several factors affect this trade-off, in the South Australian Arid Lands case study area. These include the net value of a calf-producing cow, the degree of kangaroo competition for grazing vegetation, and calf death rates. In considering the results presented, it should be noted that the costs of alternative measures to manage kangaroo populations were not considered.

Results from this study show that when calf death rates are high, which is more likely in drought conditions, beef producers have more opportunities to receive net benefits from implementing wild dog control measures. As the net value of calf-producing cows increases and/or the percentage of kangaroo competition increases, the cost of kangaroo competition increases relative to the benefits of wild dog controls reducing the scope to attain net benefits from wild dog control measures. In more favourable rainfall conditions, calf deaths as a result of wild dog attacks decline, which in turn reduces the benefits of wild dog controls relative to the cost of kangaroo competition. In this circumstance, it is likely that a baiting program will not result in net benefits to beef producers unless the net value of a calf-producing cow and the percentage of kangaroo competition are so low that the cost of grazing vegetation lost to kangaroos is smaller than the benefits from reducing calf deaths.

This study also showed that decisions to implement wild dog controls will vary over time for all beef producers and among beef producers in any time period. Temporal adjustments result from changes in environmental conditions, which are shown to affect the decision to implement controls. Beef producers' decisions to implement controls will also depend on market conditions. For example, a producer's estimate of the net value of a calf-producing cow will depend on its expected market value.

References

Allen, B 2012, 'The effects of lethal control on the conservation values of *Canis lupis dingo'*, in AP Maia & HF Crussi (eds), *Wolves: Biology, behavior, and conservation*, Nova Science Publishers, New York.

Allen, BL 2010a, 'The effect of regional dingo control on calf production in northern South Australia, 1972–2008', paper presented to the Queensland Pest Animal Symposium, Gladstone, Queensland.

—— 2010b, 'Experimental evidence for predation of beef cattle calves by wild dogs in northern South Australia', unpublished report to the South Australian Natural Resources Management Board, Port Augusta, South Australia.

Allen, LR 2005, *The impact of wild dog predation and wild dog control on beef cattle production*, The University of Queensland.

Allen, LR & Sparkes, EC 2001, 'The effect of dingo control on sheep and beef cattle in Queensland', J*ournal of Applied Ecology*, pp. 76–87.

Cao, L, Klijn, N & Gleeson, T 2002, 'Modelling the effects of a temporary loss of export markets in case of a foot and mouth disease outbreak in Australia: Preliminary results on costs to Australian beef producers and consumers', paper presented to 46th Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra, 12–15 February.

Caughley, G & Sinclair, ARE 1994, *Wildlife ecology and management*, Blackwell Sciences, Cambridge, Massachusetts.

Coulson, G & Eldridge, M 2010, *Macropods: The biology of kangaroos, wallabies and rat-kangaroos*, CSIRO Publishing, Melbourne.

DEH 2009, *2010 Commercial kangaroo harvest quota report for South Australia*, Department of Environment and Heritage, Government of South Australia, Adelaide.

Eldridge, SR, Shakeshaft, BJ & Nano, TJ 2002, *The impact of wild dog control on cattle, native and introduced herbivores and introduced predators in central Australia*, Parks and Wildlife Commission of the Northern Territory, Alice Springs.

Fitzgerald, G & Wilkinson, R 2009, *Assessing the social impact of invasive animals in Australia*, Invasive Animals Cooperative Research Centre, Canberra.

Fleming, P, Corbett, L, Harden, R & Thomson, P 2001, *Managing the impacts of dingoes and other wild dogs*, Bureau of Rural Sciences, Canberra.

Fleming, PJS, Allen, BL & Ballard, G 2011, 'Seven considerations about dingoes as biodiversity engineers: the socio-ecological niches of dogs in Australia', *Australian Mammalogy*, no. in press.

Gong, W, Sinden, J, Braysher, M & Jones, R 2009, *The economic impacts of vertebrate pests in Australia*, Invasive Animals Cooperative Research Centre, Canberra.

Griffith, GR, I'Anson, K, Hill, DJ, Lubett, R & Vere, DT 2001, *Previous demand elasticity estimates for Australian meat products*, NSW Agriculture, Orange.

Hewitt, L 2010, *Post-project Analysis – Blueprint for the Bush: Raising the awareness of coordinated wild dog control*, a report prepared for Agforce Queensland.

Holroyd, R 1987, 'Foetal and calf wastage in *Bos indicus* cross beef genotypes', *Australian Veterinary Journal*, vol. 64, pp. 133–37.

Jonzén, N, Pople, AR, Grigg, GC & Possingham, HP 2005, 'Of sheep and rain: large-scale population dynamics of the red kangaroo', *Journal of Animal Ecology*, vol. 74, pp. 22–30.

Kompas, T & Che, N 2009, *A practical optimal surveillance measure: papaya fruit fly in Australia*, Crawford School of Economics and Government, Canberra.

Letnic, M, Ritchie, EG & Dickman, CR 2011, 'Top predators as biodiversity regulators: the dingo Canis lupus dingo as a case study ', *Biological Review*s, no. in press.

Lightfoot, C 2010, *Social Benefit Cost Analysis Wild Dog Management in Victoria*, Tyne Group.

McLaren, C 1997, *Dry sheep equivalents for comparing different classes of livestock*, Department of Primary Industries.

McLeod, R 2004, *Counting the cost: impact of invasive animals in Australia 2004*, Cooperative Research Centre for Pest Animal Control, Canberra.

Parliament of the Commonwealth of Australia 2005, *Taking Control: a national approach to pest animals*, House of Representatives Standing Committee on Agriculture, Fisheries and Forestry, Canberra.

Thompson, T & Martin, P 2011, *Australian beef: Financial performance of beef cattle producing farms, 2008–09 to 2010–11*, ABARES report prepared for Meat and Livestock Australia, Canberra.

Yelland, L 2001, *Holding the line: A history of the South Australian Dog Fence Board, 1947 to 2000*, Primary Industries and Resources South Australia, Adelaide.