CENTRE FOR
INVASIVE SPECIES SOLUTIONS

ANNUAL COSTS OF FERAL DEER IN AUSTRALIA

ROSS MCLEOD

NSW GOVERNMENT

COLLABORATION | INNOVATION | IMPACT

www.pestsmart.org.au

Citation: McLeod, R. (2023). *Annual Costs of Feral Deer in Australia*. Report prepared by eSYS Development Pty Ltd, Centre for Invasive Species Solutions, Canberra.

Print ISBN: 978-1-922971-19-7
Web ISBN: 978-1-922971-18-0

Published by: the Centre for Invasive Species Solutions

The Centre for Invasive Species Solutions gratefully acknowledges the funding support for this publication through the Australian Government Department of Agriculture, Fisheries and Forestry. In-kind support was provided by Vertebrate Pest Research Unit, NSW Department of Primary Industries, Orange, New South Wales.

Disclaimer: The information contained in this publication has been prepared with care and is based on knowledge and understanding at the time of writing (2023). Some of the information in this document is provided by third parties, and all information is provided "as is", without warranty of any kind, to the extent permitted by law. After publication, circumstances may change and before relying on this information the user needs to take care to update as necessary.

No Product Preferences: The product trade names in this publication are supplied on the understanding that no preference between equivalent products is intended and that the inclusion of a product name does not imply endorsement over any equivalent product from another manufacturer.

ACKNOWLEDGEMENTS

The author thanks the many State, Commonwealth, NGO and industry representatives that participated in a workshop to discuss the draft report and provided feedback during the preparation of the report. They and other people contacted are listed at Table 9. Particular thanks to Dr Dave Forsyth for support during study implementation, Assoc. Prof Richard Price and Andreas Glanznig for feedback on the report, Dr Annelise Wiebkin for providing data on South Australian feral deer costs and organising the national workshop; and Jeanette for report editing.

Cover images:

- Front — Red Deer breaking through a fence (Peter Jesser).
- Back— Deer exclusion fence on the Bogong High Plains, Victoria (Elaine Thomas, Parks Victoria).

CONTENTS

TABLES

FIGURES

LIST OF ACRONYMS

ABC	Australian Broadcasting Corporation
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSE	Dry Sheep Equivalent
LLS	Local Land Services
MLA	Meat & Livestock Australia
NSW DPI	NSW Department of Primary Industries
PIRSA	The Department of Primary Industries and Regions, Government of South Australia
QDAF	Queensland Department of Agriculture and Fisheries

EXECUTIVE SUMMARY

OBJECTIVE

The objective of this study was to generate an estimate of the annual economic impact of feral deer in Australia in 2021.

METHOD

A loss-expenditure approach was used to determine the costs impacts of feral deer in Australia for 2021. Annual production losses (agricultural output losses) due to competition with feral deer in 2021 were estimated for the horticultural, plantation timber, and livestock industries (dairy, wool, sheep meat and beef). Estimates of the annual expenditure on deer control (e.g., fencing and shooting) borne by landholders and the public sector, and on motor vehicle and train collisions with deer were also prepared These various costs were summed to obtain an overall economic impact assessment for 2021.

Annual production losses were estimated at $55.8 million in 2021. Beef and sheep losses accounted for around half of these agricultural sector production losses (see Figure 1 for estimates for high-, mean- and low-impact scenarios.) The estimate for annual feral deer control costs at the farm level ($13.2 million) was based on the results of the national ABARES pest and weed survey in 2019 by Stenekes and Kancans (2021). These costs are converted to 2021 values using the consumer price index published by ABS (2023) to account for inflation. The combined cost of deer control and production loss due to feral deer for the included agricultural industries was thus estimated at $69.1 million for 2021.

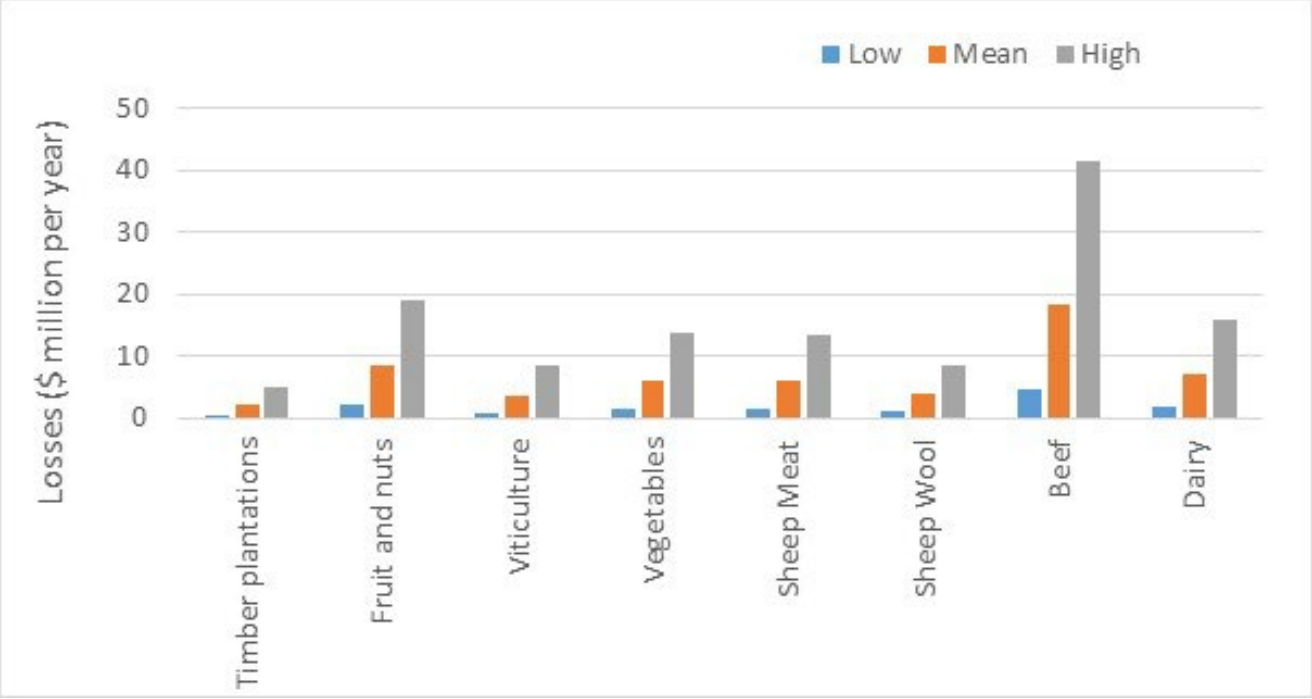

Figure 1: Combined annual agricultural production losses and control costs due to feral deer in Australia in 2021 for low-, mean- and high-impact scenarios.

Source: this study.

RESULTS

MOTOR VEHICLE AND TRAIN IMPACTS INVOLVING FERAL DEER

Motor vehicle and train impacts involving deer were estimated to cost $3.3 million and $1.2 million per year, respectively. Although there were far more motor vehicle incidents than train incidents involving deer (numbers being estimated at 300 and 30 per year, respectively), the cost for a train call-out was far higher than that for a car call-out, so the total cost for train call-outs was of a much higher order. The greatest number of train–deer impacts occurs in the Illawarra region of New South Wales (NSW), whereas vehicle–deer impacts mainly occurred across NSW, Tasmania, South Australia and Victoria.

PUBLIC EXPENDITURE ON DEER MANAGEMENT

Data relating to government expenditure on deer control was collected through discussions with the people listed in Table 9. Federal, state, and local council expenditure together totalled ~$18 million per year. High and low estimates were included, as it was difficult to separate direct deer expenditure from programs such as post-bushfire program for invasive animal control.

COMPARISON WITH THE ECONOMIC IMPACT OF OTHER FERAL VERTEBRATE PESTS

Several costing studies have been conducted to estimate the economic impact of the various feral vertebrate pests in Australia and at the state level. Bomford and Hart (2002) calculated the national annual agricultural losses, research costs and management costs associated with 10 key introduced vertebrate pests to be around $500 million in 2002, with rabbits ($225 million) and feral pigs ($107 million) representing approximately two-thirds of the total costs of 10 major pests.[1]

Similarly, the national annual costing of vertebrate pests as estimated by McLeod (2004) was $374 million per year, with rabbits ($113 million) and feral pigs ($107 million) making the biggest contribution to the costs. Gong et al. (2009) reported that rabbits inflicted the largest cost (estimated at $206 million per year across Australia), followed by wild dogs ($49 million) and foxes ($21 million) in 2008. By 2013-14, these costs had increased: rabbits ($217 million), wild dogs ($89 million) and foxes ($28 million) (McLeod 2016). The present study indicates that feral deer were responsible for an estimated annual national cost of ~$91.3 million per year in 2021, which reflects the economic impact of this taxa relative to that of other vertebrate pests.

The distributions of feral deer populations are expanding across Australia, and densities are increasing. Consequently, the annual cost of feral deer is expected to increase to significantly more than $91.3 million per year over the next decade unless major strategic management programs are deployed. The large potential costs from an expansion in feral deer numbers was reported by Frontier Economics (2022) for Victoria. These authors calculated that the current number of feral deer in Victoria could increase from 1 million to between 1.7 to 4.6 million by 2050. The costs of feral deer were estimated to be more than $1.5 billion at a 7% discount rate over 30 years and $2.2 billion at a 4% discount rate over the same time period should nothing be done to stem population growth and spread.

[1] European rabbit (*Oryctolagus cuniculus*), red fox (*Vulpes vulpes*), feral goat (*Capra hircus*), feral pig (*Sus scrofa*), house mouse (*Mus musculus*), feral dog (*Canis familiaris*) and dingo (*Canis lupus dingo*), feral cat (*Felis catus*), non-indigenous birds, cane toad (*Bufo marinus*) and European carp (*Cyprinus carpio*).

The Victorian study included costs for feral deer competition with grazing industries, car collisions, impacts on the timber plantation industry, farm level control costs and reduced recreation use values because of feral deer activity. Our national study is a snapshot annual cost for 2021 which includes a number of these cost components but does not capture the large potential future costs that could occur with increasing feral deer numbers.

Feral deer also have differing impacts across Australia, as deer densities vary, along with the value of agricultural activity they impact. Relatively large production loss values were reported in pockets of South Australia by BDO EconSearch (2022), where high value viticulture and livestock production are impacted by feral deer. The report estimated a state-wide production loss of $36 million in 2022. This study estimated productivity losses at a disaggregated level and the approach accounts for variations in feral deer densities and values of impacted production.

Our study uses average Australia-wide estimates of feral deer-related production losses due to the paucity of impact data at the national level, so is subject to uncertainty. High and low production loss ranges are included to accommodate uncertainty, however, national calculations that account for regional impacts are required for sub-national impacts to be explicitly considered. ABARES are in the process of undertaking such an analysis using results of the latest national pest and weed survey, which will help address data gaps identified in our cost calculations.

The impacts of vertebrate pests on environmental values, such as ecosystem degradation, and losses in biodiversity, have been large cost components of vertebrate pest impact studies. For example, McLeod (2004) estimated that $190 million of the $228 million national annual impacts of foxes across Australia was attributable to biodiversity losses. These types of costs are not included in our feral deer costing report. Feral deer cause significant environmental damage, along with impact water supply, so the omission of these costs undervalues the national cost estimate for 2021 presented in the report.

CONCLUSIONS

It is estimated that feral deer imposed an overall cost of ~$91.3 million per year upon the agricultural industry and the Australian population in general across Australia in 2021. Agricultural losses made up the largest share of this cost (~$69.1 million), while public control expenditure was estimated at ~$17.8 million, motor vehicle impacts involving deer at ~$3.3 million and train impacts involving deer at ~$1.2 million per year. There is considerable uncertainty related to the assumptions upon which these estimates were based, so the economic impact was presented in Table 1 as low-, mean- and high-impact scenario estimations, and the overall annual cost estimate ranged from $45.2 million to $205.8 million in 2021 (Table 1).

Table 1: Estimated annual costs of feral deer in Australia in 2021 ($ million) for low-, mean- and high-impact scenarios.

	Low	Mean	High
Agricultural losses	27.2	69.1	164.0
Motor vehicle – deer collisions	1.1	3.3	13.2
Train – deer collisions	0.8	1.2	2.0
Government management and research	16.1	17.8	26.7
Total	45.2	91.3	205.8

Source: this study.

1 INTRODUCTION

Feral deer are found across a large part of Australia, but there are a series of 'pockets' in which deer populations are most abundant. In these locations, they impact agricultural production, natural ecosystems and biodiversity, and public and private infrastructure. They have been nominated by the Invasive Species Council (2022) as Australia's worst emerging pest animal problem; however, there has been no nationwide costing of the impact of feral deer. The economic impact of feral deer is comprised of management costs (including fencing, trapping, and shooting), agricultural production losses associated with feral deer feeding, damage and competition, and costs of collisions with trains and motor vehicles. The various costs have been quantified and have been presented as ranges, given the considerable uncertainty associated with the key assumptions underpinning the estimations.

1.1 THE NATIONAL DISTRIBUTION AND POPULATION SIZE OF FERAL DEER

Six species of feral deer [sambar deer (*Cervus unicolor*), red deer (*Cervus elaphus*), rusa deer (*Cervus timorensis*), fallow deer (*Dama dama*), chital deer (*Axis axis*) and hog deer (*Axis porcinus*)] have become widespread in Australia, with most feral deer being found in south-eastern Australia. The overall population of feral deer and the area of land that they occupy has been increasing. Feral deer are a protected wildlife species in Victoria and Tasmania for game hunting. Under this status, feral deer (except hog deer, for which culling can be done under permit) can be culled in national parks, or by land managers or their nominees on their property, when deer are causing damage to property or production. In other states and territories, feral deer are treated as pest animals under biosecurity policies and legislation. Davis et al. (2016) list the impact of fire, native vegetation modification, expansion of primary production, climate change, and human population growth as contributing to the increased numbers and expanded distribution. Other contributors also include farmed deer that escaped, or were released, or that were relocated for recreational hunting. The 2016 and potential distributions of feral deer have been mapped and are presented in Figure 2, taken from Davis et al. (2016).

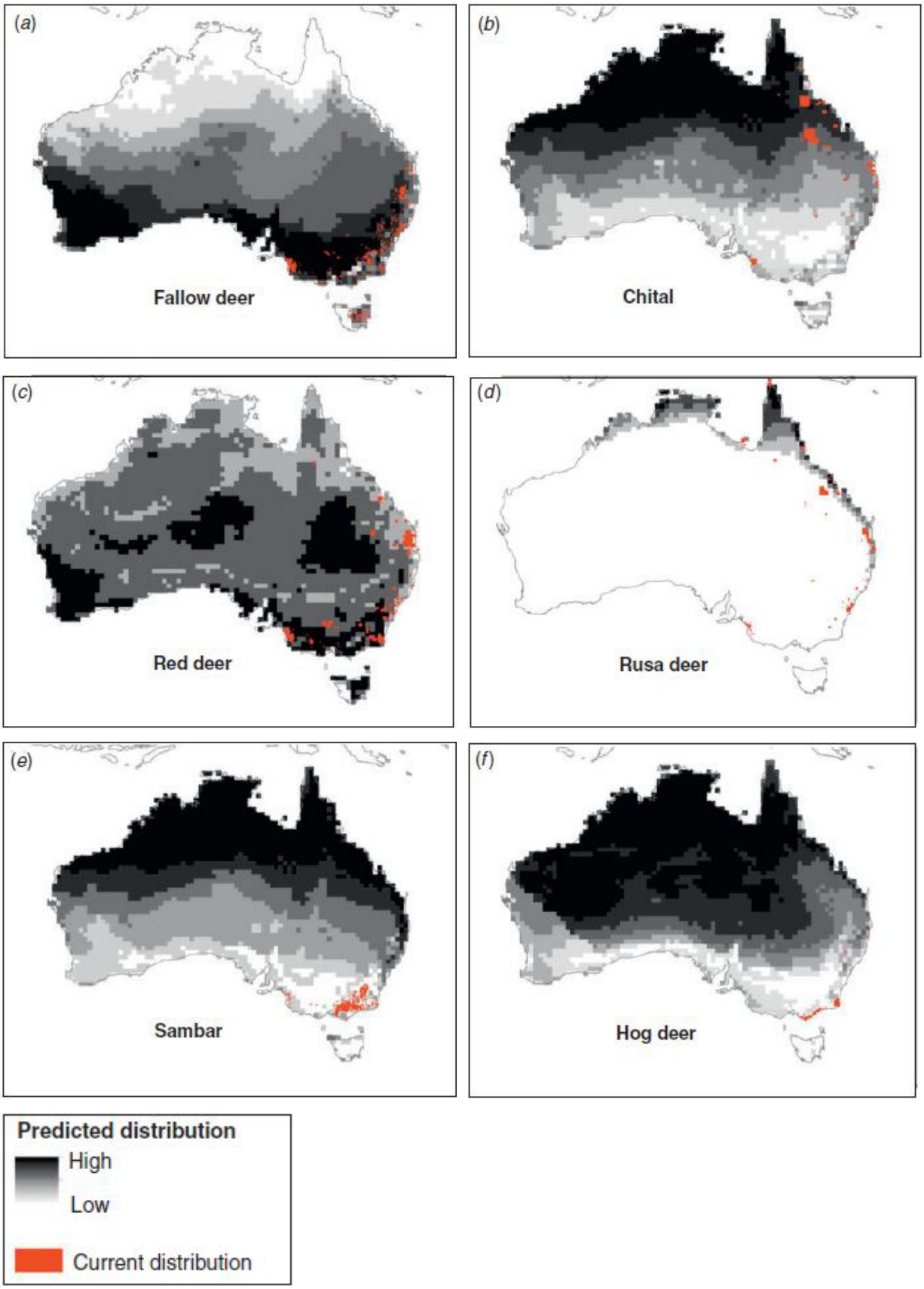

Figure 1: Current and potential distribution maps for the six species of deer in Australia

Source: Davis et al. (2016), Fig. 2, p. 519,. Reproduced, without change, under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International Public License. 'High' indicates many animals seen or sign of animals on more than 80% of searches; 'Low' indicates few or no sightings."

The likely 2022 national population size of feral deer is reported in the draft National Feral Deer Action Plan at between 1-2 million (Government of South Australia 2022). Numbers vary across Australian states and territories.

Mapping of feral deer species' distributions by the NSW Department of Primary Industries (NSW DPI) showed feral deer to be located across 180,443 square kilometres (22%) of NSW in 2020. NSW DPI (2022) have reported that fallow deer are currently the most widespread species in the state, and that they have increased in distribution by 60% between 2016 and 2020, while sambar deer have increased in the north and west and chital deer have shifted from Central West and Western Local Land Services (LLS) regions across NSW. All 11 LLS regions across NSW have identified feral deer as a priority pest in their Regional Strategic Pest Animal Management Plans.

In Victoria, feral deer are found throughout large areas of the State (DELWP 2020) Sambar deer is the most common and widespread species in the state, with a 2015 study estimating the breeding distribution to be 66,915 square kilometres (29% of Victoria's land area) (Forsyth et al 2015). Densities of 15.3 km^2 have been recorded in some locations, such as the Cardinia Creek Catchment (NSW DPI, 2021).

Feral deer are also an issue in Queensland, ACT, Tasmania and South Australia. Feedback from local governments in Queensland [summarised in the Local Government Association of Queensland Ltd (2018) submission to the Federal Government Senate Inquiry into '*The impact of feral deer, pigs and goats in Australia*' (hereafter, the 'senate inquiry 2018')] indicated that 6 of the 10 regions considered feral deer to be a high-priority species for control. The National Parks Association of the ACT (2018) senate inquiry 2018 submission also highlighted concern about the increase in deer numbers. An aerial survey of the Central and North-eastern regions of Tasmania in 2019 estimated the state's deer population to be ~54,000 (Lethbridge et al. 2020). Based on a population growth rate of 11.5%, the Invasive Species Council inferred that there are now up to 100,000 feral fallow deer in Tasmania covering nearly 30% of the state. (Invasive Species Council, 2021). A report by BDO EconSearch (2022) estimates there are 40,000 feral deer in South Australia, mostly concentrated in the south east of the state.

The spread of feral deer is impacting agriculture and the environment, resulting in train and motor vehicle collisions, and requiring farmers and others to implement costly control measures such as fencing and shooting. Davis et al. (2016) noted that data on the diets, energy requirements, distributions and abundance of deer need to be modelled and mapped for the various seasons, locations, landscapes, and species to predict crop and pasture competition impacts. Comprehensive damage data are currently not available, so the impact estimate assumptions in this study rely on expert opinion to supplement the limited data available in the literature.

Studies from the USA indicate that the most economically significant impacts of feral deer are collisions with cars (Drake et al. 2005). In accordance with that, surveys of landholders' perceptions in South Australia ranked "traffic hazard" as the most serious risk that deer pose to human safety (Peacock 2008). The economic impact of collisions with deer in Australia was quantified in our report using incident reports and insurance data.

1.2 COSTING METHOD

Losses in agricultural production for 2021 as a result of feral deer competition and damage have been quantified using the value of agricultural commodities published by the Australian Bureau of Statistics (ABS) (2022) for 2020-2021 for livestock and horticulture, while ABARES (2023) value of Australian plantation data has been used for timber industries. The ABS indicated that valuations involve gross prices being calculated where ownership of the commodity is relinquished by the agricultural industry and this data is collected using the ABS Livestock Products quarterly survey and other surveys.

Loss assumptions (see Table 4) for feral deer competition were applied to industry values of production and are assumed to reflect the net value cost of losses. The assumptions are provided in tables that accompany the impact assessment for the loss–expenditure analysis and in the Appendix (see Table 10). High- and low-production-loss impact assumptions were included in the present study to gauge the sensitivity of production loss costs for each included agricultural industry, given the uncertainty of these loss estimates across the feral deer range.

The feral-deer-control expenditures at the farm level are derived from the results of the ABARES 'Pest Animal and Weed Management Land Manager Survey in 2016 and 2019–reported by Stenekes and Kancans (2021) to gauge pest and weed management practices and impacts. The survey included 8,059 broadacre, horticultural, dairy, and other livestock farmers across 53 of the 56 natural resource management (NRM) regions in Australia. Only farms with a revenue of more than $5,000 were included in the survey sample.

The public sector (at the federal, state, and local council level) directs resources towards feral deer research and control. Public agencies were contacted to obtain public expenditure data, and a list of the people contacted is provided in Table 9. The impact of deer on biodiversity is described qualitatively, but there are limited data available with which to quantify this impact, so biodiversity impacts have not been included in the present cost estimates.

2 AGRICULTURAL PRODUCTION LOSSES AND CONTROL COSTS

The impact of feral deer on agricultural lands has been estimated using a loss–expenditure approach. Farmers loose income through reduced livestock-carrying capacities or reduced horticultural and timber plantation yields because of deer activity. These losses are quantified using assumptions derived from impact studies and expert opinion.

Lindeman and Forsyth (2008) assessed agricultural impacts on farmers who had obtained Authority to Control Wildlife permits between 2002 and 2007 in Victoria. Of the 35 landholders interviewed, 15 provided an estimate of their agricultural impact costs ranging from $200 to $20,000 per farm. The Invasive Species Council conducted a survey of 80 farmers in NE Victoria in 2021 to gauge feral deer cost impacts. The overall costs over 3 years (July 2018 to July 2021) were $12,245 per landowner across 80 respondents (Invasive Species Council, 2023).

In the present study, production loss costs were estimated for sheep, beef, fruit, viticulture, vegetable, and timber plantation industries, then aggregated to the national level using ABS estimates of agricultural industry values. Loss costs were then combined with the expenditures associated with deer control measures, including fencing, trapping, and ground- and helicopter-based shooting by land managers of both public land and private land.

2.1 PROPORTIONS OF AGRICULTURAL INDUSTRIES IMPACTED BY FERAL DEER.

From the results of Stenekes and Kancans (2021) the proportions of farmers citing feral deer as a major problem are presented in Figure 3. It is evident that at least 15% farmers indicated feral deer were a major problem in pockets in North-east Victoria, East Gippsland, South-east NSW, and the Northern Tablelands of NSW. The numbers of cattle and sheep residing in each region were multiplied by the proportion of farmers reporting feral deer as a major problem. It was estimated that 0.5 million cattle and 2 million sheep are stocked in areas in which feral deer are a major problem. These livestock numbers correspond with around 3% of the national beef herd and sheep flock, respectively.

Proportions of agricultural industries assumed to be impacted by feral deer are provided in Table 2. These data indicate that around 3% of livestock production occurs in areas that have major feral deer impacts. There is a high degree of uncertainty about these estimates. The response rate to the survey was around 50%, so the impacts may be overstated; in addition, deer impacts can vary according to the type of agricultural production.

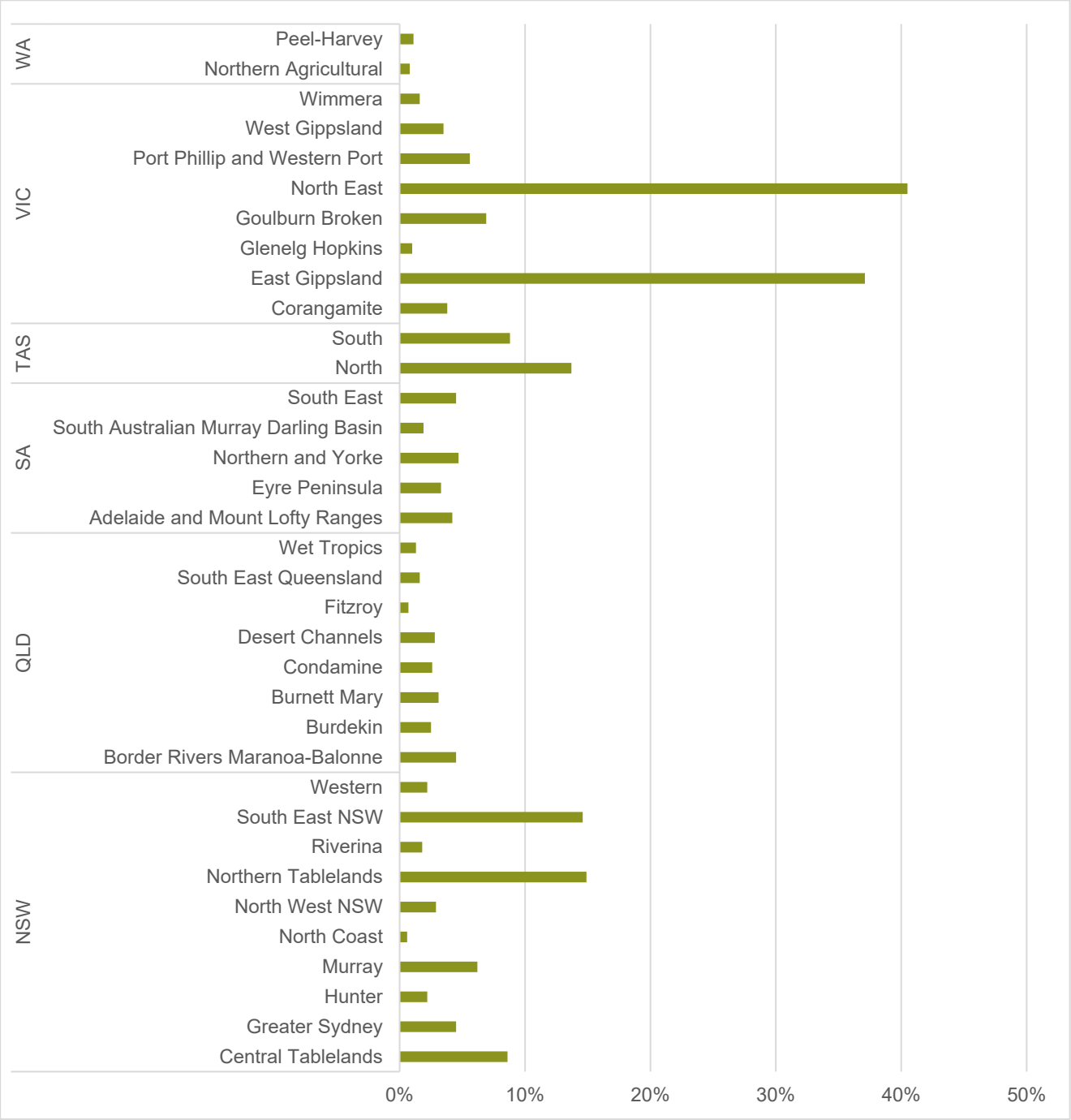

Figure 2: Proportion of respondents to the ABARES Survey 2016–2019 who cited feral deer as a major problem.

Source: Stenekes and Kancans (2021).

Table 2: Proportions of agricultural industries impacted by feral deer and national industry values in 2021.

	Assumed proportion of industry impacted by feral deer (%)	Hectares or head	Receipts per ha/head ($)	Local industry value ($ millions)
Timber plantations [a]	6.0%	1,744,178 ha	$1,092	$1,904
Fruit and nuts [b]	3.0%	227,215 ha	$24,853	$5,647
Viticulture [b]	3.0%	141,479 ha	$12,538	$1,774
Vegetables [b]	3.0%	127,624 ha	$31,642	$4,038
Sheep Meat [b]	3.0%	68,047,402 head	$58	$3,973
Sheep Wool [b]	3.0%	68,047,402 head	$37	$2,517
Beef [b]	3.0%	22,048,333 head	$560	$12,341
Dairy [b]	3.0%	2,382,840 head	$1,967	$4,688
Total				$36,882

[a] Timber plantation for the fiscal year July 2020 – June 2021 (data from ABARES, 2023). b Local values of agricultural industries for the fiscal year July 2020 – June 2021 (data from ABS, 2022a) and hectares used for production July 2020 – June 2021 or livestock at year end for July 2020 – June 2021 (data from ABS, 2022b). NA = not available, ha = hectares.

2.2 ESTIMATION OF LOST PRODUCTION

Production losses are estimated in terms of decrease in the net value of production because of yield losses and reduced carrying capacities due to feral deer. However, there are limited data to support feral deer loss assumptions in Australia.

Stenekes and Kancans (2021) surveyed agricultural land managers to determine the nature of the impacts of pest animals and weeds over the previous 12 months in 2019. Nearly 90% of respondents reported that feral deer were not a problem, but 5% reported that they were a major problem, and a similar percentage reported them to be a minor problem. The farmers were asked to rate how effective the control measures had been at managing the pest.[2] Control was deemed to be less than effective (less than a score of 2) in many regions in which feral deer were thought to be a major problem (see Figure 4). Given the limited effectiveness of the control measures, feral deer are likely to have caused significant production losses in these areas.

[2] Survey question: "How effective do you consider the overall pest animal and weed management actions by all stakeholders in your local area in the past 12 months to have been for the following pests and weeds?" Effectiveness was measured on a scale of 1 = not effective, 2 = a little effective, 3 = moderately effective, and 4 = very effective.

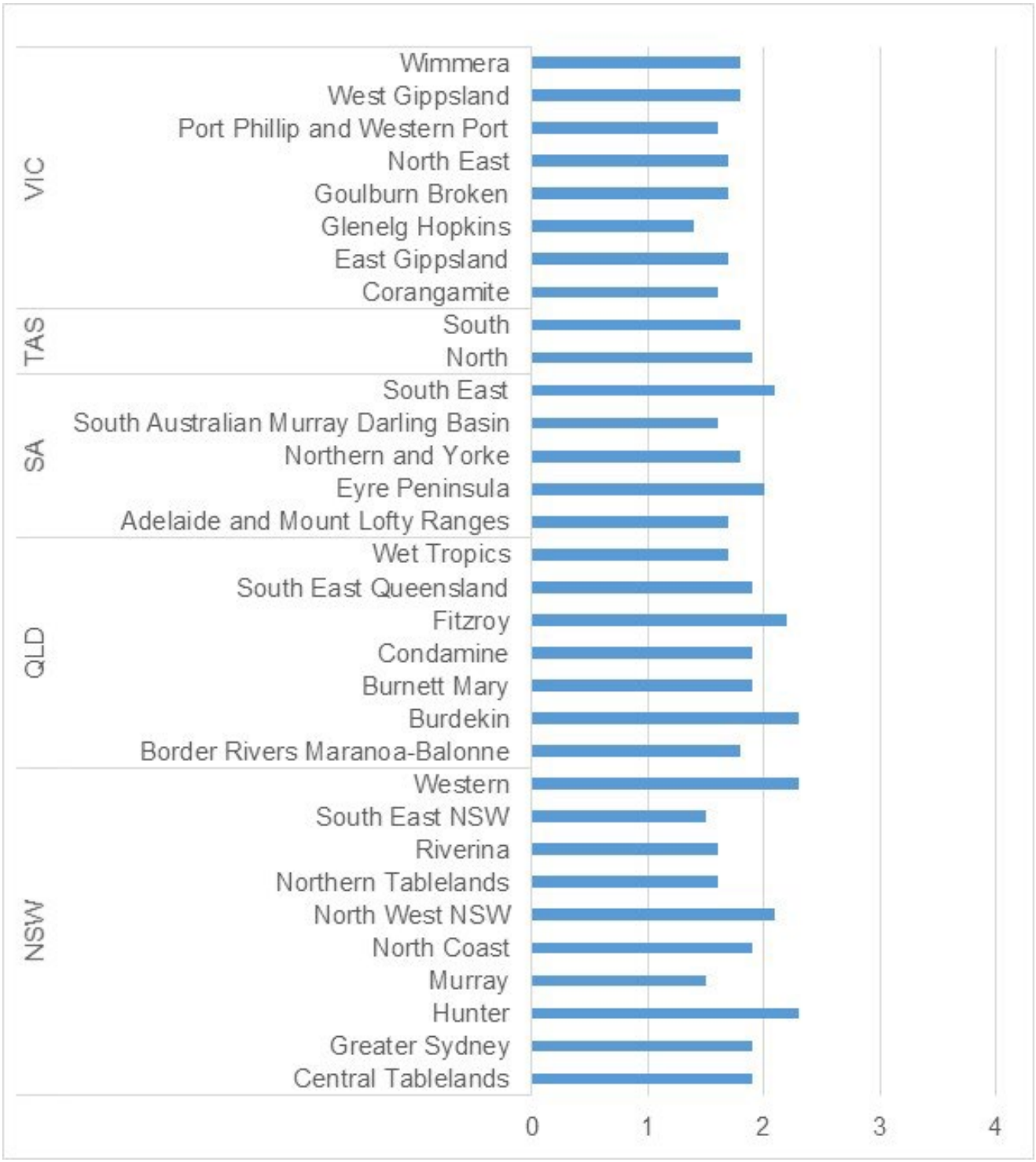

Figure 3: ABARES Survey 2016–2019 respondents' perception of feral deer control effectiveness
Source: Stenekes and Kancans (2021).

The production loss estimates listed in Table 3 were used in the present costing study to quantify feral deer impacts. Estimates are largely based on author estimates derived from limited literature.

Latham et al. (2020) reviewed the nature of deer impacts in New Zealand and international literature. They noted that damage to arable crops by deer in New Zealand was largely limited to being anecdotal or qualitative, but cited research in Hungary in which economic damage to crops by red deer and Eurasian feral pigs averaged around NZ$3.4–5.3 per km^2 per year (Bleier et al. 2012), with arable crops being resistant to damage from feral deer when there were deer densities of less than 0.8 deer harvested per km^2. However, the deer-harvested rate does not provide an accurate assessment of population density (Mysterud et al. 2007; Pettorelli et al. 2007). Thus, the damage function that maps feral deer densities to crop and livestock production loss reductions is unclear.

Not only is a damage relationship across impacted industries lacking, but feral deer densities are not available across Australia. Bengsen et al. (in press) used aerial surveys to estimate deer densities at nine sites in eastern Australia. Their highest estimate was 39 deer per km^2 for a mixed fallow and red deer population in the Liverpool Plains region of NSW. An aerial survey in Tasmania found the average fallow deer population densities across central and north-eastern Tasmania to be 2.7 deer per km^2 (Lethbridge et al. 2020). Broadacre crops have not been included in this costing analysis, given the limited impacts of deer at this density. A landholder survey in South Australia found that the most serious perceived impact of feral deer on properties was “eating fodder” (Natural Resources Management South East Board 2017).

Losses have been quantified for livestock (given the noted impact of fodder competition), and for feral deer damage to timber plantations and high-value horticultural industries. The net value of production losses is estimated at between 2% and 7% of the value of agricultural production in areas in which feral deer is considered a major problem. High- and low-impact estimates were included in Table 3, given the uncertainty around the loss estimates. This uncertainly is also seen in loss impacts for other vertebrate pests.

Table 3: Estimated crop and livestock production lost as a result of deer competition.

Industry	Value of crop and livestock lost to feral deer competition (% of industry local value) in impacted areas			Notes
	Low	Average	High	
Timber plantations	1.0%	2.0%	3.0%	Author assumption derived from Greening Australia Tasmanian tree death data (2016)
Fruit and nuts (not grapes)	2.5%	5.0%	7.5%	Author assumption based on other included industries
Viticulture	3.5%	7.0%	10.5%	Author assumption derived from relatively high deer impact in South Australian study
Vegetables	2.5%	5.0%	7.5%	Author assumption based on other included industries
Sheep Meat	2.5%	5.0%	7.5%	Author assumption based on other included livestock industries
Sheep Wool	2.5%	5.0%	7.5%	Author assumption derived from Frontier Economics (2022) and reviews
Beef	2.5%	5.0%	7.5%	Author assumption derived from Frontier Economics (2022) and reviews
Dairy	2.5%	5.0%	7.5%	Author assumption derived from Frontier Economics (2022) and reviews

Source: this study.

BEEF AND DAIRY CATTLE

There are a range of views about feral deer impacts on grazing industries. Lindeman and Forsyth (2008) surveyed a number of Victorian producers who had obtained permits for deer control. Some believed that the impact of deer on orchards and plantations was likely to be far more important than that of competition for pasture. They noted that feral deer compete with cattle and sheep for pasture, as do wombats, rabbits, and kangaroos. The cattle farmer surveyed considered wombats and kangaroos to be more serious competitors with cattle than sambar deer. Similarly, Latham et al. (2020) indicated that deer damage to pastures is usually localised, citing the study of Putman et al. (2011).

Conversely, media articles such as by Ellicott (2018a, b; 2020) have highlighted opinion that in some areas feral deer can have a serious impact on livestock farming. For example, a farmer in the Snowy Mountains reported lost production of nearly $100,000 a year from cattle competing with deer, with stocking rates being reduced by as much as 67%. This view was reflected in submissions to the senate inquiry 2018. Cattle farmers in the South East region of NSW calculated the pasture competition associated with fallow and sambar deer in their region. They observed a reduction in stocking capacity of up to 50%, with an estimated 200 fallow deer per night on some properties, despite intensive ground shooting over many years (Rowley and Roberts 2018)

The Tallangatta Valley Landcare Group (2018) also calculated the cost of reduced carrying capacity associated with feral deer. Their calculation included a potential profit per Dry Sheep Equivalent (DSE) of $80 per year, one mature breeding sambar deer being equivalent to five DSE per year and a deer density of 50 per km. This translated into an annual loss of $2 million in the Tallangatta Valley alone – which is 35 km long and accommodates 50 farms. One farmer indicated an additional $10,000 per year was used to purchase fodder because of grazing pressure with feral deer.

The prevalence of high-density populations, such as that in the Tallangatta Valley, appears to be limited across the whole of the feral deer range. NSW feral deer distribution mapping reported by NSW DPI (2021) found six deer species across 180,443 km^2 (22% of the state area). In NSW, less than 3% of the state's land area appears to have a relatively high abundance of feral deer[3]: this figure was based on survey results through discussions at survey mapping meetings across LLS regions of NSW and in the Australian Capital Territory (ACT), involving 83 people. The survey findings were reported in terms of sighting activity, rather than densities, so the data could not be used for impact assessment.

In 2015, the breeding distribution of sambar deer was reported as covering 66,915 km^2 (29%) of the Victorian land area (Forsyth et al. (2015). The breeding distributions of fallow deer, red deer, and hog deer in Victoria in 2015 were 21,400 km^2, 3,900 km^2 and 2,336 km^2, respectively (Forsyth et al. 2016). Invasive Species Council analysis of 2020 mapping indicates that feral deer now occupy 37% of the Victorian land area. (Peter Jacobs, personal communication, April 2023).

The Frontier Economics (2022) feral deer in Victoria impact study utilised Tallangatta Valley DSE displacement productivity data and expert opinion to derive grazing industry losses. They assumed that 10% of the 1 million feral deer estimated to be in Victoria in 2022 would on average displace 3 DSEs, valued at $13-34 per DSE. This amounts to an annual cost of around $7 million. Given the local value of grazing industries across Victoria in 2021 was around $5 billion (ABS, 2022b) for wool, sheep meat and beef production, this net loss equates to 0.1% of total Victorian industry value, or 1.4% in the 10% of the industry that is impacted by feral deer.

[3] 'High abundance' was defined as many animals being seen at any time, animals always observed, or significant sign of animals on more than 80% of searches.

The South Australian study of feral deer impacts (BDO EconSearch, 2022) estimated higher net losses as a proportion of industry value. In the absence of data, our report assumes a 5% beef industry net value production decline as an average value for deer impacted areas. A lower bound estimates of 2.5% was included as a sensitivity analysis which is more in line with Victorian grazing industry losses. Relatively higher production loss values were reported in South Australia, which may reflect deer density and the higher value of agricultural production in impacted areas. A higher bound production loss value of 7.5% is included in our study as to reflect this heterogeneity.

It was assumed that feral deer impact 3% of beef grazing industries for our national cost estimates. The 3% proportion was derived from the ABARES pest and weed survey outlined by Stenekes and Kancans (2021). The national cattle population grazing in areas with problematic deer was estimated as a proportion of the Australian herd (See Table 13). A similar proportion of dairy cattle and production losses were included. In our study, the annual feral deer-related production loss costs in 2021 for all agricultural industries were estimated at $55.8 million (see Table 4), with half of that figure related to the beef and sheep industries.

Table 4: National annual production losses due to competition between agriculture and feral deer, 2021

	Proportion of industry impacted by feral deer (%)			**Production losses due to competition with feral deer (% receipts)**			**Industry losses due to competition with feral deer ($ million)**		
	Low	Av.	High	Low	Av.	High	Low	Av.	High
Timber plantations	3.0%	6.0%	9.0%	1.0%	2.0%	3.0%	0.6	2.3	5.1
Fruit and nuts	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	2.1	8.5	19.1
Viticulture	1.5%	3.0%	4.5%	3.5%	7.0%	10.5%	0.9	3.7	8.4
Vegetables	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	1.5	6.1	13.6
Sheep Meat	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	1.5	6.0	13.4
Sheep Wool	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	0.9	3.8	8.5
Beef	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	4.6	18.5	41.6
Dairy	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	1.8	7.0	15.8
Total							**14.0**	**55.8**	**125.6**

Av. = average.

SHEEP INDUSTRIES

Feral deer competition impacts have been estimated for sheep producers. National industry values of sheep meat and wool production in 2021 are presented in Table 2 using ABS (2022) data for 2020-2021. The proportion of sheep estimated to be impacted by deer was estimated by multiplying the proportion of farmers in each region that reported deer to be a major problem in the Stenekes and Kancans (2021) survey by the numbers of sheep in each region at the end of 2021. This calculation presented in Table 13, resulted in 3% of the national flock residing in these areas. Similarly to beef, it has been assumed that feral deer cause a 5% net value reduction in sheep meat and wool production across the deer impacted national flock.

LIVESTOCK DISEASES

Feral deer are a reservoir for a number of livestock diseases. Wildlife Health Australia (2013) indicated that 16 diseases, including hydatid disease and leptospirosis, are carried by feral deer. The Queensland Feral Deer Management Strategy of the Queensland Department of Agriculture, Fisheries and Forestry (2013) identified feral deer as hosts for cattle ticks. Bovine Johne's disease (associated with *Mycobacterium paratuberculosis*) has been found in deer, and deer could also act as a host for foot-and-mouth disease (FMD). The cost of one FMD outbreak in Australia has been estimated at AU$50 billion spread over a decade. Costs related to potential impact through livestock diseases have not been included in the present assessment.

TIMBER PLANTATIONS.

Australia's total timber plantation value in 2021 was around $2 billion (ABARES, 2023) with hardwood plantations accounting for $647 million and softwood plantations $1,258 million. (See Table 5). Tasmanian blue gum (*Eucalyptus globulus*) and shining gum (*E. nitens*) are common hardwood plantation species, and radiata pine (*Pinus radiata*) and southern pines (*P. elliottii* var. *elliottii*, *P. caribaea* var. *hondurensis* and hybrids) for sawlog production from softwood plantations. Softwood plantation production is largest in Victoria and NSW, where feral deer are most prevalent.

Feral deer can cause damage to timber plantations. Lindeman and Forsyth (2008) noted that sambar deer cause damage to radiata pine in New Zealand, citing a study reporting that 74% of 8-year-old trees in one stand showed "moderate to severe levels of damage" (New Zealand Forest Owners Association 2005). Latham et al. (2020) cited studies in Europe in which deer at low densities (2 deer per km^2) were reported to cause little damage to young trees, but tree growth and survival were found to decline when deer densities increased to 3–4.5 deer per km^2 (Holloway 1967; Kraus 1987).

More severe timber production losses have been reported in Australia. Frontier Economics (2022) estimated feral deer impacts in Victoria based on expert feedback and simulation modelling studies conducted in Europe. An annual cost of feral deer of around $20 million is evident for Victoria in 2022 based on 40% of Victorian timber plantations experiencing a 5.5% productivity loss, combined with average log values of 72-$129/$m^3$ and state log production of 9 million cubic metres. The loss estimate was based on the study of Ward (2004) which quantified reductions in sawn logs because of multiple stemming resulting from roe deer browsing in the United Kingdom.

In Tasmania, Greening Australia (2016) indicated they had planted more than 300,000 trees and shrubs in the midlands and Derwent Valley, over an area of 1,100 ha and including the establishment of a tree trial. Deer smashed branches and ringbarked stems, resulting in 1% of snow gums (*Eucalyptus pauciflora*) and 5% of Silver Peppermint Tree (*Eucalyptus tenniramis*) plants being killed. A 2% annual loss across impacted areas was included in our feral deer impact costing study based on the Tasmanian data.

Nation-wide data was not available on which to quantify the distribution of Australian timber plantations impacted by feral deer. The Frontier Economics (2022) analysis assumed 40% of the state's plantations were impacted. Surveys of broadacre and horticultural farmers by ABARES (Stenekes and Kancans 2021) indicated that 41% of farmers in NE Victoria and 37% in East Gippsland felt feral deer were a major problem, however, lower proportions of farmers in other states had this perception. When the proportions of farmers in each region who consider deer to cause major impact was overlaid across the national plantation area, around 6% of the national timber plantation would be categorised as a major impacted area. This proportion was used in our analysis due to a lack of forest industry data. The estimate was subject to sensitivity analysis.

Table 5: Value of timber plantation outputs, 2016–2021

	Units	2015–2016	2016–2017	2017–2018	2018–2019	2019–2020	2020–2021
New South Wales							
Hardwood native	$m	109.5	126.7	128.5	135.3	92.7	62.2
Hardwood plantation	$m	5.1	6.8	21.9	30.7	28.8	32.4
Softwood	$m	343.5	373.6	398.3	348.1	420.9	360.8
Total	$m	458.1	507.1	548.7	514.1	542.4	455.4
Victoria							
Hardwood native	$m	112.0	111.0	103.5	95.6	86.8	90.1
Hardwood plantation	$m	194.3	297.7	262.3	301.6	202.7	154.1
Softwood	$m	292.6	321.2	341.5	336.7	344.3	319.4
Total	$m	598.9	729.9	707.2	733.9	633.8	563.6
Queensland							
Hardwood native	$m	43.3	42.4	39.7	54.1	46.3	48.5
Hardwood plantation	$m	0.9	1.1	0	0	2.7	8.8
Softwood	$m	205.1	225.7	257.6	250.9	221.1	181.9
Total	$m	249.3	269.2	297.3	305	270.1	239.1
Australia							
Hardwood native	$m	370.6	396.1	386.4	382.5	356.5	311.2
Hardwood plantation	$m	705.7	802.2	851.0	969.4	791.2	646.8
Softwood	$m	1193.7	1372.6	1430.4	1405.4	1411.6	1257.5
Total	**$m**	**2270.0**	**2570.9**	**2667.8**	**2757.3**	**2559.2**	**2215.5**

Source: Downham and Gavran (2020) and ABARES (2023)

HORTICULTURE

Lindeman and Forsyth (2008) observed orchards that had received some damage from sambar deer, but they did not attempt to develop a methodology for rapidly assessing the deer impacts on the fruit trees because the damaged trees had been pruned. In the absence of data, a 5% loss in 3% of the growing area was estimated for fruit and vegetable production, excluding grapes. This assumption is derived from limited impacts outlined by Lindeman and Forsyth (2008).

The South Australian feral deer impact study of BDO EconSearch (2022) found the viticulture industry to be particularly impacted. Correspondingly, a higher 7% production loss across 3% of the national industry is included in our analysis for the grape producing industry.

.

Grape production areas outlined in ABS (2022) were overlaid with the proportion of farmers in the ABARES pest and weed survey in 2019 (Stenekes and Kancans, 2021) to determine the proportion of the industry within feral deer impact areas. Around 3% of national grape production areas were estimated to be in deer impacted areas (See Table 13).

AGRICULTURAL LOSSES ACROSS INCLUDED INDUSTRIES

Using the loss–expenditure approach, the annual production loss impact of feral deer on agriculture Australia-wide was estimated to be around $55.8 million per year in 2021. The contributing costs can be seen in Figure 5. It is evident that the beef and sheep industries suffer much of the loss cost

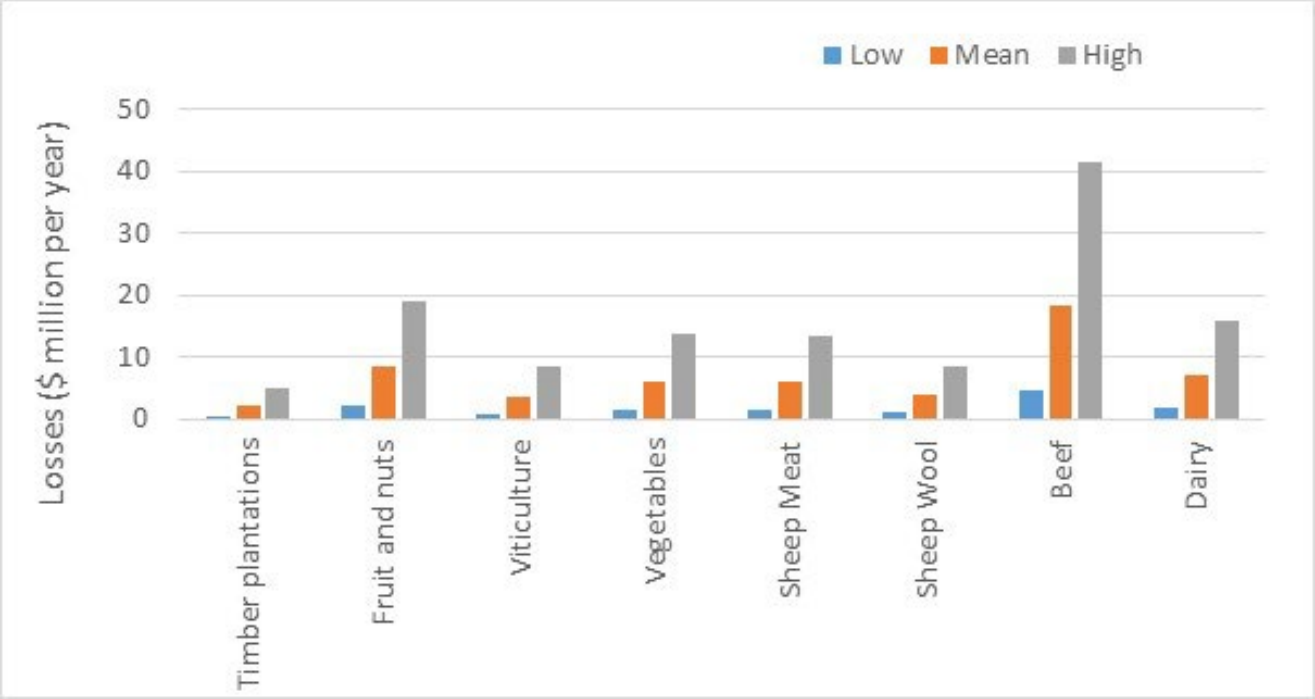

Figure 4: Low, mean, and high estimates of annual production loss due to feral deer, for 2021

Source: this study.

There is a high degree of uncertainty around these estimates, as many of the loss and control assumptions are based on limited data. High- and low-cost scenarios were included to gauge how robust the cost estimates were to changes in the key assumptions. The bounds included were 50% higher and 50% lower costs than the mean estimate. Loss cost estimates vary from $14 million to $126 million for the low- and high-range production loss parameters (see Table 3).

2.3 ESTIMATION OF DEER-CONTROL EXPENDITURE FOR FARMERS

At present, feral deer can be managed through aerial- and ground shooting, trapping, and using exclusion fencing. Previous feral animal studies found control costs to be a significant component of the overall costs. For example, baiting, fencing and shooting were found to be large costs in the McLeod (2004) study, which also included control costs of wild dogs, feral cats, rabbits, and foxes. Fencing and shooting are also major feral deer control costs. The national cost estimates for farm-level deer control for 2020 used in calculations here were based on expenditures reported by Stenekes and Kancans (2021). They are reported as low, mean and high estimates, given the substantial uncertainty in control costs across all feral deer–impacted areas in Australia.

COSTS OF FENCING AND TRAPPING

Davis et al. (2016) noted that exclusion fencing is used to reduce the impacts of feral deer in Australia. However, fencing is usually used at small scales (fencing areas of <100 ha) (Lorimer and Lorimer 2005). Fencing costs have been significant in selected areas. For example, NSW National Parks and Wildlife Service has been helping fund fences and electrical skirting of fences on several properties near Dalgety. More than $200,000 was spent on one property alone. It is unclear how much deer-related fencing has been established in Australia. Lindeman and Forsyth (2008) surveyed farmers had obtained permits in Victoria. Only two of the 35 landholders interviewed had invested in deer-proof fencing to protect tree crops, however anecdotally the number of farmers investing in fences in Victoria and New South Wales has increased since this study, as feral deer numbers have grown and spread.

Trapping is also being used across parts of Australia. Jackson and colleagues (2021) reviewed the methods, costs, and effectiveness of different approaches. The authors interviewed trappers in Queensland and NSW. They found paddock traps could cost $72,000 for 62.5 ha, while corral traps cost about $15 thousand each. They noted that more than 1,000 deer had been trapped since 2011 in these states, with the cost of trapping averaging $1,325 per feral deer.

OTHER COSTS OF DEER CONTROL

Private landholders also spend money controlling deer by shooting, and there appears to be considerable variation in the expenditure. Lindeman and Forsyth (2008) noted that many landholders have agreements with recreational deer hunters, who sometimes provide a deer-hunting service without cost to the farmers. Around 14% of surveyed farmers purchased firearms to control deer, and 12% considered the costs to be negligible. On the other hand, the Southeast NSW Farmers (2018) submission to the senate inquiry 2018 indicated that farmers buy ammunition in $1000 bulk amounts every few months. That submission indicated that the purchase of rifles, spotlighting and shooting equipment was estimated by these farmers to cost their businesses $25,000/year.

Professional shooters are employed on vineyards and strawberry farms in the Yarra Valley, Victoria, at a significant cost to landholders (Friends of the Helmeted Honeyeater 2018). Some professional shooters supply game meat. For example, the Australian Deer Magazine (2020) noted that Feral Game Resources contracts 'harvesters' on the Victoria–NSW border and reported a fluctuating quantity of between 60 and 120 carcasses a week, with $0.25 per kg of venison going to farmers and $2 per kg going to the harvesters. This form of professional control has limited uptake.

NATIONAL COSTS OF DEER CONTROL

Stenekes and Kancans (2021) surveyed producers to gauge farm-level expenditure on deer control. The costs for feral deer management per region are presented in Table 6. It was not specified in the survey whether the expenditure was on shooting or fencing, but both were included within the totals. It was evident that the expenditure per property was highest in Victoria. The North East region and Port Phillip and Western Port region had expenditures of more than $6,000 per property. When numbers of properties, proportions reporting positive expenditure, and average expenditures per property were combined, the annual farm-level cost of feral deer control was estimated to be around $13 million/year when 2019 survey data was inflated to 2021 using ABS (2023) consumer price indexation.

Farm-level costs reported in the survey were expenditures, and they were typically quantified from cash transactions. The value of owner-farmer labour and that of their family was not included in Table 6, but was, however, included in Table 7, using the days of work reported for feral deer management in Stenekes and Kancans (2021) and farm wages published by the Fair Work Ombudsman (2021). With labour included, the estimated national feral-deer-control farm-level cost per year was ~$38 million per year. This value was used as an upper estimate of farm-level control expenditures.

Table 6: Farmer-reported feral annual deer control expenditures, 2019

NRM region	State	$ per property	Percentage of properties reporting expenditure (%)	No. of properties in NRM region	Total $ per NRM spent by farmers on feral deer control
Central Tablelands	NSW	1,655	5	3,717	307,582
Greater Sydney	NSW	529	2	1,985	21,001
Hunter	NSW	760	7	3,463	184,232
Murray	NSW	4,603	8	2,809	1,034,386
Northern Tablelands	NSW	1,085	10	2,976	322,896
Riverina	NSW	810	3	5,165	125,510
Southeast	NSW	1,520	19	4,509	1,302,199
Border Rivers Maranoa–Balonne	QLD	2,944	4	2,535	298,522
Burnett Mary	QLD	669	5	4,841	161,931
Southeast Queensland	QLD	265	4	4,383	46,460
Adelaide and Mount Lofty Ranges	SA	1,003	6	2,945	177,230
Northern and Yorke	SA	923	4	2,484	91,709
Southeast	SA	903	12	2,511	272,092
North	TAS	5,575	13	1,391	1,008,127
South	TAS	1,605	12	930	179,118
East Gippsland	VIC	2,021	28	762	431,201
Goulburn Broken	VIC	2,328	3	4,476	312,604
North East	VIC	6,230	33	2,306	4,740,905
Port Phillip and Western Port	VIC	9,018	5	3,776	1,702,598
West Gippsland	VIC	495	7	1,868	64,726
Total					**12,785,029**

Source: Stenekes and Kancans (2021)

Table 7: Farmer-reported feral deer control labour inputs, 2019

NRM region	State	Total $ per NRM	Days per reporting farm	$ owner and family labour, valued using wage[a]	Total $
Central Tablelands	NSW	307,582	9	1,759	634,484
Greater Sydney	NSW	21,001	0	0	21,001
Hunter	NSW	184,232	0	0	184,232
Murray	NSW	1,034,386	13	2,541	1,605,337
Northern Tablelands	NSW	322,896	6	1,173	671,874
Riverina	NSW	125,510	31	6,059	1,064,296
South East	NSW	1,302,199	17	3,322	4,148,601
Border Rivers Maranoa–Balonne	QLD	298,522	4	782	377,792
Burnett Mary	QLD	161,931	6	1,173	445,769
Southeast Queensland	QLD	46,460	11	2,150	423,370
Adelaide and Mount Lofty Ranges	SA	177,230	24	4,691	1,006,052
Northern and Yorke	SA	91,709	2	391	130,547
South East	SA	272,092	5	977	566,542
North	TAS	1,008,127	22	4,300	1,785,638
South	TAS	179,118	18	3,518	571,718
East Gippsland	VIC	431,201	37	7,231	1,974,066
Goulburn Broken	VIC	312,604	9	1,759	548,797
North East	VIC	4,740,905	23	4,495	8,161,602
Port Phillip and Western Port	VIC	1,702,598	323	63,127	13,620,999
West Gippsland	VIC	64,726	7	1,368	454,629
Total		**12,785,029**	**567**		**38,397,345**

[a]Based on hourly labour rate published by the Fair Work Ombudsman (2021): farm and livestock hand level 8, $25.43 per hour. NRM = Natural Resource Management

.

3 PUBLIC FERAL DEER CONTROL EXPENDITURE

Government expenditure associated with feral deer includes the costs associated with control measures in national parks and local government areas, research, and public infrastructure. Federal, state, and local council agencies (see Table 9) were contacted as part of this costing study to determine annual public expenditures. Cash estimates (for activities such as aerial shooting and contracting) and staff-time equivalents are presented in Table 8.

Feral deer management costs in NSW are borne by LLS regions, NSW DPI, and NSW National Parks and Wildlife Service. The costs largely relate to aerial shooting, fencing, trapping, ground shooting, and research. Game management costs have not been included in the present study, as these would be offset to some extent by licensing revenue. Victoria launched a deer management strategy in late 2020 (Victorian DELWP, 2021). It aims to be a "long term coordinated plan to control feral deer numbers and reduce the threat they pose to the environment, farming, public safety and Aboriginal cultural heritage", with an initial $1 million allocated to manage deer in the outer northern and eastern suburbs of Melbourne. [4] The plan launch was followed by a funding announcement of $18.25 million over four years.

Feral deer represent a potential threat to a number of State and Commonwealth managed national parks, and a variety of deer control efforts have been deployed, particularly in national parks. For example, the Invasive Species Council (2021) described a project in the Bogong High Plains in Victoria's Alpine National Park in which fences have been established to protect a 5-ha enclosure in a small catchment The fencing was estimated to cost $50 per metre, and it has ongoing maintenance costs, plus the cost of dropping sections of the fence each year before the first snowfall and then re-instating them after the snow has melted. Where the data were available, state national park expenditures have been included in Table 8.

Various feral deer management activities are funded at the local council level. Background information about some of these programs was presented to the senate inquiry 2018. The Local Government Association of Queensland Ltd senate submission (2018) to the senate inquiry 2018 noted that the resident feral rusa deer population had originated from escaped farmed deer, and that the cost to council to remove the deer population would be more than $100,000.

In the Wollongong Local Government Area, NSW, it was estimated that funding of $400,000 per year would be required for deer control (Wollongong City Council 2018), including for ground control operations and a funded program coordinator. It was proposed that at least 50% of this should be provided by state or federal government. In addition to NSW local council costs, costs have been provided by Queensland councils.

[4] https://www.premier.vic.gov.au/new-deer-control-strategy-victoria. Accessed 23 January 2022.

Table 8: Public feral deer expenditure per year

Jurisdiction	Low, $million/ year	Mean, $million /year	High, $million/ year	Notes
NSW				
Local Land Services (LLS), NSW Department of Primary Industries (DPI), NSW National Parks and Ferallife Service	4.7	5.7	6.7	Mainly aerial shooting, trapping, some ground shooting, possibly fencing and research. Helicopter operating costs are a large expenditure item. The numbers of full-time equivalent staff were provided during discussions with the people listed in Table 9.
QLD				
State department and local councils	1.0	1.7	2.0	Costs include Queensland Department of Agriculture and Fisheries (QDAF) expenditure on deer research and the costs of research staff (Control is also undertaken at the council level. Costs are included for City of Gold Coast, Sunshine Coast Regional Council, Moreton Bay Regional Council, and Brisbane City Council, using an average cost per council per year derived from data provided during discussions with the people listed in Table 9.
Victoria				
Parks Victoria, Melbourne Water and the Department of Environment, Land, Water and Planning (DELWP)	5.4	5.4	10.0	Recurrent expenditure of deer control for Parks Victoria, DELWP and Melbourne Water are estimated to be around $5.4 million per year. Support from the Bushfire Biodiversity Recovery Response that has been allocated for deer control and a carry-forward fund from the Biodiversity Response Plan are substantial, but have subset provisions. An upper estimate for this funding has been estimated at $10 million
Other (SA, ACT and Tasmania)				
State departments	3.0	3.0	3.0	Costs are included for Tasmanian, ACT and SA staff dedicated to deer management.

Jurisdiction	Low, $million/ year	Mean, $million /year	High, $million/ year	Notes
Federal				
Commonwealth research grants and partner commitments	2.0	2.0	5.0	Over 5 years, around $8 million has been committed or spent on feral deer management and research, including Commonwealth investment in CISS projects dealing with deer research and extension (~$3.3 million), $0.4 million for feral deer control in Tasmania, member investments (largely by state agencies) (~$4.6 million) and third-party investment (largely by local governments and universities) (~$0.33 million). A total mean annual expenditure estimates of ~$2 million is reported here for the most recent year.
Total	**16.1**	**17.8**	**26.7**	

There are limited data available on how much state and federal agencies are spending on deer research. Ellicott reported in *The Land* (2020) that at least $20 million has been allocated to feral deer research over the next 5 years, or around $4 million per year. Federal expenditure on deer management is delivered through funding for national science programs. For example, the National Environmental Science Program (NESP) supports environment and climate science projects with funding of $145 million (from 2015 to 2021) across six environmental research hubs. Funding is matched with cash or in-kind co-contributions from the hubs. The Threatened Species Recovery Hub and the Northern Australia Environmental Resources Hub are delivering projects related to feral deer (Australian Department of the Environment and Energy, 2018). Federal expenditure of $2 million per year is included for research. The total national public deer expenditure is estimated to be ~$18 million per year.

4 COSTS OF MOTOR VEHICLE – DEER COLLISIONS

The costs of deer collisions with motor vehicles have been estimated in the USA and the UK. The Wisconsin Department of Transportation in the USA (2020) reported that nearly 7,000 deer–vehicle collisions occur in the state per year. The average hit in 2018 was estimated as costing between $2,500 and $6,000, as deer "commonly take out the hood, grill, air conditioning condenser, the radiator, fan assembly, and front inner structure components." State Farm Insurance reported the average cost for hitting a deer in 2018 at US$4,341.

In the UK, it is estimated that there are more than 450 deer – motor vehicle collisions a year involving human injury, including 10–20 fatal collisions. In Scotland, the number of deer – motor vehicle collisions involving human injury was ~120 per year, and a costing study for 2016 estimated an economic impact of ~£13.8 million (Scottish Deer Working Group, 2019). Langbein et al (2011) evaluated English road accident data for 2007–2010 and estimated that deer were associated with 348 road accidents per year involving injury. The economic cost of 350 human injuries resulting from collisions with deer has been calculated at £24 million per year in England (Putman 2012).

There are limited data relating to the number of deer-related motor vehicle collisions in Australia. The Wollongong and Lake Illawarra police command recorded 107 motor vehicle – deer accidents (~8 per year) during the 13-year period 2005 and 2017, with 90 rated as 'serious', including 28 resulting in injuries and 1 fatality. The Illawarra suburbs of Helensburgh and Otford recorded the greatest number of major collisions between motorists and feral deer over the past 13 years, including 1 fatality in 2012 (Ellicott 2018b). The actual number of the collisions may be higher. For example, the First-Person Consulting Evaluation of the Northern Illawarra Feral Deer Management Program (2016) surveyed urban residents of this region in 2012 and 2014, and approximately 30% of respondents reported having experienced a near miss and approximately 5% had collided with a deer.

Page et al. (2017) cited a survey of landholders' perceptions of deer impacts in South Australia, in which respondents ranked "traffic hazard" as the most serious risk that deer pose to human safety (Peacock 2008). The number of deer hit by cars each year in Victoria increased in 3 of the 4 years from 2011 to 2015. Australia-wide, collisions with animals have been estimated to account for ~5% of fatal car accidents (Budget Direct 2019). Kangaroo and wallaby collisions are thought to comprise ~90% of these. AAMI (2019) car accident data indicated that there were 7,992 kangaroo collision claims in 2019 (83% of all animal collisions); ~152 claims related to collisions with deer. The Bureau of Transport Economics (2000) estimated the cost per collision with a deer at from $1.65 million for a fatality to $5,808 for a minor incident. Royal Automobile Club of Victoria insurance data in Victoria was cited by McLeod (2004) as having processed ~$2 million worth of claims across 1,000 animal incidents per year, i.e., ~$2000 per collision.

The Frontier Economics (2022) study calculated the costs of car collisions with deer in Victoria. The authors used Royal Automobile Club of Victoria data which indicated there were around 87 car accidents associated with feral deer in 2016. The costs per crash were estimated from Australian Transport Assessment and Planning (2013) data which suggested a repair cost of $11,000 for each serious incident. For the purposes of our national economic impact study, an average per deer incident cost of $11,000 has been assumed. A figure of 300 deer-related collisions per year Australia-wide has been used in the present economic impact calculation, i.e., approximately three times the number estimated in Victoria using Royal Automobile Club of Victoria data. The aggregate cost of this component was thus estimated to be ~$3.3 million per year.

5 COSTS OF PROPERTY DAMAGE

The First-Person Consulting Evaluation (2016) of the Northern Illawarra Feral Deer Management Program found that many urban and rural residents had reported property damage due to deer. They noted that around half of the rural respondents annually had property or infrastructure damage due to feral deer, and that the value of damage due to deer for urban respondents varied from less than $50 to more than $5,000 per year. The mean damage was $354 per urban respondent in 2012 and $255 per respondent in 2014. The mean damage reported by the rural resident's subsection of the respondents, was $578 per respondent in 2014 and $1780 per respondent in 2013. The increased costs for this subsection were largely a result of increased fencing costs. These costs were included earlier in the cost assessment as part of the farm control expenditure section.

6 COSTS OF TRAIN-DEER COLLISIONS

Deer collisions have an impact on rail networks. The First-Person Consulting Evaluation (2016) of the Northern Illawarra Feral Deer Management Program reported that train collisions with deer in that rail corridor cost in the order of $145,000 for incident callouts per year and ~$242,000 for the economic costs of delays.[5] Sydney Trains indicated to ABC Illawarra (2017) that there had been more than 30 collisions involving deer moving into the rail corridor over the past 12 months, with 24 of them in the Illawarra region. Around $1 million was spent on fencing to prevent deer moving across tracks on the south-coast rail line. Since the 2010–2011 fiscal year, over 212 deer have been struck by trains in the Northern Illawarra region. The Yarra Ranges Council's submission to the senate inquiry 2018 noted that the costs of deer impact on the Sydney Railway were estimated at over $1 million per year. In the present assessment, the NSW cost estimate of $0.6 million[6] per year has been doubled to yield a national base estimate of $1.2 million per year.

[5] Data supplied by Sydney Trains in an unpublished report: "2015 Draft Illawarra Deer Management Program Business Matrix".

[6] This figure assumes that $1 million in fencing is replaced every 5 years.

8 ENVIRONMENTAL IMPACTS

eral deer can contribute to degradation of native vegetation, wallow formation, streambank erosion, facilitation of weed spread, and competition with native herbivores (Hampton and Davis, 2020). Burns et al. (2021) noted there has been limited research assessing the impacts of deer, particularly in threatened ecological communities. Davis et al. (2008) and Forsyth and Davis (2011) noted that the potential range overlap between native herbivores and deer is high, but that there was limited demonstrated evidence for competition for the same resources. The reviews highlighted a study by Pedersen et al. (2014), which showed a negative correlation between the abundance of small mammal species and rusa deer.

Deer are large herbivores and consume relatively large amounts of vegetation. Moriarty (2004) examined the rumen contents of rusa deer in Royal National Park (NSW) and estimated that the deer population there (nearly 3,000 in 2001) consumed 36 million litres of vegetation per year, including 155 native plant species. The senate inquiry 2018 received a submission from the Friends of the Waite Conservation Reserve (2018). The Waite Conservation Reserve comprises 121 ha of Grey Box (*Eucalyptus microcarpa*) Grassy Woodland. The submission indicated that, in the reserve, deer had killed or severely damaged many sapling trees, including saplings of Drooping Sheoak (*Allocasuarina verticillata*), Native Cherry (*Exocarpos cupressiformis*), Golden Wattle (*Acacia pycnantha*) and Sticky Hopbush (*Dodonaea viscosa*). Most damage was a result of rubbing or thrashing by deer, which killed plants by ringbarking. The most serious impact of the deer there, however, was thought to result from the dispersal of weed seeds. A further adverse environmental impact of deer relates to their hard hoofs. Sambar deer wallows (and trampling) have been observed in alpine mossbeds, which are particularly sensitive to damage (Tolsma 2009).

9 CONCLUSION

Feral deer are estimated to impose a cost of ~$91.3 million per year across Australia in 2021. This total annual cost estimate includes control costs and production losses for agricultural industries (~$69.1 million), public control expenditure (~$18 million), deer – motor vehicle collisions (~$3.3 million) and deer–train collisions ($~1.2 million). The inclusion of low- and high-impact assumptions generates a cost range of $45 million to $206 million per year.

A range of studies have been conducted to estimate the costs associated with feral pests. Bomford and Hart (2002) estimated the national agricultural losses, and research and management costs associated with key introduced vertebrate pests to total ~$500 million per year, with rabbits (~$225 million) and feral pigs (~$107 million) representing approximately two-thirds of the total cost of 10 major pests.[7]

The impacts of rabbits were reviewed by Fleming et al. (2002) and Croft et al. (2002), and grazing industry productivity losses of between 2% and 3% were included in the national costing by McLeod (2004). The production losses varied between higher rainfall and more arid areas, due to variations in the rabbit densities and in the carrying capacities of the agricultural ecosystems. McLeod (2004) estimated the national annual economic costs of vertebrate pests to be ~$374 million per year, with rabbits (~$113 million) and feral pigs (~$107 million) causing the most substantial costs. Gong et al. (2009) concluded that rabbits were responsible for the largest annual cost (~$206 million) in Australia, followed by feral dogs (~$49 million) and foxes (~$21 million). McLeod (2016)

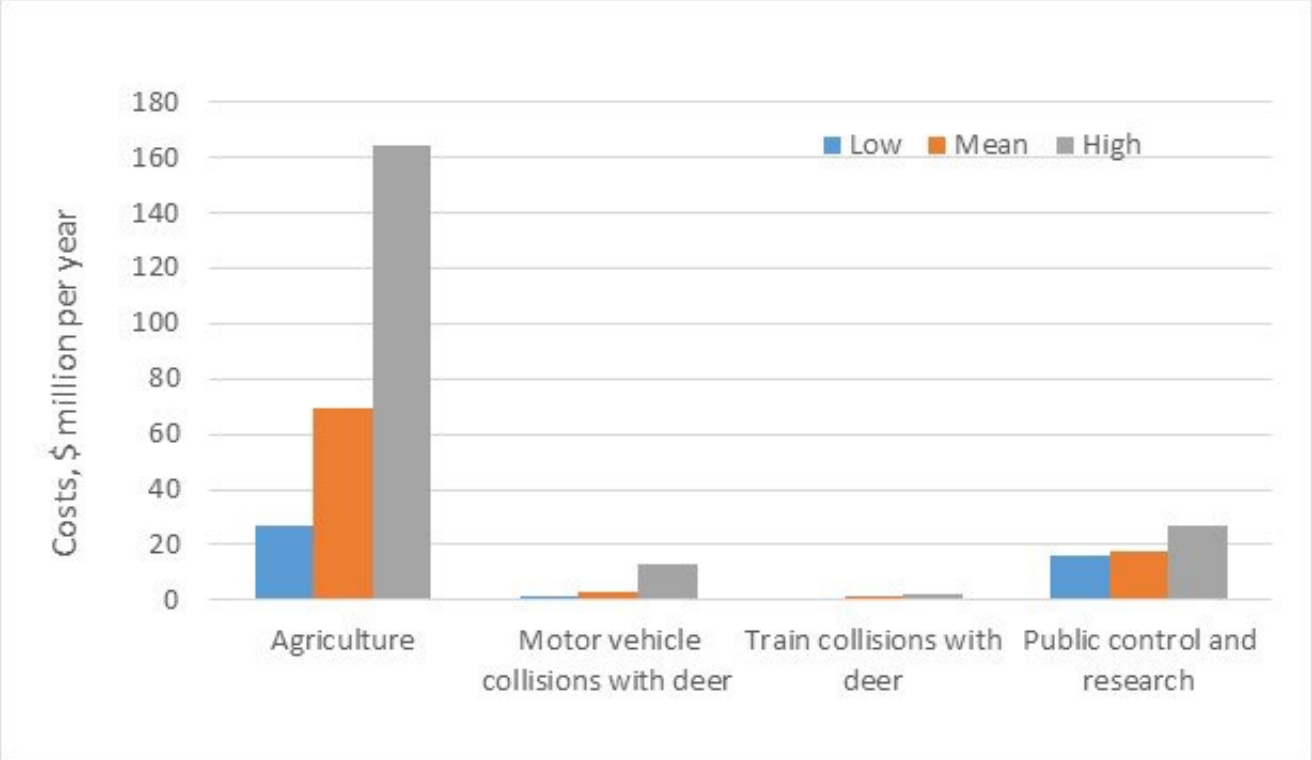

Figure 5: The estimated costs of annual agricultural production loss, collisions, public control measures and research expenditure related to deer for 2021.

Source: this study.

[7] European rabbit, red fox, feral goat, feral pig, house mouse, feral dog and dingo, feral cat, non-indigenous birds, cane toad and European carp.

calculated these annual costs had increased for rabbits ($217 million), wild dogs ($89 million) and foxes ($28 million) in 2013-14.

Sloane et al. (1988) indicated that kangaroos were responsible for the largest grazing competition that impacts the wool industry. Of the estimated total $304 million per year vertebrate pest cost impact, kangaroos were deemed to be responsible for $200 million per year. Grazing competition between sheep and kangaroos is likely to be most pronounced in drier areas, which led McLeod (2004) to assume that in drier areas there was a 1% reduced carrying capacity from kangaroos in the drier areas but 0.5% in the wetter wheat–sheep regions.

These studies highlight that vertebrate pest impacts vary at a sub-national level. Our study used national averages to estimate production losses due to the paucity of data across all regions where feral deer cause impact. Studies which investigate regional deer densities, sub-national values of production that are impacted and the level of damage as a function of deer density are required to refine estimates in our national cost study.

This report has estimated that feral deer are responsible for an annual national cost of ~$91.3 million per year, which indicates the economic significance of the taxa relative to other vertebrate pests. Deer distributions and densities are expanding; hence, the calculated 2021 cost is likely to increase over the next decade unless effective management programs are deployed. Furthermore, a large impact of feral deer is that on environmental value. This cost component was not considered in our analysis. Research is required to quantify this value, which is likely to be substantial

9 REFERENCES

AAMI. (2019). AAMI animal car accidents data 2019. https://www.aami.com.au/aami-informed/on-the-road/safe-driving/aami-reveals-peak-periods-for-animal-collisions.html. Accessed 23 January 2022.

ABC Illawarra. (2017). Feral deer problem on the rise in NSW as calls grow to declare the animal a pest https://www.abc.net.au/news/2017-08-01/feral-deer-on-rise-nsw-calls-to-declare-pest/8741434. Accessed 23 January 2022.

Australian Bureau of Agricultural and Resource Economics (ABARES). (2023). Australian forest and wood products statistics, March and June quarters 2022, https://www.agriculture.gov.au/abares/research-topics/forests/forest-economics/forest-wood-products-statistics. Accessed 28 March 2023.

Australian Bureau of Statistics (ABS). (2022a). Value of agricultural commodities produced, Australia, 2020–21. https://www.abs.gov.au/statistics/industry/agriculture/value-agricultural-commodities-produced-australia/2020-21, Accessed 28 March 2023.

Australian Bureau of Statistics (ABS). (2022b). Agricultural commodities, Australia, 2020–21. https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/2020-21, Accessed 28 March 2023.

Australian Bureau of Statistics (ABS). (2023). Consumer Price Index, Australia. https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/consumer-price-index-australia/jun-2022, Accessed 28 March 2023

Australian Deer Magazine. (2020). A situation analysis of commercial feral deer harvesting in Australia with reference to New Zealand. Vol. 45, No. 5, September/October 2020.

Australian Department of the Environment and Energy. (2018). Submission 2, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022.

Australian Transport Assessment and Planning (2013), Serious and other industry per crash costs, https://www.atap.gov.au/parameter-values/road-transport/4-crash-costs. Accessed 23 March 2023

BDO EconSearch (2022). Feral Deer Control Economic Analysis, A Report for Primary Industries and Regions SA, 1 April 2022, https://pir.sa.gov.au/__data/assets/pdf_file/0003/422175/feral-deer-control-economic-analysis.pdf. Accessed 28 March 2023.

Bengsen, A.J., Forsyth, D.M., Pople, A.R., Brennan, M., Amos, M., Leeson, M., Cox, T.E., Gray, B., Orgill, O., Hampton, J.O., Crittle, T. and Haebich, K. In Press. Effectiveness and costs of helicopter-based shooting of deer. *Wildlife Research* 2022.

Bleier, N., Lehoczki, R., Újváry, D., Szemethy, L. and Csányi, S. (2012). Relationships between feral ungulates density and crop damage in Hungary. *Acta Theriologica* 57: 351–359.

Bomford, M. and Hart, Q. (2002). Non-indigenous vertebrates in Australia. In: Pimentel, D. (Ed.) *Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal, and Microbe Species* (pp. 25–44). CRC Press, Boca Raton, FL, USA. https://pestsmart.org.au/wp-content/uploads/sites/3/2020/06/Non-Indigenous-Vertebrates-in-Australia.pdf. Accessed 23 January 2022.

Budget Direct. (2019). Kangaroo car accident statistics. https://www.budgetdirect.com.au/car-insurance/research/kangaroo-car-accident-statistics.html. Accessed 23 January 2022.

Bureau of Transport Economics. (2000). Road crash costs in Australia. Report 102. Bureau of Transport Economics, Canberra, ACT, Australia.

Burns, H., Gibbons, P. and Claridge, A. (2021). Quantifying variations in browsing pressure caused by feral deer for a range of threatened ecological communities and plant growth forms. *Austral Ecology* 46: 1156–1169.

Croft, J.D., Fleming, P.J.S. and van de Ven, R. (2002). The impact of rabbits on a grazing system in eastern NSW 1. Ground cover and pastures. *Australian Journal of Experimental Agriculture* 2002: 909–916.

Davis, N.E., Bennett, A., Forsyth, D.M., Bowman, D.M.J.S., Lefroy, E.C., Wood, S.W., Woolnough, A.P., West, P., Hampton, J.O. and Johnson, C.N. (2016). A systematic review of the impacts and management of introduced deer (family Cervidae) in Australia. *Wildlife Research* 43 (6): 515–532.

Davis, N.E., Coulson, G. and Forsyth, D.M. (2008). Diets of native and introduced mammalian herbivores in shrub-encroached grassy woodland, south-eastern Australia. *Wildlife Research* 35: 684–694.

DELWP (2020). Victorian Deer Control Strategy, https://www.environment.vic.gov.au/__data/assets/pdf_file/0031/528817/FINALVicDeerControlStrategy-June-2021.pdf. Accessed 10th April 2023

Downham, R. and Gavran, M. (2020). Australian plantation statistics 2020 update, ABARES, Canberra, ACT, Australia. Accessed 23 January 2022.

Drake, D., Paulin, J.B., Curtis, P.D., Decker, D.J. and San Julian, G.J. (2005). Assessment of negative economic impacts from deer in the Northeastern United States. *Journal of Extension*, https://joe.org/joe/2005february/rb5.php 6. Accessed 23 January 2022.

Ellicott, J. (2018a). Deer cost Snowy cattle farmer $100,000 a year in lost production. *The Land* 30 November 2018. https://www.theland.com.au/story/5786828/fences-helping-win-feral-war-but-farms-still-suffer. Accessed 23 January 2022.

Ellicott, J. (2018b) New police data shows serious number of collisions with deer. *The Land* 20 August 2018. https://www.theland.com.au/story/5594725/deer-protection-puts-motorists-at-risk/. Accessed 23 January 2022.

Ellicott, J. (2020). New detailed mapping shows spread of feral deer in many areas. *The Land* 12 November 2020. https://www.theland.com.au/story/7009771/mapped-now-feral-deer-need-to-be-trapped/. Accessed 23 January 2022.

Fair Work Ombudsman. (2021). Farm and livestock hand level 8, $25.43 per hour. Pay Guide - Pastoral Award, [MA000035], Published 26 November 2021. https://portal.fairwork.gov.au/ArticleDocuments/872/pastoral-award-ma000035-pay-guide.pdf.aspx. Accessed 23 January 2022.

First Person Consulting. (2016). Evaluation of the Northern Illawarra Feral Deer Management Program – Report. https://www.aph.gov.au/DocumentStore.ashx?id=20a0bb4c-7c92-4a91-b159-5fe01ec7e512&subId=665019. Accessed 23 January 2022.

Fleming, P.J.S., Croft, J.D. and Nicol, H.I. (2002). The impact of rabbits on a grazing system in eastern NSW 2. Sheep production. *Australian Journal of Experimental Agriculture* 2002: 917–923.

Forsyth, D.M. and Davis, N.E. (2011). Diets of non-native deer in Australia estimated by macroscopic versus microhistological rumen analysis. *Journal of Wildlife Management* 75: 1488–1497.

Forsyth, D.M., Stamation, K. and Woodford, L. (2015). Distributions of sambar deer, rusa deer and sika deer in Victoria. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the

Biosecurity Branch, Department of Economic Development, Jobs, Transport and Resources. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Friends of the Helmeted Honeyeater. (2018). Submission 11, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022.

Frontier Economics (2022). Counting the doe: an analysis of the economic, social & environmental cost of feral deer in Victoria. Report for the Invasive Species Council, 10 June 2022.

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

Greening Australia. (2016). Submission to Legislative Council Sessional Committee Government Administration: Feral fallow deer. https://www.parliament.tas.gov.au/ctee/council/Submissions/GAA%20Deer/49%20Greening%20Australia,%20Tasmania.pdf. Accessed 23 January 2022.

Government of South Australia (2022) Draft National Feral Deer Action Plan: 2022-27. https://feraldeerplan.org.au/wp-content/uploads/2022/12/NationalFeralDeer_ActionPlan.pdf, Accessed 10th April 2023.

Hampton, J.O. and Davis, N.E. (2020). Impacts of introduced deer in Victoria. *The Victorian Naturalist,* 137(6): 276–281.

Holloway, C.W. (1967). The effect of red deer and other animals on naturally regenerated Scots pine. PhD thesis, University of Abeedeen, Aberdeen, UK.

Invasive Species Council. (2017). Feral deer could occupy nearly all of Australia, Feral Herald, August 22, 2017. https://invasives.org.au/blog/australia-occupy-feral-deer/. Accessed 23 January 2022.

Invasive Species Council. (2021). High cost of fencing out ferals in Australia's Alps. https://invasives.org.au/blog/high-cost-of-fencing-out-ferals-in-australias-alps. Accessed 23 January 2022.

Invasive Species Council (2021). Feral Deer Control: A Strategy for Tasmania. https://invasives.org.au/wp-content/uploads/2021/08/Feral-Deer-Control-A-Strategy-for-Tasmania-2021.pdf. Accessed 10 April 2022

Invasive Species Council. (2022). Feral deer. https://invasives.org.au/our-work/feral-animals/feral-deer/. Accessed 23 January 2022.

Invasive Species Council. (2023). The Impact of Feral Deer Survey of Landowners in North East Victoria. Unpublished Report provided by the Invasive Species Council.

Jackson, S.M., Bengsen, A., Forsyth, D.M. and Comte, S. (2021). A review of the methods used to trap feral deer in New South Wales and Queensland. Vertebrate Pest Research Unit, Department of Primary Industries, Orange, New South Wales, Australia.

Kraus, P. (1987). The use of vegetation by red deer as an indicator of their population density. *Zeitschrift fur Jagdwissenschaft* 33: 42–59.

Langbein, J. (2011). Monitoring deer vehicle collisions in England to end 2010. Final report to Highways Agency, Deer Initiative, Wrexham. https://www.researchgate.net/publication/284170158_Monitoring_Deer_vehicle_collisions_in_England_to_end_2010. Accessed 16 January 2022.

Latham, A.D.M., Latham, M.C., Norbury, G.L., Forsyth, D.M. and Warburton, B. (2020). A review of the damage caused by invasive feral mammalian herbivores to primary production in New Zealand. *New Zealand Journal of Zoology* 47: 20–52. doi:

Lethbridge, M.R., Stead, M.G., Wells, C. and Shute, E.R. (2020). Baseline aerial survey of fallow deer and forester kangaroo populations, Tasmania. Report to Tasmanian Department of Primary Industries, Parks, Water and Environment.

Lindeman, M.J. and Forsyth, D.M. (2008). Agricultural impacts of feral deer in Victoria. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Melbourne, Australia.

Local Government Association of Queensland Ltd. (2018). Submission 15, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019 https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022

Lorimer, G.S. and Lorimer, D.J. (2005). The conservation status of the shiny nematolepis (*Nematolepis wilsonii*) in 2005. Biosphere, Melbourne, Australia.

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

McLeod, R. (2016). Cost of Pest Animals in NSW and Australia, 2013-14. Centre for Invasive Species Solutions, Canberra, ACT, Australia. https://invasives.com.au/wp-content/uploads/2019/02/Cost-of-Pest-Animals-in-NSW-and-Aus-2013-14-web-HR.pdf. Accessed 10 April 2023

Moloney, P. and Hampton, J. (2019). Estimates of the 2019 deer harvest in Victoria: Results from surveys of Victorian Game Licence holders in 2019. Game Management Authority, Melbourne, Australia. https://www.gma.vic.gov.au/__data/assets/pdf_file/0019/606700/Victorian-deer-harvest-Estimates-2019.pdf. Accessed 23 January 2022.

Moriarty, A. J. (2004). Ecology and environmental impact of Javan rusa deer (*Cervus timorensis russa*) in the Royal National Park. PhD Thesis, University of Western Sydney.

Mysterud, A., Meisingset, E.L., Veiberg, V., Langvatn, R., Solberg, E.J., Loe, L.E. and Stenseth, N.C. (2007). Monitoring population size of red deer *Cervus elaphus*: an evaluation of two types of census data from Norway. *Wildlife Biology* 13(3): 285–298.

National Parks Association of the ACT. (2018). Submission 28, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022.

Natural Resources Southeast Board. (2017). 'Landholder Survey on Feral Deer' of landholders in the South East in 2017. South Australian Department of Environment, Water and Natural Resources, Adelaide, South Australia.

New Zealand Forest Owners Association. (2005). New Zealand Forest Owners Association submission on future sambar deer management, October 2005.

NSW DPI. (2021). Distribution maps for vertebrate pests https://www.dpi.nsw.gov.au/biosecurity/vertebrate-pests/publications/distribution-maps-for-vertebrate-pests. Accessed 23 January 2022.

NSW DPI (2021). Cardinia Creek Catchment Thermal Surveys Report, 28 July 2021, https://vdccn.org.au/wp-content/uploads/2022/04/Cardinia-Creek-Report-2021.pdf. Accessed 10 April 2023.

NSW DPI. (2022). Feral deer. https://www.dpi.nsw.gov.au/biosecurity/vertebrate-pests/pest-animals-in-nsw/feral-deer/feral-deer. Accessed 23 January 2022.

Page, B., Pelton, G., Austin, J., Peters, K., Forsyth, D.M., Wiebkin, A., Freeman, E., Howlett, B., Williams, L., Williams, G., Waycott, M. and Woolnough, A. (2017) Agricultural and economic impacts of feral deer. In: Forsyth, D., Pople, T., Page, B., Moriarty, A., Ramsey, D., Parkes, J., Wiebkin, A. and Lane, C. (Eds). *2016 National Feral Deer Management Workshop Proceedings, South Australian Aquatic Sciences Centre, Australia 17–18 November, 2016*, pp. 10–13. Invasive Animals Cooperative Research Centre, Canberra, Australia. https://pestsmart.org.au/wp-content/uploads/sites/3/2020/06/Proceedings-2016-National-Workshop-on-Deer-Management_FINAL.pdf. Accessed 23 January 2022.

Peacock, D. (2008). Feral deer distribution, abundance and impact, and associated landholder attitudes: results of an extremely successful postal survey of rural landholders in southeast South Australia. In: Saunders, G. and Lane, C. (Eds). *Proceedings of the 14th Australasian Vertebrate Pest Conference', Darwin, Australia, 10–13 June 2008*, p. 123. The Vertebrate Pests Committee and the Invasive Animals Cooperative Research Centre, Canberra, ACT, Australia.

Pedersen, S., Andreassen, H.P., Keith, D.A., Skarpe, C., Dickman, C.R., Gordon, I.J., Crowther, M.S. and McArthur, C. (2014). Relationships between native small mammals and native and introduced large herbivores. *Austral Ecology* 39: 236–243. doi:

Pettorelli, N., Coté, S.D., Ginras, A., Potvin, F. and Huot, J. (2007). Aerial surveys vs hunting statistics to monitor deer density: the example of Anticosti Island, Quebec, Canada. *Wildlife Biology* 13(3): 321–327.

Putman, R. (2012). Scoping the economic benefits and costs of feral deer and their management in Scotland, SNH Commissioned Report No. 526. https://www.nature.scot/doc/naturescot-commisioned-report-526-scoping-economic-benefits-and-costs-feral-deer-and-their-management. Accessed 23 January 2022.

Putman, R., Langbein, J., Green, P. and Watson, P. (2011). Identifying threshold densities for feral deer in the UK above which negative impacts may occur. *Mammal Review* 41: 175–196.

Queensland Department of Agriculture, Fisheries and Forestry. (2013). Feral deer management strategy 2013–18. Queensland Government Department of Agriculture, Fisheries and Forestry, Brisbane, Queensland, Australia.

RMCG. (2019). Economic and social impacts of recreational hunting and shooting, final report, September 2019. https://www.health.gov.au/sites/default/files/documents/2019/10/foi-request-1294-recreational-shooting-on-economy-health-well-being-and-social-cohesion-rm-consulting-group-economic-and-social-benefits-of-recreational-hunting-and-shooting-report_0.pdf. Accessed 23 January 2022.

Rowley, T. and Roberts, J. (2018). Submission 12, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022.

Scottish Deer Working Group. (2019). The management of feral deer in Scotland. Presented to Scottish Ministers, 2019. https://www.gov.scot/publications/management-feral-deer-scotland/documents/. Accessed 23 January 2022.

SE NSW Farmers. (2018). Submission 35, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022.

Sloane, Cook and King Pty Ltd. (1988). The economic impact of pasture weeds, pests and diseases on the Australian wool industry. Australian Wool Corporation, Melbourne, Victoria, Australia.

Stenekes, N. and Kancans, R. (2021). Pest Animal and Weed Management Survey 2016–19: national land manager survey results, ABARES research report, Canberra, ACT, Australia. doi: 10.25814/x9qn-6v09..

Tallangatta Valley Landcare Group. (2018). Submission 6, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022.

Tolsma, A. (2009). An assessment of mossbeds across the Victorian Alps, 2004–2009. Report to Parks Victoria. Victorian Department for Sustainability and Environment. Cited in https://www.aph.gov.au/DocumentStore.ashx?id=2778101f-416c-44c4-8255-77b99edd0f61&subId=662171. Accessed 23 January 2022.

Victorian DELWP. (2021). Victorian Deer Control Strategy. https://www.environment.vic.gov.au/invasive-plants-and-animals/deer-control-strategy. Accessed 23 January 2022.

West, P. (2011). National mapping of the abundance of established new and emerging pest animals to improve decision-making and the assessment of Government investment programs. Stage 1: pest animals report to the Australian Bureau of Agricultural and Resource Economics and Sciences, Department of Agriculture, Fisheries and Forestry. NSW Department of Primary Industries and the Invasive Animals Cooperative Research Centre, Orange, New South Wales, Australia.

Wildlife Health Australia. (2013). WHA Factsheet: disease agents identified in feral animal in Australia. Wildlife Health Australia. https://www.ferallifehealthaustralia.com.au/Portals/0/Documents/FactSheets/Mammals/Disease%20Agents%20Identified%20in%20Feral%20Animals%20in%20Australia%20May%202013%20(1.4).pdf. Accessed 23 January 2022.

Ward, A, White, P, Smith, A and Critchley, C (2004) 'Modelling the cost of roe deer browsing damage to forestry' Forestry Ecology and Management 191, 301-310.

Wisconsin Department of Transportation in the USA. (2020). Cost of deer v vehicle collision repairs on the rise as mating season peaks. Reported to WSAW. https://www.wsaw.com/2020/11/19/cost-of-deer-v-vehicle-collision-repairs-on-the-rise-as-mating-season-peaks/. Accessed 23 January 2022.

Wollongong City Council. (2018). Submission 68, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019 https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022.

Yarra Ranges Council. (2018). Submission 3, to the *Senate Standing Committees on Environment and Communications,* Inquiry related to the impact of feral deer, pigs and goats in Australia, ending with 45th Parliament, 23 July 2019. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/FeralDeerPigsandGoats/Submissions. Accessed 23 January 2022.

10. PEOPLE CONTACTED

Table 9: People contacted.

Person	Agency
NSW	
David Forsyth, Principal Research Scientist, Vertebrate Pest Research Unit	NSW Department of Primary Industries
Troy Crittle, Invasive Species Officer	NSW Department of Primary Industries
Mal Leeson, Senior Project and Programs Coordinator, Mudgee	Local Land Services, NSW
Jake Tanner, Business Partner – Invasive Species, Bega	Local Land Services, NSW
Ben Russell, Manager, Feral Animal and Weeds	NSW National Parks and Wildlife Service
Peta Norris, Manager, Invasive Species,	NSW National Parks and Wildlife Service
Queensland	
Tony Pople, Invasive Plants and Animals Research, Biosecurity Queensland	Department of Agriculture and Fisheries
Michael Brennan	Department of Agriculture and Fisheries
Iain Jamieson	City of Gold Coast
Tony Cathcart	Sunshine Coast Regional Council
Darren Sheil	Moreton Bay Regional Council
Bill Manners	Brisbane City Council
Victoria	
Ben Fahey, Manager Conservation Programs, Environment and Science Division	Parks Victoria
Sandie Czarka, Program Lead, Deer Environment and Science Division	Parks Victoria
Stefan Kaiser	Department of Environment, Land, Water and Planning
Amy Kirk, Project Coordinator, Animal Damage	HVP Plantations
Peter Jacobs, Deer Project Officer (Victoria)	Invasive Species Council
Michelle Hanslow	Department of Energy, Environment and Climate Action
Peter Kambouris	Department of Energy, Environment and Climate Action
Daniel Besley	Melbourne Water
Joanna Mundy	Melbourne Water
South Australia	
Giverny Rodgers	Department of Primary Industries and Regions, Government of South Australia
Brad Page, Principal Biosecurity Officer	Department of Primary Industries and Regions, Government of South Australia
Steve Bourne	Limestone Coast Landscape Board

Person	Agency
Robbie Davis, Board Member	Limestone Coast Landscape Board
Annelise Wiebkin, National Deer Management Coordinator	Department of Primary Industries and Regions, Government of South Australia
Tasmania	
Eric Schwarz, Senior Wildlife Management Officer	Department of Natural Resources and Environment Tasmania
Western Australia	
Stuart Dawson	Department of Primary Industries & Regional Development
ACT	
Mark Sweaney, Project Manager, Invasive Animals and Overabundant Wildlife	ACT Government, Environment, Planning and Sustainable Development Directorate
Sally McIntosh	ACT Government, Environment, Planning and Sustainable Development Directorate
Centre for Invasive Species Solutions, Canberra	
Andreas Glanznig, CEO	Centre for Invasive Species Solutions
Richard Price, Portfolio Director	Centre for Invasive Species Solutions
Other Commonwealth	
Ahmed Hafi, Senior Economist	Australian Bureau of Agricultural and Resource Economics and Sciences
Kirstin Proft, Scientist	Australian Bureau of Agricultural and Resource Economics and Sciences
Tony Arthur, Senior Scientist	Australian Bureau of Agricultural and Resource Economics and Sciences

APPENDIX 1: LOSS–EXPENDITURE ESTIMATES

Table 10: Value of industry, industry affected and production loss assumptions, 2021.

	Industry value ($ million), 2021				Proportion of industry impacted by deer (%)			Percentage of net production value lost to deer competition (%)			Industry losses due to deer competition ($)		
	Unit	Hectares or head	Value ha/head ($)	Industry value ($ millions)	Low	Average	High	Low	Average	High	Low	Average	High
Timber plantation [a]	ha	1,744,178	$1,092	$1,904	3.0%	6.0%	9.0%	1.0%	2.0%	3.0%	571,296	2,285,184	5,141,664
Fruit and nuts [b]	ha	227,215	$24,853	$5,647	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	2,117,595	8,470,379	19,058,352
Viticulture [b]	ha	141,479	$12,538	$1,774	1.5%	3.0%	4.5%	3.5%	7.0%	10.5%	931,245	3,724,982	8,381,209
Vegetables [b]	ha	127,624	$31,642	$4,038	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	1,514,364	6,057,456	13,629,276
Sheep Meat [b]	head	68,047,402	$58	$3,973	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	1,490,031	5,960,126	13,410,282
Sheep Wool [b]	head	68,047,402	$37	$2,517	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	943,795	3,775,179	8,494,153
Beef [b]	head	22,048,333	$560	$12,341	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	4,627,772	18,511,090	41,649,952
Dairy [b]	head	2,382,840	$1,967	$4,688	1.5%	3.0%	4.5%	2.5%	5.0%	7.5%	1,757,986	7,031,945	15,821,876
Total				**$36,882**							**13,954,085**	**55,816,340**	**125,586,764**

[a] Timber plantation for the fiscal year July 2020 – June 2021 (data from ABARES, 2023). b Local values of agricultural industries for the fiscal year July 2020 – June 2021 (data from ABS, 2022a) and hectares used for production July 2020 – June 2021 or livestock at year end for July 2020 – June 2021 (data from ABS, 2022b). NA = not available, ha = hectares

Table 11: Respondents indicating that deer were a major problem, and livestock numbers impacted.

State	Region	% of respondents indicating deer to be a major problem [a]	Effectiveness [a]
NSW	Central Tablelands	9%	1.9
	Greater Sydney	5%	1.9
	Hunter	2%	2.3
	Murray	6%	1.5
	North Coast	1%	1.9
	North West NSW	3%	2.1
	Northern Tablelands	15%	1.6
	Riverina	2%	1.6
	South East NSW	15%	1.5
	Western	2%	2.3
QLD	Border Rivers Maranoa–Balonne	5%	1.8
	Burdekin	3%	2.3
	Burnett Mary	3%	1.9
	Condamine	3%	1.9
	Desert Channels	3%	0
	Fitzroy	1%	2.2
	South East Queensland	2%	1.9
	Wet Tropics	1%	1.7
SA	Adelaide and Mount Lofty Ranges	4%	1.7
	Eyre Peninsula	3%	2
	Northern and Yorke	5%	1.8
	South Australian Murray Darling Basin	2%	1.6
	South East	5%	2.1
TAS	North	14%	1.9
	South	9%	1.8
VIC	Corangamite	4%	1.6
	East Gippsland	37%	1.7
	Glenelg Hopkins	1%	1.4
	Goulburn Broken	7%	1.7
	North East	41%	1.7
	Port Phillip and Western Port	6%	1.6
	West Gippsland	4%	1.8
	Wimmera	2%	1.8
WA	Northern Agricultural	1%	0
	Peel–Harvey	1%	0

Source: Stenekes, N. and Kancans, R. (2021). Pest Animal and Weed Management Survey 2016–19: National land manager survey results. ABARES research report, Australian Bureau of Agricultural and Resource Economics and Sciences, Commonwealth of Australia, Canberra.

Table 12: Farmers' reported deer control costs in 2019 (ABARES survey results)

State	NRM region	$ per property	% of properties reporting expenditure	No. of properties in NRM region	Total $ per NRM region
NSW	Central Tablelands	1,655	5	3,717	307,582
	Greater Sydney	529	2	1,985	21,001
	Hunter	760	7	3,463	184,232
	Murray	4,603	8	2,809	1,034,386
	Northern Tablelands	1,085	10	2,976	322,896
	Riverina	810	3	5,165	125,510
	South East NSW	1,520	19	4,509	1,302,199
QLD	Border Rivers Maranoa–Balonne	2,944	4	2,535	298,522
	Burnett Mary	669	5	4,841	161,931
	South East Queensland	265	4	4,383	46,460
SA	Adelaide and Mount Lofty Ranges	1,003	6	2,945	177,230
	Northern and Yorke	923	4	2,484	91,709
	South East	903	12	2,511	272,092
TAS	North	5,575	13	1,391	1,008,127
	South	1,605	12	930	179,118
VIC	East Gippsland	2,021	28	762	431,201
	Goulburn Broken	2,328	3	4,476	312,604
	Northeast	6,230	33	2,306	4,740,905
	Port Phillip and Western Port	9,018	5	3,776	1,702,598
	West Gippsland	495	7	1,868	64,726
	Total				**12,785,029**

Source: Stenekes, N. and Kancans, R. 2021, *Pest Animal and Weed Management Survey 2016–19: National land manager survey results*. ABARES research report, Australian Bureau of Agricultural and Resource Economics and Sciences, Commonwealth of Australia, Canberra. doi: 10.25814/x9qn-6v09. NRM = Natural Resource Management; NSW = New South Wales; QLD = Queensland; SA = South Australia; TAS = Tasmania; VIC = Victoria.

Table 13: Cattle, sheep, and grape production areas in feral deer major impact areas in 2019 (ABARES survey results and ABS data)

State	Region	% respondents major problem	Total meat cattle (head year end)	Total sheep (head year end)	Grape area (hectares)
NSW	Central Tablelands	9%	250,461	2,075,922	2,594
	Greater Sydney	5%	18,059	3,076	7
	Hunter	2%	246,930	61,695	2,703
	Murray	6%	422,622	2,499,459	958
	North Coast	1%	264,959	3,957	22
	North West NSW	3%	561,196	1,024,709	1
	Northern Tablelands	15%	537,011	911,814	43
	Riverina	2%	445,310	4,975,380	16,886
	South East NSW	15%	279,385	3,002,830	852
	Western	2%	103,656	2,335,028	1,606
QLD	Border Rivers Maranoa-Balonne	5%			
	Burdekin	3%			
	Burnett Mary	3%	728,224	4,765	321
	Condamine	3%	495,194	32,690	
	Desert Channels	3%	1,267,542	845,663	
	Fitzroy	1%	2,545,211	18,708	985
	South East Queensland	2%	205,533	2,530	36
	Wet Tropics	1%	205,532		
SA	Adelaide and Mount Lofty Ranges	4%	51,529	299,827	20,126
	Eyre Peninsula	3%	11,574	1,441,334	354
	Northern and Yorke	5%	36,116	2,023,018	4,588
	South Australian Murray Darling Basin	2%	72,581	1,415,922	28,817
	South East	5%	567,771	3,887,605	14,259
TAS	North	14%	127,255	983,385	605
	South	9%	39,512	953,849	884

State	Region	% respondents major problem	Total meat cattle (head year end)	Total sheep (head year end)	Grape area (hectares)
VIC	Corangamite	4%	169,094	1,457,240	406
	East Gippsland	37%	106,181	173,166	84
	Glenelg Hopkins	1%	528,293	5,428,715	484
	Goulburn Broken	7%	250,494	1,635,856	2,797
	North East	41%	120,831	322,153	2,490
	Port Phillip and Western Port	6%	154,986	133,955	2,880
	West Gippsland	4%	284,275	381,426	65
	Wimmera	2%	35,904	2,343,525	446
WA	Northern Agricultural	1%	127,606	1,577,605	223
	Peel-Harvey	1%	64,074	918,735	297
Australia			21,141,836	63,529,366	136,221
Total major problem			**488,005**	**2,178,854**	**4,681**
% major problem			**2.3%**	**3.4%**	**3.4%**

Source: Stenekes, N. and Kancans, R. 2021, *Pest Animal and Weed Management Survey 2016–19: National land manager survey results*. ABARES research report, Australian Bureau of Agricultural and Resource Economics and Sciences, Commonwealth of Australia, Canberra. doi: 10.25814/x9qn-6v09. NRM = Natural Resource Management; NSW = New South Wales; QLD = Queensland; SA = South Australia; TAS = Tasmania; VIC = Victoria. Livestock at year end for 2019 and grape area (data from ABS, 2022b).

CENTRE FOR INVASIVE SPECIES SOLUTIONS

Building 22, University of Canberra
University Drive South, BRUCE ACT 2617
T 02 6201 2887
E communications@invasives.com.au