An economic analysis of the impacts of deer in Victoria

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CONTENTS

EXECUTIVE SUMMARY

This report assesses damage to agriculture, forestry and conservation interests by fallow and sambar deer over the next 20 years under a base case scenario which assumes (a) no direct public investment in deer control, (b) ongoing recreational hunting, and (c) no change in land use. The analysis does not extend to an evaluation of options for controlling deer, but rather provides the base case consequences against which the benefits of options can be evaluated.

The estimated state-wide losses to agriculture, forestry and conservation stemming from deer over the next 20 years amounts to $1.1 billion. The greatest losses will be borne by the public via impacts on biodiversity. Using regions defined by the Australian Bureau of Statistics at the resolution of 'Statistical Area Level4', predicted losses to agriculture and forestry are concentrated in the Hume and Gippsland-Latrobe regions. These losses are predicted despite the inclusion in analyses of an increase in harvesting via recreational hunting.

Analyses undertaken elsewhere (RMCG 2020) indicate substantial benefits associated with deer hunting, especially in the Hume and Gippsland-Latrobe regions. Aggregate costs at the scale of the entire state of Victoria are broadly comparable to benefits associated with recreational deer hunting. At a regional scale, contested interests in hunting, agriculture and forestry in the Hume and Gippsland-Latrobe regions will likely present policy challenges over the next decade. In areas of high conservation value and water production there is a clearer argument for controlling deer, assuming feasible and effective measures for doing so are available.

1.0 INTRODUCTION

This report describes quantitative estimates of the impact of two deer species - fallow deer (*Dama dama*) and sambar deer (*Cervus unicolor*) - on agriculture, forestry and conservation, with qualitative description of impacts on Aboriginal culture heritage and public health.

The Victorian Acclimatisation Society was formed in 1861. Deer were of keen interest to the Society from inception, with imports peaking between 1860 and 1880, including red deer (*Cervus elaphas*), fallow deer, sambar deer, hog deer (*Axis porcinus*) and axis deer or chital (*Axis axis*).

Since their release or escape to the wild, range expansion for Victorian populations of fallow and sambar deer were modest up to the 1950s. Bentley (1957) reports that fallow deer were *limited to three comparatively small areas. The first is in the ranges about Healesville in east-central Victoria. The second is a small overflow herd from New South Wales and is located west of Albury on the Murray River. The third is a penetration from southeastern South Australia into the country near Casterton.*

For sambar deer, Bentley (1957) records: *The greatest numbers are to be found in the Gippsland forest in eastern Victoria. There are two other localities in the western part of the state where they occur - in the Grampians and in the timbered country at Mount Cole.*

Regarding impact, Bentley (1957) considered deer in the 1950's a largely benign presence: *In Australia the deer population is not large and only makes itself felt in isolated localities. Complaints of deer damage come mainly from potato growers and orchardists.*

Since the 1950s, the range and area of occupancy of both species has increased substantially (Figure 1). Impacts are no longer benign or localised. In a nation-wide qualitative review of adverse impacts, Davis et al. (2016) document material harm to the natural environment, agriculture and horticulture, human health, water and soil.

In terms of positive impacts, the success of deer in colonising a range of habitats throughout Victoria has provided enhanced and accessible opportunities for game hunting. In a recent analysis of the economic benefits of game hunting to Victoria, RMCG (2020) estimate a very substantial contribution from deer hunting (see Section 5 Box 3 for further detail).

This report provides a quantitative analysis of a subset of the negative impacts. Collectively, insights on both benefits and costs will provide policy-makers with an improved evidence base for effective state-wide management.

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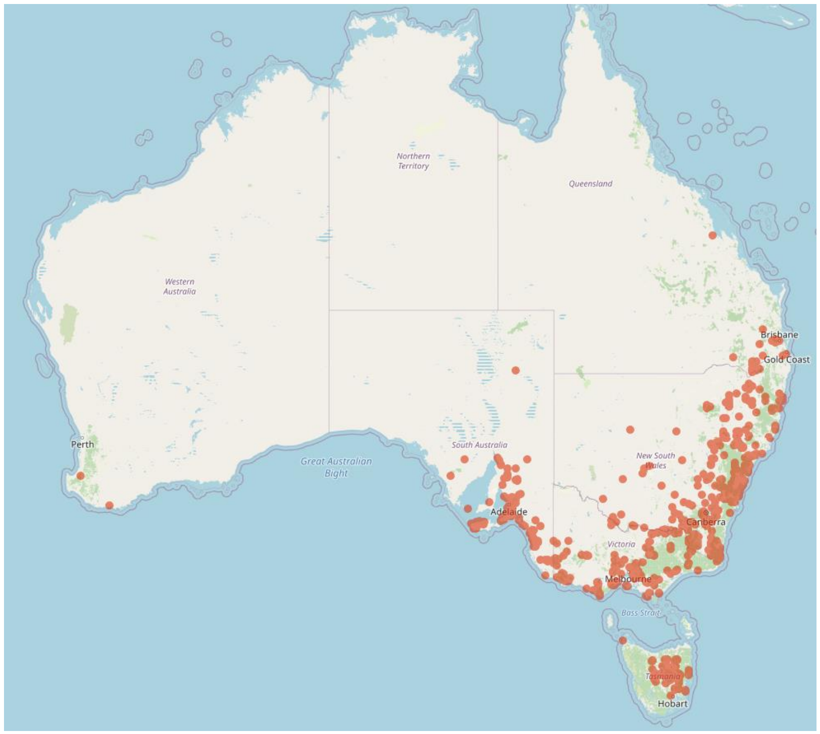

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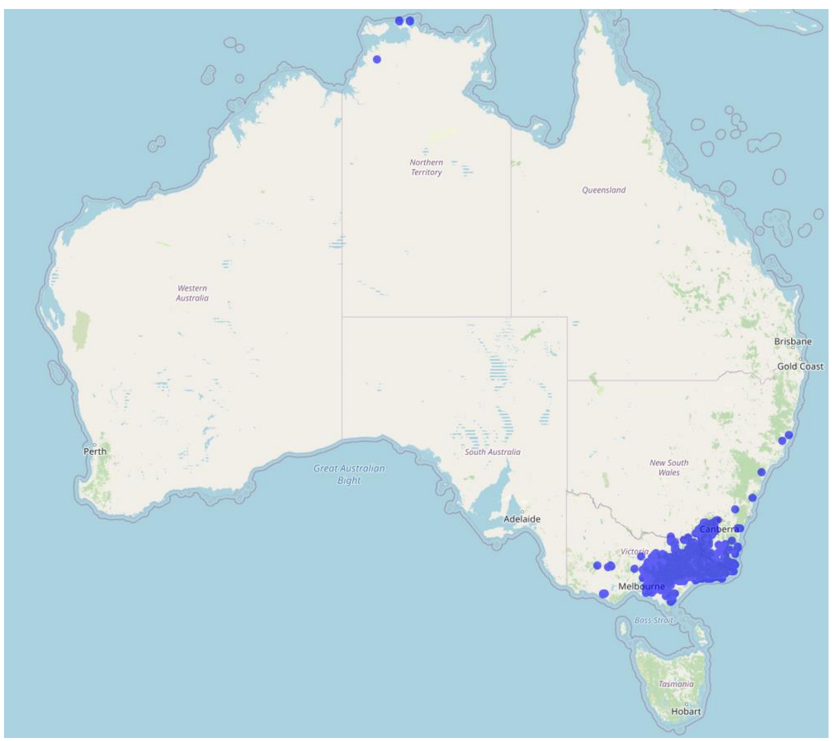

Figure 1. Occurrence records throughout Australia for (a) fallow deer and (b) sambar deer. Source: Atlas of Living Australia https://spatial.ala.org.au/

2.0 THE ESTIMATED TRAJECTORY FOR DEER OVER THE NEXT 20 YEARS

2.1 MODELLING METHODS

We performed spatially-explicit population simulations (Visintin et al. 2020) for two deer species, fallow and sambar deer, across the state of Victoria. Our time horizon was 20 years (to year 2040). Both deer species models included population estimates of survivorship and fecundity that depended on location specific density and carrying capacity. Models also included dispersal and harvesting and were spatially organised by raster grids that described the habitat suitability for each species. Habitat suitability values were predicted from correlative models that related locations of known species observations to environmental information. The resolution of grid cells (surrogates for patches) was four square kilometres (2000m x 2000m). Only grid cells that could potentially contain populations of deer were included. Areas where deer were known to be absent, such as waterbodies, were excluded from the analysis on the basis of expert judgment. While both deer models shared the same structure, the input parameters were specific to each species and are described in more detail in the following sections.

HABITAT SUITABILITY

For each grid cell, habitat suitability for fallow deer was predicted by regressing known observations and randomly selected background observations (pseudo-absences) on tree density. The model included a quadratic term to allow a curved relationship consistent with the understanding of fallow deer's association with forest of intermediate tree density. Three-hundred replicates of the model were fitted across the entire grid, each selecting a different random set of pseudo-absences. The models performed well and the predicted values of habitat suitability for all replicates were averaged for each grid cell (Figure 2).

Predictions of habitat suitability for sambar deer were informed by Sotorra et al (2020) and generated by multiplying tree density (scaled between zero and one) with distance to water (again rescaled to be between zero and one). Known observations of sambar deer were plotted over the predictions and indicated good correspondence.

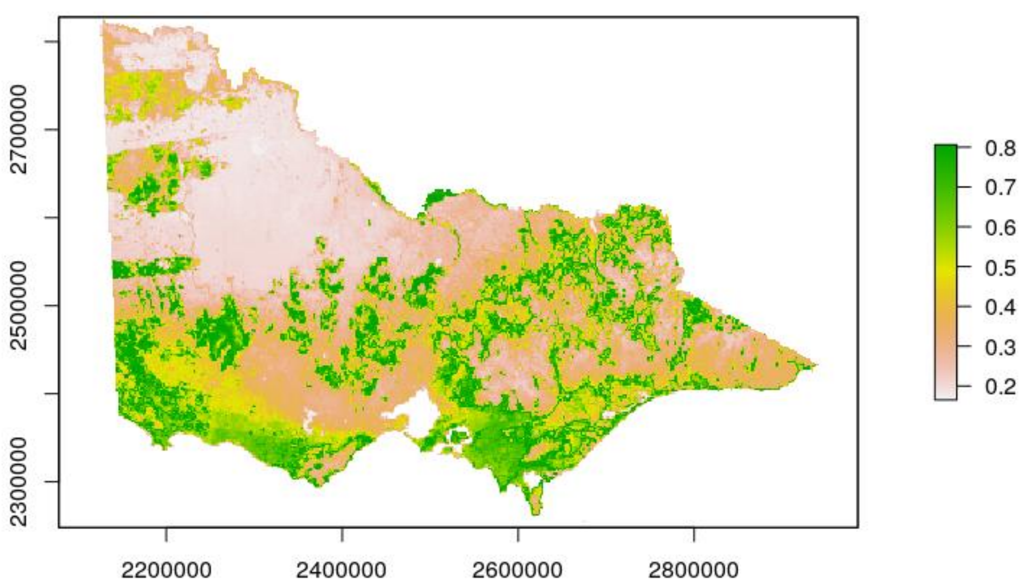

Figure 2. Habitat suitability map generated by a statistical model for fallow deer.

CARRYING CAPACITY

The maximum number of individuals that could occupy a grid cell (i.e. patch) was determined by the predicted habitat suitability for that cell. For the highest suitability values, an upper limit of 80 fallow deer (20 individuals per square kilometre, Fattorini et al. 2011) and 40 sambar deer (10 individuals per square kilometre) was applied. The relationship between habitat suitability and carrying capacity was described by a logistic function that allowed more individuals in higher quality habitat than in lower quality habitat. Both deer species used very similar functional shapes (Figure 3).

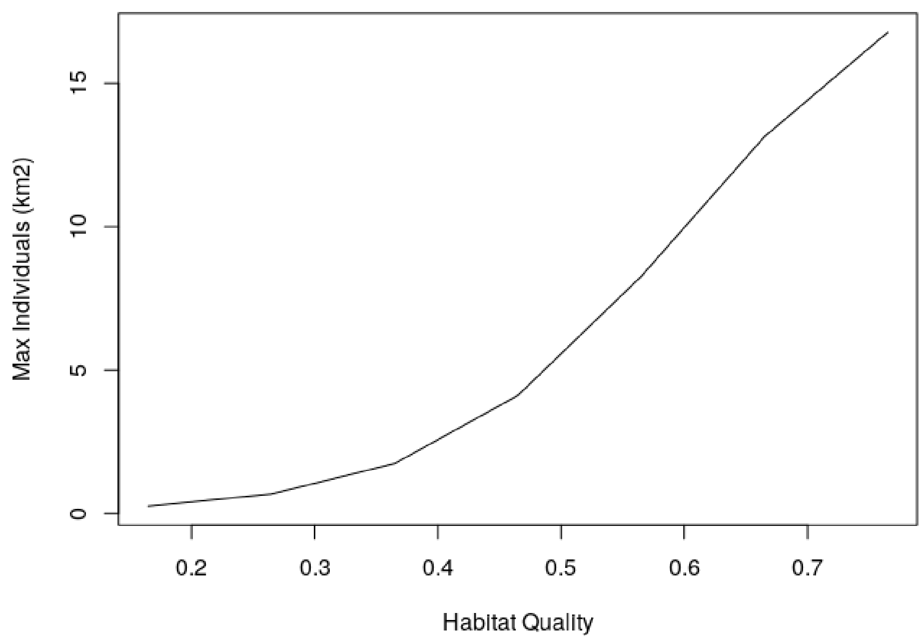

Figure 3. The relationship between habitat quality and carrying capacity specified for fallow deer.

VITAL RATES

Survival and fecundity were defined in two-sex, multi-stage transition matrices. The life-stages were classified as fawns, yearlings, sub-adults, and adults for both species, but the values of survival and fecundity varied between them. Fallow deer values were based on Focardi et al (1996). For sambar deer, values were loosely based on Watter et al (2020), but adjusted until stable states were obtained, consistent with Leslie (2011). The maximum population growth rate for both species was 1.49, based on Hone et al (2010). All values were randomly adjusted within all simulations to represent environmental stochasticity. Demographic stochasticity was also present in all of the simulations.

INITIAL POPULATIONS

The starting populations were produced by placing the maximum numbers of individuals in each of the grid cells based on habitat suitability above a threshold and known occurrences. For fallow deer that threshold was 0.78 and for sambar deer it was 0.30. In each grid cell, the total populations were then divided into the life-stage classes based on stable age distributions (obtained analytically from the transition matrices). The total starting population of fallow deer was 255,469 and sambar Deer was 456,785. From these starting populations we allowed 10 years of 'burn-in' simulation, before progressing to the 20 year simulation from which outcomes are reported in Section 2.2 below.

DISPERSAL

Dispersal around the landscape depended on carrying capacity, habitat suitability, and spatial information on barriers and restrictions to movement. For carrying capacity, dispersal was encountered where resources were limiting (i.e. more deer dispersed as populations approached their respective carrying capacities). Movements were based on cellular automaton (individuals moved according to defined rulesets). Individuals were allowed to move up to a maximum number of cells (zero for fawns and yearlings, two for female sub-adults and adults, five for male adults, and ten for male sub-adults). Directions of dispersal contained a random element, however, was weighted more favourably based on adjacent habitat quality and/or available space. During dispersal, movements were also influenced by additional spatial information and ecological understanding. For example, both tree density and distance to water were used for fallow deer (they follow water courses with tree cover) and slope was used for sambar deer (as they tend to track ridge lines and valleys).

HARVESTING

The popularity of deer hunting appears to be increasing in Victoria (RMCG 2020). Two different functions were used to simulate harvesting for the two species over the next 20 years, with estimates based on trends and variability documented in recent deer harvest reporting for Victoria (Moloney and Hampton 2019). For fallow deer, we specified a proportion of the population that was based on annual take and also included an annual increase. The initial proportions were 0.23 for female sub-adults, 0.23 for female adults, 0.11 for male sub-adults, and 0.23 for male adults. They incrementally increased to 0.27, 0.28, 0.13, and 0.28 in the last year of the simulation. Sambar deer were harvested at an initial mean annual take of 12,000 (+/-10%) female sub-adults, 66,000 (+/-10%) female adults, 8,000 (+/-10%) male sub-adults, and 44,000 (+/-10%) male adults. These estimates were increased by 5 percent each year. Harvesting was excluded in cells designated as national park as hunting is prohibited in these areas (i.e. the model assumed full compliance).

SIMULATIONS

Each species simulation was replicated 100 times to allow stochastic (random) effects to propagate through the projections. For each species, spatially-explicit projections of populations across Victoria were obtained for each of twenty years by averaging the total populations in each grid cell across all replicates in each respective year. The final spatially explicit population projections were used to produce summary statistics used in impact analyses.

2.2 MODELLING RESULTS

Even with increased harvesting, both modelled species are expected to increase in numbers at a state-wide scale over the next 20 years, but not dramatically so (Figures 4 and 5).

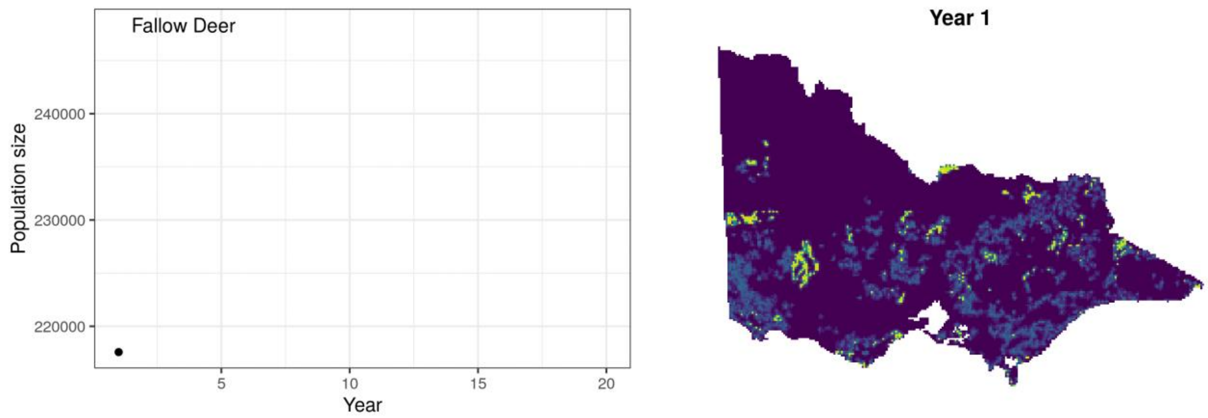

Figure 4. Model predictions for the trajectory of Fallow Deer over the next 20 years. Double click on the image to activate the animation. Year zero is the end of the model burn-in.

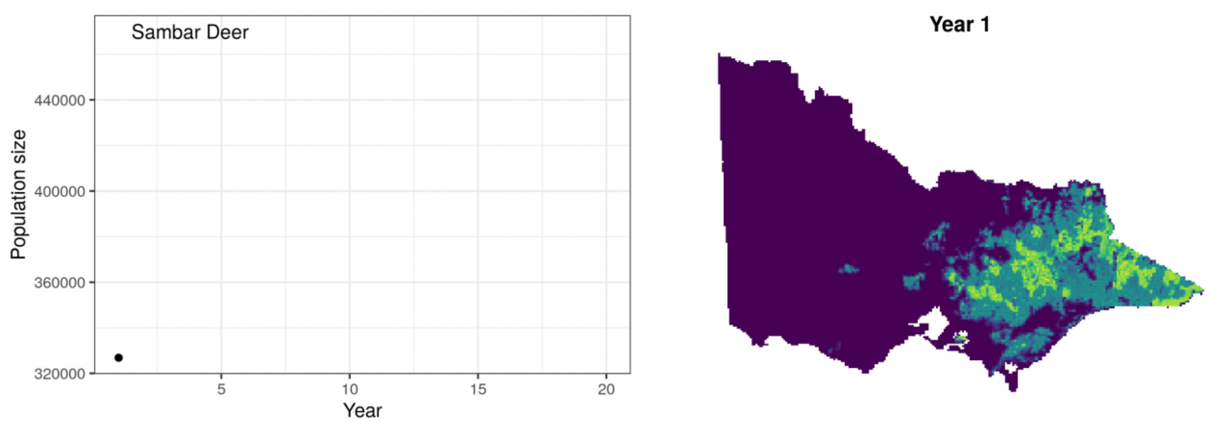

Figure 5. Model predictions for the trajectory of Sambar Deer over the next 20 years. Double click on the image to activate the animation. Year zero is the end of the model burn-in.

Model results were aggregated at a regional scale using Statistical Area Level 4 (SA4) boundaries (ABS 2016, Figure 6) because at this regional scale we were able to obtain data describing land use and its economic value (described in Section 3). The state-wide increase in population size stems from a general increase in both area occupied and the density of deer within occupied areas, although regional contrasts exist (Figures 7 and 8).

The regions with the highest proportion of their landscape predicted to be occupied by deer and highest densities are:

- Latrobe - Gippsland,
- Hume,
- Melbourne – Outer East, and
- Melbourne – North East.

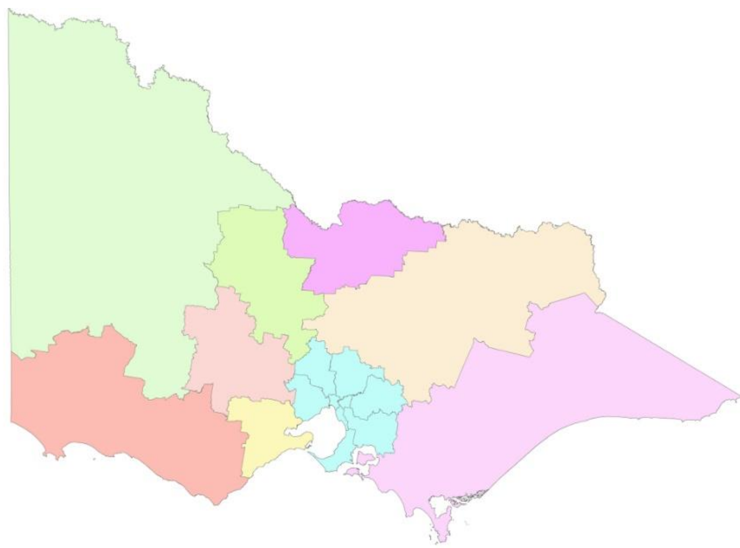

Figure 6. Statistical Area Level 4 (SA4) regions of Victoria. Regions comprise Ballarat, Bendigo, Geelong, Hume, Latrobe – Gippsland, Melbourne – Inner, Melbourne - Inner East, Melbourne - Inner South, Melbourne - North East, Melbourne - North West, Melbourne - Outer East, Melbourne - South East, Melbourne – West, Mornington Peninsula, North West, Shepparton, and Warrnambool and South West.

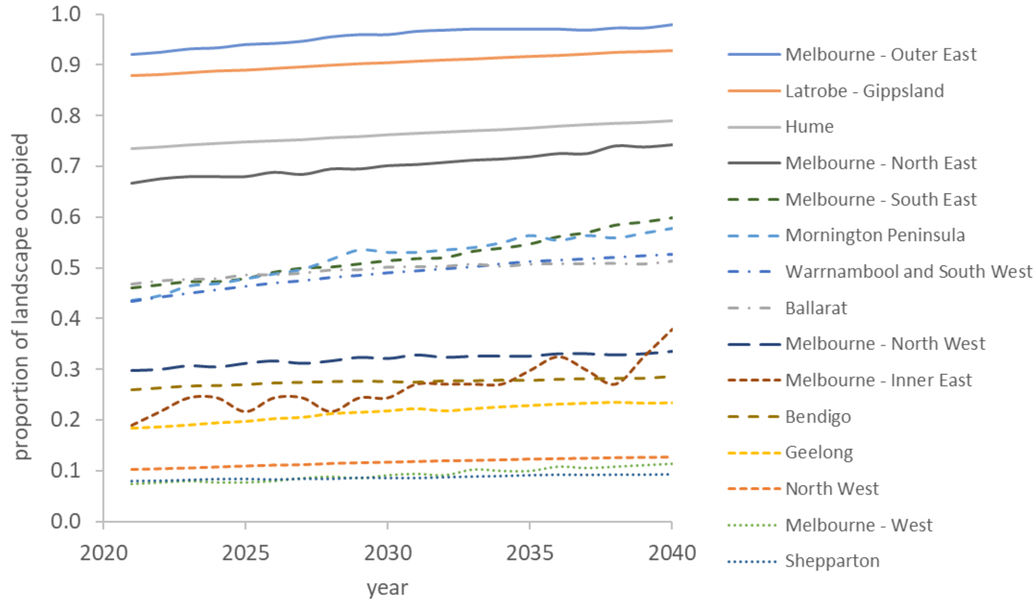

Figure 7. The proportion of the landscape predicted to be occupied by deer over the next 20 years, for each region. Note that predictions for Melbourne's Inner and Inner South (not shown) were predicted to be zero throughout.

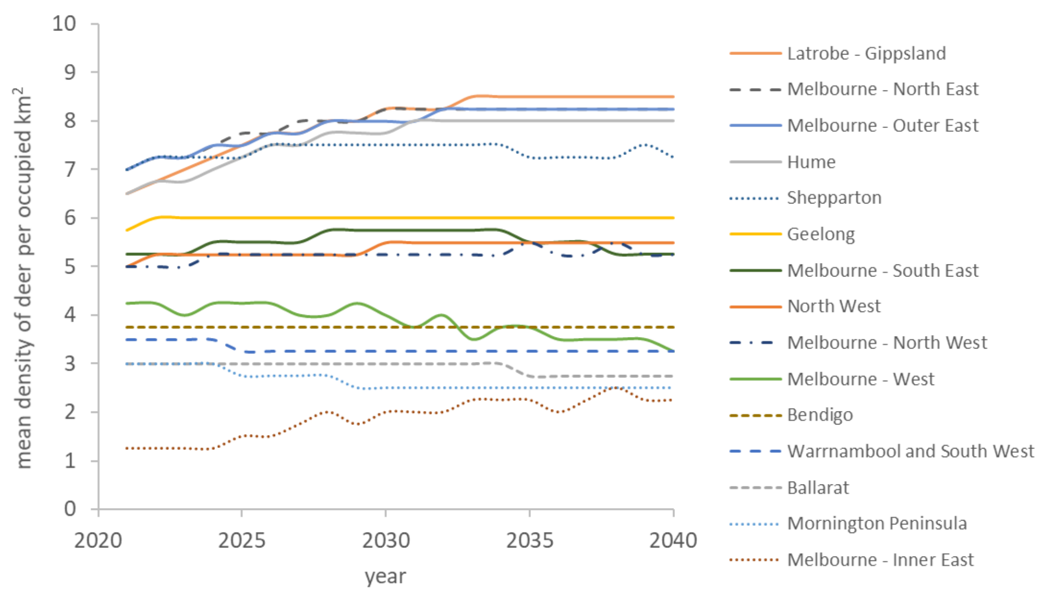

Figure 8. The predicted mean density of deer (within the proportion of the landscape occupied) over the next 20 years, for each region.

3.0 QUANTITATIVE ANALYSIS OF IMPACTS

This analysis assesses damage to agriculture, forestry and conservation interests by deer over the next 20 years under a base case scenario which assumes (a) no direct public investment in deer control, (b) ongoing recreational hunting, and (c) no change in land use. The analysis does not extend to an evaluation of options for controlling deer, but rather provides the base case consequences against which the benefits of options can be evaluated.

Social and economic values exposed to adverse impacts of deer include (Davis et al. 2016):

- Agricultural production losses,
- forest production losses,
- biodiversity losses,
- damage to the cultural heritage of Traditional Owners, and
- public health impacts.

In this report we've been able to provide quantitative estimates of adverse impacts on agriculture, forestry and conservation. Below we describe how each of these impacts were estimated.

For cultural heritage and public health, we considered the evidence base for quantitative estimation to be insufficient. We provide brief qualitative commentary on each in Section 4.

For agriculture, forest production and biodiversity losses, we monetised impacts over a 20 year time horizon, using the outputs of deer model simulations. In reporting total impact over 20 years, we use the present value of losses (reported in 2019-20 AUD), which includes standard exponential discounting at a rate of 5% per annum.

3.1 AGRICULTURE

Among reasons cited by landholders seeking a permit to control deer are pasture losses, tree damage, browsing of fruit and vegetable crops, trampling, fouling and fence damage (Lindeman and Forsyth 2008). Although not included in analyses presented here, deer also pose a disease risk to livestock production systems (Davis et al. 2016).

We considered two broad classes of impact on agriculture – losses associated with livestock production and losses associated with crop production (including horticulture). Losses for both were estimated from the value of production, area impacted, and intensity of impact.

The values of livestock and crop production in each SA4 region over the last three years for which data are available are shown at Appendix 1. We used the average of these three years to estimate the value of agricultural production in each region that could potentially be impacted by deer.

We assumed deer can only cause losses at the interface of its habitat and farmland. Smith et al. (2012) found the magnitude of pasture loss decreased with increasing distance from the edge of cover vegetation, but observed losses up to 800 m from the edge. Lindeman and Forsyth (2008) made direct observations of deer feeding on pasture/clover about 200m from State Forest. In analyses presented here, we assume impacts are uniform over a distance of 200 m from the edge. Note that an 'edge' in the context of our analysis refers to the interface between agricultural land and any non-zero deer density reported by the models described in Section 2, irrespective of tenure.

Spatial analyses used the Australian Land Use and Management (ALUM) Classification Version 8 (ABARES 2016). The following ALUM classifications were interpreted as livestock production areas:

- 3.2.0 Grazing modified pastures
- 4.2.0 Grazing irrigated modified pastures

The following were interpreted as crop production:

- 3.3.0 Cropping
- 3.4.0 Perennial horticulture
- 3.5.0 Seasonal horticulture
- 4.3.0 Irrigated cropping
- 4.4.0 Irrigated perennial horticulture
- 4.5.0 Irrigated seasonal horticulture

Aggregate area statements for classifications interpreted as livestock and crop production within 200 m of modelled deer presence were prepared for each SA4 region and each time step (years 1 to 20).

The intensity of impact at any grid cell varied with deer density at any single time step, and was modelled as a proportional loss of production within the 200 m impact zone. Deer density was the sum of predictions for fallow and sambar deer. The proportional loss was described using a logistic function,

$$f(x) = \frac{L}{1 + e^{-k(x-x_0)}}$$

where L is the maximum loss, k describes the gradient of the curve, x is deer density, and x_0 is the x-value at the midpoint of the sigmoidal curve. Proportional loss was rescaled to the interval [0, L] across the modelled range for deer density, 0 to 20 per sq km.

The loss of agricultural production from deer is highly uncertain. Using Smith et al. (2012) as a coarse guide, we made a conservative best estimate of 0.06 (or 6%) for the maximum proportional loss, *L,* at 20 deer per sq km, with half that loss at 10 deer per sq. km (i.e. $x_0 = 10$). Around this best estimate we included an envelope of uncertainty where the lower bound takes values of $L = 0.02$ and $x_0 = 15$, and the upper bound values of $L = 0.10$ and $x_0 = 5$. The value of k was fixed at 0.5 throughout (Figure 9).

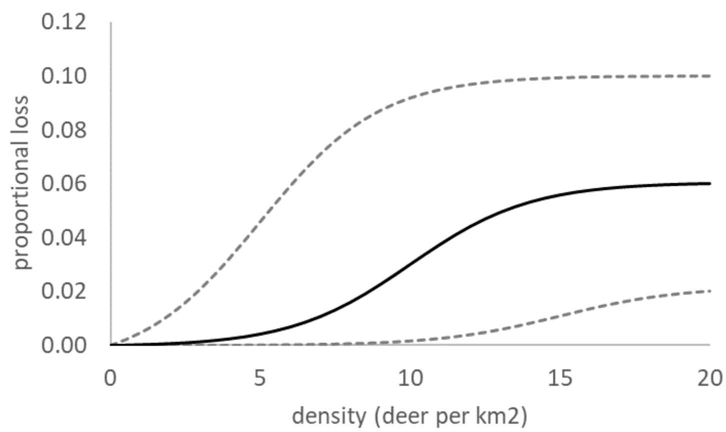

Figure 9. Best estimate loss function for agricultural losses (continuous line) and surrounding envelope of uncertainty. The same function and envelope were used for livestock and crop production losses. Proportional loss refers to impacts within 200 m of modelled deer presence.

To describe the effect of this uncertainty on estimates of agricultural losses we conducted a Monte Carlo simulation with 1,000 iterations, whereby each iteration sampled from uniform distributions in the interval [0.02, 0.10] for L, and [5, 15] for x_0.

LIVESTOCK

The total state-wide loss to livestock production over 20 years, discounted at 5% per annum, is estimated to be $84.2 million.

Uncertainty around this estimate is shown in Figure 10. The lower and upper bounds for the 90% confidence interval are $9.5 million and $347.4 million.

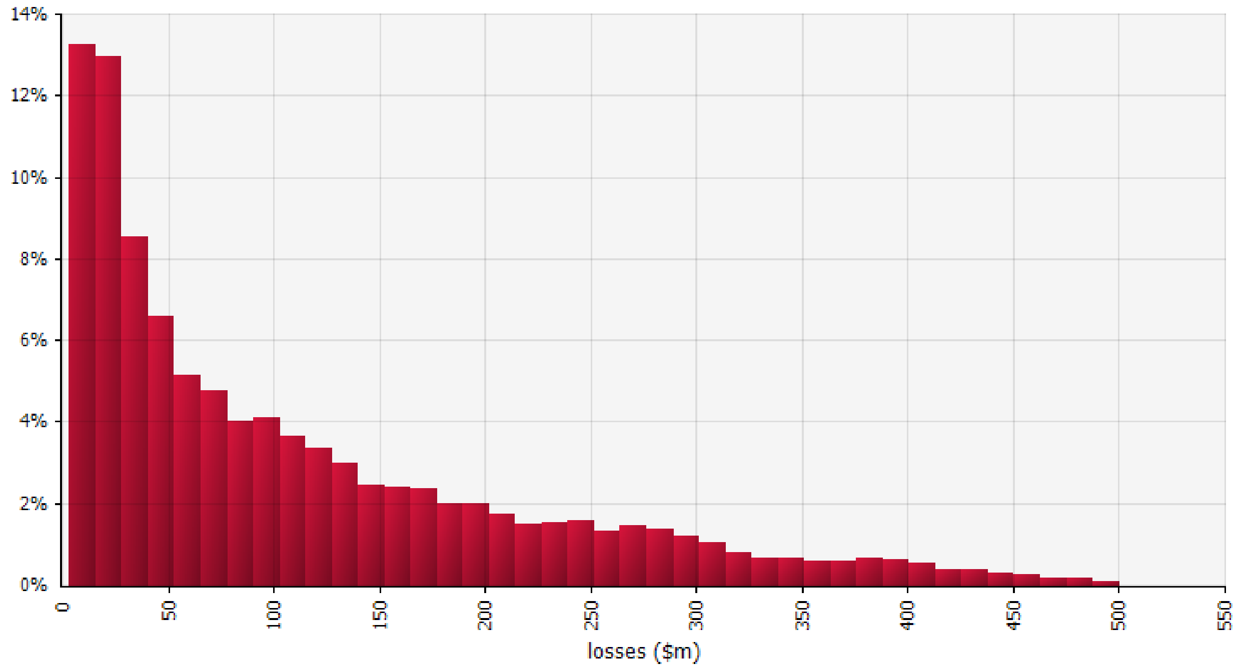

Figure 10. Uncertainty in the present value of losses over the next 20 years for livestock agriculture.

Regional losses (without discounting) are shown in Figure 11. The greatest losses are predicted to be borne by the Latrobe-Gippsland region, where large tracts of livestock production abut deer habitat, and where deer numbers are predicted to significantly increase (Figures 7 and 8). The Hume region is also exposed to considerable losses.

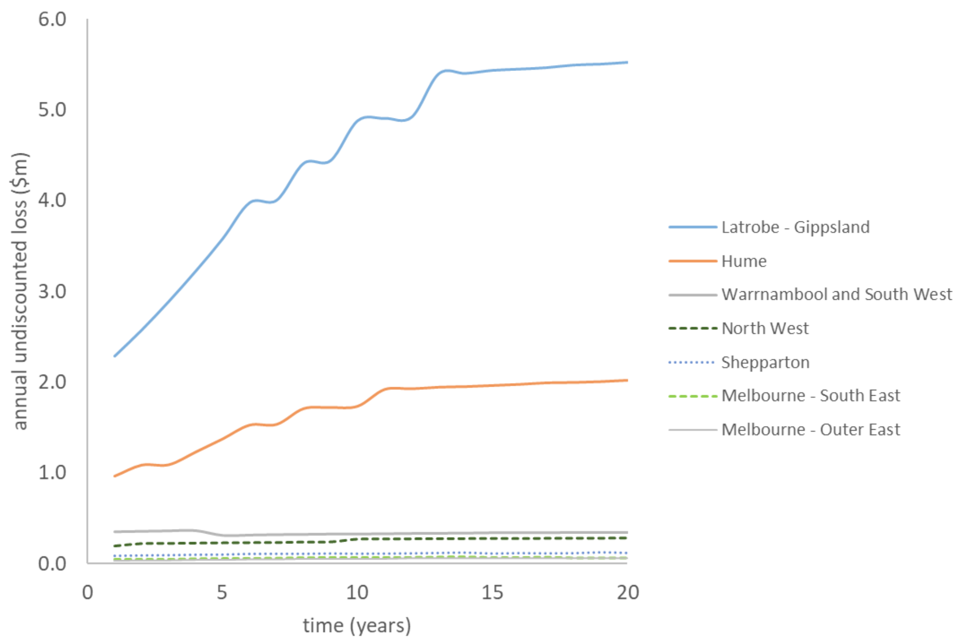

Figure 11. Estimated regional losses to livestock production over the next 20 years, in 2019-20 AUD. Note that only regions with an estimated annual loss greater than $0.05m are shown.

CROPS

The total discounted state-wide loss to crop production over 20 years is estimated to be $67.9 million, with a 90% confidence interval of [$7.8 million, $275.3 million] (Figure 12).

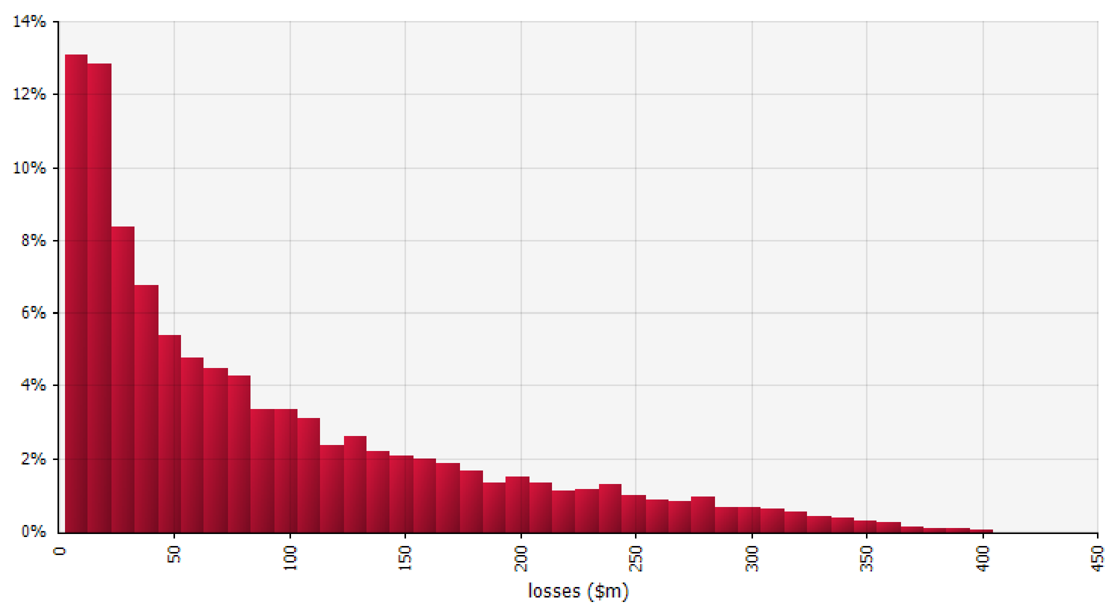

Figure 12. Uncertainty in the present value of losses over the next 20 years for crop production.

Again, the greatest losses are predicted to be borne by the Latrobe-Gippsland region, and again, the Hume region figures prominently in regional losses (Figure 13). Other notable impacts are anticipated in Melbourne's Outer East and North East, where investment in horticultural enterprises is high, alongside substantial retention of tree cover.

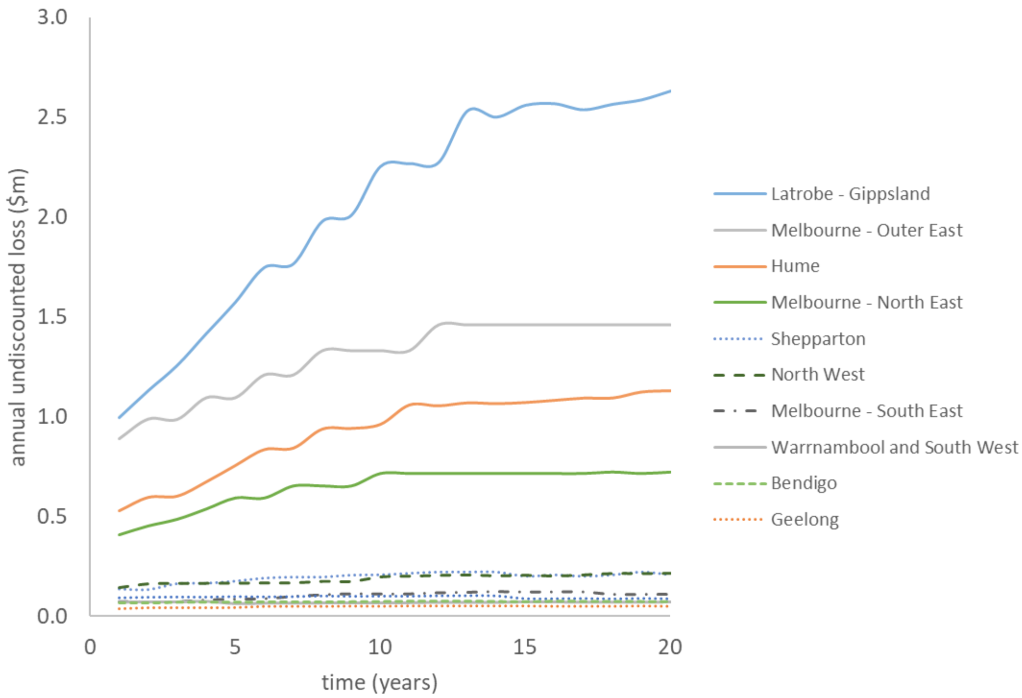

Figure 13. Estimated regional losses to crop production over the next 20 years, in 2019-20 AUD. Note that only regions with an estimated annual loss greater than $0.05m are shown.

3.2 FORESTRY

Deer can have adverse impacts on wood production through browsing of seedlings and regrowth, and partial or complete ringbarking via bark stripping or antler rubbing of established stems (Davis et al. 2012, Di Stefano et al. 2009). In pine plantations, physical damage by deer can elevate the risk of infestation by *Sirex* wood wasp.

We considered impacts on log production in Victoria's hardwood and softwood plantation sectors. We were unable to access sufficient information to make reasonable estimates of impacts to native forest timber production, or pulpwood production.

The value of log production from plantation forestry is reported at a state-wide scale. We used land cover classification data (ABARES 2016) to estimate the proportional contribution of each region to the state-wide total (Appendix 2). We used the state-wide average value over three years and the proportional contribution of each region to estimate the value of log production in each region that could potentially be impacted by deer.

For each time step, spatial analyses identified grid cells where plantation forestry intersected with modelled deer presence. The magnitude of loss was again related to predicted deer density using a logistic function.

As for impacts on agriculture, the loss of timber production from deer is highly uncertain. Our best estimate for maximum proportional loss, *L,* at 20 deer per sq km, was 7.5% with half that loss at 10 deer per sq. km (i.e. x_0 = 10). Our envelope of uncertainty comprised a lower bound function with values of L = 0.05 and x_0 = 15, and an upper bound with values of L = 0.10 and x_0 = 5. The value of k was again fixed at 0.5 throughout (Figure 14). Within this envelope of uncertainty we again conducted a Monte Carlo simulation with 1,000 iterations, with each iteration sampled from uniform distributions in the interval [0.05, 0.10] for L, and [5, 15] for x_0.

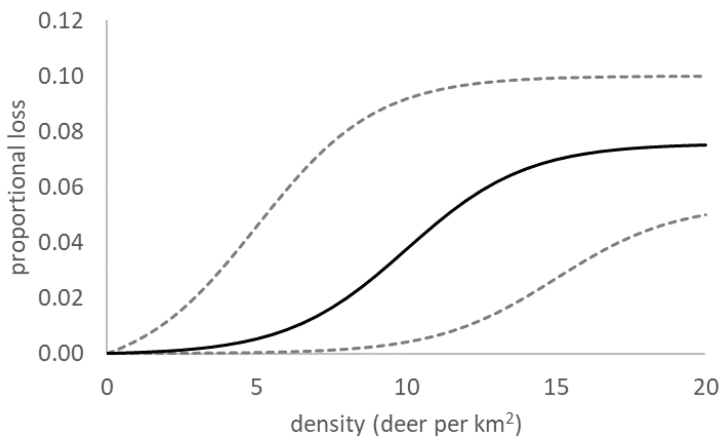

Figure 14. Loss function for forestry losses (continuous line) and surrounding envelope of uncertainty. The same function and envelope were used for softwood and hardwood plantations.

HARDWOOD PLANTATION

The total state-wide loss to log production in hardwood plantations over 20 years, discounted at 5% per annum, is estimated to be $29.0 million. Uncertainty around this estimate is shown in Figure 15. The 90% confidence interval is [$4.0 million, $114.0 million].

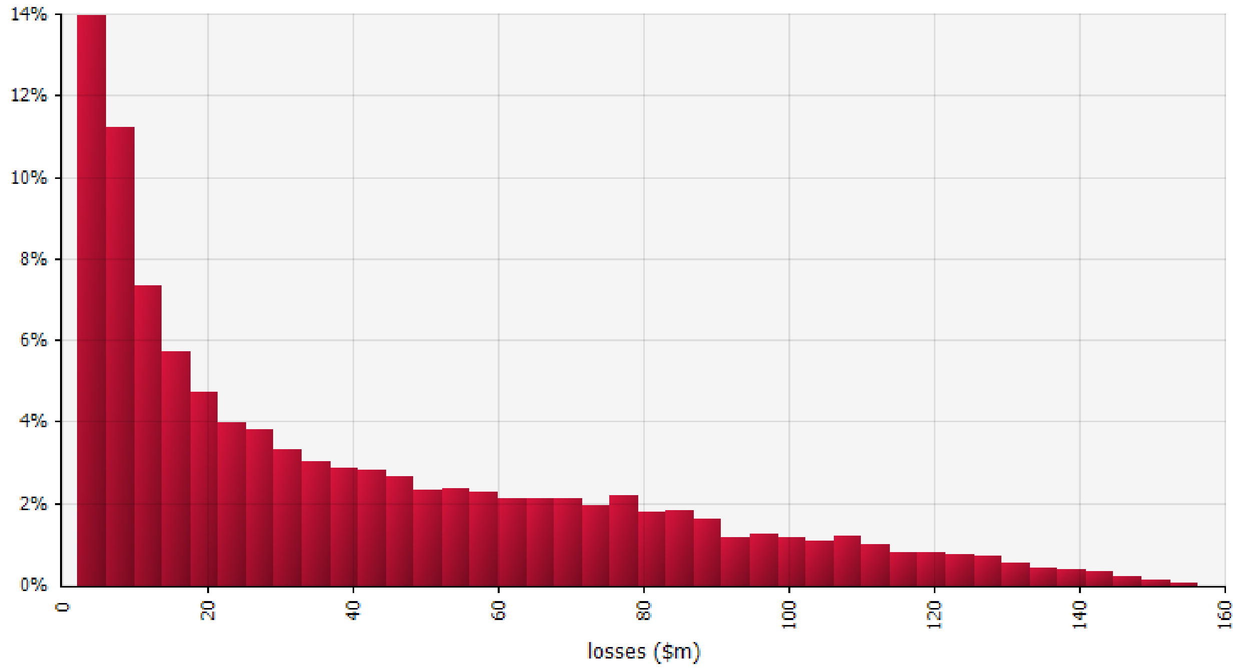

Figure 15. Uncertainty in the present value of losses over the next 20 years for hardwood plantation log production.

Best estimate predicted regional losses (without discounting) are shown in Figure 16. Losses are concentrated in the Latrobe-Gippsland region.

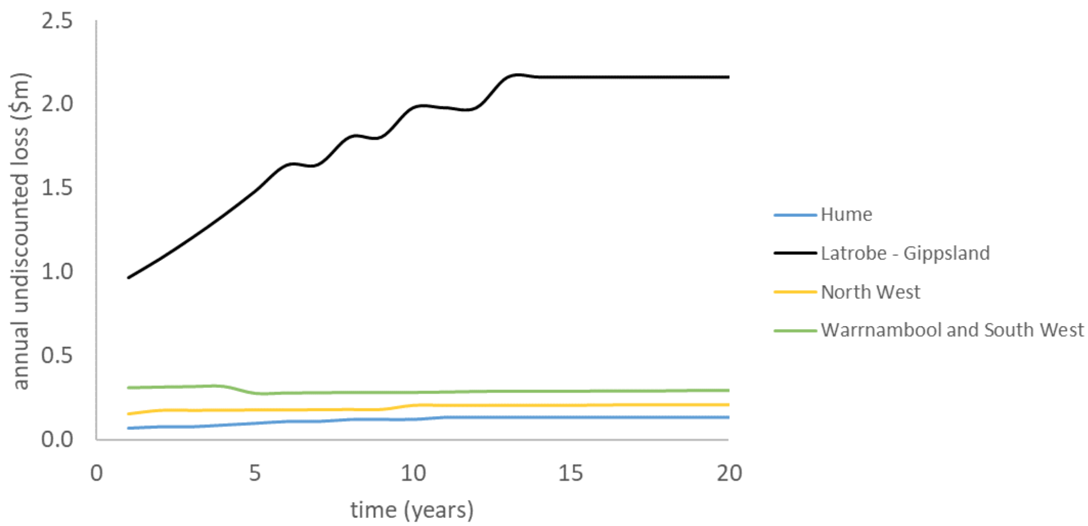

Figure 16. Estimated regional losses to hardwood plantation log production over the next 20 years. Note that only regions with an estimated annual loss greater than $0.05m are shown.

SOFTWOOD PLANTATION

The total discounted state-wide loss to softwood log production over 20 years is estimated to be $40.6 million, with a 90% confidence interval of [$5.5 million, $152.0 million] (Figure 17).

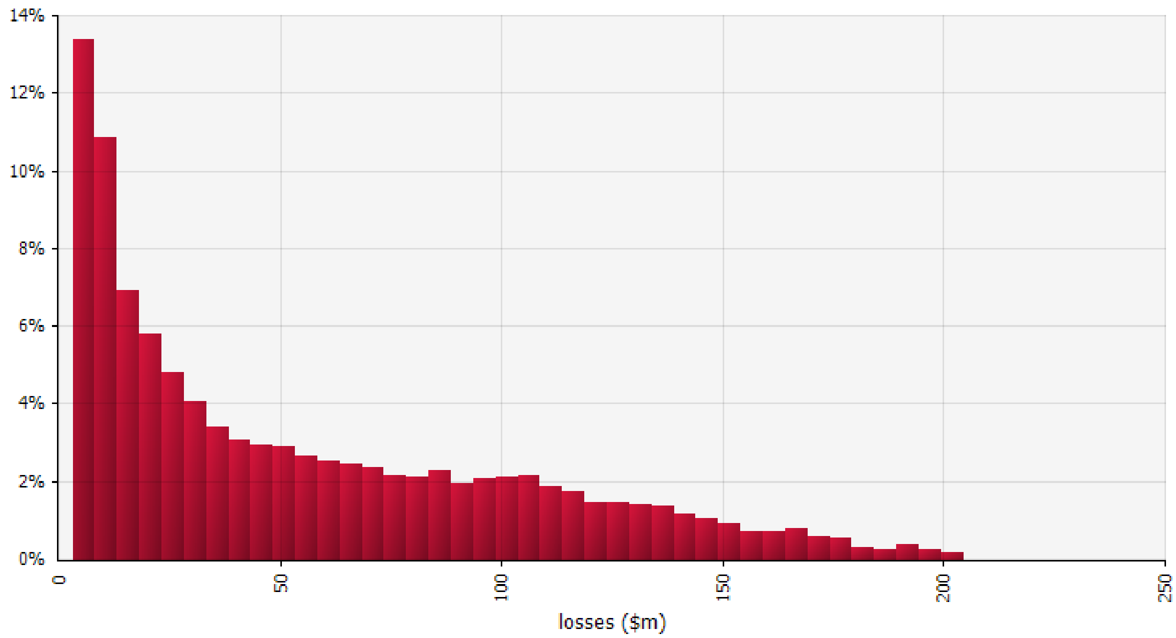

Figure 17. Uncertainty in the present value of losses over the next 20 years for softwood plantation log production.

Once again, losses are concentrated in the Latrobe-Gippsland and Hume regions, where deer densities and softwood plantations are greatest (Figure 18).

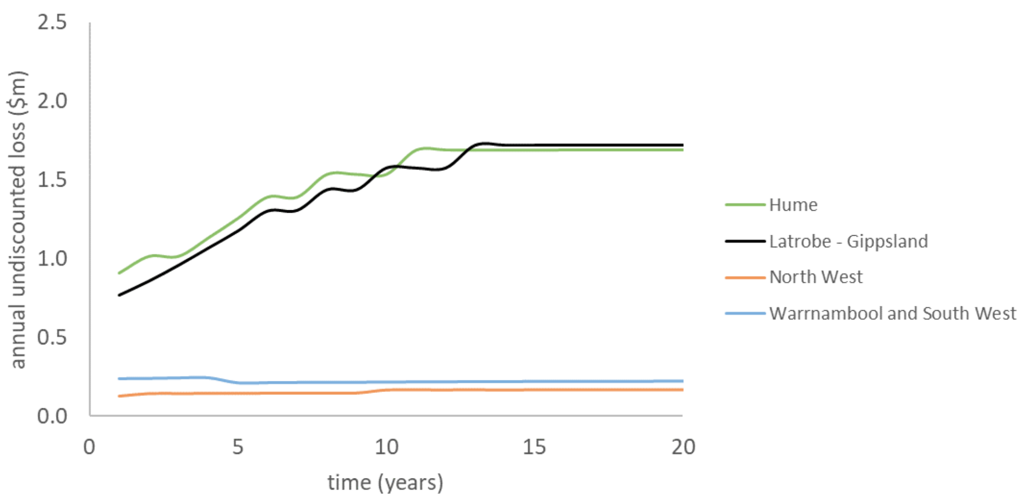

Figure 18. Estimated regional losses to softwood plantation log production over the next 20 years. Note that only regions with an estimated annual loss greater than $0.05m are shown.

BOX 1: EMERGING UNDERSTANDING OF DEER IMPACTS ON THE PLANTATION SECTOR

HVP Plantations manage over 240,000 ha of land across Victoria and has established the value loss of timber caused by deer damage as a significant and material risk to the business.

The company has embarked on a long-term monitoring and control program aimed at improving the understanding and quantifying the magnitude of animal damage to their plantations. Preliminary data analysis suggests substantial damage to tree stems from deer rubbing and stripping, as well as extensive browsing on younger trees. Both types of damage equate to significant value loss. The 2021 Animal Damage Assessment results indicate that of the 60,000 five year old trees assessed over 5000 mapped hectare plots across the entire plantation estate, 36% had evidence of animal damage in one or more quadrants of the stem. Damage was most substantial in Gippsland, where 43% of stems had damage in one or more quadrants, and 15% of stems were damaged over all four quadrants.

The company's investment in understanding and managing the risks posed by deer are themselves substantial. The monitoring program includes direct costs of $180k per year, and the costs of annual deer control are substantially greater. The company has employed a full-time animal damage co-ordinator tasked with managing the assessment programs, modelling the financial impact, and collaborating with research efforts that could help gain an understanding of population dynamics, animal behaviour and the efficacy of various control methods.

Acknowledgement: Amy Kirk and Richard Mailer, HVP Plantations

3.3 CONSERVATION

Deer can harm native species via a number of pathways. They can cause changes in the structure and composition of plant communities, compete for foraging resources with native fauna, modify habitats, and exacerbate predation risks via removal of cover and trophic interactions with foxes and wild dogs (Davis et al. 2016).

The Victorian government's Strategic Management Prospects (SMP) tool contains data describing formally elicited judgments of the impacts of a set of threats to biodiversity values, including deer (see https://www.environment.vic.gov.au/biodiversity/natureprint). Judgments describe the probability of persistence over 50 years, with and without specified management actions, for vertebrates and vascular plants. The benefit of an action for any single species is the difference between the probability of persistence with and without the action. Equivalently, this benefit can be recast as the increase in the probability of extinction in the absence of the action. For deer, the action is, *deer are controlled through coordinated ground shooting programs by skilled shooters*[1]. In total, across Victoria, the database reports 469 species that are exposed to additional extinction risk as a consequence of deer in the landscape (Table 1, Appendix 3).

[1] The specific actions included in SMP are described in the NaturePrint document, *Strategic Management Prospects inputs,* available at https://www.environment.vic.gov.au/__data/assets/pdf_file/0035/82997/5-NaturePrint-Strategic-Management-Prospects-inputs.pdf

The social cost of extinction can be estimated using non-market valuation studies. In a recent meta-analysis of these studies, Subroy et al. (2019) estimated a willingness to pay of $106 (in 2016 USD) per household per species to avoid extinction among non-charismatic species, and $572 USD for charismatic species. These estimates are one-off up-front payments, implying no need for discounting. Taking a conservative approach and using the willingness to pay for non-charismatic species, after adjusting for exchange rates (https://www.rba.gov.au/statistics/historical-data.html#exchange-rates) and inflation (https://www.rba.gov.au/calculator/) the willingness to pay in 2019/20 AUD is $150 per household per species. The number of households in Victoria recorded in the 2016 census is 2,520,912 (ABS 2019). 2016 Census. https://www.abs.gov.au/websitedbs/censushome.nsf/home/2016).

Table 1. Summary of species impacted by deer. Median impact refers to the additive increase in probability of extinction attributed to an *absence* of dedicated deer control. See Appendix 3 for details.

Group	Number of species impacted by deer in Victoria	Median impact
Amphibians	11	0.05
Birds	67	0.02
Mammals	23	0.02
Reptiles	14	0.02
Plants	354	0.04

Most non-market valuation studies focus on vertebrates. We use $150 as a best estimate of the household willingness to pay for amphibians, birds, mammals, and reptiles. For plants, we again take a conservative approach and estimate a willingness to pay of just 1% that of vertebrates, or a best estimate of $1.50 per household per species.

Translating the outcomes of valuation studies conducted elsewhere to the Victoria setting carries considerable uncertainty. Subroy et al. (2019) report an out of sample transfer error of 48%. Using 48% of $150 as an estimate of the standard deviation, we accounted for uncertainty in willingness to pay using a lognormal distribution (Figure 19). This distribution was used in a Monte Carlo simulation of 1,000 iterations to describe uncertainty in total conservation losses.

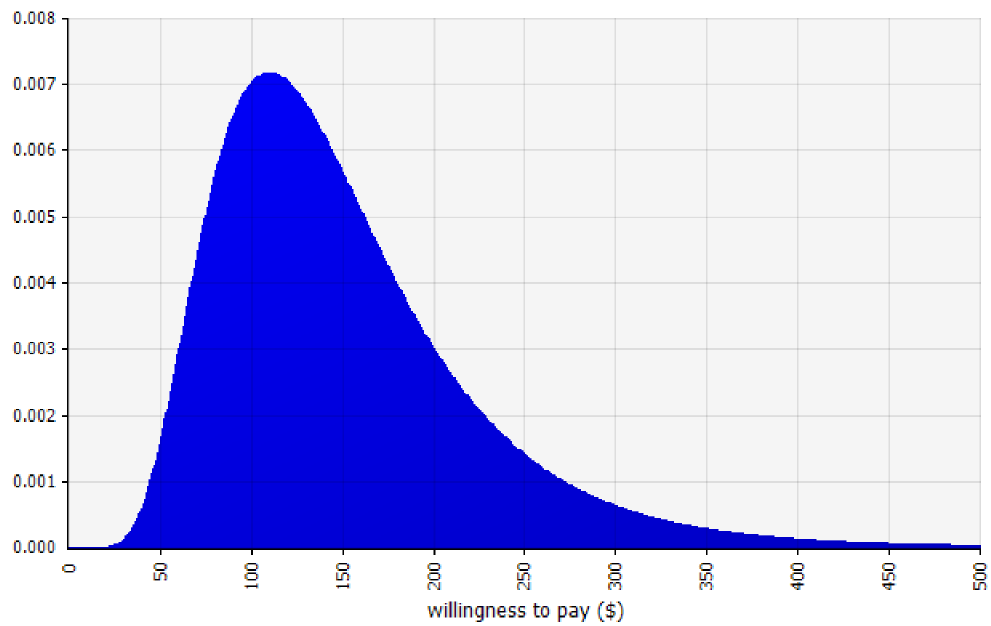

Figure 19. Uncertainty in household willingness to pay to avoid loss of a single vertebrate species around a best estimate of 2019/20 AUD $150.

SMP uses a time horizon of 50 years in describing risks of extinction and the benefits of management action. Our analysis is interested in characterising deer impacts only over the next 20 years. Interpolating from the 50 year time horizon of judgments in SMP, we need first to estimate *p*, the per annum probability of extinction, where

$p = -(-P + 1)^{1/t} + 1$,

and P_t is the probability of extinction over *t* years. For example, for $P = 0.20$ and $t = 50$, $p = 0.004$.

Now to obtain the probability of extinction over $t = 20$ years, we rearrange the equation above, so that

$P_t = 1 - (1 - p)^t$.

Where $p = 0.004$ and $t = 20$ years, $P_t = 0.09$.

For each species in Appendix 3, we use the difference in the probability of extinction over 20 years, with and without deer control, as the descriptor of adverse conservation impact. In other words our descriptor is the increase in probability of extinction without deer control.

Deer alone are unlikely to be the sole and entire cause of a species' extinction. The median impact across taxonomic groups ranges from a 2% to 5% increase in extinction risk over 20 years (Table 1). The highest additional risk posed by deer reported in SMP was a 13% increase in extinction risk over 20 years, for one amphibian and five plant species (see Appendix 3).

To describe impact in monetary terms, for each species, we multiply three terms:

the increase in probability of extinction without deer control ×
willingness to pay per household ×
number of households in Victoria.

Total state-wide conservation losses associated with uncontrolled deer are the sum of this quantity over all species.

The total over 20 years is estimated to be $935.1 million. Accounting for uncertainty in willingness to pay, the 90% confidence interval around this best estimate is [$398.0 million, $1,783 million] (Figure 20).

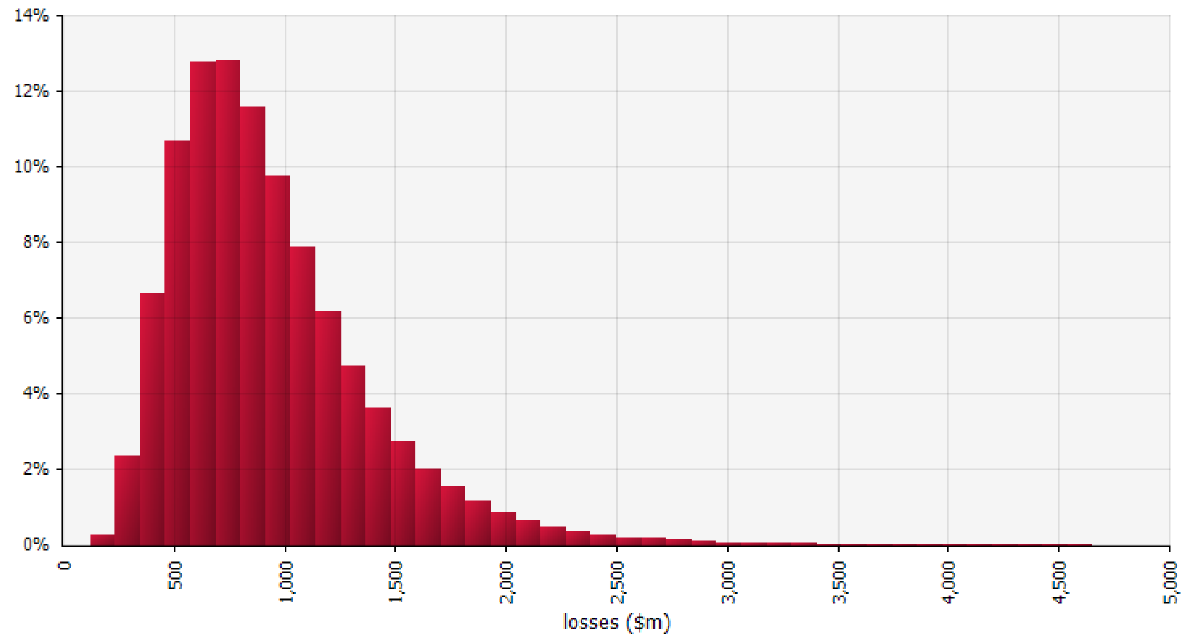

Figure 20. Uncertainty in the present value of losses over the next 20 years for conservation.

3.4 AGGREGATE LOSSES

Aggregate losses for the subset of impacts for which we were able to make quantitative monetised estimates are shown in Table 2. In total, we estimate damages of $1.157 billion in Victoria over the next 20 years.

Table 2. Aggregate losses to agriculture, forestry and conservation stemming from deer in Victoria over the next 20 years. Present values estimated using a 5% discount rate. Numbers in brackets describe 90% confidence intervals, based on uncertainty analysis

	Present value of losses ($m)
Agriculture - livestock	84.2 [9.5, 347.4]
Agriculture - crops	67.9 [7.8, 275.3]
Forestry - hardwood	29.0 [4.0, 114.0]
Forestry - softwood	40.6 [5.5, 152.0]
Conservation	935.1 [398, 1 783]
Total	**$1 157 [637, 2 107]**

The distribution of uncertainty reported by outcomes of Monte Carlo simulations is shown in Figure 21. There is an estimated 65% chance losses will exceed $1 billion, and a 7% chance of exceeding $2 billion.

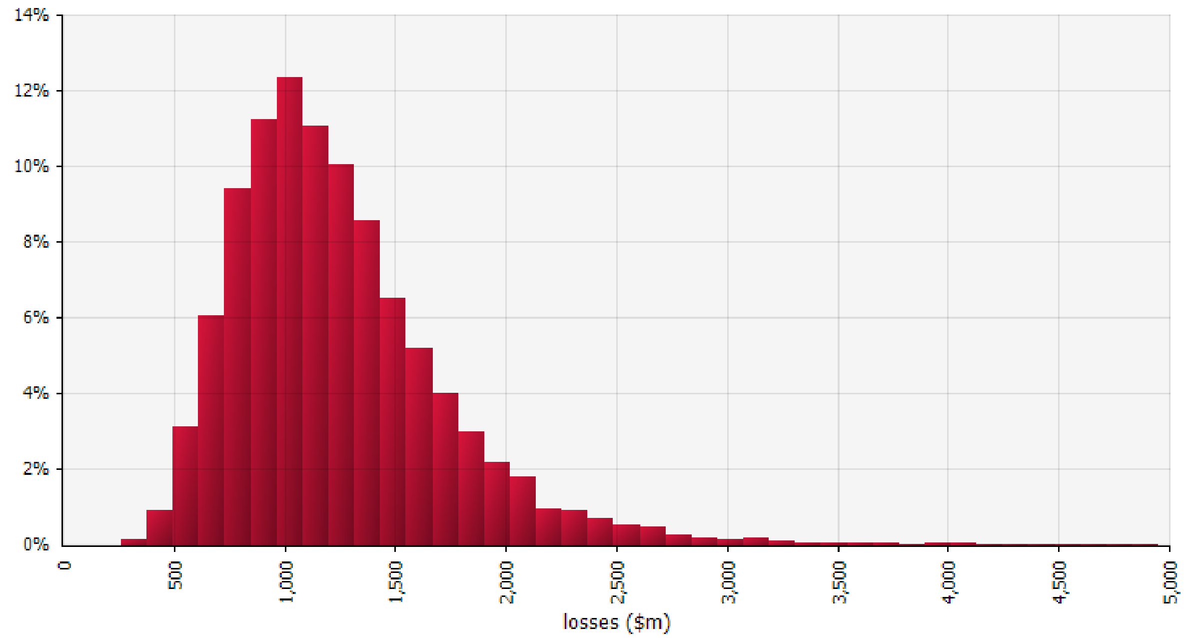

Figure 21. Uncertainty in the present value of aggregate losses over the next 20 years. The discount rate was fixed at 5%.

The majority (81%) of losses will be borne by the public interest in conservation (Figure 22). The balance is incurred by the private sector (assuming negligible public ownership of agricultural and forest plantation enterprises).

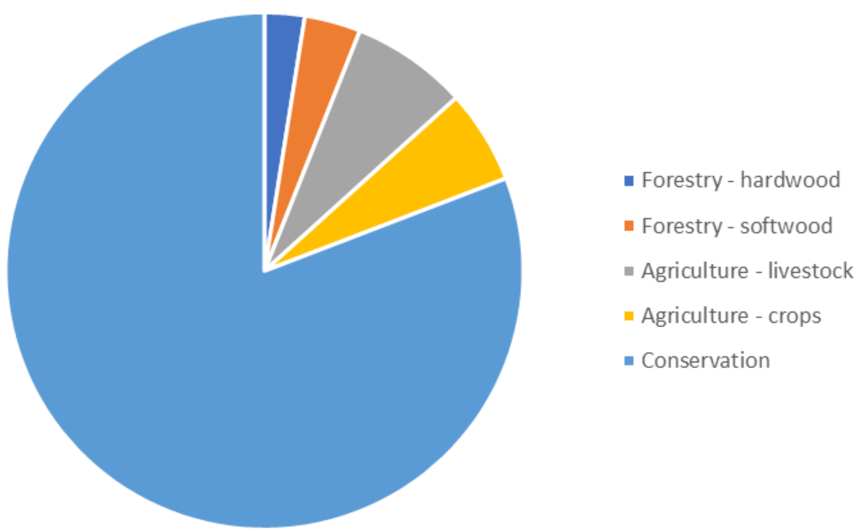

Figure 22. Losses borne by different interests as a proportion of the estimated aggregate present value of losses over 20 years of $1.157 billion.

4.0 OTHER IMPACTS

Adverse impacts of deer are not restricted to agriculture, forestry and conservation. Although we were unable to estimate their magnitude, substantial negative impacts have been observed on cultural values of Traditional Owners and public health.

The Gunaikurnai people emhasise the need for deer control in their Joint Management Plan (GKTOLMB 2018). The plan highlights the impact of deer on Country and heritage in several parks and reserves.

Public health impacts include an increased disease burden stemming from contamination of drinking water (Box 2) and mortality and morbidity associated with road accidents. VicRoads maintains a database of the cause of road accidents, but the data describing accidents involving animals generally does not describe the species or type of animal. Coarse resolution data hampers efforts to analyse and predict deer-vehicle collisions (Davies et al. 2020). Nevertheless, in peri-urban areas higher deer densities have heightened road safety anxieties, most notably in the Yarra Ranges and Nillumbik Local Government Areas. Nillumbik Shire Council have recently begun capturing data on reported 'dead deer' on Council-managed roads and roadsides. It can be assumed that these incidents have occurred as a result of a collision with a vehicle, which has also caused damage to the vehicle and potentially harm to the occupants. These numbers are likely to be a significant under-representation of the number of deer/vehicle collision incidents that occur.

BOX 2: THE RISK OF DEER TO DRINKING WATER

Cryptosporidium is a genus of single-celled parasitic species that reproduce within the guts of mammals. The human infectious species are detected primarily in cattle and humans, however they have also been detected in deer. Infection can cause gastrointestinal and respiratory illness, and can be life threatening among people with compromised immune systems.

Disinfection with chlorine is ineffective against *Cryptosporidium*, and often conventional filtration will require the addition of an ultraviolet disinfection step to manage *Cryptosporidium*. It is a very substantial public health concern for water authorities worldwide and has been responsible for numerous waterborne disease outbreaks. While most outbreaks are from human or cattle sources, deer have also been implicated, for example in Scotland (Wells et al. 2015).

Melbourne Water's protected catchments are closed to cattle grazing, but deer pose a non-trivial risk in the transmission of *Cryptosporidium*. This risk motivates an annual expenditure of approximately $300,000 in scat analysis by Melbourne Water to estimate the status and trend of *Cryptosporidium* throughout its water supply catchments. This monitoring program has demonstrated very low and stable levels of *Cryptosporidium* in the local deer population.

However, an increase in deer densities or contagion could require a reassessment of the adequacy of existing water treatment processes, potentially leading to costly upgrades. For example, adding ultraviolet disinfection treatment across the parts of Melbourne's water supply system where chlorine disinfection is currently the only treatment process for pathogens is estimated to be likely to cost hundreds of millions of dollars, which would have an impact on water bills.

Acknowledgement: Shane Haydon, Melbourne Water

5.0 DISCUSSION

The estimate of $1.1 billion in losses over the next 20 years is conservative. A paucity of information for cultural impacts, road accidents and water-borne disease preclude a fuller account of potential losses. But even within the subset of impact categories for which we were able to make quantitative estimates, our analyses did not extend to a complete capture of losses. In particular we note the following:

- Impacts on livestock production did not include biosecurity risks.
- Impacts on forestry did not include native forest based timber production, nor plantation sourced pulpwood.
- Impacts on conservation values are likely underestimates because extinction risks in the absence of deer management referred to deer *control* rather than deer eradication. That is, embedded in SMP judgments of changes in probability of persistence is a reduction in deer density, implying only a partial account of the impact of deer.

Our analysis was also restricted to just two species – fallow and sambar deer. Although our modelling suggested these two species will approach the carrying capacity for all deer in restricted parts of the state (Figures 4 and 5), there are very substantial tracts of the state where populations of other deer species will add to the impacts estimated here.

REGIONAL IMPACTS

Impacts on agricultural interests and forestry were not uniformly spread throughout the state. Losses were especially concentrated in Hume and Gippsland-Latrobe (Table 3).

Table 3. The predicted proportion of total state-wide losses in agriculture and forestry over 20 years borne by the Hume and Gippsland-Latrobe regions.

	Hume	Gippsland - Latrobe
Agriculture - livestock	24%	62%
Agriculture - crops	16%	35%
Forestry - hardwood	5%	73%
Forestry - softwood	43%	42%

Other notable regionally intensive losses include crop production (including horticulture) impacts within greater Melbourne's Outer East (23% of state-wide impacts) and North East (11%).

A COARSE COMPARISION OF POSITIVE AND NEGATIVE IMPACTS

Analyses in this report have focussed exclusively on negative impacts of deer. The main positive impact of deer in the landscape is the opportunity for hunting and its underpinning motivations, including sport, game meat, enjoyment of the outdoors, and companionship. In a recent survey of hunters, RMCG (2020) estimated a direct expenditure of $160 million among Victorian recreational hunters in 2019, including deer, duck, quail, and pest animals. Of this $160 million, we estimate $90 million expenditure stems from deer hunting, with a flow-on gross economic contribution of an additional $111 million. The total net contribution is estimated to be between $11 million and $32 million (see Box 3).

BOX 3: CONTRIBUTION OF DEER HUNTING TO THE VICTORIAN ECONOMY

Insights from more than 1600 surveys allowed RMCG (2020) to estimate a direct expenditure of $160 million among Victorian recreational hunters in 2019, including those hunting deer, duck, quail, and pest animals. Direct expenditure included retail purchases, accommodation, and hunting equipment. The flow-on or indirect economic contribution stemming from direct expenditure was an estimated additional $196 million, bringing the total contribution to $356 million.

If recreational hunting was not available in Victoria, the total *gross* economic contribution of $356 million would not be entirely lost. Some part of the expenditure would be assigned to other recreational pursuits and activities, the flow-on effects of which may be broadly comparable to those associated with hunting. RMCG (2020) provides two scenarios to account for uncertainty in the *net* economic contribution of hunting (i.e. the amount that would be foregone if recreational hunting were unavailable). In the low substitutability scenario the net contribution was $57 million, or 16% of the $356 million total gross contribution. In the high substitutability scenario, the net contribution was $19 million, or about 5% of the gross contribution.

Of the various game species included in the analysis, deer hunting provided the greatest contribution, with an estimated $201 total gross contribution. RMCG (2020) also note expenditure in deer hunting grew substantially since the previous survey in 2013, with expenditures on hunting all other species in apparent decline. The report does not provide details of the breakdown of direct and flow-on contributions for deer hunting specifically, nor does it provide deer-specific numbers for net contribution under the two uncertain substitutability scenarios. But if we assume the proportions reported for recreational hunting in aggregate are representative of deer hunting, then we estimate:

- Of the total gross contribution of $201 million for recreational deer hunting, $90 million stems from direct expenditures and $111 million from flow-on effects, and
- Under the low substitutability scenario, the total net contribution of deer hunting in 2019 was $32 million.
- Under the high substitutability scenario, the total net contribution of deer hunting in 2019 was $11 million.

How does this positive impact compare with negative impacts described in this report? Our analyses used a 20 year time horizon, but we can use estimates for the first year of our 20 year time horizon to provide a basis for comparison (Table 4).

The estimated total loss of $58.6 million does not include any attempt to capture flow-on effects. Nor is there any account of substitutability (i.e. the extent to which any reduction in the losses to livestock production via control of deer and their foraging of pasture are replaced by an increase in grazing by native and non-native herbivores). Acknowledging these complexities and uncertainties in estimates, we consider the aggregate benefits and costs of deer in the landscape today as being broadly comparable, at a state-wide scale.

Table 4. Estimated losses in the first year of the 20 year simulation. Values describe losses in 2019/20 AUD. Numbers in brackets describe 90% confidence intervals, based on uncertainty analysis.

	Year 1 losses ($m)
Agriculture - livestock	3.9 [0.4, 20.9]
Agriculture - crops	3.3 [0.4, 16.8]
Forestry - hardwood	1.5 [0.2, 7.5]
Forestry - softwood	2.0 [0.3, 9.9]
Conservation*	47.9 [20.4, 91.3]
Total	**$58.6 [33.0, 110.1]**

**Conservation losses in a single year for a single species used the difference in the per annum probability, p, with and without deer control, as the descriptor of impact, rather than the cumulative impact over* P_t *= 20 years. See section 3.3.*

At a regional scale, we highlighted the losses incurred in agriculture and forestry within the Hume and Gippsland-Latrobe regions. RMCG (2020) likewise document regional expenditures in recreational hunting. Alongside losses in agriculture and forestry, there are substantial economic benefits associated with recreational hunting in the Hume and Gippsland-Latrobe regions. Together with peri-urban Melbourne, these regions represent areas of likely stakeholder conflict over the next 20 years.

In other parts of the state, the costs of high densities of deer in the landscape may substantially exceed benefits. Areas where water production and high conservation value coincide are clearly priorities for deer control, assuming cost effective methods for doing so are available. Cost-benefit analysis is required to assess the net social benefit of various candidate configurations of land use and zoning, including analysis by management decision support tools, and an assessment of how changes would align or impact current deer control strategies.

This report, together with RMCG (2020) suggest the stakes involved are sufficiently high that further analysis could be an option for consideration.

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Values in the table below are reported in 2019-20 dollars, after accounting for inflation using the Reserve Bank of Australia's calculator (available at https://www.rba.gov.au/calculator/). Data were sourced from ABS. 75030DO001 Value of Agricultural Commodities Produced, Australia (available at https://www.abs.gov.au/statistics/industry/agriculture/value-agricultural-commodities-produced-australia/latest-release). Local value estimates in this publication are derived by subtracting transport and marketing costs from gross value. They are the value placed on recorded production at the place of production, including indirect taxes. For details, see https://www.abs.gov.au/methodologies/value-agricultural-commodities-produced-australia-methodology/2018-19. Livestock values exclude elements that are unlikely to be impacted by deer. Specifically: Livestock products – Eggs, Livestock slaughtered and other disposals – Pigs, and Livestock slaughtered and other disposals – Poultry.

Region	2016–17 ($)		2017–18 ($)		2018–19 ($)	
	Livestock	Crops	Livestock	Crops	Livestock	Crops
Ballarat	279,976,079	327,305,652	329,847,197	229,269,792	422,116,139	303,058,621
Bendigo	342,851,901	292,338,625	319,967,659	212,152,397	277,220,161	191,766,483
Geelong	143,234,735	106,472,768	182,806,472	121,686,798	179,742,118	144,195,638
Hume	533,134,064	172,966,447	812,258,613	164,841,656	857,445,488	205,041,989
Latrobe - Gippsland	1,282,665,861	346,092,836	1,377,598,029	262,504,461	1,680,032,449	340,156,270
Melbourne - Inner	0	0	99,172	0	12,495	0
Melbourne - Inner East	0	0	0	0	3,978,380	115,469
Melbourne - Inner South	0	2,042,331	61,719	9,372,931	0	4,516,514
Melbourne - North East	8,942,758	138,816,800	14,113,044	143,614,148	11,831,365	124,880,236
Melbourne - North West	15,762,941	6,041,715	21,322,908	7,760,754	24,470,272	1,479,604
Melbourne - Outer East	5,986,117	280,691,950	16,347,914	306,804,642	8,782,593	306,085,058
Melbourne - South East	140,877,470	188,477,837	154,509,325	224,270,401	82,681,433	203,477,854
Melbourne - West	10,336,958	121,818,553	3,965,963	91,300,268	837,635	70,903,142
Mornington Peninsula	9,712,938	117,960,134	8,522,125	103,424,518	6,580,695	123,394,726
North West	801,506,760	3,064,796,834	1,220,384,585	2,718,835,424	1,152,900,280	2,750,464,362
Shepparton	755,433,681	711,835,441	913,632,895	847,511,912	917,092,523	837,170,134
Warrnambool and South West	2,194,663,015	230,688,489	2,392,717,417	174,470,928	2,564,056,866	340,614,117
Livestock and crops total		*$ 12,633,431,694*		*$ 13,385,976,064*		*$ 14,137,101,110*

Values in the table below are reported in 2019-20 dollars, for the whole of Victoria, after accounting for inflation using the Reserve Bank of Australia's calculator (available at https://www.rba.gov.au/calculator/). Data were sourced ABARES (2020). Australian forest and wood product statistics datasets. ABARES. Commonwealth of Australia, available at https://www.agriculture.gov.au/abares/research-topics/forests/forest-economics/forest-wood-products-statistics The estimated gross value of logs delivered to mill door (or wharf gate) excludes firewood removals. Softwood includes native cypress pine.

Gross value of log production	2016–17 $m	2017–18 $m	2018–19 $m
Hardwood plantation	313	270	306
Softwood	337	352	341

To estimate the region-specific (SA4) value of plantation forestry from these state-wide estimates, we used area statements from the Australian Land Use and Management (ALUM) Classification Version 8 (ABARES 2016) for

- 3.1.1 Hardwood plantation forestry, and
- 3.1.2 Softwood plantation forestry

Under a coarse assumption that area of plantation alone describes the proportional contribution of each region to the state-wide aggregate (i.e. we did not account for variation in growth rates between regions), we estimated the proportional contributions tabulated below.

Estimated proportional contribution of region to total HARDWOOD PLANTATION production.

Region	Proportion
Ballarat	0.029
Bendigo	0.002
Geelong	0.004
Hume	0.023
Latrobe - Gippsland	0.306
Melbourne - Inner	0.000
Melbourne - Inner East	0.000
Melbourne - Inner South	0.000
Melbourne - North East	0.003
Melbourne - North West	0.000
Melbourne - Outer East	0.000
Melbourne - South East	0.000
Melbourne - West	0.000
Mornington Peninsula	0.000
North West	0.107
Shepparton	0.000
Warrnambool and South West	0.526
Total	*1.000*

Estimated proportional contribution of region to total SOFTWOOD production.

Region	Proportion
Ballarat	0.108
Bendigo	0.001
Geelong	0.008
Hume	0.248
Latrobe - Gippsland	0.210
Melbourne - Inner	0.000
Melbourne - Inner East	0.000
Melbourne - Inner South	0.000
Melbourne - North East	0.005
Melbourne - North West	0.004
Melbourne - Outer East	0.000
Melbourne - South East	0.000
Melbourne - West	0.000
Mornington Peninsula	0.000
North West	0.076
Shepparton	0.000
Warrnambool and South West	0.338
Total	*1.000*

The species tabulated below are inclusions in SMP that have non-zero impacts from deer. The increase in the probability of extinction without deer control refers to a 20 year time horizon. See section 3.3 for details.

Species	Group	Willingness to pay	increase in probability of extinction without deer control
Heleioporus australiacus	amphibians	100%	0.05
Litoria aurea	amphibians	100%	0.04
Litoria littlejohni	amphibians	100%	0.05
Litoria spenceri	amphibians	100%	0.02
Litoria verreauxii alpina	amphibians	100%	0.05
Philoria frosti	amphibians	100%	0.03
Pseudophryne bibronii	amphibians	100%	0.13
Pseudophryne dendyi	amphibians	100%	0.08
Pseudophryne semimarmorata	amphibians	100%	0.01
Uperoleia rugosa	amphibians	100%	0.04
Uperoleia tyleri	amphibians	100%	0.05
Acanthiza iredalei hedleyi	birds	100%	0.01
Burhinus grallarius	birds	100%	0.04
Calamanthus campestris	birds	100%	0.01
Calidris tenuirostris	birds	100%	0.09
Calyptorhynchus banksii graptogyne	birds	100%	0.01
Calyptorhynchus lathami lathami	birds	100%	0.02
Charadrius leschenaultii	birds	100%	0.02
Chthonicola sagittatus	birds	100%	0.01
Cinclosoma punctatum	birds	100%	0.01
Dasyornis brachypterus brachypterus	birds	100%	0.01
Dasyornis broadbenti broadbenti	birds	100%	0.01
Dasyornis broadbenti caryochrous	birds	100%	0.02
Dromaius novaehollandiae	birds	100%	0.04
Falco hypoleucos	birds	100%	0.02
Grantiella picta	birds	100%	0.02
Haliaeetus leucogaster	birds	100%	0.11
Hirundapus caudacutus	birds	100%	0.01
Ixobrychus flavicollis australis	birds	100%	0.01
Larus pacificus pacificus	birds	100%	0.04
Lichenostomus cratitius	birds	100%	0.04
Neophema pulchella	birds	100%	0.06
Ninox strenua	birds	100%	0.01
Numenius madagascariensis	birds	100%	0.01
Oxyura australis	birds	100%	0.01
Pezoporus wallicus wallicus	birds	100%	0.04

Pyrrholaemus brunneus	birds	100%	0.03
Thinornis rubricollis rubricollis	birds	100%	0.01
Tringa stagnatilis	birds	100%	0.04
Tyto novaehollandiae novaehollandiae	birds	100%	0.01
Tyto tenebricosa tenebricosa	birds	100%	0.02
Burramys parvus	mammals	100%	0.02
Cercartetus concinnus minor	mammals	100%	0.02
Cercartetus lepidus	mammals	100%	0.02
Cercartetus nanus	mammals	100%	0.02
Dasyurus maculatus maculatus	mammals	100%	0.02
Gymnobelideus leadbeateri	mammals	100%	0.01
Isoodon obesulus obesulus	mammals	100%	0.01
Mastacomys fuscus mordicus	mammals	100%	0.03
Miniopterus schreibersii bassanii	mammals	100%	0.03
Miniopterus schreibersii oceanensis	mammals	100%	0.03
Notomys mitchelli	mammals	100%	0.00
Petauroides volans	mammals	100%	0.01
Petaurus norfolcensis	mammals	100%	0.02
Petrogale penicillata	mammals	100%	0.04
Potorous longipes	mammals	100%	0.03
Potorous tridactylus tridactylus	mammals	100%	0.02
Pseudomys apodemoides	mammals	100%	0.02
Pseudomys fumeus	mammals	100%	0.02
Pseudomys novaehollandiae	mammals	100%	0.05
Pseudomys shortridgei	mammals	100%	0.03
Rhinolophus megaphyllus megaphyllus	mammals	100%	0.03
Saccolaimus flaviventris	mammals	100%	0.02
Sminthopsis leucopus	mammals	100%	0.02
Cyclodomorphus michaeli	reptiles	100%	0.02
Cyclodomorphus praealtus	reptiles	100%	0.06
Echiopsis curta	reptiles	100%	0.01
Eulamprus kosciuskoi	reptiles	100%	0.05
Hemiergis peronii	reptiles	100%	0.02
Liopholis guthega	reptiles	100%	0.05
Liopholis montana	reptiles	100%	0.03
Lissolepis coventryi	reptiles	100%	0.01
Morelia spilota spilota	reptiles	100%	0.01
Pogona barbata	reptiles	100%	0.02
Pseudemoia cryodroma	reptiles	100%	0.08
Pseudemoia rawlinsoni	reptiles	100%	0.04
Tiliqua occipitalis	reptiles	100%	0.01
Varanus varius	reptiles	100%	0.00
Abrotanella nivigena	plants	1%	0.06

Acacia alpina	plants	1%	0.03
Acacia amoena	plants	1%	0.04
Acacia boormanii	plants	1%	0.05
Acacia dallachiana	plants	1%	0.03
Acacia decora	plants	1%	0.04
Acacia doratoxylon	plants	1%	0.05
Acacia farinosa	plants	1%	0.04
Acacia flexifolia	plants	1%	0.04
Acacia kybeanensis	plants	1%	0.04
Acacia lineata	plants	1%	0.09
Acacia lucasii	plants	1%	0.06
Acacia maidenii	plants	1%	0.04
Acacia nano-dealbata	plants	1%	0.04
Acacia phlebophylla	plants	1%	0.03
Acacia stictophylla	plants	1%	0.04
Acacia subtilinervis	plants	1%	0.05
Acacia verticillata subsp. ruscifolia	plants	1%	0.04
Acacia williamsonii	plants	1%	0.04
Aciphylla glacialis	plants	1%	0.09
Aciphylla simplicifolia	plants	1%	0.04
Acronychia oblongifolia	plants	1%	0.05
Acrothamnus montanus	plants	1%	0.02
Acrotriche cordata	plants	1%	0.06
Acrotriche leucocarpa	plants	1%	0.03
Adiantum diaphanum	plants	1%	0.09
Adriana tomentosa var. tomentosa	plants	1%	0.04
Agrostis muelleriana	plants	1%	0.04
Alchemilla sp. 1	plants	1%	0.01
Allocasuarina grampiana	plants	1%	0.04
Allocasuarina nana	plants	1%	0.09
Almaleea capitata	plants	1%	0.07
Amyema linophylla subsp. orientale	plants	1%	0.04
Angophora floribunda	plants	1%	0.04
Anthosachne multiflora subsp. multiflora	plants	1%	0.04
Argyrotegium nitidulum	plants	1%	0.11
Arthropodium sp. 1 (robust glaucous)	plants	1%	0.01
Asperula ambleia	plants	1%	0.04
Asperula minima	plants	1%	0.05
Asplenium hookerianum	plants	1%	0.04
Astelia australiana	plants	1%	0.04
Asterolasia phebalioides	plants	1%	0.09
Astrotricha sp. 4	plants	1%	0.09
Australopyrum retrofractum	plants	1%	0.02

Australopyrum velutinum	plants	1%	0.01
Avicennia marina subsp. australasica	plants	1%	0.04
Banksia saxicola	plants	1%	0.02
Barbarea grayi	plants	1%	0.04
Bauera sessiliflora	plants	1%	0.05
Baumea laxa	plants	1%	0.03
Bertya cunninghamii subsp. pubiramula	plants	1%	0.04
Bertya findlayi	plants	1%	0.04
Beyeria lanceolata	plants	1%	0.04
Boronia algida	plants	1%	0.04
Boronia citrata	plants	1%	0.05
Boronia galbraithiae	plants	1%	0.04
Boronia latipinna	plants	1%	0.04
Boronia ledifolia	plants	1%	0.06
Bossiaea bracteosa	plants	1%	0.02
Bossiaea cordigera	plants	1%	0.02
Bossiaea ensata	plants	1%	0.06
Bossiaea heterophylla	plants	1%	0.03
Bossiaea riparia	plants	1%	0.03
Bossiaea rosmarinifolia	plants	1%	0.04
Brachyloma depressum	plants	1%	0.09
Brachyscome muelleroides	plants	1%	0.02
Brachyscome obovata	plants	1%	0.04
Brachyscome petrophila	plants	1%	0.05
Brachyscome ptychocarpa	plants	1%	0.08
Brachyscome radicans	plants	1%	0.09
Brachyscome readeri	plants	1%	0.06
Brachyscome riparia	plants	1%	0.04
Brachyscome sp. 3	plants	1%	0.07
Burnettia cuneata	plants	1%	0.04
Caladenia aurantiaca	plants	1%	0.02
Caladenia australis	plants	1%	0.03
Caladenia calcicola	plants	1%	0.04
Caladenia flavovirens	plants	1%	0.01
Caladenia insularis	plants	1%	0.01
Caladenia tensa	plants	1%	0.04
Caladenia tessellata	plants	1%	0.04
Caladenia valida	plants	1%	0.02
Caladenia venusta	plants	1%	0.06
Caladenia versicolor	plants	1%	0.01
Callistemon brachyandrus	plants	1%	0.02
Callistemon kenmorrisonii	plants	1%	0.05
Callistemon subulatus	plants	1%	0.02

Calochilus therophilus	plants	1%	0.04
Calotis lappulacea	plants	1%	0.04
Calystegia soldanella	plants	1%	0.09
Carex alsophila	plants	1%	0.06
Carex blakei	plants	1%	0.04
Carex canescens	plants	1%	0.13
Carex capillacea	plants	1%	0.04
Carex cephalotes	plants	1%	0.03
Carex chlorantha	plants	1%	0.11
Carex echinata	plants	1%	0.05
Carex jackiana	plants	1%	0.07
Carex paupera	plants	1%	0.04
Carex raleighii	plants	1%	0.06
Carpha alpina	plants	1%	0.06
Carpha nivicola	plants	1%	0.13
Celmisia sericophylla	plants	1%	0.05
Chenopodium erosum	plants	1%	0.04
Chorizandra australis	plants	1%	0.02
Comesperma polygaloides	plants	1%	0.05
Coopernookia barbata	plants	1%	0.03
Coprosma moorei	plants	1%	0.06
Coprosma nivalis	plants	1%	0.04
Coprosma perpusilla subsp. perpusilla	plants	1%	0.04
Correa aemula	plants	1%	0.09
Correa reflexa var. angustifolia	plants	1%	0.06
Correa reflexa var. lobata	plants	1%	0.05
Corunastylis ciliata	plants	1%	0.03
Corybas aconitiflorus	plants	1%	0.04
Corybas despectans	plants	1%	0.04
Corybas fimbriatus	plants	1%	0.03
Corybas hispidus	plants	1%	0.01
Corymbia gummifera	plants	1%	0.06
Craspedia alba	plants	1%	0.02
Craspedia crocata	plants	1%	0.02
Cryptostylis erecta	plants	1%	0.02
Cryptostylis hunteriana	plants	1%	0.09
Cyathea cunninghamii	plants	1%	0.02
Cyathea leichhardtiana	plants	1%	0.02
Cyathea X marcescens	plants	1%	0.09
Cyathochaeta diandra	plants	1%	0.02
Cymbonotus lawsonianus	plants	1%	0.04
Cymbopogon obtectus	plants	1%	0.09
Cyperus concinnus	plants	1%	0.09

Cyperus flaccidus	plants	1%	0.02
Cyperus pygmaeus	plants	1%	0.04
Cyphanthera albicans subsp. albicans	plants	1%	0.01
Cyphanthera anthocercidea	plants	1%	0.05
Dampiera fusca	plants	1%	0.04
Dampiera purpurea	plants	1%	0.06
Darwinia camptostylis	plants	1%	0.07
Darwinia micropetala	plants	1%	0.07
Deschampsia cespitosa	plants	1%	0.04
Desmodium brachypodum	plants	1%	0.06
Deyeuxia affinis	plants	1%	0.08
Deyeuxia carinata	plants	1%	0.05
Deyeuxia crassiuscula	plants	1%	0.04
Deyeuxia decipiens	plants	1%	0.05
Deyeuxia pungens	plants	1%	0.04
Digitaria ammophila	plants	1%	0.04
Dillwynia oreodoxa	plants	1%	0.02
Dillwynia prostrata	plants	1%	0.05
Dillwynia uncinata	plants	1%	0.09
Diplaspis nivis	plants	1%	0.07
Dipodium hamiltonianum	plants	1%	0.03
Discaria nitida	plants	1%	0.04
Discaria pubescens	plants	1%	0.05
Diuris palustris	plants	1%	0.06
Diuris X palachila	plants	1%	0.08
Dockrillia striolata subsp. striolata	plants	1%	0.02
Dodonaea rhombifolia	plants	1%	0.06
Dodonaea truncatiales	plants	1%	0.04
Drabastrum alpestre	plants	1%	0.01
Drosera arcturi	plants	1%	0.07
Echinopogon caespitosus var. caespitosus	plants	1%	0.04
Eleocharis pallens	plants	1%	0.02
Eleocharis plana	plants	1%	0.04
Enneapogon gracilis	plants	1%	0.07
Entolasia stricta	plants	1%	0.01
Epacris glacialis	plants	1%	0.03
Epacris microphylla var. rhombifolia	plants	1%	0.08
Epacris petrophila	plants	1%	0.05
Epilobium curtisiae	plants	1%	0.06
Epilobium sarmentaceum	plants	1%	0.04
Epilobium tasmanicum	plants	1%	0.06
Epilobium willisii	plants	1%	0.04
Eremophila bignoniiflora	plants	1%	0.04

Erigeron nitidus	plants	1%	0.07
Eriocaulon australasicum	plants	1%	0.04
Eriocaulon scariosum	plants	1%	0.05
Eucalyptus agglomerata	plants	1%	0.01
Eucalyptus aggregata	plants	1%	0.01
Eucalyptus brookeriana	plants	1%	0.01
Eucalyptus denticulata	plants	1%	0.04
Eucalyptus fasciculosa	plants	1%	0.04
Eucalyptus froggattii	plants	1%	0.06
Eucalyptus glaucescens	plants	1%	0.03
Eucalyptus globulus subsp. maidenii	plants	1%	0.02
Eucalyptus kybeanensis	plants	1%	0.06
Eucalyptus mitchelliana	plants	1%	0.06
Eucalyptus neglecta	plants	1%	0.13
Eucalyptus perriniana	plants	1%	0.01
Eucalyptus polyanthemos subsp. longior	plants	1%	0.01
Eucalyptus saxatilis	plants	1%	0.04
Eucalyptus yarraensis	plants	1%	0.02
Euchiton traversii	plants	1%	0.04
Euchiton umbricola	plants	1%	0.04
Euphrasia caudata	plants	1%	0.03
Euphrasia eichleri	plants	1%	0.04
Euphrasia gibbsiae subsp. subglabrifolia	plants	1%	0.04
Euphrasia lasianthera	plants	1%	0.09
Euphrasia scabra	plants	1%	0.05
Eupomatia laurina	plants	1%	0.05
Ewartia nubigena	plants	1%	0.07
Exocarpos syrticola	plants	1%	0.08
Fimbristylis aestivalis	plants	1%	0.09
Fimbristylis velata	plants	1%	0.04
Frankenia sessilis	plants	1%	0.04
Gahnia grandis	plants	1%	0.02
Gahnia microstachya	plants	1%	0.04
Galium compactum	plants	1%	0.05
Galium curvihirtum	plants	1%	0.05
Geranium neglectum	plants	1%	0.03
Gingidia harveyana	plants	1%	0.04
Glossodia minor	plants	1%	0.01
Glossostigma cleistanthum	plants	1%	0.02
Glycine canescens	plants	1%	0.02
Glycine latrobeana	plants	1%	0.06
Gnephosis drummondii	plants	1%	0.06
Gompholobium glabratum	plants	1%	0.06

Gonocarpus mezianus	plants	1%	0.05
Goodenia benthamiana	plants	1%	0.04
Goodenia lineata	plants	1%	0.03
Goodenia stelligera	plants	1%	0.06
Goodia medicaginea	plants	1%	0.06
Gratiola pedunculata	plants	1%	0.03
Grevillea barklyana	plants	1%	0.05
Grevillea bedggoodiana	plants	1%	0.01
Grevillea celata	plants	1%	0.03
Grevillea chrysophaea	plants	1%	0.04
Grevillea confertifolia	plants	1%	0.03
Grevillea dimorpha	plants	1%	0.06
Grevillea floripendula	plants	1%	0.05
Grevillea jephcottii	plants	1%	0.13
Grevillea microstegia	plants	1%	0.10
Grevillea miqueliana subsp. miqueliana	plants	1%	0.07
Grevillea montis-cole subsp. montis-cole	plants	1%	0.03
Grevillea repens	plants	1%	0.04
Grevillea steiglitziana	plants	1%	0.07
Grevillea willisii	plants	1%	0.05
Haegiela tatei	plants	1%	0.09
Hakea lissosperma	plants	1%	0.04
Halophila australis	plants	1%	0.09
Haloragis exalata subsp. exalata var. exalata	plants	1%	0.06
Haloragodendron baeuerlenii	plants	1%	0.02
Herpolirion novae-zelandiae	plants	1%	0.05
Hibbertia cistiflora subsp. rostrata	plants	1%	0.06
Hibbertia diffusa	plants	1%	0.06
Hibbertia hermanniifolia subsp. recondita	plants	1%	0.04
Hibbertia rufa	plants	1%	0.03
Hibbertia sessiliflora	plants	1%	0.05
Hibbertia spathulata	plants	1%	0.08
Hibiscus brachysiphonius	plants	1%	0.02
Hierochloe submutica	plants	1%	0.06
Huperzia australiana	plants	1%	0.05
Hybanthus monopetalus	plants	1%	0.04
Hypsela tridens	plants	1%	0.04
Isolepis australiensis	plants	1%	0.01
Isolepis montivaga	plants	1%	0.06
Isolepis wakefieldiana	plants	1%	0.09
Isopogon prostratus	plants	1%	0.03
Juncus antarcticus	plants	1%	0.02
Juncus falcatus subsp. falcatus	plants	1%	0.04

Juncus phaeanthus	plants	1%	0.05
Kelleria laxa	plants	1%	0.04
Lachnagrostis adamsonii	plants	1%	0.09
Lachnagrostis meionectes	plants	1%	0.03
Lasiopetalum schulzenii	plants	1%	0.04
Lastreopsis hispida	plants	1%	0.04
Laxmannia gracilis	plants	1%	0.04
Leiocarpa gatesii	plants	1%	0.04
Lemna trisulca	plants	1%	0.02
Lepidium desvauxii	plants	1%	0.05
Lepidium fasciculatum	plants	1%	0.02
Lepidium hyssopifolium	plants	1%	0.07
Lepidium papillosum	plants	1%	0.13
Lepidosperma canescens	plants	1%	0.01
Lepidosperma limicola	plants	1%	0.06
Leptecophylla juniperina subsp. oxycedrus	plants	1%	0.04
Leptorhynchos elongatus	plants	1%	0.02
Leptorhynchos squamatus subsp. alpinus	plants	1%	0.02
Leptospermum emarginatum	plants	1%	0.06
Lepyrodia anarthria	plants	1%	0.04
Lepyrodia flexuosa	plants	1%	0.03
Lespedeza juncea subsp. sericea	plants	1%	0.06
Leucopogon attenuatus	plants	1%	0.02
Leucopogon esquamatus	plants	1%	0.09
Leucopogon juniperinus	plants	1%	0.04
Leucopogon microphyllus var. pilibundus	plants	1%	0.04
Leucopogon neurophyllus	plants	1%	0.05
Leucopogon riparius	plants	1%	0.05
Leucopogon thymifolius	plants	1%	0.05
Levenhookia sonderi	plants	1%	0.02
Lindsaea microphylla	plants	1%	0.02
Lipocarpha microcephala	plants	1%	0.08
Livistona australis	plants	1%	0.02
Logania pusilla	plants	1%	0.09
Lotus australis var. australis	plants	1%	0.05
Luzula acutifolia subsp. acutifolia	plants	1%	0.04
Luzula alpestris	plants	1%	0.04
Luzula atrata	plants	1%	0.04
Lycopodiella serpentina	plants	1%	0.09
Lycopodium scariosum	plants	1%	0.03
Marianthus bignoniaceus	plants	1%	0.05
Marsdenia flavescens	plants	1%	0.05
Melaleuca halmaturorum	plants	1%	0.09

Myriophyllum alpinum	plants	1%	0.04
Notogrammitis angustifolia subsp. nothofageti	plants	1%	0.01
Olearia stellulata	plants	1%	0.03
Oreobolus oxycarpus subsp. oxycarpus	plants	1%	0.04
Oxalis magellanica	plants	1%	0.03
Ozothamnus adnatus	plants	1%	0.06
Ozothamnus alpinus	plants	1%	0.04
Ozothamnus argophyllus	plants	1%	0.08
Ozothamnus rogersianus	plants	1%	0.05
Ozothamnus stirlingii	plants	1%	0.06
Persoonia subvelutina	plants	1%	0.04
Philotheca difformis subsp. difformis	plants	1%	0.04
Philotheca virgata	plants	1%	0.09
Pimelea curviflora var. aff. subglabrata	plants	1%	0.01
Poa amplexicaulis	plants	1%	0.04
Poa billardierei	plants	1%	0.09
Pomaderris brunnea	plants	1%	0.08
Pomaderris discolor	plants	1%	0.10
Pomaderris ligustrina subsp. ligustrina	plants	1%	0.04
Pomaderris vacciniifolia	plants	1%	0.06
Prasophyllum diversiflorum	plants	1%	0.02
Prasophyllum sphacelatum	plants	1%	0.04
Prostanthera saxicola var. bracteolata	plants	1%	0.02
Psychrophila introloba	plants	1%	0.04
Pterostylis despectans	plants	1%	0.04
Ranunculus millanii	plants	1%	0.04
Rytidosperma alpicola	plants	1%	0.09
Rytidosperma australe	plants	1%	0.09
Rytidosperma nivicola	plants	1%	0.05
Sambucus australasica	plants	1%	0.04
Sannantha crenulata	plants	1%	0.06
Schoenus turbinatus	plants	1%	0.04
Senecio pinnatifolius var. alpinus	plants	1%	0.01
Senna aciphylla	plants	1%	0.04
Sporadanthus tasmanicus	plants	1%	0.02
Swainsona galegifolia	plants	1%	0.09
Tecticornia syncarpa	plants	1%	0.09
Tetrarrhena turfosa	plants	1%	0.05
Tetratheca stenocarpa	plants	1%	0.02
Thelymitra epipactoides	plants	1%	0.04
Tmesipteris elongata	plants	1%	0.04
Tmesipteris ovata	plants	1%	0.02
Tmesipteris parva	plants	1%	0.04

Trichanthodium baracchianum	plants	1%	0.03
Trochocarpa clarkei	plants	1%	0.02
Wahlenbergia planiflora subsp. planiflora	plants	1%	0.02
Westringia glabra	plants	1%	0.04
Wittsteinia vacciniacea	plants	1%	0.01
Wurmbea biglandulosa subsp. biglandulosa	plants	1%	0.02
Xanthosia leiophylla	plants	1%	0.02
Xerochrysum palustre	plants	1%	0.03
Zieria smithii subsp. smithii	plants	1%	0.04