CENTRE FOR
INVASIVE SPECIES SOLUTIONS

GLOVEBOX GUIDE TO MANAGING FERAL DEER

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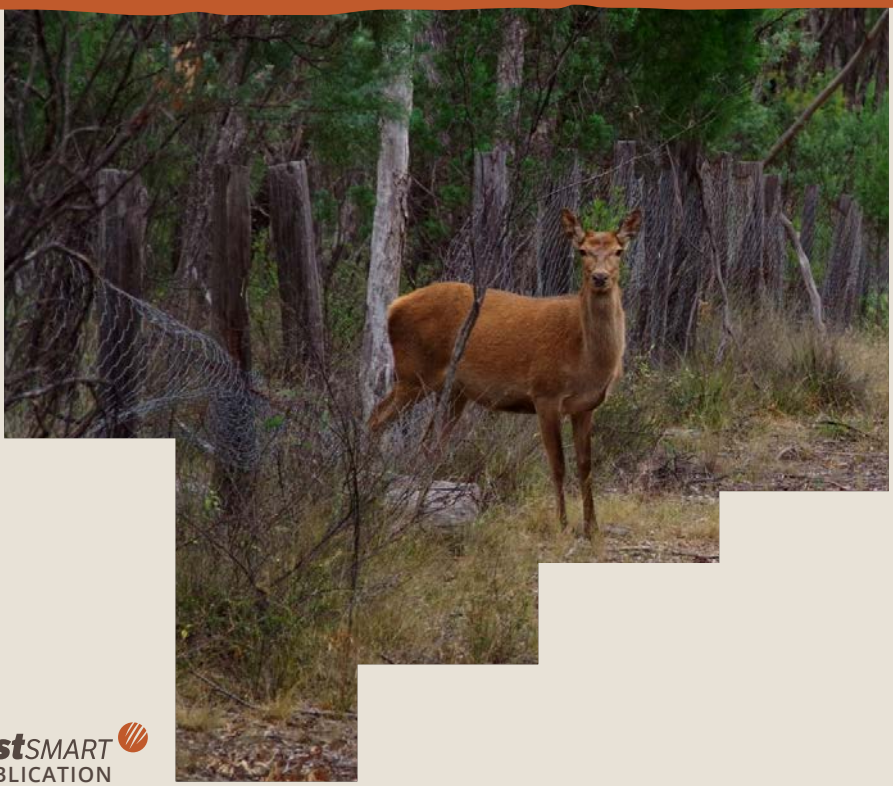

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What you'll get out of this Guide

This *Glovebox Guide to Managing Feral Deer* is a practical resource designed to assist Australian land managers (farmers, public land managers and Indigenous groups) to manage the impacts of feral deer.

A large part of tackling a deer problem depends on your awareness of the situation, and being informed on how best to reduce their undesirable impacts. This guide aims to:

1. increase your understanding of where and how deer live
2. outline your options for control, and their benefits and potential constraints
3. summarise monitoring and management strategies/ techniques you could implement
4. help you develop a cost-effective deer management plan.

The guide is structured to help you **understand** feral deer, their impacts and behaviours; then **plan**, **manage** and **improve** a control program.

By planning before you start, management will likely be cheaper and more effective

Planning is important: explore the issue and options and determine what, if any, integration is required.

Thinking about the cause(s) of the problem – instead of the 'symptoms' – will help identify the cheapest and most effective management. **Understanding deer behaviour** is also important.

Attempting to **quantify the impacts** of feral deer can help you understand the extent of the deer problem before you act. Such **benchmarking** can enable you to assess the effectiveness of your deer management.

Finally, it is useful to consider the consequences of a management plan and whether there is potential for **any adverse consequences**, as well as the **expected benefits**. An integrated management program can help reduce the risk of adverse consequences.

Adaptive management lets you tailor and adjust your management actions

Adaptive management is sometimes referred to as structured 'learning by doing' – it's about implementing management while learning which actions turn out to be most effective for your specified objectives.

It is a useful way to compare the effectiveness of different management actions.

Important in the process is that **you determine for your own situation** the objectives, opportunities and risks, actions, planning, monitoring and review process.

See ***Your notes for creating a plan*** on page 63.

The questions cover:

- knowing your 'target'
- assessing the problem
- what you want to achieve
- implementing control techniques and strategies that suit you
- monitoring how it goes
- evaluating and revising the plan for effectiveness and cost.

This Guide gives you the information you need to answer these questions for your own plan.

This Guide contains a deer management planner for you to use (Your notes for creating a plan, page 63). Your answers to its questions will help you create your own **realistic and comprehensive, but simple, management plan**.

UNDERSTAND

Fallow deer. Source: B Boyle.

This section helps you get familiar with the deer species present in Australia, and their impacts.

Deer quickly learn to avoid some management efforts. Understanding deer, and the impacts that they are having, is critical for cost-effective management.

Having access to key information lets you devise a solution that best suits your situation.

You might also benefit from discussing your situation with other people or groups managing deer.

Identify the problem

Define your deer problems using impacts rather than presence

Start your planning by carefully defining what you want to address – doing this will help determine what you do next.

The problem with pest animals is not actually their presence – it's the damage they cause.

Although it can take time, you should focus on describing the specific undesirable impacts that deer are having on people, livestock, crops, wildlife and habitat. For example:

- "This year's crop yield was down 24% compared to the local average due to trampling and consumption by deer."
- "There were 12 collisions between deer and vehicles in our shire this year, two of which resulted in people going to hospital."

It is important to note that **in some situations, deer might not be the only cause of the impact**. Examples are grazing and browsing, which could be due to other ungulates (mammals with hooves) and native animals. Similarly, wallows might also be created or used by feral pigs or feral horses.

If you are uncertain that deer are causing the impacts, then you should confirm that they are the cause before embarking on potentially costly management (see *How to monitor activities and outcomes* on page 52).

Know your target and how they fit within the landscape

Another step is to consider **how the deer interact with other native animals, pests and weeds**:

- predator–prey relationships
- competing for feed or habitat
- potentially beneficial relationships.

Location matters for management options and costs

Mapping the areas impacted by deer can help you decide where you need to manage deer.

It might only be part of a property (e.g. paddocks adjacent to a forest), or it could be multiple adjoining properties.

This will also help you to **determine who could do what or who could contribute financially**. For example, a forestry company might conduct deer control on their property to reduce impacts of deer on neighbouring paddocks. A group of adjoining land managers might all contribute to an aerial shooting operation over all the properties.

Fallow deer. Source: Z Mckenzie.

Red deer. Source: P Jesser.

Understanding the six deer species in Australia

There are over 50 species of deer in the world. None are native to Australia.

Six species of deer have established self-sustaining free-ranging populations in Australia. All six species are mixed grazers/browsers and are most active at dawn, dusk and night.

Only males have antlers, which they shed and regrow each year. Antlers that are actively growing are soft (called 'velvet') and when the antlers stop growing, they harden (called 'hard antler').

Key features of each species[1]

Fallow deer *(Dama dama)*[2]

♂
up to 95 cm
50–100 kg

♀
up to 80 cm
35–55 kg

Appearance

Gregarious, medium-sized deer with wide variation in coat colour – ranging from white through to black.

Coat: Variable – black, red–brown with spots, lighter brown, and pure white. A white patch on rump highlights a dark stripe on the tail.

Antlers: Many tines, often like an open hand ('palmate').

Habitat, distribution and behaviour

Pastoral land, and forest and woodland with grassy understoreys. Fallow deer feed on grassy clearings and on improved pastures and crops.

Distribution: Present in all states and territories except NT.

Behaviour: They form large groups; adult males often separate from females outside the March–April rut. Males 'croak' during the rut.

[1] *Source of images: Victorian Game Management Authority.*
[2] *Taxonomy through this Guide follows Jackson and Groves (2015).*

Sambar deer *(Cervus unicolor)*

♂
up to 130 cm
130–245 kg

♀
up to 115 cm
110–180 kg

Appearance

Australia's largest deer, with large rounded ears. They emit a loud 'honk' when disturbed.

Coat: Uniformly dark brown; in winter it can appear black. The long bushy tail is raised when alarmed.

Antlers: Three tines on each antler; the front tine of the fork is the longest.

Habitat, distribution and behaviour

Forest, woodland and shrub habitats from the coast to the alpine tree line.

Distribution: Present in Vic, ACT, NSW, SA and NT.

Behaviour: Seldom seen far from thick cover during daytime. Breed throughout the year, but the peak is September–November. Commonly hybridise with rusa deer.

Rusa deer *(Cervus timorensis)*

♂
up to 110 cm
80–140 kg

♀
up to 95 cm
50–75 kg

Appearance

Can be confused with sambar deer – with which they readily hybridise – but is smaller, has pointed rather than round ears, and the rear tine of the fork is the longest.

Coat: Summer coat is red–brown; winter coat is thicker and greyer. Chin, throat and underparts are cream. They have a long, brown tail.

Antlers: Three tines on each antler; the rear tine of the fork is the longest.

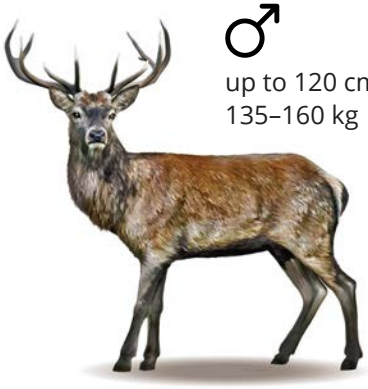
Habitat, distribution and behaviour

Wide range of lower elevation forests, shrublands and woodlands. Often feeds in grassy clearings.

Distribution: Present in NSW, Qld, NT, SA and WA.

Behaviour: Forms large groups; males separate from females outside the June–August breeding season.

Red deer *(Cervus elaphus)*



♂
up to 120 cm
135–160 kg

♀
up to 90 cm
65–100 kg

Appearance

Males have long antlers, commonly with many tines, and are vocal during the March–April breeding season. They are commonly farmed.

Coat: Distinctive red coat in summer with a black dorsal stripe; winter coat is brown. Tail is shorter than that of rusa deer. Distinctive, large white rump patch.

Antlers: Long; can have six or more tines on each antler.

Habitat, distribution and behaviour

Open forest and woodland with grassy understoreys. They often feed on pastures and crops.

Distribution: Present in Qld, NSW, ACT, Vic, SA and WA.

Behaviour: Gregarious. Males separate from females outside the March–April breeding season.

Chital deer *(Axis axis)*

♂
up to 90 cm
75–100 kg

♀
up to 80 cm
45–60 kg

Appearance

A white-spotted deer with a distinctive white throat.

Coat: Reddish brown with white spots, white throat, black band on nose, and a dark stripe along spine from neck to tail. No white patch on the rump. Tail larger than that of fallow deer. White spots are more clearly defined than in spotted-coat phases of fallow deer.

Antlers: Three long, slender tines on each antler.

Habitat, distribution and behaviour

Grassy woodlands near water.

Distribution: Present in Qld, NSW, SA and NT.

Behaviour: Gregarious; frequently seen in large groups. They breed throughout the year.

Hog deer *(Axis porcinus)*

♂
up to 70 cm
35–50 kg

♀
up to 60 cm
18–25 kg

Appearance

Smallest deer species in Australia. They have large ears, and run with their head down.

Coat: Summer coat is red–brown; winter coat is dark brown.

Antlers: Three tines on each antler.

Habitat, distribution and behaviour

Coastal woodlands, heathlands and shrublands, which are near to grassy areas.

Distribution: Present in Vic.

Behaviour: Solitary or small groups. They breed in December–January.

Fallow deer adult female ('common' colour phase). Source: NSW Department of Primary Industries.

Fallow deer adult male in velvet ('melanistic' colour phase). Source: NSW Department of Primary Industries.

Rusa deer adult male in hard antler. Source: Biosecurity Queensland.

Rusa deer adult female and juvenile. Source: Biosecurity Queensland.

Sambar deer adult male in hard antler. Source: C Davies.

Red deer adult male in velvet. Source: NSW Department of Primary Industries.

Chital deer adult male (in hard antler) and adult female. Source: M Brennan, Biosecurity Queensland.

Hog deer adult male in velvet. Source: Arthur Rylah Institute.

Signs of deer

Deer footprints are triangular, but can be very similar to pig, goat and sheep footprints

Deer have hooves similar to those of pigs, goats and sheep.

Ungulate footprints vary in size and depth according to the surface of the ground and size of the animal, so we cannot identify a species of deer or even specific ungulate from their footprints.

However, deer footprints are often more triangular-shaped than other ungulate species (pigs are generally square; sheep and goats are generally rectangular).

Front feet of adult female deer (left to right): fallow, rusa and red deer. Source: T Crittle, NSW Department of Primary Industries.

Game trails are used over and over by deer and other animals

Deer use the same trails to walk between resting and feeding areas, and to watering points.

These 'game trails' can be used by many other species (e.g. pigs, goats and macropods), but are excellent places to look for signs of deer (e.g. footprints and faecal pellets), and to place cameras to detect deer and other wildlife.

A 'game trail' used by chital deer (and feral pigs and macropods) in North Queensland. Source: D Forsyth.

Deer faecal pellets ('scats') are similar to those of goats and sheep

Deer, goats and sheep all produce rounded, oval or cylindrical faecal pellets ('scats') that are usually deposited in groups of tens or, sometimes, hundreds.

There is a lot of overlap in pellet size, shape and colour between species. Fresh faecal pellets can be swabbed for DNA and analysed to determine which deer species (or other ungulate) they came from.

The pellets of sambar deer (Australia's largest deer) can be up to 25 mm long. The pellets of macropods are typically more spherical and larger than those of deer.

Deer typically void pellets in groups of tens or, sometimes, hundreds. Source: A Bengsen.

Wallows are for comfort and breeding behaviours

Deer will often create 'wallows' in drainage lines or other shallow, wet areas where they roll and cover themselves with mud. After wallowing, deer will often rub the mud (and some of their hair) off on adjacent trees.

Feral pigs and feral horses also create and use wallows.

Sambar deer wallow in north-east Victoria. On the left, you can see mud rubbed on the tree. Source: D Forsyth.

Deer rub or thrash saplings and trees with their antlers

Male deer use saplings to rub off the velvet on their maturing antlers. During the mating season, deer will thrash saplings and trees, which can kill plants or change how they grow.

*Sambar deer antler damage on a cherry ballart (*Exocarpos cupressiformis*) in Victoria; to the right, a game trail leads into the river. Source: D Forsyth.*

*Examples of sambar deer antler damage on (left to right): silver wattle (*Acacia dealbata*) and endangered shiny nematolepis (*Nematolepis wilsonii*) in Victoria. Source: A Bennett.*

Impacts and costs

Economic: feral deer cost Australia tens of millions of dollars every year

The highest costs from deer impacts are borne by:

1. grazing industries (production losses and expenditure on deer management)
2. federal, state and local government expenditure on management and research.

There are also significant costs when motor vehicles and trains collide with deer. All of these costs will rise as the distribution and abundance of deer in Australia increase.

Human health: deer are involved in vehicle accidents, and host pathogens

Feral deer are seldom aggressive towards people. However, collisions between deer and vehicles injure (and occasionally kill) people.

Several pathogens have been detected in feral deer in Australia – some of which can pose a risk to human or animal health. For example, sambar deer living in Melbourne's drinking water catchments carry *Cryptosporidium* and *Giardia* parasites that can cause gastrointestinal illness in people drinking contaminated water.

Agricultural: deer eat and trample crops and pasture, damage fences and saplings

Grazing, feeding, trampling, fouling and rubbing by feral deer damage:

- crops – especially lucerne and oats
- cattle and sheep pastures
- fruit and vegetable crops
- radiata pine (*Pinus radiata*) seedlings, saplings and bark
- foliage of trees growing in native forest plantations.

Deer easily jump standard livestock fences, but can damage them when they try to push through or under.

Table 1. How much chital and fallow deer eat compared to cows and merino sheep

Deer species	How much they eat compared to livestock
Chital deer (55 kg) in North Queensland wet season[1]	25% of the grass needed for a cow (450 kg)[2]
Chital deer (55 kg) in North Queensland dry season[1]	15% of the grass needed for a cow (450 kg)[2]
Adult female (38 kg) and adult male (85 kg) fallow deer	2.0 dry sheep equivalents (DSEs)[3]

Notes: [1] Average feral chital deer. [2] A non-pregnant, non-lactating cow. [3] The energy required by a 50-kg merino wether to maintain its weight.

Environmental: deer degrade habitats, damage plants, are food for feral animals, compete with native herbivores

Deer are listed in:

- NSW as a *Key Threatening Process* for herbivory and environmental degradation (all species; *New South Wales Biodiversity Conservation Act 2016*)
- Victoria as a potentially threatening process for reduction in biodiversity of native vegetation (sambar deer; *Flora and Fauna Guarantee Act 1988*).

It can be difficult to distinguish between damage from browsing and grazing by deer versus other herbivores. The most reliable way to determine the effects of *only* deer is by excluding them (but not other herbivores) from areas.

Deer can cause environmental damage by:

- eating their preferred food plants which can reduce plant biomass and alter the composition of plant communities
- rubbing their antlers on saplings
- creating wallows in drainage lines and in alpine peatlands (an endangered ecological community) – although we do not yet know if this also reduces water quality
- eating and spreading viable weed seeds in their faeces
- providing food (e.g. as carcasses) for wild dogs/dingoes, foxes and feral pigs
- competing with native herbivores of similar mass with similar diets, such as common wombats and macropods.

Illegal hunting: poaching can create stress for landowners

Deer hunting is a popular recreational activity. Unfortunately, deer in an area can encourage illegal hunting (poaching), especially at night, which can cause stress for people living on those properties.

Peri-urban: suburbia is not immune

Peri-urban areas are where urban areas transition into bushland or farmland – a land type that is increasing in Australia. Deer live in the peri-urban areas of Adelaide, Melbourne, Wollongong, Sydney and Brisbane.

Vehicles, including trains, sometimes collide with deer in peri-urban areas. Deer eat garden plants and damage fences, and browsing and antler damage can kill ornamental and fruit trees.

Sambar deer have damaged this citrus tree in Harrietville, Victoria. Note the broken stems on the ground and the height of the browsing. Source: D Forsyth.

PLAN

Chital deer. Source: M Elliott.

Planning is the critical first step in cost-effective management of feral deer.

It can be tempting to jump straight to control methods, especially in a stressful situation, but careful planning can greatly increase the likelihood of control being successful.

Monitoring can sometimes seem unimportant in the face of significant and distressing impacts. However, monitoring data empowers you to not only know if you are succeeding but also to design the most cost-effective program possible.

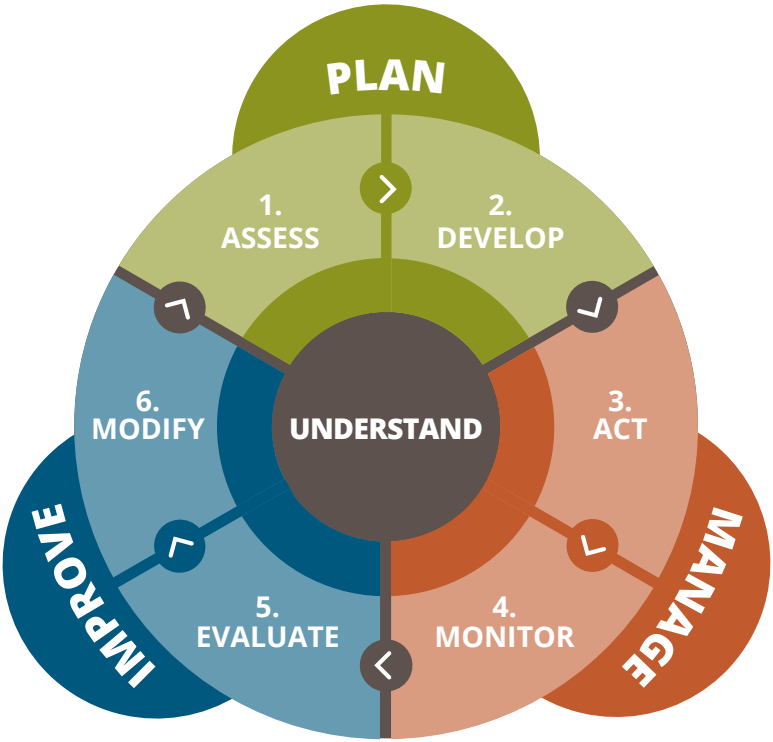
To prevent a deer population from increasing, you need to reduce the population by over one-third each year (> 35%). This is how much a low-density deer population can increase in good conditions.

To do that, you need to know your starting point. This also reduces the likelihood that the problem will recur because of an unaddressed cause.

A deer management plan should aim for long-term and cost-effective outcomes. This means using control techniques that are best suited to your situation.

We will take you through a simple but thorough planning process in this Guide.

Chital deer.
Source: M Brennan.



In adaptive management, you first plan (define the problem and know your target; assess and understand the problem; develop a plan and set clear objectives), then manage (choose control techniques and strategies; monitor the outcomes) and improve (evaluate and modify as required).

A responsive approach that aims for cost-effective, long-term success

Is your goal eradication or sustained control?

Eradicating a population is **only possible** if you can do **all** of these things:

- prevent immigration
- kill all deer that could potentially breed – with available control techniques
- remove deer faster than their maximum annual rate of population growth (35% is the rule of thumb).

Removing the last few deer can be **extremely expensive** because survivors usually inhabit inaccessible areas and have learned to avoid being killed.

In practice, eradication is usually only feasible for small populations that have recently established (e.g. from a farm escape) or live on islands.

The best documented, successful Australian deer eradication program is of fallow deer on Kangaroo Island (Masters et al. 2018, PDF 1.9 MB). This primer (PDF, 1.7 MB) also gives detailed descriptions of the phases of the eradication process and management decisions that need to be made.

Sustained control is the ongoing management of a population.

Because eradication is seldom feasible, sustained control is the most common deer management strategy. If you aim for sustained control, usually your goal will be to **minimise the current and future undesirable impacts** of deer.

Who else might be affected by the deer, or take part in managing the deer?

You should **identify and involve other people or groups** during your planning process. Consulting with them could better define the impacts and increase the scale of a control program.

They could include:

- neighbours
- state or local government agencies involved in natural resource (e.g. national parks, water) or pest management
- local shooters (volunteer, commercial, contractors) and fencing contractors
- community groups (e.g. Landcare).

Integrated pest management is about dealing with problems together

Integrated pest management seeks optimal outcomes with methods such as thoughtful timing of interventions, collaborating with neighbours, or dealing with associated pest and weed problems as a community.

There is a sense of fitting pest control into property management and of operating within a community and a landscape.

Planning is critical to integrated pest control. It involves exploring the issues and options and determining what, if any, integration is required. It is also useful to identify, if appropriate, any thresholds that could trigger a change in the management plan.

Control techniques – mix, sequence and timing

When a range of control techniques is available, it is important to understand the features and benefits of each. The options may be suited to different situations, including habitat/terrain, whether livestock are present, deer density, social setting and time of year.

Attention to timing may focus on periods when the target pest is most vulnerable, or when control will generate the biggest overall benefit. If applied at the wrong time or in the wrong order, the best control techniques may be ineffective and a waste of investment – or even have adverse effects.

Applied wisely, the same techniques can add value to each other, generating 'more bang for your buck'.

Neighbours – coordination and collaboration

Working with neighbours is important because individual deer can move across multiple properties. A cross-boundary or 'cross-tenure' approach may be needed.

Some land managers will find support, encouragement and fellowship from being involved in a group. Similarly, involvement in training and learning new techniques increases the likelihood of success of management efforts. Coordination and collaboration with neighbouring land managers may reduce management costs for individual land managers.

Cross tenure: when everyone who looks after land in an area works together to manage a specific pest. Group control can achieve a far greater impact. The collective identifies the scope of the issue, and management tools and resources required.

Property management and embedding pest control

Pest control is integral to property management, and ideally should be embedded within a broader property management plan – normalising pest control as an integral part of property management, business operations and biosecurity.

It may be as simple as a guiding strategy (e.g. to coordinate an annual ground-based shooting program), with the effort depending on seasonal conditions and the availability of skilled shooters.

Alternatively, tactics could be spelled out in more detail and/or integrated into an annual calendar of property operations.

Develop a feasible plan that outlines expected benefits and costs

After using this Guide's deer-management planner (based on adaptive management), you will have clear ideas about:

- the specifics of deer in your situation
- exactly what the problem is
- what you want to achieve
- which control techniques and strategies likely suit
- how you will monitor and evaluate your plan.

Where possible, goals in your plan should be *SMART*:

Specific – e.g. what change in deer impacts or abundance do you seek?

Measurable – e.g. how will achievement be demonstrated?

Achievable – e.g. is your objective within the means (financial or otherwise) of you/the land manager group/agency?

Relevant – e.g. will a change in deer impacts or abundance actually contribute to achieving your objective?

Time-bound – e.g. when will you know if the objective has been achieved?

Use your answers to the questions to **decide which management actions are feasible, practically and financially**.

For example, if land managers will be implementing the management (e.g. ground-based shooting or fencing), do they have the time and budget needed? Are there more practical and cheaper options to achieve the objectives?

Consulting with others (e.g. state pest management agencies, contractors, other land manager groups) can be helpful.

Preliminary **expected benefits and costs should be evaluated** for the deer management. These should cover:

- ongoing maintenance costs
- any 'transition periods'
- initial 'knockdown' expenses (including time, money and the necessary duration of the work)
- un-priced benefits (such as improved ecosystems or better mental health for landholders).

These ideas will help in your evaluation and in determining what outcomes or benefits to monitor, rather than just 'number of pests removed'.

For example, for large-scale helicopter shooting operations, a pre-shoot estimate of deer abundance can assist with budgeting the number of flying hours required to reduce the population by a desired amount (e.g. a 50% or 80% reduction).

Depending on the size and complexity of the objectives and area to be managed, **multiple cycles of drafting and reviewing might be needed** before you finalise and implement your plan.

A finalised plan should **include a review date**. The review should determine whether each of the objectives was achieved. What worked best? What could be done better? Are there new management methods that could be tried? The plan should be updated accordingly.

MANAGE

Source: T Dalman and R Gillmore, project leads for the Native Vegetation Improvement Project, Parks Victoria.

Summary of deer control tools

Where and when to use	Benefits	Potential constraints
Aerial (helicopter-based) shooting		
• larger areas with good visibility (e.g. pastoral areas and woodlands)	• target-specific • with appropriate effort, achieves a large and rapid knockdown • other pests can also be shot • 'fly back' procedure maximises animal welfare outcomes for shot deer	• requires a skilled shooter and pilot • not suitable for peri-urban areas • can expose wildlife scavengers to toxic lead if lead-based ammunition is used
Ground shooting		
• smaller areas with good network of roads and tracks for access • some peri-urban areas • most effective when done at night with a spotlight or thermal equipment	• target-specific • other pests can also be shot • recreational shooters/ commercial harvesters may provide the service for free, or pay to provide the service • contract shooters can achieve comparable time from first shooting to death as that in aerial shooting • carcasses can be used for human/pet/zoo animal/captive wildlife consumption	• relatively ineffective in large, poorly tracked, steep or densely-forested areas • recreational and commercial shooters are unlikely to reduce deer populations to low densities over large areas • not all shooters have thermal and other equipment that can increase kill rates • perception that contract shooters are 'expensive' • removing carcasses can be expensive and have manual handling risks • can expose wildlife scavengers to toxic lead if lead-based ammunition is used

Where and when to use	Benefits	Potential constraints
Exclusion fencing		
• in conservation settings, small areas of high value • in agricultural settings, can fence high-value paddocks or have a 'back-boundary' fence	• can completely exclude deer (also other pest species) • existing stock fences can often be 'topped-up' to exclude deer • fences last for > 15 years with minimal maintenance	• expensive to construct • require regular inspection and maintenance • floods and falling trees can allow deer to pass through breaks in the fence
Trapping		
• peri-urban areas where ground shooting options are limited • most effective when food is scarce (e.g. during drought)	• in Clover traps, deer can be killed by shooting or chemical injection • traps can be moved around	• corral traps are expensive to construct (labour and materials) and run • can capture non-target species • exposed to theft or vandalism • requires food to be replenished • deer may be reluctant to enter a trap, especially if there is abundant food outside the trap • deer (and non-target species) in Clover traps need to be dealt with as soon as possible after capture to minimise adverse welfare outcomes • carcasses need to be removed and appropriately disposed of • if deer are killed by chemical injection, then carcasses need to be disposed of by deep burial to prevent fatal secondary toxicity in wildlife scavengers

Deer control tools

Aerial (helicopter-based) shooting

Where and when to use:

- larger areas with good visibility (e.g. pastoral areas and woodlands)

Benefits:

- target-specific
- with appropriate effort, achieves a large and rapid knockdown
- other pests can also be shot
- 'fly back' procedure maximises animal welfare outcomes for shot deer

Potential constraints:

- requires a skilled shooter and pilot
- not suitable for peri-urban areas
- can expose wildlife scavengers to toxic lead if lead-based ammunition is used

Of the available management methods, helicopter-based ('aerial') shooting can achieve the largest reductions in deer populations over large areas in the shortest time (days or weeks rather than months or years). If deer density is high, then shooting from a helicopter can remove 50 or more deer per hour. An advantage of aerial shooting is that other pest species such as feral pigs can also be shot in the same operation.

Aerial shooting is most cost-effective in more open landscapes (i.e. pastoral and cropping lands, and native grasslands and grassy woodlands) where deer can be quickly detected and the helicopter rapidly manoeuvred to within shooting range.

Aerial shooting is unsuitable for peri-urban settings and is less suited to small properties (< 1,000 ha) – unless the deer population is restricted to only that property or those smaller properties are part of a larger group of properties working together. Aerial shooting is, however, scaleable to very large areas (e.g. 500,000 ha).

The size of the population reduction achieved by aerial shooting depends on the effort (hours of shooting) and the deer density (deer/km^2). Conducting pre-control monitoring to estimate deer density is therefore valuable for predicting the effort and cost required to achieve a desired outcome, and for evaluating the actual outcome achieved.

As a rule of thumb, if the aim is to suppress a fallow deer population that will recover at its maximum growth rate, then aerial shooting operations should aim to commit **at least 11 hours of shooting effort per 1,000 deer present**.

The largest cost of aerial shooting is helicopter charter; ammunition is a significant cost only at high deer densities. The cheapest helicopter for aerial shooting is the two-seater piston engine Robinson R22. Some state agencies mandate having an observer on board (in addition to the pilot and shooter) and using the more expensive turbine-powered helicopters such as the Bell206 JetRanger and Eurocopter AS350 Squirrel.

For shooting operations aiming to suppress the growth of fallow deer populations (i.e. removal of 35% of the population) over an area of 135 km^2, the predicted cost of shooting operations using a JetRanger (based on 2020 costs) ranges from $15,880 at 5 deer/$km^2$ to $136,590 at 40 deer/$km^2$.

Deer that survive aerial-shooting operations can learn behaviours that help them avoid subsequent aerial shooting, but survivors do not disperse or change their home ranges in response to aerial shooting.

Aerial shooting of an adult male chital deer in Queensland. Source: J Hampton.

Using thermal imaging equipment in aerial-shooting programs (either by the shooter or via a dedicated thermal operator) can increase the number of detections of deer, particularly in densely vegetated habitats. Caution should be exercised if a dedicated thermal operator is used but the shooter does not use a thermal scope, because deer detected in dense habitat by the thermal operator can be difficult for the shooter to detect.

The seating configuration of crew and the type of thermal equipment allowed for the shooter are different across the states and territories, and should be confirmed before considering using thermal equipment.

Procedural documents used to guide the aerial shooting of deer in Australia vary between states and territories. There is a national model standard operating procedure for the aerial shooting of deer (National SOP, 2023; PDF 297 kB).

Current procedural documents range from those with many stipulations, such as used by NSW's Feral Animal Aerial Shooter Training (FAAST), to those with few stipulations, such as those used in Queensland (Standing Committee on Agriculture, Animal Health Committee 2002). These stipulations govern several variables of potential relevance to animal welfare outcomes, including firearm type (i.e. rifle or shotgun) and calibre or gauge, bullet construction and mass, and pilot and shooter training.

Procedural documents also vary in their specifications for how shooting should be conducted. Several aerial-shooting procedural documents require that helicopters return to fly over shot animals after initial shooting ('fly back') and conduct repeat shooting to minimise the time to death and the likelihood of non-fatal wounding.

A semi-automatic .308 rifle is typically used for aerial shooting of deer, but a pump-action or semi-automatic shotgun with buckshot is sometimes used.

The best animal welfare outcomes are achieved when the helicopter flies back over shot animals and additional shots are placed in the chest and head. If this fly-back procedure is used, then about four shots are fired for each deer killed, on average. Non-fatal wounding is most likely to occur when wounded deer can hide from the helicopter in dense vegetation.

Ground shooting

Where and when to use:

- smaller areas with good networks of roads and tracks for access
- some peri-urban areas
- most effective when done at night with a spotlight or thermal equipment

Benefits:

- target-specific
- other pests can also be shot
- recreational shooters or commercial harvesters may provide the service for free, or pay to provide the service
- contract shooters can achieve comparable time from first shooting to death as that in aerial shooting
- carcasses can be used for human/pet/zoo animal/captive wildlife consumption

Potential constraints:

- relatively ineffective in large, poorly tracked, steep or densely-forested areas
- recreational and commercial shooters are unlikely to reduce deer populations to low densities over large areas
- not all shooters have thermal and other equipment that can increase kill rates
- perception that contract shooters are 'expensive'
- removing carcasses can be expensive and have manual handling risks
- can expose wildlife scavengers to toxic lead if lead-based ammunition is used

Shooting deer from a vehicle or on foot ('ground shooting') is performed by professional shooters, commercial harvesters, land managers and their employees, recreational hunters and volunteer shooters.

Ground shooting is most effective in areas with a high density of roads and tracks that facilitate the movement of shooters; and least effective in steep/rough, remote and densely-vegetated areas. Ground shooting by professional shooters is commonly used in peri-urban settings.

All shooters must have firearms licences and property-access approvals, as per state and territory laws and regulations.

Ground shooting is sometimes contentious because of concerns about animal welfare outcomes – concerns that tend to be exacerbated in peri-urban areas. There is a standard operating procedure for ground shooting of deer (NSW Department of Primary Industries, 2022a; PDF, 518 kB), but a unique procedure is often developed for a deer control program.

Shooters target the head (brain), or chest (heart/lung); the head is preferred from an animal welfare perspective because it is more likely to cause immediate death. The maximum shooting distance should reflect the range at which a shooter is confident of achieving rapid death of the deer, sometimes called 'ethical shooting distance'. It will be influenced by the size of the deer, the anatomical target chosen, the skill of the shooter(s), and environmental factors such as wind speed.

The calibre of rifle used to ground shoot deer will depend on the size of the deer species and relevant state or territory guidelines. For sambar deer (the largest species), the minimum recommended calibre is .308 with a 150-grain projectile. For small deer (hog and fallow), the minimum recommended calibre is .243 with a 100-grain projectile.

Professional shooters with extensive experience and excellent marksmanship might use smaller calibres in some situations. For example, a smaller rifle calibre such as .223 and a 55-grain projectile is preferred in peri-urban areas because the projectile travels a shorter distance and the noise is less compared to those fired from most larger-calibre rifles; in this situation, only the head is targeted.

Standard operating procedures can govern other key factors affecting animal welfare outcomes of ground shooting, including seasons (so that dependent young are not orphaned) and shooter training and proficiency. Shooter proficiency has been shown to be a critical determinant of animal welfare outcomes of ground shooting of deer, so training shooters to a high standard will maximise the animal welfare outcomes of ground-shooting programs. The accuracy and precision of firearms should always be tested on inanimate targets prior to shooting in the field.

Using a suitably trained dog to find wounded deer can also improve animal welfare outcomes by reducing the frequency of wounded deer escaping.

Additional equipment can improve the efficiency of operations through increased shooting opportunities and reduced shooting distances. Telescopic sights are essential for ground-based shooting. When shooting at night, either a spotlight (sometimes with a red filter) or thermal-imaging equipment is used to find deer. Thermal handheld monoculars or binoculars can be used to find deer if there is suitable contrast between deer and the background (usually at night and early morning). Thermal scopes are also popular, particularly with professional shooters. Thermal equipment is, however, expensive compared to traditional non-thermal equipment.

Sound suppressors ('silencers') reduce the peak noise level of a gunshot away from the line of fire, potentially reducing the fleeing behaviour of peripheral deer and providing the shooter with additional shooting opportunities. Suppressors are considered essential by some professional shooters from a health and wellbeing perspective because they significantly reduce noise for the shooter. Suppressors are also commonly used in peri-urban areas because they reduce noise disturbance for residents; however, not all jurisdictions permit the use of suppressors.

In dense vegetation, an indicator dog can greatly increase the success of deer hunters. A dog can also reduce the time to find deer that have been shot, further increasing efficiency.

A typical set-up for ground shooting of deer, including a thermal scope and thermal monocular and a suppressor. Source: M Lamb, Pest Lures Ltd.

Professional shooters ('contract shooters' or 'contractors') are also motivated by financial incentives (usually a fee per unit of time). Professional shooters generally have more experience in control operations, and already possess the licences and insurance required to participate in management programs. They are also likely to have more expensive state-of-the-art equipment (such as thermal scopes and monoculars or binoculars) that can greatly increase their effectiveness. In some jurisdictions, professional shooters are permitted to use sound suppressors and semi-automatic rifles.

Recreational deer hunting is a popular activity in many parts of Australia, and many land managers use recreational hunters (sometimes called 'sporting shooters') to control deer.

Some recreational hunters may volunteer as shooters in deer control programs. Volunteer shooters give their time and experience without financial return, although expenses such as accommodation, fuel and food are sometimes paid by the managing agency or landholder. Volunteers are usually local recreational hunters motivated by the experience of hunting in areas that might otherwise be unavailable, the opportunity to collect meat, social interactions, or by the satisfaction of being part of management programs.

The costs of managing volunteer shooters for an agency are often underappreciated and can be considerable.

Given the same access opportunities and similar equipment, in a recent trial in Victoria, contract ground-based shooters killed four times more sambar deer per hour than volunteer shooters. This higher CPUE (catch-per-unit-effort) compensated for most, but not all, of the greater cost of contract shooters. Hence, professional shooters were, on average, approximately 10% more expensive per deer killed than volunteer shooters.

Contractors, and especially volunteer shooters, mostly used roads and tracks to move within the areas of operation. Contract shooters covered more area than volunteer shooters, but there were still large parts of the treatment areas with little or no shooting effort after five years. If there is a limited time frame for deer control (days or weeks, rather than months) then contract shooters can be expected to remove more deer at a faster rate than volunteer shooters, but at a (slightly) greater cost.

A limited time frame for control may occur when access to sites is limited to a short period of time for health and safety concerns (e.g. in areas used by the public). If there is more than a small window of time to

conduct the control, then involving local recreational hunters as volunteer shooters could decrease the cost of the program. However, increasing the role of volunteer shooters in deer control programs might not always be possible given the limited amount of time that most volunteers can contribute.

Management should be cost-effective, but community support is also important. There will often be greater community support for lethal control of deer when local people can contribute to a program. Involving local hunters as volunteer shooters in a ground-shooting program can therefore provide benefits to those individuals and increase community support for the program. Another way to increase community support for a ground-shooting program is to use carcasses to feed people or animals.

Commercial harvesters shoot deer and sell the carcasses for processing into products for human or pet consumption. Commercial harvesting of deer currently occurs in Qld, NSW, Vic and SA, and is being considered in Tas. Commercial harvesting of deer is usually done similarly to that of macropods (i.e. from vehicles at night on private property).

Processors often only accept carcasses that are head-shot, or pay a lower price for deer shot in the chest. Sometimes the commercial harvester will pay the land manager a fee (e.g. price/kg harvested) for access.

The current economics of the industry mean that only areas accessible by vehicle and with moderate to high densities of deer are subject to commercial deer harvesting. Commercial harvesting is directly linked to the market forces of supply and demand, and the deer population reduction from commercial shooting may not meet control objectives (e.g. at least 35% annual reduction).

Ground-based shooters such as this volunteer can be an effective control option in areas that have good access via roads or tracks. Source: Parks Victoria.

Exclusion fencing

Where and when to use:

- in conservation settings, small areas of high value
- in agricultural settings, high-value paddocks or to create a 'back-boundary' fence

Benefits:

- can completely exclude deer (and other pest species)
- existing stock fences can often be 'topped up' to exclude deer
- they can last for > 15 years with minimal maintenance

Potential constraints:

- expensive to construct
- require regular inspection and maintenance
- floods and falling trees can allow deer to pass through breaks in the fence

Exclusion fencing is widely used in Australia to manage the undesirable impacts of medium- to large-sized mammals, including wild dogs, feral pigs and macropods. Fencing has been widely used to manage the impacts of feral deer overseas.

The method has high social acceptability. **Evidence-based fencing standards** for deer have been developed as a result of the long history of farming deer in Australia and New Zealand:

- To exclude deer, fences should be a minimum of 1.9 m in height, with mesh netting of 17/190/15 and posts spaced at a maximum of 10 m. These specifications also exclude macropods, feral pigs and wild dogs jumping over or pushing through fencing.
- To prevent animals from pushing or digging under fencing and creating holes for deer to move through, a 30-cm netting apron is also desirable. If an apron is used, the post spacing needs to be shorter (typically, at 5-m intervals).
- An electric outrigger wire outside the fence (20–60 cm above the ground, depending on the mix of species to be excluded) can reduce the pressure on the fence and apron from deer, feral pigs, macropods and wild dogs.

An important distinction is whether you will use deer exclusion fences in an agricultural or conservation setting.

In **agricultural** settings, it is usually desirable for the fence to also exclude macropods, feral pigs, and wild dogs (if they are present), and you would usually construct a fence along boundaries or around high-value paddocks. Existing sheep/cattle fences can be modified to exclude deer, and new fence lines are usually cleared and levelled with heavy machinery.

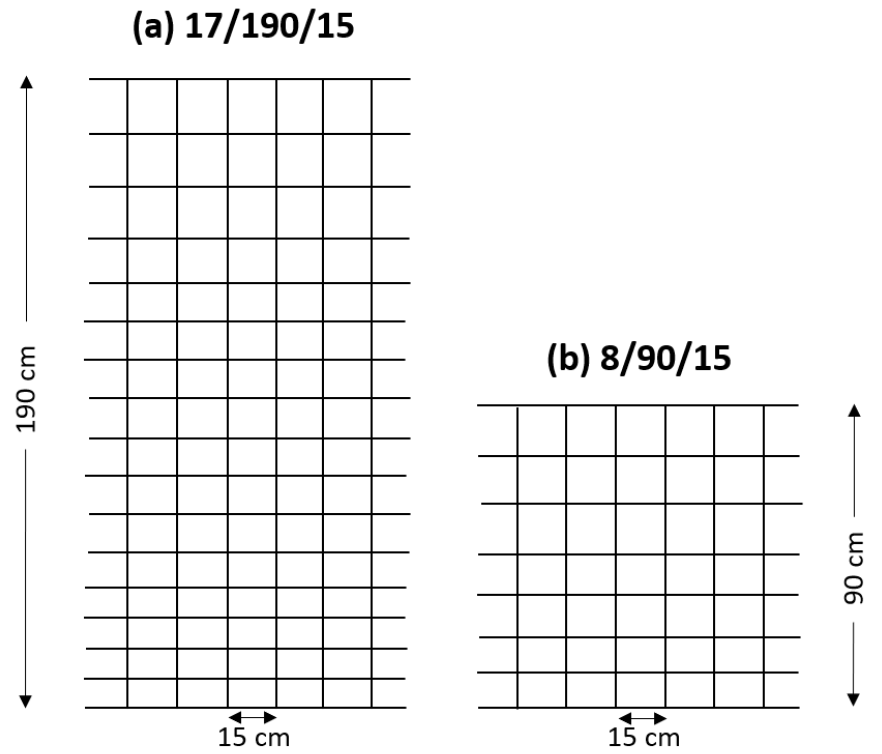
In **conservation** settings, you would typically use fences to enclose smaller areas and in more remote locations – it is often not desirable or practical to clear and grade the fence lines with heavy machinery. Deer exclusion fences in these settings can be designed to facilitate the movement of native mammals by leaving a gap at the bottom of the fence – although this increases the risk of small deer getting through.

Other considerations for designing and constructing a deer exclusion fence are:

- the topography, and the difficulty of clearing the fence line (including if trees need to be removed) – e.g. fences constructed in remote forested or alpine areas incur greater costs
- whether the fence needs to exclude all deer and other species of interest – e.g. an indicative cost for using heavy machinery to clear and grade a fence line on an agricultural property, and constructing a fence that will exclude deer, macropods, feral pigs, and wild dogs (i.e. including an apron) is greater than $20,000 per km
- how easy it will be to inspect, maintain and repair the fence – well-constructed fences are expensive but should last > 15 years with minimal maintenance. You will need to regularly inspect for holes and breaks if there are trees within falling distance of the fence, and as soon as possible after floods.

For more details on exclusion fencing for deer, see Forsyth (2023) (PDF, 5.4 MB).

Deer exclusion fencing on (upper) a pastoral property in NSW and (lower) Mount Bullfight Nature Conservation Reserve, Victoria. Sources: D Forsyth, T Dalman and R Gillmore (project leads for the Native Vegetation Improvement Project, Parks Victoria), respectively.



Two examples illustrating fence netting specifications:

(a) Fence that has 17 horizontal (line) wires, is 190 cm high and has vertical (picket) wires spaced at 15 cm (i.e. 17/190/15). Note the graduated line wire spaces (closest nearer the ground, to prevent young deer/fawns from pushing through). This netting is suitable for deer exclusion fencing.

(b) Fence that has eight horizontal (line) wires, is 90 cm high and has vertical (picket) wires spaced at 15 cm (i.e. 8/90/15). This netting is used for sheep and cattle, but is not high enough to exclude deer.

Trapping

Where and when to use:

- peri-urban areas where ground-shooting options are limited
- most effective when food is scarce (e.g. during drought)

Benefits:

- traps can be moved around
- in Clover traps, deer can be killed by shooting or chemical injection

Potential constraints:

- can capture non-target species
- traps are exposed to theft or vandalism
- require food to be replenished
- deer may be reluctant to enter a trap, especially if there is abundant food outside the trap
- corral traps are expensive to construct (labour and materials) and run
- animals in Clover traps need to be dealt with as soon as possible after capture to minimise adverse welfare outcomes
- if deer are killed by chemical injection, then carcasses need to be disposed of by deep burial to prevent fatal secondary toxicity in wildlife scavengers

Deer traps are used in areas where safe shooting zones are limited, or when deer are needed alive (e.g. for research). Trapping is typically most effective when the availability of natural food is low.

Some traps are commercially available, and others are purpose-built by land managers.

There is a standard operating procedure for trapping deer (NSW Department of Primary Industries, 2022b; PDF, 509 kB), but a unique procedure is often developed for a deer control program.

Two main types of trap are used to catch deer: corral traps and Clover traps. If Clover traps are used, then trapped deer can be killed by chemical injection: this type of trap is best suited to peri-urban areas where shooting is not possible.

Corral traps

Corral traps typically range in size from 15 m × 15 m (0.023 ha) to 160 m × 80 m (1.28 ha). A circular corral trap design reduces the risk of trapped deer injuring themselves, because it does not have corners for deer to run into. Corral traps should be at least 2 m high to prevent trapped deer from jumping out.

You can catch large numbers of deer in corral traps (e.g. 58 fallow deer were captured in one night in a trap of size 80 m × 160 m = 1.28 ha, and 27 chital deer in a trap of size 19 m × 27 m = 0.05 ha). However, constructing and running a corral trap is time-consuming.

The fencing materials used to construct corral traps include (i) temporary construction-site fencing panels, (ii) cattle or horse yard panels, or (iii) deer fencing. Corral traps cost from $6,454 to $26,000.

Corral traps made of panels are usually constructed over a period of at least 6–8 weeks, because deer are often highly cautious of any modifications to their environment and are easily scared away.

More than 1,000 deer have been trapped in New South Wales and Queensland since 2011. However, individual trappers have had mixed success, with the cost of trapping each deer varying between $80 and $8,333 (average $1,325). Those costs exclude ongoing staffing costs to maintain the traps of approximately one day per week for one person. The species most and least captured were fallow deer and sambar deer, respectively.

Trap packages (including drop-down gates, remote gate-release mechanisms and networked motion-sensitive cameras) are available from commercial suppliers.

Chital deer inside and outside a corral trap with gate. Source: M Elliott.

In these systems, the cameras detect the movement of an animal and send a photo to registered phone numbers. The person receiving the images can then send a message back to the camera to shut the gate. If this occurs, the camera then sends a message to the control box to shut the gate. If the trapper has direct sight of the trap, a handheld manual-release trigger can be used to shut the gate. Several trappers have used these systems; however, due to concerns about deer being wary of walking under the gate (which is only 1.5 m above the ground), some trappers have modified the system to work with swinging gates and higher cross bars (approximately 2.1 m high).

You can set up motion-sensitive cameras around new traps to determine the location of the deer outside and inside the trap before and after trapping commences. Several camera manufacturers offer models that can send images to phones using mobile networks.

Corral trap recommendations

- Allow a minimum of 6–8 weeks to set up a trap made of panels, and ideally several months. Each time a new alteration is made to the trap, it is best to allow at least two weeks for the deer to become acclimatised to the changes. You can check on the return of the deer using motion-sensitive cameras.
- Put hessian or, preferably shade cloth, around part of the fencing to reduce the deer's motivation to charge at, or attempt to climb over, the trap fence.
- Leave the trap in place over the long term (ideally, greater than a year).
- Place the trap in an area where the deer naturally feed or rest, and include some vegetation inside wherever possible.
- Ideally, paint the trap with camouflage colours to blend in with the surrounding vegetation.
- Consider using a swinging gate rather than a drop-down gate.
- If trap fence panels consist of horizontal bars that have a spacing of greater than approximately 15 cm, place mesh over them to a height of at least 1.5 m, so that female and young deer do not squeeze through the lower bars.

Clover traps

In contrast to corral traps, Clover traps are designed to catch one deer at a time. Clover traps are small and inexpensive compared with corral traps. They cost $1,000–$1,500 to construct.

Clover traps consist of a rectangular frame (approximately 1.2–1.5 m wide × 1.5–2.1 m long and 1.5–1.8 m high) made of aluminium or steel rods. The frames are covered in a nylon mesh that has a diameter of approximately 4 mm, and a gap across the square sides of approximately 40 mm to 50 mm.

The trap door mechanism used for Clover traps is very different to that used for corral traps and involves a trip wire (such as monofilament or fluorocarbon fishing line) located at the far end of the trap.

When the deer reaches the end of the trap and lifts its head the trip wire is pulled, and a pin is pulled out of a washer that is under tension. The trip wire line extends up the side of the trap and across the top to the mesh gate, which is released and drops down to the ground.

Clover traps are best suited to areas where shooting is not possible, as the small size of the trap enables the deer to be killed by chemical injection. In a peri-urban Queensland setting, 8–10 Clover traps were set simultaneously, with another 30 Clover traps being pre-fed and with the door tied open.

Clover trap recommendations

- Integrate Clover traps into the vegetation.
- Make sure that both the frame and the nylon mesh of the trap has adequate structural rigidity for the species you are targeting.
- Ensure the trip wire and release mechanism are working properly.
- Ensure the trap has been well pinned down so that captured deer cannot lift it or move it if they panic and run into it.

Adult male rusa deer captured in a Clover trap (note the grain bait and peg for the release mechanism at the rear of the trap). Source: G Alchin.

- Attach the corners of Clover traps to posts or star pickets so that trapped deer cannot move them.
- Pre-feed outside and inside the trap, with the door tied open, until the deer become accustomed to the trap and are known (by using motion-sensitive cameras) to enter it.
- When you are setting the trap, place food under the trip wire and remove most of the food from outside the trap.

Attracting deer into traps

Trapping is most successful during periods of low natural food availability, because food can be used to attract deer into the trap.

Foods used to attract deer include rolled barley, lucerne hay, dried corn and oats. These foods are sometimes mixed with molasses. Plants such as ryegrass, clover and chicory can be sown inside a trap to attract deer.

Food can be provided in a feeder (e.g. the automatic Moultrie tripod deer feeder that allows the timing of feeding to be set each day). If you don't use an automated feeder, then you will need to visit the site at least twice a week to replace the eaten food.

You should typically provide food in and around the trap area before trapping commences, so deer have time to become attracted to the food being offered and to entering the trap to consume it. For corral traps, food is typically offered at the outside of the entrance and inside the trap – often as a continuous trail.

Welfare outcomes of trapping

There is often a perception that trapping has better animal welfare outcomes than aerial or ground-based shooting, but this is unlikely to be the case:

- Most trapped deer are also eventually killed – so trapping is a lethal control method. Trapped deer are usually shot from outside the trap (e.g. through the fence or from a hide overlooking the trap).
- Trapped deer are constrained from normal daily activities until they are killed.
- Animals may be exposed to extreme environmental conditions (e.g. cold nights) while trapped and are unable to seek shelter.
- When people approach a trap containing deer, the animals may panic and injure themselves.
- Non-target species may be caught in deer traps.

These factors often mean that trapped animals die from stress-related syndromes such as capture myopathy, or sustain self-inflicted traumatic injuries while attempting to escape.

For example, when multiple deer are caught in a Clover trap, it is common for deer to be injured because of kicks received from another trapped deer. In Australia, feedback from trappers suggests that injuries are usually minor abrasions and mouth injuries.

Overall, there is a need to minimise the time that deer or other animals are held within a trap – to minimise their distress and the potential for injury. Therefore, set traps must be checked daily if you cannot remotely monitor them. Native non-target animals that have injuries should be taken to a veterinarian for treatment.

To minimise adverse animal welfare outcomes, there should be:

- a well-developed capture protocol specific to each species of deer that is targeted
- an experienced and trained professional capture team
- qualified shooters (or veterinarian, if chemicals are used) to kill the deer as quickly as possible
- a review of any capture-related mortality that occurs.

Repellents

A wide variety of olfactory, visual and acoustic repellents are commercially available in North America and Europe to repel or deter deer (Conover 2001). Repellents are mostly used by people affected by deer in peri-urban settings.

Some repellents that are applied to the surface of plants do provide short-term protection from deer browsing, but they need to be re-applied regularly. Deer will often become habituated to visual and acoustic devices.

Constructing deer-proof fencing is generally considered more effective than using olfactory, visual or acoustic repellents.

Poison baiting

Poison baiting is not a lawful method of managing deer in Australia.

IMPROVE

Motion-sensitive cameras are an excellent way to detect and monitor deer and other wildlife. Source: A Bengsen.

As you roll out your plan, it is essential to monitor and evaluate its **effectiveness and cost**.

Your plan should include a **review or an end date**, depending on whether the feral deer problem is reduced after a short-term, high-intensity intervention or if ongoing management is needed.

Monitoring and evaluating the outcomes of management is needed to determine whether or not your objectives have been achieved.

How to monitor activities and outcomes

Think about what information to collect, and why. For instance:

- Who is the information for and how will they use it?
- Who will gather it?
- Who will analyse it?
- If you need to give information back/onwards to others, how will you do it, when, and in what format?

As an indication: in management programs conducted by state agencies, it is recommended that 10–20% of the budget is spent on monitoring.

You can measure changes in deer impacts, deer numbers and management activities

Recording management activities: operational monitoring

You can record what management activities were done, where, by whom and at what cost.

How many nights and hours of shooting was conducted by whom, and how many deer were killed? How many kilometres of fencing was constructed? Contractors should report this information as part of their service.

Operational monitoring lets you find efficiencies and more accurately budget future work.

Measuring changes in feral deer impacts or numbers: outcome monitoring

Outcome (or 'performance') monitoring measures changes in deer impacts and/or abundance after management activities, so you can determine if your objectives were achieved.

For individual farmers, feasible outcome monitoring might mean counting how many deer they see on key paddocks (e.g. winter feed or newly sown grass) at night.

For state agencies, it might involve comparing replicated and randomly-assigned treatment and non-treatment areas.

If eradication is the objective, then progress towards eradication (e.g. declining abundance) and ultimately the probability that deer are absent should be measured.

Monitoring deer numbers and density (abundance)

Direct estimates of abundance using helicopters or motion-sensitive cameras

Methods that robustly estimate the number and density of deer for an area are typically **more expensive and require greater technical expertise** than indirect methods (i.e. indices of abundance).

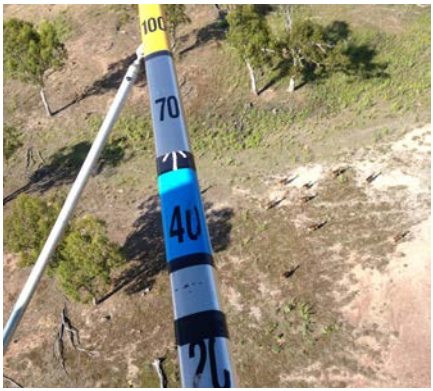
Hence, direct estimates of abundance are typically feasible only for state and territory pest management and natural resource management agencies, and for well-resourced non-government organisations.

Estimating abundance before control assists with:

- budgeting for the control effort (e.g. number of helicopter hours needed for aerial shooting)
- estimating the percentage reduction achieved by the control (if the number of deer removed is recorded).

For large areas (> 3,000 ha) **with relatively open canopy or understorey**, we recommend helicopter mark–recapture distance sampling (MRDS; Bengsen et al. in press). A minimum of 60 detections of deer (and preferably more) is needed to robustly estimate deer abundance and density. If there is a lot of dense vegetation then helicopter thermal imaging might be useful, but this method is likely to be more expensive than MRDS.

For smaller areas, and **larger areas that have dense canopy or understorey precluding aerial survey**, we recommend using motion-sensitive cameras. Cameras can either be placed in a grid for 90 days (see Bengsen et al. 2022) or used in a distance-sampling design (see Ramsey et al. 2019).



Helicopter MRDS is rapid and lower cost for large areas with good visibility, such as for these chital deer on a pastoral property in North Queensland. Source: M Amos.

Indices of abundance calculate changes in populations indirectly

An index of abundance that is repeated over time monitors [assumed] changes in the deer population (e.g. increase, decrease, or no change) without directly estimating the number of deer.

The assumption underpinning the usefulness of indices is that they are positively correlated with deer abundance. Indices of abundance can be **cheaper to collect and more precise** than direct estimates of deer abundance.

Common measures include:

- **Spotlight (or thermal-imager) counts** – usually conducted at night, from a vehicle or on foot, following the same paths (e.g. 10-km transects). The number of deer observed per km is the index of abundance. See Hocking and Driessen (1992) for an Australian spotlight protocol that includes deer.
- **Individual faecal pellets or pellet groups** – counted in plots or along transects. Plots can be cleared of pellets then revisited (e.g. 30 days later), so that the faecal accumulation rate (pellets per day or week) can be calculated. Pellets degrade, so you need a thorough definition of which pellets should and should not be counted; and goat/sheep pellets cannot be reliably distinguished from those of deer. See Forsyth (2005) for a widely used Australian/NZ protocol.
- **Images of deer per day (or week)** – captured by a network of motion-sensitive cameras (or 'camera traps'), and usually allow you to identify the species of deer. However, good-quality cameras are expensive, and cameras are unlikely to be suitable for most peri-urban areas due to the risk of theft and vandalism.

Monitoring 'bang for buck' (your catch-per-unit-effort)

Catch-per-unit-effort (CPUE) describes how many deer you removed from an area for the amount of removal effort (e.g. deer shot per hour of spotlighting or aerial shooting, or per night of ground shooting).

If the deer population declines, then CPUE should also decline. Declines in CPUE may also be due to other factors, such as surviving deer learning to avoid shooters.

Monitoring declining deer impacts from management efforts

The objective of most deer management is to reduce undesirable impacts. It is therefore important to monitor how those impacts respond to your management plan.

Browsing on seedlings and saplings is a commonly measured impact of deer, but you have to carefully separate it from browsing by other species (e.g. wallabies). Larger deer species will browse higher (> 1 m) than most wallabies. See Burns et al. (2021) and Bennett et al. (2022) for protocols for south-east Australian forests.

You could build exclosure fences to measure how excluding deer affects the **growth and survival of plants**, and **changes in plant communities**. Again, you need to be careful about differentiating the impacts of deer from other species (e.g. by constructing exclosures that exclude deer but not macropods; see Bennett and Coulson 2008).

For pastoral properties, you can calculate how much forage livestock vs deer need, to estimate the **competitive cost of deer when forage is limited**. You would need an accurate direct estimate of deer abundance (i.e. number of deer present) to use this approach.

In peri-urban settings, **collisions between deer and vehicles** might be recorded by road and rail authorities. **Resident complaints** about deer might be recorded by the council. Changes in these impacts could help you assess the effectiveness of management in peri-urban areas.

Changes in **ground degradation** (i.e. trampling and pugging) and **water turbidity** have been used to monitor the response of alpine peatlands (including natural pools and wallows) in Victoria to sambar deer control. These methods monitor ecological assets before and after management operations.

Detecting deer, especially at low population densities

Signs of deer can include **tracks**, **faecal pellets**, **wallows** and **antler damage** to saplings and trees (see images on pages 17–19).

But even if you don't observe any sign of deer, small numbers of deer could still be present.

Motion-sensitive cameras are an excellent way to confirm that deer (and other wildlife of interest) – and which species of deer – are present. You can set them up along trails near high-use areas such as grassy clearings and dams.

Fresh faecal pellets can be swabbed for DNA and analysed to identify the deer species (or they

might be from other ungulates such as goat or sheep).

Environmental DNA (eDNA) from water or other environmental sources (e.g. bark, soil) is an emerging tool for detecting deer and other pests. Under optimal conditions, the chance of detecting target species' eDNA can be > 90%.

Free mapping, monitoring website and app: DeerScan

DeerScan (Apple app or Android app, or online at www.deerscan.org.au) is a free, secure, discreet resource for landholders, community groups and pest controllers. You can use it to:

- map sightings
- report problems or damage caused by deer
- document your management actions.

Using DeerScan to record new (and historical) observations of deer in your local area will help build a detailed picture of deer populations. Recording is easy:

1. Register your name or just use your email address.
2. Record where you saw feral deer, evidence, damage or conducted management.
3. Submit your record, and see it appear on the website.
4. View other sightings in your local area.

Evaluating and reviewing your plan

To evaluate your plan, consider:

- if the objectives were achieved
- what features worked and why
- what features didn't work and why
- if you spent more or less money than you planned
- if you could spend money better next time
- what you would change to make the plan work better next time.

Modify your management plan as required and repeat the process until you are satisfied your management is the best it can be. It might mean:

- changing where or when control is carried out
- adding other tools
- stopping management to reassess the situation.

If the management plan is achieving its desired outcomes, then it is worth considering if the program can be improved or made more cost-efficient.

If you want help evaluating your plan, contact your local biosecurity officer or land management authority.

RESOURCES

The PestSmart website (pestsmart.org.au) has many resources to help you manage deer, and is updated as new information and innovations become available.

Policies and Acts

Feral deer management is legislated and administered by states and territories. These laws and policies cover:

- land tenure, for example the status of deer may differ on public versus private land
- obligations of landowners to control deer
- specific control tools, for example which firearms and ammunition are permitted to be used to control deer
- animal welfare requirements for control tools
- threatened species and the processes threatening them.

Laws and policies can change, so you need to check with your relevant state or territory agency for current legislation and policies. The agency should be able to assist you with information and advice specific to your situation.

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Your notes for creating a plan

Here you answer questions – for **your** region, **your** situation, **your** feral deer problem – to help create a **tailored and realistic feral deer management plan**.

Information to help you answer these questions is in relevant sections of this Guide.

UNDERSTAND

Define the problem

1. What impacts are feral deer having?

    a. What are the symptoms and why are they a problem?

    b. What is the root cause of the problem and why has it arisen?

Know your target

2. Where do the feral deer occur, and how widespread and abundant are they?

3. What aspects of the deer species, or where they occur, make them susceptible to management?

PLAN

Assess the problem

4. Are any other animals (pests, native fauna or livestock) or weeds associated with the feral deer because of:

   a. competition for feed or habitat?

b. predator–prey relationships?

c. weeds providing harbour, or being spread by the deer (e.g. blackberries)?

5. Could controlling the feral deer have any adverse effects?

6. Will controlling feral deer help, or be helped by, the control of other pests or weeds?

7. Are there other people or agencies dealing with the same problems who may have advice or experiences to share?

Develop a plan and set clear objectives

8. What outcome do you want to achieve?

9. Are the feral deer also using adjacent properties, and so need to be managed there?

10. Are there control tools available that may suit different circumstances, complement each other, or fit best with other aspects of your property management?

MANAGE

Implement the plan – tailor control techniques and strategies to suit

11. Which tool or combination of available control tools will best suit your situation?

12. Is the timing or sequencing of control tools important for the best results and best fit with your other property management operations?

Monitor the outcomes of your plan

13. What will you measure to know if your plan achieved what you set out to?

14. How and when will you collect information to measure the effectiveness of your plan?

IMPROVE

Evaluate the plan

15. Which aspects of the plan were most successful, and which weren't?

16. For aspects that weren't as successful as you hoped, was it because of problems implementing them, or because the expected outcomes didn't occur?

Revise – modify as required and repeat as necessary

What changes do you need to make for the plan to be more effective and efficient?

pestSMART

VISIT OUR FERAL DEER TOOLKIT

pestsmart.org.au/toolkits/feral-deer/

Deer quickly learn to avoid some management efforts. Understanding deer, and the impacts that they are having, is critical for cost-effective management.

pestsmart.org.au