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Ecology and Management of Vertebrate Pests in NSW

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Compiled by Birgitte Verbeek, edited by Lynette McLeod, Invasive Species Unit, NSW Department of Primary Industries, Locked Bag 21, 161 Kite Street Orange 2800

See individual chapters for further acknowledgments.

Front Cover Image: David Croft

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Introduction

Vertebrate pests cause damage estimated at around $1 billion to primary production, biodiversity, ecosystem services, health and tourism in Australia each year.

This manual provides information on the ecology and management practices for a range of important vertebrate pests in New South Wales (NSW). It aims to provide background knowledge for staff of Local Land Services (LLS), National Parks and Wildlife Service (NPWS), and all other organisations involved in vertebrate pest management activities in NSW.

Best-practice pest animal management

Adopting 'best-practice management' is considered the most suitable approach for dealing with a pest issue. Rather than simply trying to kill as many pest animals as possible, the best-practice management approach recommends detailed planning, coordination and monitoring. Best-practice management involves 3 stages:

Stage 1: Planning. This stage involves identifying the trigger for action, determining who takes responsibility for the pest issue, describing the area(s) of concern, gathering all necessary information, and reviewing the information to identify suitable land management units for further action.

Stage 2: Determining pest management priorities. This stage involves setting land management areas, ranking land management areas for production and conservation values, ranking land management areas for threat from pest animals, determining the overall rank to identify priorities, and doing a reality check to decide which land management areas require an action.

Stage 3: Developing and implementing local pest management plans. This stage involves defining the management problem in terms of damage to assets/infrastructure/crops/natural resources, developing the management plan, implementing the plan, and monitoring and assessing performance.

The best-practice pest management approach also recognises the principles of strategic pest management – recommending the use of many control techniques, coordination with neighbours, evaluating management options, detailed monitoring, and measurement of the effectiveness of management decisions in reducing a pest problem, pest numbers and/or the damage they cause.

It may seem like a lot of effort to go to, but pest animal management specialists and scientists believe that adopting the best-practice management approach is the most effective way to deliver long-lasting benefits – 'a bigger bang for your buck'.

For more information see NSW Vertebrate Pesticide Manual.

Feral pigs

Background

Description

The feral pig in Australia is a descendant of various breeds of the domestic pig, *Sus scrofa*.

Origin

Pigs arrived with the first fleet in 1788 and were the only stock that thrived in the early years of settlement. By 1795, free-ranging pigs were such a nuisance that an order was issued allowing landholders to shoot any pig found on their property. Nonetheless, pigs were generally kept in an unrestrained, semi-feral state until the 1860's when property fencing started to become widespread. These conditions allowed feral populations to establish in many areas. By the 1880's feral pigs were widespread throughout much of NSW. Extended periods of above-average rainfall allowed pigs to disperse along water courses into areas where they had not previously been introduced, particularly into western regions of the state. Historical distribution maps suggest that pig populations have continued to spread throughout the country since the 1950's.

Distribution

Today, feral pigs are widely distributed in NSW, Queensland, the Northern Territory and the Australian Capital Territory. Their natural spread and persistence in the landscape has been assisted by illegal, deliberate releases and translocations. Isolated populations also occur in Victoria, South Australia and Western Australia, and on Flinders Island in Bass Strait. Many of these populations are continuing to expand.

In NSW feral pigs are found in most regions west of the Great Dividing Range; including the tablelands. High densities of feral pigs are found in western NSW floodplains and ephemeral wetlands as well as the northern slopes and plains.

Ecology and biology

Habitat

Feral pigs are remarkably adaptable and are able to thrive in a wide range of environmental conditions and take advantage of diverse food resources. They occur in tropical and temperate rainforests, monsoon forests, paperbark swamps, open floodplains, marshes, coastal fringes, semi-arid floodplains, dry woodlands, subalpine grasslands and agricultural systems such as cereal and cotton crops (Figure 1). However, pigs have limited ability to reduce their body temperature. Because of this, they require regular access to free water and shelter, particularly in hot conditions.

Diet

Feral pigs are opportunistic omnivores – their nutritional needs can be met from a wide range of food sources. However, they are not very efficient grazers so they require higher quality feed than ruminants such as cattle, sheep and goats. Sows, in particular, require a consistent high-protein food source, such as animal material or green pick, for successful breeding and rearing of young. Nutrient- and energy-rich foods such as succulent green vegetation, fruit, grain, bulbs, corms, fungi and animal material are often consumed preferentially when they are available.

Home range and movement

Not surprisingly for an animal that exploits such a wide range of habitats, home range and movement patterns vary widely across different regions and environmental conditions (Table 1). A pig's home range can be considered as the area travelled by an individual during its normal activities of foraging, mating and caring for young. Home range size is largely determined by habitat type, food supply, the size of individual animals and population density. Daily home range sizes are often quite small, although long-term home ranges may be much larger. Mature males tend to have a larger home range than sows in the same population. Pigs in semi-arid or sub-alpine areas tend to have larger daily home ranges than those in areas where food resources are more abundant.

Feral pigs are largely sedentary; it is a common misconception that they make frequent long-distance movements between different habitats. During hot weather, days may be spent in one area and nights spent feeding in another nearby. In some habitats there is a seasonal trend of movement between specific areas, depending on the current food supply. However, their ability to exploit a wide range of food sources often allows pigs to adapt to changing conditions and avoid having to move to other locations.

Figure 1. Feral pigs occupy a wide range of habitat types in Australia (Photos Andrew Bengsen, Troy Crittle).

Table 1. Estimated average home range sizes of feral pigs at different Australian locations.

Location	Habitat	Home range duration	Male home range (km^2)	Female home range (km^2)
Kosciuszko National Park[1]	Sub-alpine grasslands and woodlands	> 3 months	35.0	11.1
Northern Territory, Douglas/Daly Rivers[2]	Tropical woodland	12 months	33.5	24.1
North-west NSW[3]	Semi-arid shrub and woodlands	7 days	15.1	3.4
North-west NSW[4]	Semi-arid shrub and woodlands	5-9 days	7.9 – 11.6	4.2 – 8.0
NSW Central Tablelands[5]	Sclerophyll forest and grazing land	> 6 months	10.7	4.9
NSW Central Tablelands[5]	Sclerophyll forest and grazing land	1 day	1.4	0.8
Qld Wet Tropics[6]	Lowland forest	3 days	1.58	0.99
Qld Wet Tropics[6]	Mixed rainforest/agricultural	3 days	0.78	0.74
Qld Wet Tropics[6]	Highland rainforest	3 days	0.69	1.42

[1]Saunders, G. (1993). The demography of feral pigs (*Sus scrofa*) in Kosciusko National Park, New South Wales. *Wildlife Research*. [2]Caley, P. (1997). Movements, activity patterns and habitat use of feral pigs (*Sus scrofa*) in a tropical habitat. *Wildlife Research* 24: 77-87. [3]Giles, J. R. (1980). The ecology of feral pigs in western New South Wales. PhD, University of Sydney. [4]Dexter, N. (1999). The influence of pasture distribution, temperature and sex on home-range size of feral pigs in a semi-arid environment. *Wildlife Research* 26: 755-762. [5]Saunders, G., & Kay, B. (1991). Movements of feral pigs (*Sus scrofa*) at Sunny Corner, New South Wales. *Wildlife Research* 18: 49-61. [6]Mitchell, J., Dorney, W., Mayer, R., & McIlroy, J. (2009). Migration of feral pigs (*Sus scrofa*) in rainforests of north Queensland: fact or fiction? *Wildlife Research* 36: 110-116.

Feral pigs generally restrict their activity to cooler parts of the day, even when the weather is not especially hot. Very hot weather can greatly restrict their movements, resulting in lower food intake, reduced mating opportunities and reduced visibility in the landscape to casual observers.

Pigs often use trails to travel between regularly visited areas, such as from shelter to food supply or water. They also use sheep and cattle pads to and from water. Trails that are frequently used by pigs can often be identified by the presence of tracks, dung and trees or logs that have been rubbed or tusked by pigs (Figure 2). Trails such as these can serve as markers to other pigs, indicating routes to food or water.

Social structure

Sows and piglets generally run together as a group. Immature males and females may also stay with the group until they reach maturity, or they may run as a juvenile group until they mate. At about 18 months males tend to become more solitary, re-joining a group only for mating or to feed on localised food sources.

Group sizes vary depending on the season and habitat. In forested areas of south-west WA group sizes rarely exceed 12, whereas in more open country up to 40 or 50 pigs may form a mob. In times of severe food and water shortage large groups of 100 or more may gather around remaining waterholes.

Figure 2. A well-used trail into a sorghum crop (Photo Jason Wishart).

Reproduction

Feral pig breeding is heavily influenced by the amount and type of feed that is available. Pigs are able to breed throughout the year in many areas, but breeding may be distinctly seasonal in others where food is limited. Breeding success depends on the availability of nutrients, in particular energy and protein. Peak birthing periods usually coincide with the seasonal abundance of food in different habitats.

Female feral pigs reach sexual maturity once they reach a weight of 25 to 30 kg, which normally occurs between 7 and 12 months depending on conditions. Males become sexually mature around 18 months. Average litter sizes are usually about four to six piglets. Abundant high quality feed allows pigs to increase their reproductive output. It reduces the age at which sows can start breeding, reduces the interval between breeding events, and increases litter sizes. Conversely, during poor conditions, pigs are able to reduce their breeding activity and invest energy in survival instead of reproduction. The result of this flexible reproductive strategy is that pig populations can persist in the landscape through extended unfavourable conditions, and then increase rapidly when conditions improve again, through increased reproductive output and greater survival and recruitment of young pigs into the breeding population.

Mortality

Mortality of feral pigs from the foetal stage to weaning is generally high, but can be highly variable depending on local conditions. Most pigs born will never reach their first birthday. Mortality is due to factors such as adverse weather conditions, accidental suffocation by sows, loss of contact, predation and starvation. Adult mortality can vary from 15% to 50%. In most areas, few feral pigs are likely to survive beyond five years.

Starvation can affect pigs of all ages: lactation of sows can cease if protein levels are not adequate and excessive tooth wear in older pigs can interfere with eating. Malnutrition also leaves feral pigs more susceptible to parasites and diseases.

Impact of feral pigs

Agricultural impact

Feral pigs prey on newborn lambs and goats. Crop destruction through feeding and trampling reduces yields in summer and winter grain crops, sugarcane, fruit and vegetable. Fences and water sources can be damaged and dams and waterholes fouled through wallowing and defecation. Feral pigs also compete with livestock for pasture and damage pasture through up-rooting vegetation.

Figure 3. Feral pig rooting in pasture (Photo Andrew Bengsen).

Figure 4. Feral pig with sheep carcass (Photo Peter O'Brien).

Environmental impact

Feral pigs disturb natural environments through rooting up soils, native grasses and forest litter, consuming a range of native plants and fouling freshwater systems. Feral pigs also eat a range of native animals including, earthworms, beetles, centipedes, amphipods, snails, frogs, lizards, snakes, turtles and their eggs and small ground-nesting birds and their eggs. Environmental impacts of feral pigs are so serious that they are listed as a Key Threatening Process under the *NSW Threatened Species Conservation Act 1995*. At the time of writing, 53 threatened species, populations or communities were listed as threatened by predation, habitat degradation, competition or disease transmission from feral pigs.

Disease impact

Feral pigs can be hosts or vectors of a number of endemic parasites and diseases, some of which can affect other animals or people. Livestock health can be significantly affected by:

- leptospirosis
- porcine brucellosis
- melioidosis
- tuberculosis
- sparganosis
- porcine parvovirus
- Murray Valley encephalitis and other arboviruses.

For example, leptospirosis can cause illness, abortion and death in sheep and cattle. Surveys in the Central West district showed that about three quarters of feral pig mobs tested for the presence of one of the main bacteria that cause leptospirosis had been infected at some stage, and about 30% of those mobs included individuals that were actively shedding bacteria that could be picked up by sheep or cattle. About 60% of sheep flocks and 50% of cattle herds also tested positive for exposure to the bacterium.

A number of worm species also carried by feral pigs can affect livestock.

Human health can be affected by:

- leptospirosis, through contact with the urine of affected feral pigs
- porcine brucellosis, through handling raw feral pig meat
- tuberculosis and sparganosis, through eating inadequately cooked feral pig meat.

Feral pigs are also susceptible to, and can be hosts or vectors of, a number of exotic parasites and diseases. Feral pigs would also be capable of carrying and spreading a number of exotic diseases and parasites if these were to enter Australia. These include: foot-and-mouth disease; swine vesicular disease; African swine fever; Aujeszky's disease; trichinosis; and classical swine fever.

Social impact

Feral pigs can impact the well-being of individuals and the community. Negative impacts include human-disease spread, damage-related stress and damage to visual amenity.

However feral pig hunting can generate positive social impacts through the contribution of hunting-based tourism to local communities and hunting as a recreational activity.

Figure 5. Feral pigs can host and amplify important diseases of livestock, and transmit disease to stock when they are in close contact or when they share resources such as feeding areas or water points (Photo Jason Wishart).

Figure 6. Feral pig damage around a freshwater lagoon (Photo Jim Mitchell).

Recognition and signs

There are a number of signs to indicate feral pig activity and abundance in an area. Regular sightings of pigs and abundant fresh sign (tracks and scat) normally means high numbers of feral pigs; some sightings of pigs and obvious fresh sign indicates medium numbers of feral pigs; no or few sightings of pigs and very little fresh sign often indicates low numbers of pigs.

Camera traps are a useful way of detecting the presence of feral pigs and can give an indication of group size and activity patterns. If used intensively and systematically as part of a carefully designed survey, camera traps can be used to estimate local changes in feral pig numbers. Pigs can also be detected by using spotlight observation at night, although they do not have reflective eye shine, and by aerial survey. Trained dogs can be used to detect feral pigs at low densities or in thick cover.

During daylight, many feral pigs shelter in deep cover and are rarely seen. The presence and number of pigs are more reliably evaluated by observing signs of their activity and impact. An experienced observer can rapidly estimate the presence and coarse relative abundance of feral pigs by carefully examining these signs.

Rooting: Feral pigs use their snouts and teeth to dig for underground food, including small animals and tubers, particularly where soil is soft or after rain. The result varies from selective uprooting of specific types of plants to the creation of extensive areas resembling ploughed paddocks. The distribution of rooting areas is a reliable guide to the location of pigs at night.

Crop damage: Feral pigs damage crops by eating them, by trampling and bedding in them, and by uprooting seed and seedlings. Significant damage over a short period of time can be seen during crop planting, especially in legume and pulse crops such as chickpea and faba beans. Damage is also common at the end of the growing season, as crops mature and protein content of grain increases; improving palatability.

Fence damage: Pigs will push through fences, usually enlarging an existing gap under the bottom wire; these holes are then used by other animals. Mud or coarse bristly hair on the wire or post indicates feral pigs.

Pads: Pigs often create pads when travelling in single file to frequently used food and water sources. Pads can be a reliable sign of feral pigs and are often an effective way of identifying feral pig bedding and feeding areas (Figure 2).

Tracks: Feral pigs leave hoof-prints in any soft surface. Their tracks have a distinctive square shape and can often be differentiated from other cloven hooved animals by the presence of two widely-separated dew claws.

Faeces: Pigs defecate on and off pads. The size, shape and consistency of the scat varies with age and diet, but it is typically 3 to 6 cm wide, 7 to 22 cm long and fairly well formed. Close examination will reveal finely chewed plant matter, grain and occasional bone fragments, pig bristles, wool or other hair.

Tusk-marks: Adult boars slash the trunks of growing trees with their tusks, leaving a distinctive pattern of cut-marks. The trees selected for cutting and rubbing are often next to pads and near water. Because boars stand on toes and reach up when tusk-marking, the height of the mark can be a guide to the size of the pig. Marking may serve to notify other boars of the marker's presence and size.

Nests: Just before farrowing, sows make nests from the available vegetation, which they uproot and carry by mouth. If long, grassy vegetation is plentiful, the nest can be very large – up to 3 m by 1.5 m and 1 m high, with a domed roof. For the first 1 to 5 days of life, the piglets stay in the nest and the sow is usually also inside or nearby. In cold temperatures boars and non-farrowing sows may also build and use nests. Nests are usually less than 2 km from permanent water. They should be approached with caution.

Wallows: Pigs wallow by lying in moist or wet areas, often near permanent water. Wallowing may help to control the animal's temperature and protect it against insects and external parasites. Wallows are distinctive oval depressions in mud and can show how recently and for how long pigs have been in the area.

Mud-rubs: After wallowing, pigs often rub their heads, shoulders and sides on nearby vertical objects such as tree trunks and fence posts. The result is a distinctive muddy rub site at pig height. Thick course hairs are often found embedded in mud-rubs.

Figure 7. Mud rub on a tree trunk by a trail (Photo Jason Wishart).

Figure 8. Feral pig in a bore drain (Photo David Croft).

Management principles

Pest status

Feral pigs are declared pest animals under the *Local Land Services Act 2013*. This declaration means that feral pigs are to be continually suppressed and destroyed by land managers. It is illegal to keep or transport live feral pigs.

Strategic approach

Feral pig control should always aim to reduce the impacts of pigs on the resource or resources that need protecting, rather than simply aiming to remove as many pigs as possible. However, quantifiable information on the damage caused by pigs to many resources is scarce, so it can be difficult to determine how much control is needed to achieve a useful outcome.

In many situations, feral pig impacts are likely to be proportional to feral pig density. Furthermore, the removal of pigs from a population increases the resources available for pigs that survive initial control, which will usually lead to increased reproductive output in those survivors. For these reasons, sustained management of feral pig populations is usually best achieved by a large initial population knockdown followed by ongoing control operations to limit recovery. The proportion of the population that needs to be removed each year will depend on environmental conditions and the timing of control operations. However, population growth rate estimates from across Australia suggest that about 70% of the population should be removed each year to prevent rapid recovery to pre-control levels. This can usually only be achieved by integrating multiple control methods as part of an ongoing strategic management program. Local eradication of feral pig populations is highly unlikely in most cases.

The most effective and efficient primary feral pig control techniques are usually poison baiting and aerial shooting. While each of these control techniques can be effective they are most efficient when used together. Any pig control activities must be conducted in accordance with the Model Code of Practice for Humane Control of Feral Pigs (see Further Information at the end of this section).

Feral pig populations can recover quickly, even after large reductions and ongoing, secondary control is essential. Secondary control builds on the effort and investment made in primary feral pig control. Feral pig control programs that do not plan for secondary and ongoing control are unlikely to be successful in the medium- to long-term. It is important that follow up feral pig control makes use of different control techniques, is coordinated across property boundaries and is ongoing.

Timing of feral pig control

Feral pig control is most effective if timed to coincide with environmental conditions that cause acute stress in the population. These can include drought, flood or excessive heat or cold. Resource stress usually causes feral pig populations to concentrate around refuge or resource areas, effectively reducing home ranges. Control carried out at this time will expose the maximum proportion of the population to the control technique. For example sodium fluoroacetate (1080) baiting at remaining water points during a drought can be very effective.

Control techniques

Fencing

Fencing can be used to protect high value crops or environmental assets. Pig proof fences have been designed but are expensive and require regular maintenance.

Poisoning – ground baiting

1080 poisoning: 1080 is currently the only registered poison for controlling feral pigs in NSW. 1080 poisoning can be an effective method of controlling pig numbers if undertaken in a methodical manner. It is particularly effective if green feed and other food sources are limited. Involving neighbours and undertaking a broad-scale coordinated baiting program will result in a more effective control program. When undertaking a poisoning program, it is vital that other control methods cease for the duration of the free feeding and poisoning events, allowing the pigs to feed undisturbed. Other control methods such as aerial or ground shooting can then be used for follow up control until the next baiting event. Follow up control methods are also important because a proportion of any pig population will usually be reluctant to take poison bait.

Feral pig bait material can only be prepared by mixing 1080 poison with grain or manufactured pellets. Grain, pellets, fruit and vegetables can be used as attractants in bait stations or traps.

Only Authorised Control Officers (ACOs) in NSW can prepare bait and supply it to land managers. 1080 is classified as a schedule 7 Dangerous poison and is regulated under a Pesticide Control Order (PCO) that prescribes its use. The use of 1080 bait products requires a current chemical application accreditation at a minimum Australian Qualification Framework level three (AQF3) or the EPA accredited course delivered by the Local Lands Service.

Bait stations are constructed by enclosing an area with fencing that will not allow livestock and non-target species in, but can allow pigs to enter by pushing underneath. Bait material is placed in a shallow depression within the fenced area.

Bait stations must be used in areas where livestock are present. Bait stations can be left in place and reused as required. Bait stations can be placed near active pig pads, at watering points frequented by pigs and at holes in fences.

Free Feeding: Free feeding is a legal requirement of baiting feral pigs. It is essential that adequate free-feeding of un-poisoned bait material occurs for at least three nights prior to poisoning but longer free feed periods (up to ten days) are recommended. Pigs that become conditioned to free feed will often create a trail to the bait station that can be discovered and exploited by other pigs. Consequently, the number of pigs feeding at a bait station often increases, up to a point, over time. Effective free feeding ensures that the maximum numbers of pigs are attracted to and feeding on the free feed material and that excessive poisoned bait is not placed out.

Camera traps can help increase the effectiveness of baiting programs. The use of cameras at bait stations shows how many pigs are coming to feed at the site, helping to gauge the amount of free feed and ultimately 1080 baited feed required. Cameras can also show how many different mobs are coming into the sites and at what time they are feeding. Cameras are also very useful in identifying surviving pigs after control programs. Cameras can also be used to monitor the presence or absence of non-target species visiting bait stations.

Inadequate free feeding and poor quality information on the number of pigs using bait stations can often lead to insufficient toxin bait being provided. This, in turn, can result in pigs ingesting sub-lethal doses. 1080 causes intense nausea in pigs and other mammals, and pigs that ingest sub-lethal doses are likely to become bait shy and resistant to future baiting operations.

Feral pigs may take some time to begin to feed on the bait material provided, depending on what food sources are already available. Once they begin to feed at the bait station, progressively offer more bait material until consumption is no longer increasing. Once the amount being taken is consistent, adjust accordingly to ensure a small amount of free feed material remains at the end of a night’s feeding.

Due to the effect of 1080 feral pigs will tend to eat less toxic bait than they would non-toxic free feed. For this reason, the amount of poisoned bait used should only be about 75% of what was consistently taken during free feeding. This will minimise the amount of left-over 1080 bait. Poisoned bait material can be provided for a maximum of three consecutive nights. After this time all remaining poisoned bait must be removed and, where possible, carcasses of poisoned pigs should be collected and buried to prevent poisoning of non-target wildlife or domestic animals.

Figure 9. Camera traps can be helpful for estimating how many pigs are using a free-feeding site and how much poisoned bait is likely to be required (Photo Bec Gray).

Poisoning – aerial baiting

Aerial baiting programs may be an effective means for dealing with a feral pig problem where ground control is impractical or where impacts are significant or potentially significant.

There are a number of restrictions and legal requirements associated with aerial baiting programs. The intended program should be discussed with the LLS ACO several months in advance. Only Pigout® Feral Pig Bait can be used for aerial baiting and it can only be applied by helicopter.

Aerial shooting

Shooting feral pigs from helicopters can be a very effective method for achieving an initial population knockdown or it can be used as a follow up control method. This type of shooting is species-specific and can be used in areas that are inaccessible from the ground or when pigs are heavily concentrated due to drought or flood. Aerial shooting can be expensive over a short period of time, however due to the rapid population reduction it can achieve; it can often be a very financially and temporally efficient control method. Like most control methods, it is important to have coordination and cooperation from a number of groups and across land tenure boundaries to increase effectiveness. It can also be a valuable tool for controlling feral pigs in tall standing crops and when feed sources are plentiful and when baiting is less effective.

In NSW aerial shooting is undertaken by private contractors and the NSW Government. NSW Government shooters are a part of the Feral Animal Aerial Shooting Team (FAAST) which is made up of NPWS and LLS staff. FAAST is not the same as aerial shooting under by private contractors. FAAST operates under strict controls and guidelines under the FAAST manual.

Ground shooting

Ground shooting and recreational hunting is a less effective primary control option for feral pig control, especially in areas of high pig populations. Shooting feral pigs from the ground is a method normally used opportunistically to follow up and maintain low numbers after a primary control program has occurred. Often ground shooting is conducted using dogs to locate feral pigs. Hunters must ensure both the dogs and the pigs are treated in a humane manner. Ground shooting should not be conducted prior to, or during, any other program of control, as it disrupts normal feral pig activity and may cause feral pigs to break into smaller groups and move to other areas.

Trapping

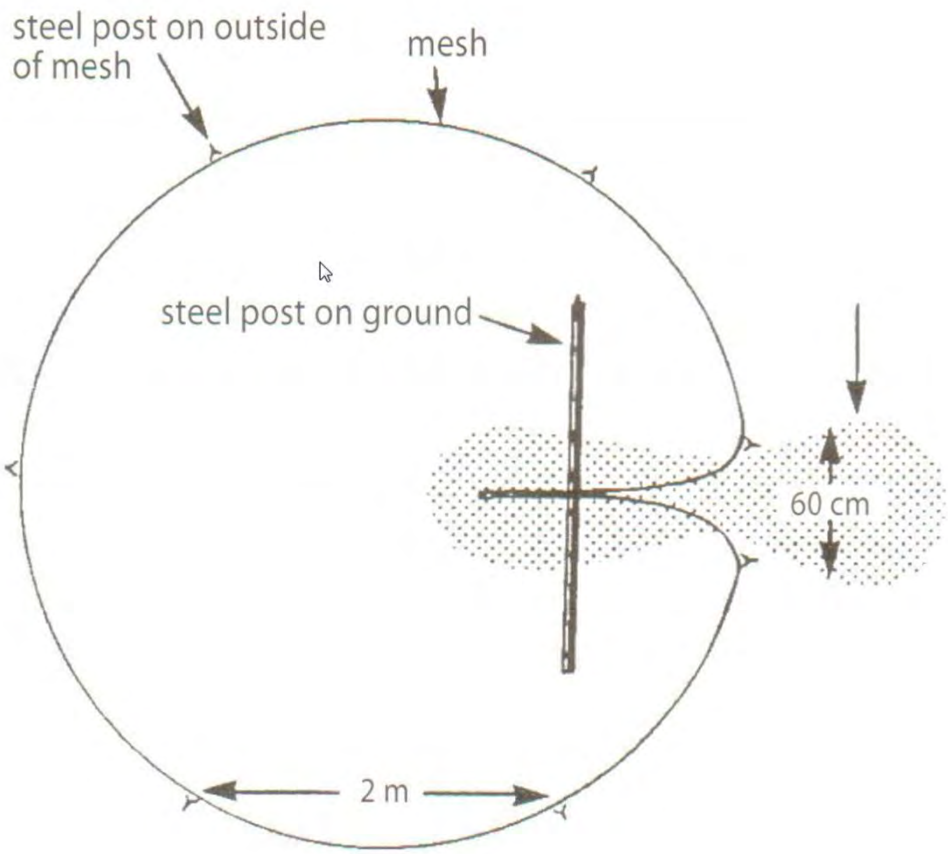
Trapping of feral pigs is an effective technique to use as a follow-up after an initial knockdown of a population and as a maintenance technique to prevent numbers from building back up. Trapping is flexible, as most traps can be easily moved to where pig activity is current. The exact numbers of pigs controlled is known and there is very low risk to non-target animals. Traps must be checked daily. Traps are also useful where baiting cannot be carried out; for example, due to distance restrictions or where the risk to non-target animals is high.

Feral pig traps can be as simple as a sheet of mesh formed into a heart shape and secured with steel posts (Figures 11, 12). These traps are relatively portable and easy to set. Traps can also be constructed using mesh panels secured with steel posts (Figure 10). These traps can have either a swing gate or a more solid top-hinged drop gate. Panel traps shorter than 1.5 m in height should have a mesh roof to prevent pigs from climbing or jumping out. The construction of the entrance door to the trap is a critical part of the design, and several different configurations are possible (e.g. Figure 14). The door must work effectively to allow pigs to enter the trap but not allow them to back out. Trap selection depends on permanency and ease of access or portability.

Traps should be set up where feral pig activity is current; such as near waterholes, on regular trails, or at other sites where pigs are moving regularly, such as through a hole in a fence. Traps should always be sited in a location where they can be partially shaded because of pigs' poor ability to dissipate body heat (Figure 13).

Figure 10. Feral pigs in a panel trap (Photo Jason Neville).

Figure 11. Schematic diagram heart-shaped or silo trap.



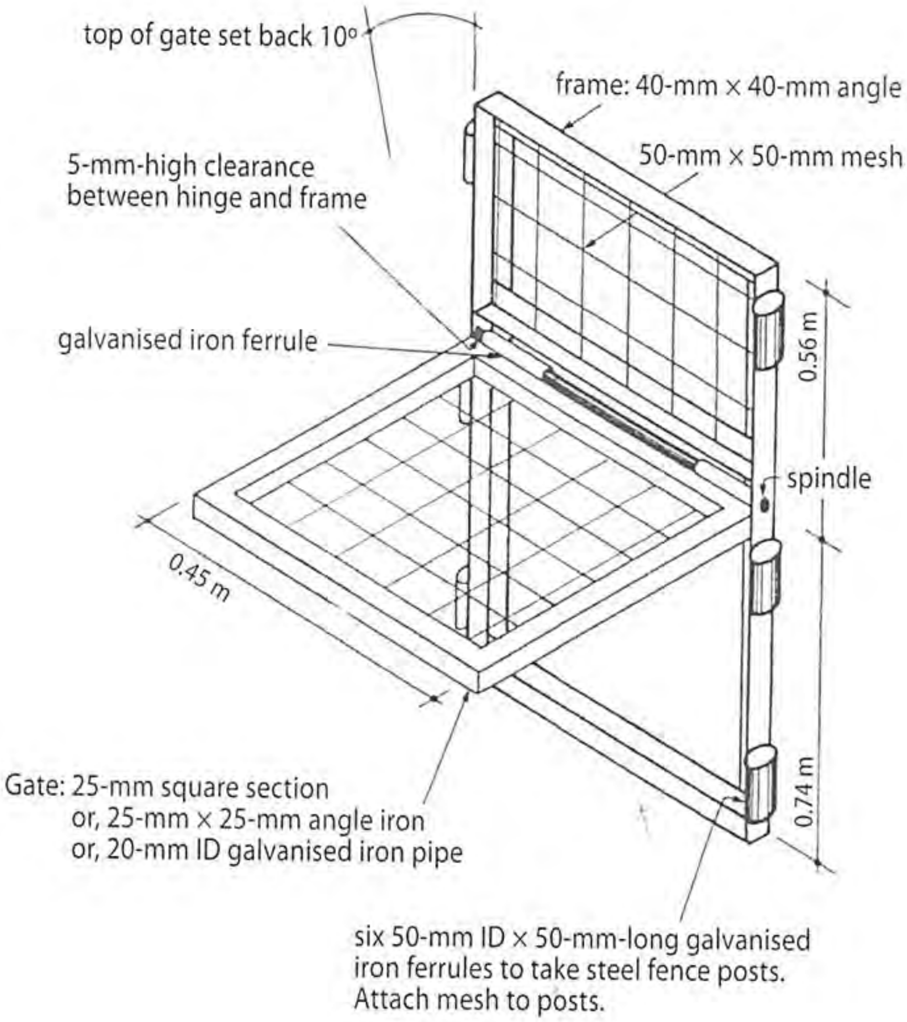
Trapping must start by providing bait material at the site. Bait types can include grain or commercial pellets, vegetables and fruit that they are already feeding on. Due to the risk of transmitting disease it is illegal in NSW to use animal carcasses as free feed or as bait in feral pig traps.

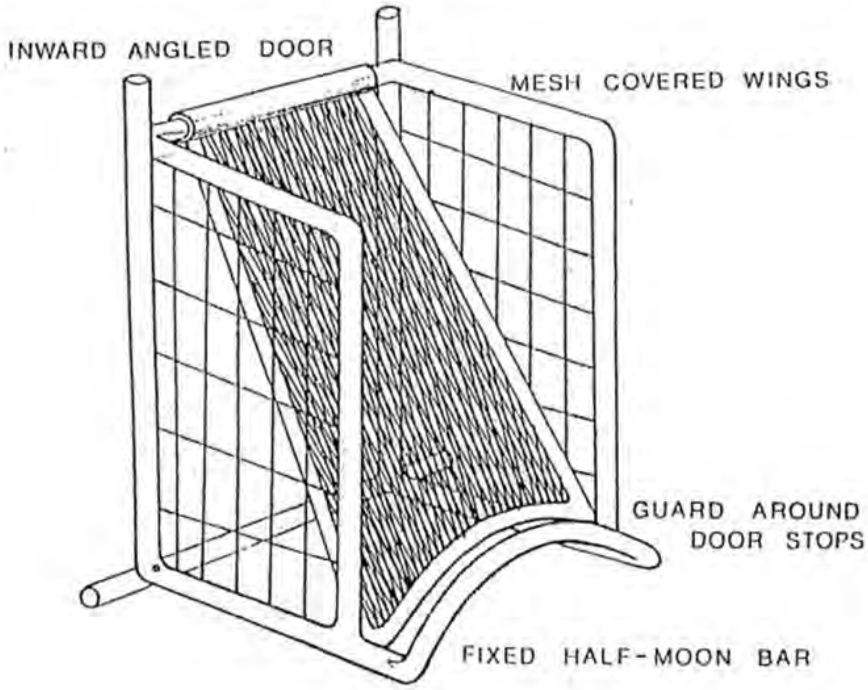
Once pigs are readily consuming the bait, construct a trap around the bait site with a trail of bait leading to the trap entrance. Leave the trap door tied open for a number of nights until pigs are readily entering the trap to feed. The trap can then be set. Check the trap regularly, every day and humanely destroy any pigs caught. Pigs should not be left for excessive periods in traps. Using camera traps over pig traps enables the observation of pig behaviour around the trap and gives an indication of numbers.

Figure 12. Construction of a heart-shaped trap fitted with a side-opening gate (Photo Jim Mitchell).

Figure 13. Panel trap set near recent pig digging. An army surplus camouflage net provides shade over a mesh roof (Photo Andrew Bengsen).

Figure 14. Examples of top-hinged drop gate designs for feral pig traps. The lower example is more bulky and difficult to transport than the top example, but the side wings prevent pigs from exiting the trap when new pigs enter and the half-moon base prevents pigs from opening the door from within the trap.





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Further information is also available on the internet at http://www.pestsmart.org.au

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Rabbit

Background

Description

The European wild rabbit, *Oryctolagus cuniculus*, is distinguished from all other mammals by its long ears, long hind legs and short fluffy tail.

Origin

The rabbit is native to north-western Africa, Spain and Portugal and it is now found in the USA, Chile and most of western Europe as far north as Scandinavia. The rabbit is considered a pest in many of the countries it was introduced to, but the release into Australia and New Zealand caused the greatest problems.

Domesticated meat rabbits arrived in Australia with the First Fleet and rabbits were released onto many islands in the Bass Strait and the Tasman Sea to provide sustenance for shipwrecked sailors. The first genetically wild rabbits were imported into Victoria in 1859. This small population of 24 individuals grew to over 14,000 within 7 years.

Rabbits quickly spread across Victoria and the rest of the continent. Within 70 years rabbits had colonised two-thirds of the Australian continent. This is the fastest rate of spread of any pest animal anywhere in the world. This rate of spread suggests that humans contributed to their distribution with swaggies known to carry rabbits around. Trappers and shooters were probably also responsible for the rapid spread.

Distribution

Rabbits presently inhabit approximately 5.3 million square kilometres or 70% of southern Australia. They have established in environments ranging from subalpine areas to stony deserts, from subtropical grasslands to wet coastal plains, and particularly prefer Mediterranean type climates where soils for warren construction are suitable; these areas are generally associated with livestock production and support much of Australia’s rural production.

The rabbit is found throughout most of NSW with the general exception of the black soil areas. Although there is no accurate figure on the present distribution, past surveys indicate that at least three-quarters of the State has some degree of rabbit infestation. Approximately 8% would have a high and detrimental population of rabbits, however, given the high level of fluctuation that occurs in rabbit populations, this estimate can change considerably.

Ecology and biology

Habitat

Rabbits can adapt to a wide variety of habitats, though in general they avoid large cultivated areas, forests, floodplains and black soil country. They prefer short grass areas either found naturally or resulting from heavily grazed pastures, with harbour (warrens, blackberries, fallen logs or human-made structures such as sheds or shipping containers) nearby. Human habitation does not deter rabbits and they may become a problem around home gardens, shearing sheds and other farm buildings.

Diet

Rabbits are herbivorous, and eat a wide variety of plants, including crops, roots, pastures, young trees and young vines and prefer short, succulent plants.

With an average body weight of 1.6 kg, a rabbit can consume up to one-third of its own weight daily, although the average daily intake is around 100 to 150 g. The maintenance requirements for a rabbit and a 45 kg sheep are 284 MJ (megajoules) and 2438 MJ respectively. This equates to a ratio of approximately nine rabbits to one dry sheep equivalent (DSE).

The skulls of lagomorphs (rabbits and hares) are easily recognised by their very obvious chisel-shaped incisors (as in rodents) with a small second pair of upper incisors close behind the first. The lower incisors fit between these upper pairs, keeping them well ground and sharp. While rabbits can graze plants to ground level, they have a small mouth and prefer soft, short and succulent plants rather than woody or stalky taller species. Grazing generally continues throughout the night for 2.5 to 6 hours. Where the warren complex supports a large population of rabbits, feeding grounds or 'rabbit lawns' develop a short distance from the warren.

Food is well masticated, entering the stomach as fine particles. As part of their digestive process they form both soft and hard faecal pellets. The soft pellets, which have a high bacterial content, are produced mainly during the daylight hours when the rabbits are not grazing. These soft pellets are eaten directly from the anus during the day and re-ingested. This process, called coprophagy, is used to extract the remaining protein and moisture from food and allows a more complete digestion of the fibrous plant material. It also enables rabbits to survive with minimum free water. The hard pellets seen on the ground and at dung heaps are the end result of the digestion process and are usually dropped during the normal grazing period from late afternoon and throughout the night.

Home range and movement

Rabbits construct large warrens up to 3 m deep and 45 m long. Warren complexes are generally larger in more open country. Warrens provide cover and protection from predators and extreme temperatures, and allow rabbits to live in open grasslands, grazed pasture and arid land. Where there is abundant surface cover, rabbits may live above the ground.

Daily movements are generally within 150 to 200m of the warren, but this distance can increase during droughts (up to 1,500m has been observed) or decrease during the breeding season.

Rabbits are crepuscular - active from late afternoon until early morning, but they can be active at any time if they are undisturbed or if their numbers are high. Activity appears to decrease at night if there are high winds or rain, which limits their ability to detect predators.

Very young rabbits 20 to 60 days old are more likely to disperse than older rabbits. Adult rabbits rarely disperse. Most dispersal is from warrens with a high rabbit density to warrens with a low density or to adjacent social groups. Rabbits usually do not travel vast distances, but movements in excess of 20 km have occasionally been recorded.

Newly emerged kittens may move up to 1.5 km to a new warren complex. The general rule of thumb is that movement and reinvasion of control areas can and will occur, yet mass movements over long distances occur mostly when food is limiting. It is usually difficult to distinguish between re-colonisation and reproduction in situ after a control program, so it is better to conduct a control program that includes a buffer area against migration. Active warrens within 1km and up to 3km from a control program will affect the success of the control program and reinvasion from these active warrens can occur.

Social structure

The warren complex forms the basis for a distinct social structure with a well-defined hierarchy closely aligned with the breeding season. The dominant buck has freedom of movement within the home range and so has access to the greatest number of females. Territorial boundaries are well defined and are marked mainly by the dominant buck with urine, faeces and scent exuded from a chin gland. These boundaries are strictly maintained and defended by all the members of the group. At the end of the breeding season these boundaries may break down, allowing for the dispersal and spread of the young rabbits, however, the group tends to stay together.

Communication is mainly by smell, but alarm signals are given by flashing the tail while running and by thumping with the hind feet.

Reproduction

Rabbits can breed at any time provided there is short green feed supplying sufficient protein. A 50% water content level in vegetation will trigger breeding, so a significant rainfall event, regardless of season, will result in breeding; however, being a Mediterranean species, the main breeding season occurs over winter, with the first kittens emerging late August/early September as vegetation increases.

Harsh conditions occurring during the breeding season may induce anoestrus and cause the doe to cease lactating and/or resorb any foetuses. This mechanism allows the breeding nucleus to be preserved at the expense of the more vulnerable young.

With the onset of breeding, social groups of 7 to 10 rabbits form, governed by a dominant buck and a dominant doe. There is a high level of aggression, strong territorial behaviour and the evolution of social hierarchies. A few breeding groups together form a social entity and occupy a common grazing and sheltering ground. Strong social hierarchies develop both within and between groups.

Both males and females reach sexual maturity between 3 and 4 months of age. Does are induced ovulators, a phenomenon that results in synchronisation of oestrus. With a large number of receptive females, subordinate bucks are able to mate while the dominant buck is mating with other does.

The gestation period for rabbits is 28 to 30 days. There is no post-partum anoestrus and the doe generally mates again within an hour of giving birth. Under favourable conditions an adult female can produce 7 or 8 litters in a year. Although the litter size varies according to the doe's age and social status, seasonal conditions and nutrition, the average number is 2 or 3 kittens in the first litter, rising to 7-8 by the end of the season. Consequently, one doe may produce between 50 and 60 offspring, however, 30 is about average in a single breeding season. When the females from this doe's first litters reach sexual maturity they too will reproduce. So in one breeding season one adult doe may be responsible for the production of in excess of 100 rabbits.

CSIRO researchers found that although dominant females made up only 24% of the population, they produced 51% of the kittens. The second-ranking does made up 43% and produced 42% of the kittens, while the third- and fourth-ranking subordinates - 33% - produced only 7% of the kittens.

The young are usually born in nests of grass and belly fur, which may be in part of the warren complex or, if from a subordinate female, in a breeding stop. The breeding stop is a short single-entrance burrow less than one metre long and about 30 cm below ground. After the birth and first feeding, the doe leaves the stop. She will visit the stop four or five times each 24 hour period to feed the young, concealing the entrance at each departure.

The kittens are born blind and eyes open after 7 to 10 days. They emerge from the warren at about 18 days. They are usually weaned at this stage, leaving the nest when 23 to 25 days old. If the doe dies or abandons her young, they can survive from 16 to 18 days of age.

Figure 15. Kitten rabbits at 1 day old (L), kitten rabbit at 20 days (R) (Photo David Croft).

Mortality

Apart from human intervention for control or sport, natural adult rabbit mortality does not generally suppress a rabbit population. Kitten mortality in the wild is extremely high, with up to 80% dying before they reach 3 months of age. However in a favourable year with a temperate Mediterranean climate in excess of 85% mortality is needed to suppress a 10-fold population increase.

Disease: There are currently three diseases that are known to impact heavily on rabbit populations. Myxomatosis is a disease caused by the myxoma virus: a poxvirus which in its natural host, the South American jungle rabbit (*Sylvilagus brasiliensis*), causes non-fatal, localised fibromas. However, in the European wild rabbit it forms a pustule that affects the lymphoid tissue leading to profound suppression of the immune system and generalised systemic disease. Lesions develop around the infection site, usually the head, followed by severe conjunctivitis. The rabbit, because of a suppressed immune system, is unable to fight off subsequent secondary bacterial infections which result in death. Death due to myxomatosis is prolonged and while in acute cases death can occur within 8 to 12 days (or 3 to 5 days after clinical signs develop), quite often death can occur anytime within 2-6 weeks.

Rabbit haemorrhagic disease virus (RHDV) is a calicivirus that was first reported in China in 1984 where it killed 140 million domestic rabbits in less than 12 months. Two strains of RHDV have been identified, RHDV1 and RHDV2. RHDV1s generally only infects adult rabbits. RHDV2s affect both adult and young (~ 30 days old) rabbits. Rabbits with RHDV usually develop signs of fever within 36 hours of infection and are often dead within 6–12 hours after the onset of fever. Rabbits with RHDV often become lethargic and can die suddenly. Occasionally rabbits may squeal, become excited or exhibit paddling behaviour. Outwardly, animals that have died from RHDV appear healthy. On occasions a bloody discharge from the nose may be present.

Both the myxoma virus and RHDV1 strains have been introduced into Australia as biological control agents to suppress rabbit numbers across the landscape (myxomatosis in 1950, RHDV1 in 1995, and RHDV1 K5 strain in 2017). RHDV2 was identified in the Australian rabbit population in May 2015. When myxoma virus and RHDV1 were first released they reduced rabbit populations by up to 98% in some areas. Both myxoma and RHDV are transmitted by insect vectors. Biting insects such as fleas and mosquitoes are important vectors for the myxoma virus and flies, particularly bush flies and blow flies, are important vectors for RHDV. RHDV1s do not cause disease or death in any other species of animal, including hares. RHDV2s have caused disease and death in species of hare, including the European brown hare (Lepus europaeus) found in Australia. Myxomatosis very rarely affects the European brown hare.

Myxomatosis currently kills 30-50% of the rabbits it infects and is still an effective biological control agent in some areas of the country. RHDV1s are still effective across much of Australia, particularly in the arid and semi-arid regions with an average mortality of 75%. The impact of RHDV2 on the Australian rabbit population is yet to be determined.

Coccidiosis may also impact rabbits. Coccidiosis is a common worldwide protozoal disease of rabbits that occurs in two forms – hepatic and intestinal. Hepatic coccidiosis is caused by, *Eimeria stiedai* with intestinal coccidiosis caused by a number of other species of *Eimeria*. Young rabbits are most susceptible to hepatic coccidiosis with severe infections resulting in death. Intestinal coccidiosis is rarely fatal.

Predation: Predation can account for substantial losses of both healthy and starving rabbits. Besides the fox, dingo, cat and dog there are a number of avian species that prey on the rabbit in Australia. The wedge tailed eagle is probably the most effective, followed by goshawks, falcons and barn owls. Ravens, goannas and snakes may also prey on kittens.

When rabbit numbers are low, predation can reduce the annual crop of young by approximately 25%. In denser populations this proportion decreases to about 10%, with predation playing little part in population control.

Starvation: The only non-disease factor that seems to operate in a density-reducing manner is starvation. The lack of food stops reproduction and can result in the deaths of nestlings; followed eventually by adults. Drought causes dispersal, which leads to exposure and vulnerability to prey. This is the time when control programs are the most effective.

Impact of rabbits

Agricultural impact

The annual cost of rabbits to agriculture in Australia exceeds $200 million making it the most costly vertebrate pest animal. Rabbits directly compete in agricultural enterprises with livestock for pasture. This may result in running fewer livestock, lower wool clips and breaks in the wool, lower reproduction rates, lower weight gains and possibly earlier deaths during drought.

The colonisation of rabbits across much of Australia has undoubtedly facilitated the spread of other introduced animals such as the fox and reduced lambing rates may occur due to higher fox numbers being maintained by a high rabbit population.

Environmental impact

Rabbits impact 304 species of plant and animal and five threatened ecological communities. Australian native vegetation is very sensitive to rabbit damage. With densities as low as 0.5 rabbits per ha all seedlings of the more palatable native trees and shrubs, including threatened or endangered plant species, can be removed preventing regeneration. Forestry and tree plantations may also suffer extensive losses due to grazing rabbits. Erosion caused by denuded vegetation from rabbit grazing has a major impact on dam catchments, water supplies and maintaining topsoil. The burrowing behaviour of rabbits may undermine roads, culverts, buildings and sites of cultural significance.

Rabbits have been strongly implicated in the extinction of native species such as the burrowing bettong. While there have been few known native mammal extinctions north of the range of the rabbit since European settlement. Many species disappeared from records after the rabbit arrived in 1859 and before the successful introduction of the fox in 1871.

Rabbits can also significantly affect native fauna through their aggressive and territorial behaviour. Rabbits have been observed attacking yellow-footed rock wallabies and in one observed case injured a burrowing bettong so badly it died from its wounds. Large animals such as the red kangaroo may be vulnerable to competition when both species rely on refuge areas of some green pasture during drought. Both the Eyrean grasswren and the plains-wanderer are impacted due to the destruction of habitat by rabbits.

Competition and grazing by rabbits is listed as a Key Threatening Process under the *Threatened Special Conservation Act 1995* see www.environment.nsw.gov.au/threatenedspecies

Social Impact

Rabbits can impact on individuals and the community indirectly through loss of ecosystem services at the catchment scale and damage to visual amenity, or higher prices for rabbit-affected commodities (such as wool).

Recognition and sign

The only animal in Australia that could be confused with the rabbit is the hare (*Lepus europaeus*). However, the hare has longer, black tipped ears, longer legs and a loping gait. Rabbits and hares are generally easier to observe during daylight than other introduced pest animals because they frequent open ground and are at least partly diurnal. Their footprints are also distinctive. Rabbit droppings are often similar to hares', depending on the food eaten, but they are distinguished from lamb faeces by the absence of flat facets on the surface. Scrapes, dung heaps, burrows and warrens are evident when rabbits are present.

Management principles

Pest status

Wild rabbits are declared pest animals under the *Local Land Services Act 2013*. This declaration means that land managers have an obligation to control wild rabbits on their land.

Figure 16. Rabbits western NSW (Photo Mark Fosdick).

Strategic approach

The primary goal in rabbit control is to minimise the economic and environmental damage caused by rabbits by reducing the population to a level where it cannot quickly build up. The success of a rabbit control program is not the number of rabbits killed, but the number of breeding females that remain after to re-establish the population.

A number of steps are required to ensure rabbit numbers remain low. Too often the control program is halted after the first step and rabbit numbers rapidly build up again. It is also important to apply a number of techniques to control rabbits. The integration of conventional control techniques such as warren ripping and shooting, in conjunction with the arrival of myxomatosis or RHDV, will maximise effort and suppress rabbit numbers over a longer period.

There is a proven recipe for successful rabbit control. Successful rabbit control relies on targeting the warren (and/or other harbour), and the timely application of a number of techniques in the correct order. Research has shown that with the application of the following techniques, in the correct order, using best practice, can result in >20 years benefit. Any deviation from the recipe will result in reduced efficacy. Effective rabbit management can be divided into four steps and can be thought of as the four R's – reduce, remove, reassess and reapply. The four R's are explained below.

Step 1 – Reduce rabbit numbers

Rabbit numbers need to be at their lowest to achieve successful long-term management outcomes. If rabbit densities are medium to high, the first step is to reduce the population to a manageable level. This can be achieved through either the release/arrival of RHDV and/or through a poisoning program with either 1080 or pindone.

Step 2 – Remove warrens/harbour

This phase is the most important part of the control program because it is where an effective reduction of rabbits and harbour should be achieved. The initial control brings the population down to a manageable level, while extensive control further reduces the population to a level where it cannot recover quickly. The key component of this step is the destruction of the warren (most commonly through ripping) and the removal of above-ground harbour. To be effective, a minimum of 75% of the warrens in the target area must be treated in the control program to be successful. Any less than 75% will result in the failure of the ripping program in the long-term due to the breeding rate of rabbits and therefore the reopening rate of treated warrens. On the night that warren ripping/harbour removal has taken place, shooting can be used most effectively to mop-up those animals that have been displaced during the program that day. Where warren ripping/harbour removal cannot be applied, fumigation and warren collapse using hand tools is recommended.

Step 3 – Reassess rabbit numbers

After the destruction of the warren and removal of harbour, rabbit numbers should be reassessed to ensure population reduction has been achieved. Rabbit populations should be regularly monitored to ensure that numbers are not building up to unacceptable levels. As the complete eradication of rabbits is often unachievable, a threshold level of rabbit numbers should be set. This threshold level will be enterprise dependant. The threshold is used as a trigger for action to ensure rabbits do not once again get out of control.

Step 4 – Reapply control techniques where necessary

Following an extensive control program it is important to maintain the gains that have been made. After ripping the warren should be checked for re-openings. Any re-openings can be fumigated and minor baiting done where necessary. Regular and effective monitoring of the rabbit population is an important part of this phase.

If these steps are followed correctly, and the last two steps repeated as part of the overall property management program, then it should be unnecessary to repeat the first two steps for up to 20 years. This should be the goal of all land managers.

Figure 17. Preparing rabbit warrens for ripping by removing excess timber (Photo David Croft).

Control techniques

Poisoning

Poisons can be an effective way of reducing rabbits as a first step. Two main poisons are used in NSW, 1080 and pindone. In NSW rabbit poisoning is regulated by the *Pesticides Act 1999* and is carried out under the conditions set out in the current PCOs for 1080 and pindone and with the label or where specified under the PCO. Copies of the PCOs can be obtained on line at www.epa.nsw.gov.au/pesticides/pco.htm or from your local LLS. The use of the poisons currently requires a minimum chemcalAQF3 or the EPA accredited course delivered by the LLS.

Essential points

- The time to poison rabbits is when they are not breeding. During breeding, rabbit movements are much more limited by territory boundaries and consequently the rabbits are less likely to find the bait unless much more trail is laid. Moreover, kittens over 18 days old may survive, even if the female is poisoned, and subsequent breeding by these survivors may cause rapid rebound of the population numbers.
- Poisoning should be carried out in paddocks that have been heavily grazed or when grass is cured and feed is scarce. This helps rabbits to find trail and eat the bait and provides a better opportunity for rabbits to willingly take up the bait. It also allows the land manager to graze those paddocks to fully use the pasture before poisoning, Paddocks where bait has been laid must not be grazed until bait has been covered or weathered sufficiently for 1080 to be leached out.
- The objective is to decrease the population and consequent rabbit damage and prevent rapid population build up. If only a small part of an infested area is successfully poisoned, even a total kill will be ineffective because the population will rapidly re-establish due to immigration from surrounding areas.
- A kill of close to 100% over a large area must be obtained for a successful poisoning operation. Keep in mind that it is not the number of rabbits killed but the number left alive that is important. Percentage reductions mean little if rabbit numbers are large. A 5% residual from an original population of 5000 is 250 rabbits, whereas 5% of an original population of 500 is only 25 rabbits and the latter is much easier to manage in follow up control treatment.
- Land managers must adhere to all the requirements of the PCOs and inform all adjoining neighbours at least 3 days before laying poison baits.

- Rabbit poisoning is only the first step in the control program. Poisoning should be followed rapidly by harbour destruction, including warren ripping, log burning and weed removal e.g. blackberries; and by continual fumigating, shooting and dogging the survivors of the initial poisoning.

Rabbit baits for poisoning – carrots, pellets and oats

Carrots are effective rabbit bait, being used extensively throughout more than two-thirds of NSW and combining high acceptability with reasonable economy. Carrot baits are cut in a carrot cutter before the poisoning operation. This cutter should have a swift, clean action that avoids cutting too many small chaffy pieces or large chunks. Carrot pieces should be roughly 2 cm cubes and about 5 g in weight.

While carrots are generally recommended, oat grain has certain advantages in dry seasons because it is readily available, suitable for storage, easier to handle and it does not deteriorate or require processing. Pellets, when available, have similar advantages to oat grain. However, caution is required when using oats or pellets, particularly during dry times when livestock may be being hand fed with similar products. After poison is added the bait is bagged and transported to the control site. Baited carrots should be kept cool prior to use and used as soon as possible to avoid bait sweating, which may degrade the carrots and poison.

Figure 18. Serious rabbit problem – note bait trail (Photo David Croft).

Free feeding

A minimum of three free feeds is required prior to laying poison bait except where an ACO recommends otherwise. Free feeding provides a more accurate determination of the amount of poisoned bait required to give maximum knock-down yet leave minimum bait for non-target species. Rabbits vary in their readiness to accept strange food so free feeding over a number of days allows rabbits to become accustomed to the food. Some dominant rabbits may monopolise the trail and keep the shy feeders away. Consequently, the longer free feeding bait is available the more chance there is of controlling the maximum number of rabbits. Failure to administer the required number of free feeds is poor practice and a breach of the current PCOs and penalties apply.

For different infestation levels, a general rule of thumb is to start the first free feed with the quantities shown in Table 2. The amount of bait in the second free feed should be increased if most of the first free feed was taken during the first night or decreased if bait remained after the second night. If the rate of acceptance is variable during the first and second free feeding, then it is essential to put out a third free feed.

Table 2. Suggested quantities of bait for first free feeding of rabbits.

Level of infestation				
	Carrots & oats (kg/km)	Pellets (kg/km)	Carrots (kg/ha)	Carrots (kg/ha)
light	4–8	1–2	4–8	n/a
medium	6–10	2–3	8–10	4
heavy	15–30	> 3	10–15	6

Poisoned bait is laid after the free feed period at two-thirds to three-quarters of the optimum free feed rate. Poisoned baits are applied at the following intervals after the last free feed:

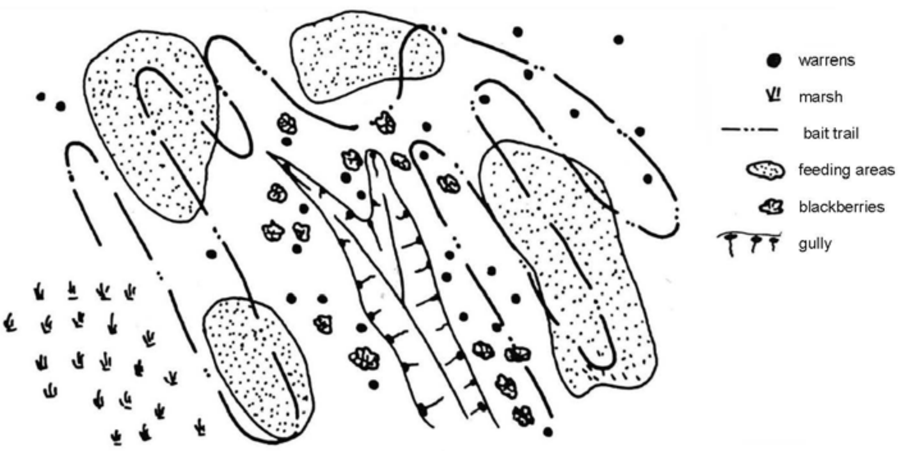
- Trailing (carrots and oats) – minimum of 2 days
- Trailing (pellets) – minimum of 4 days
- Broadcasting (carrots) – 3 to 5 days.

Placement of baits – trailing

Trailing is cutting a continuous furrow with a disc or bait layer. This furrow should be cut cleanly, about 10 cm wide and 2 cm deep. A cut furrow provides a visible guide to the location of the trail and to the bait. Also, the freshly turned soil is intended to attract rabbits. Prior to trailing, warrens, any other surface harbour and the feeding grounds should be located, Figure 19.

Feeding grounds and areas around and between warrens should be trailed. Feeding grounds can often be identified during a spot light count or by open areas where the grass is short and lawn like and where scratching is common. Rabbits do not feed on the warren. Trails may circle a warren however a gap of 3 to 5 m should be kept between the trail and the warren. If rabbits are in small isolated areas they too should be trailed. A general rule of thumb is to use up to 16 km of trail per 100 ha, with trails about 40 m apart.

Figure 19. Ideal placement of a bait trail around warrens but through feeding areas.



Placement of baits – broadcasting

Broadcasting is where bait is spread over the area to be poisoned by hand, by rotary super spreader or by aircraft. This method is mainly used in areas where it is impractical or impossible to run a trail because of the presence of terrain, large rocks, fallen timber or crops; or because trailing may lead to erosion. Free feeding with 3 free feeds at least 2 days apart should be used.

Broadcasting bait by hand

Hand broadcasting from horseback, motor bike or on foot is an effective means of dealing with rabbits in areas inaccessible to the trailing. Baits are simply broadcast by hand close to warrens and on feeding or play grounds. Rabbits will not feed on or in the burrow, so all bait should be placed at least three metres away from the burrow mouth. Hand broadcasting may be used in conjunction with a trailing program or as a separate spot poisoning program. If carried out along the same lines as that for trail baiting, excellent results can be obtained.

Aerial baiting

Aerial baiting requires approval by NSW DPI and needs to be coordinated in conjunction with the relevant LLS. A land manager should discuss the intended program with the LLS several months in advance and the authorising officer must ensure that all the conditions in the current 1080 PCO can be met.

Aerial baiting programs are an effective means of dealing with a rabbit problem in steep, rocky and hilly areas where ground baiting techniques cannot be employed.

- The program needs to be undertaken at a time when rabbits are stressed for food, usually about mid to late summer so they will readily seek out the bait
- The area to be baited should be heavily grazed before the program. However the area cannot be restocked until sufficient rain has fallen to render baits safe because it is not possible to collect or cover baits. This may take some time.

Application for approval must be made by the LLS. Approval will be based on:

- the extent of the rabbit problem requiring aerial baiting
- why the problem cannot be dealt with by the conventional means of ground baiting and harbour destruction
- written permission from all government authorities and private land managers whose land will be treated under the proposed program. National Parks and Nature Reserves require a separate application
- an appropriate map of the area to be treated including bait flight lines and bait lines must be digitised and provided to the aerial contractor prior to aerial baiting
- the name of the ACO and manager who will have the overall supervision and responsibility for the program.

Applications must be submitted from the LLS to the NSW DPI officer, at least two months before the proposed date of baiting.

Poisoning – important points

In addition to the information required in the application, the baiting program itself must adhere to the following conditions:

- All the requirements specified in the current 1080 PCO must be met
- GPS coordinates must indicate to the aircraft where the bait is to be laid.

Some important factors to remember about toxicity and use of pindone are:

- As an anticoagulant it will take a number of days to kill. Poisoning programs should not be assessed until 10 to 14 days after the first poisoned feeding up to 21 days in some instances
- Increased application rates have little influence on shortening the time until death if the bait is constantly available

- Excessively large doses have little influence on shortening the time until death if the bait is constantly available
- Most anticoagulant concentrates have been formulated to be more acceptable to the target species, therefore increasing above the recommended rate may significantly diminish bate acceptance.

Figure 20. Preparing for a major rabbit poisoning campaign (Photo Reg Eade).

Post poisoning procedure

Any poisoned bait remaining after poisoning is a danger to livestock unless it is thoroughly covered or broken down. The use of an agricultural implement, such as a scarifier, to cover the bait will reduce the possibility of excessive baits remaining accessible to non-target species. While it is generally agreed 100 mm of steady rainfall for carrots and 50 mm of steady rainfall for oats and pellets may breakdown 1080 this is only a guide and is not guaranteed. The longer the period before restocking, the less likely is the hazard, especially if a good growth of pasture results from the rain.

Myxomatosis and RHDV

An effective epidemic of either myxomatosis or RHDV should be followed up with extensive control efforts. Regular monitoring of the rabbit population for signs of myxomatosis (rabbits with obvious skin lesions and pustules) or RHDV (dead rabbits that appear outwardly healthy and show no obvious cause of death) should be undertaken to maximise opportunistic control efforts.

RHDV1 and the new K5 strain, released in 2017, are available through the LLS on baited carrot. Baiting should not be undertaken during the breeding season as rabbits younger than 12 weeks are more likely to become immune adults. A free feed of carrots should be applied in the feeding areas of rabbits. Follow the label instructions carefully and be sure to lay the bait as soon as possible after preparation. It is best to lay bait late in the day, just before rabbits come out to feed in the early evening

RHDV has the potential to spread rapidly from individual infected rabbits to rabbits within the same warren and to new warrens in the same area or some distance away from the initial site of infection if weather conditions are suitable. However, the rate of movement and the proportion of warrens affected are highly variable. No guarantee can be given that the virus will spread from an infected rabbit or warren to other rabbits.

Transmission of myxomatosis

Rabbits usually become infected with myxomatosis after being bitten by an insect vector that has picked up virus particles from the blood of an infected rabbit. These virus particles are carried on the mouthparts of insects that bite or pierce the skin of rabbits.

Mosquitoes are the usual vectors of myxomatosis virus during summer outbreaks of the disease. An outbreak caused by mosquito transmission generally spreads rapidly and infects a large number of rabbits at any one time. The European rabbit flea, *Spilopsyllus cuniculi* brought to Australia in 1966 is a useful vector for myxomatosis, being present on the rabbit throughout the year. The flea breeds only when the rabbit breeds, since it requires a hormone present in pregnant rabbits to mature its eggs. Flea numbers are therefore greatest during the breeding season, when they are most useful for spreading myxomatosis. However, the European rabbit flea cannot tolerate hot dry conditions and requires the blood from pregnant rabbits for its own survival. Therefore the Spanish rabbit flea, *Xenopsylla cunicularis* was released in the 1990s into a number of rabbit populations in the semi-arid areas of Australia, including a number of sites in western NSW. Although the distribution of European and Spanish fleas may overlap in the central districts of the State, the Spanish rabbit flea thrives in dry climates. Spanish rabbit fleas do not require rabbit hormones to breed and thus can breed all year round, albeit slowly in winter. They spend most of their time in the warren, jumping on to a rabbit only to feed. Thus they feed on many different rabbits and as a result are excellent vectors of myxomatosis. Several other insects that parasitise rabbits, including the stickfast flea and several small mites, also transmit myxomatosis, but their importance in field outbreaks is thought to be insignificant.

Transmission of RHDV

Unlike myxomatosis, RHDV is normally transmitted by direct contact, so it does not necessarily need a vector to spread it from one rabbit to another. Trials have shown however, that the Spanish flea, mosquitoes and in particular, bush flies and blowflies are vectors of the disease.

Harbour destruction

The removal of harbour is the most effective means of reducing the rabbit population. The main forms of rabbit harbour are warrens and woody weeds such as blackberry bushes, African boxthorn, other vegetation and fallen logs. Any property with extensive harbour will almost always become re-infested with rabbits after initial control. Fallen logs should be heaped and burnt and a woody weed control implemented. For more information on weed control, consult with the local council weeds officer.

Warren Ripping

Effective warren ripping at best practice is the key to a successful rabbit control program. Ripping techniques depend heavily on soil type and location of the warren such as, the slope or waterways and erosion potential, as well as the equipment available. The tractor and rippers used must be suitable for the job and the driver should be accredited, experienced and competent. The land manager will have to rely on local experience to determine the most suitable techniques for the area.

Ripping should take place immediately (the next day) after a successful baiting program. Rabbits do not readily dig new warrens so destruction of warrens greatly inhibits resurgence and re-colonisation of poisoned areas, especially if surface harbour is removed and follow-on control by ripping or fumigation is undertaken.

Start by running barking dogs over the area to force surface rabbits into warrens before the start of ripping.

Use tines at least 900 mm long and keep tine rip-lines ≤ 50 cm apart. Start ripping at least 3 m beyond the outermost burrow opening of the warren. This allows the ripper to get to a maximum depth before the warren is reached and increases the chance of ripping tunnels outside the visible warren diameter. Obstacles and harbour such as logs and blackberries should be removed to increase the effectiveness of ripping. If the warren is uneven then it is worth levelling the warren with a bulldozer or front end loader blade to allow better and more even penetration of the tines on a level surface.

If parts of a warren cannot be ripped because of obstructions such as trees or fences, be sure to fumigate these burrows a few hours before ripping. If ripping near trees or stumps back the tractor up to them and rip away from the trees so that the tines travel along roots and not cut across them.

Figure 21. Warren ripping: note length of tynes (Photo David Croft).

In general, clay soils should be ripped when damp and sandy soils when dry, but be guided by local experience. Where possible, scatter some grass seed over the ripped area to allow for faster regeneration of the site. Unless ridges and hollows are severe there is no need to smooth them over. These ridges tend to catch water and wind-blown seed and disperse the 'rabbit' smell, allowing for a faster rejuvenation of the site. Back filling with the tractor blade can remove excessive ridges or furrows to prevent rabbits digging back in. Smaller or shallow warrens can be successfully destroyed with a chisel plough or discs, but regular monitoring is essential with openings treated as soon as they occur.

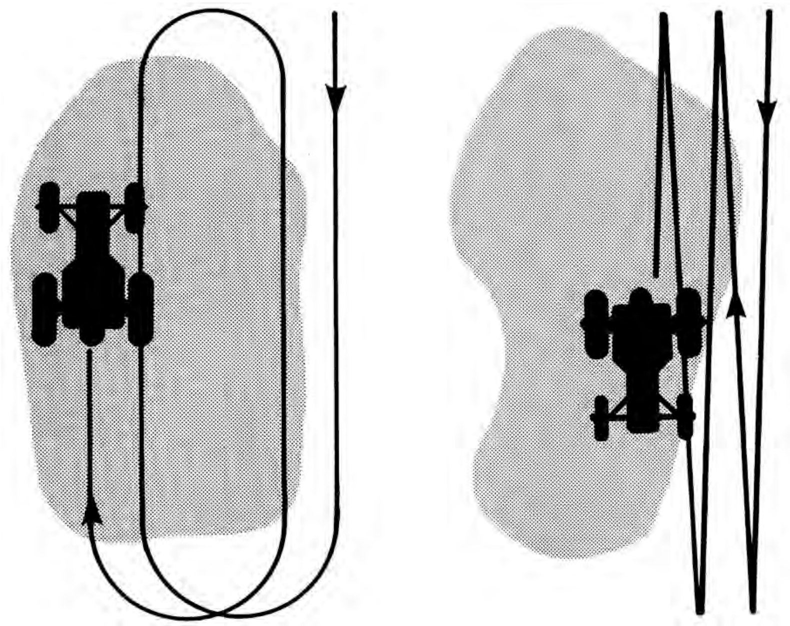
An economical ripping technique, particularly applicable to open country, is to begin ripping from one of the long sides of the warren and to avoid turning completely around for the second rip line, move across and follow with the second rip down the centre. Next rip towards the centre from the first rip and out toward the other edge from the second rip, Figure 23a; repeat until the warren is fully covered.

Figure 22. Warren ripping in deep sand – Menindee Lakes (Photo David Croft).

An alternative ripping technique that can also be used in more hilly terrain is to begin ripping from one of the long sides of the warren, each time reversing over the last rip, Figure 23b. Each new rip starts only in the same direction as the first rip. This technique increases the packing effect of the ripped warren. It is recommended that all ripping be done across the slope, and that slopes exceeding 18° should not be ripped. If it is not possible to rip the entire warren across the slope, at least two or three cross rips should be used to reduce the risk of erosion.

In some cases cross-ripping might be necessary or advisable if the soil type is 'tight'. Cross-ripping means to rip in one direction and then again at 90° to the original rip line to completely destroy the warren complex.

Figure 23. Typical ripping patterns (a) on flat ground and (b) on hilly terrain.



Warren destruction by blasting

Blasting is a follow up technique sometimes used to destroy warrens that cannot be ripped, such as those among rocks and boulders and under trees. However, explosives may be used only by trained and licensed operators. Contact WorkCover Authority NSW for licensing requirements or go to http://www.safework.nsw.gov.au/

Fumigation

Phospine is the recommended fumigant for rabbits. Phospine is produced from aluminium phosphide tablets available under a number of registered brand names. Tablets come in tubes, strips and packs ranging from 30 to 100 tablets.

Fumigation can be very effective for controlling rabbits:

- as a follow up technique to ripping or blasting
- in inaccessible places such as rocky outcrops, along fences and around trees, on riverbanks where it is not possible to rip
- for treating small, isolated infestations
- in places where ripping is undesirable because of the risk of erosion
- as an alternative to 1080 poisoning on properties where 1080 cannot be used: the property may be too close to town; the occupier may not allow 1080; the removal of livestock may not be possible; or the use of poisoning is not advisable because the rabbits are breeding.

There are some basic rules when undertaking fumigation:

- Fumigants may be lethal to humans. Labels and safety directions must be read and approved personal protective equipment (PPE) worn
- Run dogs over the area to chase rabbits underground
- All openings of a warren must be found and sealed
- Follow up is essential and fumigated burrows must be checked for re-openings on the sixth day, sixth week and sixth month.

This is a very dangerous procedures and the relevant PPE is essential. Phosphine is extremely dangerous in enclosed spaces. Partly used tubes of phosphine tablets must not be returned to storage. Phospine tablets may be placed inside resealable flasks kept on hand especially for that purpose. Do not store phosphine tablets in an open tube, unless the tube is placed in a sealable can.

Fumigation Procedure

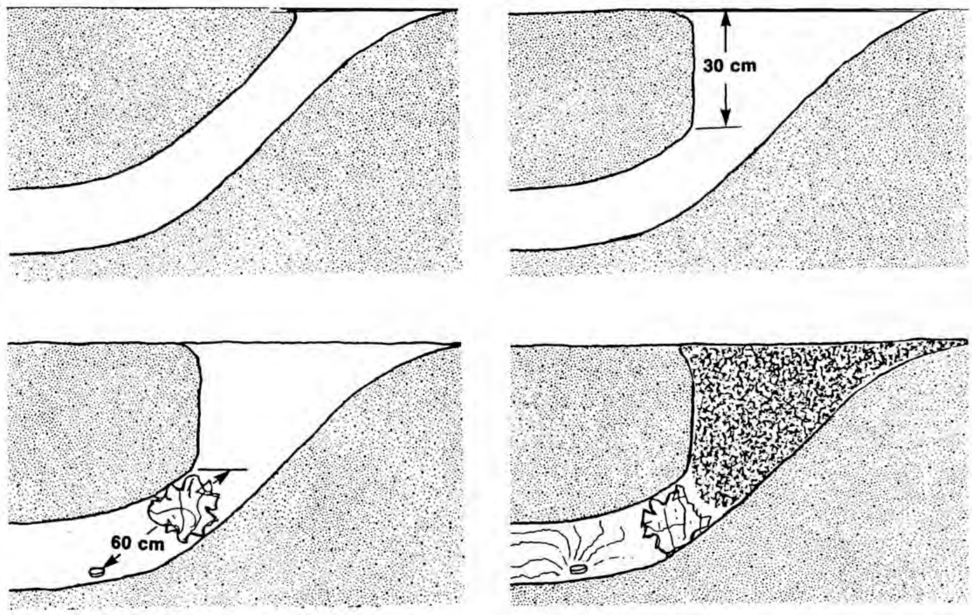
Following the dogs prepare the warren for fumigation by cutting back each burrow mouth until there is at least 30 cm of soil between the surface and the burrow tunnel see Figure 24. This not only ensures a better seal when blocking the hole, but also exposes any branches of the tunnel that are close to the outlet.

Once the hole is cut back, place the fumigant at least 60 cm down each burrow. With phosphine this only requires placing a tablet well down the hole by rolling the round tablet down a length of poly pipe. Under dry conditions it is advisable to place wet newspaper down the hole before adding the tablet.

Once the fumigant is in the burrow, carefully seal the opening with a clod of dirt that has a tuft of grass attached with the grass facing down the hole or with a ball of crumpled newspaper. This prevents loose dirt from covering the fumigant and also makes it more difficult for a rabbit to dig out. Finally, break in the sides of the hole level with the surrounding soil and tramp down to give a good seal.

Repeat process until all entrances and pop holes in the warren are sealed. Fumigation can be a slow process.

Figure 24: Static fumigation steps.



Final mop-up

Mopping-up is used when rabbit numbers are at a very low level. When rabbit numbers are very low, the removal of each rabbit has a far greater long-term effect on the potential for reinfestation. When the rabbit population is high, each individual rabbit removed does not have much effect therefore a large percentage must be removed to have any effect.

Once this advanced stage is reached, only periodic checks and the occasional use of a specific control method will be necessary to keep a property rabbit free.

Shooting

On smaller properties regular shooting can help maintain rabbit numbers at low levels so that their impacts are minimal. Shooting is largely ineffective at controlling a large, rapidly breeding population of rabbits. Shooting is an easy and effective way to remove rabbits when numbers are low and is particularly useful as a mop-up tool the night a ripping program has taken place. Good numbers can be taken this way. Shooters can sit off warrens or cover and shoot animals as they appear. Dogs can also be used to flush animals from cover for shooting by shotgun. Night shooting using a rifle or shotgun and a spotlight can be effective. A .22 calibre rifle or shotgun is recommended.

Foot-hold Trapping

Trapping is permitted under the *Local Land Service Act 2013* if it is part of a rabbit control program but it should be used only to clean up the last few rabbits. Trapping should not be used as a primary method of control when rabbit numbers are high because it is largely ineffective at removing sufficient numbers in a large population of rapidly breeding rabbits. All traps, particularly soft-jawed spring traps must be used in accordance with the Code of Practice.

Traps may be placed in any area showing signs of rabbit activity including entrances to burrows or warrens, dung heaps, earth mounds, along rabbit netting fences or near hollow trees and logs. Traps set on dung heaps, along fences and on mounds near warren openings usually trap only older rabbits. Traps set in burrow openings will trap both kittens and older rabbits

When using it is essential that:

- all traps are to be checked as soon as possible after dawn to reduce unnecessary suffering to captured animals
- all traps are to be inactivated after dawn to prevent capture of non target animals during the day

- when setting traps where other animals could accidentally be caught, dig a deeper trench so that the trap is set in a depression of 5 to 6 cm. Most larger animals will step over such a depression, while rabbits will be attracted to the fresh soil.

Barrel netting or mesh traps

These traps are relatively easy to make. The trap consists of a cylinder, 12 to 15 cm in diameter and a metre in length, made from rabbit netting or light mesh. One end is closed off and the cylinder has two hinged gates or flaps, making three sections about 35 cm long. At the gates, heavy gauge wire on light steel rod supports the trap and acts as a non-return frame for the gate. When the rabbit pushes into the cylinder and moves past a gate, the gate closes behind it. If the rabbit pushes back, the gate will press against the retaining circle of wire and prevent escape. Place the trap in the entrance and peg it to prevent it rolling. To have any success with these types of traps, every entrance should contain a trap as adult rabbits will avoid strange objects. It may take weeks before rabbits use the trap. Free feed in the trap may assist in attracting rabbits out of the entrance.

Other techniques

Fencing

Rabbit-proof netting fences are very expensive and the extra cost and time involved in construction means they are generally not used by many land managers. Rabbit proof netting fences are now most often used to protect a relatively small, high value crop or a tree lot or to exclude harbour areas such as rocky hills. Yet, when stressed, rabbits will climb over or dig under most rabbit-proof fences. It is important that all fences are checked regularly for holes or for any object leaning against the fence if the integrity of the fence is to be maintained. If necessary, a capping or electric wire or foot netting may be needed to stop rabbits going over or under the fence.

If a rabbit-proof fence is required, netting barriers should be used to protect posts and stays and gates should be swung so that rabbits can't move between the gate and posts or get underneath. A correctly positioned bed-log will prevent rabbits from moving under a gate.

Deterrents and revegetation

After a major harbour destruction program with ripping, explosives, fumigation or poisoning freshly treated warrens need to be seeded to re-vegetate the area as quickly as possible and minimise re-colonisation. The use of fertiliser or commercial animal repellents may reduce the rate of rabbit visitation and allow vegetation to re-establish. Use clean seed suitable for the area that will give a reasonable cover. Cereal seed such as cereal rye is fast growing and useful pioneer species that will provide quick vegetation cover. The quicker the warren surface is covered in vegetation the sooner the area will recover and reduce reinvasion by rabbits.

Further information

Braysher M & Saunders G, Best practice pest animal management. Primefact 502, NSW DPI. https://www.dpi.nsw.gov.au/biosecurity/vertebrate-pests/publications/best-practice-pest-animal-mgt

Sharp T & Saunders G 2005, Humane Pest Control: Codes of Practice and Standard Operating Procedures. NSW DPI.

Williams K, Parer I, Coman B, Burley J & Braysher M 1995, Managing Vertebrate Pests: Rabbits. Australian Publishing Service, Canberra.

Further information is also available on the internet at http://www.pestsmart.org.au

Acknowledgements

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2017 review completed by Tarnya Cox, Troy Crittle, NSW DPI.

Pest birds and flying foxes

Impact of pest birds and flying foxes

There are over 100 bird species in Australia that can cause significant losses to fruit, nut, grain, rice and aquaculture industries, create conflicts in urban areas, damage infrastructure, reduce aesthetic values, and pose risks to the environment and to human health. (Table 3).

For example:

- European Starlings, House Sparrows, European Blackbirds, Silvereyes, parrots and lorikeets, cockatoos, honeyeaters, crows and ravens are the main pests of cultivated fruit, nuts, olives and grapes.
- Sulphur-crested Cockatoos, Galahs, corellas and cockatiels are the main pests of course grains, pulses and oilseeds.
- Pacific Black Ducks, Australian Wood Ducks, Grey Teal and other waterfowl are the main pests of rice.
- Cormorants, herons and egrets are the main pests of aquaculture.

Introduced pests, including European Starlings, Common Mynas, feral pigeons and House Sparrows can damage feed storage areas, feedlots and infrastructure, reduce amenity values and impact on native species.

Native flying foxes may also impact fruit growers in periods when native blossom and fruit is scarce. Three species are native to NSW (Grey-headed, Little Red and Black flying foxes) and all are protected species. Flying foxes can become a pest on stone fruit, pomme fruit and tropical fruit orchards.

Figure 25. Starlings roosting on a silo. Introduced species such as starlings can defecate in food storage areas, raising health concerns (Photo Brian Lukins).

Table 3. Impacts by Australian birds and fruit bats.

	Cherries	Stone fruit	Pomme fruits	Grapes	Tropical fruit	Berries	Citrus	Nuts	Flowers	Olives	Vegetables	Grain	Legumes	Rice	Sunflower	Sugar Cane	Pasture	Livestock	Stockfeed	Forestry	Aquaculture	Apiary (Beekeeping)	Urban	Airport	Infrastructure	Potential disease	Weed spreading	Environmental
INTRODUCED BIRD SPECIES (COMMON NAMES)																												
Starlings	Serious	Serious	Serious	Serious	Serious	Serious				Serious	Serious	Moderate							Moderate				Moderate		Moderate	Moderate	Serious	Serious
Indian Myna				Serious		Serious																						
European Blackbirds	Serious	Moderate	Moderate	Serious						Moderate	Moderate																Serious	Serious
House Sparrow	Moderate	Serious	Moderate	Serious							Serious								Moderate									
Feral pigeon																							Serious		Serious	Infrequent		
European Goldfinches				Infrequent																								
European Greenfinches				Infrequent																								
Red-whiskered bulbuls #	Infrequent	Infrequent	Infrequent	Infrequent	Infrequent	Infrequent			Infrequent		Infrequent																Infrequent	Infrequent
Indian House Crow #		Serious	Serious	Serious	Serious							Serious			Serious			Serious					Moderate					Moderate
NATIVE BIRD SPECIES (COMMON SPECIES)																												
Cockatoos, corellas, galahs	Serious	Serious	Serious	Moderate	Serious		Moderate	Serious	Moderate			Serious	Serious		Serious					Moderate								
Cockatiels												Serious	Serious															
Parrots, Rosellas, Lorikeets	Serious	Serious	Serious	Serious	Serious	Serious	Moderate	Serious	Moderate	Infrequent	Infrequent									Moderate								
Crows and Ravens	Serious	Serious	Serious	Serious	Serious		Serious	Serious		Serious	Serious	Moderate						Serious					Moderate			Infrequent		
Australian Magpie																							Moderate					
Currawongs	Moderate	Moderate	Moderate	Serious	Moderate		Moderate	Moderate		Serious																		
Silvereyes	Serious	Serious	Serious	Serious	Serious	Serious																					Serious	
Honeyeaters				Moderate	Serious	Moderate			Moderate																			
Friarbirds	Serious	Serious	Serious	Serious	Moderate	Serious																						
Wattlebirds	Serious	Serious	Serious	Serious						Serious																		
Rainbow bee-eaters																						Infrequent						
Mistletoe birds				Infrequent																								
Swallows, Martins																							Infrequent					
Noisy Miners																												Moderate
Bowerbirds		Infrequent					Infrequent				Infrequent																	
Cuckoo shrikes		Moderate	Moderate	Moderate		Moderate																						
Ducks								Infrequent			Infrequent			Serious			Moderate											
Black Swans											Infrequent			Serious			Moderate											
Magpie Geese					Moderate				Infrequent		Infrequent			Serious			Moderate											
Swamphen, native hen, coots											Moderate			Serious			Moderate											
Egrets, herons, cormorants																					Serious							
Silver Gull																								Serious				
Australian Ibis																		Infrequent					Infrequent			Moderate		
Brush turkey					Infrequent	Infrequent	Infrequent				Moderate									Moderate								
Wedge-tailed eagle																		Serious										
Emu												Infrequent	Infrequent															
NATIVE FRUIT BATS (3 species in NSW)																												
Flying fox (little red, grey-headed, black)					Serious																		Infrequent			Infrequent		

References

Serious	Reported to cause serious damage	# Species not yet established in Australia but their potential to cause damage is indicated
Moderate	Moderate damage, less frequent pest	
Infrequent	Infrequent pests, low rates of damage	

Figure 26. A starling nest in a eucalypt hollow previously occupied by an eastern rosella. Starlings and common mynas are known to spoil natural nest hollows, reducing breeding opportunities for native species (Photo Peter West).

Management principles

There is a diverse range of options for managing pest birds. They have variable effectiveness and no single solution is applicable to all situations

For flying foxes, permanent netting is the most effective method for protecting crops.

Strategic approach

Bird management is often not initiated until after considerable damage has already occurred. Integrated pest management is a concept well understood for insect and disease problems, but birds are rarely managed in the same strategic way.

Rather than focusing on total number of pest birds or flying foxes culled, it is now realised that management needs to be carefully planned and coordinated and the focus needs to be on reducing damage to an acceptable level. Control of pest birds and flying foxes is just one aspect of an integrated approach to the management of production. Many birds are highly mobile and can readily replace those that are culled in control programs. For non-lethal control, pest birds and flying foxes will also become habituated to regularly used scaring methods. Unless actions are well planned and coordinated, most control programs are unlikely to have a lasting effect.

A range of landscape and habitat factors influence the number of pest birds and the damage they cause. These factors can be considered when the manager is attempting to minimise losses. The varieties grown and timing of maturity can be important. For example, growing varieties that mature simultaneously can help to alleviate the damage to individual growers. Depending on the birds involved, sites with adjacent roosting habitat or powerlines can have higher losses.

The numbers of pest birds and the levels of damage will vary according to the preferred habitat of different species. For example, Common Mynas prefer urban environments; cockatoos and European Starlings are most abundant in cleared agricultural and peri-urban areas; and most native species prefer native vegetation. These factors can be considered before planting new crops.

Figure 27. Starlings roosting in blackberry, Rubus fruticosus. Impacts can be greater where perching and roosting opportunities are available (Photo John Tracey).

When planning bird and flying fox management, consider these important steps that should be considered.

What is the problem?

Firstly determine if the problem is real or perceived. If it's real then define the impacts the birds or flying foxes are having. It may be that there are reduced crop yields, environmental or infrastructure damage, declining aesthetic amenity, complaints from neighbours, or emotional stress from worrying about the next attack. Several factors have an impact on each of these problems, and the control of birds or flying foxes is often only part of the solution. The following questions will help define the problem:

- Where is the problem?
- How severe is the problem?
- Will the problem change with time?

Identify the species involved

Implementing an effective bird or flying fox control program requires a basic understanding of the ecology and biology of the targeted pest species, and in some cases those species affected directly or indirectly (e.g. non-targets and prey species) by a control program. It is also essential to understand the impact created by the pest.

Control strategies can be targeted for particular birds or flying foxes. For example, some species, such as silvereyes and many honeyeaters, are highly migratory, moving into crops only during specific periods. Therefore, out-of-season control may be inappropriate for these species. Similarly for fruit flying foxes, damage to fruit crops may only be a sporadic issue during seasons when native blossom and fruit is scarce.

Native birds and flying foxes need to be identified because most of these species are protected and permits are required for their control. Furthermore, native birds and flying foxes can provide beneficial ecosystem services such as control of insects and pollination of flowers, so it is important that management does not affect these species. Conversely, some birds and flying foxes can be both beneficial and pests. For example honeyeaters members of the Meliphagidae family can become a more serious problem in orchards during seasons of poor Eucalyptus spp. flowering, but also have a benefit by consuming many damaging insects throughout the year.

Figure 28. Red wattlebird in a vineyard. Honeyeaters can cause serious damage in orchards and vineyards when fruit is ripe but also consume large numbers of insects (Photo John Tracey).

Estimate the impacts

Estimating the amount of damage and calculating the cost will provide a basis for deciding how to best reduce pest impacts and how much the land manager can afford to invest in any control effort. In agriculture this is simpler. The percentage of crop damaged by birds or flying foxes in an orchard block can be estimated by randomly or systematically sampling rows, plants, and individual fruit or bunches. Bird and flying fox damage to individual fruit or bunches can be estimated by counting, weighing or by using a visual estimate. However, estimating the other types of damage and social and environmental costs is often more difficult. These impacts need to be quantified to allow an evaluation of the management program.

Identify any key constraints

Consider legal, social and environmental issues. For example, will scare devices be acceptable to the local community, and are the techniques legally and/or environmentally responsible and acceptable? Some devices are extremely noisy and can become offensive close to residential areas.

Decide on most cost-effective time to implement a management plan

Even when good information is available, it is often not practicable to be immediately responsive to short-term fluctuations in bird or flying foxes numbers, or the damage they cause. When damage becomes significant, it is usually too late to implement control. For example, effective use of scaring often requires a ‘start early’ approach to prevent birds establishing a feeding pattern. Likewise, investment in netting cannot be simply withdrawn for those seasons in which damage is below the cost–benefit threshold. Instead, we may need to look at costs and benefits over a longer time frame and make decisions accordingly. If damage in the area is likely to be high or there is a history of high levels of damage, the manager should be more inclined to invest in continuing management action. Measuring damage this year will help in selecting the optimal management option next year and beyond.

Figure 29. Measuring damage in a vineyard. Estimating impacts is an essential step in managing pest birds effectively – it provides a basis for deciding how to best reduce impacts and how much to invest in control effort (Photo Bruce Mitchell).

Developing the most appropriate bird or flying fox management plan

Importantly, a management plan must firstly identify the issue and have details of what will be done, who will do it, when it will be done and how much it will cost. Options can include individual techniques or combinations, and different levels of application. The plan should have long-term, year-to-year strategies to prevent damage and short-term reactive strategies to cope with sudden increases in impacts. For example, in the long term, managers may use netting over their high-value crops every year. In the short term, when damage is higher, they may also implement a scaring program.

Monitor and evaluate

For any management plan, it is critical to know whether the implemented management practices have been successful. Estimating damage is the most direct way to measure the effectiveness of any management program. All costs of implementing control, including labour should also be determined. For example, nets may significantly reduce bird and flying fox damage, but if they are repeatedly removed for maintenance or spraying of the crop, there will likely be additional costs incurred. It is therefore critical to look at the costs and benefits associated with the bird management plan to determine whether it was/is financially viable.

Evaluating the management practices undertaken will help to improve decision-making for future strategies and allows actions to be modified to maximise economic return. It is advisable to document what worked; what didn't; and what can be improved for the following year.

There is no one simple solution for effectively managing birds and reducing their impacts. However, the following information may help managers decide on the most appropriate actions for their situation.

Control techniques

Scaring

Many visual and sound devices are used by managers in an attempt to scare birds, including:

- acetylene and LPG gas guns
- pyrotechnic charged shotgun cartridges and firecrackers
- flashing or rotating lights
- reflective mirrors or tape
- predator models
- playback of danger or distressed bird calls
- humming tape or line
- kites, flags and bunting
- scarecrows
- helium- or air-filled balloons
- bird scaring drones/UVAs
- ultrasonic bird repellents

Habituation to the deterrent is the main drawback of all types of scaring devices. Birds and flying foxes quickly become accustomed to the noise and visual cues, rendering them ineffective. Ultrasonic devices that have been trialled have also been found to be ineffective, with most birds unable to hear ultrasound ≥ 20 kHz. In addition, birds of prey rarely call when hunting; hence pre-recorded raptor calls are likely to represent something novel to birds rather than create an avoidance response from a predator.

Figure 30. An acetylene gas gun for deterring birds. Using a combination of techniques, starting early, Reinforcement, timing and placement are important considerations for effective scaring (Photo John Tracey).

Figure 31. Peaceful Pyramid®, a visual reflective deterrent for birds (Photo John Tracey).

To improve or prolong the effectiveness of scaring devices use a combination of scaring techniques:

- scare the birds and flying foxes prior to them establishing a feeding pattern;
- reinforce the sound by shooting or some form of threat. For example, pyrotechnic cartridges which are fired from a shotgun result in an explosion accompanied by a flash and cloud of white smoke;
- ensure the timing and placement of devices are changed frequently, at irregular and unpredictable intervals;
- use loud sounds rather than quiet sounds as they are more aversive;
- use sounds with a wide frequency range;
- aim auditory devices down-wind to increase sound projection;
- use the devices for the shortest time necessary for a response and discontinue their use when birds or flying foxes are not feeding in the crop or the device is no longer effective;
- camouflage scare devices so birds and flying foxes don't associate the sound with the device;
- target adult birds as they are more easily scared compared with juveniles; and
- target the sound to the bird or flying fox species that is causing the problem. Some sounds are species specific and may cause an investigative response rather than an escape response.

Fruit flying foxes are perceived to be an issue in urban areas where large camps of roosting flying foxes can be noisy and emit a strong smell. In some areas, roosting flying foxes can also pose a disease risk to livestock. Non-lethal methods for moving camps of fruit flying foxes from urban areas have shown some success. Smoke, non-lethal plastic shot (BirdFrite) and loud noises were used to move a camp of flying foxes from roosting trees in urban areas. These measures needed to be repeated to prevent the flying foxes re-establishing at the roost tree. Community involvement and education is an important part of successful management of fruit flying foxes in urban areas (See Case studies in further reading - Philips, *et al*., 2007). Trials of non-lethal methods to move flying fox colonies at Royal Botanic Gardens in Sydney showed the 'Phoenix Wailer' was effective for moving flying foxes and was within the ambient noise range for urban areas (See Case studies in further reading – Richards, 2002).

Birds of prey

Attracting birds of prey or the use of falconry is often perceived to be of value in scaring birds or reducing pest numbers. However, although falconry has been used previously in airports to reduce bird strikes, it is impractical in most situations. Falconry is strictly regulated in Australia, requires skilled handlers and considerable training and is labour intensive.

Encouraging raptors to specific areas is difficult, as different species occupy different ecological niches. For example, Sparrowhawks and Goshawks prefer hunting among trees and tall shrubs to surprise prey, while most falcons prefer open country and Australian Hobbies prefer lightly timbered country along watercourses. In addition, the most effective predators of adult birds are unlikely to be attracted by carrion or other food sources as they prefer live prey. Species that may be attracted to an area by these additional food resources, including Wedge-Tailed Eagles, Little Eagles and Whistling Kites, do not normally hunt birds in flight and may cause greater problems for livestock production, especially during lambing.

Some studies have shown that providing perches and nesting boxes near the target crop increases the number of wild birds of prey in the area. However, a clear link between attracting these birds and a reduction in the number of pest birds or the damage they cause has not yet been demonstrated. However, the establishment of nesting boxes for birds of prey and suitable perches around crops could be used as part of an integrated solution to bird control that also includes more conventional methods such as netting and scare devices.

Figure 32. Brown Goshawk under bird netting. Birds of prey can be effective predators of pest birds but their ability to reduce impacts on crops is unknown (Photo John Tracey).

Lethal control

Many attempts to kill birds, despite alleviating frustration, often do not reduce damage. The techniques used are usually labour intensive and may have legal, welfare and social concerns. In NSW, native game bird species can only be hunted under the NSW Native Game Bird Management Program, administered by the DPI Game Licensing Unit.
See http://www.dpi.nsw.gov.au/hunting/game-and-pests/native-game-birds for further information.

Pest birds, particularly introduced species, have high population turnover rates and high rates of natural juvenile mortality. Attempts to reduce populations in the long term need to remove a greater number of birds than what is being replaced. Therefore, greater effectiveness may be achieved if the breeding population is targeted or when using lethal control as part of a scaring program, see Shooting.

Trapping

The use of traps to reduce bird numbers requires considerable labour and is often cost prohibitive and likely to be used only opportunistically. However, trapping may be of benefit in situations where a single resident species is involved and a large proportion of the population can be trapped. A multitude of different trap designs is available, including remotely operated nets, cages and roost traps, funnel entrance traps, modified Australian Crow traps and nest box traps. Some local councils and LLS staff may be able to provide traps to landowners for the control of certain species of pest birds.

The success of trapping varies according to the skill of the operator and the time of year. For example, large numbers of starlings can be captured after the breeding season, between late December and May, when many juveniles are congregating. However, this may have little long-term effect on the population size owing to the high breeding potential of starlings, which can produce an average of two clutches of four chicks each season. Hence, removing birds prior to or during the breeding season, August to November, may result in the capture of fewer individuals but has greater potential to reduce the population size for the following summer and autumn. The standard operating procedure for trapping pest birds is available at https://www.pestsmart.org.au/wp-content/uploads/2018/01/180110_SOP_BIR002_web.pdf

Shooting

Shooting is most beneficial when employed as part of a scaring program. To reduce habituation to scaring devices, shooting should be done at the same time scaring devices are employed. The use of both techniques concurrently will help birds associate the scaring noise with an actual threat and increase the likelihood of birds avoiding the area.

Some native duck species can be harvested by licenced properties and hunters in NSW under the Native Game Bird Management Program. Hunting of these ducks is only allowed after authorities have set annual quotas to ensure sustainable harvests, and only on agricultural lands to assist in damage mitigation. See http://www.dpi.nsw.gov.au/hunting/game-and-pests/native-game-birds for further information.

Poisons

Several bait products are registered through the Australian Pesticides and Veterinary Medicines Authority (APVMA) for use on introduced pest birds in NSW. It is illegal to poison native bird or flying fox species. Products registered for use on introduced bird species either contain alpha-chloralose or 4-aminopyridine as their active ingredient. Alpha-chloralose may be used to control introduced species and only in and around buildings. A licence to use 4-aminopyridine must be obtained from NSW National Parks and Wildlife Services, and must only be used around buildings and for introduced bird species including feral pigeons, European Starlings, House Sparrows and Common Mynas (http://www.environment.nsw.gov.au/resources/wildlifelicences/Pesticidesaplnbirds.pdf). Both products can only be used to control pest birds by authorised persons who have successfully completed the Environment Protection Authority (EPA) approved course.

Chemical deterrents, including aluminium ammonium sulfate and polybutene are available for bird control in NSW. However, these must only be used in garden areas (for aluminium ammonium sulfate) or on hard surfaces such as ledges, sills and railings (for polybutene).

Figure 33. A starling consuming free-feed bait at a waste-water treatment plant. Lethal poisons for birds are strictly regulated and are not available for broad-scale agricultural use in NSW (Photo Brian Lukins).

Fertility control and hatching success

Various fertility-control chemicals (e.g. nicarbazin baits for feral pigeon control) have been identified and assessed for birds, but none have been sufficiently field tested, nor are any currently commercially available.

Reducing breeding success by removing eggs or nests, applying oil to eggs or egg pricking is labour intensive. This method may be appropriate for highly fecund species and reduces the need to trap and/or kill large numbers of birds, but requires more research. Permits must be obtained for the lethal control of native bird species in Australia.

Alternative foods

Providing alternative food sources by decoy or sacrificial planting may be effective for some situations or when used in combination with other techniques. This relies on knowledge of the feeding habits of the main pest birds or flying foxes involved. A decoy planting ideally will produce food of equivalent or enhanced nutritional requirements and attractiveness for birds. It will be available just before and during the time that the crop is susceptible to damage. For honeyeaters and lorikeets, revegetating areas with local native trees and shrubs will increase the availability of their preferred food source. This may offer a long-term solution in reducing damage and has obvious environmental benefits.

For fruit flying foxes, replanting spring flowering native species can improve the availability of native food sources, reducing the need for flying foxes to seek out orchards (e.g. http://publications.rzsnsw.org.au/doi/pdf/10.7882/FS.2002.041).

Birds such as European Starlings that prefer insects may be attracted to irrigated areas where large numbers of insects are available. However, supplying alternative foods may also attract more pest birds to the area. Hence, for honeyeaters and lorikeets, a more regional approach to revegetation, rather than localised plantings, may be required. Additionally, a scaring program is likely to be more effective if alternative food sources are available.

Decoy feeding on alternative waterbodies (i.e. water storage dams and wastewater treatment ponds) can be an effective method to keep waterbirds such as ducks off rice fields during the critical period post seeding. Decoy feeding is most effective when combined with scaring and/or shooting over the rice fields at a time when the waterbirds are coming in to feed.

Figure 34. Large flocks of plumed whistling ducks can occasionally cause extensive damage to newly sown rice fields (Photo Mal Carnegie).

Netting

Exclusion netting using throw-over or permanent nets has high up-front costs but may be appropriate where high-value crops are grown and levels of damage are high. A variety of netting options are available. Machines can be used to install and remove drape-over nets of varying width: one, two or four rows. 'Lock-out' netting provides a continuous cover of netting by joining draped nets without the need for poles and cables. Nets can also be used on infrastructure to prevent birds roosting or nesting. If maintained, netting with ultraviolet stabilisers can provide between 5 and 10 years of protection. Smaller gauge crossweave netting can provide crop protection from both hail and bird damage e.g. (http://www.haverford.com.au/products/nets-netting/bird-netting/category/48-crossweave-netting-white-70gsm)

Permanent netting covering the whole orchard is the best solution for parrots and fruit flying foxes raiding fruit crops. Permanent netting is easier to maintain and allows easier spraying of vines and trees. Throw-over netting is more easily damaged than permanent netting and often does not provide as much protection. Netting overcomes many of the legal, environmental, social and animal welfare concerns associated with other techniques. Depending on the type of netting used, permanent netting can serve a dual purpose and provide protection of crops from weather related damage e.g. hail. The decision to net is mainly an economic one. Will the increase in returns from excluding birds be beneficial over the life of the netting? As an example, cost–benefit analyses on vineyard netting suggest that drape-over nets are cost-effective when damage is consistently greater than 10% and permanent nets are cost-effective when damage is over 25%.

The cost of permanent netting can potentially be offset by increased yields due to reduced pest damage. Custard apple orchardists reported a 90% loss of crop to flying foxes in the unnetted portion of their orchard. The cost of netting the entire orchard was recovered in profits for the first season and the netting is still standing 20 years later (See Case studies in further reading). Permanent netting enclosures were also a cost-effective solution for new, intensively grown cherry orchards with high yielding fruit, even at moderate to low levels of bird damage (Bomford, 1992 - See Case studies in further reading). The value of the crop and the practicalities of netting must be considered.

Figure 35. A permanent netting structure in a vineyard. Netting is likely to be the most effective technique for reducing damage but has significant and often prohibitive up-front costs (Photo John Tracey).

Roosting deterrents

A variety of spikes, coils and wire products are available to exclude birds from perching on buildings and infrastructure. Electrified wires, which can be attached to the tops of vineyard trellises, are also available. These wires give birds a small electric shock but do not harm them. Monofilament lines have been successful for deterring larger birds from fish farms but are ineffective for deterring smaller species from fruit or nut crops.

Chemical deterrents and taste aversion

There are several chemical deterrent products for use on birds commercially available in Australia. Check with the APVMA (http://apvma.gov.au/) for up-to-date registration information and appropriate applications. Currently there are no chemical deterrents for use on flying foxes.

Some deterrents are based on polybutene, which is a tactile roosting repellent; aluminium ammonium sulfate, which acts on a sense of smell and taste; or methiocarb, which is an insecticide that causes conditioned aversion in birds.

- Polybutene is a sticky substance that irritates the bird's feet and can prevent birds from roosting on infrastructure; hence is applicable for buildings and urban areas.
- Aluminium ammonium sulfate may be applied to vegetables, nuts, fruit, orchard trees and vines, provided that the label instructions are adhered to, e.g. thorough washing before consumption.
- Methiocarb is a secondary repellent that causes birds to become ill, creating a learned aversion to the food. This product may be applied only to ornamental plants, but it is not registered for use on edible fruit or nuts.
- Garlic and chilli sprays have been used to deter birds from feeding, but these are unlikely to be effective. As there are no registered products for bird deterrence, their use is also illegal.

Further information

Pest bird and flying fox management and case studies

Tracey J P, Bomford M, Hart Q, Saunders G & Sinclair R (2007), Managing Bird Damage to Fruit and other Horticultural Crops. Bureau of Rural Sciences, Canberra. https://www.dpi.nsw.gov.au/agriculture/horticulture/pests-diseases-hort/information-for-multiple-crops/managing-bird-damage

PestSmart Connect - Resources related to management of pest bird species in Australia http://www.pestsmart.org.au/pest-animal-species/pest-birds/

Queensland Government Department of Primary Industries and Fisheries (2003), Flying fox control methods research findings. Queensland Flying Fox Consultative committee. https://www.daf.qld.gov.au/plants/weeds-pest-animals-ants/pest-animals/control-methods/flying-fox-control-methods-research

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Replanting alternative food sources for birds and fruit flying foxes

Law, B., Eby, P., and Somerville, D. (2002) Tree-planting to conserve flying-foxes and reduce orchard damage. In 'Managing the Grey-headed Flying-fox.' (Eds. P Eby and D Lunney) pp. 84-90. (Royal Zoological Society of New South Wales: Mosman NSW) http://publications.rzsnsw.org.au/doi/pdf/10.7882/FS.2002.041

Standard operating procedures for humane lethal control of pest birds and flying foxes

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https://www.pestsmart.org.au/wp-content/uploads/2018/01/180110_SOP_BIR002_web.pdf

Licensing requirements for lethal control of pest birds and flying foxes in NSW

Fruit Flying foxes

http://www.environment.nsw.gov.au/wildlifelicences/s120licence.htm

http://www.environment.nsw.gov.au/resources/wildlifelicences/150425-flying-fox-application-harm.pdf

Waterfowl

http://www.dpi.nsw.gov.au/hunting/game-and-pests/native-game-birds

Native birds and fauna

http://www.environment.nsw.gov.au/animals/ProtectedSpecies.htm

http://www.environment.nsw.gov.au/wildlifelicences/OccupierLicences.htm

Control of Introduced birds with pesticide

http://www.environment.nsw.gov.au/resources/wildlifelicences/Pesticidesaplnbirds.pdf

Birdlife Pest Bird Management Policy

http://www.birdlife.org.au/documents/POL-Pest-Bird-mngment.pdf

General information – flying foxes

http://www.environment.nsw.gov.au/animals/flyingfoxes.htm

Scare device suppliers

http://eagleeyebird.com.au/

http://www.pestawayaust.com.au/

Birds of prey

http://www.winesandvines.com/template.cfm?section=features&content=162592&ftitle=Attracting%20Birds%20of%20Prey

Wildlife Friendly Netting and Fencing

http://www.wildlifefriendlyfencing.com/WFF/Netting.html

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Foxes

Background

Description

The European red fox (*Vulpes vulpes*) is a small to medium sized, burnished rusty red coloured canid, although other pelage colour variations do exist in Australia. They are from the family Canidae together with domestic dogs, wolves and dingoes. Adult European red fox weigh about 3 to 9 kg with males generally heavier than females and from 700 mm to 1000 mm in length including 300 mm to 350 mm of bushy red tail. The red fox is an athletic animal that can run, leap fences and with partly retractable claws, climb fences and some trees.

Origin

There are 11 species of fox worldwide, occurring naturally in North America, Europe, Asia and North Africa. The European red fox is the most widely distributed species and was introduced into Australia around 1845. In Australia, other successful releases followed in southern Victoria in the 1870's and within 20 years, the red fox had achieved pest status.

Distribution

Foxes have spread throughout most habitats of mainland Australia. The expansion was probably facilitated in some areas by the spread of the rabbit, a major food source. However in those areas which have no rabbits, native species dominate their food preferences.

The fox distribution on mainland Australia may be still expanding northwards into the tropics, having reached the Tanami desert in late 1970's and now common around Tennant Creek in the Northern Territory. Foxes are probably limited by the climatic conditions of the tropics and the northern population boundary probably fluctuates with the seasons.

Tasmania was the only state where foxes were not introduced or were unsuccessful possibly due to the more aggressive Tasmanian devil. There have been sporadic reported sightings and the odd carcass of the red fox found in Tasmania over the years particularly around ports. With the decline in Tasmanian devil numbers due to disease there is concern that they may be able to successfully breed and colonise.

Ecology and biology

Habitat

In NSW, the fox occurs throughout most habitat types although higher abundances and larger home ranges are recorded in primary production landscapes. Densities vary from around 1/km^2 in the coastal forests, 2 to 5/km^2 in the semi-arid and subalpine regions and 6 to 8/km^2 in the temperate grazing lands that cover most of NSW. Populations of the red fox are well established in peri-urban and urban areas where food is abundant and densities may reach 16km^2.

Diet

The red fox is best described as an opportunistic predator and scavenger. Largely carnivorous, foxes eat a diet of 300 g to 450 g/day of small prey in the weight range of 5 to 15 kg, including native animals, birds, rabbits, house mice and carrion. They readily eat and disperse fruits such as bitou bush and blackberry, and eat insects such as scarab or 'Christmas' beetles when they are in abundance. Fox scats may be identified by the amount of invertebrate residue present at different times of the year. When food is abundant, foxes will often bury or 'cache' food that is consumed at some point in the future.

Home range and movement

Foxes are territorial with home range sizes varying from 2 to >5 km^2 depending on the habitat type, availability of food and population density of foxes. They usually move within their own territories but may travel greater than 25 km at certain stages of their life history.

Foxes are predominately a nocturnal animal although diurnal activity is common, particularly after prolonged periods of rainfall and during the breeding season when hungry cubs require constant feeding.

Social structure

Foxes form family groups comprising a male or dog and vixen with helper vixens from the previous litter. They continuously mark their home range with urine, faeces and anal scent. Scent marking or olfactory communication is used to communicate with other foxes and co-existing species. Olfactory communication may leave information on the sex and breeding status of the fox, or may act as a statement of territoriality.

Reproduction

Females come into oestrus for 2 to 3 days over 2 to 3 weeks in winter. Males are fertile throughout winter and early spring. Gestation lasts 51 to 53 days and a litter of 3 to 5, bluey grey cubs are born whelped in the den. Weaning occurs at 4 to 6 weeks by which time most of the grey colouring has gone.

The young appear from the den in late spring, at about 6 weeks of age. During this time daytime activity by adults feeding cubs is common. The cubs leave the den at about 10 to 12 weeks and by 6 months of age, are independent. Both sexes reach sexual maturity in their first year. Where there is low mortality in the family group, a proportion of the female population may not breed. These helper vixens may assist to raise the cubs. Once foxes are independent they begin to move or disperse out of the family group to find a breeding partner and /or establish new territories. Dispersal can occur over long distances e.g. over 300 km but is often within about 50 km. The inherent ability of the red fox to rapidly establish new territories over short or long distances ensures they are perfectly adapted to compensate for any population decline due to control programs.

Mortality

Litter survivorship and diseases such as distemper, parvo virus and sarcoptic mange have an influence in regulating the fox population, along with shooting and road kills. However, the greatest single mortality occurs with targeted control programs using the toxin 1080.

Figure 36. The red fox cub is grey.

Impact of foxes

Agricultural impact

Fox predation has an economic impact on sheep, goat, poultry and cattle enterprises. Estimates of more than $227 million/year in agricultural costs have been proposed. Foxes are also known to help spread weeds such as blackberries which may indirectly impact on agricultural production, and feed on dung beetles (important for controlling fly breeding and improving soil nutrients).

Environmental impact

Fox predation is recognised as having a serious impact on many native animals, and is considered to be a major contributor to extinction of several species. Some of the species impacted include: brush tailed and yellow footed rock wallabies, bettongs, numbats, mallee fowl, pied oyster catcher, little tern, plains wanderer, bush stone curlew and the Murray river turtle. Foxes are also known to help spread environmental weeds such as bitou bush.

Fox predation is listed as a Key Threatening Process in NSW and a NSW Fox Threat Abatement Plan has been prepared
see: http://www.environment.nsw.gov.au/resources/pestsweeds/110791FoxTAP2010.pdf

Disease impact

The cost of disease spread by foxes has never been quantified despite their role in the epidemiology of many diseases such as *Neospora caninum* and Leptospirosis. Foxes would play an important role in the spread of rabies if it was introduced into Australia.

Social impact

Constant predation pressure by foxes can make it difficult to keep poultry and small pets such as guinea pigs and rabbits. This can cause stress and anxiety for many individuals.

Management principles

Pest status

Foxes are declared pest animals under the *Local Land Services Act 2013*. This declaration means that land managers have a general obligation to control foxes on their land. In certain circumstances the LLS can issue an eradication order to individual landholders to eradicate foxes on their land. It is illegal to keep foxes in NSW without a permit.

Strategic approach

Reducing the impact of the red fox requires an integrated and strategic approach, often across tenure boundaries using numerous control techniques including poison baiting, shooting, trapping, fencing and guard animals. No single control effort will be successful without a sustained program to limit reinvasion or immigration from existing untreated areas, which can occur within 2 to 6 weeks.

Most fox control programs on private land are coordinated in association with the LLS and may involve local landholder groups, Landcare or other organisations. In NSW NPWS lands undertake their own fox control programs but these are often across tenure, especially those undertaken in accordance with the NSW Fox Threat Abatement Plan.

Timing of fox control

One of the aims of pest control is to have a large group of land managers reduce the impact of the red fox over as much of the landscape as possible in autumn and spring, the period of time most critical for the survival of livestock and native fauna. However, a long term and regular baiting effort throughout the year will have the greatest impact for the longest time.

Control techniques

Poison baiting

1080 is the commonly used poison for fox baiting programs and is regulated in NSW by the current 1080 Pest Control Order. The use of 1080 bait products requires a current chemical application accreditation at a minimum AQF3 level or the EPA accredited course delivered by Local Lands Services. In 2016 the toxin PAPP (para-aminopropiophenone) was also approved.

Bait can be deployed by air (1080 only) or ground. Ground deployed baits can be buried in a shallow hole to reduce removal by non-target species.

Baits are usually laid at 500 – 1000m intervals along tracks, ridge-lines and fences. Placing too close together only encourages foxes to cache baits.

When fox control is aimed at increasing reproductive success, it should commence at least 1-2 weeks before the period of highest risk to the target species. Preferably continue poisoning at weekly intervals until bait uptake declines. Ideally continue baiting at 6-8 weekly intervals or when fox activity begins to increase. Bait stations using non-lethal baits may be set up in sensitive areas to monitor the activity of non-target animals prior to baiting.

Bait stations should be marked with tape or tags and a GPS point recorded. All baits not removed at the end of the baiting period should be collected and buried according to the current 1080 PCO. Recording bait uptake is important for reporting purposes; however, overall control program efficacy can only be measured by quantifying the reduction in damage or impact.

Spotlight counts or camera trap transects before and shortly after baiting may determine if there was a reduction in fox numbers. However, a more robust monitoring program using techniques appropriate to quantify changes to the target species or damage are essential and should be considered integral to the control program.

Where rabbits are the preferred prey item, a coordinated rabbit control program can also be undertaken to prevent an increase in rabbit abundance following predator removal.

Electric fencing

The red fox may be excluded from accessing some areas by use of electric fencing. Existing conventional fences may be upgraded by two offset live wires. One about 200 mm from the ground and about 200 mm offset from the fence and another near the top of and offset a similar distance. These wires should prevent foxes going under or over the fence. Any conventional 6 or 7 wire electric fence is effective provided the wire spacing prevents foxes from running through or crawling underneath. Foxes may go over a fence at ramps, stays, posts and under or over gates. Effective fox proof exclusion fencing for threatened species colonies is very expensive. A typical example from Western Australia consists of rabbit netting 2500 mm tall with 600 mm curved overhang supported by wires and 600 mm of foot netting on the predator approach side and offset electric fencing to keep both foxes and other animals such as wombats and kangaroos from damaging the fence.

Shooting

About 13% of respondents to a survey in NSW used shooting as the main technique for fox control. The next highest rated technique was baiting at 77%. Group shooting programs and fox drives or battues can be effective. Shooting provides a viable alternative in areas where foxes will not eat baits, baiting is not feasible or not a preferred option. Artificial distress calls may be used to call up foxes to within shooting range. To reduce welfare issues with injured animals a high velocity rifle fitted with a telescopic sight is recommended during both day and night. At night a spotlight of at least 100 W is necessary.

Trapping

The common live trapping device used to capture foxes is leg hold traps, although cage traps can be used in some locations. Trapping requires a thorough understanding of how to effectively deploy the devices and euthanase trapped animals.

Figure 37. Cage trap being prepared and concealed (Photo Birgitte Verbeek).

Cage traps are most successful in towns and around houses or where landholders object to poisons and shooting. Cage traps should be relatively large, 1200 mm x 500 mm x 500 mm. The trap must be pegged down to prevent the fox rolling it over and releasing the door and the wire floor should be covered with soil. It may be necessary to try different bait types in an area to determine the most attractive. One of the more successful baits for cage traps is chicken fast food or rabbit. One advantage of cage traps is that domestic pets and non-target animals captured in the trap can be released unharmed. All traps should be well concealed and well away from public gaze.

Guard animals

A number of species of animals including llamas, alpacas, donkeys and specially bred dogs have been used to protect animals from fox predation. Guard dogs have been used to varying success to protect cattle, sheep, goats, poultry and fairy penguins from foxes.

Habitat manipulation

Non-lethal strategies to deter fox presence include the destruction of dens and harbour such as weed infestations, fallen timber and rubbish sites. The destruction of other food sources, particularly carcasses and management of food for domestic working dogs and pets can further reduce fox activity.

Further information

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Further information is also available on the internet at http://www.pestsmart.org.au

Acknowledgements

First compiled by David Croft, NSW DPI, May 2007

2017 review completed by Paul Meek and Lynette McLeod, NSW DPI

Mice

Background

Description

Mice are normally light brown to dark grey on the body, with a light cream belly. Adults have a body length of about 75 mm and weigh up to 30 g. The tail is about as long as the body and is almost hairless. In relation to their body, the ears are large and the eyes and feet are small. The long whiskers are very sensitive and are used as sensors when moving about in the dark. Mice have prominent incisor teeth that grow continuously: the length of the teeth is controlled by gnawing. Material may be gnawed yet not tasted or swallowed, so it is difficult to devise a repellent coating against mice.

- The house mouse is distinguished from Australian native mice by:
- their teeth – the house mouse has a well-marked notch or ledge behind the tip of the upper incisors into which the lower teeth fit whereas native species have smooth chisel edges
- the number of nipples on the female – native species have only four teats whereas house mice have ten.

Origin

The house mouse, *Mus domesticus,* originated near the present border of Iran and the former USSR, from where they spread to Europe and subsequently throughout the world. They were probably introduced into Australia by the first European settlers and quickly established throughout the continent. Within 100 years of introduction, mouse plagues were being reported which resulted in devastating damage to agricultural production.

Distribution

The house mouse is not restricted to houses or buildings as its name might suggest. They are found throughout NSW in all habitats and have adapted to a wide range of environmental conditions. They are common on all agricultural lands, particularly cereal and summer cropping areas.

Ecology and biology

Habitat

Mice are generally described as ‘commensal’ rodents – i.e., they live with humans, and are adapted to living in houses and buildings. Most farm buildings have a few mice. In the field, mice are always present but in most years are in relatively low numbers. Refuge areas such as channel banks and dense pastures are ideal habitat where detection is difficult. Poultry and pig sheds or grain storage facilities are also favoured, particularly if the ground can be excavated easily to establish burrows.

Diet

Mice consume a wide range of foods, eating 3–5 g daily. In a field situation, mice survive on the seeds of native grasses and thrive on introduced cereal grains. In food storage areas, their diet can include grains, vegetables, meat, fruit and dairy products. They are particularly attracted to high protein grains and aromatic vegetable oils. When selecting a bait type, it is important to know that mice will sample all foodstuffs within their range, but may not return to a particular feed type for many days.

Mice can successfully live and breed without free water if the moisture content of the food is at least 15%. Where mice live in sheds and areas where the food supply has a low moisture content, they need 1–2 ml of water daily to survive. In these situations their activity can be limited by cutting off their access to water.

Home range and movement

Mice are most active at night but can also be seen during the day, particularly around buildings or areas with adequate cover. Their home range is limited to an area of about 5 m^2 in closed buildings, but in crop situations, with available food and water, the home range may be even less. Young mice are forced to seek new areas during periods of high breeding and this is one of the factors associated with the development of a plague. When mice move, they tend to follow the same path from refuge to feeding area. Paths are often confined to walls, pipes or natural barriers, so the tell-tale smear marks can be an indication of mouse activity. In the field, distinct tracks through the vegetation become obvious.

Mice can swim and remain under water for lengthy periods. They can dig, jump upwards at least 30 cm, jump downwards at least 2.5 m without injury and squeeze through openings as small as 8 mm in width. In addition they can climb almost any rough surface, climb upside down and run down ropes and coated electric wires.

Social structure

The social behaviour of the house mouse is not rigidly fixed and depends on the environmental context. In situations where water or food supply may be limiting and the mice are living in relatively low densities with large territories, they display territorial behaviour with both females and males displaying aggressive behaviour to other individuals of the same sex. Males mark their territory by scent marking with urine. In marked territories, intruders showed significantly lower aggression than the territory residents.

When mice are living in dense populations with small home ranges, they switch from territorial behaviour to a hierarchy of individuals, and aggression is often mediated as the risk of injury becomes too great.

The social unit of house mouse populations generally consists of one male and two or more females, usually related. These groups breed cooperatively, with the females communally nursing. This cooperative breeding and rearing by related females helps increase reproductive success. When no related females are present, breeding groups can form from non-related females.

House mice show a male-biased dispersal; males generally leave their birth sites and migrate to form new territories whereas females generally stay and are opportunistic breeders rather than seasonal.

Figure 38. From very few, mouse numbers can build up rapidly (Photos David Croft).

Reproduction

Mice can start breeding at 6–10 weeks of age and produce 10–12 litters per year. The gestation period is 19–21 days, with the female re-mating almost immediately after giving birth. Young mice begin eating solid food at 11 days and are weaned at 21 days of age. They have a life span of only one year in field situations.

Litter size is generally 5–6 but can be up to 10. The young are born hairless and blind in a nest of collected materials such as grass, paper, hair, cloth remnants or anything soft that is available.

If there is no infant mortality, one breeding pair of mice could theoretically produce 500 mice within 21 weeks.

In Australia, mice living under field conditions have a seasonal pattern of breeding. This generally begins in early spring and continues until cold or wet conditions develop in late autumn (approximately 8-9 months duration). Mice living in unfavourable seasonal conditions may have a shorter breeding period, while those with nests in the warmth of buildings or haystacks are likely to have an extended breeding period.

Figure 39. A mouse nest (Photo David Croft).

Plagues

Mouse plagues tend to occur when there is plenty of food and water available, environmental temperatures are not extreme, soil is moist and easy to dig, nesting conditions are favourable and diseases, parasites and predation are at a low level.

Widespread mouse plagues in Australia were reported as early as 1900 and they have occurred on average once every 4 years since then. Mouse plagues can have dramatic agricultural, environmental and sociological impacts.

Figure 40. Mouse climbing to a nest in a brick wall (Photo David Croft).

Mortality

Predation may play a role in regulating mouse numbers until there is a rapid population build-up. Predators are unlikely to have any effect on numbers once plague proportions are reached. A noticeable increase in the number of predators in an area may indicate a large increase in the mouse population.

In south-eastern Australia the main predators of mice are foxes, feral cats, snakes and all birds of prey. The presence of itinerant bird species such as the black-shouldered kite is a good indicator that mouse populations may be increasing. Domestic cats have no impact on localised mouse populations, contrary to popular myth.

Although disease can cause a sudden decline in mouse numbers, marking the end of a mouse plague, declines in numbers occur mainly when mice are stressed from restricted food and shelter. It is more likely that overcrowding will allow parasite infestations to develop and contribute to the spread of disease.

Impact of mice

Agricultural impact

Sown crops

Mice cause damage to almost all sown crops, no matter whether they are winter or summer crops or seeds of cereal, oilseed, maize or pasture. By digging into the loose soil immediately after sowing, mice are able to establish nests and feed on the seed or newly emerging seedlings.

Most crops suffer damage prior to seedling emergence and when the grain or seed begins to mature. However, in cereal crops such as wheat, mice chew the growing nodes of the plant and can stop the development of the head or cause the stem to collapse.

Mice can also damage horticultural crops like melons, pumpkins and tomatoes.

Stored produce, buildings and machinery

Mice will be active in most farm areas where produce is stored. Normally, there may be little pressure put on such storage until there are mice in plague numbers that will test security to the limit. Mice can find the smallest hole and gnaw on it until it is large enough to allow entry. During a plague it is difficult to maintain the mouse-free status of any facility unless there has been a mouse-proof component incorporated into the initial design and construction.

In machinery sheds, mice can cause expensive damage to electrical wiring, plastic and rubber components and upholstery.

Figure 41. Mouse damage to tomatoes (Photo Reg Eade).

Environmental impact

Mice have the potential to compete with native fauna for resources, deplete the native seedbank, and increase the risk of soil erosion through removal of ground cover and soil disturbance. During a plague they can cause an imbalance in predator abundance, putting added pressure on native prey once mouse numbers are depleted.

Disease impact

In Australia, rodents can carry a variety of infectious diseases which may be transmitted to humans and other livestock, including:

- Bacterial infections – Leptospirosis, *Leptospira celledoni*; Lyme disease, *Borrelia burgdorferi*; *melioidosis*, *Pseudomonas pseudomallei*; salmonellosis, *Salmonella* spp.; *Streptobacillus moniliformis*; *Spirillum minus*; *Campylobacter* spp. and *leptospira icterohaemorrhagiae*
- Fungal infections – Ringworm, *Trichophyton* spp.
- Viral infections – Ross River virus
- Rickettsial infections – Queensland tick typhus; scrub typhus (mite transmitted)
- Parasitic infections – Fleas; mites; tapeworms; nematodes, *Physaloptera* spp.
- Protozoan infections – Pneumocystosis; toxoplasmosis, *Toxoplasma gondii*.

In particular, mice can transmit: salmonella to one another, to humans and to domestic animals; encephalomyocarditis virus to pigs; fungal skin diseases (ringworms) to cats and humans; and leptospirosis to humans and domestic pigs.

Social impact

Plagues of mice can cause enormous social stress to farmers and communities. Along with the stress of coping with a plague (i.e. trapping, baiting, and cleaning up activities), there is the additional worry of financial loss, accidental poisoning, and impact on other livestock, as well as the increased risk of disease and fire.

Management principles

Pest status

Mice are classed as nuisance animals in NSW under the *Local Land Services Act 2013*. There is no obligation for a landholder to control this pest, however they are encouraged to monitor populations so appropriate measures can be taken when numbers increase.

Strategic approach

A strategic approach to management is required to reduce the frequency and severity of mouse plagues. Monitoring is essential to provide early warning of a build-up in mouse numbers to allow early intervention. Effective mouse management involves a combination of land management practices to reduce food and shelter availability supplemented by poison bait control as required.

Monitoring

Regular inspections around buildings, crop perimeters and throughout the crop at all stages of sowing and crop growth is key to detecting a build-up in mouse numbers. Mouse chew cards can be used to assist this process, with practical guidance on the preparation and use of these available at: http://www.pestsmart.org.au/wp-content/uploads/2010/07/mouse-survival-guide.pdf?c6c65f

The Grains Research and Development Corporation (GRDC) has supported national mouse monitoring programs and activity reports can also be obtained from the 'MouseAlert' website: https://www.feralscan.org.au/mousealert/

Seasonal conditions can provide a prompt for when crop producers should step up their monitoring activity – e.g. warmer weather after a period of high rainfall resulting in ample food availability from high yielding crops.

CSIRO provides the following general guidance for monitoring:

- There can be unexplained variability in mouse activity from one paddock to the next on some properties. It is therefore advisable to monitor across multiple paddocks to get a true indication of numbers to inform management decisions.
- Look for evidence of active burrows, rather than relying on mouse chew cards as these are not as effective when abundant alternative food is present. To look for active burrows, walk about 30 metres in from the edge of the paddock and set a 100-metre (1 metre wide) transect through the crop, following the furrows. Walk slowly along the transect scanning for evidence of mouse burrows, taking note of any burrow that looks active and recording the number of burrows per 100-metre transect, and then repeat across 2-4 transects. If there are more than 2-3 active burrows per 100 metres, there is a mouse problem. Corn flour can be used to mark potentially active burrows, but the transect will need to be inspected the next day for signs of activity.

Control techniques

Deterrents

Although numerous physical and chemical deterrents have been suggested and used for repelling mice, none have proved to be successful. Ultrasonic devices and coated or impregnated wires for example have been extensively tested in Australia and overseas and have not been found to have any value in repelling mice.

Reducing mouse access to food and shelter

Mouse control should be part of an organised and ongoing program aiming to reduce the frequency and severity of plague events. Mouse-proofing facilities, grazing or mowing irrigation channel banks, keeping rubbish around farm buildings to a minimum, minimising spilt grain and general good farm hygiene should reduce the potential for a rapid and unexpected mouse build-up. Reducing harbour for mice (e.g. through rolling of stubbles and slashing crop perimeters) increases predation risk and may limit the foraging activity of mice.

Once mice are in plague numbers, farmers can do little to control their populations. Mouse numbers irrupt when food, temperature and nesting conditions are favourable, but there are a number of control options that are available when a plague is imminent.

Barriers

Unless the building has been constructed with good concrete foundations and sheet metal barriers, the cost of erecting barriers at a later time has to be weighed up against the potential value of any loss. The costing involved in construction of mouse-proof barriers would need to include foundations, walls, floors, doors and windows, rooves and eaves, sewerage and drains. Details on mouse-proofing are available from the major pest control companies and the GRDC.

Figure 42. Shed with galvanised barrier (Photo David Croft).

Traps

Trapping will have little impact on numbers in a mouse plague and is only suited to domestic situations. The use of traps may be useful early in a plague to reduce invasion of a home or to monitor the rate of increase during a plague. If using such traps, the most attractive baiting material is a small patch of leather or felt soaked with peanut butter, linseed or any other vegetable oil and secured to the trigger plate. Bacon rind, pumpkin seeds, raisins or cheese securely fixed on to the trigger plate also works well.

Poisons

Small-scale baiting

The use of poison bait around buildings and storage facilities may be relatively successful for controlling small populations of mice. However, once mice begin to plague and the numbers of dead mice appear to be increasing, there may be little or no effect on the overall population. Most of the mouse poisons available are anticoagulants, which are safer than acute poisons, for use around humans and domestic animals, except pigs, which have very low tolerance to anticoagulants.

Registered 'first generation' anticoagulants for rodent control around buildings are:

- coumatetralyl
- warfarin
- diphacinone.

Registered 'second generation' anticoagulants for rodent control around buildings are:

- brodifacoum
- bromadiolone
- difenacoum
- difethialone
- flocoumafen

Large-scale (broad-acre) baiting – Zinc phosphide

Zinc phosphide is the only registered rodenticide for broad-acre baiting. Bait can only be applied by aerial application or accurately calibrated ground application equipment.

The rate of application of zinc phosphide is 1 kg/ha to achieve an even coverage of 2-3 grains/m^2. At this rate there should be sufficient bait to kill about 20-30,000 mice/ha.

CSIRO provides the following general guidance for zinc phosphide baiting:

- Apply bait according to the label.
- Apply baits 6 weeks prior to sowing if there is sufficient evidence to bait (if planning to bait only once, then bait at sowing).
- Allow at least 4-6 weeks before re-application of baits to minimise the chance of bait aversion. This allows mice that have previously tried the bait to try it again and also targets news animals in the population that are susceptible to the bait.
- If baiting at sowing, apply directly after sowing (e.g. bait spreader on the back of the seeder). Mice increase foraging activity after sowing because of the soil disturbance. If a novel food is available on the surface they will eat that in preference to digging up the planted seed. Baiting more than 24 hours after sowing will not be as effective.
- Bait over large areas. Encourage neighbours to bait at the same time if they also have a mouse problem. The larger the area treated, the lower the chance of re-invasion post treatment.

Further information

http://www.dpi.nsw.gov.au/content/agriculture/pests-weeds/vertebrate-pests/pest-animals-in-nsw/mouse-plagues-early-detection

http://www.pestsmart.org.au/pest-animal-species/mouse/

https://www.feralscan.org.au/mousealert/

https://grdc.com.au/Resources/Factsheets/2011/05/Mouse-Management

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Feral goats

Background

Description

The feral goat is a descendant from a mixture of breeds of the domestic goat, *Capra hircus*. They can have a variety of coat colours. Adult females are around 45 kg and males 60 kg.

Origin

The goat was one of the first animals to be domesticated, eight to ten thousand years ago. The origins of the wild goats, *Capra aegagrus* extend around the dry hills of the Mediterranean basin, including Turkey, Iran and Pakistan.

Goats arrived in Australia with the First Fleet in 1788. They were a convenient livestock animal for early European settlers, being relatively small eating a wide range of plants and providing both meat and milk. The present feral goat populations are descendants from animals introduced for a variety of reasons since 1788. During the 19th Century, sailors released many goats onto islands and the mainland for emergency food supplies. Cashmere and Angora goats were imported in an attempt to start a fibre industry in Australia. Goats were spread around Australia by settlers, railway construction gangs and miners who used these domesticated animals as a source of milk and meat. These domestic goats escaped, were abandoned or were deliberately released and established feral herds.

Distribution

Feral goats are found in many areas of NSW. They are widely distributed and abundant throughout the western division of NSW and are locally abundant in the northern and central slopes and scattered throughout the tablelands and coastal regions. They have benefited from sheep grazing practices, the provision of artificial water points and control of predators throughout the dryer regions of NSW.

Ecology and biology

Habitat

Feral goats are common in most habitats of the semi-arid rangelands but prefer areas with shrubby vegetation or rocky or hilly country for shelter and refuge. These areas provide security from predators and disturbance by humans. Goats are less commonly found on flat treeless plains and cropping country, preferring country with some dense shrub cover, but wider distribution on open country has been evident as populations have increased. Favourable habitat requires availability of shelter, surface water and an abundance of preferred food species, both pasture and browse. Goats do not occur in areas where wild dogs are in moderate or high numbers.

Diet

Although goats are generalist herbivores that require a range of forages, including grasses and forbs with high digestible energy, roughage from senescent grasses, twigs, plant litter, bark and roots. They also eat the foliage of shrubs, saplings and trees, and flowers, fruit, seed heads and fungi. Goats can eat the majority of plants in the pastoral zone of Australia and many poisonous or bitter plants and species avoided by sheep and cattle. Although they will eat leguminous herbs such as clovers and medics, they avoid these when grasses are available.

During hot and dry times goats need to drink water daily. An average-sized goat will drink between 2 and 4.5 L of water per day, depending upon temperatures, humidity and reproductive status. Goats can obtain a large proportion of their water requirements from their forage, particularly by browsing leaves and stems, and eating roots. They rarely drink during wet or cooler month in the high rainfall zone and can survive in areas with no permanent fresh water.

Home range and movement

A good knowledge of the home range of feral goats is a prerequisite to both the effective management of this animal as a resource and the establishment of appropriate strategies for control.

The size of the home ranges of feral goats varies across Australia, being smaller in areas where food, water and shelter are freely available and much larger in semi-arid pastoral regions. The size of female average home ranges can be predicted from mean annual rainfall, with home ranges being usually less than 10 km^2 when rainfall exceeds about 500mm. Home range boundaries are not rigidly defined and are not actively defended to exclude other goats.

Feral goats in higher rainfall areas with ample water and food have small, non-exclusive home ranges generally of about 1.0 to 13.5 km^2, with males having larger ranges than females. In pastoral regions goat movements are generally much larger, with non-exclusive home ranges. These are usually centred close to, or around, permanent water. Radio tracking of goats on Yerilla Station, in the pastoral area of Western Australia showed the average female home range was 50 km^2 ranging from 14 to 118 km^2. Males averaged 271 km^2, ranging from 102 to 460 km^2. Data recorded from the Broken Hill region also confirm similar large home ranges. South Australian data indicates that home ranges are larger during wet seasonal conditions, increasing the difficulty of management during these periods. Males are highly mobile while nannies have a preference to be relatively sedentary.

Long distance movements of goats have been recorded in semi-arid regions and landholders suggest regional migration patterns. One male in western NSW moved 87 km in a 10-month period. This degree of mobility makes goat control very difficult, as the rate of re-infestation can be very high. It also makes eradication or containment almost impossible in the event of an exotic disease outbreak. However, feral goats in higher rainfall zones are more sedentary, with few goats moving permanently outside their home range.

Social structure

Feral goats are social animals and are found in herds, the basic social unit being adult females and their recent offspring. The males leave these matriarchal groups to form loose associations with similar aged males or larger mixed-aged groups, which associate with the female’s home range during the breeding season but range over larger areas at other times.

Group size within herds of feral goats varies on both a daily and seasonal basis. Much of the seasonal variation seems to be related to the availability of surface water. When water is abundant, groups are generally small and well dispersed. During drier months, groups come together and increase in size, consisting of both males and females of all age classes. During droughts they tend to congregate in large numbers sometimes, 500 to 800 goats and remain near water.

In temperate regions, feral goats show great fidelity to their home range and matrilineal family groups, which average 15 goats and usually number fewer than 40 individuals. Group composition is highly flexible in variable rainfall areas. Feral goats continually form, break and re-amalgamate into herds. Many new associations are formed when congregating around water sources. At high densities like those found in the temperate zone, goats prefer their own company, but mixing with other stock is common in rangeland environments, especially at water points.

Reproduction

Conception occurs in feral goats in all months of the year, but the peak rate occurs from late summer to mid-winter, so that births are fewer in summer than in other seasons. Breeding rates are influenced by rainfall and, in semi-arid areas most kids are produced in the cooler times of the year. In drier districts, all sexually mature females in a herd may come into oestrus at the same time and it is thought that this is synchronised by male sexual activity. This can reduce the effects of predation by having a glut of potential victims in the form of young kids all of the same age.

Females can begin breeding at 6 months of age or when they weigh over 15 kg. Males reach sexual maturity at approximately 8 months, but competition for access to oestrus females is fierce and it is unlikely that young males are able to mate until they become large, dominant individuals.

Females can become pregnant again soon after giving birth, as lactation does not stop oestrus or pregnancy. Therefore, they can breed twice in a year, as their usual gestation period is only 150 days. Twins and triplets are common, although it is very rare for all three triplets to be raised to independence. At any time in the high rainfall zone, between 16 and 53% of females have kids at foot. The average litter size is 1.3 kids per female.

Females that are about to give birth leave the group and give birth in a protected spot. Kids are fully active soon after birth, but most, although not all, are hidden by their mothers and visited only for feeding. A few days after birth they join the mother on her travels. Females may then remain separate from herds containing adult males for 1 to 2 months.

Figure 43. Feral goat and sheep interaction – a potential spread of disease and parasites (Photo Peter Fleming).

Mortality

The mortality rate of kids from birth to 6 months can be high. Natural mortality rates amongst adults are unknown for arid zone goats but assumed to be about 10%. In temperate regions, annual survival rates of unharvested and uncontrolled goats are high (~95%). Adult mortality rates, from all causes including hunting and harvesting are about 26% in temperate regions.

Wild dogs, foxes, wedge-tailed eagles and feral pigs are all predators of feral goats. Wild dogs are the main predators of adult goats and appear to affect feral goat distribution. In areas unprotected by predator fencing goats are rarely present unless wild dogs are absent or controlled to low densities. Foxes are the main predators of feral goat kids in areas where wild dogs are absent.

Goats have a high rate of increase and so populations can rapidly replenish after harvesting and control operations. High levels of removal of feral goats from a population may increase survival rates and result in a faster than normal rate of increase and this possibly has contributed to the increase in goat populations over the last decade. Goats have the potential to double their population every 1.6 years in the absence of mortality caused by human control and harvesting efforts and predation.

Impact of feral goats

Agricultural impact

Feral goats may compete with domestic livestock for food, water and shelter. This can be most evident during droughts, or if feral goat numbers have not been taken into consideration in terms of total grazing pressure. Overgrazing and movements of goats can lead to soil erosion.

Other impacts may include damage to infrastructure, particularly fences, damage to heritage sites and economic losses associated with controlling feral goats.

Environmental impact

Goats have very destructive grazing habits, as they can completely strip shrubs of bark and leaves. Goats can destroy the vegetation cover, disturb the balance of species in a vegetation community and spread weeds. Disturbance of the soil by the sharp hooves of goats and the characteristic pawing of the ground by males leaves the soil open to the erosive forces of the rain and wind. Goats may compete with native animals for shelter; without protection these animals can be exposed to the heat and become easy prey for foxes and other predators.

Competition and habitat degradation by feral goats are listed as a Key Threatening Process, see www.environment.nsw.gov.au/threatenedspecies

Figure 44. Goats impacting mallee fowl nest Nymagee area (Photo LLS) and goat browse line (Photo NPWS).

Disease impact

Feral goats can carry internal and external parasites, some of which affect sheep and cattle. For example, feral goats can carry and spread ovine footrot, and they could also act as a reservoir for, and be a vector of, exotic diseases, including foot and mouth, bluetongue and rindepest. This makes them a cause for concern to animal health authorities because of the role they may play if an exotic disease outbreak should occur.

Social impact

Feral goats can impact on individuals and the community indirectly through, loss of ecosystem services at the catchment scale and damage to visual amenity, or higher prices for goat-affected commodities (such as wool).

Management principles

Pest status

Feral goats have not been declared as a pest animal under the *Local Land Services Act 2013*. Therefore land managers have no obligation to control this species on their land.

Strategic approach

Ideally, land managers need to understand how goats are affecting resources and impacting on their enterprise so that they can determine how to maximise the benefits of control compared with the costs of the chosen management technique.

A strategic approach to feral goat management at a local and regional level is recommended.

It is important that the advantages and disadvantages of each control method be carefully considered before use and the relevant codes of practice followed. Usually no single control method will be suitable or efficient for long-term sustained management operations and so a combination of techniques must be used.

Commercial use

Increasing overseas demand for goat meat has seen the value of goats increase substantially over the last decade. Feral goat management must now be considered in the context of a pest versus resource dilemma but there remains an underlying issue of environmental impact especially in semi-arid environments. Managing grazing pressure is a key to sustainable land management in western NSW, but is not possible where both goats and kangaroos have unrestricted movement.

Most goat production occurs through opportunistic harvesting through the construction of trap facilities on water points, or localised mustering where terrain is suitable. This can be a lucrative enterprise as minimal input in terms of husbandry or infrastructure is required. However turnoff is subject to seasonal conditions and there is difficulty in catching goats when cool conditions predominate and surface water is present. The consequent inconsistency of supply is a limiting factor in the development of export markets. Opportunistic harvesting has limited impact as a pest control measure as unmarketable goats are usually released and populations are rapidly replenished by movement from adjacent areas. For this reason there is generally a limited improvement in environmental condition as evidenced by groundcover. Opportunity costs arise through the slower growth rates of feral stock and the poor performance of rangeland pastures in terms of biomass and species composition under continuous heavy grazing pressure.

Goat enterprises managed behind appropriate fencing provide for greater consistency of supply and improved pasture productivity through planned grazing strategies including periods of spelling. Managed goats also provide the opportunity to introduce improved genetics (e.g. Boer bloodlines) to improve growth rates as is usual for other livestock. Biosecurity is substantially improved when goats are managed behind appropriate fencing.

Figure 45. Feral goats as a resource (Photo David Croft).

Control techniques

Fencing

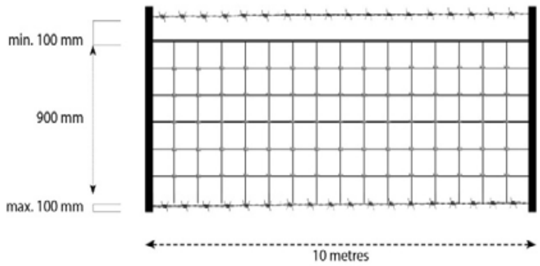
Fencing methods to control goats are well established, based on prefabricated mesh products or proprietary electric fencing systems. To ensure effectiveness, construction must be of a high standard with attention to detail. Where prefabricated mesh products are used, there can be a head entrapment hazard if vertical wires are less than 30 cm apart. Height of the bottom wire (no more than 10 cm above ground level), total height of mesh (90 cm preferred) and distance between support pickets (maximum 10 m) are important factors. Multi plain wire fences have advantages in reducing the head entrapment hazard and improving ease of repair.

NPWS research in western NSW has demonstrated that goats rarely travel more than 3 km from a water source and are therefore highly dependent on artificial watering points such as ground tanks and bores, which have been created to water stock. Strategic closure of on-park artificial watering points and goat-proof fencing on NPWS boundaries near watering points has significantly reduced immigration into parks from surrounding properties and led to a significant decrease in goat numbers on some national park estates.

Figure 46. Fencing options include A: Pre-fabricated mesh with barbed or plain wire. B: Multi-line plain wire or C: Electric fence.

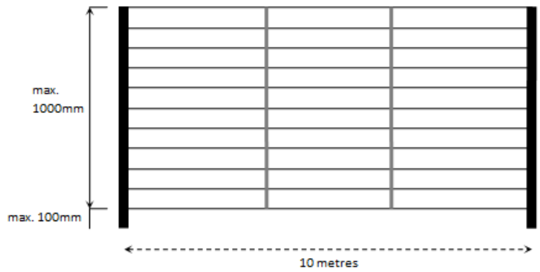
A: Minimum Standard Description:

- Pre-fabricated mesh (7/90/30) with 2.5 mm top and bottom
- 2.5 mm high tensile top and belly plain wire supports
- 1.57 mm top and bottom plain or barbed wire
- 165 cm star pickets at 10 m spacing <500 m strainer spacing



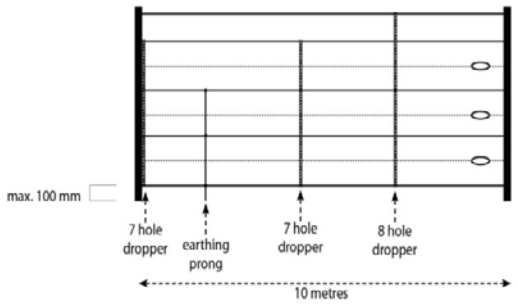
B: Minimum Standard Description:

- Eleven line plain wire 2.5 mm
- 165 cm star pickets at 10m spacing
- 2 droppers per 10 m spacing
- <500m strainer spacing



C: Minimum Standard Description:

- 7 wire, 2.8 mm high tensile
- 3 live wires (in a 7 wire fence) at 7,500 volts (at 75% capacity)
- 165 cm star pickets at 10 m spacing
- 2 internal droppers (plus dropper on each post) <500 m strainer spacing



Mustering

Mustering can reduce goat populations and has the advantage that costs can be offset by the sale of captured goats. Goats can be managed as a resource in this way by balancing impacts with economic returns. Many land managers muster opportunistically when they notice a large group of goats on their land. This can be particularly successful during dry periods when goats congregate in large groups near water.

Helicopter or light aircraft are often used to flush goats out of rough country. It has been estimated that an experienced highly skilled pilot can muster 80% of goats in an area of rough hills. In more open flat country, people can easily herd goats into yards on horse or motorbikes, usually with the help of working dogs.

It is important that before the mustered goats are transported from the property that all requirements and documentation are completed to comply with the National Livestock Identification System (NLIS). For further advice contact your LLS.

Trapping at water

Feral goats in semi-arid areas must drink during dry conditions. Therefore, traps at watering points can be effective methods of removing goats. Traps are goat-proof fences surrounding a watering point and incorporating a one-way gate. Such gates will include spear gates, one-way swinging gates or jump-down ramps.

These traps can be used over a long period of time and are particularly effective during periods of drought. They can be ineffective in high rainfall environments and where extensive permanent bodies of water are present or during high rainfall seasons when surface water is abundant. While traps can be used to remove large numbers of goats, their impact on pasture management is dependent on the rate of recolonization of the waterpoint. In general, opportunistic trapping does not deliver significant improvements in pasture condition where areas are open to the free movement of goats.

Traps must be constructed to ensure the welfare of goats and other animals, especially kangaroos. Small trap areas present high risks of stress and injury to both goats and wildlife, whereas larger trap areas improve welfare, reduce pressure on infrastructure and provide a safety margin for the timing of removal of captured animals. The sale of these goats can readily offset the building and maintenance costs of these traps. Well-built facilities can readily be adapted for managing domestic stock with minimum labour.

Figure 47. A simple goat trap (Photo David Croft).

Figure 48. Goat trap (Photo David Croft)

Ground-based shooting

Shooting is seldom used for management in western NSW except for targeting particular goats to finalise removal from fenced exclusion areas. Hunting of feral goats is mainly of recreational value.

Shooting feral goats from the ground is most successful in the more open pastoral areas, especially when goats are forced to visit water points. However, too much harassment can prompt some goats to find alternative water sites or to drink at night.

Shooting from helicopters

Shooting from helicopters can be an effective means of removal of feral goats, particularly in rugged terrain. Costs will vary with the initial density, habitat, weather and type of helicopter used. This method has been used to manage goats at both high and low densities. An aerial shoot can be particularly successful for removing survivors of mustering or trapping campaigns. It should be noted that survivors of populations that are repeatedly controlled by aerial shooting become wary of helicopters and, while initial cull rates may be high, as few as 21% of known animals may be culled in later shoots.

Figure 49. Goats from the air. (Photo Peter Fleming)

Judas goat

The Judas goat technique uses tracking equipment to locate herds of feral goats. A captured, or 'Judas', goat will be fitted with a collar, to which a radio transmitter is attached. Goats are strongly social species and within a few days the Judas goat will join up with a herd of feral goats. This group can be located with the radio-tracking equipment and shot either from the ground or from helicopters.

If the Judas goat is not shot it will move away and locate other groups of feral goats. If it is shot, the radio transmitter can be recovered and fitted to another goat, which is then released. Male, female and domesticated wether goats have been used successfully as Judas goats. Sterilized female goats that have had prolonged oestrus induced with hormone implants have been used successfully overseas.

This method is used to find groups that are difficult to locate by normal shooting methods. These are usually low-density populations or goats that have survived other control methods have become particularly wary.

Figure 50. A Judas goat (Photo Peter Fleming).

Poisoning

No pesticides are currently approved for use in the control of feral goats in NSW however research in New Zealand and Australia has identified a number of potential bait presentation techniques which may have future application for feral goat management. Prior to any approval or adoption of baiting as an additional control method such techniques would be required to demonstrate a high level of target selectivity, be matched with an approved toxicant and produce consistent results during approved field research trials.

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Further information is also available on the internet at https://www.pestsmart.org.au/pest-animal-species/feral-goat/

Acknowledgements

First compiled by David Croft, NSW DPI, May 2007

2017 review completed by Troy Crittle, Peter Fleming, Rob Hunt.

Wild dogs

Background

Description

Wild dogs, *Canis familiaris*, are defined as: 'any dog, including a dingo, that is, or has become wild, but excludes any dog kept in accordance with the *Companion Animals Act 1998*, the *Exhibited Animals Protection Act 1986*, or the *Animal Research Act 1985* or any legislation made in replacement of any of those Acts'.

Weights of adult wild dogs range from 7 to 22 kg for females and 11 to 25 kg for males dependent on habitat, resource availability and season. They are predominately golden or yellow but can also be white, black, black and tan, brown, brindle, patchy and any combination of these.

Origin

Wild dogs are believed to have originated from the Thai wolf about 10,000 years ago. They are a cosmopolitan species and found across Asia and include the 'singing dog' of Papua New Guinea. They were first introduced to Australia approximately 3,500 to 4,000 years ago, probably by Asian seafarers who landed regularly on northern Australia.

Distribution

Wild dogs are found across NSW, the eastern ranges, the coastal hinterland and tablelands have the highest populations, although their range and numbers are increasing. Wild dogs are found close to towns where they intermingle with local dogs and create hybrids.

Figure 51. Dingo in bushland (Photo David Croft).

Ecology and biology

Habitat

The wild dog is highly adaptable and as long as shelter, food and water is available they can live in a wide variety of habitats - from arid to rainforest environments, remote locations to close proximity to human settlements.

Diet

Wild dogs mostly eat fresh meat and carrion. Food habits vary between locations and seasons, but medium-sized mammal including wallabies, rabbits, possums, wombats are preferred. Smaller animals, including rodents, echidnas, birds, reptiles, small mammals and plaguing insects are also eaten when available. Domestic livestock may constitute a larger portion of the wild dog's diet in agricultural areas and large kangaroos are important foods in some areas. In the peri-urban environment they will adapt to available food resources and will scavenge around houses, rubbish tips and orchards.

Home range and movement

Wild dogs have a flexible social system based on small groups that occupy and defend a territory. Each member of the group occupies a home range within the territory and home ranges of pack members may overlap.

Individual home ranges vary from 400 to 100,000 ha, averaging about 2,700 ha in size in the tablelands and up to 90,000 ha in dry western environments.

As could be expected, areas with the greatest food sources and key water points within home ranges are used most frequently and others parts may be rarely visited. Depending on season and reproductive phase, the group meets intermittently as a pack. Instead, members meet and separate over time or rely on vocal communication. Most preferred prey is hunted by individual dogs although they do hunt as a pack when necessary.

Movements often follow well defined paths and topographic features. The shape of the territory can be determined by topography, roads and distinguishing features such as mountain spurs or rivers forming boundaries. Wild dogs may move throughout the day and night but are mostly active at sunrise and sunset and least active during the middle of the day.

Surplus killing occurs when a predator attacks and either kills or injures a number of prey animals such as sheep in one event. The number of prey animals killed is in excess to the predator's nutritional requirements. This behaviour occurs with many predators including wild dogs and foxes. The resulting multiple domestic livestock losses can be devastating for livestock producers.

Social structure

Wild dogs are social animals and when conditions are favourable they generally live in a hierarchical structured group (or pack) with a dominant (alpha) male and female controlling breeding. However in areas where there are regular wild dog control programs, and where hybridisation is prevalent, social structures may differ and groups may be less stable.

Cohesion within wild dog groups and separation between groups is maintained by a variety of communication methods. Boundaries of territories are marked by scents in urine and faeces, scratching or raking, while vocalisations such as howling allow longer distance communication. When individuals meet, facial expressions and body postures are used to communicate dominance or submission. Aggression between animals is not uncommon and is used to establish or maintain social position.

Reproduction

Wild dogs usually breed once a year. With the seasonal nature of food supply it is very rare for two litters to be successfully raised in one year. Some bitches may breed in their first year but not all do. This may be the result of social dominance of younger animals by older animals.

After a 63 day pregnancy, a litter typically of 4 to 6 pups, is born in a hollow log or cave den. This den may be used in successive years by the bitch or taken over by other bitches in subsequent years. Small pups are confined to the den, suckled and fed solid food and water brought to them by the adults. This solid food may be carried and regurgitated for the pups by both adults.

Once old enough the pups are taken from the den to kills. They may also be moved to various dens throughout the home range of the adults. Weaning occurs at 6 to 8 weeks but the pups remain with the adults until 6 to 12 months of age.

Mortality

Pups are vulnerable to predation by other dogs, foxes and raptors. Older, more experienced pups have a higher survival rate than pups that become independent at an early age. These pups often die because of inexperience in food gathering.

Adult wild dog survival can be influenced by a range of diseases including canine distemper (Paramyxovirus), hookworms (*Unicinaria stenocephala* and *Ancylostoma caninum*) and canine heartworm (*Dirofilaria immitis*).

Impact of wild dogs

Agricultural impact

Wild dogs may significantly affect domestic livestock industries such as sheep, cattle, goats and poultry, through predation and disease. The sheep industry is the most significantly impacted but attacks on goats, calves and larger cattle are quite common.

Livestock enterprises located adjacent to wild dog habitat may suffer severe localised predation. The cost of predation is not confined to direct losses through livestock deaths. Injured livestock require treatment and the livestock owner spends time supervising and protecting their flock. Indirect impacts include, poor weight gain, reduced wool growth in sheep and mismothering and loss of lambs. Financially, capital outlay for control techniques such as trapping, shooting and baiting may be substantial.

Cattle are also susceptible to wild dog attack. Young calves or young cattle are most vulnerable and older cows, steers and bulls may be maimed and killed. In areas where hydatids is endemic in wild dogs, a large proportion of cattle offal may be condemned at abattoirs to minimise risk of transmission.

Predation may occur in all months of the year and patterns vary slightly among areas but commonly peak in March to June on the tablelands and inland, and in October to November on the coast.

Figure 52. Sheep after a dog attack (Photo Glen Saunders).

Environmental impact

The impacts of wild dogs on native species vary between areas. Predation by wild dogs can have negative impacts on some threatened species. For example, wild dog predation can be a high source of mortality in koala populations and this combined with habitat fragmentation has the potential to cause local extinctions. To a large extent, the real impact of wild dogs on native species is rarely measured but predation by wild dogs in combination with other natural landscape impacts e.g. fire may have deleterious effects on some species.

Management of wild dogs is challenging as some sections of the community view dingoes, wild dogs as a native species that needs to be conserved. In NSW, public land managers aim to control wild dogs in areas where they impact on agriculture or other values, while conserving dingo populations in other areas.

Predation and hybridisation by feral dogs is listed as a Key Threatening Process, see www.environment.nsw.gov.au/threatenedspecies

Disease impact

Wild dogs can act as a reservoir for parasites and diseases that affect livestock, wildlife and domestic pets, including sheep measles, hydatidosis, mange, distemper, hepatitis, parvovirus, *Neospora caninum* and toxoplasmosis.

Wild dogs may also act as a reservoir of infection for some exotic diseases such as rabies. This would make eradication of the disease difficult and may have far reaching economic and social implications.

Social impact

Wild dog predation not only threatens the economic viability of properties, but can take an enormous toll on the mental health and well-being of individuals and communities. Farmers affected by wild dog predation experiences a wide range of emotions from anger, fear, distress and anxiety, with many choosing to make major changes to their enterprise type, and a small number leaving the industry altogether.

Wild dogs harbour a number of parasites of significance to human health such as, roundworms, hookworms and hydatids. The most important of these is the hydatid tapeworm which is present in a high percentage of wild dogs. The intermediate stage, the hydatid cyst, is sometimes fatal to humans. Care should be taken to wear gloves and wash hands thoroughly with soap and water after handling wild dogs and domestic livestock with injuries.

Figure 53. Dog and fox prints in a sand pad (Photo David Croft).

Recognition and signs of predation

The first sign of wild dog predation is often livestock carcasses, flightiness of livestock in response to disturbance or mustering with dogs or injured straggling livestock. The age, body position and location of a sheep or calf carcass may give some idea whether wild dogs were involved. Wild dogs will attack sheep of all ages but rarely attack cattle older than 12 months. Attacks can occur anywhere, whereas livestock dying of natural causes generally die in a protected area. A carcass with signs of ‘paddling’ would suggest predation was unlikely.

When carcasses are fresh, inspect for signs of blood, saliva and bite marks and footprints around the animal. The presence of dog footprints at the carcasses does not necessarily mean predation was the cause of death. Pieces of wool with patches of skin attached and blood trails, are good indicators of wild dog attacks. If these are not apparent and there are no other obvious explanations for the death, skin the neck area and bruising and tooth marks will be obvious if dogs have attacked and killed the animal. One should never discount stray town or farm dogs as potential killers.

Wild dogs often attack from behind as sheep or calves move away. If attacked animals survive, they may have substantial tissue damage around the hindquarters, be lame, be without tails or have skin hanging from them. Sometimes, ears and tails are chewed on older cattle. Surviving calves often show only teeth marks as evidence of dog attack and the area around the bite becomes swollen through infection and flystrike.

Management principles

Pest status

Wild dogs are declared pest animals under the *Local Land Services Act 2013*. This declaration means that land managers have an obligation to control wild dogs on their land.

Strategic approach

The primary goal of wild dog control is to reduce livestock losses. Wild dogs may have large home ranges that include a number of land holdings. Therefore it is important for land managers to approach wild dog problems as a group. A general aim of reducing wild dog numbers might not reduce their impact because a few individual dogs may be causing most of the damage.

The aim of wild dog control should be to minimise the likelihood of wild dogs interacting with domestic livestock. No single control technique will solve a persistent wild dog predation problem. A combination of methods, such as ground or aerial baiting, trapping, shooting and fencing should be applied if the impacts of those pest animals are to be successfully managed.

It is only through accurate reporting of wild dog sightings and attacks that wild dog management plans can be developed.

Control techniques

1080 poisoning

Wild dog poisoning with 1080 in NSW is regulated by the *Pesticide Act 1999* and can be carried out only under the conditions set down in the current 1080 PCO. Copies of the 1080 PCO can be obtained on line at www.epa.nsw.gov.au/pesticides/pco.htm or your local LLS.

The use of 1080 currently requires a minimum chemical use accreditation at AQF3 or the EPA accredited course delivered by LLS. Fresh meat and manufactured baits containing 1080 are available from the LLS.

Distance restrictions from habitation, boundaries, roads and water sources; signage which must be displayed, before and for one month after the baiting program; notification of all neighbours within 1 kilometre of the baiting location; are all conditions contained in the current 1080 PCO.

Ground baiting

For ground baiting, where practical, 1080 wild dog baits should be laid in such a way that uneaten baits can be found readily and destroyed. These baits should be placed in a shallow depression and lightly covered with earth. If practical, tether the baits to a fence or equivalent and mark the burial spot.

Ground baiting may be used when there is predation problem caused by wild dogs. The use of more than fifty 1080 baits on a large property or number of properties must be organised by an ACO employed by the LLS or equivalent organisation. The ACO, who supplies the 1080 baits, must undertake a risk assessment of the program.

A person who lays 1080 baits on a property of less than 100 ha must check the baits within five days of laying the baits and must collect any untaken baits within seven days. All untaken baits are to be disposed of by deep burial as detailed in the current 1080 PCO. Replacement baiting for longer than seven days may occur if baits continue to be taken.

Figure 54. 1080 meat bait (Photo David Croft).

Emergency ground baiting

A person whose livestock are being injured, killed or harassed can lay up to 16 baits per 100 ha to a maximum of 50, 1080 baits, with the prior approval of an ACO. This is the only occasion where the normal 3 day public notice period is not required. The land manager must, however, notify anyone whose property boundary lies within 1km of a baiting location immediately before laying the baits. Where soil conditions allow, baits must be placed in a shallow hole and covered with earth. If practical, tether baits to a fence or fixed object to reduce the poisoning risk to non-target animals.

Bait stations

Bait stations may be set up using meat or manufactured 1080 baits. The baits are lightly covered by raked sand or soil or placed on the surface and soil mounded on top. The soil around the bait or mound is raked to form a square about 1 m2. This allows for the identification of animals that visit the mound through tracks and scat observation. This approach is only necessary where visitation and bait removal must be monitored. Soil from the immediate area is preferred because it avoids unusual odours that wild dogs may avoid. Wild dogs will often tear the bait mound apart to get the bait while foxes mostly make a neat hole in one side or above.

Wild dogs cover enough ground to encounter bait stations from 500 to 1000 metres apart. Fewer bait stations not only equates to fewer opportunities for non target animals to take baits, it also means fewer opportunities for baits to be removed by foxes and cached elsewhere. When reducing the number of stations it is preferable to increase the area being baited and extend the length of time for which the baits are available.

Free feeding using non-poisonous baits in bait stations may be carried out to identify visitation by non-target species but this is an additional cost and rarely necessary. Bait stations visited by non-target species are discontinued. The remaining bait stations may then be poisoned with a single 1080 poisoned bait and regularly checked. Baiting should continue until wild dogs stop taking baits. Individual bait stations may then be stopped if non-target animals are taking poison bait.

Canid pest ejectors

Canid pest ejectors (CPE's) are baited, spring-activated devices that propel the contents of a capsule into the mouth of a wild dog or fox as it pulls upwards with sufficient force on a baited lure head. Ejectors have been deployed in the United States by the US Department of Agriculture since the late 1930's for the control of coyotes, red and grey foxes, and wild dogs. CPE's were first used in NSW by Armidale Pastures Protection Board Veterinarian Don Walker in 1955 with 13 wild dogs and 36 foxes controlled using cyanide ejector capsules.

CPE's have a number of benefits which can increase the success of wild dog or fox baiting programs. The devices cannot be cached or moved by foxes allowing a level of bait security not available when baiting. CPE's can easily be disarmed and reset at any time ensuring the safety of working dogs operating within fox and wild dog control areas. The device also allows an additional level of target selectivity as a direct upward pull of sufficient force is required to activate the device.

Due to the 1080 being protected inside a weather-proof capsule within the bait head of the ejector the device remains lethal until activated. This allows savings in labour as ejectors only need to be checked every few weeks to ensure the bait head remains attractive to wild dogs and foxes. Wild dog trappers often use ejectors to remove foxes from an area before setting traps for wild dogs.

Situations where CPE's would be of most benefit include:

- Areas where domestic or working dogs are at risk from meat baiting programs where bait security cannot be assured.
- Sites where foxes avoid or continually cache baits
- Long term fox and wild dog control sites where resources do not allow year round baiting or trapping – ejectors can be checked monthly
- Reducing fox activity prior to wild dog trapping programs to ensure traps remain set for wild dogs rather than foxes – once ejectors are removed from an area, trappers can be confident that valuable working dogs will not be exposed to 1080
- Expanding current wild dog and fox control programs to include areas where difficult or remote access restricts regular meat baiting.

Aerial baiting

An approval process managed by NPWS and LLS governs wild dog aerial baiting programs using helicopters or fixed wing aircraft in NSW. Aerial baiting can be conducted from fixed wing aircraft only in the Western Division of NSW.

The conditions for approval of wild dog aerial baiting programs are broadly stated in the 1080 PCO.

Aerial baiting is arranged through the LLS and NPWS in close cooperation with the local Wild Dog Control Associations and relevant government agencies such as Forestry Corporation, Crown Lands and local government.

The application process is available from the LLS and NPWS.

Information generally required on the application forms includes:

- name and information on the objectives of the Wild Dog Management Plan for the aerial baiting area
- historical information on stock losses and wild dog sightings and sign
- livestock loss and injuries over the last 12 months
- sightings and sign of wild dogs
- participating land managers and property names

- specific reasons for aerial baiting such as steep terrain, inaccessible for ground control operations or historical evidence that wild dog predation is likely to occur
- ACO responsible for applying 1080 poison to bait
- timing
- quantity of 1080 poisoned bait required
- name, address and phone number of a contact person within the Wild Dog Control Association, NPWS or LLS
- topographic maps showing proposed flight paths for each baiting including number of baits deployed, how they are deployed and the transect distance
- Approval to bait written authorities should be obtained from all private and public land managers who participate in aerial baiting.

NPWS are required to submit more detailed applications for aerial baiting in accordance with policy.

If required, more than one aerial baiting program can be undertaken each year. However, each case for aerial baiting will require a new application and approval and must meet the established criteria. It is essential to establish through accurate historical data that predation is occurring or there is a high probability that it is likely to occur.

Planning of aerial baiting

The local Wild Dog Control Association meets with the ACO from the local LLS, private land managers and government agencies such as Forestry Corporation, Crown Lands and NPWS to prepare an application for aerial baiting.

Written approval from Forestry Corporation and Crown Lands is submitted with the application depending on the proponent.

At the meeting the application and maps may be modified if necessary. The fully completed application and maps of proposed bait transects and all the necessary public land manager approvals are submitted at least two months before the proposed date of baiting to LLS for private land and non-NPWS estate, and to NPWS for all programs on NPWS estate.

LLS and NPWS consider the aerial baiting conditions stated in the current 1080 PCO when assessing the necessity of the proposed aerial baiting program. The history of predation, wild dog sightings and sign, a description of the terrain, the maps and that the proposed baiting is part of an agreed and signed Wild Dog Management Plan, in most cases, is sufficient to justify ongoing aerial bait transects or changes in bait transects.

The mapped bait flight paths must be digitised for the GPS navigation system in the helicopter prior to the aerial baiting program. Bait flight paths may be changed with prior approval of the relevant authority as long as amended digitised maps of the bait flight paths are completed prior to the program.

Approvals are usually sent directly to the applicant, in most cases, either the LLS or NPWS Regional Manager.

Participating land holders and managers must abide by all the conditions for use of 1080 wild dog baits in the current PCO for 1080 liquid concentrate.

On the baiting day, the LLS/NPWS must ensure that all indemnity forms are signed and delete from the maps any areas that are not covered by indemnity forms.

It is the responsibility of the aircraft pilot to ensure that the digitised bait flight paths are uploaded to the GPS, navigation system prior to each bait drop and that bait is placed as accurately as practical along these pre-approved bait flight paths.

It is the responsibility of the applicant to ensure that relevant distance restrictions for the placement of baits are followed, the bait does not exceed the quantities specified in the current PCO for 1080 liquid concentrate and other conditions in the PCO are adhered to.

Where possible, Wild Dog Control Associations should arrange aerial baiting programs to coordinate with neighbouring Associations.

Trapping

Trapping wild dogs is best conducted by experienced or trained operators. Only soft-jawed or padded jawed spring traps should be used for the control of wild dogs in NSW.

Figure 55. Victor soft-jawed trap (Photo David Croft).

Traps are best used in conjunction with other control techniques and may be very effective after a coordinated baiting program to control wild dogs that did not encounter, or pick up a bait.

Wild dogs often use well known paths to travel around their territory so traps are often set on or near a regular dog path. Wild dogs scent mark these paths with urine, so trappers may use trained dogs to identify fresh wild dog sign and place their traps. Wild dogs may be attracted to the trap location by using a lure. Research has shown that the most attractive lures for wild dogs contain dog urine.

Trappers also set traps on scratchings known as ‘rakes’. Setting traps around old animal carcases or with food lures should be done carefully because it tends to attract other non-target species such as quolls, goannas or birds.

Wild dog traps are usually anchored to stakes, fixed objects or drags. It is imperative that a shock absorbing device such as an in-line spring is fitted to a short anchor chain, < 50 cm and a swivel attaching the chain to the trap. These techniques are designed to prevent unnecessary injuries.

Traps should be visited at least once each day. Where daily checking is impracticable toxin can be placed around the jaws so that wild dogs die quickly, rather than from exposure or thirst. Trapped wild dogs should be euthanased as quickly as possible by a single shot to the brain.

Shooting

Shooting may be effective in situations where wild dogs are known to be in the area.

A shooter may be able to 'howl up' the wild dog or dispatch an animal that has established a regular pattern of visiting a particular paddock.

Electronic callers, predator calls and trail/game cameras can be used to increase the numbers of dogs shot.

Most shooting however is opportunistic. Shooting can play an important role in controlling wild dogs, but usually does not have as significant an impact on a regional basis as poisoning.

Figure 56. Trapped wild dog (Photo David Croft).

Fencing

Barrier fencing may include conventional and electric fencing. Conventional fences are generally not as effective a barrier as kangaroos, wombats and feral pigs quickly create holes, leaving an opening for a wild dog.

Most land managers upgrade existing old fences with electric outriggers or construct a much cheaper all-electric fence. Electric barrier fences are of particular help when a property adjoins wild dog habitat or when neighbours neglect control. When designing electric fences it is important to consider the behaviour of wild dogs. As a general rule, wild dogs prefer to push through, push under or dig under the fence.

Barrier fencing may only provide an effective barrier to wild dogs providing it is adequately maintained. The incorporation of a monitoring system into the fence will assist supervision.

Figure 57. Recommended electric fence for feral animal and wildlife control.

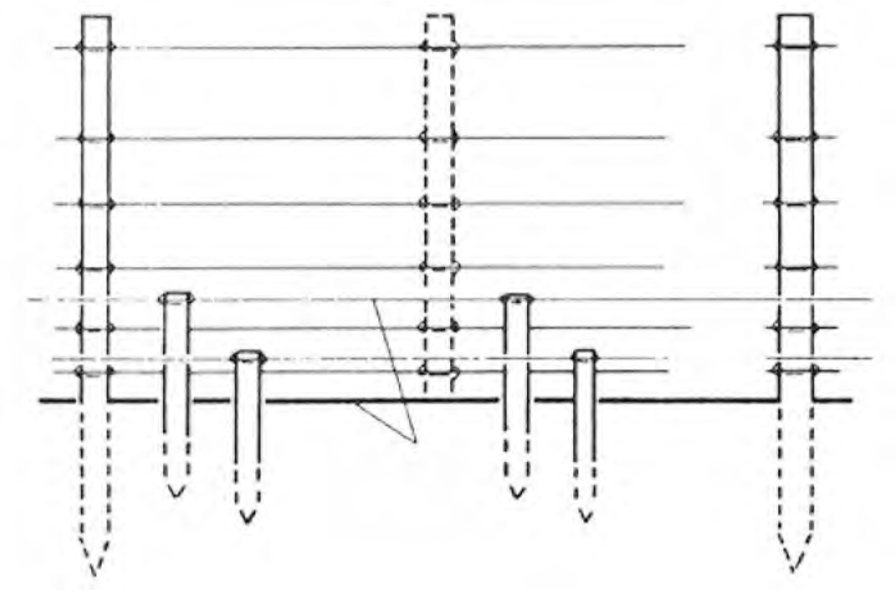

Figure 58. A well-constructed and maintained dog fence (Photo Peter Fleming).

Livestock guard animals

Guard dogs have been used for centuries in Europe to protect sheep and goats from wolves and, more recently, in America against coyotes. Guard dogs take many forms and the Maremma is the most common breed. They have certainly proved successful against foxes and increases in lambing rates of 10%–20% have been cited. Guardian dogs are susceptible to 1080.

Recent research indicates when properly trained and maintained, guard dogs have a high fidelity to the fields where they are placed. Poor training and inadequate feeding of guard dogs however may contribute to predation problems instead of lessening them. There is little empirical evidence that guardian dogs are an effective solution to mitigating the effects of wild dogs.

Alpacas, llamas and donkeys have also been used to protect livestock on some properties.

Dog control in town areas

Individual dogs or dog packs, wild or domestic creating a nuisance within a town or village are the responsibility of the local government. However, the increasing occurrence of wild dogs in peri urban areas has become an LLS and DPI issue. Suitable management of populations in areas adjacent to towns may help reduce wild dog activity in peri urban areas.

Further information

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Further information http://www.pestsmart.org.au

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2017 review completed by Guy Ballard, Peter Fleming, Mark Tarrant, Michael Leane, Grant Eccles, Rob Hunt

Monitoring

The best-practice management approach in pest management recommends detailed monitoring in association with any control program. It is important to ask the question: Does your pest control translate into measurable benefits to your farm or the environment?

This section will provide readers with fundamental information on the importance of monitoring. Specifically how to plan, choose and undertake monitoring as an integral part of pest management. The principles behind implementing successful monitoring programs are explained, and then some of the commonly used techniques for monitoring pest animal populations are described, with focus on the species addressed in this document.

Why monitor?

Monitoring represents a fundamental step in any pest animal management program, but one that is often neglected because of the resource demands. Governments, land managers, and landholders alike are investing significantly in programs to address the impacts of pest species by directly controlling pest populations where they cause unacceptable levels of damage. Wherever this control is undertaken, it is important to know whether there have been benefits from the control effort. Simply assuming that a control program is successful, without actually measuring the outcomes (in terms of benefits) can lead to false conclusions, poor management decisions, and a waste of valuable resources.

Monitoring serves as a tool to:

1. Identify priorities for immediate and future management (e.g. planning and resourcing). Where are the areas that need control?
2. Measure the effectiveness of control activities in reducing pest populations or the impact they cause (economic, social and environmental).
3. Evaluate management activities and control programs - What are the benefits gained or weaknesses of the control program? It serves as a valuable feedback mechanism in an adaptive management framework, providing information to be considered in modifying and improving future planning actions.
4. Improve knowledge and understanding (e.g. relationship between animal numbers and their impacts). How does the damage caused by pests change with a reduction in animal numbers?
5. Raise awareness of issues, opportunities, and limitations, as well as provide information on current and potential problems. What issues need to be considered in your pest management program?

Defining monitoring objectives

Monitoring should be performed for a specific purpose, and produce results that are easily understood. The objective(s) should be clearly defined - what you will measure, the temporal and spatial scale and what you will report.

An example monitoring objective:

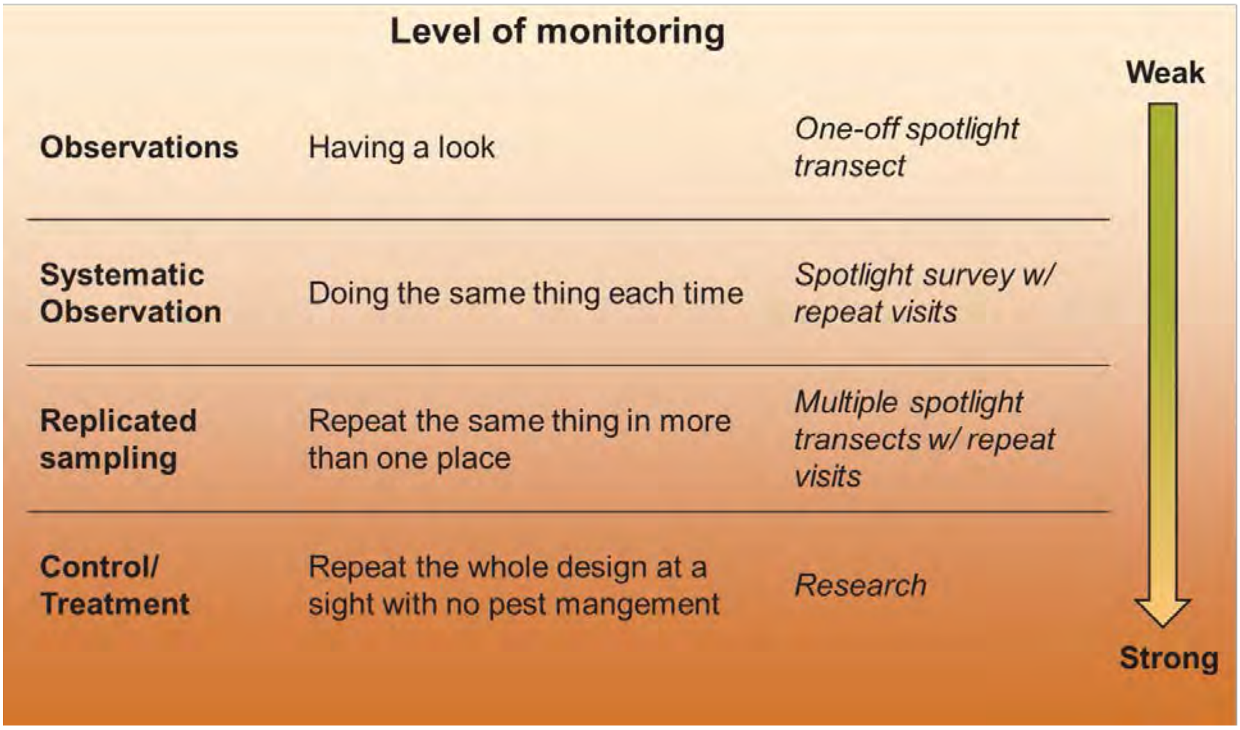
Evaluate clutch and fledgling numbers of Little terns annually for 5 years in response to sustained fox and wild dog control at Nine Mile Beach.

By defining the objective(s) clearly, it will also be easier to identify suitable techniques to use in the monitoring program.

Monitoring design

The objectives of a monitoring program will determine what is directly measured, what level of monitoring is needed, and how often it is undertaken. Monitoring can be used to measure damage caused by pests, detect the presence of species, estimate animal abundance, record change in animal abundance over time, measure operational effort and costs, assess habitat use, and measure unforeseen consequences from actions. Monitoring can be undertaken at different frequencies - one-off (to identify priority areas for control), repeated (to evaluate change in a pest population or damage over time), or ongoing (to measure change in pests or resource condition over longer periods). To be able to confidently attribute reduced damage or pest numbers to control activities it is essential to conduct the strongest level of monitoring possible, i.e. replicated sampling with a control (no treatment) site (Figure 59).

Figure 59. The level of monitoring will depend on the strength of information required to achieve the monitoring objectives (courtesy of A. McSorley and B. Mitchell, NPWS).



Other factors to consider when designing a monitoring program are:

- features of the target species or impact - such as density, location, ease of detection
- feasibility of selected techniques - including landscape vegetation and access, as well as cost (time, equipment, manpower)
- standardisation of methods - measures comparing across time should use the same methods, occur in the same location, and under similar conditions (rainfall, season, wind, temperature, time of day/night)

Monitoring the impacts caused by pest animals

Measuring changes in the damage caused by pests (such as crop or threatened plant species damage, livestock predation, or fledging success for shorebirds) is the best means of assessing the effectiveness of control or management decisions.

Measuring the damage caused by a pest can help a land manager to:

- determine the level of control necessary to reduce the damage caused by pest animals to an acceptable level
- assess the effectiveness of control by comparing pre- and post-control levels of pest related damage
- identify any changes needed to a control program to maximise its effectiveness
- gain a thorough understanding of the relationship between numbers of a pest and the damage they cause to a property.

To determine the level of damage caused by a pest requires direct or indirect measurements of damage before and after control. The same method should be used for all measurements, so any changes can be easily identified.

The focus of landholders and land managers should be on reducing damage until it reaches an 'acceptable' level. The trigger for control is usually a point in which the level of damage associated with a pest species reached unacceptable levels. Therefore, before any control is undertaken, it is prudent to decide what level of damage is acceptable, and then to aim at reducing damage back to that level. If damage levels are not reduced to an 'acceptable level' after control, then further control may be required.

Techniques for monitoring impacts

Pest animals are responsible for a wide variety of damage throughout Australia to social, economic and environmental values/assets. The damage caused by a pest animal also varies substantially throughout their range, and across different locations and at different times. Damage also varies with the asset/crop/resource being damaged, the condition of the asset, pest species, other species present, the duration the pest has been present, local circumstances, and many other factors. For these reasons, measuring damage is also complex, and it is difficult to recommend techniques that can be used to monitoring/measure damage in all circumstances. Most techniques are also limited in what they measure, and are suitable for a few different impact types.

There are numerous ways in which impact monitoring can be performed, and the direct and indirect techniques that should be used will be different with every circumstance. Below is a short illustration of the range of techniques available to make measures of pest animal damage.

For pest birds and flying foxes, some techniques used for measuring damage include: weighing, counting or visual assessment of damage to fruit, grains or horticultural crops; economic valuations of damage associated with aircraft strikes; clean-up costs where they may roost in public venues; estimates of economic losses to aquaculture, and repair costs where they damage infrastructure.

For herbivores, commonly used techniques measure changes in pasture biomass, vegetation cover, plant species richness, crop damage, soil erosion, competition with livestock, spread of weeds, disease and parasites.

For introduced predators, common ways of measuring damage include counts of stock losses and the number of stock mauled, estimates of lamb predation or changes in survivorship/ recruitment of a threatened species.

For rodents, damage to crops can be measured with observations/counts of seed heads or chewed stems, or husks at the base of plants. Other measures include using census cards (as described below). Rodent damage can also be caused by grain contamination rather than grain consumption, so losses associated with crop disposal can also be measured and recorded.

There are usually a broad range of indirect costs associated with pest animal damage, and many techniques to measure those costs. Wherever possible, costs should be recorded and monitored over time, such as the cost of control, as well as the costs of lost earnings associated with repairing damage, controlling pests, and the time required to address a pest problem.

Monitoring pest animal numbers

Pest animals can be monitored using observation, indirect or direct counts.

Observations are non-systematic, incidental sightings and can be used to confirm the presence (not absence) of a species in a particular area. This information can be used to:

- detect expansion or contraction in the range of species (including new incursions)
- determine the feasibility of management options and the scale of management required.

Indirect counts of pest animals, using measures of sign (e.g. dung / pellet transects, sign counts) or cameras, are used to calculate a relative measure of abundance. This can be useful to monitor a change in the abundance of the target species after a control action, especially if they are difficult or costly to count directly.

Direct counts of pest animals (e.g. aerial surveys, spotlight counts) can be used to measure the abundance or density of pest animals which can help to:

- identify priorities, problems and opportunities for management
- assess species whose occurrence or extent changes vary little in response to control, but whose relative numbers are a measureable and meaningful indicator of population size
- identify the relationships between pest numbers and damage associated with pests
- evaluate the effectiveness of management in terms of change in the numbers of pest animals in a given area (but should not be considered in isolation to measuring damage to imply control effectiveness. A change in the numbers of a pest does not always directly translate into a reduction in the damage they cause, as in some instances, for example wild dogs, it may be only a few individuals causing the problem).

Techniques for monitoring pest animal numbers

There are a wide range of techniques available for monitoring pest animal populations. Some are more suitable than others, and each varies in suitability according to species and circumstances. The section below presents a brief summary of some of the techniques available for monitoring pest animal populations. Care is required when implementing monitoring techniques, and it is recommended that operators seek advice on methodology and become thoroughly familiar with these techniques before field application. Monitoring requires good planning and organisation. A poorly planned monitoring program may provide you with misleading results.

Some of the techniques commonly used are:

- Camera trapping
- Spotlight counts
- Aerial survey (basic)
- Tracks and scats/dung
- Bait uptake
- Warren counts/active entrance counts
- Population sampling (using traps)
- Census cards and tracking tunnels
- Observations (sightings, howling etc.)
- Sand plots / pads

Their suitability to measure different pest species is shown in Table 4.

Table 4. A range of techniques and their applicability to common pest species: H=high, M=medium, L=low suitability.

Technique	Pest Animal							
	Rabbit	Fox	Wild dog	Feral pig	Mice	Goats	Birds	Deer
Camera trapping	H	H	H	H	M	M	L	H
Spotlight counts		M	L	M		M		M
Aerial survey (basic)	H			H		H		H
Sign Counts (tracks, scats/dung, damage)	M	M	M	M	L	H	L	H
Bait uptake	M	L	L	M	H	L	M	L
Warren /active entrance counts	H				M			
Population sampling (traps)	L	L	L	L	M	L	M	L
Census cards					M			
Observation (sightings etc.)	H	L	L	M	L	M	M	M
Sand plots / pads	L	L	L	L	L	L	L	L

Camera trapping

Camera traps are devices that detect heat-in-motion or can be set on time-lapse throughout the landscape for long periods of time (depending on battery life). Commonly used models are triggered to take photos or videos when a subject passes the detection zone in front of the camera. There are a variety of camera trap types and models ranging in price from <$350 up to $1000 (see Further information). Choosing the right model that is fit for purpose you require is critical to the success of your monitoring program (see Table 5).

The techniques used will vary between survey objectives, species targeted, habitat and camera models. Camera traps can be used to measure presence/absence, activity patterns and to estimate indexes of abundance. Camera sites can be passive, for example, no attractant and often along tracks, or active, where a bait or lure is used to attract and hold animals at a chosen point.

When using camera trapping in monitoring it is essential that users are completely familiar with how the camera trap works and how to maximise its detection capabilities. If animal detection is critical to the measurement of the population, many camera traps are required to cover an appropriate area and sample the population adequately. Consultation with a biometrician may be necessary to ensure you collect a robust data set.

The correct settings and placement is integral to data collection. There are several books and guides available on the internet and a detailed guide on camera trapping is available from PestSmart connect (see Further information and Appendix 1 for fox and wild dog standard operating procedures).

It is important that camera trap users understand their relevant legal responsibilities, prior to deploying these devices. A minimum requirement before deployment of devices should be to advise that cameras are being deployed in an area without being specific of when and where. The placement of signs at main entry points will provide a warning that camera traps could be deployed without giving away the exact placement so as not to direct the public to expensive equipment in the area that may result in theft, damage and large numbers of additional images being captured.

Users have an obligation to manage all images appropriately, according to the relevant policy of their organisation. Under all of the surveillance acts, there are legal requirements for the storage of data collected from optical surveillance devices, including storing in a secure place and destroying the records after a defined period (e.g. five years). The privacy of all individuals must be respected, and where images indicate an illegal activity, appropriate recording of the event must be formally reported to a senior officer.

Table 5. Points to consider when selecting the best camera for your monitoring program

Question	Helpful camera trap features
What is the objective of your monitoring?	Cameras without infra-red and pseudo-video options are limited to confirming species presence and species inventory Cameras with infra-red flash and pseudo-video options are well suited for behavioural observations
Is the subject species easy to differentiate from other species?	Colour images help with ID Infra-red flash with black & white image will impede ID Video capability collects behavioural data that may aid ID
Do you need to ID individual animals?	Colour images assist ID of markings Incandescent flash for colour night photos assist in ID of markings
Is the size of subject species small or large?	Wide detection zone is better for larger animals e.g. deer size Images of small animals may be overexposed by incandescent flash if camera is located too close
Is the subject species fast moving and/or hard to detect?	Fast moving animals need a wide detection zone and trigger speed Fast recovery time ensures rapid-firing and multiple photos
Is the subject species nocturnal or diurnal?	Type of flash is important Colour images may be critical Passive or active infra-red needs consideration High trigger speed important
Do you want the camera to be undetectable to the subject?	Incandescent flash will spook some species Infra-red can be better option but is still detectable

Spotlight counts

Spotlight counting can be a valuable tool for estimating the density of some species but relies on a suitable design for any useful analysis to be possible. Spotlighting efficacy is dependent on operator experience, equipment, target species detectability and spatial and temporal scale. Considerable bias can be introduced dependent on the above factors and is habitat dependent; for example spotlighting rabbits in dense understory is pointless.

Selecting a route

Prior to the selection of night spotlight count routes, the area must be thoroughly inspected and marked out during the daytime. Hazards or sensitive areas should be identified and adequately marked. In addition, an inspection can be carried out at night to verify and/or assist in highlighting areas that should be included in the spotlight count.

The route selected should cover an area that is typical of the topography, vegetation, density and distribution of the pest being controlled or monitored. The count routes should be placed to cover approximately 5% to 10% of the area involved. Those areas that should have count routes are chosen by:

- selecting areas that have historically had high pest numbers or where poisoning has not been carried out
- selecting areas that you or the land manager considers could have the potential to cause problems for various reasons
- covering a variety of land use types, habitat and topography, where possible
- ensuring that there is a reasonable distribution and length of count routes throughout the area selected.

The route length is largely dependent on the target species, their ecology, the type of terrain to be traversed and is restricted by what can be easily covered in one session (or in approximately 1 to 1.5 hours). If the count period or route is too long, operator tiredness may result in inaccurate or inconsistent data. If the route is too short, it may not adequately sample the area of interest.

When spotlight count routes are being marked, planning is essential. Care must be taken to avoid instances where your spotlight route may result in counting animals more than once, such as where a route changes direction. You must also ensure that the entire spotlight route is accessible at all times when counts are required (e.g. check that a gully, creek or stream can be crossed after rain).

Spotlight count routes can include sections of vehicle tracks or roads, although counting along busy roads can bias results and can present safety issues.

The spotlight count route should be permanently marked at distance intervals commensurate with the method i.e. driving (1km) or by foot (100 m). Reflectors, reflective tape or brightly coloured ribbon can be used. Where the route deviates, landmarks such as gates, fences, trees, rocky outcrops etc. should also be marked so the spotlight route is well defined. This will ensure that the same route is taken each night.

All spotlight count routes should be marked on individual property maps and start and finish GPS points, preferably record the route. This ensures that routes can be undertaken by someone else if the need arises.

Conducting a spotlight count

Each spotlight count should be conducted as consistently as possible. It is recommended that counts are carried out following the same route, by the same observer, using the same vehicle (or vehicle type), using the same spotlight wattage, driven at the same speed (approximately 10 to 15 km/hr); and thus ensuring the same amount of time is spent covering the count route on each occasion. Where possible, counts should be commenced at a similar time each night. The starting time will depend on the species being targeted and practitioners are advised to consider the known activity patterns of the species before arbitrarily selecting a time.

Adverse weather conditions, such as moon cycle, rain, wind or extremes of temperature can influence animal behaviour. Cold temperatures can reduce the activity of many animals. Rain, particularly if heavy or persistent, can cause significant change to the emergence of some animals. Similarly, moon phases and wind may also deter animals from foraging. Ideal conditions for a spotlight count are a mild evening with no rain, low light, and calm - slight breeze.

Spotlight counts should involve a minimum of three counts on consecutive nights or as close as practicable under similar weather conditions. If the difference in the nightly number of animals counted is more than 10% between the first, second and/or third nights, then up to five night counts should be conducted.

Figure 60. Vehicle set up for a spotlight count. Note the light on the roof so the observer can remain in the passenger seat. This removes any work safety issues of travelling in the back of a vehicle (Photo Ross Gardiner).

The person conducting the spotlight survey should count animals only within a set 90 to 180 degree arc and a set distance from the vehicle and this must remain constant. A maximum distance of 50 m to 100 m from the vehicle is sufficient. Counts should include the number of target species, and also the number of other species such as predators, native animals, etc. Either progressively or at the end of each kilometre (or section), the data needs to be recorded on an appropriate standardised recording form/data sheet/phone app (see Appendix 2) to ensure that an accurate record is kept.

If during a spotlight count, you find that some sections of the route are not able to be counted owing to changes in landscape (e.g. cropping, heavy stocking, fog, etc.), record 'not counted' (NC) on the data sheet in the appropriate columns of the recording form and a reason in that row of the count sheet. If part of a section was unable to be counted, record pest numbers, etc. and note in the comments column that the entire section was not counted, and a reason. If less than 60% of the spotlight route is counted, then you will need to recount the whole section.

Data can be recorded either using a tape recorder, using one person to observe and another to record data, or using a hand-held tally counter (when animal numbers are high).

Aerial survey

An aerial survey is a visual count of a species seen from the air. It is best if the aircraft is either a high-fixed-wing plane such as a small Cessna or a helicopter.

Marks applied to either the strut or wing support allows observers to determine the distance that animals are seen from the aircrafts flight line. These distances are usually grouped into zones (such as colour zones) that correspond with distances. This method assists with rapid counting and distance sampling during an aerial survey. An alternative method is to attach a marked rod to aircraft (see Figure 61).

Flying height is usually determined by agreed standards, and would normally be around 150 feet for helicopters and 250 feet for fixed-wing aircraft. Flying height must conform to regulations.

There are many issues to consider with aerial surveys, but information gained from aerial surveys can be very useful. Unlike many other methods, aerial surveys are also useful for surveying large areas quickly. However, aerial surveys can be expensive and require good planning and coordination. They should not be performed without training and consultation with scientific expertise.

Figure 61: Marked rods allows observers to determine the distance that animals are seen from the flight line during helicopter aerial counts (Photo Rachel Ladd)

Tracks, scats and dung counts

Identification of tracks

Animal tracks are sometimes used to identify whether a species is present in an area. Some animal tracks are easy to identify if only a few different species are present. But to differentiate between wild dogs and foxes or between feral pigs and other cloven-hoofed animals may require more skill and knowledge. In many cases, there are subtle distinguishing features to look for.

There are a number of reference books on tracks and scats that will assist in the identification process (see Further information). If the use of scats and tracks is a valuable tool for a particular monitoring program, then it might be worth engaging someone with the skills to identify those animals of concern.

Identification of scats

In a similar way, animal scats can be used to identify whether a species is present in an area. Some animal scats are relatively straight forward to identify, others are more difficult. It is easy to distinguish between the scats of feral pigs and rabbits. However, to differentiate between rabbits and sheep, or fox and quoll may need a little more experience.

There are several field guides which can be used to validate identification of scats (see Further information). Where scat identification is uncertain, consult an expert.

Dung counts

One method of assessing animal density in an area is to undertake dung or pellet counts. This usually involves removal of dung / pellets from a site, and returning at a later date to measure the accumulation of new dung. Like many monitoring techniques, there are a range of issues to consider with this technique. If planning a detailed monitoring program with dung counts, consult a research specialist.

An example of a typical sampling design for pellet transects would be 30 transects randomly situated within the study area. Transects 100m long x 2m wide are marked with pegs at the start and end point to allow accurate re-sampling (flagging tape can be used every 10m to accurately mark the transect). Start and end point coordinates are recorded with unique identifiers. Counts can be as simple as all fresh dung 1m either side of transects counted and recorded by species and can be as complex as measuring the distance that each pellet group is from the transect (distance sampling) and sweeping the transect clear of all dung at the completion of the count. Depending on the species being monitored, counts may be conducted in autumn and spring each year. Faecal accumulation is used as an index of abundance and changes in the index can indicate the success or otherwise of the management actions. Circular plots are sometimes used instead of a strip transect.

Bait uptake

Bait uptake involves using a quantified amount of food placed in a location that can be examined to measure visitation by an animal. For some species, bait uptake can be a false measure of the success of control (e.g. foxes cache baits), but it is a good method to determine the presence of a species in an area for the purposes of monitoring.

A bait station is a device/location that contains food that attracts animals. It can be as simple as a pile of grain on a roadside, a dish, tray, or length of poly pipe, or an elaborate device attached to a tree above the ground that excludes all animals except the target species (e.g. possums in New Zealand). The choice of bait is crucial and needs to attract the target species. For example, if you are using a bait station for rabbits, then oats or carrots would be used. Similarly, for mice a grain or pellet type bait would be suitable, although be aware as the crops mature and protein or sugar levels change, so does the food preference of mice. For foxes and dogs, meats that are tethered or buried might be suitable. The bait station may also need to be fenced to keep non-target or larger animals out of it.

Bait stations are particularly useful if animals follow movement patterns or feed in an area that is easily accessible (e.g. foxes and wild dogs). The benefits of this technique are the flexible timing of sampling and that sampling can be done during the day, while the animal may move around by night. The drawbacks of this technique include the risk that bait stations may be destroyed by rain or human activity, they are not an accurate measure of abundance, and they take considerable time to set up, especially if putting in a number of sampling sites.

Bait uptake will not provide an accurate estimate of the density of animals in an area but can provide an indication of an animals 'presence'. Sand pads or camera traps can be used to measure activity at or around the bait station. Baits can be dyed with food dye or using bits of coloured plastic in the food to act as markers. A search for scats around a bait station and examination of these scats may give an idea of the species consuming bait, or it may indicate where the animals have travelled from that particular feeding area.

Figure 62. A simple bait station for mice made from an upturned ice cream container (Photo David Croft).

Figure 63. Pig traps used as bait stations to monitor activity without disturbing the group (Photo David Croft).

How to do a bait uptake assessment

Select a number of sites to be monitored, such as roads, between refuge areas or known feeding areas. Always mark each bait station with a numbered post or tag and a GPS point so that return visits are easily undertaken. Count and record all baits removed or measure uptake the following day and if necessary, reset the station.

The best time to check bait stations is early in the morning, before other animals have had a chance to feed on any residual food, especially if combined with monitoring foot prints around the bait. If using camera traps this is not necessary.

For some species a simple calculation can help to identify how many animals have visited a station. For mice monitoring, the amount (weight) of food remaining can be used to estimate the number of mice that have visited the bait, as mice will consume approximately 3 g of food a night. If there has been 30 g of food removed (with no obvious sign of non-target species being present) then potentially 10 mice may have visited that particular bait station.

Warren / active burrow counts

The number of active burrow entrances counted per unit area (e.g. hectare) can provide an estimate of the density of rabbits or mice in that area.

Where a high proportion of entrances in a rabbit warren are active, showing regular animal movement in and out of the entrance and lack of cob-webs, leaves and debris, this would indicate a very active warren.

A simple technique to count active versus inactive burrow entrances in a large warren is to walk around and work towards the centre, placing a marker (such as strips of coloured cardboard or plastic) in each hole until all holes have been identified. Then walk back and pick up the strips with the ‘active’ strips in the right hand and the ‘inactive’ strips in the left hand. A bit of simple maths will give you a percentage of active to inactive holes.

Similarly, counting holes during a walk through a crop, along contour banks, along grass verges or fence lines can give an indication of mouse activity. Freshly dug soil at the entrance to a burrow indicates that the burrow is active.

Another simple observation technique for mouse activity is to walk along a crop row or a set path and collapse all mouse holes encountered in 100 m (or some other pre-determined distance). Then count all the re-openings each day for 2 or 3 days.

Figure 64. Holes can be counted, filled in and checked for reopening (Photo Reg Eade).

Population sampling (using traps)

Traps can be used for monitoring pest species to:

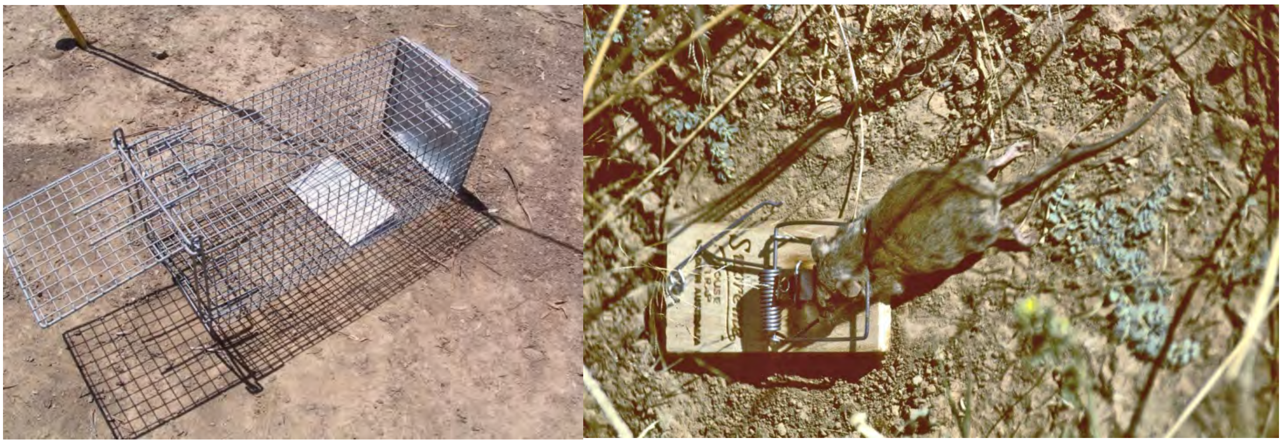
- record presence in a particular area
- provide an indirect measure of abundance of the target species by calculating the catch per unit effort (CPUE)

The benefits of using traps are that they can be easily moved to where pest activity is current, and can be used repeatedly. However trapping is very time consuming, and operators need to pay significant attention to prevent injury or harm to non-target animals, including humans and livestock. Where live capture traps are used, operators need to also prevent injury or harm to the target species. The placement, attractant and checking of traps on a regular basis need to be considered carefully and it is advisable to always check with an experienced trapper before using traps. No animals should be left in traps for excessive periods.

A number of live capture traps for pest animals are available commercially (such as Elliott, Victor and cage traps), or traps can be built fairly cheaply. Elliott and cage traps are commonly used for rodents and smaller carnivores such as cats or foxes, while soft jawed leg-hold traps are used for canids such as foxes or wild dogs. These may be traps such as the Victor Soft Catch® that has no metal contact with an animal's limb and rubber-wrapped jaws. Details on modifying steel traps to rubber-jawed traps are available through NSW DPI and PestSmart connect.

Lethal traps (i.e. those that result in the death of the animal when the trap is activated) can also be used to monitor pest animals, most notably rodents. The most well-known lethal trap is the snap-back or wooden mouse trap. These snap-back traps are an effective means of monitoring rodent populations, as well as being suitable for removing low numbers of mice in homes, buildings, or where poisons pose a risk to people or animals.

Figure 65. A cage trap used for foxes and feral cats, and mouse in a snap-back trap (Photos David Croft).



Census cards

Census cards are squares of gridded paper soaked in linseed or canola oil and are used for monitoring mice. These cards are simple and can be used by any operator. Sample census cards and instructions for use are shown in Appendix 3.

When placed at suitable intervals, either in or around the susceptible crop they can act as guide as to where baiting would be the most effective. If they are placed in a suitable grid pattern they can be used to estimate the mouse population.

If census cards have been chewed then there is a high probability that mice will take bait. However, the use of census cards to monitor mouse populations after baiting may have limited success.

Figure 66. A census card that has been chewed (Photo David Croft).

Observations (sightings, howling)

Keeping records of incidental animal sightings or records of the calls of animals (such as howling behaviour in wild dogs or barking foxes) is another useful technique that anyone can use. Such information, particularly if collected over time, can be used to identify areas where pest animals are common, and may help to identify areas where control could be a future management option.

It is also important to recognise that keeping a record of observations can also be used to identify movement behaviour - where pest animals may cross roads to forage or hunt. This information, particularly if used in combination with records of damage (such as stock losses), and information gathered from other monitoring techniques, can be used in the design of control programs, or used to measure the effectiveness of management decisions.

For documenting observations, record the time, date, locations of sightings/howling, weather conditions, observer details, and any other relevant information.

Mouse observations

As mice are found in most agricultural enterprises constantly, there is always need to maintain some form of monitoring or observation that can relate to changing populations. Apart from those monitoring techniques already covered, there are other observational methods that can be used to monitor mouse numbers.

One of the first places mice are observed is around buildings and sheds. The signs of an increasing presence of mice are:

- increased droppings
- gnawing
- burrows
- smudges on walls or rafters
- dark runways along skirtings or rafters
- tracks and worn pathways
- smell, sight and sounds
- mounds of soil and/or seed.

In protected areas, talcum powder or flour can be used to note tracks and to identify mouse activity.

There are a number of visual sighting techniques available to farmers in the field. A regular walk through a maturing crop or stubble paddock can provide valuable information on mouse activity. The presence of burrows, or worn paths between cracks of soil are good indicators that mice are present. In addition to holes and burrows, mice will nest under any shelter such as field bins, sheets of iron, timber or in pipes. These nesting sites should be checked regularly to see whether mouse numbers are increasing. If young mice are found in nests during summer and autumn, then there is potential for a rapid increase even to plague proportions.

In irrigation areas, farmers have relied on sight and smell when using syphons. Syphons that have not been used for a while will quite often have a very ‘mousy’ smell if mice are active, or there may be mice running out of the ends of the syphons that can be counted and recorded.

Counting numbers of mice seen on a road regularly travelled at night or the number of mice seen in a 1-minute period after switching on a light in a shed can also provide evidence of their increasing presence.

Sand pads or sand plots

A sand pad is a patch of raked sand or soil that can be used to show a foot or pad imprint when an animal walks over it. Sand pads can be useful where animals follow set paths or there is a road or track that is easily accessible.

The drawbacks of this technique include that animal tracks may be destroyed by weather or humans, their usefulness can vary seasonally, they are not an accurate measure of abundance, and they take time to set up if you are putting in a number of sampling sites.

A sand pad does not provide an accurate density of animals in an area but can provide an indication of the ‘presence’ and activity of a species, or many species simultaneously. In recent years this technique has almost become redundant with the advent of more accurate methods such as camera trapping becoming available. **Therefore, this technique is not recommended and should really only be used if there are no viable alternatives.** Sand pads are easy to prepare with limited materials required. Select a number of sites to be monitored (e.g. roads or between refuge areas and known feeding areas). Sand pads should be spaced at 1 km intervals for approximately 25 km for wild dogs. Smaller animals like foxes and cats tend to move shorter distances so sand pads spacing is recommended.

If possible physically mark the locations of sand pads with posts with reflectors so that future surveys can use the same site and GPS the location where possible. Once set out, sand pads should be used repeatedly, and not moved in future surveys, so that valid comparisons can be made.

Put down a layer of sand or fine soil enough to hold a print (2 to 3 cm deep) approximately 1 m long across the entire width of the road or counting area. If the pad is not naturally sandy or dusty, then sand may have to be brought in. However, local soils are less likely to be a deterrent to animals. Sweep smooth with a rake, broom or concrete rake to minimise ridges and allow for better prints.

How to do the count

Count and record all animal tracks the following day and then sweep the sand pad area clean again. The best time to check is early in the morning when the sun is still low in the sky as this provides a better shadow across the tracks. If this is not possible, then the use of a strong torch shone at an angle tends to highlight the ridges and depressions of the print and allows for better recognition. Record all tracks seen on a count sheet, not forgetting those that might not be easily identified. Repeat the count for 3 consecutive days.

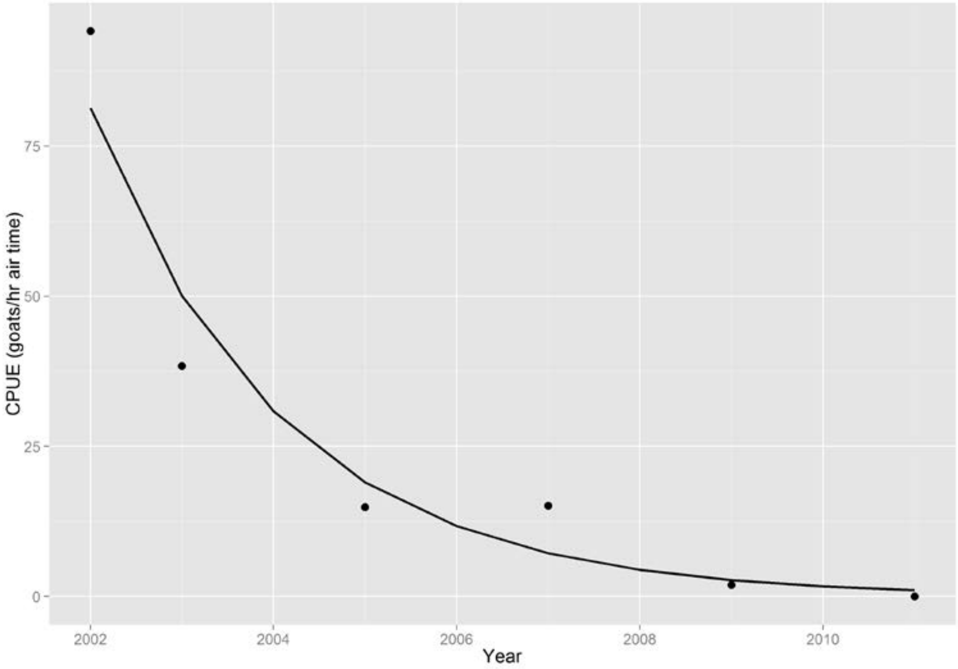
Figure 67: Constructing a sand pad.

Monitoring operational effort

Measuring operational effort (e.g. cost of control, hours spent, number of animals shot, baits used) allows a land manager to:

- document how funds were spent
- assess the cost-effectiveness of chosen control actions (in association with impact measurements)
- identify if operational improvements can be made to the current management program
- provide an indirect measure of abundance of the target species by calculating the catch per unit effort (CPUE) in cases where individual animals are identifiable, such as shooting or trapping (see Figure 68).

Figure 68: The number of goats shot per hour (calculated as a catch per unit effort) during an aerial shooting program (courtesy of A. McSorley and B. Mitchell, NPWS).



Monitoring for possible adverse impacts to non-target species/communities

Control techniques have the potential to adversely affect non-target species if best practice principles are not adopted. Monitoring of non-target species before, during and after a control program can help to ascertain whether a technique is adversely impacting on these species.

Monitoring before a control activity can be used to evaluate the risk to non-targets by:

- identifying whether any non-target species occur in the area of proposed control
- determining if non-target species are attracted to a proposed control method
- identifying the potential species of concern.

If a possible impact is identified, appropriate actions can be taken to reduce the risk such as:

- limiting the area of control - reduce the distribution of bait in areas where pest animal populations are low and/or non-target species are high
- limiting the amount of control applied - by only undertaking control where a pest species is known to occur, or limiting the amount of bait used, you can minimise the risk of non-target impacts to native animals, and save valuable funds in the process
- preventing non-target access - for example, remove stock paddocks
- relocating control activities to areas with less risk.

In NSW, the *Pesticides Act 1999* requires a review of the environmental factors before a decision to use toxic baits can be made. Prior to poison baiting, non-poisoned baits (free-feeding) can be used to check whether non-target animals (including threatened species) occur in an area or are attracted to the bait station.

Free feeding can also draw in target species, such as pigs to a feeding trough, helping you to centre your control efforts.

Bait stations can also be monitored during a control program to identify whether any non-target species are attracted to the site.

The method used for monitoring non-target species after control should be the same as that used before control, so any impacts can be easily identified.

Additional monitoring tools

Some important additional monitoring tools are:

Record keeping - land managers and landholder alike can play a vital role in recording and reporting information on pest animals and possible non-target species, such as native animals when detected. If incorporated into a control program, such information can be used to target pests and minimise non-target impacts simultaneously.

Situation reporting - information obtained before, during, or after a control program can be used to prepare a ‘pest situation report’. These can be used to gain a greater understanding of issues and opportunities, and can be used to communicate the status of a situation to neighbours or local authorities. Situation reports can be used to ensure possible non-target impacts are well identified and appropriately addressed.

Mapping - recording and mapping information on the locations of pest animals, non-target species such as threatened species/communities, sensitive areas, or historical information on suitable site maps can be very useful in identifying priorities, planning and coordinating control, documenting activities, and to minimise possible adverse consequences from your management decisions. Maps can also be a powerful tool in communicating control outcomes to landholders, neighbours, and collaborators.

Figure 69: Maps can be a powerful tool for communicating pest animal issues to landholders (Photo Peter Fleming).

Creating a property map to monitor rabbit populations

Creating a property map of where rabbits occur is the first step in determining the abundance and distribution of rabbits on a property. This map may be refined to warren locations, feeding grounds and harbour sites. Information of abundance and the potential for rabbit habitation can also be recorded using the codes in Tables 6 and 7 (see below). Potential is indicated by the factors that contribute to the quick build-up of rabbits. Such as the presence of warrens, logs, blackberries, boxthorn and pressure from nearby heavily infested areas. Probable trail lines, priority numbering and timing, as well as possible control techniques, should also be suggested. These maps may be used as part of the overall property management plan and to assess progress over the years.

Table 6. Codes for rabbit abundance and how to determine the level of rabbit abundance

Code	Density	Definition
0	nil	No rabbit sighting or sign.
1	low	Few or no sightings and/or little active sign.
2	medium	Some rabbits seen at any time and/or much active sign.
3	high	Rabbits seen at any time much sign of activity – active warrens, dung hills, scratchings.

Table 7. The potential for rabbit habitation

Code	Definition
A	No factors present.
B	Little harbour, single holes, easily destroyed.
C	Significant harbour, warrens, burrows, logs, bushes, etc., which with concentrated effort could be eliminated.
D	Intractable harbour, ie. areas where it is impossible to eliminate all harbour, e.g. rocky hills, steep gullies, etc.

* This system was developed by Eric Dekkers, former Ranger of Tamworth RLPB.

Further information

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Further information is available from:

http://www.pestsmart.org.au

https://www.dpi.nsw.gov.au/biosecurity/vertebrate-pests/publications/monitoring-techniques

For contemporary reviews of camera trap models https://www.trailcampro.com/collections/trail-camera-reviews

Manuals and guidelines can be found at many sites including Australian https://www.pestsmart.org.au/camera-trapping-for-wildlife-surveys/ http://www.nespnorthern.edu.au/wp-content/uploads/2015/10/5.2.4_a_guide_to_use_of_remote_cameras_for_wildlife_surveys_final_web.pdf and International sites https://www.wwf.org.uk/conservationtechnology/documents/CameraTraps-WWF-guidelines.pdf.

Acknowledgements

First compiled by David Croft, NSW DPI, May 2007

2017 review completed by Paul Meek, Guy Ballard, Bruce Mitchell, Lynette McLeod

Appendix 1: Standard operating procedure: Camera trapping wild dogs and foxes

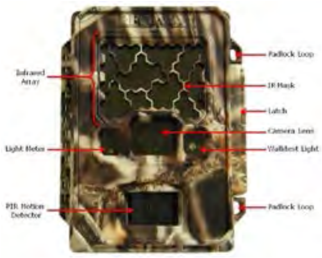
Camera trapping is the most widely used survey tool being used in wildlife monitoring throughout the world. Effective use of this equipment requires an understanding of how camera traps work and how they are deployed to maximise their value as a sampling tool. This SOP provides a general guide for practitioners interested in using camera traps to survey wild dogs and foxes, links to other resources are provided for more specific details.

What camera trap model?

The choice of camera trap will depend upon the specific question you are trying to answer. All models are different in how they detect animals, their detection speed, their illumination and settings are constantly changing with new models.

To be consistent in data collection with broad programs across Australia and internationally, and to enable spatial and temporal comparisons in monitoring programs, the model most commonly used for wildlife monitoring purposes is the Reconyx HC600. Comparisons between models cannot be undertaken unless adequate calibration analysis has been conducted to reduce detection errors between models.

How do camera traps work?



HC600 camera traps use a passive infra-red (PIR) sensor to detect the differential between the background temperature in front of the camera and a moving heat source. Animals will only be photographed when the heat signature of an animal is detected to move across the PIR, so camera trap placement is crucial.

Power sources

NIMH batteries are the preferred choice of power system for the HC600. Alkaline batteries should <u>never</u> be used. Lithium batteries operate well under temperature extremes but they are expensive and can't be recharged. NIMH batteries should be charged to >80% for deployment. <u>Never</u> mix battery types.

How many camera traps do I need?

The number of camera traps used will depend on the question asked. A robust monitoring program will often have at least 20-30 camera traps spaced ~1km apart. Consult an expert or biometrician for design advice to suit the survey question.

Settings

The settings used for monitoring programs will vary between models and the intended outcome of the study. Most models have the capacity to record stills and videos, however for consistency and rigour, stills/photographs are the preferred data collection mode. A general recommendation for setting HC600 camera traps for consistency between studies and to optimise detection is;

1. Rapidfire
2. No delay
3. 10 images per trigger
4. 3.1 mp resolution
5. High-medium sensitivity
6. Night mode: fast shutter or high quality

Where do I place them?

In predator detection and monitoring surveys, camera traps should be placed along roadsides because wild dogs, foxes and feral cats will use these thoroughfares often and the chance of encounter is higher than off the track. This placement is passive, so do not use bait or a lure.

How do I place them?

Attachment – HC600's have a female thread that can be used to attach to a bracket, tripod or alike. It is important that when using several camera traps they are all placed the same way. Cords can also be used to tie them to posts or trees but this is not ideal. Steel security boxes can also be used. *Distance from road edge* – we recommend placing the camera traps 30cm from the road edge.

Height – the optimal height of the Fresnel lens for dogs and foxes is 50cm above the ground to ensure the body signature is detected by the PIR.

Orientation – DPI research recommends that orienting the camera trap 23° to the direction of the road or track optimises detection of animals as they walk past.

Deployment period – 4 weeks is the minimum period of deployment recommended.

Checklist - Equipment

1. Checklist - Setting up in the Field GPS
2. Flagging tape
3. Locks with Keys if using python locks
4. Tripods and posts (pickets or droppers etc.) if being used
5. Batteries and chargers
6. Spare memory cards (each remote camera brand can use different cards)
7. Additional rope, Velcro, tie wire or cords for fixing cameras
8. Image viewing device for setting up and checking during deployment e.g. laptop or SD card viewer
9. Tools i.e. hammer, saw, knife, secateurs, hedge pruners, machete, pliers, rubber gloves
10. Lens wipes
11. Door / builders' wedges for setting camera angles against trees etc.

1. Make sure all batteries are charged before deployment.
2. If CODELOC is used remember to have a written record so you can program and set the camera trap
3. Check settings including date and time stamp are correct including a site specific user label code
4. Position the camera facing south if possible and in shade to prevent false positives
5. Avoid rock outcrops, reflective surfaces and shadows in the field of view
6. Aim the camera at a 23-degree angle to the path of the animal, make sure that the detection point of the camera is 4-6 metres from the camera
7. The height to set the camera at is 50cm above the ground.
8. The camera should ideally be set parallel to the ground although this may vary depending on topography. Use wedges behind the device to aim the camera properly. Viewers and other computers can be used to check camera fields of view.
9. To ensure that the camera is not triggered by false subjects ensure that vegetation that can move in the wind is removed from the field of view.
10. Use the walk test to check and verify motion detector's range. Take a photo with camera trap and upload the image to check the placement is correct.
11. Record location data on data sheets or electronic storage application including a GPS point.
12. Store data in a location that allows other people to locate the camera traps if you cant

Note: Check you have armed the camera before you leave.

Appendix 2: Spotlight count sheet

M.A.	SITE.			
SURVEY CODE	SPECIES TARGETED:			
MGA REFERENCE	Start	Easting	Northing	
	End	Easting	Northing	
LOCATION DESCRIPTION				
BROAD HABITAT TYPE	Rainforest ☐ Subtropical ☐ Dry ☐ Temperate	Sclerophyll ☐ Wet Sclerophyll ☐ Dry Sclerophyll ☐ Swamp Sclerophyll	Woodland ☐ Shrub Woodland ☐ Heath Woodland ☐ Tall Woodland	

CENSUS 1	Date	Observer(s)		
METHODS				
TIME	Start	Finish	Total Time	
WEATHER	Temperature: Dry	Wet	Relative Humidity (optional): %	Time taken:
Wind (1 only)	☐ calm ☐ light - leaves rustle		☐ moderate - moves branches ☐ strong - impedes progress	
Rain (1 only)	☐ rain during survey ☐ evidence of rain in last 24 hrs		☐ no evidence of rain in the last 24 hrs	
Wind (1 only)	☐0 ☐¼ ☐½		☐¾ ☐1	

CENSUS 2	Date	Observer(s)		
METHODS				
TIME	Start Time	Finish Time	Total Time	
WEATHER	Temperature: Dry	Wet	Relative Humidity (optional): %	Time taken:
Wind (1 only)	☐ calm ☐ light - leaves rustle		☐ moderate - moves branches ☐ strong - impedes progress	
Rain (1 only)	☐ rain during survey ☐ evidence of rain in last 24 hrs		☐ no evidence of rain in the last 24 hrs	
Wind (1 only)	☐0 ☐¼ ☐½		☐¾ ☐1	

OBSERVATION DETAILS — Observation Type: O= Observed, W= Heard Call, E= Nest / Roost, P= Scat / Pellet, K= Dead

CENSUS	SPECIES	OBS. TYPE	COUNT (add 'E' if estimate)	LOCATION		NOTES (AMG if threatened and not as above)
				DISTANCE	BEARING	
				(+/-)		
				(+/-)		
				(+/-)		
				(+/-)		
				(+/-)		
				(+/-)		
				(+/-)		
				(+/-)		
				(+/-)		
				(+/-)		

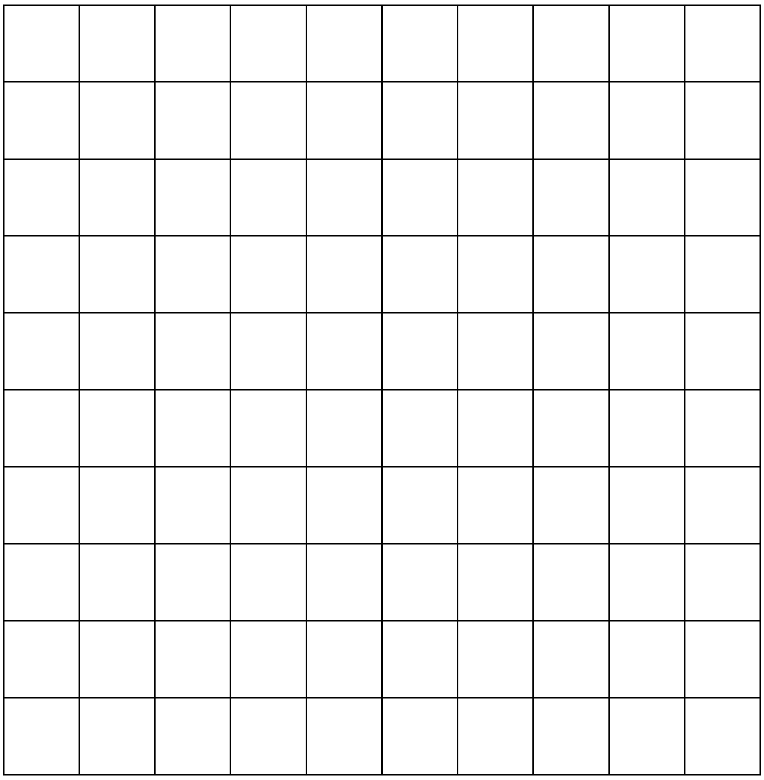
Appendix 3: Census cards for assessing the presence of mice in the field

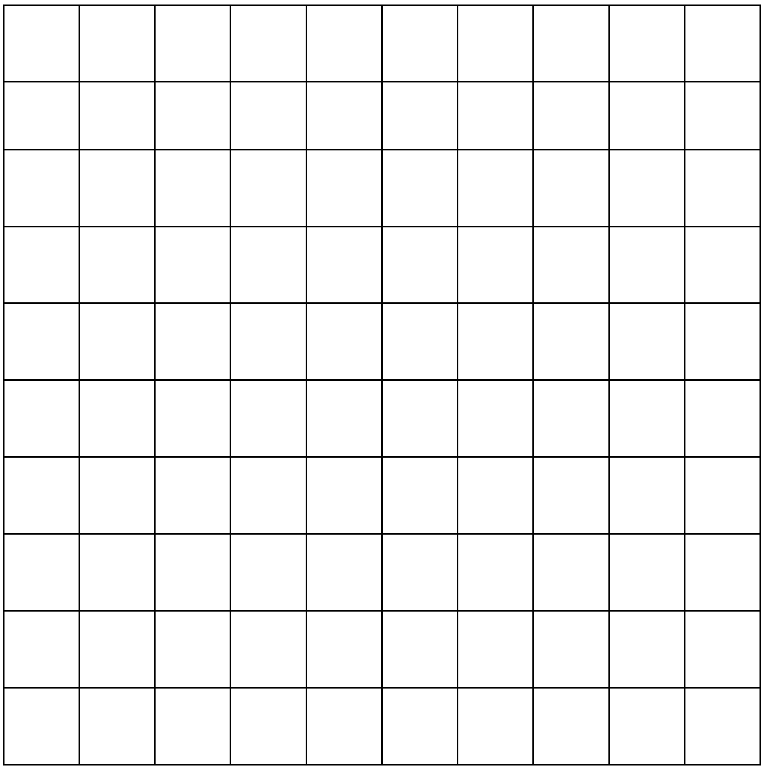
Mice are present all the time in the field living in holes and under cover from predators. They tend to be more active at night and so it is not always easy to determine how many mice are present at any one time.

There is no really accurate way to count mice, except for extensive trapping (which is very labour intensive) over a number of nights. However, the use of census cards can provide an indication of mice and whether they are increasing or declining.

Preparing and using census cards:

1. Cut sufficient cards to do each night's count. You need 10 cards per monitoring line (fewer cards is not a reliable indicator).
2. Each card is 10 cm × 10 cm cut from white bond (e.g. photocopy) paper.
3. Soak cards in canola oil for at least 1 hour.
4. When ready for dispensing, drain cards for 10 minutes.
5. Cards are put out in the afternoon (the later the better).
6. Each monitoring line should be marked and noted (recording the type of vegetation).
7. Place 10 cards in a row in the paddock at 10 m (12 paces) intervals.
8. Fix cards to the ground with wire spikes (not clods of dirt) to prevent cards being carried off or blown away.
9. Retrieve cards the following morning.
10. Mouse presence and damage potential can be assessed by determining the percentage of each card eaten.
11. Counting the number of squares eaten will give a percentage. Greater than 10% to 15% of the card eaten indicates there could be a potential mouse problem.
12. Assessment using this technique can be done any time monitoring is required.





Note: These grids can be cut out, put in a plastic bag or laminated and used as a template.

The census cards should be 10 × 10 cm which is the same dimensions as the outside edge of the template shown here.