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MONITORING TECHNIQUES FOR VERTEBRATE PESTS

RABBITS

BRUCE MITCHELL AND
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WHY MONITOR VERTEBRATE PESTS

Since 1993, the Bureau of Rural Sciences has produced a series of 'best practice' national guidelines to manage the agricultural and environmental damage caused by vertebrate pests. These publications set down principles and strategic approaches for managing vertebrate pests.

The strategic approach to pest animal management is based on six key steps (Braysher 1993):

1. define the problem in terms of impact
2. determine the objectives and performance indicators
3. identify and evaluate management options
4. implement the program
5. **monitor the management program**
6. evaluate the overall management program.

The focus of this manual is to provide details of the techniques available to researchers, land managers and policymakers for monitoring mice in Australia. The manual covers simple monitoring techniques and analysis as well as highly complex and detailed techniques for specialist areas. It is acknowledged that many techniques described here will be impractical for routine farm-level monitoring, while others will not be precise enough for research. End users are encouraged to develop specific monitoring tools for their own purposes based on the descriptions in this manual.

The management program should be monitored before, during and after control, especially if it is a long-term program.

- Monitoring is done **before** the program to establish a benchmark of vertebrate pest abundance and to identify actual or potential damage. This will allow objectives and performance indicators to be determined.
- Monitoring **during** the program is done to determine how the program is progressing against set objectives. The monitoring may provide an early warning that a change in the management program is required so as to achieve control success. This form of adaptive management is recommended to help achieve outcomes within timeframes and budgets without sustaining too much damage; however, it is rarely suitable for research.
- Monitoring **after** the program finishes is aimed at determining the success of the program against the performance indicators, and finding out whether the program objectives have been achieved.

Monitoring of vertebrate pest impacts and their abundance is critical in determining whether a management program has been successful or not.

A management program that incorporates monitoring of both vertebrate pest abundance and the impacts that the pests have will probably be more successful than one that monitors only one of these factors.

There are numerous research and management reasons for initiating monitoring programs of animal populations. Monitoring plays a fundamental role in conservation, by providing an 'early warning system' to identify problems before they become irreparable, and it can also suggest possible solutions (Goldsmith 1991; Thomas 1996). An example of this is monitoring the abundance of threatened and endangered native species as part of pest animal control programs that aim to protect them.

When an animal species conflicts with human interests (i.e. becomes a pest to agriculture and the environment) and requires management, the need for monitoring its abundance or impact would seem self-evident (Engeman & Witmer 2000). However, this is often a forgotten component of pest management, although it is an essential function that can guide future management practices and should be an integral and budgeted component of existing and proposed management programs (Braysher 1993; Olsen 1998).

Monitoring in vertebrate pest management has two functions: to provide the necessary information to trigger management action (i.e. to act as an 'early warning system') (Elzinga *et al.* 2001); and to indicate whether a management strategy is achieving its objectives or is in need of alteration (performance monitoring) (Possingham 2001; Edwards *et al.* 2004).

Ideally, it is the damage caused by a particular pest that should be monitored (Hone 1994). However, it is often difficult or impractical to survey pest animal impact and, typically, pest abundance is monitored and used as a surrogate indication of associated damage (Edwards *et al.* 2004). This type of monitoring makes the assumption that there is a known relationship between population size and damage.

The most obvious application for pest animal monitoring is to determine the efficacy of control programs to reduce vertebrate pest abundance. In an ideal world, monitoring should compare treated sites (where the control operation occurs) with untreated sites (where no control has been undertaken), and accurately measure damage and abundance before, during and after control. As already stated, measurements of damage are often not available, so assessments of abundance alone are usually used. However, estimates of the absolute abundance of wild animals are expensive to obtain, and may be unnecessary for many pest management decisions (Caughley 1980). Furthermore, complete counts of all pest animals in an area are rarely practical, and more often than not sample counts are done to provide an index of abundance.

In order for monitoring programs to be effective, efficient and reliable estimates of changes in population or damage need to be obtained (Thomas 1996). In addition, these estimates need to be repeatable, to allow meaningful conclusions to be drawn from any changes. An appropriate way of achieving this is to standardise the methodology. An important component of standardisation is education and training. Two or more people could act on written instructions and get quite different results. Physical demonstration of the monitoring technique and the chance to calibrate measurements against those of experienced operators would be likely to improve the accuracy and precision of any monitoring efforts.

The purpose of this manual is to provide details of the techniques available for monitoring mice in Australia. By providing a step-by-step description of each technique, it will be possible to standardise many monitoring programs and make valid comparisons of abundance and damage across the nation. This is becoming increasingly important for the states, territories and the Australian Government, to help evaluate and prioritise natural resource management investments.

KNOW THE PEST: THE RABBIT

History

The European rabbit (*Oryctolagus cuniculus*) is native to north-western Africa, Spain and Portugal. The first successful introduction of rabbits to the Australian mainland probably originated from a shipment of 24 genetically wild rabbits in 1859 to 'Barwon Park', near Geelong (Rolls 1969). The spread north and west across Victoria was rapid. By 1880, rabbits had crossed the Murray River, and by 1886 they had reached the Queensland border. By the late 1880s, rabbits had begun to consolidate on the land they had invaded, with their population density peaking concurrently with sheep numbers. Rabbits had also crossed South Australia into Western Australia, arriving at Geraldton in 1886.

Impacts

The rabbit is considered to be Australia's most damaging vertebrate pest and has adverse effects on pastoral and crop industries, as well as native fauna and flora. Rabbits compete with stock for feed and can cause reduced production via poorer stock condition and wool quality. They also limit the ability of sheep and cattle to survive and recover from drought. On a grazing property in South Australia, the stocking rate was able to be increased by 40% after rabbit control, and these rates were able to be maintained during subsequent drought conditions (Williams *et al.* 1995). Other impacts are land and vegetation degradation where the loss of vegetation exposes the soil to the erosive forces of wind and rain. Forestry and tree plantations suffer browsing damage and crop yields can be significantly reduced. Native fauna suffer from direct competition with rabbits for food and shelter and it has been noted that there has been no known native mammal extinctions north of the range of rabbits since they were introduced (Williams *et al*. 1995). Grazing, browsing and ringbarking of native flora have caused declines in native species and facilitated the invasion of exotic species. Rabbits are commonly believed to cause damage only when they occur in higher numbers, but in areas of low productivity, densities as low as 1 rabbit ha^{-1} can prevent native plant regeneration.

Distribution

Rabbits now inhabit approximately 4 million km^2 of Australia, mostly south of the Tropic of Capricorn. They have become established in environments ranging from sub-alpine areas to stony deserts, and from sub-tropical grasslands to wet coastal plains; but particularly in areas with Mediterranean climates. These are areas generally associated with livestock production, or those that support the great majority of Australia's rural production.

Habitat

Rabbits prefer short grass areas (either found naturally as in semi-arid areas or resulting from heavily grazed pastures), with harbour (e.g. warrens, blackberries, fallen logs, native vegetation) nearby. These animals can adapt to a wide variety of habitats, but in general they avoid large cultivated areas, forests, floodplains and black soil country. Human habitation does not deter rabbits, and they may become a problem around home gardens, shearing sheds and other farm buildings. In suitable habitats, most rabbits live above ground and need burrows only for breeding.

Rabbit warren

Rabbit habitat

Biology

Diet

Rabbits are herbivorous and eat a wide variety of plants, including crops, roots, pastures, young trees and young vines. As calculated from maintenance requirements, approximately nine rabbits are equivalent to one DSE (dry sheep equivalent). Rabbits can graze plants to ground level 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. Rabbits produce a special soft faecal pellet that is reingested, so that the additional digestion phase and adding of bacteria can help in cellulose breakdown and better absorption of nutrients.

Reproduction

Rabbits can breed at any time, provided there is short green feed supplying sufficient protein. Rainfall and the early growth of high-protein plants primarily determine the main breeding season. Harsh conditions may induce anoestrus or cause females to cease lactating and/or resorb any foetuses. This mechanism allows the breeding core of a group to be preserved at the expense of the more vulnerable young.

Both males and females reach sexual maturity between 3 and 4 months of age.

The gestation period for rabbits is 28 to 30 days. There is no post-partum anoestrus, and females generally mate again within an hour of giving birth. Ovulation is triggered by the mating act (i.e. rabbits are reflex ovulators). Under very favourable conditions an adult female can produce seven or eight litters in a year, but more commonly three to five. Litter size varies according to the female's age and social status, seasonal conditions and nutrition, with the average number of young produced by one female per year being between 18 to 30 (Williams *et al.* 1995).

Mortality

Natural adult rabbit mortality does not generally suppress rabbit population size, and population size is more likely to be controlled by human intervention for control or sport. Kitten mortality in the wild can be extremely high; up to 80% of kittens die before they reach 3 months of age.

Two of the most devastating diseases to rabbits are myxomatosis and rabbit haemorrhagic disease (RHD), commonly known in Australia and New Zealand as rabbit calicivirus disease (RCD), which can commonly cause 70% mortality. However, transmission of these diseases requires vectors, along with close contact, and unless mosquitoes or rabbit fleas are present and active, infection will be stunted. This, with the variable virulence of different strains, and with viral attenuation, means that myxomatosis and RHD should not be relied on as primary control methods.

Burrows ripped by a 'dozer

In cold wet climates, apart from drowning in flooded burrows, rabbits are more likely to be killed by coccidiosis than by myxomatosis and RHD. This disease is caused by an internal parasite, *Eimeria stiedae*. Internal parasites affect adults mainly by impairing reproduction and thus reducing population size, but they can also cause high mortality rates in the young by causing diarrhoea and wasting.

Rabbits have few external parasites, except fleas. The rabbit flea, *Spilopsyllus cuniculi*, is an important vector for myxomatosis, whereas stick-fast or other fleas have little direct effect. The Spanish rabbit flea, *Xenopsylla cunicularis*, has been released throughout the semi-arid areas of Australia as an additional vector for myxomatosis.

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. Corvids (birds such as crows), 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.

The only factor that seems to operate as a population-regulating factor is drought. The subsequent lack of food stops reproduction and can result in the deaths of nestlings, and it will result in population crashes. Drought also causes dispersal, which leads to exposure and vulnerability to prey. Control programs are therefore likely to be most effective immediately after drought.

Social structure

The warren complex forms the basis of a distinct social structure that has a well-defined hierarchy closely aligned with the breeding season. Once breeding stops, this structure weakens and eventually breaks down. With the onset of breeding, social groups of seven 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.

Movements and home range

Rabbits are most 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. Communication is mainly by smell, but alarm signals are given by flashing the tail while running and by thumping with the hind feet. Daily movements are generally within 150 to 200 m of the warren, but this distance can increase during drought (up to 1500 m has been observed), or decrease during the breeding season.

Rabbits do not usually travel vast distances, but movements of more than 20 km have been recorded. Very young rabbits (20 to 60 days old) are more likely to disperse than older rabbits. Adult rabbits rarely disperse, although they can move 0.5 to 1 km or up to 15 km away. Most dispersal is from warrens with high rabbit densities to warrens with low densities or to adjacent social groups. The general rule of thumb is that movement (and reinvasion of control areas) can – and will – occur, yet mass movements over long distances take place mostly when food is limited. Even so, most rabbits will die on site rather than move to new areas, even when food is limited.

MONITORING RABBIT ABUNDANCE

This section discusses the different methods that can be used to monitor rabbit abundance. The summary tables at the end of this handbook summarise these methods and compare them with the methods of monitoring rabbit impact presented in the next section.

Spotlighting

Night-time counting using spotlights, either on foot or from vehicles, has been used for many years to survey animal species such as the rabbit, *Oryctolagus cuniculus* (Myers 1957; Dunnet 1957b; Parer & Price 1987; Twigg *et al.* 1998a; Ballinger & Morgan 2002; Caley & Morley 2002). This is mainly because spotlighting is easy to do and can cover large areas in a relatively short time. Spotlighting can sample different vegetation types and compare them under similar conditions within a site (i.e. season, time, weather).

Simple indexes of abundance can be produced from these counts. Examples are the number of animals seen per kilometre travelled. However, indexes created from spotlighting counts have bias caused by difference between observers and also in visibility, or 'sightability', which can change with vegetation density and animal behaviour (Twigg *et al.* 1998a; Saunders *et al.* 1999; Wilson & Delahy 2001). This monitoring method is also unsuitable in high wind or rain conditions, as these affect rabbit behaviour (Ballinger & Morgan 2002). Other sources of potential variation include the time of night that the survey is done, seasonal variations in animal behaviour and abundance, and the use of roads as transects (vegetation types will not be surveyed evenly) (Weber *et al.* 1991; Thompson *et al.* 1998).

Despite these shortcomings, spotlighting has been found to be a reliable means of monitoring relative population size in rabbits (Twigg *et al.* 1998a; Ballinger & Morgan 2002; Caley & Morley 2002). For example, in New Zealand, spotlighting along fixed transects has become the standard method used by Regional Councils and the Ministry of Agriculture and Fisheries to assess rabbit populations (Fletcher *et al.* 1999). However, there has been little standardisation of the technique, thus creating difficulties with comparisons between studies.

Distance sampling

Density estimates from spotlight counts can be made by using the distance-sampling method, where the distance to the animal is used to correct for visibility bias (Buckland *et al.* 1993). Studies using this method have produced results consistent with more labour-intensive techniques such as mark–recapture counts (Palomares 2001; Newey *et al.* 2003). Key assumptions of distance sampling for unbiased estimates are that:

- objects (i.e. target animals) directly on the transect line are detected with certainty
- individuals are detected in their initial location and do not move before detection by the observer, or if they do move it is in a random direction
- movement away from observer = evasion and bias towards underestimation
- movement towards observer = attraction and bias towards overestimation)
- individuals are not recorded twice; and distance measurements (and angles) are accurate (Buckland *et al.* 1993; Rudran *et al.* 1996).

Problems that arise from these assumptions can lead to inaccuracies in the density estimates obtained by distance sampling. Detection of all animals on a transect may not be achievable, although double sampling (using two independent observers) may alleviate this problem. Visual estimates of perpendicular distance are prone to error (Heydon *et al.* 2000; Ruette *et al.* 2003; Saunders & McLeod 2007), but Heydon *et al.* (2000) suggested that the use of hand-held laser range finders could overcome this difficulty.

Transects

Before starting a spotlight count it is necessary to determine and standardise the technique. The route being taken, including the length of the transect, must be established and plotted on a map. Take care to ensure that the transect passes through areas that represent all vegetation types in the area being sampled and that the route is traversable in all weather conditions. The best way to achieve this is to inspect the area during the daytime, before the placement of the transect. If possible, mark out transects (e.g. with reflectors) so that future surveys can easily follow the same path. Once set out, this transect must be used for all further surveys so that valid comparisons with prior surveys can be made (i.e. the transect must be 'fixed'). The vehicle speed needs to remain the same.

Preparing for the survey

Surveys need to be conducted at least quarterly to account for seasonal differences in abundance of animals, but more frequent surveys would provide even greater information. If the monitoring is being done to check on the success of pest control, then surveys need to be done just before the control event and then about 1 week post control. Regardless of the frequency, a survey needs to be made up of counts repeated on three or four consecutive nights. Where possible, repeat the counts until they give similar indexes in order to achieve a consistent level of precision (standard error of counts should be within 10% of the mean) (Saunders *et al.* 1995). Weather conditions must be similar for all counts; avoid nights of high wind or heavy rain (Ballinger & Morgan 2002).

Starting at the same time for each survey is also important. To be effective, the spotlight count needs to coincide with the period of highest activity of the rabbit. Generally a start time of at least half an hour after sunset will be adequate to survey rabbits.

The length of the transect depends on the size of the area being surveyed. Indexes of abundance are calculated as animals per kilometre; therefore a transect should be a minimum of 1 km, but the longer the transect the more accurate the estimate. Somewhere between 2 and 10 km would be ideal, or 2 km for every 100 ha being surveyed (Bloomfield 1999). There are three ways to conduct a spotlighting count, two using vehicles and one walked. Distance sampling can utilise all three techniques, but it involves extra time and work. All four sampling methods are described below.

Spotlighting for rabbits

Vehicle spotlight counts

Materials required

Vehicle – 4WD with an enclosed cabin and a fixed roof-mounted spotlight (passenger side), with the observer sitting within the cabin and operating the spotlight by a swivel handle, or using a hand-held spotlight.

People – 1 driver, 1 or more observers

Spotlight – 100-W, 12-V (narrow beam)

Spotlight count sheet and clipboard

Reflectors and star posts to mark out the transect

How to do the count

- Establish a transect path such that most rabbits are between the vehicle and rabbit refuge i.e. set up so you only need to cover 90° with the occasional 180° sweep.
- Start approximately half an hour after sunset from an established start point.
- One person drives and another person counts the animals.
- Drive at a constant slow speed (10–15 km/h; 15 km/h is the unofficial standard).
- Observer scans a 90° arc ahead of the vehicle with the spotlight and counts animals seen within 50 m on either side (a hand-held tally counter is effective when the rabbit occurs in high numbers).
- Every 1 km, record the tally on a standardised spotlight count sheet (see example and Table 1).
- Repeat the count on three or more consecutive nights of similar weather.
- On subsequent counts start at the same time as the first count, use the same route (distance and direction), vehicle, speed, spotlight and people.
- After the completion of the survey determine the average of the counts and divide by the length of the transect to get a simple index of abundance (animals km^{-1}).

Variations on technique

Two people counting – use two hand-held spotlights of the same power, with observers counting only one side each of the vehicle in a 90° arc ahead of the vehicle.

Use a tape recorder to record what was seen, rather than a count sheet, and transcribe the data at a later date.

Use a laptop computer to record data (forms can be made using programs such as Microsoft Visual Basic© or Microsoft Access©).

Standards

Route – use the same transect and travel in the same direction for each count

Time – use the same start time for each count i.e. at least half an hour after sunset

Rate of travel – 10 to 15 km/h (constant speed)

Spotlight power – 100-W, 12-V (narrow beam)

Observer – use the same observer(s) for each count

Vehicle – use the same vehicle for each count

Swathe – 50 to 100 m, 90° arc in front of vehicle

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

Driver and observer must be familiar with the track in daylight conditions, having driven it before starting the survey to make sure it is readily navigable. Ensure that the spotlight is well maintained, with leads connected securely to the battery terminals and insulated from other components. Always disconnect the spotlight from the power source before changing the globe or making repairs. Switch the spotlight off when not surveying (i.e. do not leave the spotlight switched on face-down on the seat or on heat-sensitive material). Do not run the spotlight for long periods without the motor running. All occupants should carry drinking water, a torch and sufficient clothing for warmth in the event of the vehicle becoming stranded. Avoid shining the spotlight beam into other people's eyes. Check previous rainfall and surface conditions before the survey. The driver and observer must not be fatigued at the time they do the spotlight survey. The observer should wear adequate clothing during cold weather. Drive at the correct speed and continually watch the surface ahead on the track. Remove dangerous overhanging obstructions before you start the survey. Record your observations only when the vehicle is stationary.

Training required

4WD training

Instruction in setting up and using spotlight equipment

Headlight counts

Materials required

Vehicle – 4WD

People – 1 driver, 1 observer

Spotlight count sheet and clipboard

How to do the count

- Establish a transect path such that most rabbits are between the vehicle and rabbit refuge i.e. set up so you only need to cover 90°, with an occasional 180° sweep.
- Start about half an hour after sunset from a set start point.
- Drive at a constant slow speed (10–15 km/h).
- Count animals seen within 100 m in front of the vehicle using high beam.
- Every 1 km, record the tally on a spotlight count sheet (see Table 1).
- Repeat the count on three or more consecutive nights of similar weather.
- On subsequent counts start at the same time as the first count, use the same route (distance and direction), vehicle, speed and people.
- After completion of the survey determine the average of the counts and divide by the length of the transect to get a simple index of abundance (animals/km).

Standards

Route – use the same transect and travel in the same direction for each count.

Time – use the same start time for each count i.e. at least half an hour after sunset.

Rate of travel – 10 to 15 km/h (maintain a constant speed e.g. 15 km/h).

Headlight power – use the same constant strength (high or low beam) for each count.

Distance to count animals – up to 100 m in front of vehicle.

Observer – use the same observer for each count.

Vehicle – use the same vehicle for each count.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

As for 'Vehicle Spotlight Counts'

Training required

4WD training

Walked spotlight counts

Materials required

People – 1 observer

Spotlight – hand-held with battery backpack: 100-W, 12-V (narrow beam)

Spotlight count sheet and clipboard

How to do the count

- Establish a transect path such that most rabbits are between the person and rabbit refuge i.e. set up so that you only need to cover 90°, with the occasional 180° sweep.
- Start about half an hour after sunset from a set start point.
- Walk at a constant easy pace.
- Scan a 90° arc ahead with the spotlight (with battery backpack) and count animals seen within 50 m.
- Every 0.5 km, record the tally on a standardised spotlight count sheet (see Table 1).
- Repeat the count on two or more consecutive nights of similar weather.
- On subsequent counts start at the same time as the first count, use the same route (distance and direction), spotlight and people.
- After completion of the survey determine the average of the counts and divide by the length of the transect to get a simple index of abundance (animals/km).
- Use a GPS to help you maintain your path.

Variations on technique

Two people counting – use two hand-held spotlights of the same power with battery packs, with observers counting only one side each in a 90° arc ahead of them.

Standards

Route – use the same transect and travel in the same direction for each count.

Time – use the same start time for each count (i.e. at least half an hour after sunset).

Rate of travel – constant, easy, slow pace.

Spotlight power – 100-W, 12-V.

Distance to count animals – 50 m either side of observer, 180° arc (one observer) 90° arc each (two observers).

Observer – use the same observer(s) for each count.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

As for 'Vehicle Spotlight Counts'. Check the previous rainfall and surface conditions before the survey. The observer should wear adequate clothing during cold weather. In remote situations, carry a mobile phone or (if necessary) a satellite phone or Emergency Position Indicating Radio Beacons (EPIRB).

Training required

Instruction in setting up and using spotlight equipment

Worked example of a spotlight count

Evaluating the success of a rabbit control operation. Transect length 16 km.

Rabbits seen pre-control:

1st count: 461, 2nd count: 503, 3rd count: 497
total: 1461
average: $1461 \div 3 = 487$
number of rabbits per km: $487 \div 16 = 30.44$ rabbits km^{-1}

Rabbits seen post-control:

1st count: 49, 2nd count: 63, 3rd count: 68
total: 180
average: $180 \div 3 = 60$
number of rabbits per km: $60 \div 16 = 3.75$ rabbits km^{-1}

The percentage reduction in rabbit numbers can be estimated from these figures.

$3.75 \div 30.44 \times 100 = 12.32$
$100 - 12.32 = 87.68\%$ reduction

Distance sampling

Materials required

See above techniques, plus:

Range finder

Compass or GPS

Computer software for density estimates

How to do the count

- Transects should be as straight as possible and avoid roads (if feasible).
- Each time a rabbit or group of rabbits is encountered, stop the vehicle and estimate the perpendicular distance from the transect line (group distances into 10 m intervals e.g. 1–10 m, 10–20 m) or the radial distance from the observer to the rabbit(s) and the sighting angle between the line of sight to the rabbit(s) and the transect line at the moment of detection. See Table 2 for an example of a work sheet used to record distance sampling.
- Density estimates are computed by software, e.g. DISTANCE (Laake *et al.* 1993). For an extensive review of distance sampling see Buckland *et al.* (1993).

Standards

See above techniques

Animal welfare considerations

See above techniques

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

See above techniques

Training required

See above techniques

Measurement of distances and angles training

Computer software training

Sight counts

Sight counts are walked transects similar to spotlight counts, with the difference being that sight counts are completed during daylight. This method will generally give an indication of only adult rabbits, as kittens tend to emerge close to nightfall.

Materials required

People – 1 observer

Count sheet and clipboard

How to do the count

- Establish a transect path such that most rabbits are between the vehicle and rabbit refuge i.e. set up so that you only need to cover 90°, with an occasional 180° sweep.
- Start approximately 1 or 2 hours before sunset from a set start point.
- Walk at a constant easy pace.
- Scan a 90° arc ahead and count the rabbits seen within 50 m.
- Every 0.5 km, record the tally on a standardised count sheet (see example in Table 1).
- Repeat the count on three or more consecutive afternoons of similar weather.
- On subsequent counts, start at the same time as the first count and use the same route (distance and direction) and observers.
- After completion of survey determine the average of the counts and divide by the length of the transect to get a simple index of abundance (animals km^{-1}).

Standards

Route – use the same transect and travel in the same direction for each count.

Time – use the same start time for each count.

Rate of travel – constant easy, slow pace.

Table 1. Example of a spotlight count sheet using encounter rates

Date:		Site:				Page: of	
Start time:		Start odometer:		Observer:		Vehicle:	
Finish time:		Finish odometer:		Driver:		Speed:	
Spotlight power: V W		Position: roof-mounted sitting hand-held					
Temperature: cold cool mild warm hot				Wind: nil light medium strong			Direction:
Cloud: nil 20% 40% 60% 80% 100%				Moon visibility: 0 1/4 1/2 3/4 full			
Last rain: > week ago this week yesterday today now				Surface condition: dry wet slushy dew frost			
Transect section	Rabbits	Foxes (dogs/cats)	Kangaroos	Other	Stock	Vegetation type & condition	

Comments:

Table 2. Example of a spotlight count sheet using distance sampling

Date:			Site:				Page: of	
Start time:			Start odometer:		Observer:		Vehicle:	
Finish time:			Finish odometer:		Driver:		Speed:	
Spotlight power: V W			Position: roof-mounted sitting hand-held					
Temperature: cold cool mild warm hot					Wind: nil light medium strong			Direction:
Cloud: nil 20% 40% 60% 80% 100%					Moon visibility: 0 1/4 1/2 3/4 full			
Last rain: > week ago this week yesterday today now					Surface condition: dry wet slushy dew frost			
Species	Number	Range	Bearing	Habitat	Waypoint	Easting	Northing	Time

P – pig, K – kangaroo, C – cat, R – rabbit, W – wallaroo, F – fox, D – dingo/dog

Distance to count animals – 50 m either side of observer.

Observer – use the same observer(s) for each count.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

None

Warren counts

Estimation of rabbit abundance from warren counts has been used in Australia since the1970s, when changes in the use of burrows were found useful for estimating changes in the number of rabbits using the burrows (Myers *et al.* 1975; Myers & Parker 1975a; Myers & Parker 1975b). Warren counts can be as simple as counting the number of active or inactive burrow entrances and using it as an index of rabbit abundance, or they can be made more statistically robust by using estimates of warren density per unit area to assess rabbit density (Low 1983; Williams *et al.* 1995). The number of rabbits on or near warrens can also be used to estimate abundance, although this method is not suited to densely vegetated areas.

Attempts to validate simple active entrance counts have found high correlations between active burrows and population size (Myers *et al.* 1975; Parer 1982; Parer and Wood 1986; Ballinger and Morgan 2002). Parer (1982), using data collected from many different habitats and climates in the non-breeding season, found a relationship between active entrances and rabbit population: for every 1.66 active entrances there was 1 rabbit. There was also found to be a difference between soil type, with clay soil having a conversion factor of 1.36 and sandy soil 1.80 (Parer 1982). A breeding season study found a higher conversion factor of 2.76 but also concluded that the relationship between active entrances and number of rabbits using them was highly variable when there were young rabbits present (Parer & Wood 1986). Since the initial studies, few attempts have been made to validate this technique until recently. Ballinger and Morgan (2002) concluded that one conversion factor (3.3) could be used for the entire year, as rabbits in Australia have no defined breeding season. However, these correlations must be treated with caution, as they are site and time specific.

Simple counts of warrens are rapid and give indexes of abundance that can be used to determine relative changes in rabbit populations. A more detailed approach of determining warren density per unit area combines transect counts of warrens with estimates of warren density in plots of known size for each land type (Low 1983; Williams *et al.* 1995).

Rabbit warrens in sandy soil

Rabbits on an active warren

Simple warren counts

Materials required

Vehicle to travel between sites

Star pickets and tags

Map and GPS (if possible)

Warren count sheet

How to do the count

Adapted from Williams *et al.* (1995)

- Divide the land area that needs to be monitored into distinguishable land types on the basis of soil, land-use, vegetation type or other appropriate maps.
- Set out several parallel, straight-line transects across the area, encompassing all land types but avoiding (where possible) roads and running along the edges of land types (the number and distance between transects will be determined by the size and variation in land type of the area/property being monitored).
- Physically mark out the transects (e.g. with reflectors) so that future surveys can easily follow the same path.
- Count and record the number of warrens (active and inactive) 10 m either side of the transect for each land type.

Estimate the density (D) and standard error (S.E.) of warrens per unit area for each land type (accuracy is acceptable if the S.E. is within 15% of the mean):

$$D = \Sigma w \div \Sigma a$$

$$S.E._{(D)} = n \div \Sigma a \times \sqrt{[(w^2 + D^2 \Sigma a^2 - 2D \Sigma aw) \div n(n-1)]} \times \sqrt{[1 - (\Sigma a) \div A]}$$

w – number of warrens in a transect
a – area of transect (transect length × width)
n – number of transects in the land system
A – total area of the land system

Estimate the number (Y) and S.E. of warrens:

$$Y = A \times D$$

$$S.E._{(Y)} = A \times S.E._{(D)}$$

Calculate the total number (T) and S.E. of warrens across land systems:

$$T = \Sigma Y$$

$$S.E._{(\Sigma Y)} = \sqrt{[\Sigma (S.E._{(Y)})^2]}$$

Warren density can be transformed to a rabbit density estimate by using the number of active entrances multiplied by an appropriate conversion factor, as discussed in the following section.

Standards

None

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

None

Active entrance counts

Materials required

Vehicle to travel between sites

Star pickets and tags

Map

GPS (if possible)

Data recording sheet (see example in Table 3)

How to do the count

- The number of monitoring sites will depend on the size of the property or the desired research outcome (ideally more than five sites that correspond to a spotlight transect).
- Select a site that is between 1 and 5 ha, is representative of the general topography and vegetation, and has more than five warrens (each warren has more than three entrances).
- Mark each warren (e.g. put a star picket in the middle of the warren with a tag indicating the site and warren [site 1 warren 1]).
- Record the location and site information of each warren on a map of the area or property (and GPS if possible).
- Measure the size of the warren e.g. the number of paces NE–SW from the star picket.
- Count and record the number of active burrow entrances (active entrance: smooth floor, recent soil disturbances, feet and claw impressions in the soil, fresh urine/pellets, hair).
- Count and record the number of inactive entrances (inactive entrance: leaves, grass-heads or weeds on floor, wind-blown or rain-washed soil, layers of old pellets, spider webs).
- Convert the active entrance numbers into the number of rabbits for each warren, by generalisation. To do this, divide the number of active entrances by an appropriate conversion factor:

  breeding season – conversion factor: 3

  non-breeding season – conversion factor: 1.6

  i.e. in the non-breeding season for every 1.6 active entrances there is approximately 1 adult or sub-adult rabbit.
- Compare the results with those of previous surveys done at the same time (i.e. breeding or non-breeding season).

Standards

Site – use the same sites and warrens for each count.

Observer – use the same observer for each count.

Conversion factors – use a conversion factor appropriate for the season when the count is conducted.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

None

Counts of rabbits on or near warrens

Materials required

Vehicle to travel between sites

People – 1 or more

Star pickets and tags

Map and GPS (if possible)

Warren count sheet (see example in Table 4)

Binoculars

How to do the count

- Select sites that:
  - are representative of general topography and vegetation and have two or more warrens (the number of warrens monitored will depend on the number of observers available)
  - limit the effect of observers on rabbit behaviour and activity
  - provide good visibility for observers and clear definition of the warren boundary.
- Mark each site (e.g. star picket in the middle of the warren with a tag indicating site and warren [site 1 warren 1]).
- Record the location and site information of each warren on a map of the area or property (and GPS if possible).

Table 4. Warren counts: example of an active entrance count sheet

Date:		Observer:				Page of
Last rain: > 4 weeks ago; 4 weeks ago; 3 weeks ago; 2 weeks ago; 1 week ago; this week						
Site	Warren	Size	Active entrances	Inactive entrances	Est. no. rabbits	Comments

- To allow rabbits to return to normal behaviour, arrive at the site half an hour before you start the count.
- Count and record the number of rabbits (juveniles, sub-adults and adults) that are on, or emerge from, the warren. Observe the presence of any predators.
- Counts should coincide with the time of peak rabbit activity (determined by pre-count observations), or, alternatively counts can be made for approximately three-quarters of an hour at the same time before dusk each day.
- Repeat the count on three or more consecutive nights of similar weather.
- On subsequent counts approach the site from the same direction, start at the same time as for the first count, use the same observer, and record any disturbance to the site.
- Count the number of warrens every month.

Standards

Observer – use the same observer for each count.

Route – use the same approach to each site.

Time – use the same start time for each count (always arrive half an hour before beginning the count to allow rabbits to return to normal behaviour).

Number of counts – three or more on consecutive nights of similar weather.

Site variables – record weather, season and time of day.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

None

Dung counts

The dung (faecal pellets) of many species is more conspicuous than the animals themselves, especially during the day in the case of predominantly nocturnal species such as the rabbit (Sutherland 1996). Counting the dung of rabbits offers a relatively easy way of monitoring rabbits during daylight hours. Dung counting can be as simple as walking a transect and recording the number of pellets via a 1 to 10 scale of density (Gibb scale – developed by staff of the Ecology Division of the Department of Scientific and Industrial Research, New Zealand), or it can be made more precise by the use of quadrats. This latter technique has been used to estimate the density of rabbits and other lagomorphs to varying degrees of accuracy (Krebs *et al.* 1987; Wood 1988; Iborra & Lumaret 1997; Forys & Humphrey 1997; Diaz 1998; Krebs *et al.* 2001; Palomares 2001; Murray *et al.* 2002).

Rabbit dung

The accuracy of dung counts is influenced by variables such as defaecation and accumulation rates, decay rates, the sampling unit selected, movement of dung by wind or heavy rain, and the season and habitat (Wood 1988). Ways of overcoming some of these sources of error include counting only fresh pellets (Iborra & Lumaret 1997), determining the rate of decay or persistence of pellets at the study site, and correctly selecting sampling sites (Palomares 2001). Newey *et al.* (2003) suggested randomised sampling of 1-km^2 blocks with 30 to 50 plots in each block, whereas Palomares (2001) used transects established for spotlight counts and placed plots 80 to 100 m apart.

Because of these difficulties, dung counts are not always accurate and are usually used to obtain indexes of abundance rather than relative densities of rabbits.

Using the Gibb scale

Materials required

Gibb scale sheet (see Table 6) and photographs illustrating the levels on the scale

Count sheet

How to do the count

- Select the sites to be sampled.
- Establish a transect across the sites.
- Walk the transect and record a score between 1 and 10 for every 100 m (see Gibb scale below).
- At the end of the transect, add the scores and divide by the number of scores to get an average figure for the site.

Standards

Observer – use the same observer for each count.

Route – use the same transect for each count.

Frequency – repeat counts every 6 months.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

None

Table 5. Warren counts: example of a sheet for counting rabbits on or near warrens

Date:	Observer:			Vehicle:			Page of
Temperature: cold cool mild warm hot				Wind: nil light medium strong			Direction:
Cloud: nil 20% 40% 60% 80% 100%				Last rain: > week ago, this week, yesterday, today, now			
Site	Warren	Arrival time	Start time	Finish time	Rabbits	Predators	Comments

Table 6. Dung counts: example of a Gibb scale count sheet

Date:	Observer:																			Page of
Last rain: > 4 weeks ago, 4 weeks ago, 3 weeks ago, 2 weeks ago, 1 week ago, this week																				
Site:	Density of dung by 100-m section average																			Comments

Gibb scale

1. very few droppings, sometimes grouped, easily overlooked
2. very infrequent heaps; little if any scatter
3. infrequent heaps; very light and patchy scatter
4. frequent heaps; light and patchy scatter
5. heaps occasionally within five paces of each other; moderate scatter overall
6. heaps often within five paces of each other; moderate scatter overall
7. usually two or three heaps within five paces of each other; dense scatter
8. usually three or more heaps within five paces of each other; dense scatter overall
9. some heaps almost merging; very dense scatter
10. some heaps merging; very dense scatter overall

Dung-pellet counts

Materials required

1-m^2 quadrats (minimum 15 per transect)

Map and GPS (optional)

Count sheet (see example in Table 6)

How to do the count

- Select the sites to be sampled.
- Establish a transect across the site and place quadrats 100 m apart, or alternatively randomly place quadrats across the site.
- Mark quadrat locations on a map and/or GPS or with a small post or peg.
- Count pellets within the quadrat and then clear the pellets from the quadrat when finished counting.
- Repeat the count every 2 months.
- As a variation you can use dung mass as an index:
- Establish a transect across the site and place quadrats 100 m apart or alternatively randomly place quadrats across site.
- Mark quadrat locations on a map and/or GPS or with a small post or peg.
- Collect pellets once a year and weigh (g per m^2) (Mutze *et al.* 2002).

Standards

Observer – use the same observer for each count.

Quadrats – use the same fixed quadrats for each count.

Frequency – repeat counts every 2 months.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

None

Table 6. Dung counts: example of a dung-pellet count sheet

Date:		Site:				Page of
Observer:					Quadrat size (m^2):	Quadrat shape:
Last rain: > 4 weeks ago, 4 weeks ago, 3 weeks ago, 2 weeks ago, 1 week ago, this week						
Quadrat no.	No. of pellets	Quadrat no.	No. of pellets	Comments		

Other rabbit signs

Other signs of rabbits can be used to monitor rabbit activity and abundance. These signs include tracks, bait station visitation and diggings. Counting tracks can be passive (animal behaviour is not altered by detection; e.g. by placing sand plots across a road or track) or active (animals are attracted by a lure, e.g. by using scent and bait stations). Track counts are used predominantly for elusive animals or those found in low densities, such as foxes (Saunders *et al.* 1995) and wild dogs (Fleming *et al.* 2001). Track counts using sand plots that are swept clean each day have been used successfully for rabbits where other more commonly used monitoring techniques were not feasible (Twigg *et al.* 2001) and may be useful in areas where vegetation or terrain make other counting methods difficult.

Bait stations can be used to monitor rabbit abundance by using free-feeding or toxic bait. Using free-feed stations can indicate where 'hotspots' of rabbit activity are, whereas monitoring toxic bait station activity will measure the efficacy of control programs.

Bait stations are portable and can be moved from one site to another as needed. However, a drawback to using bait stations is that relatively large proportions of rabbit populations are reluctant to enter bait stations (Twigg *et al.* 2002; Brown 2002).

Counting the number of rabbit diggings or scratchings along a standardised walk transect will also yield an index of abundance. Twigg *et al.* (2002) found this to be an unreliable index of changes in rabbit abundance, but they suggested that when this was combined with track counts a reliable index could be obtained, particularly in areas where other techniques were not practical.

Problems with using rabbit sign to monitor changes in abundance include the effects of weather, seasons and humans. Strong wind and rain can reduce the clarity of, or remove, tracks and diggings, making identification difficult or impossible. Rabbit activity may vary seasonally and with rabbit density, and the actions of humans may wipe out signs such as tracks (Williams *et al.* 1995).

Sand plots

Materials required

Vehicle – utility or vehicle with trailer

Sand – not required if the plot is situated in a sandy or dusty area

Shovel

Drag for sweeping the transect (e.g. steel bar)

Count sheet

GPS (if possible)

How to do the count

- Select sites to be monitored (e.g. roads or areas between refuge areas and known feeding areas.)
- Set routes (50–500 m, but the longer the better) and, if possible, physically mark out the transect (e.g. with posts with reflectors) so that future surveys can easily follow the same path. Once set out, this transect must be used for all further surveys so that valid comparisons with prior surveys can be made (fixed transect).

Sand plots made on used access ways. Check weather forecasts prior to setting up.

- Put down a thin layer of sand (1 to 3 cm deep) approximately 2 to 3 m wide across the entire width of the transect (not needed if the transect is naturally sandy/dusty) and sweep it smooth with a drag (e.g. a steel bar) towed behind a vehicle.
- Count and record all rabbit tracks the following day and then sweep clean again.
- Convert tracks recorded to number of tracks per 100 m.
- Repeat count for 3 consecutive days.

Standards

Route – use the same transect for each count.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

Identification of tracks

Non-toxic bait stations

Materials required

Vehicle – utility or vehicle with trailer

Portable bait stations – e.g. 200-L drum cut in half longitudinally with rabbit access holes cut into each end; the drum covers a 40-cm saucer with bait

Bait – e.g. oats or carrots

Portable fencing – to keep larger herbivores out of bait station

Sand – not required if plot is situated in a sandy or dusty area

Shovel, broom and drag

Count sheet

GPS (if possible)

How to do the count

- Select sites to be monitored and record locations on map (use GPS if possible).
- Set up bait stations.
- Enclose bait station in portable fencing to exclude livestock and other non-targets such as wallabies.
- Set up and mark a transect within 5 to 10 m of the bait stations and between the stations and rabbit refuge areas.

- Put down a thin layer of sand (1 to 3 cm deep) approximately 2 to 3 m wide across the entire width of the transect (not needed if the transect is naturally sandy or dusty) and drag the track with a chain to sweep it smooth.
- Count and record all rabbit tracks the following day and then sweep clean again.
- Convert tracks recorded to number of tracks per 100 m.
- Repeat count for 3 consecutive days.

Standards

Bait stations – set up as per standard operating procedures (see below).

Route – use the same transect for each count.

Animal welfare considerations

Impact on target animals – nil if non-toxic bait used

Impact on non-target animals – nil if non-toxic bait used

National Standard Operating Procedures for humane control and research

RAB002 *ground baiting of rabbits with 1080* (Sharp & Saunders 2005)

RAB003 *ground baiting of rabbits with pindone* (Sharp & Saunders 2005)

RES005 *measurement and sampling of pest animals used in research* (Sharp & Saunders 2005)

Training required

Identification of tracks

Diggings

Materials required

Count sheet (see example in Table 7)

Gardening trowel

GPS if available

How to do the count

- Select area to be monitored
- Randomly allocate a 200 to 500 m long transect through the site and if possible physically mark out the transect (e.g. with reflectors, GPS) so that future surveys can easily follow the same path. Once set out, this transect must be used for all further surveys so that valid comparisons with prior surveys can be made (fixed transect).
- Fill in all rabbit diggings within 2 m either side of the middle line.
- Walk the transect and count all the fresh diggings within a 4 m wide transect the following day. Fill in the fresh diggings.
- Record the diggings for each 100-m interval.
- At the end of the transect add the numbers of diggings together and divide by the number of sections to get an average figure per 100 m for the site.
- Repeat the count on 3 consecutive days.

Standards

Route – use the same transect for each count.

Observer – use the same observer(s) for each count.

Frequency – counts must be made on consecutive days.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

None

Table 7. Example of a diggings count sheet

Date:	Observer:																			Page of
Last rain: > 4 weeks ago, 4 weeks ago, 3 weeks ago, 2 weeks ago, 1 week ago, this week																				
Site:	Number of diggings by 100-m section average																			Comments

Live trapping

The use of live trapping to assess mammal population numbers has a long history and most often involves the capture, marking and then subsequent recapture of animals to estimate population size. Various mark–recapture methods are available and have been reviewed in detail elsewhere (Seber 1982; Pollock *et al.* 1990; Schwarz & Seber 1999; Buckland *et al.* 2000). All these methods make assumptions that should be satisfied in order to produce valid estimates. Assumptions common to all mark-recapture models are:

1. all animals have equal catchability (marked animals at any given sampling time have the same chances of capture as unmarked animals)
2. marked animals are not affected by being marked (in behaviour or life expectancy)
3. marks are not lost or overlooked (Krebs 1989; Southwood 1989).

Most models also assume that the populations are closed at the time of census (i.e. little/no immigration occurs).

There are also legal considerations in the use of mark–recapture (e.g. regarding the release of a declared pest animal such as the rabbit). Check the appropriate legislation in your State or Territory and seek approval from the relevant agency to carry out these types of studies. Furthermore, for many animals there are easier techniques to estimate abundance than mark–recapture, and these should be considered in the decision-making process (Krebs 1989).

The most common method of live-trapping rabbits is to use cage traps. These traps are generally made from wire mesh and use a floor-treadle mechanism to close the trapdoor. They vary in size (e.g. 600 × 200 × 200 mm) and are often collapsible for easy storage and transportation. Traps are set in a grid formation or around warrens (Southern 1940; Dunnet 1957a; Daly 1980; King & Wheeler 1985; Twigg *et al.* 1996; Forys & Humphrey 1997; Twigg *et al.* 1998b; Twigg & Williams 1999). Ferrets are sometimes used to drive rabbits from burrows and into nets (Cowan 1984; Cooke *et al.* 2002).

Trapping grids

The optimal grid formation is best determined by pilot study, as different studies have used varying layouts. Twigg *et al.* (1998) used 4 × 20 grids with a 20-m spacing between traps, whereas Forys and Humphrey (1997) placed traps in a 6 × 6 formation spaced 25 m apart. The number of traps used will also be influenced by the size of the area being monitored.

Materials required

Cage traps

People – at least two

Bait – diced carrots or oats

Identification tags for rabbits

Calico bags

Flagging tape to mark trap sites

Data sheet

Field note books

Monitoring using live capture rabbit traps

How to do the trapping

- Select site for monitoring and mark on a map (and GPS).
- Set out traps in grid formation.
- Leave traps closed for 2 or 3 days for habituation. You can pre-feed the rabbits with bait at this time.
- Place bait inside the traps and set the treadles (approximately 100 to 150 g [i.e. a handful] of carrot diced into 2-cm cubes, or an equivalent amount of oats).
- Cover the trap with a shadecloth.
- Check traps each morning for at least 4 days
- When a trap is found with a rabbit inside, release the animal into a calico bag for ease of handling.
- Mark the rabbit with a unique ear tag (or other unique mark) so that it can be identified if recaptured.
- Record the grid location, sex, breeding status, weight and age class (adult, kitten) of the animal
- Release the rabbit where it was captured.
- Leave traps closed during the day and reset them in the late afternoon, before dusk
- On subsequent mornings examine captured rabbits for tags or marks and record any recaptures. If the animal is unmarked, process it as above.
- After four or more trapnights remove and clean the traps.
- After completion of trapping determine a rabbit population estimate using methods such as a modified Petersen estimate, or a Schnabel, Schumacher, Burnham and Overton or Jolly-Seber method (Caughley 1977; Krebs 1989).
- Repeat trapping every 3 months.

Standards

None

Animal welfare considerations

Impact on target animals – carefully follow the standard operating procedures (see below) to ensure animal welfare is maintained.

Impact on non-target animals – carefully follow the standard operating procedures (see below) to ensure animal welfare is maintained, and immediately release any non-target animals caught. You may need a wildlife permit if large numbers of non-target animals are expected to be caught – or at least advise the relevant agency.

National Standard Operating Procedures for humane control and research

RES001 *live capture of pest animals used in research* (Sharp & Saunders 2005)

RES002 *restraint and handling of pest animals used in research* (Sharp & Saunders 2005)

RES004 *marking of pest animals used in research* (Sharp & Saunders 2005)

RES005 *measurement and sampling of pest animals used in research* (Sharp & Saunders 2005)

RAB008 *trapping of rabbits using padded-jaw traps* (Sharp & Saunders 2005)

Health and safety considerations

None

Training required

Trapping skills

Warren trapping of live rabbits

Materials required

Cage traps

People – at least two

Bait – diced carrots or oats

Identification tags for rabbits

Calico bags

Flagging tape to mark trap sites

Data sheet

Field note books

How to do the trapping

- Select warren for monitoring and mark on a map (and GPS).
- Set out traps around the warren.
- Leave traps closed for 2 or 3 days for habituation. You can pre-feed the rabbits with bait at this time.
- Place bait inside the traps and set the treadles (approximately 100–150 g [i.e. a handful] of carrot diced into 2 cm cubes, or an equivalent amount of oats).
- Cover the traps with shadecloth.
- Check traps each morning for at least 4 days.
- When a trap is found with a rabbit inside, release the animal into a calico bag for ease of handling.
- Mark the rabbit with a unique ear tag (or other unique mark) so that it can be identified if recaptured.
- Record the sex, breeding status, weight and age class (adult, sub-adult or kitten) of the animal.
- Release the rabbit where it was captured.
- Leave traps closed during the day and reset them in the late afternoon, before dusk.

- On subsequent mornings examine captured rabbits for tags or marks and record any recaptures. If the animal is unmarked, handle it as above.
- After four or more trapnights remove and clean the traps.
- After completion of trapping, estimate the rabbit population by using methods such as a modified Petersen estimate, or a Schnabel, Schumacher, Burnham and Overton or Jolly-Seber method (Caughley 1977; Krebs 1989).
- Repeat trapping every 3 months.

Standards

Trap at the same time and same place each session.

Animal welfare considerations

Impact on target animals – follow standard operating procedures (see below) to ensure animal welfare is maintained.

Impact on non-target animals – follow standard operating procedures (see below) to ensure animal welfare is maintained.

National Standard Operating Procedures for humane control and research

RES001 *live capture of pest animals used in research* (Sharp & Saunders 2005)

RES002 *restraint and handling of pest animals used in research* (Sharp & Saunders 2005)

RES004 *marking of pest animals used in research* (Sharp & Saunders 2005)

RES005 *measurement and sampling of pest animals used in research* (Sharp & Saunders 2005)

RAB008 *trapping of rabbits using padded-jaw traps* (Sharp & Saunders 2005)

Health and safety considerations

None

Training required

Trapping skills

Smeuse traps

Smeuse trapping is a modification of trapping around warrens. This technique uses rabbit-proof netting to enclose the warren with outlets (smeuses) with swinging doors allowing access for rabbits to and from the warren (Southern 1940; Dunnet 1957a; Twigg & Williams 1999; Cooke *et al.* 2002). When it is time to start trapping, the smeuses are converted to one-directional doors with traps attached to all exit points. Note that, because of animal welfare concerns, the use of smeuses is not always recommended.

Materials required

Cage traps or similar

Rabbit-proof netting

People – at least two

Identification tags for rabbits

Calico bags

Flagging tape to mark trap sites

Data sheet

How to do the trapping

- Select the warren for monitoring and mark it on a map (and GPS).
- Install rabbit-proof netting to enclose the entire warren.
- Set out traps at all smeuses.
- Cover the traps with shadecloth.
- Set and monitor traps for at least 4 days.
- When a trap is found with a rabbit inside, release the animal into a calico bag for ease of handling.
- Mark the rabbit with a unique ear tag (or other unique mark) so that it can be identified if recaptured.
- Record the sex, breeding status, weight and age class (adult, sub-adult or kitten) of the animal.
- Release the rabbit where it was captured.
- Remove traps during the day and reset them in the late afternoon before dusk.
- On subsequent mornings examine captured rabbits for tags or marks and record any recaptures. If the animal is unmarked, handle it as above.
- After four or more trapnights remove and clean the traps.
- After completion of trapping use dusk counts of rabbits on or near the warren (as described earlier) to determine changes in demography.
- Repeat trapping every 3 months.

Standards

Trap at the same time and same place each session.

Animal welfare considerations

Impact on target animals – follow standard operating procedures (see below) to ensure animal welfare is maintained.

Impact on non-target animals – follow standard operating procedures (see below) to ensure animal welfare is maintained.

National Standard Operating Procedures for humane control and research

RES001 *live capture of pest animals used in research* (Sharp & Saunders 2005)

RES002 *restraint and handling of pest animals used in research* (Sharp & Saunders 2005)

RES004 *marking of pest animals used in research* (Sharp & Saunders 2005])

RES005 *measurement and sampling of pest animals used in research* (Sharp & Saunders 2005)

RAB008 *trapping of rabbits using padded-jaw traps* (Sharp & Saunders 2005)

Health and safety considerations

None

Training required

Trapping skills

MONITORING RABBIT IMPACT

This section discusses the different methods that can be used to monitor the impact caused by rabbits. The summary tables at the end of this handbook summarise these methods and compare them with the methods of monitoring rabbit abundance discussed in the previous section.

Monitoring economic costs

Costs of control

The cost and/or effort involved with annual rabbit control can be used to show broad regional trends in rabbit abundance. Warren-ripping costs can be evaluated, and either the total cost or cost for the property (ha^{-1}) and the number of warrens ripped can be used as an index of rabbit abundance. This assumes that all rabbit warrens are located and destroyed. Other rabbit control strategies can be similarly monitored (e.g. the quantity of bait dispensed at a regional scale). Table 8 gives some examples of the costs of warren ripping.

Table 8. Examples of costs of warren ripping

Size of property	8500 ha	Warrens ripped h^{-1}	4.5
Size of area ripped	2054 ha	Total cost	$10 987.20
No. of warrens	872	Cost $warren^{-1}$	$12.60
Total hours	193.8	Cost ha^{-1}	$1.29

Other costs

It is difficult to estimate accurately the agricultural costs attributable to rabbits in Australia on a national, State or regional level (Bomford & Hart 2002). Conservative estimates have placed a monetary value of $113.11 million on the national annual cost impact of rabbits (McLeod 2004). However, this value is based on limited information that has been extrapolated from sources such as government agency estimates and landholder surveys, and it has been acknowledged that there are many gaps in the knowledge (Bomford & Hart 2002; McLeod 2004). Individual landholders may therefore play a significant role in filling these gaps by calculating and monitoring all the costs attributable to rabbits. These costs include control expenditure (as already discussed) and others such as poisoning or fumigating; infrastructure installation, inspection and maintenance (e.g. fencing); and changes in livestock and crop production output. These costs could be recorded as part of the economical management of a property; if so, there is little extra expense to the landholder. The inference that is made from cost monitoring is that a decline in costs is associated with a decline in rabbit abundance. Table 9 is an example of a sheet used to monitor other costs.

Table 9. Example of a sheet used to monitor other costs

ACTIVITY	LABOUR ……h @ $ h^{-1}	MATERIAL	COST $
Poison baiting		Vehicle @ $ km^{-1} Poison bait	
Fumigating		Vehicle @ $ km^{-1}	
Exclusion fence maintenance		Posts Wire	
Sheep productive output			

Monitoring rabbit damage: general information

The quantification of rabbit impact is generally difficult and costly and often requires a lot of time and scientific expertise. Examples of these are changes in total biomass of vegetation (Leigh *et al.* 1989; Parkes 2001; Croft *et al.* 2002) and wool production of sheep (Holmyard 1968; Fleming *et al.* 2002) at different rabbit densities. However, there are a number of more qualitative techniques that may be used to monitor the impact of rabbits. These methods include the use of exclosures, crop damage assessments, photopoints and stock equivalents. To be effective, damage assessment methods must be properly applied, with a realistic view of the amount of time involved, or the entire program will most likely be a waste of time. It would also be prudent to have someone with expertise in damage assessment appraise the project design (Wallace & Bartholomaeus 1997). Rabbit damage can also be recognised by observations made during the course of normal activities. These include: 40-cm-high grazing lines on shrubs; twigs cut through with chisel-like cuts; crops eaten out 50 m from warrens; scratching and soil disturbance; and weedy pastures (Williams *et al.* 1995). The development of simple and economical indexes of rabbit impact has been identified as an area requiring further research (Williams *et al.* 1995).

Using enclosures

Enclosure of known densities of rabbits has been used to study their effects on vegetation, with small exclosures sometimes used within the enclosures to delineate ungrazed and grazed areas. Myers & Poole (1963) placed varying densities of rabbits in 0.8-ha enclosures and recorded the changes in pasture species composition over a 2.5-year period. Pasture yield was demonstrated to decline by up to 25% at a density of 25 to 50 rabbits ha^{-1}, and the numbers of weeds and unpalatable grasses increased. Rabbit grazing pressure on the survival of four species of Acacia seedlings was examined in enclosures and was shown to considerably limit the recruitment of these plants in the absence of stock in the Australian arid zone (Lange & Graham 1983). A criticism of using enclosures has been the lack of statistical analysis applied to interpreting the results of many studies (Hone 1994). Examples of more robust and informative designs include the study by Croft *et al.* (2002), who used a randomised block design with replication of four different densities of rabbits to investigate the effects of these herbivores on the composition, cover and productivity of an improved pasture and the changes in these parameters over time (3 years). Other research in the United Kingdom used known densities of rabbits in enclosures, combined with randomly situated exclosures erected at different time intervals, to assess the grazing impact of rabbits (Bell *et al.* 1998; Dendy *et al.* 2003).

Enclosures have also been used to examine the impact of rabbits on wool production in sheep. Fleming *et al.* (2002) demonstrated that the relationship between rabbit density and wool production was not a simple linear function. This study was completed in conjunction with the work of Croft *et al.* (2002), using the same design (i.e. replicated plots with rabbits at four different densities with constant sheep density), and found that high rabbit abundance (72 rabbits ha^{-1}) negatively affected wool production and sheep live weights. Conversely, there was evidence that lower densities of rabbits had beneficial effects. Fleming *et al.* (2002) concluded that the long-term effects of rabbits on sheep production and the replacement of rabbits with the equivalent biomass in sheep need to be examined before direct replacement can be recommended.

Using exclosures

Exclosures are generally small fenced areas designed to selectively exclude herbivores by body size. They can be used to examine the damage and losses caused to crops as well as the grazing effect on vegetation over time, and they are useful for showing the effects of total grazing pressure. They may also be valuable seed reservoirs for plant species that are not regenerating in the face of grazing pressure. Rabbit impact is determined by the differences in vegetation composition and damage between exclosures that are ungrazed, are grazed only by rabbits, and/or are grazed by all herbivores (Wallace & Bartholomaeus 1997). Problems with this technique are that: the impacts of grazing insects cannot be measured; rabbits have a tendency to graze selectively where stock are excluded (Grice & Barchia 1992); evidence of the effects of grazing is environmentally dependent and may take a long time to become apparent (Bridle & Kirkpatrick 1999); and plant composition may be more greatly influenced by other factors such as rainfall in arid and semi-arid areas (Foran *et al.* 1985). As a result, using exclosures to interpret the impacts of different herbivores may be beyond the resources of most monitoring programs (Williams *et al.* 1995).

The exclusion of rabbits requires the incorporation of underground fencing (to a depth > 20 cm) into the exclosure design to eliminate entry via burrowing activity. The number and size of exclosures depends on the desired outcome of the study. The size varies from 2 × 2 m (e.g. for crop damage assessment) up to 4 ha (Cochrane & McDonald 1966; Foran *et al.* 1985; Cooke 1987; Wheeler and Nicholas 1987; Crawley and Weiner 1991; Grice and Barchia 1992; Grice and Barchia 1992; Copson and Whinam 1998; Bridle and Kirkpatrick 1999; Allcock and Hik 2004). Pasture damage assessment usually involves excluding larger areas (e.g. 1 ha) and comparing total biomass or changes in plant composition. Crop yield losses can be assessed by using small exclosures within a crop.

Monitoring changes in herbage mass

Accurate estimates of herbage mass can be achieved by clipping all vegetation at ground level inside randomly located quadrats (e.g. 0.5 m2) within an experimental plot (e.g. an exclosure). The samples are pooled for each plot, oven-dried and then weighed. The dry-weight from an exclosure can then be compared with those of samples from outside the exclosure and the vegetation loss estimated using the formula:

$$\% \text{ loss} = \frac{(\text{weight of inside exclosure sample} - \text{weight of outside exclosure sample}) \times 100}{\text{weight of inside exclosure sample}}$$

Alternatively, herbage mass can be used to assess the effect of rabbit control measures by using before and after control measurements. There are several methods available for estimating herbage mass, with the most accurate being destructive sampling methods such as the median quadrat technique (see below). However, these techniques involve a laborious process, and other methods that are more simple to conduct may be more appropriate for landholders. Examples of these are calibrated visual assessments such as the comparative yield method used with photostandards (see below) (Haydock & Shaw 1975; Friedel & Bastin 1988).

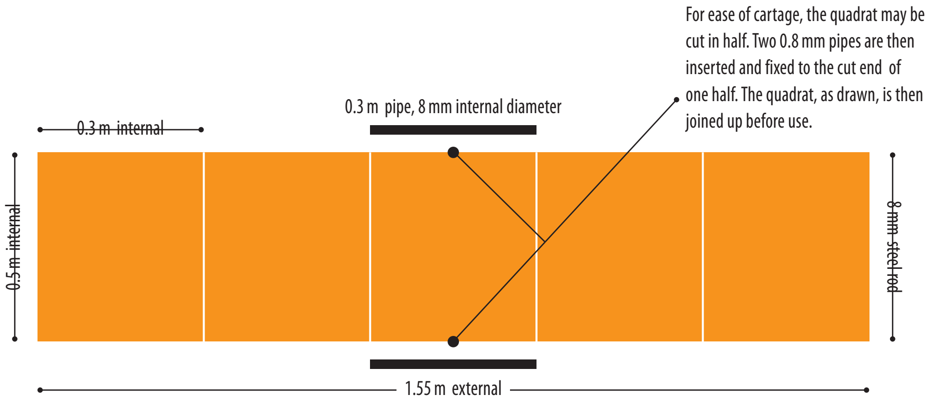

Figure 1: Median quadrant design (Allen & Bell 1996)

Median quadrat technique

(adapted from Prograze: Profitable, Sustainable Grazing (Allen & Bell 1996))

Materials required

1 median quadrat – 1.55 × 0.5 m. These dimensions need to be applied accurately in order for the calculations used to work properly (see Figure 1).

Shears – hand- or battery-operated

Plastic bags

4 marker pegs

Fan-forced or microwave oven

Scales – capable of measuring to a gram, but a balance scale that measures to the nearest 0.1 g is preferable

Tweezers or forceps

Pen and paper

How to do the count

- Select the area of pasture to be monitored (approximately 30 × 30 m). The area selected should represent average yield (herbage mass) and composition (green, dead, legume and weed) of the whole paddock.
- Mark the corners of the area boundary with pegs.
- Walk a set number of paces (e.g. 10) inwards from the edge of the area and place the quadrat at your toe. Vegetation that has been bent over by the quadrat should be straightened.
- Choose the median subquadrat by determining and omitting the two highest-yielding and two lowest-yielding subquadrats by eye. Clip all vegetation within the remaining subquadrat (median) to ground level and store in a plastic bag. Discard stones, dirt and faeces from the sample.
- Starting from the cut area, change direction and repeat the previous two steps until 10 subquadrats have been clipped (when the boundary of the selected area is reached, turn 90°, turning back into the area, and continue pacing).
- Record the weight of herbage in each bag to the nearest 0.1 g (or nearest gram if this is not possible), ensuring that the weight of the bag is not included. Calculate the average weight of the cut quadrats and record on a data sheet (see Table 10).
- Combine the clipped vegetation from all bags and thoroughly mix until it appears uniform throughout. Split the vegetation into four equal amounts. Discard two diagonally opposite portions. Recombine the remaining two portions.
- Repeat this step until a sample equal to one that could be heaped onto a large dinner plate (approximately 150 g) remains.

Table 10. Median quadrat technique: herbage mass data sheet (Allen & Bell 1996)

HERBAGE SAMPLING

OBSERVER	**DATE**	
PADDOCK NAME	**QUADRAT NUMBER**	**WET WEIGHT (g)**
NOTES	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	TOTAL	
	AVERAGE WET WEIGHT	

DRY MATTER % CALCULATION

Weight of container (g)	
Weight of wet sample (g)	
TOTAL (G)	
DRYING TIME IN OVEN	Container (g)
	Dry weight (g)
DM% = weight of sample dry (g) ÷ weight of sample wet (g) × 100 =	

- To estimate the pasture dry matter percentage (DM%), first record the weight of the sample. Then place the sample in a fan-forced oven for at least 24 h at 70°C (i.e. until the weight of the sample is constant). Alternatively, a microwave oven can be used:
  - place the sample on a microwave dish in the oven, along with a cup of water. Refill the cup if the water level gets too low.
  - set the microwave to maximum power for 5 minutes
  - weigh the sample, turn it over and loosen it (the sample tends to compact while drying)
  - repeat the previous two steps until the weight remains constant at successive weighings. As the sample becomes dry, 1-minute intervals in the microwave are recommended.
- To calculate the dry matter percentage, use the following formula:

  $$\text{DM\%} = \text{weight of sample dry (g)} \div \text{weight of sample wet (g)} \times 100$$

- To estimate herbage mass (kg DM ha^{-1}) for the sample area, first multiply the average weight of herbage (calculated earlier) by the DM%:

  $$\text{Herbage mass (kg DM ha}^{-1}\text{)} = \text{average wet weight (g)} \times \text{DM\%} \times 67$$

  For this formula to be appropriate, the dimensions given for the median quadrat must be followed accurately.
- To obtain an estimate of pasture composition (% legume, % green and % dead) use the oven-dried sample. If the sample is significantly larger than an open handful, it can be reduced by using the technique described earlier. Sort the sample into fractions of interest, usually 'green legume', 'dead legume', 'other dead' and 'other green'. Tweezers or forceps are useful for the sorting process.
- An estimate of each pasture component's contribution to the paddock dry matter can be made by weighing each fraction to determine the percentage and yield (kg DM ha^{-1}) of each component.

Standards

Median quadrat – construct the quadrat to the specified dimensions and use for all quadrats.

Sampling area – use the same area(s) for subsequent monitoring efforts.

Sampling timing – sample vegetation at the same time each year.

Animal welfare considerations

None

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

Take care when using shears to clip vegetation.

Training required

Use of quatrats

HERBAGE MASS

Herbage mass (kg DM ha^{-1}) = average wet weight (g) × DM% × 67

PASTURE COMPOSITION

COMPONENT	DRY WEIGHT (g)	PERCENTAGE OF TOTAL	HERBAGE MASS (kg DM ha^{-1})
Green legume			
Green grass			
Green other			
Dead legume			
Dead other			
TOTAL			
TOTAL LEGUME			
TOTAL GREEN			
TOTAL DEAD			

Comparative yield technique

Materials required

1 quadrat – 1 × 1 m. These dimensions need to be the same as those used for quadrats in photostandards (see below).

50 pegs to mark sampling points

Pen and paper

For reference photostandards:

Camera

Shears – hand- or battery-operated

Plastic bags

Fan-forced or microwave oven

Scales capable of measuring to a gram, but a balance scale that measures to the nearest 0.1 g is preferable

How to make reference photostandards

- Select monitoring sites (suggested size of individual sites is 2 ha).
- In an area next to, or close to, the study site, select five quadrats that will be used to create reference photostandards to assess estimates in the sample site. The first reference should be a quadrat that is an area of low yield (ref. 1) and the second should be taken from a high-yield area (ref. 5). Next find an area that is halfway between the yield of 1 and 5 (ref. 3). Similarly, find areas that are between 1 and 3 (ref. 2) and 3 and 5 (ref. 4).
- Place the quadrat within the selected areas and take photos to be used as reference standards. Take oblique and vertical photographs of each area (refs. 1–5).
- Clip, dry and weigh the vegetation, as discussed for the median quadrat technique.
- Allocate the dry matter (DM) weight of each reference with the corresponding photograph (e.g. ref. 1 = 100 g DM, 2 = 165 g DM, etc.)

How to do the count

- Divide the monitoring site evenly so that there are 50 sampling points (e.g. a site 100 × 200 m would have a grid of 5 × 10 points spaced 20 m apart).
- Drive pegs into the ground to permanently mark sampling points.
- Place quadrat over the pegs and compare the vegetation within the quadrat with the reference photostandards. Allocate the appropriate photostandard number to the sample point. If the vegetation yield is in between the photostandards use increments of 0.5.
- When the grid is completed, calculate the average yield for the monitoring site:

  Herbage mass (kg DM ha^{-1}) = average wet weight (g) × DM% × 10

  This yield will work only if the quadrat size is 1 m^2.

Standards

Quadrat – use the same size quadrat for each sampling point.

Sampling point – use the same sampling points for comparative assessments.

Reference photos – use the same camera for each reference and use the reference photostandards for subsequent assessments.

Observer – use the same observer(s) for each sampling effort.

Animal welfare considerations

None

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

Prograze®

Monitoring changes in vegetation cover and composition

Rabbits can alter the diversity of vegetation by selective grazing, browsing or ringbarking and by overgrazing in general. Also, the regeneration of many species is limited by this behaviour and it has facilitated the invasion of exotic species and increases in the density of 'woody weeds' in some areas (Williams *et al.* 1995). Vegetation composition is an important component of landscape management, particularly in grazing land where knowledge of the make-up of a pasture can help with decision-making. The most often used methods for estimating pasture composition are the median quadrat technique (Allen & Bell 1996) (Tothill *et al.* 1992) (see above) or a point method, of which there are a few variations (Tothill *et al.* 1992; Forge 1994; Allen & Bell 1996; Buckley 2003). The median quadrat technique requires a quantity of vegetation to be clipped, dried and separated into categories and is carried out in conjunction with biomass estimation (see the 'Monitoring changes in herbage mass' section above). This process is time consuming and does not record any details of bare ground. Point methods are quick and simple techniques that require little training and also provide information on the proportion of bare ground. The basic idea behind point methods is to randomly throw a stick onto the ground, recording the vegetation type or bare ground that the ends of the stick are touching. Alternatively, walking a set number of steps and recording what is at the toe of your boot can be used. The process is repeated 50 to 100 times throughout a paddock and a proportional representation of vegetation is then determined.

Point method

(adapted from Buckley 2003)

Materials required

'*Wingdinger*' – a simple cross with cross-members approximately 50 cm long lashed together. The material can be fibreglass electric fence droppers, small-diameter dowel, or any similar material that is lightweight. Paint (or mark) each end a different colour to help with the recording process.

Data sheet and pen/pencil

How to do the count

- Select the paddock or area that is to be monitored and divide the area up into a grid so that at least 50 points are available.
- Use the approximate distance between each point to determine the number of steps that need to be taken between each sample. For example, the paddock to be monitored is approximately 300 × 600 m and it has been decided that there will be 75 sampling points. This means that along the longer length of paddock there will be 15 rows of points spaced approximately 40 m apart and 5 rows on the shorter length spaced 60 m apart to give a grid of 75 points.
- Estimate the number of steps that will be taken in between these points, to use as a guide when doing the count.
- Walk along the chosen path and stop at the required number of steps. Throw the wingdinger a short distance forward.
- Record the pasture component touched or directly below each of the four points of the wingdinger (see Table 11).
- Walk to the next point and repeat the process until all points are recorded.
- Calculate the pasture composition. The total hits for each vegetation component divided by the total number of hits gives the percentage of each component in the pasture.

Standards

Sampling time – monitor vegetation at the same time each year (e.g. in early winter when ground cover is established but pasture is not tall).

Number of sampling points – use the same number of sampling points when comparing a site between years.

National Standard Operating Procedures for humane control and research

None

Table 11. Point method: example of a data sheet

SITE				
OBSERVER				**DATE**
Key: bare ground (B), improved grass (IG), clover (C), weed (W), annual grass (A), dead pasture (D)				
SAMPLE	**RED POINT**	**WHITE POINT**	**BLUE POINT**	**YELLOW POINT**
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Health and safety considerations

None

Training required

Vegetation identification

Step point method

(adapted from Forge 1994)

Materials required

3 star pickets

Data sheet and pen/pencil

How to do the count

- Select the paddock or area that is to be monitored and place a transect that is approximately 300 m long across the paddock. The transect can be randomly placed for large paddocks. It may be easier to use a triangular transect (especially in smaller paddocks).
- Drive star pickets into the ground at the beginning, middle and end of the transect to use as permanent markers.
- Walk along the chosen path and take recordings at every pace. Look straight ahead while placing your feet to limit bias.
- Record the ground cover and species touched or directly in front of the point of your boot (see Table 12). If a plant is pushed over by the point of your boot, record the ground cover that is being obscured (i.e. what the point of your boot would be touching if the plant hadn't been pushed over).
- Take another pace and repeat the process until the transect is completed.
- Calculate the ground cover and composition.

Standards

Sampling time – monitor vegetation at the same time each year (e.g. in early winter when ground cover is established but pasture is not tall)

Transect – use the same transect when comparing a site between years.

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

Vegetation identification

Table 12. Step point method: example of a data sheet

<table>
<tr><td colspan="5">SITE</td></tr>
<tr><td colspan="3">OBSERVER</td><td colspan="2">DATE</td></tr>
<tr><td colspan="2">GROUND COVER</td><td>COUNT</td><td>SUB-TOTAL</td><td>%</td></tr>
<tr><td colspan="2">Grass or herbage</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Woody plant (tree or shrub)</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Litter (fallen leaves, sticks, manure, rocks)</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Bare (not covered by any of the above)</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Groundcover % = sub-total ÷ total × 100</td><td></td><td>TOTAL</td><td>100</td></tr>
<tr><td colspan="2">SPECIES COMPOSITION</td><td>COUNT</td><td>SUB-TOTAL</td><td>%</td></tr>
<tr><td rowspan="6">KEY SPECIES</td><td>1.</td><td></td><td></td><td></td></tr>
<tr><td>2.</td><td></td><td></td><td></td></tr>
<tr><td>3.</td><td></td><td></td><td></td></tr>
<tr><td>4.</td><td></td><td></td><td></td></tr>
<tr><td>5.</td><td></td><td></td><td></td></tr>
<tr><td>6.</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Groundcover % = sub-total ÷ total × 100</td><td>TOTAL</td><td>100</td></tr>
</table>

Monitoring crop yield/seedling loss

Assessing the impact of rabbits on crop yield involves the installation of small exclosures immediately after seeding to compare protected and unprotected areas. Problems with this technique include the potential effects of the fencing on the crop because of changes in sunlight, humidity and wind flow. This can be partly overcome by sampling only from the centre of the exclosure. However, the fencing also provides perching sites for birds that will potentially increase the rate of bird damage to the protected area.

Using exclosures to monitor crop yield and seedling loss

Materials required

4 star pickets or similar per exclosure (3 or more exclosures per crop)

Rabbit netting

Fencing wire

Shovel and post driver

Exclosure construction

- Construct exclosures immediately after you finish sowing the crop/planting seedlings.
- Place exclosures at intervals of 10, 20 and 50 m from the edge of the crop (if possible construct two exclosures at each distance for replication).
- Each exclosure should be the same size (e.g. 2 × 2 m.)
- Drive posts into ground in a square formation and put fencing up so that it is buried to approximately 0.2 m. Alternatively, the bottom 0.2 m can be folded onto the ground with rocks placed on top of it to keep it in place and stop rabbits digging under.
- Secure the fencing with wire between the posts and ensure that the construction is rabbit proof.

Standards

None

Animal welfare considerations

None

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

Prograze®

Using transects to monitor damage

Assessing crop damage

Crop damage can be assessed by using transect plots. Small quadrats are placed along a transect within a crop and the number of stalks and average head length of the grain used to compare damaged and undamaged areas (Wallace & Bartholomaeus 1997). Rabbits usually damage the periphery of crops rather than the interior, but other factors (e.g. microclimate) may also reduce productivity on crop edges (Williams *et al.* 1995). Therefore, one problem with this measure of crop damage is that microclimatic effects are ignored, making it difficult to obtain reliable measurements of rabbit damage.

Materials required

Circular quadrat (0.5 m^2) – polythene pipe 2.5 m long connected with a socket will give a circle the correct size.

Small tape measure or ruler

Count sheet, clipboard and pencils

How to do the count

- Systematically place transects in the crop selected for monitoring (use at least three transects).
- Randomly allocate quadrats along the transect in damaged areas and undamaged areas (at least three in each).
- Count the number of stalks and measure the average head length of the grain in each plot.
- Multiply the two figures together in each plot.
- Average the multiplied figure for all plots in the damaged area.
- Repeat the process for the undamaged area.
- Calculate the percentage damage:
  % damage = damaged figure ÷ undamaged figure × 100

Standards

Quadrat size – use the same quadrat size for all counts.

Animal welfare considerations

None

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

Prograze®

Assessing forestry plantation damage

The impact of rabbits on forestry operations can be assessed by comparing plantations with and without rabbit control or before and after control measures are undertaken. Transects are established, with seedlings labelled and checked for damage at regular intervals. A serious problem with this method is the difficulty of determining the cause of damage. There may be many animals that could be responsible for damage such as browsing, uprooting, trampling and bitten-off stems that are left uneaten (e.g. wallabies, rabbits, hares, possums, pigs, birds, insects, goats). Before and after control, monitoring may give an indication of the damage that rabbits had been causing. In New Zealand, damage and mortality of seedlings was shown to cease after rabbit control was undertaken, suggesting that they were the primary cause of damage (Gillman & Ogden 2003).

Materials required

Plastic labels/tags

Plastic-coated wire (green or brown)

Count sheet, clipboard and pencils

How to do the count

- Select the plantations that are to be monitored and randomly place transects 100 to 300 m long across the area.
- Immediately after planting, attach individually marked labels with wire to each seedling so that the labels lie flat on the ground and are approximately 10 cm away from the stem.
- Return every 6 weeks to examine and record the condition of seedlings (e.g. undamaged; damaged – litterfall; damaged – browsed; damaged – uprooted; damaged – trampled; damaged – bitten off; damaged – other such as disease, frost).

Animal welfare considerations

None

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

None

Training required

None

Photopoint monitoring

Photopoint monitoring is useful for providing a visual record of the change in both vegetation density and composition (Wallace & Bartholomaeus 1997). Photopoints consist of permanently marked sites that will allow identical, repeated pictures to be taken of the same piece of vegetation over time. Photographs can be compared biannually and over years to obtain a good impression of changes that are occurring, for example, as a result of rabbit control (Mutze 1991; Sandell 2001). Photopoints should be established to record different vegetation types (often related to landforms). This simple monitoring method is much quicker and requires less training than laborious scientific techniques such as total biomass. More advanced methods of photopoints using digital images and computer software packages have been developed (Roshier *et al.* 1997; Paruelo *et al.* 2000), but these may be presently beyond the scope of most monitoring studies. However, they should prove to be useful for large (e.g. regional) scale monitoring. Remote sensing may also be used in the future for similar purposes.

Materials required

Camera

Star picket (1.8 m)

50 × 50-mm wooden stakes (300 mm long)

Post driver and sledge hammer

GPS

How to do the count

- Select sites to be monitored.
- Drive a star picket into the ground to a height suitable for supporting the camera (e.g. 1.5 m).
- Mark the post with an identification tag.
- Drive the wooden stake 150 mm into the ground 10 m away from the star picket.
- Although it is not essential, locating photopoint posts north/south is beneficial as it avoids direct sunlight in the shot: taking the photo facing south prevents glare. If this is difficult to do, careful selection of the time of day when you choose to take the photo will avoid sun glare in the picture.
- Take a photograph with the camera resting on the star picket.
- The wooden stake is used as the focal point (it should be in the centre of the photograph).
- Ideally, photographs should be taken at each photo plot twice a year: one in autumn (before rain if possible) and one in spring when many plants are flowering.
- Record any relevant information (e.g. site location, seasonal conditions, estimate of rabbit abundance).

Standards

Camera – the same camera and lens should be used and where possible, by the same photographer.

Lens – if it is not possible to use the same camera, the same-sized lens must be used. It is best to use a 50-mm fixed lens. Be wary of using zoom lenses, as they may not be set to the same focal length (e.g. 50 mm, 70 mm). If digital cameras are used, zoom out to the full extent to maintain a standard focal length.

Animal welfare considerations

None

National Standard Operating Procedures for humane control and research

None

Health and safety considerations

Take care to prevent injuries when driving star pickets and wooden stakes into the ground.

Training required

None

Estimating dry stock equivalents

Comparing rabbits as dry stock equivalents (DSEs) to sheep or cattle in terms of biomass consumed is a popular measure of rabbit impact. In order to estimate the rabbit equivalent to one sheep, for example, the amount of food the average rabbit and sheep (50 kg wether maintaining a constant weight; Davies 2004) eats must be calculated. From these figures it is then possible to estimate how many rabbits will eat as much as one sheep by dividing the amount a rabbit eats by the amount a sheep eats (Wallace & Bartholomaeus 1997).

Dry Stock Equivalent = amount stock eats ÷ amount rabbit eats

The ratio of rabbits per sheep equivalent has been estimated between 7 and 16 rabbits per dry sheep equivalent (Myers & Poole 1963; Short 1985; Croft 1986), with subjective estimates of 10 to 12 most often quoted (Saunders *et al.* 2002). The ratio for cattle has been estimated at 100 rabbits per dry cow equivalent (Foran *et al.* 1985). Estimates of DSE are influenced by factors such as stock breed, pasture and environment, weather conditions and breeding condition of rabbits. Therefore, if rabbit density on a property has been assessed, it is then possible to obtain an estimate of the amount of lost production. It must be noted that this assumes that all pasture consumed by rabbits would be available to increase the number of livestock carried (Choquenot 1992). However, if rabbit density is reduced, total grazing pressure may not have a corresponding reduction, as other herbivorous competitors (e.g. kangaroos, goats, pigs) may be present. Also, rabbits will not always eat the same food as livestock. There is evidence from the Western Division of NSW that competition between rabbits and sheep is low until pasture biomass falls below 250 kg ha^{-1} (Short 1985; Williams 1991). Therefore, DSEs are probably only a useful method of calculating lost stock income where feed is in low supply (Wallace & Bartholomaeus 1997).

Comparing stock returns

This method compares stock returns before and after control measures to reduce rabbit density. There are other factors that may affect production and need to be corrected for, such as weather sequences, changes in management practices and changes in the population densities of other wild herbivores (Williams *et al.* 1995). This method would be accurate only if untreated control areas were established for comparison, but these are expensive to maintain. There is also the problem of recolonisation of the treated sites by rabbits from the control site. This is an impractical measure of rabbit impact that can produce results open to interpretation, and as such is not recommended.

Monitoring native animal abundance

Rabbits compete with native animals directly for food and shelter and have been implicated in the decline and extinction of many of Australia's small terrestrial mammals in the critical weight range (CWR) of 35 to 5500 g (Burbidge & McKenzie 1989; Environment Australia 1999). There is also evidence for rabbits limiting the distribution and abundance of larger marsupials and birds (Martin & Sobey 1983; Priddell 1991; Bridgewater & Potter 1993; Mutze & Cooke 1998). It is very difficult to demonstrate the existence of competition between species and measure its effect: the only way to clearly demonstrate this is to conduct rabbit removal experiments. Therefore, it might be more appropriate to monitor such things as threatened species abundance or numbers of breeding pairs and active nests. You can then combine the results with rabbit abundance count data before and after control operations and look for trends to determine the success or other of the rabbit control. For example, seabird nesting has been observed to improve following the eradication of rabbits from islands (Martin & Sobey 1983), and in north-western Victoria the density of kangaroos increased dramatically after successful rabbit control (Bridgewater & Potter 1993). However, this case highlights the complexity of interactions between feral and native animals: the aim of this project was to reduce grazing pressure on native vegetation and facilitate the reintroduction of plant and animal species. The kangaroo density increased to such a point that there was no discernible difference between grazing pressure in areas with and without rabbit control.

Feral predator management (especially foxes and feral cats) also needs to be undertaken in conjunction with rabbit control if the aim of the project is to promote the conservation of native fauna species. Rabbits can support high numbers of these predators and thus put stress on native animal populations, especially if they are in low numbers. Declines in the density of rabbit populations may lead to increased predation pressure on native animals (prey-switching) (King *et al.* 1981; Catling 1988; Dickman 1996; Newsome *et al.* 1997; Norbury 2001; Corbett 2001). However, this may be a short-term problem: the number of foxes and cats decreased substantially 6 to 10 months after the successful introduction of rabbit haemorrhagic disease (RHD) to the Flinders Ranges, and total predation on native fauna is considered to have declined (Holden & Mutze 2002). An example of the complex relationships between rabbits, predators and native fauna can be found with the malleefowl *Leiopa ocellata*, which is endangered in NSW. Malleefowl have shown little recovery after predator control (Priddell 1991), with competition for food with rabbits a likely cause (Frith 1962). Thus it is often necessary to implement integrated management to make sure the outcomes of conservation management projects are realised and that focusing on one aspect does not lead to increases in other pressures.

Soil erosion monitoring

The rabbit has been implicated as a causal agent of soil erosion by removing vegetation and not allowing regeneration, leaving soil open to erosive forces (Cochrane & McDonald 1966; Gillespie 1981; Friedel 1985; Leigh *et al.* 1987; Norman 1988; Scott 1988; Williams *et al.* 1995). A more direct cause of erosion is the construction and expansion of warren systems. The process of warren excavation is continual, resulting in extensive undermining and soil disturbance in the vicinity of the complex (Parer *et al.* 1987; Myers *et al.* 1994). In semi-arid Australia, the soils around warrens are notable for their lack of cryptogamic crusts (layers of plants such as lichens and mosses), which stabilise the soil surface against water and wind erosion (Eldridge & Myers 2001). Furthermore, they facilitate the proliferation of exotic weeds over native perennials (Eldridge & Simpson 2001). However, on Macquarie Island, the status of the rabbit as an agent of erosion has been called into question: its contribution to land instability is suspected to have been overrated in the past (Selkirk *et al.* 1983; Scott 1988), and in central

Australia no significant correlation between soil erosion and warren density has been found (Friedel 1985). Conversely, a close relationship between high rabbit density and soil erosion was demonstrated in the Flinders Ranges (Greenwood *et al.* 1989). Despite these inconsistent results, there has been little quantification of the effects of rabbits on erosion, and this is an area of rabbit impact that requires further investigation. Until a monitoring system is devised that is shown to be suitable for the relationship between rabbits and soil erosion, short-term impact monitoring can be achieved by using abundance estimates (e.g. spotlight counts). The assumption is that any decrease in rabbit abundance will be associated with an increase in soil stability and vegetation regeneration (i.e. less erosion). An approach to longer-term monitoring of the effectiveness of rabbit control in halting erosion would be to use photopoints to examine the same areas of land over time. The difficulty with attempting to monitor the success of rabbit control in relation to soil erosion is that the land may be degraded to such a point before control operations that the cessation of erosion may not be possible without remedial action (e.g. tree planting) taking place. Therefore, another way to monitor the impact of rabbits is to keep records of the amount of effort (e.g. labour, materials) put into restoration of degraded land or (if no restoration is undertaken) the amount of land that is unusable due to loss of vegetation or erosion.

Mapping rabbit damage and population densities

Mapping the distribution of rabbit damage and density over a given area (e.g. individual property or region) facilitates the development and assessment of land and rabbit management plans (Williams *et al.* 1995; Wallace & Bartholomaeus 1997). Regular updating of these maps allows for the modification of existing management plans. These maps can be as simple as hand-drawn property charts, or as complex as more detailed and accurate topographic maps or computerised maps generated with GIS software. The choice of map type will depend largely on the scale of the area involved, the cost and availability of the technique, and the extent of the rabbit problem (Williams *et al.* 1995). For example, in NSW a rough outline of where rabbits occur can be circled on a property map by RLPB staff during a property inspection or by the land manager. The map can then be refined to include priority warrens, small warren complexes, and feeding grounds, with codes for population density. Probable trail lines, priority numbering and timing, as well as possible control techniques should also be suggested. These maps can be used as part of the overall property management plan and to assess progress over the years. At a larger scale, the NSW Department of Primary Industries has surveyed NSW Rural Lands Protection Boards and NSW National Parks and Wildlife Rangers to develop State-wide maps of pest species distribution and abundance (West & Saunders 2003). These GIS-generated maps are currently being updated to determine any changes in density of these species (P. West, pers. comm.).

Information to include on maps is:

- scale and north (magnetic/grid)
- name and location of property
- size of property
- property boundaries, permanent fences, gates, and roads
- topographic features such as watercourses, hill contours, rock outcrops
- vegetation other than pasture/crop (e.g. woodland, shrubland)
- warren locations and the ratio of active holes to the total number of holes (e.g. 9/14 (9 active holes from a total of 14 holes)
- size of warren
- other rabbit abundance estimates (e.g. spotlight indexes)
- areas of damage, with a scale of damage (crops damaged, areas that lack regeneration of vegetation)
- type of agricultural or other activities on this and adjoining properties
- harbour (e.g. blackberry, fallen logs)
- rabbit feeding locations.

It is important to make new maps with each new assessment. In this way new maps can be compared (or overlayed) with the previous map to evaluate the current management. If damage occurs in areas close to rabbit infestations (as determined from warren locations and abundance monitoring), then it is reasonable to assume that rabbits are causing the damage and management practices need to be adjusted accordingly. Conversely, if damage is occurring in areas away from rabbit infestations, it is likely that other species are the cause (e.g. wallabies, birds, grasshoppers).

SUMMARY OF RABBIT MONITORING TECHNIQUES

The various rabbit abundance and impact monitoring techniques discussed in this manual, and their advantages and disadvantages, are listed in Table 13. Table 14 compares the different monitoring techniques.

Table 13. Advantages and disadvantages of the monitoring techniques discussed in this manual

MONITORING TECHNIQUE	ADVANTAGES	DISADVANTAGES
Vehicle spotlight counts	• quick and simple • suitable for large properties • generally accurate • cost-effective	• counts can be highly variable between observers unless standard methods are used • sightability can be affected by height of pasture, vegetation or habitat type • unreliable method in wet and windy conditions • can be difficult to compare counts between variable weather conditions
Headlight counts	• quick and simple • can be done by one person	• counts can be highly variable between observers • sightability can be affected by height of pasture, vegetation or habitat type • unreliable method in wet and windy conditions • difficult to compare counts between variable weather conditions • not very accurate unless done by experienced operators
Walked spotlight counts	• quick and simple • can be done by one person • suitable for small properties/areas • helps locate rabbit feeding grounds for poisoning	• counts can be highly variable unless the observers are highly experienced • sightability can be affected by height of pasture, vegetation or habitat type • unreliable method in wet and windy conditions • difficult to compare counts between variable weather conditions unless operators are experienced
Distance sampling	• quick and simple • suitable for large properties • produces relative rabbit density	• counts can be highly variable between observers • sightability can be affected by height of pasture, vegetation or habitat type • unreliable method in wet and windy conditions • difficult to compare counts between variable weather conditions • extra training required • may not be suitable for use in many Australian conditions
Warren counts	• reliable measure • indicates long-term rabbit-proneness and infestation • can estimate total rabbit abundance per land type • warren ripping costs can be estimated	• may require specialist help (implementation of assessment and calculations) • warrens may be difficult to detect in sand-dune areas during drought • impractical in areas where rabbits use few or no warrens

MONITORING TECHNIQUE	ADVANTAGES	DISADVANTAGES
Active entrance counts	• quick and simple • can be done at any time of day • can estimate total abundance of rabbits • reliable for individual observers • can estimate the effectiveness of control • can provide evidence of recolonisation	• prolonged dry weather and heavy rain affect count • difficult to compare between observers—experience required • impractical in areas where rabbits use few or no warrens
Counts of rabbits on or near warrens	• useful where transect counts are not possible • suitable for small properties or small areas of infestation	• time-consuming—use only as a last resort
Dung counts	• can be done in areas where rabbits do not use warrens • limited effect of wind, temperature, vegetation or terrain • flexible timing of sampling and can be done during the day	• cannot be used for some time after rain • rate of dung production varies with season and quality of diet • not an accurate measure of absolute numbers but good for assessing relative numbers
Sand plots	• flexible timing of sampling and can be done during the day	• sign may be destroyed by weather or human and vary seasonally • not an accurate measure • long set-up time • for these reasons, not always appropriate for use with rabbits
Non-toxic bait stations	• flexible timing of sampling and can be done during the day	• sign may be destroyed by weather or human and vary seasonally • not an accurate measure • long set-up time
Diggings	• quick and simple • flexible timing of sampling and can be done during the day	• sign may be destroyed by weather and vary seasonally • not an accurate measure
Trapping	• accurate measure	• time consuming • relatively high cost
Annual costs of rabbit control	• easily incorporated into existing economic management	• rabbits not monitored when no control is undertaken or only monitored again when control is needed (i.e. when rabbit abundance is high)
Economic costs	• easily incorporated into existing economic management	• rabbits not monitored when no control is undertaken or only monitored again when control is needed
Enclosures	• accurate measure of grazing pressure	• expensive to set up and maintain • time consuming
Exclosures	• can indicate effects of total grazing pressure • valuable seed reservoir	• interpreting impact of different grazers requires scientific expertise • expensive to set up and maintain
Changes in herbage mass—median quadrat technique	• measures the effects of total grazing pressure • when combined with exclosures the impact of rabbit grazing can be estimated	• time consuming

MONITORING TECHNIQUE	ADVANTAGES	DISADVANTAGES
Changes in herbage mass—comparative yield technique	• measures the effects of total grazing pressure • when combined with exclosures the impact of rabbit grazing can be estimated • more simple than median quadrat technique	• time consuming
Changes in vegetation cover and composition—point method	• quick and simple • information on bare ground recorded	
Changes in vegetation cover and composition—step point method	• quick and simple • information on bare ground recorded	
Crop yield/seedling loss	• indicates proportion of crop being damaged by rabbits	• simplistic measure of impact— microclimatic effects are ignored
Crop damage	• indicates proportion of crop being damaged by rabbits	• unreliable indicator • results not comparable between sites
Plantation damage	• indicates proportion of seedlings being damaged	• difficulty in determining the cause of damage
Photopoints	• inexpensive • quick and simple • good indicator of damage over time	• need reasonable light for good photos
Dry stock equivalents	• simple	• subjective
Stock returns	• simple	• too simple—NOT recommended
Native animals	• Assessment of existing rabbit management for conservation purposes	• the abundance of native animals may not be directly related to rabbit abundance
Soil erosion	• land condition monitored	• erosion may not stop after rabbit control without remedial action
Mapping rabbit damage and density	• facilitates the development and assessment of land and rabbit management plans • allows for modification of existing management plans • can be simple	• can be time consuming depending on the method used

Table 14. Rabbit monitoring techniques ranking table

	LABOUR	START-UP COST	EXPERTISE AND TRAINING	SPECIALISED EQUIPMENT	HUMANENESS	OH&S RISK
Vehicle spotlight counts	High	Moderate	Moderate	Moderate	High	Low
Headlight counts	High	Low	Moderate	Low	High	Low
Walked spotlight counts	High	Moderate	Moderate	Moderate	High	Low
Distance sampling	High	Moderate	Moderate	Moderate	High	Low
Sight counts	High	Low	Low	Low	High	Low
Warren counts	High	Low	Low	Low	High	Low
Active entrance counts	High	Low	Low	Low	High	Low
Counts of rabbits on or near warrens	High	Low	Low	Low	High	Low
Dung counts – Gibb scale	High	Low	Moderate	Low	High	Low
Dung-pellet counts	High	Low	Moderate	Low	High	Low
Sand plots	High	Moderate	Moderate	Low	High	Low
Bait stations	Moderate	Moderate	Low	Low	High	Low
Diggings	High	Low	Low	Low	High	Low
Trapping grids	High	Moderate	Moderate	High	Moderate	Low
Warren trapping	High	Moderate	Moderate	High	Moderate	Low
Smeuse trapping	High	Moderate	Moderate	High	Moderate/ low (predators, fighting etc.)	Low
Enclosures	High	Moderate	Moderate	Moderate	High	Low
Exclosures	High	Moderate	Moderate	Moderate	High	Low
Changes in herbage mass	High	Moderate	Moderate	Moderate	High	Low
Changes in vegetation cover and composition	High	Moderate	Moderate	Moderate	High	Low
Crop yield/seedling loss	High	Low	Moderate	Low	High	Low
Assessing crop damage transects	High	Low	Moderate	Low	High	Low
Assessing forestry plantation damage— transects	High	Low	Moderate	Low	High	Low
Photopoints	Low	Moderate	Low	High	High	Low

GLOSSARY

Dispersal

Movement of an animal from its place of birth to another area where it reproduces. This process is important to population dynamics, because dispersal is when immigration and emigration occur.

Gibb scale

A measure of the density of rabbit pellets per unit area; developed by staff of the Ecology Division of DSIR, New Zealand.

Index of abundance

A relative measure of the abundance of a species (e.g., catch per unit effort).

Lagomorph

An order of mammals that includes rabbits, hares, and pikas.

Petersen estimate

A method of estimating population abundance on the basis of the ratio of marked to unmarked individuals within a population. It assumes that the population is closed to immigration and emigration and assumes that population size is related to the number of marked and released animals in the same way that the total caught at a subsequent time is related to the number recaptured.

Photopoint

A permanently marked site that is photographed to give identical, repeated pictures of the same piece of vegetation over time.

Quadrat

An ecological sampling unit that consists of a square frame of known area. The quadrat is used for quantifying the number or percentage cover of a given plant species within a given area.

Smeuse trap

An outlet with a swinging door that allows rabbits access to and from the warren; the rest of the warren is enclosed in rabbit-proof netting.

Star picket

Three sided steel or fibreglass fence post.

Transect

A straight line placed on the ground along which ecological measurements are taken. A fixed transect is one that is set out for use in all further surveys so that valid comparisons with prior surveys can be made.

Trap night

The number of traps placed out multiplied by the number of nights of trapping.

Track-station night

The number of track stations multiplied by the number of nights of tracking.

Treadle snare

A trap that relies on an animal treading on a trip mechanism and being caught by a noose. For example, one form may consist of a hole covered by sticks, over which a loop of cord attached to a bent stick is placed. When the animal steps on the sticks it falls into the hole and its foot is snared by the noose.

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