



NSW DEPARTMENT OF
PRIMARY INDUSTRIES

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<http://www.dpi.nsw.gov.au/agriculture/pests-weeds/vertebrate-pests/general/monitoring-techniques>

The number of animals removed must be accurately known, and their removal must not affect the index method; for example, if aerial shooting is used to remove feral goats, indexes cannot be established by aerial survey (Caughley 1980).

Dung counts

The faeces or dung of many species are more conspicuous than the animals themselves, and therefore provide a good method of detecting the presence or absence of animals (Sutherland 1996). Dung counts may be used as indexes of abundance and to estimate animal density. There are two main approaches to completing dung counts: calculating the faecal standing crop (FSC) or the faecal accumulation rate (FAR) in a given area (Putman 1984; Mayle & Staines 1998).

Recently, application of line transect methodology using distance sampling has been developed (Marques *et al.* 2001). There has been little work done with feral goat dung counts, but these counts have been extensively used for other ungulates, such as deer (Seydack *et al.* 1998; Massei *et al.* 1998; Mayle & Staines 1998; Marques *et al.* 2001; Smart *et al.* 2004). The FSC is measured by counting the number of faecal pellets or pellet groups within randomly placed sample plots that are often stratified by habitat (Smart *et al.* 2004). The use of FSC counts to determine absolute abundance is beyond the resources of most studies, as defecation and decay rates must be estimated; however, these counts may be used as indexes of abundance. The advantage of using FSC is that only one visit to a site is required. Measuring

FAR involves at least two visits to a site, with plots initially marked out and cleared of all dung. After a fixed time interval the same plots are visited again and the pellets that have accumulated are counted (Mayle & Staines 1998). FAR may provide more accurate estimates at high feral goat densities, as only defecation rates are required, but a large number of plots are required in areas of low feral goat density, as many plots may contain zero pellets (Marques *et al.* 2001).

Line transect sampling of faecal density uses distance sampling methodology, in which linear transects are walked across representative areas of the study area and the number of pellets and the perpendicular distance to them recorded. The distance to the pellets is used to correct for visibility bias (Buckland *et al.* 1993; Thompson *et al.* 1998).

The key assumptions that apply to dung counts in distance sampling for unbiased estimates are that:

- every target pellet group on the transect is detected with certainty, and pellet groups are not recorded twice
- distance measurements (and angles) are accurate (Buckland *et al.* 1993; Rudran *et al.* 1996). Buckland *et al.* (1993) also suggested that a large sample size (e.g. > 60 animal sightings) is needed for accurate density estimation. To convert faecal density estimates to feral goat density, habitat-specific decay rates and defecation rates of dung are required.

Defecation and decay rates are time consuming and costly to calculate, but by making the assumptions that these rates are constant across habitats and time, and that faecal density has a generally linear relationship with feral goat abundance, the FSC and FAR methods can provide cost-effective indexes of abundance that can be used to compare relative feral goat abundance within a site over time. Line transect sampling of faecal density should be contemplated only if the defecation and decay rates can be calculated. If this is achievable, this method, as well as FSC and FAR, may be used to estimate feral goat density and compare densities between sites over time.

Another important limitation of dung counts for feral goats is that they should be used only in areas where goats do not coincide with sheep. Goat and sheep dung look very similar and are not easily differentiated. Mathematical models have been developed to account for dung that cannot be distinguished (Landsberg *et al.* 1994), but they are not easy to use.

Before starting a dung count program, standardise the technique. The location and length of transects should be established and plotted on a map. Take care to ensure that the transects encompass areas representative of all vegetation types in the area. If possible, transects should be marked out with reflectors or flagging tape, so that future surveys can follow the same route. Once set, this transect must be used for all subsequent dung surveys, so comparisons with previous surveys can be made.

Faecal standing crop

Materials required

Count sheet and pencils

GPS

Map

Tape measure

Steel pegs

Flagging tape and marker pens

Cord (1 m lengths) for circular plots

Gloves

How to do the count

- Select sites to be monitored from a map of the study area.
- Stratify the sampling design into habitat types if necessary
- Determine the number of transects (a minimum 30 per stratum and 50 per site).
- Randomly allocate transect locations to each stratum (transects are 150 m long), ensuring that there is no overlap of transects.
- Give each transect an individual identity and record locations on a map.

- Use GPS to navigate to and locate the transect.
- Use flagging tape every 10 m to mark out the 150 m transect.

Strip counts

- Count and record the number of intact feral goat pellets and pellet groups 1 m either side of the transect; pellet groups are pellets that have been deposited in the same defecation. Include defecations where pellet groups occupy more than half the plot.

Circular plots

- Push a peg into the ground every 5 m along the transect.
- Tie cord to each peg so that it extends 1 m from the peg.
- Use the string to draw a circle around the peg.
- Count and record the number of intact feral goat pellets and pellet groups within that circle.
- Remove the pegs at the completion of the count.

Standards

Sampling site – use the same sampling plots for each count.

Sampling time – compare only those counts that were conducted at the same time of year.

Training required

Identification of dung

Faecal accumulation rate

Materials required

Count sheet and pencils

GPS

Map

Tape measure

Steel pegs

Flagging tape and marker pens

Gloves

How to do the count

- Select sites to be monitored from a map of the study area.
- Stratify the sampling design into habitat types if necessary.
- Determine the number of transects (a minimum of 30 per stratum and 50 per site).
- Randomly allocate transect locations to each stratum (transects are 150 m long), ensuring that there is no overlap of transects.
- Give each transect an individual identity and record the locations on a map.

- Use GPS to navigate to transect sites and locate the transect.
- Use flagging tape every 10 m to mark out the 150 m transect.

Strip counts

- Clear the plot of all dung 1 m either side of the transect.
- Return to the plots after two months.
- Count and record the number of intact feral goat pellets and pellet groups 1 m either side of the transect; pellet groups are pellets that have been deposited in the same defecation. Include defecations where pellet groups occupy more than half the plot.

Circular plots

- Push a peg into the ground every 5 m along the transect.
- Tie cord to each peg so that it extends 1 m from the peg.
- Use the string to draw a circle around the peg.
- Clear the circle of all dung.
- Return to the circular plots after two months.
- Count and record the number of intact feral goat pellets and pellet groups within the circular plots.
- Clear the plot of all dung.

Standards

Sampling site – use the same sampling plots for each count.

Sampling time – compare only those counts that were conducted at the same time of year.

Training required

Identification of dung

Line transects

Materials required

Count sheet and pencils

GPS

2 × 30 m tape measure

Flagging tape and marker pens

25 m length of rope or cable

Gloves

How to do the count

- Select sites to be monitored from a map of the study area.
- Stratify the sampling design into habitat types if necessary.
- Determine the number of transects (a minimum of 30 per stratum and 50 per site).

- Randomly allocate transect locations to each stratum (transects are 150 m long), ensuring that there is no overlap of transects.
- Give each transect an individual identity and record locations on a map.
- Use GPS to navigate and place the transect.
- Use flagging tape every 10 m to mark out the 150 m transect.
- Use the 25 m rope or cable to delineate sections of the transect.
- Walk the transect, count and record the number of intact feral goat pellets and pellet groups.
- Measure the perpendicular distance to the centre of each pellet or pellet group.

Standards

Sampling site – use the same sampling plots for each count.

Sampling time – compare only those counts that were conducted at the same time of year.

Training required

Identification of dung



MONITORING FERAL GOAT IMPACTS

This section discusses the methods used to monitor the impacts caused by feral goats. A summary table at the end of this handbook compares these methods.

Economic cost monitoring

Costs of control

The costs involved with annual feral goat control can be used as a method for estimating trends in feral goat abundance. There are numerous methods available for controlling feral goats, including mustering, trapping at water points, shooting from ground or helicopter and the use of Judas feral goats. Detailed records need to be kept of the labour, material and vehicle costs so that useful information can be drawn from them.

Other costs

It is difficult to accurately estimate the agricultural costs attributable to feral goats in Australia on a national, state or regional level (Bomford & Hart 2002). Conservative estimates have placed a monetary value of \$7.7 million on the national annual cost impact of feral goats (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 play an important role in filling these gaps by calculating and monitoring all the costs attributable to feral goats. These costs include expenditure on control, fencing, inspection time, maintenance, changes in livestock and crop productive output (see Table 1). These costs can be recorded as part of the normal accounting procedures

of a property, 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 feral goat abundance.

Table 1: Cost monitoring: example of a sheet used to calculate other costs

ACTIVITY	LABOURh @ \$ h ⁻¹	MATERIAL	COST \$
Exclusion fence maintenance		Posts Wire	
Mustering			
Harvest record (feral goats sold)			

Monitoring feral goat damage: general information

The quantification of feral goat damage is generally difficult and costly, and often requires scientific expertise. There are, however, a number of techniques that can be used to monitor goat damage. These methods include the use of exclusions, stock equivalents, photopoints, and soil condition monitoring which are described below. To be effective, damage assessment methods should be applied with a realistic view of the amount of time involved. It would also be prudent to get someone who has expertise in damage assessment to give an appraisal of the project design (Wallace & Bartholomaeus 1997).

Using exclusions

Exclusions are generally small, fenced areas designed to selectively exclude herbivores by body size (see Pickard 1992 for some designs). They can be used to examine the damage and losses caused to crops and the effect of grazing on vegetation over time. They are useful for showing the effects of total grazing pressure. They may be a valuable reservoir of plant species that are not regenerating because of grazing pressure. Feral goat impact is determined by the differences in vegetation composition and damage between exclusions that are ungrazed, grazed only by feral goats, and grazed by all herbivores (Wallace & Bartholomaeus 1997). Problems with this technique are that the impacts of grazing insects cannot be measured; that evidence of the effects of grazing depends on the environment, and may take a long time to become apparent (Bridle & Kirkpatrick 1999); and that the composition of the plant population in arid and semi-arid areas may be influenced more by other factors, such as rainfall (Foran *et al.* 1985). As a result, the use of exclusions to interpret the impact of different herbivores may be beyond the resources of most monitoring programs (Williams *et al.* 1995).

Pasture and vegetation damage assessment usually involves excluding larger areas (e.g. 40 m² to 1 ha) and comparing total biomass or changes in plant composition (Jane & Pracy 1974; Andrew *et al.* 1979).

Monitoring changes in herbage mass

There are several methods available for estimating herbage mass, with the most accurate being destructive sampling methods, such as the median quadrat technique. All vegetation at ground level is clipped inside randomly located quadrats (e.g. 0.5 m²) within an experimental plot or enclosure. The samples are pooled for each plot, oven-dried and then weighed. The dry weights of samples from an enclosure can then be compared with those of samples from outside the enclosure. The vegetation loss is estimated using the formula:

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

However, these techniques involve laborious processes, and other methods that are more simple to conduct may be more appropriate for landholders. These include calibrated visual assessments, such as the comparative yield method used with photostandards (Haydock & Shaw 1975; Friedel & Bastin 1988).

As feral goats will forage on plants to a height of 2 m, it may also be useful to monitor any vegetation that falls into this category. The Adelaide technique (Andrew *et al.* 1979) is a simple, accurate and non-destructive way of conducting shrub and small tree biomass surveys (Maas 1997; O'Grady *et al.* 2000). The basic premise of this method is that representative leafy branches of each plant species are used as units of estimation. At the completion of the survey, a number of whole shrubs are removed and the forage stripped and weighed so that calibration curves can be fitted to the data and a forage value determined (Andrew *et al.* 1979).

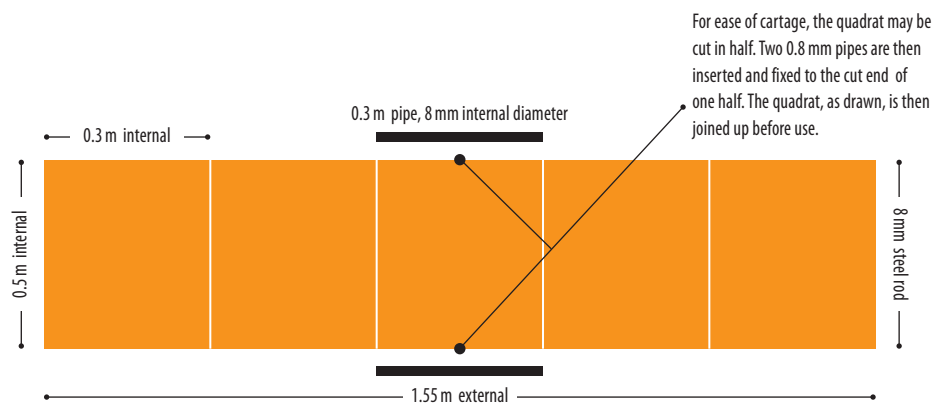


Figure 2: Median quadrat design (Allen & Bell 1996)

Median quadrat technique

This section is adapted from the *Prograze Manual* (Allen & Bell 1996).

Materials required

1 median quadrat – 1.5 × 0.5 m. These dimensions need to be applied accurately in order for the calculations used to work properly (see Figure 2)

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 (data sheet: see Table 2)

How to do the count

- Select the 30 × 30 m area of pasture to be monitored. The area selected should represent average yield 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 inwards from the edge of the area and place the quadrat at your toe. Straighten any vegetation that has been bent over by the quadrat.
- 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 quadrat 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 the nearest gram if this is not possible). Ensure that the weight of the bag is not included. Calculate the average weight of the cut quadrats and record on a data sheet.
- 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 that which could be heaped onto a large dinner plate (or approximately 150 g) remains.

- 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 hours at 70°C, until the weight of the sample is constant.
- Alternatively, a microwave oven can be used by following these steps:
 - 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 five minutes
 - weigh the sample, then 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, one minute intervals in the microwave are recommended.
- To calculate the dry matter percentage, use the following formula:

$$\text{DM}\% = \frac{\text{weight of sample dry (g)}}{\text{weight of sample wet (g)}} \times 100$$
- 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 using the technique described earlier. Sort the sample into fractions of '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 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 for subsequent monitoring efforts.

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

Training required

Use of quadrats

Table 2. 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 =	

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 the quadrats in the photostandards.

50 pegs to mark sampling points

pen and paper

For reference photostandards:

Camera

Hand- or battery-operated shears

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 approximately 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 (number 1) and the second should be taken from a high yield area (number 5). Next, find an area that is halfway between the yield of 1 and 5 (number 3). Similarly, find areas that are between 1 and 3 (number 2) and 3 and 5 (number 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 (scores 1–5).
- Clip, dry and weigh the vegetation, as discussed in the median quadrat technique.

- Allocate the dry matter (DM) weight of each reference with the corresponding photograph (e.g. 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; 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 the quadrat over the pegs and compare the vegetation within the quadrat to 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 complete, calculate the average yield for the monitoring site:

$$\text{Herbage mass (kg DM ha}^{-1}\text{)} = \text{average wet weight (g)} \times \text{DM\%} \times 67$$
 This yield will work only if the quadrat size is 1 m².

Training required

Prograze®

Adelaide technique

Materials required

Count sheet and clipboard

GPS and map

Secateurs, pruning saw, paper bags for plant sample collection

How to do the count

- Select monitoring sites – there are two options with this method: quadrats or transects.
- Quadrats – randomly establish quadrats within the site, such as 30 × 30 m, and estimate the biomass of all shrubs within the quadrat.
- Transect – randomly establish a transect across the site and estimate the biomass of all shrubs within 5 m either side of transect.
- Select and cut a leafy branch of manageable size as a unit of measurement from one of each shrub species that is to be monitored; branch size is determined by the size of the shrub.
- Visually estimate the number of units contained in a representative number of shrubs of each species.
- When the count is finished, remove at least 12 shrubs of each species, strip them of edible material and dry in an oven at 60 °C for 48 h.

- Weigh the dried material of each sample separately.
- Develop a calibration curve that estimates the amount of edible material from the individual scores of each shrub.

Training required

Identification of shrub species

Monitoring changes in vegetation cover and composition

Feral goats can alter the diversity of vegetation by defoliating and debarking shrubs and small trees. Vegetation composition is an important component of landscape management, particularly in grazing land where knowledge of the make-up of a pasture and palatable shrubs can help in decision-making. The methods most often used for estimating pasture composition are the median quadrat technique (Haydock & Shaw 1975; Tothill *et al.* 1992; Allen & Bell 1996) 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 used in conjunction with biomass estimation. This process is time-consuming and does not record any details of bare ground.

Point methods are quick and simple; little training is needed, and they 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 touched by the ends of the stick when it lands. Alternatively, walk a set number of steps and record the vegetation at the toe of a boot. The process is repeated 50 to 100 times throughout the paddock, and the proportional representation of vegetation is calculated.

Point method

This section is adapted from Buckley (2003).

Materials required

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

Data sheet (see example in Table 3) 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.



Assessing vegetation damage (note the browse line)

- 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 there will be 75 sampling points. This means 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 between these points to use as a guide for 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 by, or directly below, each of the four points of the wingdinger.
- 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.

Training required

Vegetation identification

Table 3. Monitoring vegetation changes: example of a point method 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				

Step point method

This section is adapted from Forge (1994).

Materials required

3 star pickets

Data sheet and pen or pencil

How to do the count

- Select the paddock or area to be monitored and place a transect 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 in smaller paddocks.
- Drive star pickets into the ground at the beginning, middle and end of the transect to use as permanent markers. Old tyres may be preferable to star pickets, particularly where livestock are known to rub on star pickets.
- Walk along the chosen path and take recordings at every pace. To limit bias, look straight ahead when placing the feet.
- Record the ground cover and species touched or directly in front of the point of the boot. If a plant is pushed over by the point of the boot, record the ground cover that is being obscured, that is, the point the boot would be touching if the plant hadn't been pushed over).

- Take another pace and repeat the process until finished walking the transect.
- Calculate the ground cover and composition.

Standards

Sampling time – monitor vegetation at the same time each year; early winter, when ground cover is established but pasture is not tall, is usually easier than spring or summer.

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

Training required

Vegetation identification

Table 3. Monitoring vegetation changes: example of a step point method data sheet

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

Photopoints

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 twice yearly and over years to obtain a good impression of changes that are occurring, for example, as a result of pest animal control (Mutze 1991; Sandell 2001). Photopoints should be established to record different vegetation types. This simple monitoring method is much quicker and requires less training than laborious scientific techniques, such as total biomass. More advanced methods of photopoint monitoring (using digital images and computer software packages) have been developed (Roshier *et al.* 1997; Paruelo *et al.* 2000), but these may presently be beyond the scope of most monitoring studies. However, they should prove to be useful for large-scale monitoring. Remote sensing may be used for similar purposes.

Materials required

Camera

Star pickets (1.8 m)

50 × 50 mm wooden stakes (300 mm)

Post driver and sledge hammer

GPS

How to do the count

- Select sites to be monitored.
- Drive a star picket into the ground so that it protrudes about 1.5 m and is suitable for supporting the camera.
- Mark the picket with an identification tag.
- Drive a wooden stake 150 mm into the ground, 10 m away from the star picket.
- Although it is not essential, locating photopoint pickets north–south is beneficial in order to avoid getting direct sunlight in the shot. Taking a photo while facing south prevents glare. If this is difficult to do, carefully select a time of day with minimal glare to take the photo. Mornings when there is little or reduced dust in the air are preferable.

Take a photograph with the camera resting on the star picket, using the wooden stake as the focal point

- Photographs should be taken at each photopoint twice a year, in autumn before rain and in spring, when many plants should be flowering.
- Record site location (on GPS), seasonal conditions, estimates of feral goat and other pest animal abundance.



Yellow-footed rock wallaby

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. If a digital zoom camera is used, set to a standard focal length.

Training required

Photography skills

Monitoring native animals

Feral goats compete with some native animals directly for food, water and shelter (Lim *et al.* 1992). It is sometimes difficult to demonstrate the existence of competition between pest animals and native species and to measure its effect. The only way to demonstrate this is to conduct feral goat removal experiments. The only species that feral goats are a known threat to is the malleefowl (*Leiopa ocellate*) (Benshemesh 2000), although they are a perceived threat to at least three wallaby species (Dawson & Ellis 1979; Short & Milkovits 1990; Hall & Kinnear 1991; Hill 1991). It might be more appropriate to monitor changes in threatened species abundance or number of breeding pairs and active nests. The results could be combined with feral goat abundance data recorded before and after control operations. It would be possible to examine trends to determine the success or other of the feral goat control.

Feral predator management, especially of foxes and feral cats, needs to be done in conjunction with feral goat control if the aim of the project is to promote the conservation of native fauna species (Norbury 2001, Catling 1988; Dickman 1996; Newsome *et al.* 1997; Corbett 2001). An example of the complex relationships between feral goats, rabbits, predators and native fauna can be found with the malleefowl, an endangered species in NSW. Malleefowl have shown little recovery after predator control (Priddell 1991), and competition for food with rabbits and



feral goats is a likely cause (Frith 1962). In South Australia, the yellow-footed rock wallaby (*Petrogale xanthopus*) has been able to increase its numbers and withstand drought at a more sustained level as a result of a combination of fox and feral goat control (de Preu *et al.* 2001). It is often necessary to implement integrated management to ensure that 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 feral goat has been implicated as an agent of soil erosion, because it removes vegetation and does not allow regeneration, leaving soil open to erosive forces. There has been little quantification of the effects of feral goats on soil erosion, and this is an area of feral goat impact that requires further investigation. In north-eastern NSW, the amount of soil accumulating against permeable barriers has been used to examine the impact of feral goats on soil erosion (Bayne *et al.* 2004). However, this technique was used on slopes of approximately 40°, and is suitable only for similar terrain (B. Harden pers. comm.). Another method that may be utilised is soil condition assessment (e.g. Tongway 1994; Tongway 2000) before and after feral goat control (Thompson *et al.* 1999). Until monitoring systems are devised that are shown to be accurate in detecting the relationship between feral goats and soil erosion, short-term impact monitoring can be achieved by using abundance estimates through aerial or ground surveys. The assumption is that any decrease in feral goat abundance will be associated with an increase in soil stability and

vegetation regeneration. A method of longer-term monitoring of the effectiveness of feral goat control to halt erosion would be the use of photopoints to examine the same areas of land over time. The difficulty with attempting to monitor the success of feral goat control in relation to soil erosion is that the land may have degraded to such a point before control operations start that it may not be possible to stop erosion without taking remedial action first.

Therefore, another way to monitor the impact of feral goats is to keep records of the amount of labour and materials put into the restoration of degraded land.

Mapping feral goat damage and population densities

Mapping the distribution of feral goat damage and population density over a given area aids the development of feral goat management plans (Williams *et al.* 1995). Regular updating of the maps allows existing management plans to be modified. These maps may be simple hand-drawn property diagrams, more detailed and accurate topographic maps or computerised maps generated with geographic information system (GIS) software. The choice of map type will depend largely on the scale of the area involved, the cost, availability of the technique and the extent of the feral goat problem (Williams *et al.* 1995). These maps can be used as part of the overall property management plan, and to assess progress over the years. On a larger scale, NSW Department of Primary Industries have 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).

Information to include on a map 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 and rock outcrops
- vegetation other than pastures and crops
- areas of feral goat activity and abundance estimates
- areas of damage, with a scale of damage including areas that lack regeneration of vegetation
- type of agricultural or other activities on this and adjoining properties.

It is important to make new maps with each new assessment. In this way new maps can be compared or overlaid with the previous map to evaluate the current management.

SUMMARY OF FERAL GOAT MONITORING TECHNIQUES



The various feral goat abundance and impact monitoring techniques discussed in this manual, and their advantages and disadvantages, are listed in Table 4. Table 5 compares the different monitoring techniques.

Table 4. Advantages and disadvantages of the monitoring techniques discussed in this manual

MONITORING TECHNIQUE	ADVANTAGES	DISADVANTAGES
Aerial survey	<ul style="list-style-type: none"> • can survey large spatial areas • can sample more than one species at the same time 	<ul style="list-style-type: none"> • expensive • reliable correction factors are not always available
Ground survey: line transect	<ul style="list-style-type: none"> • quick and simple • suitable for large properties • produces relative feral goat density 	<ul style="list-style-type: none"> • counts can be highly variable between observers • ability to sight feral goats 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
Ground survey: vehicle count	<ul style="list-style-type: none"> • quick and simple • inexpensive 	<ul style="list-style-type: none"> • counts can be highly variable between observers • ability to see feral goats can be affected by height of pasture, vegetation or habitat type
Ground survey: point count	<ul style="list-style-type: none"> • quick and simple • can produce relative feral goat density 	<ul style="list-style-type: none"> • extra training required
Catch per unit effort	<ul style="list-style-type: none"> • can be incorporated into control program • removes goats 	<ul style="list-style-type: none"> • expensive • labour intensive • time-consuming • trap-shy animals undetected
Capture–recapture	<ul style="list-style-type: none"> • accurate estimate of abundance • other information may be collected at the same time (e.g. home range) 	<ul style="list-style-type: none"> • expensive • labour intensive • time-consuming • trap-shy animals undetected
Radio-telemetry	<ul style="list-style-type: none"> • other information may be collected at the same time (e.g. home range) 	<ul style="list-style-type: none"> • expensive • labour intensive • time-consuming
GPS and satellite telemetry	<ul style="list-style-type: none"> • improved ability to monitor animals in rugged and remote terrain • reductions in travel and field work time 	<ul style="list-style-type: none"> • expensive • accuracy of fixes can be variable
Dung counts	<ul style="list-style-type: none"> • inexpensive • can be used in difficult terrain • sampling schedule flexible 	<ul style="list-style-type: none"> • inappropriate for monitoring short-term changes • may not detect small changes
Cost monitoring	<ul style="list-style-type: none"> • inexpensive • can be incorporated into existing economical management 	<ul style="list-style-type: none"> • assumed relationship with feral goat abundance • costs increase each year: need to account for inflation
Exclusion cages	<ul style="list-style-type: none"> • can indicate effects of total grazing pressure • valuable seed reservoir 	<ul style="list-style-type: none"> • interpreting impact of different grazers requires scientific expertise • expensive to set up and maintain

MONITORING TECHNIQUE	ADVANTAGES	DISADVANTAGES
Changes in herbage mass: median quadrat technique	<ul style="list-style-type: none"> measures the effects of total grazing pressure when combined with exclusion zones, the impact of feral goat grazing can be estimated 	<ul style="list-style-type: none"> time-consuming difficulty in determining the cause of any changes
Changes in herbage mass: comparative yield technique	<ul style="list-style-type: none"> measures the effects of total grazing pressure when combined with exclusion cages, the impact of feral goat grazing can be estimated more simple than median quadrat technique 	<ul style="list-style-type: none"> time-consuming difficulty in determining the cause of any changes
Changes in shrub biomass: Adelaide technique	<ul style="list-style-type: none"> simple 	<ul style="list-style-type: none"> difficulty in determining the cause of any changes
Changes in vegetation cover and composition: point method	<ul style="list-style-type: none"> quick and simple information on bare ground recorded 	<ul style="list-style-type: none"> difficulty in determining the cause of any changes
Changes in vegetation cover and composition: step point method	<ul style="list-style-type: none"> quick and simple information on bare ground recorded 	<ul style="list-style-type: none"> difficulty in determining the cause of any changes
Photo points	<ul style="list-style-type: none"> quick and simple good indicator of damage over time 	<ul style="list-style-type: none"> difficulty in determining the cause of any changes
Native animals	<ul style="list-style-type: none"> assessment of existing feral goat management for conservation purposes status of endangered/vulnerable species kept up to date 	<ul style="list-style-type: none"> the abundance of native animals may not be directly related to feral goat abundance
Soil erosion	<ul style="list-style-type: none"> land condition monitored 	<ul style="list-style-type: none"> erosion may not stop after feral goat control without remedial action
Mapping feral goat damage and density	<ul style="list-style-type: none"> facilitates the development and assessment of land and feral goat management plans allows for modification of existing management plans can be simple 	<ul style="list-style-type: none"> can be time-consuming, depending on the method used

Table 5. Feral goat monitoring techniques ranking table

	LABOUR	START-UP COST	EXPERTISE AND TRAINING	SPECIALISED EQUIPMENT	HUMANENESS	OH&S RISK
Aerial surveys	High	High	High	High	High	Moderate
Ground surveys	High	Low	Moderate	Low	High	Low
Trapping (catch per unit effort)	High	High	Low	Moderate	Moderate	Low
Trapping (capture–recapture)	High	High	Low	Moderate	Low	Low
Trapping (radio-telemetry)	High	High	High	High	Moderate	Moderate
Satellite and GPS telemetry	High	High	High	High	Moderate	Moderate
Index-removal-index	High	Moderate	Low	Low	Moderate	Moderate
Dung counts: faecal standing crop	High	Low	Moderate	Low	High	Low
Dung counts: faecal acc. rate	High	Low	Moderate	Low	High	Low
Dung counts: line transect	High	Low	Moderate	Low	High	Low
Exclusion	High	Moderate	Moderate	Moderate	High	Low
Changes in vegetation biomass	High	Moderate	Moderate	Moderate	High	Low
Vegetation cover and comp.	High	Moderate	Moderate	Moderate	High	Low
Photo points	Low	Moderate	Low	High	High	Low



GLOSSARY

Associative learning

Learning or conditioning that occurs when two different events occur or happen together, and are thus 'associated'.

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.

Index of abundance

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

Leslie technique

A method of estimating population, based on the principle that the catch rate is proportional to the population size.

Octal

A measure of cloud cover. A completely covered sky is scored as 8 out of 8 octals.

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.

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 species within a given area.

Stratified random sampling

(also called *proportional or quota random sampling*)

When the population is divided into homogeneous subgroups and then a simple random sample is taken from each subgroup.

Track-station night

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

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.



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