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MONITORING TECHNIQUES FOR VERTEBRATE PESTS

FERAL GOATS

BRUCE MITCHELL
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WHY MONITOR VERTEBRATE PESTS?

The purpose of this manual is to provide details of the techniques available to monitor feral goats 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.

In order for monitoring programs to be effective and efficient, reliable estimates of changes in population or damage need to be obtained (Thomas 1996). These estimates need to be repeatable, to allow meaningful conclusions to be drawn from the changes. An appropriate way of achieving this is to standardise the methodology, to prevent two people acting on the same instructions from getting quite different results.

There is no substitute for experience; however, education and training through demonstration of monitoring techniques and the chance to calibrate measurements against those of experienced operators would be likely to improve the accuracy and precision of any monitoring efforts.

Monitoring of the management program should be done before, during and after control, especially for long-term programs:

- Monitoring **before** a control program should establish a benchmark of vertebrate pest abundance and identify actual or potential damage. This benchmarking will allow objectives and performance indicators to be determined.
- Monitoring **during** the program should determine how the program is operating against set objectives. This monitoring may provide an opportunity to change a management program in response to control success. This adaptive management is recommended to achieve outcomes within timeframes and budgets; however, it may not be suitable for research purposes.
- Monitoring **after** the program determines the success of the program against the performance indicators, and finds out if the management program objectives have been achieved.

Monitoring in vertebrate pest management has two functions: to provide the necessary information to trigger management action (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 control occurs) with untreated sites (where no control is done) 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.

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

Humane pest animal control

This manual is to be read in conjunction with the following codes of practice and standard operating procedures for the control of feral goats.

Humane pest animal control – *code of practice and standard operating procedures* (Sharp & Saunders 2005)

GEN001 *methods of euthanasia*

GOA001 *ground shooting of feral goats*

GOA002 *aerial shooting of feral goats*

GOA003 *mustering of feral goats*

GOA004 *trapping of feral goats*

GOA005 *use of judas goat*

RES001 *live capture of pest animals used in research*

RES002 *restraint and handling of pest animals used in research*

RES004 *marking of pest animals used in research*

RES005 *measurement and sampling of pest animals used in research*

Health and safety considerations

Aerial surveys

- Do not ask pilots to fly under the minimum safe altitude, or close to steeply rising terrain, trees or structures, or in adverse weather conditions.
- Aerial observers should have attended an aerial observer's or *Fly the Wire* training course and be competent at observing hazards such as power lines.
- The aircraft company should have a fatigue management program in place, and the time of sorties flown should be sufficiently short to prevent fatigue in both the pilot and observers.
- Appropriate personal flight safety equipment, including fire retardant boots and clothing (polyproplene or plastic based fibre) and a helmet, is required.
- Observation transects should be loaded into the aircraft navigation equipment prior to flight.
- Aircraft support or on-ground officers should keep appropriate Search and Rescue (SAR) protocols.

Ground transects

- Ground observers must be familiar with navigation in the area. They must carry a map, compass, handheld Global Positioning System (GPS) equipment, two-way radios and spare batteries.
- All officers should be trained and competent in the use of GPS.
- The transect must be plotted on the map.
- All officers must carry sufficient drinking water and emergency food rations.
- The observer should wear suitable light-coloured clothing and sturdy footwear.

Using vehicles

- The driver and observer must drive the transect before commencing the survey, to demonstrate that it is navigable and to remove overhanging branches and obstructions.
- All occupants should carry drinking water, emergency food rations and adequate clothing in case the vehicle becomes disabled.
- The driver and observer must have a fatigue program prior to the survey.
- The observer should wear adequate clothing during cold weather.
- Driver should travel at correct speed and continually observe the road surface ahead on the track. The driver should not be counting animals.
- Observations should be recorded when the vehicle is stationary.

Trapping feral goats

- A manual handling training course is compulsory for lifting heavy items. Wearing leather gloves and eye protection will help prevent injuries from wire, steel panels and hammers.
- Routinely wash your hands and any skin surfaces contaminated by the animals' blood, faeces and/or urine.
- Attaching transmitters to animals can affect their behaviour, particularly their ability to move and survive in a harsh environment.
- To limit the impact of radio transmitters on feral goats, some general recommendations can be made (White & Garrott 1990):
  - allow several days for the animals to get used to the transmitter before collecting data that will be regarded as indicative of normal behaviour.
  - avoid capturing and attaching transmitters during the animals' reproductive cycle.

THE FERAL GOAT

History

Goats arrived in Australia with European settlement in 1788 (Rolls 1969). They were convenient livestock animals for early settlers, as they are relatively small, eat a wide range of plants, and provide both meat and milk. During the 19th Century, sailors released many goats onto islands and the mainland as emergency food supplies. Cashmere and Angora goats were also imported in an attempt to start a fibre industry in Australia (Lever 1985). Goats were further spread around Australia by settlers, railway construction gangs and miners, who used them as domestic livestock. These domestic goats escaped, were abandoned, or were deliberately released, and these animals established feral herds (Parkes *et al*. 1996).

Impacts

Feral goats may compete with both domestic stock and native animals for food, water and shelter and cause damage to infrastructure, such as fences, and sites of national significance, such as rock shelters previously used by aboriginal people for shelter and ceremony (Parkes *et al*. 1996; Thompson *et al*. 1999). The grazing habits of feral goats can have significant effects on vegetation composition, with the complete stripping of bark and leaves to a height of 2 m (Coblentz 1978; Henzell 1992; Parkes *et al*. 1996). Overgrazing and movements of feral goats can lead to soil erosion, with disturbance of the soil by the sharp hooves of feral goats and the characteristic pawing of the ground by males leaving the soil open to the erosive forces of rain and wind (Yocom 1967; Henzell 1995). Feral goats may compete with native animals for food, water and shelter (Lim *et al*. 1992).

Feral goats can carry internal and external parasites, some of which affect sheep and cattle. For example, they may carry and spread ovine footrot, and could act as reservoirs for, and vectors of, exotic diseases, including foot and mouth, rabies, bluetongue and rinderpest.

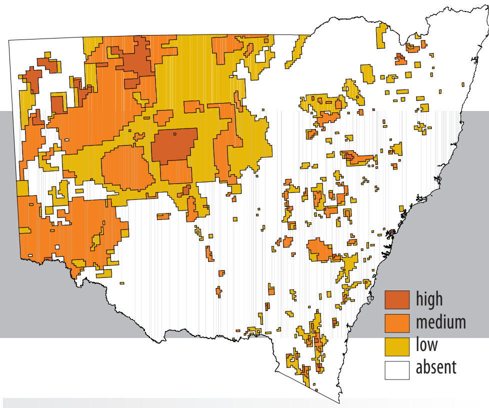
Distribution

In 1993 there were estimated to be 2.6 million feral goats in Australia (Parkes *et al*. 1996). The majority of these animals live in pastoral areas of Queensland, New South Wales, South Australia and Western Australia. Feral goats occur in all Australian states and in the Australian Capital Territory, but are rare or absent on the mainland of the Northern Territory. They occur on many Australian offshore islands. The most extensive populations live in semi-arid pastoral areas. Isolated populations occur in higher rainfall and agricultural areas.

Habitat

Feral goats require habitat that provides adequate shelter, surface water and an abundance of preferred food species (Parkes *et al*. 1996). Large numbers of feral goats do not occur in areas where dingoes are abundant. They are most common on rocky or hilly country in the semi-arid rangelands. These areas provide security from predators and human disturbance. Feral goats are not normally found on flat, treeless plains, but they can be found on flat country with dense shrub cover.

Domestic stock competing for food, water and shelter



Feral goat density (source NSW DPI)

Biology

Diet

Feral goats are generalist herbivores and will eat foliage, twigs, bark, flowers, fruit and roots, as well as plant litter, seeds and fungi (Parkes *et al*. 1996). Feral goats can eat the majority of plants in the pastoral zone of Australia, including prickly acacia, many poisonous or bitter plants, and species avoided by sheep and cattle. Although feral goats will eat just about anything, they are highly selective feeders, and any one type of shrub, grass or herb may comprise the principal part of their diet at different times or places (Parkes *et al*. 1996).

Feral goats may be able to obtain their water requirements from their food in temperate and wet climates, but in arid or semi-arid areas, or during drought, feral goats need to drink water. An average-sized feral goat (33 kg) will drink between 2 and 4.5 litres of water per day, depending upon temperature, humidity and reproductive status (Henzell 1995; Parkes *et al*. 1996).

Reproduction

Feral goats are able to breed throughout the year, but there are usually peaks in births from late summer to mid-winter (Henzell 1995). This coincides with the optimum conditions for survival of the mother and young. The gestation period lasts for 150 days, with one kid usually produced from the first birth. However, twins and triplets are common thereafter (Henzell 1992). Young are weaned after two months, and females with a kid at foot are often found to be pregnant (Jago 1999). Females reach sexual maturity at six months, and can breed twice a year (Parkes *et al*. 1996). Males reach sexual maturity at approximately eight months, but competition for access to oestrus females is fierce, and it is unlikely that young males are able to mate until they become large, dominant individuals.

Rocky and hilly habitat where goats are plentiful

Kid goat

Mortality

The mortality rate of kids from birth to six months is high (e.g. up to 45%) (Parkes *et al*. 1996). Natural mortality rates amongst older feral goats are unknown, but assumed to be about 10%. Dingoes, feral dogs, foxes, wedge-tailed eagles and feral pigs are all predators of feral goats. Dingoes and other wild dogs are the main predators of adult feral goats, and appear to affect feral goat distribution (Parkes *et al*. 1996). Causes of human-induced mortality in feral goats include mustering, trapping and shooting, and these can have significant effects on feral goat populations. However, feral goat density can rapidly increase after vigorous control programs: high levels of removal of feral goats from a population may increase survival rates and result in a faster than normal rate of increase. Feral goats have the potential to double their population every 1.6 years in the absence of mortality caused by human control efforts and predation (Parkes *et al*. 1996).

Social structure

Feral goats are social animals, and are found in herds, the basic social unit being adult females and their recent offspring (Parkes *et al*. 1996). The young males form loose associations with other males of similar age, or with larger, mixed-aged groups that associate within the females' home range during the breeding season. Group size within herds of feral goats varies on both a daily and a seasonal basis. Much of the seasonal variation seems to be related to the availability of surface water. When water is abundant, groups are generally small and well dispersed. During drier months, groups increase in size and consist of both males and females of all age classes. During droughts, feral goats tend to congregate in large numbers (500–800) and remain near water. Group composition is highly variable. Feral goats are continually forming, breaking and re-amalgamating herds. Many new associations are formed when they congregate around water sources.

Goats often occupy hilly habitat

Feral goats on the move

Movements and home ranges

The size of the home ranges of feral goats varies across Australia, being smaller in areas where food, water and shelter are freely available and much larger in semi-arid pastoral regions. The boundaries of these areas are not rigidly defined, and they are not actively defended to exclude other feral goats. Feral goats in areas with ample water and food have small, non-exclusive home ranges, generally of about 1.0–13.5 km^2, with males having larger ranges than females (Parkes *et al*. 1996). In pastoral regions, feral goat movements are generally much larger. Home ranges in these areas are usually centred close to, or around, permanent water. Radio-tracking of feral goats in the Eastern Goldfields pastoral region of Western Australia found that the average female home range was 66.6 km^2, ranging from 15.0 to 190.2 km^2, whereas males averaged 322.0 km^2, ranging from 139.2 to 587.7 km^2 (King 1992).

Feral goats have a high degree of mobility, which can make them very difficult to control, as rates of reinfestation can be very high. This also makes eradication or containment almost impossible in the event of an exotic disease outbreak. However, feral goats in higher rainfall zones are more sedentary, and few feral goats move permanently outside their home ranges.

MONITORING FERAL GOAT ABUNDANCE

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

Aerial surveys

Monitoring pest animal populations across large spatial areas can be cost-effectively achieved through the use of aerial surveys. This method is commonly used for broad-scale population surveys of the more conspicuous animals visible during daylight hours, such as horses, buffalo, pigs, kangaroos and feral goats. These surveys use either fixed-wing aircraft or helicopters. (Grigg *et al*. 1997).

Aerial surveys most often utilise transects (strip and line transects), but if the topography restricts the use of transects or the feral goats are not randomly distributed, searched units may be used (Caughley 1980; Kufield *et al*. 1980). Transects are selected at random if a population or density estimate is the principal reason for the survey. If the survey is for mapping species distribution across the survey area, systematic sampling is used, whereby transects are placed uniform distances apart. A drawback of this is the sacrificing of some precision of the population density estimate. Systematic sampling is more precise if you use the same transects on duplicate surveys, either at the same time or over time. Random transects without replacement are likely to be more accurate but less precise. Hence, to track changes in feral goat abundance over time, systematic sampling using the same transects may be more appropriate for providing an index of abundance.

Strip transects involve the aircraft travelling along a straight line, with feral goats counted within a single strip, for example 100 m either side of the aircraft. The strip is determined by markings on the wing struts in the case of fixed-wing aircraft, or on protruding poles for helicopters; these equate to the strip width when the aircraft is at survey altitude. Visibility bias, associated with the failure of observers to count all animals within the transect, can result in serious underestimates of density (Caughley 1974). Various techniques are available to correct for this bias: the most commonly used are line transect (Dendy *et al*. 2004) and double-counting (Caughley & Grice 1982).

Line transects or distance sampling (Buckland *et al*. 1993) utilise the same flight patterns but use multiple markings on the wing strut or pole to delineate distance classes, such as 20 m intervals. Animals counted perpendicular to the transect are placed in these distance classes, allowing you to derive a detection probability function and thus improve the accuracy of the density estimate. Double counting is a technique where multiple observers simultaneously count from the same side of the aircraft. A capture–recapture (Petersen) estimate, using the number of animals or groups detected by one or both observers, is used to approximate the number missed by both observers.

Even with these improvements, aerial surveys are still likely to underestimate true abundance, because of visibility bias caused by non-detection and undercounting (Caughley 1980). The probability of detecting an animal or group of animals decreases with increases in the level of vegetation cover, search speed, altitude, strip width or distance away from the observer, bad weather and observer fatigue (Pollock & Kendall 1987; Courchamp *et al*. 2003). Other sources

Aerial survey of goat populations

of visibility bias are the time of day, temperature and observer experience. Standardisation can alleviate many of these problems, and correction factors for visibility bias can be developed, to further improve the accuracy of population density estimates (Caughley 1980).

Aerial surveys are commonly used to monitor feral goats in Australia, with fixed-wing aircraft preferred over helicopters, mainly because of their lower running costs and greater ability to cover larger areas (Clancy *et al*. 1997; Pople *et al*. 1998; Clancy 1999). However, in areas of steep terrain and reduced visibility, fixed-wing aircraft are unsuitable (Southwell 1996) and helicopters have been shown to be an effective alternative (Tracey 2004).

Because of the complexity of the line transect and capture–recapture methodologies, and the associated need for correction factors, aerial surveys are best conducted by trained and experienced operators if the aim of the survey is to obtain density estimates. The unit used in these counts is the number of feral goats observed per kilometre of transect flown. Strict adherence to standardisation procedures, such as standardising observers, weather conditions and time of day, will improve the use of aerial surveys as indexes (Tracey *et al*. 2005). Caution is needed when interpreting counts where these and other variables, such as group size, change over time or between sites (Tracey *et al*. 2005); if correction factors are not used, aerial surveys can only provide indexes of relative abundance.

Materials required

Chartered aircraft and fuel supplied either by charter company (known as wet hire) or purchased separately known as (dry hire)

Trained and experienced observers

Count sheet or stereo tape/minidisk recorder, appropriate microphones and power supply

GPS receiver – most aircraft will be equipped with a receiver, but it is useful to have a backup

Vehicles for survey team

Computer equipped with database or spreadsheet software for transcribing and analysing survey data

How to do the count

- Select the survey area.
- Divide the area into potential sampling units (i.e. transects).
- Randomly or systematically select transects to sample.
- Conduct surveys in the first and last three hours of daylight.
- Fly along the transect at a constant speed and altitude. There has been considerable variation in recommended heights and speed in the literature.
- Factors such as topography and height of vegetation will limit the survey height. There are some trade-offs to be made with height in terms of improving sightability and increasing the risk of flushing the feral goats.

Line transects

Count all animals observed along the flight path and record the distance interval on a count sheet or notebook, or record onto constantly running tape recorders.

Strip transects

Count all animals seen within a 100 m strip. Use a count sheet or notebook, or record onto constantly running tape recorders.

Recording the survey

Recording onto constantly running tapes allows observers to give their full attention to the search for feral goats and to the positions of observations along the transect if the distribution of the population is to be mapped.

The recording technique depends on the population density of the feral goats. A count sheet is suitable only for low-density populations of goats.

Once the survey is complete, transpose the count sheets or tapes onto data sheets. For each transect, record the number of feral goats and the distance from the transect at each sighting entity, as well as the habitat in which the goats were seen. Combine observations made by the two observers counting on either side of the aircraft.

To estimate the number of feral goats in each transect, independently derived correction factors are used. For example, the number of sightings in each habitat is corrected for the effects of that habitat on sightability. However, other correction factors may be more appropriate, such as feral goat group size, observers, or length of time between samplings. To get a corrected estimate of the total number of feral goats in each transect, multiply the total by the average sighting size.

Standards

Speed – conduct counts while flying at a constant speed. Fixed-wing: 185 km h^{-1} (100 knots); helicopter: 85 km h^{-1} (45 knots).

Height – conduct counts while flying at a constant height. Fixed wing: 76 m (250 ft); helicopter: 30 m (100 ft) in open country, 45 m (150 ft) in country with tall trees.

Time of day – conduct counts during the first and last three hours of daylight.

Weather conditions – conduct counts under conditions of little or no cloud (< 4 octals), and at temperatures that do not exceed 25°C.

Observers – use the same experienced observers for each count.

Transect width – use the same width of searched transect for each count.

Training required

Aircraft safety and observer training

Aerial observation and survey of goat populations

Ground surveys

There are two main ways of counting feral goats from the ground: transect and point counts. If feral goats are counted on transects but no information on the distance to the animal or area surveyed is collected, absolute density cannot be estimated (Southwell 1989). Such data can provide an index of feral goat abundance, such as feral goats per kilometre, if the surveys are standardised. Counts such as these are often conducted from vehicles along fixed routes, and are an informal equivalent of line transect counts (Parkes *et al*. 1996). A major problem associated with vehicle counts is that the transects are usually on roads or trails; these are generally poor approximations of random samples of the study area, and there is an increased chance of double counting, because roads are rarely straight. The sightability of feral goats may vary with the season and the vegetation conditions, in relation to differences in herding behaviour and habitat preference.

Line transect method

The line transect method involves the establishment of linear transects across representative areas of the study area and the recording of all feral goats seen. Density estimates from line transects 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; Thompson *et al*. 1998). Key assumptions of distance sampling for unbiased estimates are that every target animal on the transect is 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, either away from observer (evasion) and bias towards underestimation, or 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). Buckland *et al*. (1993) also suggested that a large sample size of greater than 60 sightings is needed for accurate density estimation.

Some assumptions may lead to inaccuracies in the density estimates obtained by distance sampling, such as the ability to detect all the animals on a transect, although using two independent observers may alleviate this problem; visual estimates of perpendicular distance are prone to error, and the use of hand-held laser range finders should overcome this difficulty (Heydon *et al*. 2000; Ruette *et al*. 2003).

Before the transect count starts, the route and length of the transect should be plotted on a map. The transect should pass through areas that represent all the vegetation types in the area being sampled, and be traversable in all weather conditions. If possible, transects should be marked out using reflectors, so that future surveys can follow the same path. Once established, the transect may be used for further surveys, so valid comparisons with previous surveys can be made.

Point counts

Point counts from vantage points are often used as indexes, or 'minimum number known to be alive' (MNKA) estimates, where rugged terrain makes it impractical to use either aerial surveys or line transects to estimate animal densities (Caughley & Sinclair 1994; Fleming & Tracey 2003). Counts from fixed viewing points have been used for many years to estimate the density of Himalayan tahr (*Hemitragus jemlahicus*) in New Zealand (Challies 1992; Forsyth 1999; Parkes & Thomson 1999). In Australia, this technique has been used for feral goats with varying degrees of success (Bayne *et al*. 2000; Fleming & Tracey 2003).

There are two main approaches to point counts: an area count from the vantage point or distance sampling. Both methods involve counting animals for a fixed period of time. Fleming and Tracey (2003) used photographs to form a panorama of the area that was visible on the opposite slope from the observation point and subdivisions were drawn that were readily delineated and recognised in the field. Two observers counted the feral goats in each delineated subdivision, one subdivision at a time, and grouped the feral goats into light, coloured and dark classifications. The maximum number of feral goats counted from a point within a season was used to estimate the MNKA.

The advantage of using two observers is that animals seen by one observer but not the other can be included.

As with all incomplete counts, there are limitations to the interpretation of MNKA estimates; that is, not all feral goats are likely to be counted. However, if the counts are standardised, and MNKAs are reasonably close approximates or estimates of known numbers, the point count method can be used as a cheap option for obtaining known numbers (Caughley & Sinclair 1994; Fleming & Tracey 2003).

Walked line transects

Materials required

Micro-cassette recorder or count sheet and clipboard

Reflectors and star posts to mark out the transect

Range finder and compass

GPS and map of survey area

Hand-held UHF radio or mobile phone

Computer software for density estimates

How to do the count

- Establish a linear transect line over the survey area to cover the different habitats present. Up to 10 km may be traversed by an observer in a sampling session of 3–4 hrs, but this depends on the ruggedness of the terrain.
- Permanently mark out the transect with star posts and reflectors, so that subsequent surveys can follow the same path.
- Start approximately one hour after sunrise or four hours before sunset, from an established start point.
- Each time a feral goat herd or subgroup is encountered, calculate the perpendicular distance from the transect line (with a laser range finder) or the radial distance from the observer to the herd and the sighting angle between the line of sight to the feral goats and the transect line, at the moment of detection.
- Accurately count the number of feral goats in each herd or subgroup.
- The preferred method is to record the relevant information using a micro-cassette recorder and transcribe it later, as this lessens the chance of missing feral goats.
- Repeat surveys may be required to obtain an adequate sample size for density estimation. Sample size should be greater than 60 sightings. On subsequent counts, start at the same time as the first count and use the same distance, direction and observer.
- Density estimates are computed by software, such as DISTANCE (Laake *et al*. 1993). For an extensive review of distance sampling see Buckland *et al*. (1993).

Standards

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

Time – use the same start time for each count

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

Training required

Training in measurement of distances and angles

Computer software training

Vehicle sight counts

Materials required

4WD utility

Count sheet and clipboard

Reflectors and star posts to mark out the transect

GPS and map of survey area

UHF radio or mobile phone

How to do the count

- Establish a transect line over the survey area to cover the different habitats present. This will often involve the use of roads, which introduces bias into the count.
- Mark out the transect with star posts and reflectors, so that subsequent surveys can follow the same path.
- Start approximately one hour after sunrise or four hours before sunset from an established start point.
- One person drives and another person counts the animals.
- Drive at a constant 10–20 km/hr.
- Each time a feral goat herd is encountered, stop the vehicle and count the number of feral goats in each herd.
- Repeat the survey on three consecutive days, starting at the same time each day and using the same transect distance, direction and observers.
- 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 or animals per kilometre.

Standards

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

Time – use the same start time for each count

Observer – use the same observers for each count

Vehicle – use the same vehicle for each count

Rate of travel – 10–20 km h^{-1} at a constant speed

Training required

4WD training

Remote area safety training

Point counts

Materials required

Micro-cassette recorder, count sheet and clipboard

GPS and map of survey area

Hand-held UHF radio or mobile phone

Camera

If using distance sampling to estimate density:

- range finder and compass
- computer software for density estimates

How to do the count

- Establish vantage points so that the area viewed is representative of the overall survey area and more than 180° viewing is possible.
- Mark the location of vantage points using GPS so that subsequent surveys can be conducted from the same location.
- Take photographs of the viewing area so that a panorama can be formed. Draw and individually number subdivisions on the photographs that are easily recognisable in the field.
- Start approximately one hour after sunrise or four hours before sunset, with two observers.
- Each observer simultaneously counts and records all feral goats seen within each subdivision, using one subdivision at a time. Group feral goats into light, coloured and dark classifications, and ensure that observers make independent counts.
- When all subdivisions have been sampled, identify which feral goats were seen by both observers and which were seen by only one, and tally the results to get the MNKA.
- For density estimates using distance sampling, one observer is required. Each time a feral goat herd or subgroup is encountered, calculate the perpendicular distance from the transect line (with a laser range finder) or the radial distance from the observer to the herd and the sighting angle between the line of sight to the feral goats and the transect line, at the moment of detection.
- Accurately count the number of feral goats in each herd.
- The preferred method is to record the information using a voice recorder and transcribe the data later, as this lessens the chance of missing feral goats.
- Repeat surveys may be required to obtain a sample size greater than 60 for density estimation. On subsequent counts, start at the same time as the first count and use the same transect distance, direction and observer.
- Density estimates are computed by software, such as DISTANCE (Laake *et al*. 1993). For an extensive review of distance sampling see Buckland *et al*. (1993).

Standards

Vantage point – use the same vantage point and subdivided photographs for each count.

Time – use the same start time for each count.

Observer – use the same observers for each count.

Training required

If using distance sampling: measurement of distances and angles training

Feral goat trap with one-way entrance gate

Trapping

Trapping of feral goats in Australia has long been used as a control measure, and to capture animals for research and the game meat export industry (Parkes *et al*. 1996). Trapping is most successful in dry periods, as feral goats must come to water points to drink. It is less effective during wet periods, as even 5 mm of rain can produce sufficient puddles of water to reduce the need for feral goats to visit water points (Jago 1999). Traps generally consist of goat-proof fences surrounding a water point with a one-way entrance, with alternative water points fenced off (Maas 1998; Thompson *et al*. 1999).

In areas of high feral goat density, traps need to hold 500 or more feral goats in such a way that there is minimal stress on the fences and the animals are able to retreat comfortably away from people entering the trap. Shade should be provided during hot periods.

In the rangelands of Western Australia, traps are often permanently installed, with an exit gate that is sealed for trapping, as a form of self-mustering for both domestic livestock and feral goats (Underwood 2002). In areas where the traps are not permanently installed, the trap doors may have to be left open for a few weeks to encourage feral goats to enter (Jago 1999). However, in hot, dry conditions, little training of feral goats is necessary (Thompson *et al*. 1999).

Trapping alone can be used as an index of abundance, by comparing trapping events via catch per unit of trapping effort. It can be used in capture–recapture studies for population, estimates or in radio-telemetry studies to determine areas of activity and home ranges.

Materials required

Vehicle

Traps – trap design varies. Several gate types are available, including swinging one-way gates, such as Bettini, or Charleville sheep trap gates or jump-down ramps. Fence material should be 8/90/15 hinged joint wire or similar, and there should be enough to fence about 1 ha around the water point for 500 feral goats.

GPS

Count sheet

How to trap

- Select the trap site and seal off other water points.
- Construct the trap, keeping the fences as close to the ground as possible. Do not use sloping timber stays in the corners of the yard, as feral goats can walk up them.
- Ensure that there is enough space to avoid social stress of the feral goats.

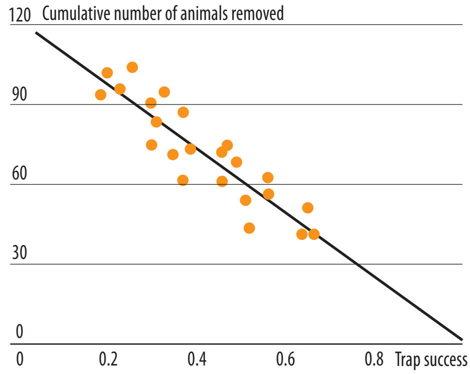


Figure 1: Hypothetical data demonstrating how CPUE can estimate population size. The line of best fit projects the population size at the start of trapping to be approaching 120.

- Leave gates open for approximately two weeks, so the feral goats become accustomed to walking through to the water.
- Set the gates to allow entrance only.
- Check the traps each morning and remove feral goats.
- Continue trapping until no more feral goats are being captured.

Standards

Trap design – use the same type of trap and entrance gate design.

Site – use the same sites for each monitoring effort.

Time – Monitor at the same time each year.

Check traps the same time of day each effort.

Training required

Setting up of traps

Handling of feral goats

Catch per unit effort

Catch per unit effort (CPUE) techniques are based on the idea that the effort expended to catch or kill animals is proportional to the number of animals in the population. For example, during a control operation the effort required to capture and remove animals will increase over time because fewer animals will be available to be caught (Lancia *et al*. 1994; Thompson *et al*. 1998).

If all animals could be removed, the expected catch would be zero, and the total number of animals removed would be equivalent to the initial population size (Lancia *et al*. 1994). Thus, the cumulative number of animals removed may be used to estimate the initial population (see Figure1). This is a special case of CPUE, the cumulative catch or Leslie's technique (Leslie & Davis 1939). The CPUE method assumes that there is a linear relationship between the cumulative number removed and the repeated observations. Other assumptions of CPUE indexes are that the population is closed except for the animals removed, all removals are known, each individual has an equal probability of being caught or killed, and the methods of removal are standardised (Caughley 1980; Thompson *et al*. 1998). Changes in kills per unit effort have been used successfully to monitor feral goats in New Zealand (Parkes 1990; Brennan *et al*. 1993; Forsyth *et al*. 2003). The number of hunting days and the number of feral goats killed are recorded and used to estimate a kill rate or kills per hunter per day, which is used as an index of feral goat abundance.

Advantages of CPUE are that feral goats are removed from the population, and this type of monitoring can be integrated into control programs. However, the assumptions of CPUE methods will not always be met, leading to bias of estimates. For example, not all feral goats will enter traps or be seen from the air for shooting, resulting in underestimates. Therefore, CPUE methods may be used as indexes of abundance, but their use as population estimators should be treated with caution.

Materials required

See 'Trapping'

How to do the count

See 'Trapping'

- Check traps each morning.
- Record the sex, weight, age and reproductive condition of captured feral goats .
- Continue trapping until no more feral goats are being trapped.
- Use the cumulative harvest of feral goats and the change in trap success to project the initial feral goat population estimate.
- Kills per unit effort will be most useful when used in conjunction with control operations such as helicopter shooting, as more accurate measurements of effort are readily obtained and there are few operators involved.

Capture–recapture and telemetry

Capture–recapture methods are based on multiple sampling and repeated capture or sightings of marked or tagged individuals to estimate population size. Animals in the first sample are marked uniquely and then released back into the population. The second sample captures marked animals (recaptures) and unmarked animals, these are marked and released, until the monitoring has finished. The capture history is used to calculate an estimate of the population.

Various capture and recapture methods are available for both closed and open populations, and have been reviewed in detail (Seber 1982; Pollock *et al*. 1990; Schwarz & Seber 1999; Buckland *et al*. 2000). All these methods make assumptions that must be satisfied in order to produce unbiased estimates.

Assumptions common to mark–recapture models are that (Caughley 1980; Krebs 1999):

- all animals have equal catchability. That is, marked animals at any given sampling time have the same chances of capture as unmarked animals
- marked animals are not affected in behaviour or life expectancy by being marked
- marks are not lost or overlooked, and all previously marked animals can be distinguished from unmarked animals.

Capture–recapture studies have not been used frequently for feral goats, and have relied on resightings as a *recapture* (Henzell & McCloud 1984; Forsyth & Hickling 1997).

Feral goats trapped and tagged

Trapped feral goats are restrained, ear-tagged and released. Resighting rates at water points or along transects are then used to estimate the number of feral goats within the sampled area. Capture–recapture is labour-intensive, and is generally only applicable to feral goats when small populations are involved and where animals need to be captured and marked for other purposes.

Materials required

See 'Trapping'.

Ear tags

How to do the count

See 'Trapping'.

- Capture feral goats.
- Record sex, weight, age, reproductive condition of captured feral goats.
- Tag the ear of the feral goat with a commercial goat tag.
- Release feral goats at point of capture.
- Return to the capture site within six weeks and count all feral goats, recording marked and unmarked animals, seen using a water point. Alternatively, use a transect search.
- Calculate a population estimate based on the number of marked and unmarked animals captured using the *Petersen estimate* method.

Training required

See 'Trapping'

Radio-telemetry

The movements of animals fitted with radio-tracking collars are measured by signals received by hand-held, aircraft or vehicle-mounted directional antennae and portable receivers. Alternatively, fixed receiver stations with immobile towers with greater range than hand-held receivers can be used. It is possible to use a Petersen estimate or derivations of this estimate using radio-located animals as a recapture and animals seen with them as unmarked captures (White & Garrott 1990; Kenward 2001; Focardi *et al*. 2002). Radio-telemetry is useful for home range estimation and for determining areas of high activity. Feral goats fitted with radio-tracking collars can be used as 'Judas' animals to locate other members of the herd. This technique has been successful at locating and destroying feral goats as part of a control program (Henzell 1987; Taylor & Katahira 1988; Keegan *et al*. 1994).

Materials required

See 'Trapping'

Radio transmitters, directional antennae and receivers

GPS

Data sheets

Vehicles for tracking

How to do the count

- Capture feral goats as per trapping or mustering guidelines.
- Record sex, weight and age, as well as reproductive and physical condition of captured feral goats.
- Prior to attaching collar, check that radio transmitter is working and that batteries have sufficient charge.
- Attach radio-collar with unique operating frequency around neck of feral goat.
- Record details of radio-collar frequency and double-check that transmitter is functioning correctly.
- Release feral goats at point of capture.
- Start tracking after several days to allow animals to get used to the radio-collars and exhibit normal behaviour.

Walked radio-tracking:

- Locate radio-collared animals by following the transmitted signal's increasing strength.
- Move in as close as possible while causing minimal disturbance to the behaviour of the animal.
- Record the animal's position using a GPS.
- Record time, habitat and animal behaviour.
- Obtain radio fixes every hour for the duration of the tracking session.

Vehicle radio-tracking:

- Use antenna attached to vehicle roof.
- Locate radio-collared animals by scanning appropriate radio frequencies while driving on roads in study area.
- Once a radio signal is detected, use the relative strength of the signal to direct the vehicle to the animal.
- Once located, track the animal on foot.

Fixed-tower tracking:

- Establish two or more fixed-location radio-tracking towers in elevated positions approximately 3–4 km apart.
- Take radio fixes every 15 minutes during a tracking session and assess 24-hour movements over two or three days.
- Use triangulation to determine the target animal's position (see White & Garrott 1990; Kenward 2001).

Training required

See 'Trapping'

Radio-telemetry training

Satellite and global positioning system telemetry

Global positioning systems (GPS) telemetry is used for monitoring animal movements. It utilises GPS receivers in radio-tracking collars attached to animals. Signals received from satellites are either logged to data storage in the collar or relayed to the satellite for remote downloading to a portable receiver (Mech & Barber 2002). On-board storage relies on the retrieval of the collar and downloading the data all at once. Retrieval can be via recapture of the collared animal or by triggering an automatic or remote drop-off mechanism to release the collar. The GPS unit is located by VHF signal. Remote downloading GPS units utilise VHF signals to send data to a portable receiver. The receiver must be within VHF receiving range either 5–10 km ground-to-ground or 15–20 km air-to-ground.

The accuracy of GPS telemetry can suffer from interference from habitat and topography for example, canopy cover or proximity to cliffs can impede satellite signals. Frequent movement in steep terrain by collared animals may cause positional error (Di Orio *et al*. 2003). When evaluating the performance of GPS collars in different habitat types in California, Di Orio *et al*. (2003) found that almost 90% of fixes were within 25 m of the true location but noted that as canopy cover and density increased the corresponding positional error also increased. GPS collar testing and monitoring of moose (*Alces alces*) movements in North America have similarly found that canopy cover influences the proportion of successful locations and that this may introduce bias into habitat-use studies, through more GPS locations being logged when the animal is in open habitat (Moen *et al*. 1996; Dussault *et al*. 1999; D'Eon *et al*. 2002). The performance of GPS collars is being examined in Australian habitats to assess areas of potential bias and error. In spite of these disadvantages GPS telemetry is the most accurate method currently available of tracking feral goats.

The great advantages of GPS telemetry are low fieldwork requirements, a high number of locations per animal, and the ability to be used in all weather conditions with little disturbance of feral goats. Disadvantages include high cost, with prices varying with the type and size of package required. GPS collars need to be returned to the manufacturer for servicing more frequently than traditional VHF collars; however, improvements in technology could soon improve service intervals.

Satellite telemetry works on signals sent from a platform transmitter terminal attached to an animal. The signals are uploaded to an Argos Data Collection and Location System (Service Argos, Inc., USA) aboard orbiting National Oceanic and Atmospheric Administration (NOAA, USA) weather satellites. These signals are downloaded to Argos ground stations, where the data can be retrieved by the wildlife researcher, often within 20 minutes of transmission and from anywhere in the world, via public data networks. The best use of satellite telemetry is for tracking migratory birds and marine mammals (Mech & Barber 2002; Javed *et al*. 2003). This technique has been successfully applied to wide-ranging terrestrial species, such as the African wild dog (*Lycaon pictus*) (Mills & Gorman 1997), and wolves (Merrill & Mech 2000).

Electronic tracking tools used to find animals when retrieving GPS loggers

Satellite telemetry has similar advantages to GPS telemetry, with a large reduction in travel and fieldwork. Animals need to be captured to attach the transmitter and recaptured to retrieve the transmitter, with no other fieldwork required. Recapturing can be facilitated by the installation of a VHF transmitter into the device. The disadvantages of this technique are high cost and variable accuracy. The cost of a single transmitter unit varies, depending on the number ordered, the manufacturer, and the size of the study animal (Mech & Barber 2002). Added to this are costs associated with data retrieval, which are based on kilobytes of information. The accuracy of satellite telemetry can vary from within 150 m to greater than 1000 m. Locations are categorised by accuracy, such that location class (LC) 3 has an accuracy of ± 150 m, LC2 ± 350 m, LC1 ± 1000 m and LC0 ± > 1000 m. Mills and Gorman (1997), while tracking African wild dogs, found that 9% of locations were LC3, 63% were LC2 and 28% were LC1. This degree of accuracy is acceptable for wide-ranging species such as African wild dogs, that have home ranges up to 900 km^2 (Mills & Gorman 1997) or for caribou (*Rangifer tarandus granti*), that migrate about 5055 km annually (Fancy *et al*. 1989). However, if the feral goat population utilises a small area, VHF or GPS telemetry techniques are more appropriate.

Index-removal-index

An estimate of population size can be made from an index of density measured before and after a known number of animals are removed from a population (Caughley 1980). This index-removal-index method assumes that the population is closed for the duration of the survey. As a result, the measurement of pre- and post-removal indexes should be done within as short a time as possible in order to minimise possible bias introduced by natural births and deaths. The pre- and post-removal population estimates are determined by using the following formulae:

Pre removal population estimate (N_1)

$$N_1 = \frac{I_1 C}{I_2 - I_1}$$

$$= \frac{\text{pre removal index} \times \text{number of animals removed (as a negative number)}}{\text{post removal index} - \text{pre removal index}}$$

Post removal population estimate (N_2)

$$N_2 = \frac{I_2 C}{I_2 - I_1}$$

$$= \frac{\text{post removal index} \times \text{number of animals removed (as a negative number)}}{\text{post removal index} - \text{pre removal index}}$$

Worked example for feral goats

pre removal density (aerial survey): 56.5
post removal density (aerial survey): 3.73
number of animals removed by mustering: 326

$N_1 = [56.5 \times (-326)] \div (3.73 - 56.5)$
$N_1 =$ 349 goats pre removal

$N_2 = [3.73 \times (-326)] \div (3.73 - 56.5)$
$N_2 =$ 23 goats post removal