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MONITORING TECHNIQUES FOR VERTEBRATE PESTS

FERAL CATS

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MONITORING VERTEBRATE PESTS

The purpose of this manual is to provide details of the techniques available for monitoring the feral cat 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.

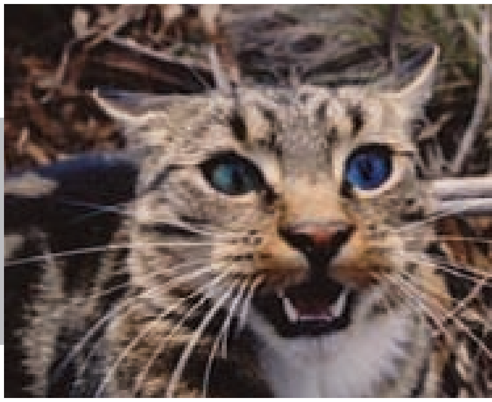
The management program should be monitored before, during and after control, especially if it is a long-term program.

- - Monitoring **before** a control program should establish a benchmark of vertebrate pest abundance and identify actual or potential damage. This will allow objectives and performance indicators to be determined.
- - Monitoring **during** the program should determine how the program is operating against set objectives, and may provide an opportunity to change the program in response to control success. This adaptive management is recommended as a way of helping 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 program's 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 (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 pest abundance is typically monitored and used as an indication of associated damage (Edwards *et al*. 2004). This type of monitoring assumes, rightly or wrongly, there is a 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



Feral cat (photo Mick Davis, Central Coast RLPB)

already stated, measurements of damage are often not available, so assessments of abundance alone are 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 animal abundance and the impacts of these 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 cats.

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

GEN001 *methods of euthanasia*

CAT001 *ground shooting of feral cats*

CAT002 *trapping of feral cats using padded jaw traps*

CAT003 *trapping of feral cats using cage traps*

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*

Animal welfare

Trapping

- - Set traps at sites where vegetation can provide shade and shelter.
- - Injuries may occur, ranging from swelling of the foot and lacerations to dislocations and fractures.
- - Captured animals should be approached carefully and quietly, to reduce panic, stress and risk of injury.
- - A wide range of non-target species, such as birds, macropods, small to medium-sized mammals, goannas, quolls, domestic dogs and sheep may be caught in traps.
- - Different groups of non-target animals may suffer different levels of injury and distress. For example, wallabies often experience serious injuries, such as dislocations, owing to the shape of their limbs and because they become very agitated when restrained; goannas may suffer from dislocations and die from hyperthermia; and birds and small to medium-sized mammals may be preyed upon by foxes, cats and wild dogs while caught in traps.

- - Traps should not be set near areas regularly frequented by non-target species, such as waterholes or gully crossings.
- - Live non-target animals caught in traps should be examined for injuries. If injuries such as cuts and abrasions are minimal, the animal should be released immediately.
- - If the injuries are serious and the animal is likely to recover, it should receive veterinary attention as soon as possible.
- - If the animal is unlikely to recover, it should be euthanased using a technique that is suitable for the species.

Occupational Health and Safety

Toxoplasmosis disease

- - Toxoplasmosis is a protozoan infection that can be caught from cats, and feral cats in particular may carry the disease. It carries the highest risk to employees working with feral cats, foxes and wild dogs. It is prevented by using gloves and washing hands when handling feral cats, foxes, wild dogs and faeces (scats). If picking up the faeces, wear gloves and use either forceps (tweezers) or a stick to push the scat into a paper bag, or use cliplock freezer bags turned inside out as a glove. Wash hands after handling scats. If conditions are very dusty, wear an appropriate dust mask and glasses.

Aerial surveys

- - Pilots should not be asked to fly at an unsafe altitude, close to steeply rising terrain, trees or structures, or in adverse weather conditions.
- - Aerial observers should have attended an Operating Safely Around Aircraft, Aerial Observer 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, 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, clothing and helmets – should be worn.
- - Observation transects should be loaded into the aircraft navigation equipment prior to the 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.
- - Observers must carry a map, compass, hand-held 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

- - Check previous rainfall and surface conditions before the survey.
- - The driver and observer must not be fatigued at the time of conducting the survey.
- - The observer should wear adequate clothing to suit the local weather conditions.
- - Dangerous overhanging obstructions should be removed before the survey.
- - The driver and observer must drive the transect before commencing the survey, to determine if it is navigable.
- - All occupants should carry drinking water, emergency food rations, torch and adequate clothing, in case the vehicle becomes disabled.
- - The driver and observer must have a fatigue management program in place prior to the survey.
- - The driver should travel at correct speed and continually observe the road surface ahead on the track.
- - The driver should not count animals.
- - Observations should be recorded when the vehicle is stationary.

Spotlights

- - Ensure that spotlights are well maintained, with the leads wired securely to the battery terminals and insulated from other components.
- - Avoid battery clips that may fall off, or spark and cause fires.
- - Always disconnect the spotlight from the power source before changing the globe or doing repairs. Switch the spotlight off when not surveying.
- - Do not leave the spotlight switched on, face-down on a seat or heat-sensitive material.
- - High-powered spotlights use a lot of battery power to operate. Do not use the spotlight without the motor running – it may be a long walk for help.
- - Do not shine a spotlight beam directly into the observer's eyes.

Trapping feral cats

- - Protective clothing, boots and leather gloves may help prevent injuries from shovels, hammers and trap jaws.
- - Trapped feral cats are usually aggressive and dangerous to handle; they could inflict serious injury. If handling is necessary, use leather gloves and a catching pole.
- - Operators must be immunised against tetanus, in case bites become infected.
- - Feral cats may carry parasites such as mange mites, which can affect humans and other animals.
- - Routinely wash hands and other skin surfaces contaminated with blood, faeces and other body fluids.
- - Manual handling training is compulsory for lifting heavy items.

Attaching transmitters

- - Attaching transmitters to animals may affect their behaviour, particularly the ability to move and survive in a harsh environment.
- - Avoid capturing animlas and attaching transmitters during the animals' reproductive cycle.
- - At least two people must be present when fitting a transmitter – one to restrain the animal while the other fits the transmitter.
- - Before starting the operation, all participants should be made familiar with the procedure and made certain of their individual roles and responsibilities.
- - Anyone fitting a transmitter must first be given on-the-job training by an experienced operator.
- - Everyone in the team restraining an animal must agree on the procedure for releasing it, and must verbally communicate to ensure that they all release the animal simultaneously.

WHY MONITOR VERTEBRATE PESTS?

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

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

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

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

Monitoring of the impacts and abundance of vertebrate pests is critical in determining whether a management program has been successful.

Feral cats in cage traps are usually aggressive and should be euthanased as soon as is practical.

The pampered domestic cat is known to exceed 15 kg when food is not a limiting factor. While there have been numerous stories of a mysterious panther prowling the Australian bush, none have been positively verified. Many of the large felines reported as panthers appear to be large feral cats. Feral cats tend to change their body shape and structure after a couple of generations, developing larger shoulders and strong forequarters with tapering hindquarters.

KNOW THE PEST: THE FERAL CAT

History

Recorded introductions of cats to Australia started in the 18th century by European settlers. However, cats may have been introduced much earlier, on Asian trading vessels or by early 17th century European explorers, such as the Dutch. There is some evidence that they may have preceded European settlement.

Cats were deliberately released in the late 18th century in an attempt to control rabbit numbers.

Feral cats can survive without human intervention. Populations are well established, and do not require replenishment from domestic or stray cats to be maintained, although domestic cats are absorbed into feral cat populations.

Biology

Diet

Feral cats are carnivorous and require little free water, being able to obtain moisture from their prey. They require large amounts of fresh protein, and prey upon small mammals, birds, reptiles, amphibians, insects and fish, though rabbits are their main food source. Feral cats weigh 2–8 kg and need to consume 5%–20% of their body weight daily for maintenance requirements. They prefer to hunt live prey (which makes baiting difficult), but when this is unavailable they will scavenge. Feral cats are capable of bringing down prey equal to their own body size, and have been implicated in the extinction of several small ground-dwelling mammals and birds. They do not chew their food, but tear off large chunks and swallow them whole.

Reproduction

Feral cats reach sexual maturity on the basis of age, not body weight, with males maturing at 12 months and females at about 7–8 months. Feral cats have no breeding season; breeding is triggered by daylight length. They may produce three litters a year in ideal conditions, with an average of four kittens to each litter. Gestation is 65 days and weaning occurs at 8 weeks.

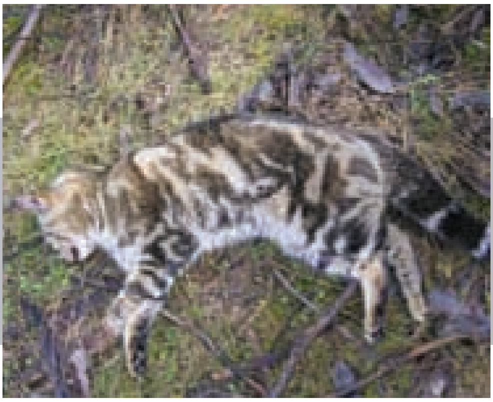
Mortality

Mortality is high in the first year. Food availability is one of the main factors limiting feral cat survival. Feral cats are prey and competitors for foxes, wild dogs, wedge-tailed eagles, quolls, Tasmanian devils, owls, raptors, snakes and lizards. Diseases and parasites also play a role in regulating feral cat populations.

Social structure

Feral cats will exhibit some social interaction, but generally they are solitary hunters. Mating usually takes place in the summer and spring. The family unit of mother and kittens usually disbands at around the time of sexual maturity; females may remain, but males disperse.

Feral cat caught in a cage trap



Feral cat displaying camouflage markings

Movements and home ranges

Feral cats are generally nocturnal. During the day they shelter in trees, hollow logs and rabbit warrens. Home range is dictated by resource availability and den sites. Feral cats maintain stable home ranges, and dominant animals have larger territories. Males have larger home ranges than females (up to 10 km^2). Feral cats have mouth, chin and anal glands, and use scratching, urination and defecation to mark territories.

Distribution

Feral cats are found throughout Australia, from desert to alpine areas, and on many offshore islands; they do not thrive in damp rainforests. Feral cats are mostly short-haired, with a variety of colours, such as tortoiseshell, black, tabby and ginger. Natural selection processes have made some colours more common in certain landscapes, as animals with coat colours that stand out in the natural scenery have been preyed upon more readily than those of other, better camouflaged colours. Tabbies are common in eucalypt bushland, and ginger cats are more common in the desert. White cats are rare in most habitats.

Impacts

Feral cats impact on other animal populations through direct predation and competition for prey. Importantly, they may also spread the disease toxoplasmosis. The Toxoplasma protozoan reproduces only in the intestines of the cat. Toxoplasmosis is particularly harmful to marsupials, causing abortion and birth defects, along with blindness and paralysis.

Feral cats need to consume large amounts of protein, and rabbits are not always in sufficient abundance to satisfy their appetite; therefore, native fauna is often on the menu. Predation by feral cats is listed as a national key threatening process.

MONITORING FERAL CAT ABUNDANCE

This section discusses the methods available for monitoring feral cat abundance. There is a comparison table at the end.

Spotlighting

Spotlighting has been used for many years to survey feral cats (e.g. Jones & Coman 1982; Brothers *et al*. 1985; Short *et al*. 1997; Molsher *et al*. 1999; Edwards *et al*. 2000; Read & Bowen 2001), because it allows large areas to be monitored fairly rapidly. Spotlighting can sample different vegetation types and compare them under similar conditions within a site.

Indexes of abundance, such as the number of animals seen per kilometre, can be produced from the spotlight counts; however, indexes created using spotlighting counts should be corrected for the bias introduced by difference between observers and changes in visibility, vegetation density and animal behaviour (Twigg *et al*. 1998; Wilson & Delahy 2001). Other sources of potential variation are time of night and seasonal variation, as well as the use of roads as transects, where vegetation types may not be evenly represented (Thompson *et al*. 1998).

Where feral cat density is low, spotlighting may fail to detect their presence; therefore, under these conditions, spotlighting may underestimate feral cat numbers (Mahon *et al*. 1998; Edwards *et al*. 2000; Read & Bowen 2001). Despite these shortcomings, spotlighting has been used extensively in Australia, and is considered a practical tool for monitoring relative population abundance of feral cats. Edwards *et al*. (2000) suggested that spotlight counts would improve in precision as the feral cat population size increased, but that they may not be able to detect small changes in abundance at low densities.

Density estimates from spotlight counts can be made 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). Studies using this method have produced results consistent with other types of counts (Heydon *et al*. 2000; Ruette *et al*. 2003).

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 evasion (biased towards underestimation) or attraction (biased towards overestimation)
- - individuals are not recorded twice
- - distance measurements are accurate (Buckland *et al*. 1993; Rudran *et al*. 1996).

Buckland *et al*. (1993) suggested that a large sample size (> 60 sightings) is needed for accurate density estimation. Therefore, distance sampling may not be feasible for monitoring the abundance of feral cats, because of their low population densities and secretive nature.

Problems that arise from these assumptions can lead to inaccuracies in the density estimates obtained by distance sampling. It may not be possible to detect all animals on a transect, although double sampling, using two independent observers, may help alleviate this problem. Most spotlight counts of feral cats are done on roads or trails, and have the associated problems discussed above, as well as an increased chance of double-counting, because roads are rarely straight, and visual estimates of perpendicular distance are prone to error (Heydon *et al*. 2000; Ruette *et al*. 2003; Saunders & McLeod 2007). Heydon *et al*. (2000) suggested that the use of hand-held laser range finders could overcome this difficulty.

Before starting a spotlight count, it is necessary to standardise the technique. The route being taken, including the length of transect, should be established and plotted on a map. All vegetation types in the area should be sampled, and the route should be traversable in all weather conditions. The best way to achieve this is to inspect the area during the daytime, before the spotlight traverse. If possible, transects should also be marked out with reflectors, so that future surveys can easily follow the same route. Once set out, the fixed transect may be used for future surveys, so that valid comparisons can be made.

Surveys need to be conducted at least quarterly to account for seasonal differences in animal abundance, but more frequent surveys would provide greater information. If the monitoring is for pest-control success purposes, surveys should be completed before the control programs, and then about 1–2 weeks after. Regardless of seasonal frequency, a survey needs to be repeated on three or four consecutive nights. Where possible, repeat counts until they give similar indexes, in order to achieve a consistent level of precision; the standard error of counts should be within 10% of the mean (Saunders *et al*. 1995). Make sure the weather conditions are similar for all counts, and avoid nights of heavy rain.

Starting at the same time for each survey is also important. In order to be effective, the spotlight count needs to coincide with the period of highest activity of the target species. Generally, a start time of at least half an hour after sunset will be adequate to survey most nocturnal species, such as feral cats.

The length of the transect depends on the size of the area being surveyed. Indexes of abundance are calculated as animals per kilometre, so a transect should be a minimum of 1 km, but the longer the transect the more accurate the estimate. Somewhere between 10 and 30 km would be ideal, although a study in the Flinders Ranges suggested that transects at least 150 km long were required to obtain a stable index (Holden & Mutze 2002).

Vehicle spotlight counts

Materials required

Vehicle – 4WD with an enclosed cabin, and with a fixed, roof-mounted spotlight. The observer sits in the cabin and operates the spotlight by a swivel handle, or uses a hand-held spotlight.

People – 1 driver; 1 or more observers

*Spotlight hand-hel*d – 100 W, 12 V

Spotlight count sheet and clipboard

How to do the count

- - Start approximately half an hour after sunset from an established starting point.
- - One person drives, and another counts the animals.
- - Select a constant low speed of either 5 or 10 km/h, depending on the terrain, and maintain that speed.
- - The observer scans a 180° arc ahead of the vehicle with the spotlight, and counts animals seen within 100 m on either side.
- - When an animal is detected (usually by its distinctive eye shine), stop the vehicle to allow an accurate identification, and record the sighting on a standardised spotlight count sheet (see example in Table 1).
- - Repeat the count on three or more consecutive nights of similar weather.
- - On subsequent counts, start at the same time as the first count, and use the same distance, direction, vehicle, speed, spotlight and observers.
- - After completing the survey, determine the average of the counts and divide by the length of the transect, to get a simple index of abundance in feral cats per kilometre.

Variations on technique

Two people counting using two hand-held spotlights of the same power, with each observer surveying one side of the vehicle in a 90° arc ahead of the vehicle.

Using a voice recorder – record what was seen instead of using a count sheet. Transcribe the data at a later time.

Using a laptop computer – record data forms using programs such as Microsoft Excel or Microsoft Access, or equivalents.

Standards

Swathe – 180° arc in front of the vehicle.

Observation distance – a maximum of 100 m from the vehicle.

Route – travel the same transect, using identical directions for each count.

Time – start at the same time each day for each count, at least half an hour after sunset.

Rate of travel – select either 5 or 10 km h^{-1}, depending on the terrain, and maintain a constant speed.

Spotlight power – 100 W, 12 V

Observer – use the same observers for each count.

Vehicle – try and use the same vehicle for each count.

Distance of transects a minimum of 20 km of transects is recommended.

Repetitions – a minimum of three consecutive nights at each monitoring period.

Training required

4WD training

Instruction in setting up and using spotlight equipment

Worked example

To evaluate the success of a feral cat control operation. The transect length is 24 km.

Cats seen pre-control:

1st count: 3, 2nd count: 4, 3rd count: 4
total = 11
average = 11 ÷ 3 = 3.67
number of feral cats per km = 3.67 ÷ 24 = 0.15 feral cats km^{-1}

Feral cats seen post-control:

1st count: 0, 2nd count: 0, 3rd count: 1
total = 1
average = 1 ÷ 3= 0.33
number of feral cats per km = 0.33 ÷ 24 = 0.01 feral cats km^{-1}

The percentage reduction of feral cat numbers can be estimated from these figures:

$0.01 \div 0.15 \times 100 = 6.67$
$100 - 6.67 = 93.33\%$ reduction

Table 1. Spotlighting: example of a count sheet using encounter rate

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

Transect section	Cat (dog/fox)	Range	Kangaroo	Other	Stock	Vegetation type & condition

Comments:

Distance sampling

Materials required

Use techniques for spotlighting with the following additions:

Laser range finder

Compass, GPS and angle board

Computer software for density estimates

See Table 2 for an example of a count sheet for distance sampling.

How to do the count

Variations on the above techniques:

- - Transects should be as straight as possible; if possible, avoid roads.
- - Each time a feral cat is encountered, stop the vehicle and calculate the perpendicular distance from the transect line (using a laser range finder), or calculate the radial distance from the observer to the feral cat and the sighting angle between the line of sight to the feral cat and the transect line, at the moment of detection.
- - 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

See above techniques

Training required

See above techniques

Training in measurement of distances and angles

Computer software training

Table 2. Spotlighting: example of a count sheet using distance sampling

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

Species	Number	Range	Bearing	Habitat	Waypoint	Easting	Northing	Time

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

Track counts

The footprints (or tracks) of animals are often among the few indications that some species are present in an area, and counting the density of these tracks may be useful for monitoring purposes. Track counts are used predominantly for elusive animals or those found in low densities, such as feral cats (Edwards *et al*. 2000), foxes (Saunders *et al*. 1995) and wild dogs (Fleming *et al*. 2001). There is an assumed relationship between the number of tracks and the abundance of the species, but there have been few validations against known populations (Wilson & Delahy 2001; Fleming *et al*. 2001). Nevertheless, track counts are considered to produce reliable indexes of abundance that may be used to detect changes in populations (Bider 1968; Newsome *et al*. 1975; Newsome & Catling 1979; Catling & Burt 1994; Allen *et al*. 1996; Stander 1998; Edwards *et al*. 2000; Engeman *et al*. 2000; Wilson & Delahy 2001; Schauster *et al*. 2002).

Counting tracks is passive, and animal behaviour is not altered by detection. It can be done with sand plots or raked earth, where strips of sand are raked across a road at set intervals (Catling & Burt 1994; Allen *et al*. 1996; Catling *et al*. 1997; Engeman *et al*. 2002), or with road counts, where a road is used as a transect and the number of sets of tracks on it counted (Mahon *et al*. 1998; Edwards *et al*. 2000; Edwards *et al*. 2002; Burrows *et al*. 2003).

Strong rain and wind may reduce the clarity of footprints or remove them altogether, making accurate identification difficult. Interference from people walking or driving over plots can likewise affect counts. There is variability in the 'detectability' of footprints along a given transect because of soil type, colour, moisture and dappled shadows. This can be corrected by determining the relative 'detectability' of footprints (Fleming *et al*. 1996). More specifically, the use of roads and tracks as sampling units creates bias, owing to non-representative sampling of the study area (Anderson 2001; Mahon *et al*. 1998; McKelvey & Pearson 2001).

The relationship between track counts and animal density is usually unknown. These indexes measure changes in species activity that may or may not be related to actual abundance. In many cases, activity is likely to change with the seasons, independently of population density. For example, feral cat home range maintenance may break down in winter, facilitating activity increases during this time (Brothers *et al*. 1985), or the movements of these animals may vary in response to changes in food resources (Langham & Porter 1991). Similarly, the ability to detect footprints may vary seasonally due to changes in climate. It is best not to rely solely on track counts to measure changes in abundance until these techniques can be validated against known populations. Stratified sampling across the survey area may overcome some bias, but it would also greatly increase the time and cost of monitoring. Furthermore, even though they may be simple to conduct, methods that produce passive indexes require large sample sizes to provide accurate estimates of low-density populations (Allen *et al*. 1996; Wilson & Delahy 2001;

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

Fleming *et al*. 2001). The scale of the survey must match the likely home range size of the target species. If this is not achieved, the survey will measure the activity of only the few animals within the survey area. Therefore, track counts are not suitable for small-scale surveys (Sargeant *et al*. 2003).

To account for the variation in footprint 'detectability', and thus allow more valid comparisons between sites, a measure of 'imprintability' should be taken (Fleming *et al*. 1996). At every track station or sand plot, the observer walks 10 paces across the area and scores the resulting imprints on a scale of 0–3 (Van Dyke *et al*. 1986): 0 – no print visible; 1 – print barely visible; 2 – complete outline of print and some detail of the sole visible; 3 – complete outline of print and all details of the sole visible. The resulting point value for each location will vary between 0 and 30, and allows you to allocate a score for the location. A score of 0–5, – poor imprintability (1); 6–15, – fair (2); 16–25, – good (3); and 26–30, – excellent (4). Any track stations that score (1) should not be included in the index. These are arbitrary cut-off points, and may need to be expanded on a site-by-site basis.

Track stations (sand or earth strips 1 m wide across the road)

Materials required

Sand, shovel, rake – where possible, use local sand from washouts and road gutters, to avoid importing weeds and novel smells.

Count sheet

Map and GPS

Track diagrams – suggested text: Triggs, B. (1996)

How to do the count

- - Select sites to be monitored, using roads with low usage; at least 26 usable track stations at 1 km intervals is recommended.
- - Set routes and mark out the transects on a map and GPS. These transects may be used for all further surveys, so that valid comparisons with past records can be made.
- - When establishing track stations, avoid overhanging foliage, because dripping dew may affect the clarity of footprints.
- - Create the track station by placing a thin layer of sand, approximately 1 m wide and 1–3 cm deep, across the road from one side to the other. Rake smooth.
- - Create a unique name for each station and mark it on a GPS.
- - Establish track stations about every 1 km along the length of the transect.

- - Determine the 'imprintability' value and then sweep the track station clean of footprints.
- - The following morning, count and record all sets of feral cat footprints and prints of other species.
- - Repeat the count for at least three consecutive mornings for more than 78 station nights.
- - Convert to indexes via the mean number of tracks per transect per day (Allen index) or the percentage of station nights with tracks (Catling index). Remember to remove track stations that have an imprintability score of 1.

Standards

Route – use the same transects for each count.

Sampling time – always conduct the survey in the same season and during similar weather conditions.

Training required

Identification of tracks

Use of GPS

Worked example

Fifty track stations were established to monitor wild dogs, foxes and feral cats in a national park and surrounding freehold land. Track stations were situated at 1 km intervals and checked for three consecutive nights in late summer and late winter. The results are shown in Table 3.

Table 3. Track station counts: example of a count sheet using the Catling index

NO. OF TRACK STATIONS	NO. OF STATION NIGHTS	NO. OF STATIONS WITH IMPRINTABILITY SCORE OF 1	NO. OPERABLE STATION NIGHTS	NO. OF STATIONS WITH FOX TRACKS	CATLING INDEX VALUE
50 (late summer)	150	0	150	41	$= 33 \div 150 \times 100$ $= 22.00$
50 (late winter)	150	32	118	29	$= 26 \div 118 \times 100$ $= 22.03$

Table 4. Track station counts: example of a count sheet using the Allen index (late summer)

TRACK STATION #	DAY 1	DAY 2	DAY 3	TRACK STATION #	DAY 1	DAY 2	DAY 3
1	0	0	0	26	0	0	0
2	0	0	1	27	0	0	0
3	1	0	1	28	0	0	0
4	1	1	1	29	0	0	0
5	1	0	0	30	1	0	0
6	0	0	0	31	1	0	0
7	0	1	0	32	0	0	0
8	0	1	0	33	0	0	0
9	0	0	0	34	0	0	0
10	0	0	0	35	1	0	0
11	1	0	0	36	0	0	1
12	1	0	0	37	0	0	1
13	0	1	0	38	0	0	0
14	0	0	1	39	0	0	0
15	0	0	1	40	0	1	1
16	0	0	0	41	0	0	1
17	1	1	1	42	0	0	0
18	1	0	1	43	0	0	0
19	0	1	0	44	0	0	0
20	0	0	0	45	0	1	0
21	0	0	0	46	0	1	0
22	0	0	0	47	0	0	0
23	0	0	0	48	0	0	0
24	0	0	0	49	1	0	1
25	0	0	0	50	0	0	1
				TOTAL	11	9	13
				MEAN	$11 \div 50 = 0.22$	$9 \div 50 = 0.18$	$13 \div 50 = 0.26$
				ALLEN INDEX	$= (0.22 + 0.18 + 0.26) \div 3 = 0.22$		

Road counts

Materials required

Sand, shovel, rake – where possible, use local sand from washouts and road gutters, to avoid importing weeds and novel smells.

Drag for sweeping transect

Count sheet

Map and GPS

Track diagrams –suggested text: Triggs, B. (1996)

How to do the count

- - Select roads with low usage.
- - Set routes and mark out transects with recommended lengths of 10 kms. Use these transects for future surveys, so valid comparisons with past surveys may be made.
- - Establish each track survey transect by placing a thin layer of sand approximately 2–3 m wide and 1–3 cm deep along the length of the road. If the transect is naturally sandy or dusty, areas may just need to be raked or swept smooth with a drag (such as a steel bar) towed behind a vehicle, to remove existing tracks and make the surface impressionable. Alternatively, sand plots 5 m long could be established at 1 km intervals along the transect.
- - Mark the location of each transect on a map using a GPS.
- - Determine the 'imprintability' value every 1 km of transect.
- - Return the following morning, and count and record all sets of individual feral cat footprints and prints of other species. Individual footprints are defined as sets of footprints occurring not less than 500 m from the previous occurrence of that species on the road.
- - Sweep the transect clear of footprints with a drag pulled behind the vehicle.
- - Repeat the count for at least three consecutive mornings.
- - Convert footprints recorded to number of footprints per km or number of sand plots with footprints (Catling index – see track stations), and use the average as the index.

Training required

Identification of tracks

Use of GPS

Worked example

Fox control by aerial baiting was being planned in central Australia, and the abundance of these animals needed to be monitored immediately before and after the operation, in order to gauge its success. Feral cat tracks were monitored at the same time, to determine whether there was an effect on this pest species. Five transects, each approximately 20 km long, were established across the baiting area. The results are shown in Tables 5 and 6.

From the track count data it was assumed that there had been a 67% increase in cat abundance following fox control.

Table 5. Road counts: pre-baiting index

	DAY 1		DAY 2		DAY 3	
	NO. TRACKS	TRACKS km^{-1}	NO. TRACKS	TRACKS km^{-1}	NO. TRACKS	TRACKS km^{-1}
TRANSECT 1 (22 km)	6	0.27	7	0.32	6	0.27
TRANSECT 2 (19 km)	2	0.11	4	0.21	4	0.21
TRANSECT 3 (20 km)	5	0.25	3	0.15	2	0.10
TRANSECT 4 (25 km)	6	0.24	2	0.20	1	0.04
TRANSECT 5 (17 km)	1	0.06	5	0.12	2	0.12
MEAN		0.19		0.20		0.15
INDEX VALUE	$= (0.19 + 0.20 + 0.15) \div 3 = 0.18$ tracks km^{-1}					

Table 6. Road counts: post-baiting index

	DAY 1		DAY 2		DAY 3	
	NO. TRACKS	TRACKS km^{-1}	NO. TRACKS	TRACKS km^{-1}	NO. TRACKS	TRACKS km^{-1}
TRANSECT 1 (22 km)	8	0.36	11	0.50	7	0.32
TRANSECT 2 (19 km)	6	0.32	7	0.37	6	0.32
TRANSECT 3 (20 km)	4	0.20	6	0.30	5	0.25
TRANSECT 4 (25 km)	5	0.20	8	0.32	4	0.16
TRANSECT 5 (17 km)	7	0.41	4	0.24	3	0.18
MEAN		0.30		0.35		0.25
INDEX VALUE	$= (0.30 + 0.35 + 0.25) \div 3 = 0.30$ tracks km^{-1}					

% CHANGE	= (pre bait index value – post bait index value) $\div$ pre bait index value $\times 100$ $= (0.18 - 0.30) \div 0.18 \times 100 = 67\%$ increase in feral cat abundance

Capture–recapture: trapping and telemetry

Recapture methods are based on multiple sampling, and use 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 and unmarked animals, which are then marked and released, and so on, until the monitoring has finished. The resultant capture history is used to produce an estimate of the population. Various recapture methods are available for both closed and open populations, and have been reviewed in detail elsewhere (Seber 1982; Pollock *et al*. 1990; Schwarz & Seber 1999; Buckland *et al*. 2000). All these methods make assumptions that must be satisfied in order to produce unbiased estimates. Assumptions common to mark–recapture models are that (Caughley 1980; Krebs 1999):

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

The most common monitoring techniques that utilise recapture methodology are trapping and radio-telemetry. Trapping of feral cats in Australia has predominantly been used to capture animals for research (e.g. Risbey *et al*. 1997; Molsher 2001; Short *et al*. 2002). Leg-hold and cage traps can be used to capture feral cats with a variety of baits or lures, but cats are often difficult to trap. Successful and humane trapping requires extensive training and experience, and trapping by inexperienced operators can make animals 'trap shy'. Trap success is variable, and is most likely related to feral cat density, ranging from 0.2 feral cats per 100 trap nights (Twyford *et al*. 2000; Keedwell & Brown 2001) to 13.7 feral cats per 100 trap nights (Denny *et al*. 2002). Short *et al*. (2002) found that different traps captured different cohorts of feral cats, with older feral cats more susceptible to leg-hold traps, and cage traps more successful at trapping young feral cats that had little hunting experience and were scavenging for food. Trapping is time-consuming and labour-intensive, and is therefore suited only to small areas.

Trapping alone can be used as an index of abundance, by comparing trapping events using catch per unit of trapping effort. It can also be used in recapture studies and combined with radio-telemetry. This involves trapping the target animals as discussed, but instead of being removed these animals are tagged with ear tags or have radio-collars attached to them. They are released at the point of capture after measurements such as sex, weight, reproductive condition of females and age are taken. Subsequent sightings by spotlight counts can be used to estimate recaptures and population size. The movements of collared animals are measured by signals received by hand-held directional antennae and portable scanner/receivers. Alternatively, fixed receiver stations, immobile towers with greater range than hand-held receivers, can be used to determine animal locations. Radio-telemetry is useful for home range estimation and habitat use.

Feral cat caught in an Ecotrap®

Trapping

Materials required

Traps – approved soft-jaw traps suitable for catching feral cats (e.g. Victor Soft Catch® trap #1½) or wire mesh cage traps.

Bait/lures – rabbit, chicken, fish, kangaroo or tinned cat food. Olfactory lures include synthetic fermented egg, catnip, tuna oil, cat urine and anal gland preparation. Cat calling machines or 'felid attraction phonic devices', which emit a cat meowing sound, can be used as auditory lures. Visual lures, such as dangling a feather in the back of a trap, can also be useful.

How to trap with soft-jaw traps

- - Select the site to be monitored.
- - Before setting each trap, ensure that it is functioning properly.
- - Set traps where feral cats are most likely to find and investigate the unfamiliar lure odour; i.e. along tracks and trails, under bushes, or at rabbit warrens.
- - Anchor the trap to about 50 cm length of chain. Alternatively, the trap may be tied to 'drags' – objects such as rocks or small logs that will move when the feral cat pulls against the trap. Traps should be anchored to stakes or fixed objects only if there is a shock-absorbing device (such as a spring) fitted to the anchor chain and a swivel attaching the chain to the trap.
- - Set the trap and place it in position in a hole dug in the ground. Ensure that surrounding shrubs or debris will not interfere with the spring mechanism.
- - Carefully camouflage the area around the trap with leaves, grass or other debris, but leave a slightly cleared area (10–15 cm) over the area of the plate.
- - Place the meat bait approximately 10–15 cm behind the plate of the trap. Lures should be placed in suitable positions around the trap.
- - It is preferable to set traps at the end of each day and check early each morning. If traps are left set during the day, they should be checked again in late afternoon.

How to trap with cage traps

- - Select the site to be monitored.
- - Before setting each trap, ensure that it is functioning properly.

- - Set traps where feral cats are most likely to find and investigate the unfamiliar lure odour; i.e. along tracks and trails, under bushes or at rabbit warrens.
- - It may be useful to partly enclose the trap in a large bag, to prevent the feral cats from attempting to take the bait through the side or back of the trap.
- - Set the cage traps squarely on the ground, and bend the doors of the trap upward to increase the openness of the trap space.
- - Peg the trap to the ground to prevent the feral cat or another animal from tipping it over and injuring itself and/or releasing the trap door.
- - Place meat baits inside the trap, and lures in suitable positions inside and outside the trap.
- - Cage traps should be clear of vegetation, so that the feral cat can walk completely around the trap before entering.
- - It is preferable to set traps at the end of each day and check early each morning. When traps are open during the day there is a greater risk of birds, such as magpies and currawongs, entering and triggering the trap.
- - If traps need to be left open during the day, they should be checked again in late afternoon.

Cage trapping feral cats. All doors need to be well secured before attempting to move a live feral cat in the trap.

Standards

Follow the standard operating procedures when setting up traps.

Sampling time – set traps at the same time each year.

Trapping sites – set traps on the same sites for each sampling time.

Training required

Trapping techniques

Animal handling

Radio-telemetry

Materials required

Radio transmitters and receivers

GPS

Data sheets

How to do it

- - Capture feral cats as per trapping guidelines.
- - If necessary, sedate the captured animal with an appropriate dosage of an intramuscular injection.
- - Record physical condition, sex, weight, reproductive condition and approximate age.

- - Clean capture injuries and treat with an antiseptic solution.
- - Attach radio-collar with unique operating frequency around the neck of the feral cat.
- - Record details of the radio-collar frequency and double-check that the transmitter is operating correctly.
- - Allow the animal to recover from the anaesthetic and release it at the 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.
- - Home in as close as possible while causing minimal disturbance to the behaviour of the animal.
- - Once located, record the animal's position using a GPS.
- - Record time, habitat and animal behaviour.
- - Obtain radio fixes every hour for the duration of tracking session.

Vehicle radio-tracking:

- - Use an antenna, attached to the 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 and record position.

Fixed-tower tracking:

- - Establish at least two fixed 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 2–3 days.
- - Use triangulation to determine the target animal's position (see White & Garrott 1990; Kenward 2001).

Standards

Observer – use the same person to estimate the direction and location of radio fixes.

Training required

Trapping techniques

Animal handling

Firearms training

Use of radio-telemetry equipment and software training for determining home range

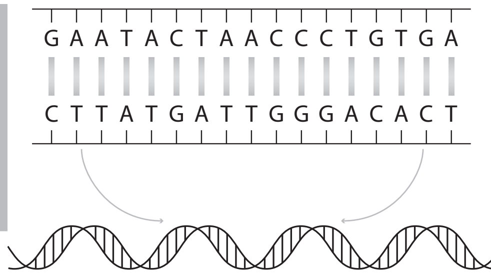
Global Positioning Systems telemetry

A further development of telemetry techniques is the utilisation of GPS to monitor the movement of animals. GPS telemetry is a relatively recent development for monitoring animal movements, and utilises GPS receivers attached to animals. These receivers use signals from satellites to determine location. There are two main methods of data storage and retrieval: onboard storage and remote download to a portable receiver (Mech & Barber 2002). Onboard storage relies on the retrieval of the collar and download of the data all at one time. Retrieval can be via recapture of the collared animal, or by triggering automatic or remote drop-off mechanisms to release the collar. The GPS unit is then located by its VHF signal. Remote downloading GPS units utilise VHF signals to send data to a portable receiver. The receiver must be within VHF receiving range (5–10 km ground to ground or 15–20 km air to ground), but allows data to be retrieved daily and minimises data loss.

The accuracy of GPS telemetry can suffer from interference from habitat and topography. For example, canopy cover may impede satellite signals, and frequent movement on steep terrain by collared animals may lead to 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 that as canopy cover and vegetation density increased, the corresponding positional error 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. There are higher numbers of successful locations 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 needs to be examined in Australian habitats to assess areas of potential bias and error. In spite of these effects, GPS telemetry appears to offer the most accurate method of tracking animals currently available.

The great advantages of GPS telemetry are the low field work requirements, the ability to determine a high number of locations per animal, the ability to be used in all weather conditions, and the fact that it causes little disturbance of the species. Animals need only be captured to attach the collar and recaptured to retrieve the transmitter, with no other field work required. Disadvantages include high cost, with prices varying with the type and size of package required. Also, the life span of GPS collars is shorter than that of VHF systems; however, this is determined by the sampling rate used.

The weight of GPS collars makes their use on feral cats difficult; in general, collars weighing more than about 3% of body mass tend to have adverse effects on the target species (Kenward 2001). However, GPS telemetry will become a valuable monitoring tool for feral cats in the near future, as technological advances allow for miniaturisation, and consequently the production of lighter collars.



Example of DNA sequence (diagram courtesy of AGAL)

DNA sampling

Sampling the DNA of animals may help overcome some of the limitations of traditional monitoring techniques, by providing accurate identification of samples to the species and individual level (Piggott & Taylor 2003). DNA collection can be invasive or non-invasive (using faecal and hair samples), with the latter being much simpler to collect, as feral cats do not need to be handled or observed. This type of sampling may be used for population and home range estimation, and can yield information on the sex ratio and source of the population.

The development of extraction methods for DNA contained in faeces and hair offers the most appealing opportunities for more precise population estimates through the derivation of genetic profiles of individual animals (Kohn & Wayne 1997; Piggott & Taylor 2003). Coyote (*Canis latrans*) abundance has been estimated from a large sample of coyote scats collected from roads. The scats were positively identified from diagnostic sections of mitochondrial DNA (Kohn *et al*. 1999). The scats were then genotyped to differentiate individual animals, and the cumulative number of unique microsatellites was expressed as a proportion of the number of scats sampled. The asymptote, or flattening out of the top of a curve, was determined as an estimate of local population size. Recapture models can be used with these types of data. A population of endangered wolverines (*Gulo gulo*) in Norway was monitored by using scats as a source of DNA to estimate population size, sex ratio, immigration rate and reproductive contribution from immigrants (Flagstad *et al*. 2004). Scats that were successfully analysed were treated as one trapping event, and then the number of times that each individual was trapped was recorded. Hair sampling has been used to estimate population size, and has been useful for studies of the grizzly bear (*Ursus arctos*) (Mowat & Strobeck 2000; Poole *et al*. 2001). Bears were sampled by removing hair at bait sites surrounded by single strands of barbed wire, and then using microsatellite profiling of the root portion of the hair to identify individuals. Subsequent sampling provided 'recaptures'. Other types of monitoring tools that may be used are catch per unit effort (Romain-Bondi *et al*. 2004) and presence or absence studies.

Molecular scatology can also be used to correct scat counts by accurately identifying scats to species level. In North American studies, scats were correctly assigned to a species in 50%–66% of cases (Halfpenny & Biesot 1986). In Great Britain, surveys of the endangered pine marten, *Martes martes*, have relied on morphological identification of scats in the field by expert naturalists; these have since been found to be unreliable in distinguishing pine marten scats from those of the red fox (Davison *et al*. 2002). In Australia, all of the larger mammalian carnivorous species – wild dogs, foxes, feral cats and quolls – produce scats that could be mistakenly identified by their morphology alone.

One of the main limitations is the high cost of extracting DNA from scats and hairs, owing to the low quantity and quality of DNA typically recovered from these types of samples (Harrison *et al*. 2002; Davison *et al*. 2002; Piggott & Taylor 2003). Fresh samples are required, and must be stored correctly in order to preserve the sample, as DNA degrades over time.

Suitable storage methods include rapid freezing at –20°C, dehydration by air-drying or alcohol treatment, and saturation in a buffer containing high concentrations of salts and other chemicals that will interfere with enzymes (Foran *et al*. 1997; Kohn *et al*. 1999; Piggott & Taylor 2003). Piggot & Taylor (2003) investigated preservation and DNA extraction methods for the faeces of mammals found in Australia, and developed a protocol that was found to be optimal for five different species, including the fox.

Their method involved air-drying of the fresh scats in paper bags (a process that is ideal for field collection), followed by surface washing to collect cells for the DNA extraction process. There is an inherent error rate in the process of DNA amplification using polymerase chain reaction (PCR), which may lead to misleading results, such as population overestimation (Wilson & Delahy 2001; Piggott 2004). Scats less than a week old will give the most accurate results, and this needs to be taken into consideration when planning a monitoring program. A minimum of three PCR replicates should be used for genotyping scats in summer, and eight replicates for winter samples (Piggott 2004). These methods, when used for population estimation, also rely on assumptions, such as defecation rates being equal among sexes and age classes and independent of social class. They also rely on recapture assumptions not being violated (Kohn *et al*. 1999; Mowat & Strobeck 2000).

In spite of these problems, DNA sampling will be an effective and efficient way of monitoring species, such as feral cats, that can be difficult to observe, exist at low densities and have large home ranges (Piggott & Taylor 2003). Collecting scats is a relatively easy way to obtain DNA samples of many carnivores, with the additional benefit of giving dietary information; however, feral cats will often bury their scats or use latrines (Triggs 1996). Nevertheless, where rabbits are present, feral cats will frequently deposit scats on rabbit warrens and make no attempt to bury them (Molsher *et al*. 1999). It might also be easy to obtain hair samples by using odorous lures to attract feral cats (Clapperton *et al*. 1994; Andelt & Woolley 1996; Edwards *et al*. 1997). Chemicals such as these elicit a scent-marking behavioural response in foxes, namely that the animals rub or roll on the source of the odour (G. Saunders pers. comm.). Simple hair snares, such as carpet squares (with protruding nails to snag hairs) with an appropriate attractant, may be attached to trees, and have been used successfully to monitor lynx (*Lynx canadensis*) populations (McDaniel *et al*. 2000). This is effectively a variation of a track station, where hair, instead of footprints, is left to indicate visitation. DNA sampling gives a more reliable population estimation than traditional track station methodology.

MONITORING FERAL CAT IMPACTS

This section discusses the different methods that can be used to monitor the impacts caused by feral cats.

Cost monitoring

Costs of control

The cost or effort involved with annual feral cat control can be used for estimating trends in cat abundance. However, feral cat control is often incorporated into fox control programs and is difficult to apportion out.

Examples of costs associated with shooting

Labour – time for driver and shooter: five hours per night

Vehicle running costs – average of 50 km per night for 5 nights

Consumables – ammunition, spotlight

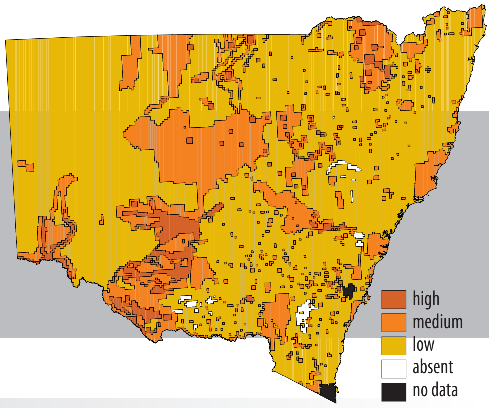
The average total cost per program can then be calculated.

Other costs

It is difficult to accurately estimate the agricultural costs attributable to feral cats in Australia on a national, state or regional level (Bomford & Hart 2002). Conservative estimates of the annual cost impact of feral cats have been put at $144 million (McLeod 2004). However, this value is made up almost entirely of environmental costs ($2 million spent on control and research), and is based on limited information extrapolated from sources such as government agency estimates. It has been acknowledged that there are many gaps in the knowledge (Bomford & Hart 2002; McLeod 2004). Conservation managers may therefore play a significant role in filling these gaps, by calculating and monitoring all the costs attributable to feral cats. These costs include control expenditure, infrastructure installation and maintenance. The inference that is made from cost monitoring is that a decline in costs is associated with a decline in feral cat abundance.

Table 7. Example of a sheet used to monitor other costs

ACTIVITY	LABOUR ......h @ $ h^{-1}	MATERIAL	COST $
Shooting		Vehicle @ $ km^{-1} Ammunition Firearm maintenance	
Trapping		Vehicle @ $ km^{-1} Trap maintenance Ammunition Firearm maintenance	
Exclusion fence maintenance		Posts Wire	



Feral cat density (source NSW DPI)

Monitoring vulnerable prey species

The predation impact of feral cats on threatened or vulnerable native species may be estimated by monitoring the populations of these prey species. The population densities of these species can be monitored before and after extensive control plans have reduced the density of feral cats. However, this has rarely been adequately attempted (Meek & Kirwood 2003), although recent threat abatement plans for foxes and feral cats have incorporated this type of monitoring into their proposed actions (NPWS 2001; DEC 2004), and in one study 11 medium-sized species responded to fox control by first increasing population size and then expanding distribution. Techniques for monitoring prey species vary for species and habitat and are situation specific, but they will often consist of small mammal trapping and track counts for larger mammals (Catling *et al*. 1997). In Heirisson Prong in Western Australia, small mammals and reptiles were monitored before and after predator control by pitfall trapping, and it was shown that small mammal numbers increased in an area of low feral cat and fox density, but where only foxes were controlled, captures of small mammals declined by 80% (Risbey *et al*. 2000).

In situations where feral cats are being controlled for native species protection, it is important that wild dogs and foxes be simultaneously controlled (Burbidge & McKenzie 1989). Control of feral competitors of the species targeted for protection may be necessary in conjunction with predator control. For example, in NSW the endangered malleefowl has shown little recovery after predator control (Priddell 1991), most likely due to competition with rabbits for food (Frith 1962). Thus, 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.

Mapping feral cat damage and population densities

Mapping the distribution and densities of feral cats over a given area facilitates the development and assessment of land and feral cat management plans. Regular updating of these plans enables existing management to be modified. These plans may be a simple hand-drawn map, or more detailed and accurate topographic maps generated with Geographic Information System software. The choice of map type will depend largely on the scale of the area involved, the cost and availability of the technique, and the extent of the feral cat problem (Saunders *et al*. 1995). These maps may include the locations of fox dens and poison baiting trails, to indicate gaps in the coverage of control programs; the locations of areas of rabbit infestation, which may indicate areas where feral cat control is needed; and refuge habitat and preferred habitat of endangered species. The maps can be used as part of an overall reserve management plan, and to assess progress over the years. At a larger scale, the NSW Department of Primary Industries has surveyed NSW Rural Lands Protection Boards and NSW National Parks and

Wildlife Rangers to develop state-wide maps of pest species distribution and abundance (West & Saunders 2003). These GIS-generated maps are regularly updated to determine changes in the population densities of these species (P. West pers. comm.).

Information to include on maps is:

- - scale and north
- - 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
- - refuge habitat, such as woodland and shrubland
- - lambing paddocks
- - feral cat abundance estimates and spotlight indexes
- - den locations
- - areas of rabbit infestation
- - types 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 with previous maps to evaluate the success of current management practices.

SUMMARY OF FERAL CAT MONITORING TECHNIQUES

The various feral cat abundance and impact monitoring techniques discussed in this manual, and their advantages and disadvantages, are listed in Table 8. Table 9 compares the different monitoring techniques.

Table 8. Advantages and disadvantages of the monitoring techniques discussed in this manual

MONITORING TECHNIQUE	ADVANTAGES	DISADVANTAGES
Spotlight counts	• quick and simple • inexpensive	• counts can be highly variable between observers • sightability can be affected by height of pasture, vegetation or habitat type • unreliable method in wet and windy conditions • difficult to compare counts between variable weather conditions
Track counts	• can monitor several different species at the same time • quick and simple • target animal doesn't need to be sighted	• unreliable method in wet and windy conditions • unknown relationship to density • not representative coverage of area • potential for interference from vehicles
Capture–recapture	• accurate estimate of abundance • other information may be collected at the same time	• expensive • labour-intensive • time-consuming • difficulty of capture
GPS telemetry	• improved ability to monitor animals in rugged and remote terrain • reductions in travel and field work time	• expensive • difficulty of capture • accuracy of fixes can be variable
DNA sampling	• target animal doesn't need to be sighted • improved accuracy of scat counts • density estimates possible	• expensive • correct storage important • time-consuming
Vulnerable prey species	• prey species may be easier to monitor than feral cats	• difficulties in determining whether abundance is related to feral cat predation
Costs of control	• inexpensive; part of control program • can be incorporated into existing economical management	• unreliable if degree of effort or methodology changes • costs increase each year; need to account for inflation
Other cost monitoring	• inexpensive • can be incorporated into existing economical management	• assumed relationship with feral cat abundance

Table 9. Feral cat monitoring techniques ranking table

	LABOUR	START-UP COST	EXPERTISE AND TRAINING	SPECIALISED EQUIPMENT	HUMANENESS	OH&S
Vehicle spotlight counts	Moderate	Moderate	Low	Low	High	High
Distance sampling	Moderate	Moderate	Moderate	Moderate	High	High
Track stations	Moderate	Low	Low	Low	High	Low
Road counts	Moderate	Low	Low	Low	High	Low
Trapping	High	High	High	Moderate	Low	Low
Radio- telemetry	High	High	Moderate	High	Moderate	Low
GPS telemetry	Moderate	High	Moderate	High	Moderate	Low
DNA sampling	Low	High	Low	High	High	Low

GLOSSARY

Allen index

The mean number of animal tracks per transect per day.

Angle board

Estimation of the sighting angle relative to the transect line can be accomplished using an angle board. By collecting and recording distance and angle measurements for each animal seen, perpendicular distance can be calculated.

Associative learning

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

Bait-station night

The number of bait stations multiplied by the number of nights of baiting.

Catling index

The percentage of station nights with animal tracks.

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 the primary motivation behind immigration and emigration.

Index of abundance

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

Microsatellites

Repeated stretches of short sequences of DNA used as genetic markers to track inheritance in families. They are short sequences of nucleotides (e.g. ATGC) that are repeated over and over again in tandem.

Mitochondrial DNA

The genetic material of the mitochondria, the organelles that generate energy for the cell. Mitochondrial DNA is passed down from the mother to all her children – males and females.

Neophobic aversion

A tendency for behaviour to be extinguished or a thing avoided as a result of the development of a new fear, usually in relation to a noxious stimulus.

Pitfall trap

A hole dug into the ground so that animals will fall in and not be able to get out.

Polymerase chain reaction (PCR)

A powerful method of amplifying specific DNA segments that exploits certain features of DNA replication.

Presence or absence study

An approach to determining diversity in an ecosystem by determining what species are present in the ecosystem.

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; a sampling method in which the population is divided into homogeneous subgroups and then a simple random sample is taken from each subgroup.

Transect

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

Trap night

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

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