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MONITORING TECHNIQUES FOR VERTEBRATE PESTS

FOXES

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WHY MONITOR VERTEBRATE PESTS?

The purpose of this manual is to provide details of the techniques available to monitor the fox 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 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 (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, that 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 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 the fox.

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

GEN001 *methods of euthanasia*

FOX001 *ground baiting of foxes with 1080*

FOX002 *aerial baiting of foxes with 1080*

FOX003 *ground shooting of foxes*

FOX004 *fumigation of fox dens using carbon monoxide*

FOX005 *trapping of foxes using padded jaw traps*

FOX006 *trapping of foxes using cage traps*

RES001 *live capture of pest animals used in researc*

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 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, release animal immediately.
- Injured animals should be euthanased using a technique that is suitable for the species.
- If the injuries are serious and the animal is likely to recover, it should receive veterinary attention as soon as possible.

Occupational Health and Safety

Hydatosis

Hydatosis is infection by the hydatid tapeworm, *Echinicoccus granulosus*. It carries the highest risk to employees working with foxes and wild dogs. Foxes and dogs are the intermediate host and human is the final host. The hydatid tapeworm causes cysts to develop in any part of the body. It is prevented by using gloves and washing hands when handling foxes, dogs and scats. If picking up the scats, wear gloves and use either forceps or 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, so parasite eggs are not inhaled.

Aerial surveys

- Pilots should not be asked to fly under unsafe conditions, close to steeply rising terrain, trees or structures, or in adverse weather conditions.
- Aerial observers should have attended the Operating Safely around Aircraft, Aerial Observer or 'Fly the Wire' training course, and be competent at observing hazards such as power lines.
- Aircraft companies 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, 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 or, carry some or all of the following: 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

- Check previous rainfall and surface conditions before the survey.
- The driver and observer must not be fatigued at the time of conducting a survey.
- The observer should wear adequate clothing during cold weather.
- Remove dangerous overhanging obstructions before the survey.
- The driver and observer must drive the transect before commencing the survey, to demonstrate that it is navigable.
- All occupants should carry drinking water, emergency food rations, a torch and adequate clothing in the event of the vehicle becoming disabled.
- The driver and observer must have a fatigue management program prior to the survey.
- The driver should travel at the 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 the spotlight is well maintained, with the leads wired securely to battery terminals and insulated from other components.
- Avoid battery clips that may fall off.
- 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 the 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 foxes

- Protective clothing, boots and leather gloves may help prevent injuries from shovels, hammers and trap jaws.
- Trapped foxes are dangerous to handle and can inflict serious bites. If handling is necessary, use leather gloves and a catching pole.
- Operators must be protected by tetanus immunisation in case of bite infection.
- Foxes may carry parasites such as hydatids or sarcoptic mange mites, which can affect humans and other animals.
- Routinely wash hands and other skin surfaces contaminated with blood, faeces and other body fluids.
- Attending a manual handling training course is recommended before lifting heavy items.

Attaching transmitters

- Attaching transmitters to animals can affect their behaviour, particularly the ability to move and survive in a harsh environment.
- Avoid capturing and attaching transmitters during the animals' reproductive cycle.
- At least two people must be present when fitting a transmitter, with 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.
- On-the-job training, by an experienced operator, must be given to a person before they fit a transmitter.
- Before releasing an animal, everyone in the team restraining an animal must agree on the release procedure, and they must verbally communicate to ensure that they all release the animal simultaneously.

KNOW THE PEST: THE FOX

History

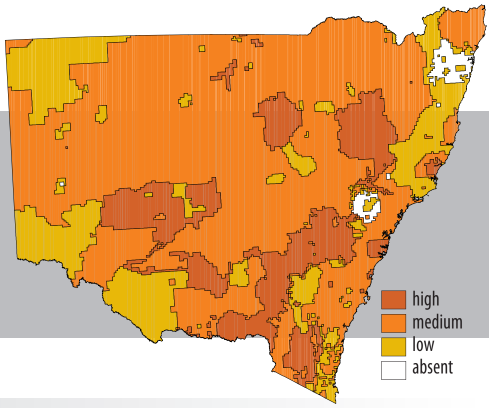
The European red fox (*Vulpes vulpes*) was introduced into Australia as early as the 1850s, although the most successful releases took place in southern Victoria in the early 1870s (Rolls 1969). Foxes were introduced primarily for sporting purposes, and they spread across Australia, closely following the dispersal of the European rabbit (*Oryctolagus cuniculus*). The rabbit had been introduced about 10 years earlier (Rolls 1969) and was the fox's main natural prey species (Newsome *et al*. 1997). Within 30 years of its introduction, the fox had attained pest status in Victoria, New South Wales and southern Queensland,. It reached Western Australia by 1915 (Jarman 1986; Saunders *et al*. 1995). By the early 1930s, foxes could be found in most habitats across the southern two-thirds of the mainland, and 20 years later they had started colonising the Kimberley region (Jarman 1986). The current distribution of the fox covers all of mainland Australia, with the exception of the tropical north (Saunders *et al*. 1995). There is evidence to indicate that a fox population has been established in Tasmania (Saunders *et al*. 2006).

Impacts

The fox is a serious predator of lambs, and earlier studies suggest that foxes enter lambing paddocks as scavengers and as predators of weak or unhealthy lambs. Recent research, using ultrasound pregnancy testing of ewes, suggests that true lamb losses may be as high as 30%, because graziers do not know how many lambs their ewes would have been carrying prior to predation.

Foxes are also implicated in the demise of Australian native fauna. Since European settlement, at least 27 mammal species have become extinct in Australia, and many others have suffered large reductions in their distribution and abundance (Department of Environment and Heritage 2004). Fox predation is considered one of the main forces behind some of these declines, especially for the 'critical weight range' (0.35–5.5 kg) mammals (Burbidge & McKenzie 1989). Predation by foxes has now been listed as a key threatening process under the *NSW Threatened Species Conservation Act 1995* and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*.

European red fox



Fox density (source NSW DPI)

Distribution

Densities vary from around 1 km^{-2} in the coastal forests and around 2 km^{-2} in the semi-arid grazing lands and subalpine regions, to 4–7 km^{-2} in the temperate grazing lands (Saunders *et al*. 1995).

Fox populations have become well established in most urban areas, where food is relatively easy to find, and they can be found in the central business districts of most large cities in Australia.

Habitat

Foxes have successfully colonised a wide range of habitats, from urban areas to deserts throughout Australia, except for the tropical far north. It has been suggested that fragmented environments are more favoured, as these habitats offer a wider range of shelter, food and den sites than in more uniform forest or rangelands (e.g. Catling & Burt 1995). There are some anecdotal accounts that suggest that where wild dogs are abundant, foxes are rare (Jarman 1986; Newsome *et al*. 1997). However, recent work has suggested that the distribution of foxes is not limited by forest habitat or wild dog presence, and other factors may be equally important (P. Fleming pers. comm.; Mitchell & Banks 2005).

Biology

Diet

Adult foxes weigh between 4 and 8.3 kg and can eat 300–550 g of food a day (Coman 1995; Saunders *et al*. 1995). The fox is an opportunistic predator and scavenger, being primarily carnivorous. In grazing areas, the primary diet of foxes consists of sheep (either as carrion or young lambs), rabbits and house mice. However, foxes will readily take small and medium-sized native animals (Mitchell & Banks 2005), and they consume fruits and insects when available, especially if other prey species are scarce. When there is abundant food, foxes will often bury or cache excess food. When food is scarce, such as in winter, cached food is recovered.

Reproduction

Foxes breed once a year, with females coming on heat for two or three days over a few weeks in late winter. The gestation period lasts 51–53 days, and an average litter of four young is born in a den (Saunders *et al*. 1995). Cubs are usually grey when first born, and change to the characteristic red colour over the first few weeks of life. Cubs leave the den at about 10–12 weeks, and are independent by 6 months of age. Both sexes reach sexual maturity in their first year.

There may be a proportion of the female population that does not breed each year, but this is more likely where there is low mortality in the group. These vixens may help in the raising of cubs (Macdonald 1979).

Mortality

Apart from human intervention through poison baiting (1080) and diseases such as sarcoptic mange, there are few limitations to fox populations. The fox has few natural predators, although birds of prey, snakes and wild dogs may prey upon cubs. However, the impact of drought and the subsequent abundance of available food appears to have a controlling influence on the overall population (Saunders *et al*. 1995). A crash of rabbit populations, a primary source of prey, during drought or control programs such as myxomatosis or rabbit calicivirus disease in the southern pastoral zones, leads to a subsequent reduction in fox population density. (Myers & Parker 1975; King & Wheeler 1985; Newsome *et al*. 1989).

Social structure

Foxes tend to live as pairs or, in areas where food is abundant, in small family groups typically consisting of a dominant adult pair and some subordinate vixens usually related to the dominant pair (Saunders *et al*. 1995). Cubs may disperse when they reach sub-adulthood in late summer.

Movements and home range

The red fox is solitary by nature, and relies on stealth to find prey and to avoid contact with humans or other predators. Foxes are most active at night, either hunting or patrolling their territory, but daytime activity is common, especially by adults feeding cubs (Saunders *et al*. 1995). By day they usually rest in their hide, which may be a hollow log or tree, an enlarged rabbit burrow or dense undergrowth.

Family territories vary with habitat type and food availability, ranging from 2 to 5 km^{-2}, and boundaries are marked by urine and faeces. Scent marking is used to indicate an individual's sex and breeding status. Foxes usually move within their own home range, but will travel up to 25 km in search of food. Individuals can disperse at about 30 km per year to find new territories.

MONITORING FOX ABUNDANCE

This section discusses the methods used to monitor fox abundance. A summary table at the end of the handbook compares the methods of monitoring fox impact.

Spotlighting

Night-time counting using spotlights has been used for many years to survey foxes (Newsome *et al*. 1989; Weber *et al*. 1991; Mahon *et al*. 1998; Heydon *et al*. 2000; Greentree *et al*. 2000; Edwards *et al*. 2000; Sharp *et al*. 2001). Spotlighting is relatively easy to do, and large areas can be covered in a short amount of time. Spotlighting can sample different vegetation types and compare them under similar conditions, such as season, time of day and weather, within a site.

Simple indexes of abundance can be produced from these counts, such as the number of animals seen per kilometre travelled. However, indexes created from spotlighting counts have bias caused by the use of different observers or changes in visibility or sightability due to vegetation density (Twigg *et al*. 1998; Wilson & Delahy 2001). Other sources of potential variation include the time of night that the survey is undertaken and seasonal variations in animal behaviour and abundance. The use of roads as transects means vegetation types may not be surveyed evenly (Weber *et al*. 1991; Thompson *et al*. 1998; Ables 1969; Stahl 1990). Where fox density is low, spotlighting may fail to detect their presence, and as a result spotlighting has a tendency to underestimate fox numbers (Mahon *et al*. 1998; Edwards *et al*. 2000; Read & Bowen 2001; Reynolds & Short 2003).

Despite these shortcomings, spotlighting has been extensively used in Australia, and is considered a practical tool for monitoring the relative size of the fox population, especially where the habitat is open grassland or open woodland where trees are sparse (Newsome *et al*. 1989; Saunders *et al*. 1995). Sharp *et al*. (2001) suggested that spotlight counts can accurately indicate fluctuations in fox population size but may not be able to detect small changes in abundance.

Density estimates from spotlight counts can be made by using the distance sampling method, by which 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, if they do move, it is in a random direction – movement away from observer is evasion (and bias towards underestimation) while movement towards observer is attraction (and bias towards overestimation)
- individuals are not recorded twice
- distance measurements (and angles) are accurate (Buckland *et al*. 1993; Rudran *et al*. 1996).

Spotlighting for foxes

Fox at night (spotlighting)

Buckland *et al*. (1993) also suggested that a sample size of at least 60 sightings is needed for accurate density estimation.

Detection of all animals on a transect may not be achievable, although double sampling, using two independent observers, may help alleviate the problem. Most spotlight counts of foxes occur on roads or trails and have associated problems (as 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.

Prior to starting the spotlight count, standardise the technique by plotting the route and length of the transect on a map. Ensure the transect passes through all vegetation types represented in the area; and that the route is traversable in all weather conditions. Inspect the area during daylight, before the placement of the transect. If possible, transects should be marked out with reflectors, so surveys can be repeated in the future. Once set out, this fixed transect should be used for all further surveys in the study, so that valid comparisons to previous observations can be made.

Surveys should be conducted quarterly, to account for seasonal differences in abundance of foxes; however, more frequent surveys may provide more information on population changes. If the monitoring is for pest control, surveys need to be completed prior to control and approximately 1–2 weeks post-control. Regardless of the frequency, a survey needs to be made up of counts repeated on three or four consecutive nights. Where possible, counts should be repeated until they give similar indexes in order to achieve a consistent level of precision or the standard error of counts should be within 10% of the mean (Saunders *et al*. 1995). Similar weather conditions for all counts are required; avoid nights of heavy rain.

Starting during the period of highest activity of the fox is important; generally, this is autumn, when males are seeking females for mating. Begin the survey at least half an hour after sunset.

The length of the transect depends on the size of the area being surveyed. Indexes of abundance are calculated as animals km^{-1}, so a transect should be a minimum of 1 km. However, the longer the transect the more accurate the estimate. Somewhere between 10 and 30 km would be ideal.

Materials required

Four-wheel drive vehicle with an enclosed cabin and a fixed roof-mounted spotlight on the passenger side, with the observer sitting within the cabin and operating the spotlight by a swivel handle or using a hand-held spotlight.

Spotlight – hand-held type: 100-W, 12-V

Count sheet and clipboard – (see example Table 1)

Reflectors and star pickets to mark out the transect

How to do the count

- Start approximately half an hour after sunset from an established start point.
- One person drives and another person counts animals.
- Drive at a constant slow speed (5–10 km/h).
- Observer scans a 180° arc ahead of the vehicle with the spotlight and counts the animals seen within 100 m on either side.
- When an animal is detected (usually by a distinctive yellow-orange eye shine), stop the vehicle to enable an accurate identification and record it on a standardised spotlight count sheet (see Table 1).

Repeat the count on three or more consecutive nights of similar weather.

On subsequent counts, start at the same time as the first count and use the same route, distance, direction, vehicle, speed, spotlight and people.

After completion of the survey, determine the average of the counts and divide by the length of the transect to get a simple index of abundance (animals km^{-1}).

Variations on technique:

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

Use a tape recorder to record what was seen rather than a count sheet, and transcribe the data at a later date, or use a laptop computer to record data. Forms can be made using programs such as Microsoft Visual Basic or Microsoft Access.

Standards

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

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

Rate of travel – 5–10 km h^{-1} at a constant speed

Spotlight power – 100-W, 12-V

Observer – use the same observer for each count

Vehicle – use the same vehicle for each count

Training required

4WD training

Instruction in setting up and using spotlight equipment

Worked example

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

Foxes seen pre-control:

1st count: 9, 2nd count: 11, 3rd count: 10
total = 30
average = 30 ÷ 3 = 10
number of foxes per km = 10 ÷ 24 = 0.42

Foxes seen post-control:

1st count: 0, 2nd count: 1, 3rd count: 3
total = 4
average = 4 ÷ 3 = 1.33

number of foxes per km = 1.33 ÷ 24 = 0.06

The percentage reduction in fox numbers is estimated from these figures:

0.06 ÷ 0.42 × 100 = 14.29
100 – 14.29 = 85.71% reduction

Distance sampling

Materials required

See above techniques, plus:

Range finder

Compass, GPS or angle board

Computer software for density estimates

How to do the count

- Transects should be as straight and flat as possible; avoid roads if possible.
- Each time a fox is encountered, stop the vehicle and calculate the perpendicular distance from the transect line (with a laser range finder) or the radial distance from the observer to the fox, as well as the sighting angle between the line of sight to the fox and the transect line at the moment of detection.
- Density estimates are computed by software, e.g. DISTANCE (Laake *et al*. 1993). For an extensive review of distance sampling see Buckland *et al*. (1993).

For an example of a count sheet used for distance sampling see Table 2.

Training required

See above techniques, plus:

Measurement of distances and angles training

Computer software training

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		

Species	Number	Range	Bearing	Habitat	Waypoint	Easting	Northing	Time

Comments:

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

Bait stations

The use of toxic or non-toxic bait and scent stations is a monitoring method that utilises lures to attract and thus detect the fox. The response of the red fox to bait stations differs between toxic and non-toxic variants. With non-toxic bait stations the frequency of bait-take initially increases until a plateau is reached. With toxic bait stations there is a decrease in bait-take over time as foxes are removed from the area.

A bait station consists of about 1 m^2 of raked sand, with meat covered or buried in the ground to a depth of 5–10 cm. Bait stations are usually situated on the verges of roads, and the meat is covered or buried to limit removal by birds and quolls (*Dasyurus* species) (Allen *et al*. 1989; Fleming 1996; Belcher 1998). Roads are utilised because foxes and wild dogs use them for movement and territorial marking. They provide easily accessed monitoring sites (Triggs 1996; Corbett 2001). To reduce non-target bait-take by quolls in poison baiting control programs, it has been suggested that baits should be buried below ground level rather than in a mound (Glen & Dickman 2003b). Scent stations have been used extensively in North America to attract coyotes and are similar to bait stations, except that they use a fatty-acid scent tablet placed on top of smoothed sand (Roughton & Sweeny 1978; Sargeant *et al*. 1998; Warrick & Harris 2001; Schauster *et al*. 2002). Scent stations have not been used widely in Australia; Allen *et al*. (1996) found that track counts were more sensitive indexes.

Simple daily indexes of abundance can be calculated from bait-take or bait station visitation (frequency of visitation = f):

$$f = \text{number of fox visits} \div \text{number of operable bait stations}$$

The total number of operable bait station nights is determined by removing from the count any stations where the bait is removed and animal tracks are not identifiable because of either rainfall, vehicle tracks or animal interference (Roughton & Sweeny 1978). Raw indexes (f) are converted by logarithimic transformation to allow interpretation, because the relationship between fox density and visitation rates is not usually linear (see below).

Index removal method

An estimate of population size may be made before and after a known number of animals are removed from the population by a poison baiting program (Caughley 1980). This is known as the index-removal-index method. It has been used with non-toxic baiting to test the efficacy of control programs, by the calculation of population estimates before and after toxic baiting, using an estimated number of fox kills (Thompson & Fleming 1994; Fleming 1997).

Catch per unit effort

Cyanide baiting, providing a catch per unit effort index, has been used before and after aerial 1080 baiting programs (Algar & Kinnear 1992; Thomson *et al*. 2000; Kinnear *et al*. 2002). However, the index-removal-index method may leave some bait-shy foxes, so it is best suited to providing population estimates where the index method does not involve baiting.

Setting a fox bait station

Some problems and solutions for bait stations

Using bait stations to monitor populations may alter the normal behaviour patterns of the fox, and this may influence results. Contagion, caused by associative learning, may increase daily visitation rates, as can immigration of new animals, leading to overestimation of the size of the fox population (Allen *et al*. 1989; Thompson & Fleming 1994). This effect may be limited if the bait stations are only active for about 4 days (Allen *et al*. 1989). The spacing of individual bait stations, the presentation of bait, habitat differences between sites, frequency of operations and quality of tracking surfaces may affect the ability of this method to estimate abundance and detect change (Thompson & Fleming 1994).

Non-toxic bait stations

At each site, visitations by foxes to bait stations are recorded as a frequency. Investigative visitation and actual removal of baits are recorded separately, but all visitations contribute to the index. Bait stations become unavailable to other animals once a fox has removed a bait; therefore, the relationship between fox density and bait take is not linear. In addition, more than one animal may visit a station, but this will be recorded as one visit. This can be accounted for with the use of a frequency-density transformation (Caughley 1980):

$$v = -\log_e (1 - f)$$

where f is the frequency of visitation to bait stations by foxes, and v is the mean density of the occurrence of fox sign per bait station (Fleming 1997).

Contagion causes the daily frequencies of bait take to form a curve that flattens out at high values (see Figure 1). An index of fox abundance can be achieved by checking bait stations daily and recording visitations until the curve has reached a plateau. The mean of three or more days after the plateau is reached is used as the index. This may take many days to achieve, with studies by Thompson and Fleming (1994) needing 10 days, Fleming (1997) 16 days, and Allen *et al*. (1996) 21 days for dingoes to achieve the required results.

Materials required

Vehicle

Sand, shovel, rake and broom – where possible, use local sand from washouts and road gutters, to avoid the importation of weeds and novel smells; these may influence the response of the target animal.

Bait and tongs – use small pieces of dried meat, either kangaroo or beef.

Count sheet

GPS and a topographic map

Track diagrams – suggested reference text: Triggs, B. 1996 *Tracks, scats and other traces: a field guide to australian mammals*, Oxford University Press, South Melbourne.

How to do the count

- Select sites to be monitored, use roads with low, (or nil) usage and record location on map.
- Set up bait stations: dig small hole for bait about 10 cm deep, then fill in, cover the soil with sand to a depth of 1–3 cm. Station should be approximately 1 m^2.
- Separate bait stations by a minimum of 500 m and place on alternate sides of the road.
- Name or number each bait station and mark individual station positions on a GPS or map.
- The morning after establishing the site, count and record (in separate columns) all visits, bait-takes and other species present.
- Replace baits as required, to maintain the same number of baits available each day.
- Sweep the station clean and do not drive over it again that day.
- Using the calculations above, convert raw data to indexes of the mean number of stations visited each night.
- Use a logarithmic transformation available in the Microsoft Excel computer program, to create a graph of the transformed data.
- Repeat count until the bait-take curve has flattened out (see Figure 1). Use the mean of at least three days after the curve has reached a plateau as the index of abundance. A few days may probably pass before it is realised that bait-take has reached that plateau.

Standards

Bait stations – use the same material for each bait station and ensure that the same size is maintained for all stations. Separate by a uniform distance of at least 500 m. Use the same dried meat bait type and weight, and the same depth of burial – about 10 cm.

Route – use the same transect for each count.

Sampling time – conduct surveys during the same season and during similar weather conditions.

Duration – always use the same number of days to compare transects (this is not a requirement when comparing surveys, as the flattening of the curve determines the duration).

Training required

Identification of tracks

Use of GPS

Worked example

One hundred bait stations were established and checked each day. The number of operable bait stations changed because of disturbance from birds and wild dogs. The results are recorded in Table 3 and Figure 1.

The index was taken after day 4, when the curve flattened out (0.73).

Table 3. Bait stations: example of count sheet for estimating fox abundance by non-toxic baiting

DAY	NUMBER OF FOX VISITS	OPERABLE BAIT STATIONS	FREQUENCY OF VISITATION	INDEX OF FOX ABUNDANCE
1	21	100	0.21	0.24
2	36	95	0.38	0.48
3	39	89	0.44	0.58
4	46	90	0.51	0.71
5	47	89	0.53	0.76
6	45	86	0.52	0.73
7	45	92	0.49	0.67
8	47	95	0.51	0.71
9	48	90	0.53	0.76

Worked examples for day 1
frequency of visitation (f)
= number of fox visits ÷ number of operable bait stations
$f = 21 \div 100, = 0.21$

index of fox abundance (v) $= -\log_e(1 - f)$
$v = -\log_e(1 - 0.21) = 0.24$

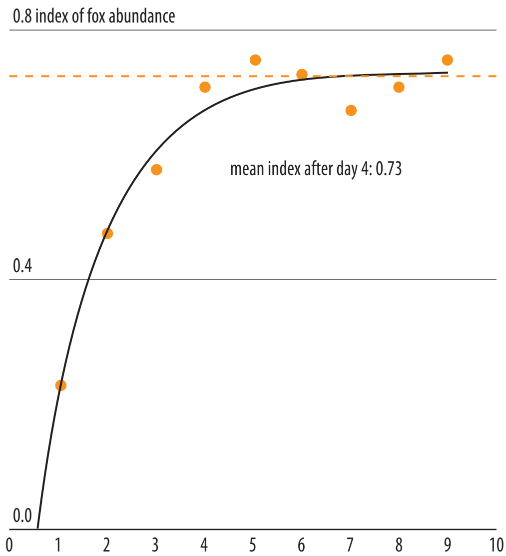


Figure 1: Index of fox abundance from bait-take data, showing flattening of curve using non-toxic baits (source: P. Fleming pers. comm.)

Toxic bait stations

The technique used is the same as non-toxic bait stations, except that 1080 is injected into the baits and, as a result, foxes are removed from the population. The same transformation of raw data is required. The response of foxes to toxic baiting is the reverse of that to non-toxic baits, with a decline in the frequency of bait take (see Figure 2). However, immigration by foxes from adjacent areas, multiple bait-take by the same animal, and caching of baits can influence these counts. The latter two problems can be minimised by being conservative with the raw data. Baits taken from consecutive bait stations or in similar topography, such as the same side of a hill, should be considered as the same animal.

Materials required

Similar equipment requirements to non toxic baiting with the following exception:

Bait – use bait materials as required by state or territory legislation.

How to do the count

- Select sites to be monitored, use roads with low usage and record location on a map with GPS.
- Set up bait stations: dig small hole for bait about 10 cm deep, place bait and cover the soil with sand to a depth of 1 to 3 cm. The bait station should be approximately 1 m^2.
- Separate bait stations by a minimum 500 m and place on alternate sides of the road.
- Create a unique name for each station and record individual station locations on a GPS.
- Count and record all fox tracks/bait-take (and those by other species) the following morning (record visits and bait-takes separately).
- Replace removed baits as required, to maintain the same number of baits available each day.
- Sweep the station clean again.
- Repeat count for a minimum of three consecutive mornings.
- All baits not taken are removed following completion of the baiting program.
- Convert raw data to indexes of the mean number of stations visited each night.

Standards

Bait stations – use the same material for each bait station and ensure that the same size is maintained for all stations. Separate by a uniform distance of at least 500 m. Use the same bait type and weight and bury baits to the same depth – about 10 cm.

Route – use the transect for each count.

Sampling time – conduct surveys at the same season and during similar weather conditions, not during high winds or rain.

Duration – always use the same number of days.

Training required

People handling poison bait must have chemical training as specified by state or territory legislation

Identification of tracks

Use of GPS

Worked example

Sixty-nine bait stations were established in a small reserve to monitor fox abundance and evaluate a fox control operation. Indexes of fox abundance were taken immediately before and after the baiting (see 'Non-toxic baiting'). Poison baiting of foxes started and was continued until bait-take had levelled off for three consecutive days (Figure 2). The number of foxes killed each day was considered – from the bait-take from consecutive bait stations and those within the same topographical unit, such as a gully or hillside – to represent the same animal.

The results are presented in Table 4 and Figure 2.

Table 4. Bait stations: example of count sheet for estimating fox abundance by toxic baiting

DAY	NUMBER OF FOX VISITS	OPERABLE BAIT STATIONS	FREQUENCY OF VISITATION	INDEX OF FOX ABUNDANCE
1	38	69	0.55	0.80
2	12	69	0.17	0.19
3	11	69	0.16	0.17
4	6	69	0.09	0.09
5	4	69	0.06	0.06
6	7	69	0.10	0.11
7	1	69	0.02	0.02

Worked examples for day 1
frequency of visitation (f)
= number of fox visits ÷ number of operable bait stations
f = 38 ÷ 69, = 0.55

index of fox abundance (v) = $-\log_e(1 - f)$
$v = -\log_e(1 - 0.55) = 0.80$

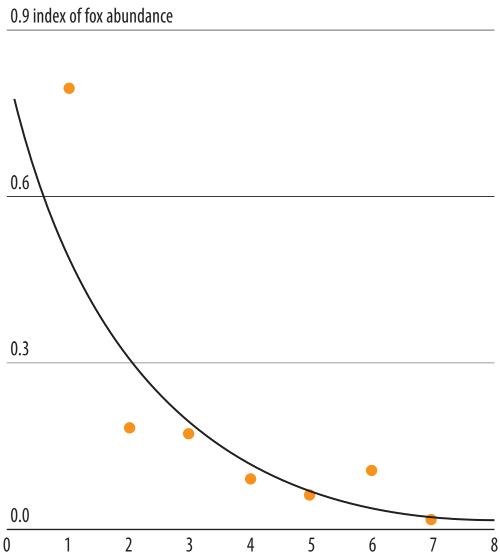


Figure 2. Index of fox abundance from toxic bait-take data. (source: J. Neville and P. Fleming pers. comm.)

Fox abundance was estimated by using the index-removal-index method (Caughley 1980):

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)

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

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

pre baiting index – 0.83
post baiting index – 0.03
estimated number of animals removed – 44

$N_1 = [0.83 \times (-44)] \div (0.03 - 0.83)$
$N_1 =$ 41 foxes pre baiting

$N_2 = [0.03 \times (-44)] \div (0.03 - 0.83)$
$N_2 =$ 1 fox post baiting

These results indicate a 97% reduction in the initial fox population of 45.

Note – this is a reduction in the red fox population that eat poisoned bait. There may be a number of animals that do not eat poisoned bait, and these are not counted. Therefore, the initial population size may be underestimated.

Track counts

For some species, footprints (or tracks) are often among the few indications that the species is 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 the fox (Saunders *et al*. 1995) and wild dog (Fleming *et al*. 2001). There is a relationship assumed between the number of tracks and actual abundance of the fox, 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, and can be used to detect changes in animal populations (Bider 1968; Newsome *et al*. 1975; Newsome & Catling 1979; Allen *et al*. 1996; Catling & Burt 1997b; Stander 1998; Engeman *et al*. 2000; Wilson & Delahy 2001; Schauster *et al*. 2002).

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

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

Strong rain and wind can reduce the clarity of footprints, making accurate identification difficult or impossible. The actions of people walking or driving over plots can likewise affect counts. There may be variability in the ability to detect footprints along a given transect because of soil type, colour, dampness and dappled shadows. These factors may be corrected by applying a score for the relative 'detectability' of sign (Fleming *et al*. 1996).

The use of roads and tracks as sampling units introduces bias, because roads are mostly placed to facilitate travel, and may not be representative of the study area (Anderson 2001; McKelvey & Pearson 2001). In addition, the relationship between track counts and animal density is usually not known. The indexes measure changes in species activity, and may not be related to actual abundance. In many cases activity is likely to change, either seasonally or annually, and

Fox footprint in sand plot

Fox and marsupial track marks

may be independent of density. For example, wild dog activity increases during the breeding season (Thomson 1992), and animal movements may vary in response to food supply (Thomson *et al*. 1992; Corbett 2001).

Similarly, the detectability of footprints may be more difficult in hot, dry and dusty conditions than with cool, damp soil surfaces. While track counts are useful to measure changes in abundance, the technique should not be relied upon unless validated against known populations.

Stratified sampling, by sampling a larger number of small sites over a range of topography, may overcome the bias, but would significantly increase the time and cost of monitoring.

Furthermore, monitoring that gives passive indexes, such as footprints, requires large sample sizes to provide accurate estimates of low-density populations (Allen *et al*. 1996; Wilson & Delahy 2001; Fleming *et al*. 2001)

The scale of the survey should match the likely home range size of the red fox. If not, the survey will measure only the activity of a few animals within the survey area. Track counts are unsuitable for small-scale surveys (Sargeant *et al*. 2003).

To account for the variation in detectability of footprints, and to make more valid comparisons between sites, a measure of 'imprintability' should be included (Fleming *et al*. 1996). At every track station or every 1 km of road count, the observer takes 10 paces across the tracking substrate and scores each imprint on a scale of 0 to 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 the allocation of a score for the location. A score of 0–5 = poor, (1); 6–15 = fair (2); 16–25 = good (3); and 26–30 = excellent (4). Any track stations that score (1) should not be discarded, although these are arbitrary cut-off points, and may need to be expanded on a site-by-site basis. For example, in a poor site with low detectability and low imprintability, a score of (1) may need to be increased from 0–5 to 1–10.

Track stations

Materials required

See materials list under 'Bait Stations'.

How to do the count

- Select sites to be monitored, use roads with low usage; at least 25 usable track stations are required.

- Set routes and mark out the transects on a map and record them on GPS, so that future surveys can easily follow the same paths. Once set out, this fixed transect should be used for future surveys, so that valid comparisons with previous surveys can be made.
- When establishing track stations, avoid situating them under overhanging foliage; dripping dew can affect obscure footprints.
- Create the track station by putting down a thin layer of sand approximately 1 m wide and 1–3 cm deep, covering the road from one side to the other; rake or sweep smooth.
- Create a unique name for each track station and mark the station's position on a GPS.
- Establish track stations every 1 km for the length of the transect.
- Count and record all sets of fox tracks and tracks of other species the following morning.
- Determine the imprintability value and then sweep the track station clean of footprints.
- Repeat count for at least three consecutive mornings or more than 75 station nights required.

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.

Training required

Identification of tracks

Use of GPS

Worked example

Fifty track stations were established to monitor foxes in a National Park and on 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 Tables 5 and 6.

Table 5. Track station monitoring using the Catling Index (percentage of station nights with tracks)

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	$= 41 \div 150 \times 100$ $= 27.33$
50 (late winter)	150	32	118	29	$= 29 \div 118 \times 100$ $= 24.58$

Table 6. Track station monitoring using the Allen index (means number of tracks per station per day) (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	2	1	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	1	0	37	0	0	1
13	0	1	1	38	0	0	0
14	0	0	1	39	0	0	1
15	0	0	1	40	1	1	1
16	0	0	0	41	0	0	1
17	1	1	1	42	0	0	0
18	2	0	1	43	0	0	0
19	0	1	1	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	1	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	14	12	15
				MEAN	$14 \div 50 = 0.28$	$12 \div 50 = 0.24$	$15 \div 50 = 0.30$
				ALLEN INDEX	$= (0.28 + 0.24 + 0.30) \div 3 = 0.27$		

Road counts

Materials required

See materials list under 'Track counts'

Drag for sweeping transect

How to do the count

- Select sites to be monitored; use roads with low usage.
- Set routes and mark out a minimum of 10 km for each transect, so that future surveys can follow the same path. Once set, these fixed transects should be used for all further surveys, so comparisons can be made.
- Place a thin layer of sand approximately 2–3 m wide and 1–3 cm deep along the length of the road. This will not be needed if the transect is naturally sandy or dusty enough to hold a footprint, although these areas may need to be tilled. Sweep smooth with a drag made of a steel bar towed behind a vehicle, to remove existing tracks and make the surface smooth. Alternatively, 5–10 m long sand plots could be established at 500 m intervals along the transect.
- Mark the location of each transect on a map using a GPS.
- Return the following morning and count and record all sets of individual fox footprints as well as those 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.
- Determine the imprintability index every 1 km of each transect.
- Sweep the transect clean of footprints with a drag pulled behind the vehicle.
- Repeat count for at least three consecutive mornings.
- Convert footprints recorded to number of footprints per kilometre 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 toxic aerial baiting was being planned in central Australia, and the abundance of these animals needed to be monitored immediately before and after the operation to gauge its success. Five transects, each approximately 20 km long, were established across the baiting area.

The results are shown in Tables 7 and 8.

From the track count data it was assumed that there had been a 97% reduction in fox abundance.

Table 7. Road count: results of monitoring using the Catling index (pre-baiting)

	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)	9	0.41	10	0.45	9	0.41
TRANSECT 2 (19 km)	5	0.26	7	0.37	7	0.37
TRANSECT 3 (20 km)	8	0.40	6	0.30	5	0.25
TRANSECT 4 (25 km)	12	0.48	11	0.44	8	0.32
TRANSECT 5 (17 km)	4	0.24	5	0.29	5	0.29
MEAN		0.36		0..37		0.33
INDEX VALUE	$= (0.36 + 0.37 + 0.33) \div 3 = 0.35$ tracks km^{-1}					

Table 8. Road count: results of monitoring using the Catling index (post-baiting)

	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)	0	0.00	1	0.05	0	0.00
TRANSECT 2 (19 km)	0	0.00	0	0.00	0	0.00
TRANSECT 3 (20 km)	0	0.00	0	0.00	0	0.00
TRANSECT 4 (25 km)	1	0.04	0	0.00	1	0.04
TRANSECT 5 (17 km)	0	0.00	0	0.00	0	0.00
MEAN		0.01		0.01		0.01
INDEX VALUE	$= (0.01 + 0.01 + 0.01) \div 3 = 0.01$ tracks km^{-1}					

% CHANGE	= (pre bait index value – post bait index value) $\div$ pre bait index value $\times 100$ $= (0.35 - 0.01) \div 0.35 \times 100 = 97\%$ reduction in fox abundance