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MONITORING TECHNIQUES FOR VERTEBRATE PESTS

WILD DOGS

BRUCE MITCHELL
AND SUZANNE BALOGH

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Acknowledgements

The authors would like to thank Glen Saunders, Steve McLeod, John Tracey, Peter Fleming, Michelle Dawson, Brian Lukins, David Croft, Matt Gentle, Peter West, Ben Russell, Quentin Hart, Dave Forsyth, Peter Thomson, Bill Atkinson and Nathan Cutter for their help with preparing this manual. Thanks also to the many other people too numerous to mention who gave the benefit of their experience.

The National Feral Animal Control Program funded the project.

The information contained in this publication is based on knowledge and understanding at the time of writing (October 2007). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of New South Wales Department of Primary Industries or the user's independent adviser.

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Citation:
Mitchell, B. and Balogh, S. (2007) NSW DPI Orange
ISBN 978 0 7347 1892 1

October 2007
ISBN 978 0 7347 1892 1
Written by Bruce Mitchell and Suzanne Balogh

Monitoring Techniques for Vertebrate Pests:
Series ISBN 978 0 7347 1888 4

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WHY MONITOR VERTEBRATE PESTS?

The purpose of this manual is to provide details of the techniques available to monitor the wild dog 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 avoid two people acting on the same instructions getting quite different results.

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

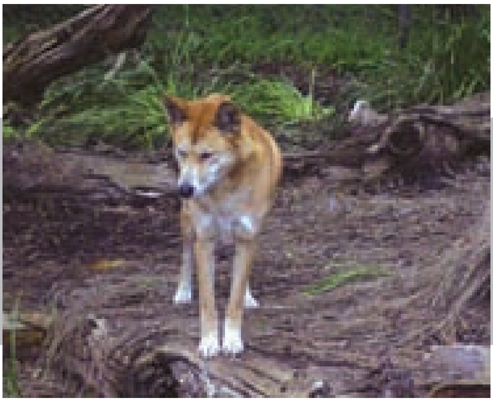
Monitoring of the management program, should be done before, during and after control, especially for long-term programs:

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

Monitoring in vertebrate pest management has two functions: to provide the necessary information that triggers management action (Elzinga *et al.* 2001); and to indicate whether a management strategy is achieving its objectives or 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, typically, pest abundance is 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



Wild dogs range in colour from the characteristic yellow to white, black, black and tan, sable and any combination of these.

Wild dog pelts

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.

Since European settlement the wild dog trapper was an occupation in demand in many areas of Austalia. In more recent years the need to control individual animals, wild dog problems associated with closely settled areas and pressure from environmental groups to reduce pesticide usage has seen a resurgence in demand for the skills associated with trapping.

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 wild dogs.

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

GEN001 *methods of euthanasia*

DOG001 *trapping of wild dogs using padded jaw traps*

DOG002 *trapping of wild dogs using cage traps*

DOG003 *ground shooting of wild dogs*

DOG004 *ground baiting of wild dogs with 1080*

DOG005 *aerial baiting of wild dogs with 1080*

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 and range 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.

Researchers handling a wild dog pup

- 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

Hydatid disease

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, 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 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 Operating Safely around Aircraft, Aerial Observer or *Fly the Wire* training courses 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.
- Observers must carry a map, compass, handheld Global Positioning System (GPS) equipment, two way radios and spare batteries.
- All officers should be trained and competent in the use of GPS.
- The transect must be plotted on the map.
- All officers must carry sufficient drinking water and emergency food rations.
- The observer should wear suitable light coloured clothing and sturdy footwear.

Using vehicles

- 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 to suit the weather conditions.
- Remove dangerous overhanging obstructions before the survey.
- The driver and observer must drive the transect before commencing the survey to demonstrate it is navigable.
- All occupants should carry drinking water, emergency food rations, 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 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 observers eyes.

Trapping wild dogs

- Protective clothing, boots and leather gloves may help prevent injuries from shovels, hammers and trap jaws.
- Trapped wild dogs may be dangerous to handle and could 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.
- Wild dogs 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 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 wild dogs 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 release of the animal, everyone in the team restraining an animal must agree on the procedure to release the animal, and they must verbally communicate to ensure that they all release the animal simultaneously.

KNOW THE PEST: THE WILD DOG

History

The wild dogs referred to in this manual are all species of *Canis lupus* including dingoes (*Canis lupus dingo*), feral dogs (*Canis lupus familiaris*) introduced by Europeans, and the hybrid descendents of both. Wild dogs range in colour from the characteristic yellow (about 43–85%) and include whites (0–7%), black (0–3%), black and tan (0–26%), sable (0–14%), similar to a german shepherd colour) and any combination of these giving rise to spotted (0–7%) and brindles (0–7%). Dingoes tend to have four colours, ginger, black, black and tan and white and are assumed to have originated in Asia (Corbett 2001). A feral dog is one either born in the wild or become habituated to living without human intervention. Dingoes and feral dogs freely interbreed and even with expert morphological and DNA assistance it is difficult to distinguish between them, hence all free living dogs are termed *wild dogs*.

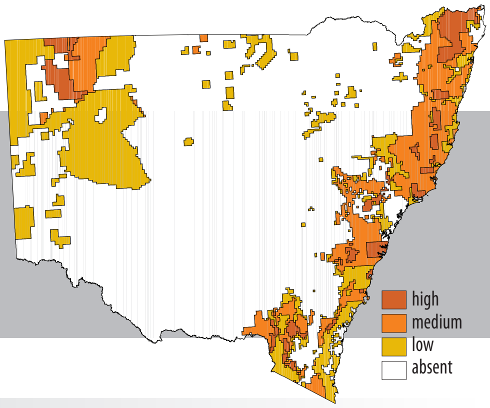
Impacts

Wild dogs have both economic and environmental impacts. Wild dogs affect livestock industries through predation and act as carriers of disease, with sheep, cattle, goats, and sometimes horses and poultry the main industries to suffer. Pastoral enterprises adjacent to, wild dog habitat often suffer severe predation. It is not uncommon for some sheep producers to lose 20 to 30 sheep a night to wild dogs. The cost of predation is not confined to direct losses from livestock being killed. Other stock are often injured and the stock owner has to spend time supervising and protecting stock. Livestock are stressed, affecting weight gain and wool growth; mismothering occurs; and capital outlay is required for fence construction or other control techniques, including trapping, shooting and baiting (Fleming *et al.* 2001). Cattle are less prone to wild dog attack than sheep because they are larger and the cows are more intimidating than ewes when defending their offspring. However, young calves or drought-affected young cattle are the most vulnerable to attack. In areas where hydatid disease is endemic in wild dogs, a large proportion of sheep and cattle offal is condemned at abattoirs.

Wild dogs affect native fauna through predation. Wild dogs have been implicated in arid zone mammal declines and the extinction from the mainland of species such as the Tasmanian tiger (*Thylacinus cynocephalus*) and Tasmanian devil, (*Sarcophilus harrisii*) (Jones 1998; Rounsevell & Mooney 1998; Corbett 2001). The survival or successful re-establishment of endangered marsupials may therefore require the management of wild dogs (Fleming *et al.* 2001). However, the tools used to manage wild dogs may have impacts on non-target species. Traps may capture non-target species such as kangaroos and quolls. Reducing the density of wild dog populations may facilitate an increase in the numbers of other exotic predators such as cats and foxes (Soulé *et al.* 1988), (Mitchell & Banks 2005).

Distribution

The distribution of wild dogs across mainland Australia has been reduced since the arrival of Europeans. This is mainly due to habitat distruction and control programs to reduce wild dog impact on livestock enterprises. The construction of barrier fences assisted control programs (Fleming *et al.* 2001). However, the expansion of pastoralism may have increased the density of wild dog populations in some areas due to increases in the number of watering points and consequently native food supply,



Dingo and wild dog density (source NSW DPI)

Wild dog barrier fence

particularly kangaroos and wallaby. Wild dogs are distributed north and west of the dog-proof fence or barrier fence, on the tablelands and in coastal environments of the east coast.

Habitat

Wild dogs are very adaptable and can live in a wide variety of habitats, they prefer areas with good prey populations and plenty of cover or other shelter. They can live successfully in semi-arid to rainforest environments, providing there is an adequate supply of food and water.

Barrier fences keep wild dogs out of pastoral areas. Most states have a section of barrier fence within their jurisdiction. Costs of these fences can range from $8000 to $12 000 per kilometre (2007) when extensive reconstruction is required. Extensive damage to the fence may be caused by floods, sandstorms, camels, kangaroos and wombats.

Biology

Diet

Wild dogs are specialist predators and scavengers, being primarily carnivorous. They have a wide range of prey, although relatively few species make up most of their diet (Corbett 2001; Mitchell & Banks 2005). The basic diet of wild dogs consists of macropods, rabbits, cattle (mostly as carrion), possums, wombats and birds. Like most large predators wild dogs often engage in surplus killing where numbers of livestock, well in excess of normal food requirements are killed in one event. Livestock appear to account for the majority of surplus kills attributed to wild dogs (Short *et al.* 2002).

Kangaroos and wallabies form the highest portion (about 30%) of the diet of the wild dog in Australia. Domestic livestock comprises less than 3%.

Reproduction

Dingoes breed once a year, usually between May and August (Corbett 2001). Wild dogs that hybridise with dingoes may cycle more than once a year without a well defined seasonal trend (Fleming *et al.* 2001), however, it is extremely rare for two litters to be successfully raised in one year. Successful reproduction in these cases is often limited by food supply. After a 58- to 69-day pregnancy, an litter of about 5–10 pups is born in a hollow log or cave den.

The den may be used in successive years by the bitch (Corbett 2001). Pups are weaned at 6 to 8 weeks, but they will remain with the family group or pack until they are 6 to 12 months old. Sexual maturity is generally reached in the second year for females and between 1 and 3 years for males.

Mortality

Wild dogs have very few natural predators, although wedge-tailed eagles (*Aquila audax*) and snakes may prey upon pups. Pups and young dogs are susceptible to a range of diseases including internal parasites, parvovirus, mange and distemper. Pups that become independent at an early age, often die young because of their small size, inexperience at food gathering and finding shelter; older, more experienced pups have a much higher survival rate (Fleming *et al.* 2001). Harden (pers comm.) noted during some seasons the females keep the pups for much longer periods and the rate of survival is very high. The use of poison baits to protect livestock from wild dogs can create dispersal sinks that facilitate the immigration of young or lone wild dogs into the vacated home range areas, perpetuating the mortality–dispersal cycle. The impact of drought and the subsequent lack of available food such as rabbits and smaller prey, appears to be a significant cause of mortality. Wild dogs are carriers of a number of important diseases of livestock, domestic animals and wildlife, such as sheep measles, hydatids and toxoplasmosis.

Social structure

Wild dogs have a flexible social system based on groups or packs that are often small. The pack occupies and defends a territory (Corbett 2001). Each member of the pack occupies a home range within the territory, and this range overlaps with the ranges of other group members. Consequently, all members of the group rarely meet as a pack. Instead, members meet and separate again throughout the days or on subsequent days. This explains why wild dogs are mostly seen as individuals. However, research suggests that as a wild dog population increases or as its prey population declines, group cohesion increases, resulting in a change in hunting and feeding strategies (Fleming *et al.* 2001). Packs form to hunt and feed upon larger prey such as large kangaroos and cattle.

Movements and home range

Activity occurs mostly at dawn and dusk. Two basic types of movement occur, searching and exploratory (Corbett 2001). Searching movement appears to be associated with hunting, because it is characterised by intense activity in a small area, typified by frequent, large, angular changes in direction. Exploratory movement appears to be used when moving from one hunting area to another, and in moving around the home range boundary.

Home ranges of wild dogs vary from 10 to 90 km^2, with the size dependent on habitat and availability of food (Fleming *et al.* 2001). Some areas of the home range are used frequently, but others rarely or not at all. About 10% of the area is used for 90% of the time.The pattern of use basically involves thoroughly searching one area before moving to another area, where further intensive food searching occurs. Movements often follow well defined paths along topographic features. Home range shape is determined partly by topography, with distinguishing features forming boundaries.

The wild dog pack often follow scent trails along roads and tracks within their home range. Trappers take advantage of these common routes and set traps where 'signs' indicate the most appropriate spot to catch problem animals.

MONITORING WILD DOG ABUNDANCE

This section discusses the various methods that may be used to monitor wild dog abundance. The summary tables at the end of this handbook reviews these methods and compares them with the methods of monitoring wild dog impact presented in the next section.

Bait stations

Wild dogs can be attracted to bait stations. These stations can be baited with toxic or non-toxic baits or other lures. The responses of wild dogs to bait stations differ between toxic and non-toxic variants. With non-toxic bait stations the frequency of bait-take initially increases until a plateau is reached, whereas with toxic bait stations there is a decreasing relationship because of the removal of wild dogs from the area. Bait stations consist of approximately 1-m^2 area of raked sand with meat covered or buried in the ground to a depth of 5 to 10 cm. The bait stations are usually situated on the verges of roads and the meat is covered or buried to limit removal by birds such as crows (Corvidae) and quolls (*Dasyurus* spp.) (Allen *et al.* 1989; Fleming 1996; Belcher 1998). Roads are used because wild dogs use them for movement and territorial marking, and they provide easily accessible monitoring sites (Triggs 1996; Corbett 2001). To reduce non-target bait-take by quolls, particularly in poison control programs, baits should be buried below ground level rather than placed in a raised mound (Glen & Dickman 2003b). Scent stations have been used extensively in North America 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, and Allen *et al.* (1996) suggest that track counts are more sensitive indices.

Simple daily indices of abundance can be calculated from bait-take or bait station visitation

$$\text{frequency of visitation} = f$$

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

The total number of operable bait station nights is determined by removing from the count any stations that are visited by a species that cannot be identified, where the bait may be removed but no clear tracks left, or another species may have destroyed the predator's tracks (Roughton & Sweeny 1978). Raw indices (f) need to be converted by logarithmic transformation to allow meaningful interpretation, as the relationship between density and visitation rates are not linear (see below).

An estimate of population size may be measured by a poison baiting program before and after a known number of animals has been removed from the population (Caughley 1980). This is known as the index-removal-index method. It has been used in fox studies, to test the efficacy of control or removal programs by calculating population estimates before and after toxic baiting, using an estimated number of fox kills (Thompson & Fleming 1994; Fleming 1997). Cyanide baiting, providing a catch per unit effort index, has been used before and after an aerial baiting campaign with 1080 (Algar & Kinnear 1992; Thomson *et al.* 2000; Kinnear *et al.* 2002). However, this would potentially leave bait adverse animals alive, so the index removal method is best suited to providing population estimates that do not involve baiting.

Problems associated with using bait stations to monitor populations centre around how the bait station may alter the normal behaviour patterns of wild dogs.

Contagion, caused by associating bait stations with food, may increase daily visitation rates, as can immigration of new animals, and this leads to overestimating of the original population (Allen *et al.* 1989; Thompson & Fleming 1994). This effect may be limited if the bait stations are active for a short period of 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 will also affect the ability of this method to estimate abundance and detect change (Thompson & Fleming 1994).

Non-toxic bait stations

The visit to a bait station by wild dogs is recorded as a frequency. Visits to investigate the bait and actual removal of the bait are recorded separately; however, all visitations contribute to the index. The relationship between density and bait-take is non-linear, because bait stations do not become available to other animals once an animal has removed a bait. More than one animal can visit a station, but this will only be recorded as one visit. This can be accounted for by using a frequency-density transformation (Caughley 1980):

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

where f is the frequency of visitation to bait stations by wild dogs, and v is the mean density of the occurrence of wild dog 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 wild dog abundance can be achieved by checking bait stations daily and recording visitations until a plateau is reached. The mean of 3 or more days after the plateau is reached is used as the index. This may take many days to achieve: studies by Thompson and Fleming (1994), foxes needed 10 days, Fleming (1997), foxes took 16 days, and in Allen *et al.* (1996), wild dogs took 21 days to achieve the required results.

Materials required

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

Bait – use small pieces of dried kangaroo or beef meat.

Count sheet

GPS and a topographic map

Track diagrams (Triggs 1996)

How to do the count

- Select roads with low or no usage to be monitored and record GPS locations on topographic map.
- Prepare the bait station: dig a small hole about 10 cm deep, add bait, fill the hole in, cover the soil with sand to a depth of 1 to 3 cm and an area of 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 bait station and mark the position of the station with a GPS.
- Count and record all wild dog visits and baits taken the following morning. Record visits and baits taken in separate columns on the count sheet.
- Replace baits as required to maintain the same number of baits available each day.
- Sweep the bait station clean.
- Convert raw data to indices of the mean number of the stations visited each night and use a logarithmic transformation available in the computer program Microsoft Excel to create a graph of the results.
- Repeat the count until the bait-take curve has flattened out.
- Use the mean of at least 3 days after the curve has reached a plateau as the index of abundance.

Standards

Bait stations – use uniform sand or soil for each bait station and ensure bait stations are of similar diameter and depth. Separate stations by at least 500 m. A consistent standard is to construct 26 bait stations 1 km apart over 25 km of road. Use dried meat baits of consistent weight and bury to about 10 cm.

Route – use the same transect for each count.

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

Duration – use the flattening of the asymptote at the top of the curve to determine the duration of the monitoring.

Training required

Identification of animal tracks

Use of GPS

Worked example (Table 1 and Figure 1)

One hundred bait stations were established and checked each day. The number of operable bait stations changed because of disturbance from birds and foxes. The index was taken after day 4, when the curve flattened out.

Table 1. Example of estimation of wild dog abundance from non-toxic bait station checking

DAY	NUMBER OF VISITS	OPERABLE BAIT STATIONS	FREQUENCY OF VISITATION	INDEX OF ABUNDANCE
1	21	100	0.21	0.24
2	12	95	0.13	0.14
3	13	89	0.15	0.16
4	15	90	0.17	0.19
5	16	89	0.18	0.19
6	14	86	0.17	0.19
7	15	92	0.16	0.18
8	16	95	0.17	0.19
9	17	90	0.18	0.19

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

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

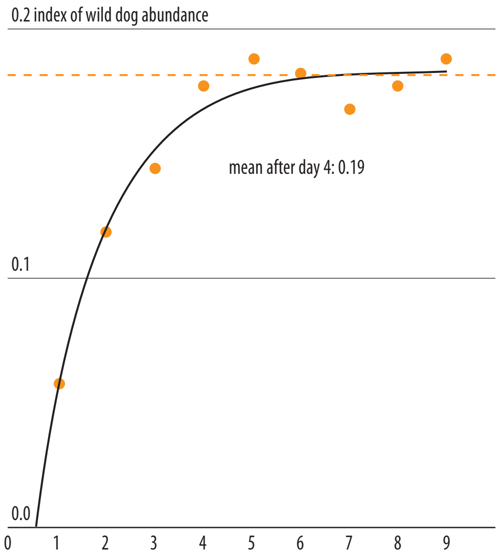


Figure 1. Index of dog abundance from bait-take data (non-toxic bait), showing flattening of curve

Toxic bait stations

The technique is the same as for non-toxic bait stations, except that 1080 is injected into the baits and wild dogs are removed from the population. The same logarithmic transformation of raw data is required. The response of wild dogs to toxic baiting is the reverse of non-toxic, with a decline in the frequency of bait-take. However, immigration by wild dogs from adjacent areas and multiple bait-take by the same animal may influence these counts. Baits taken from consecutive bait stations or in similar topography should be considered as taken by the same animal.

Materials required

See section under 'Non-toxic bait stations'

How to do the count

See section under 'Non-toxic bait stations'

Standards

See section under 'Non-toxic bait stations'

Training required

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

Identification of animal tracks

Use of GPS

4WD training

Manual handling

Worked example (Table 2 and Figure 2)

79 bait stations were established in a small reserve to monitor wild dog abundance and evaluate a wild dog control operation. Track counts of wild dogs were taken immediately before and after the baiting. Poison baiting of wild dogs was continued until bait-take had levelled off for 3 consecutive days (Figure 2). The number of wild dogs killed each day was estimated. Bait taken from consecutive bait stations or those within the same topographical unit were considered to be from the same animal (Table 2).

Table 2. Example of estimation of wild dog abundance from toxic bait station checking

DAY	NUMBER OF VISITS	OPERABLE BAIT STATIONS	FREQUENCY OF VISITATION	INDEX OF ABUNDANCE
1	9	79	0.11	0.12
2	4	79	0.05	0.05
3	4	79	0.05	0.05
4	2	79	0.03	0.03
5	1	79	0.01	0.01
6	1	79	0.01	0.01
7	0	79	0.00	0.00

Worked examples for day 1
frequency of visitation (f)
= number of wild dog visits ÷ number of operable bait stations
$f = 9 \div 79, = 0.11$

index of wild dog abundance $(v) = -\log_e(1 - f)$
$v = -\log_e(1 - 0.11) = 0.12$

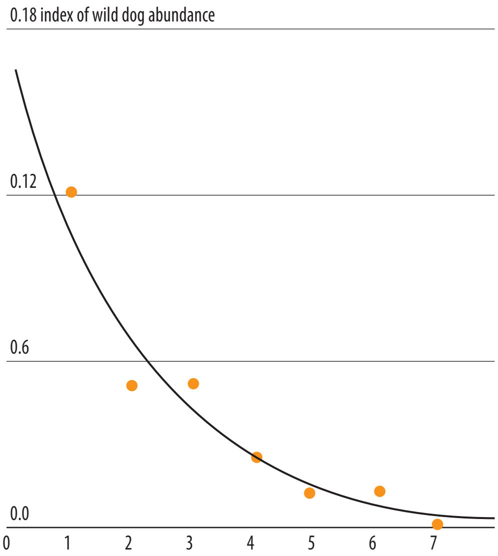


Figure 2. Index of wild dog abundance from bait-take data (toxic bait)

Wild dog abundance was estimated by using the index removal 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: 0.41
post baiting index: 0.06
based on the biology of the target, the bait size and number of sequential baits taken in one night, the estimated number of animals removed (in this case) is 10

$N_1 = [0.41 \times (-10)] \div (0.06 - 0.41)$
$N_1 = 12$ dogs pre baiting

$N_2 = [0.06 \times (-10)] \div (0.06 - 0.41)$
$N_2 = 2$ dogs post baiting

These results indicate an 83% reduction in the initial wild dog population of 12, but it must be noted that this is the population that eat meat baits. There could be an unknown number of animals that do not eat bait and these are unaccounted for. Therefore the estimate of the initial population is likely to be underestimated.

Scat counts

For many nocturnal species in particular, faeces, or scats, are more conspicuous than the animal itself. Deposition of scats provide a good method of detecting the presence or absence of wild dogs in particular (Sutherland 1996). Scats may be used to estimate abundance by either calculating the standing crop or total amount of faeces in a given area, or determining the rate of accumulation in fixed sample plots that are cleared regularly (Putman 1984). Calculating the standing crop is most likely beyond the resources of most studies (Wilson & Delahy 2001), but measuring rates of faecal accumulation has been used successfully in nationwide red fox surveys in Great Britain (Baker *et al.* 2002; Sadlier *et al.* 2004). In North America, similar studies have been reliably correlated with coyote (*Canis latrans*) and swift fox (*Vulpes velox*) abundance (Andelt & Andelt 1984; Schauster *et al.* 2002). The use of scat counts has not been widely used in Australia, although a variation on the technique, using free feed attractants to encourage scat deposition, was found to have potential as a reliable measure of abundance of relatively stable fox populations (Sharp *et al.* 2001). However, this index performed poorly when there was a rapid turnover of individuals within the population.

There are numerous factors associated with scat counts that can confound their use as a monitoring technique (Wilson & Delahy 2001; Davison *et al.* 2002; Sadlier *et al.* 2004).

- Defaecation rates vary with diet, and the age structure of the population.
- The persistence of scats varies with diet and weather conditions.
- Distribution and accumulation of scats will change as a result of seasonal variations in scent-marking behaviour.
- The removal of scats may influence subsequent defaecation rates.
- The identification of scat by species is prone to error and observer skills vary.
- Scats can be destroyed by human and animal activity.

Reliance on various conversion factors for estimating density has led to recommendations that scat counts are best suited to providing indices of relative abundance (Cavallini 1994; Wilson & Delahy 2001). This technique, however, is not suited to monitoring short term pre control or post control programs because of the confounding factors mentioned above, and it is probably most appropriate for long term studies such as the red fox surveys conducted in Great Britain (Sharp *et al.* 2001)

Determining indices from scat deposition or accumulation rates involves clearing a transect of all scats and counting the number of scats deposited after 2 to 6 weeks. Transects are most often fire trails or tracks, that wild dogs and foxes use for movement and territorial marking. Fire trails provide easily accessible monitoring sites (Triggs 1996; Corbett 2001). Scats are often found in prominent positions on or next to the roads.

Passive scat count

Materials required

Count sheet

Disposable gloves

Collection bags or paper bags – if scats are to be used for dietary or DNA analysis

GPS

Disinfectant, soap, water and hand towels

How to do the count

- Select sites to be monitored and record locations on map with GPS.
- Remove all wild dog scats from the transect. Place scats in individual paper bags and record the location with a GPS if scats are to be used for dietary or DNA analysis.
- Repeat and count the number of new wild dog scats between 2 to 6 weeks later.
- Calculate scat density (S) for each period as:

  $S = C \div (L \times D)$

  where C = number of scats counted on the second visit; L = transect length in km; and D = number of days between visits.
- Repeat the count every season or at the same time each year.
- To calculate the number of animals in each transect it is necessary to estimate defaecation rates and detection probability (see Sadlier *et al.* 2004)

Standards

Route – use the original transect for each count.

Sampling time – conduct the survey at the same time of year.

Training required

Identification of scats – wild dog, fox, cat and quoll scats may appear similar (Triggs 1996)

Use of GPS

Worked example

Scats were collected from a National Park annually to monitor the effect of baiting on wild dog abundance. There were 10 transects with a total length of 63 km.

Year 1
Scats collected: 136
Days between visits: 20

$S = 136 \div (63 \times 20) = 0.108$

Year 2
Scats collected: 122
Days between visits: 23

$S = 122 \div (63 \times 23) = 0.084$

Year 3
Scats collected: 109
Days between visits: 27

$S = 109 \div (63 \times 27) = 0.064$

These data and future data could be plotted on a graph to map any trends in abundance. To make statistical comparisons, logarithmic transformation of data is necessary(see Sadlier *et al.* 2004).

Active scat count

Materials required

Bait material – such as kangaroo meat

Stakes – with reflectors or flagging tape

Count sheet

Collection bags or paper bags – if scats are to be used for dietary or DNA analysis

GPS

Disinfectant, soap, water and hand towels

How to do the count

- Select sites to be monitored and record locations on map with GPS.
- Set up bait stations: dig a small hole for bait about 10 cm deep, cover with soil and leaf litter and mark with a stake or flagging tape.
- Separate bait stations by at least 500 m and place on alternate sides of the road.
- Create a unique name for each bait station and mark the position on a map with a GPS.
- Check and replace bait in stations every 14 days.
- Before replacing bait, count wild dog scats within a 3 m radius of the bait station.
- Continue counting for three or more replacement baitings and remove unused bait material at the completion of the count.
- Calculate scat density (S) for each individual period as:

  $S = C \div (B \times D)$

  where C = number of scats counted on the second visit; B = number of bait stations; and D = number of days between visits.
- Calculate the mean seasonal deposition as a seasonal index.
- Repeat the count every season or at the same time each year.

Standards

Bait stations – use identical soil material for each bait station. Separate by a uniform distance. Use a consistent type of bait.

Route – use the same transect for each count.

Sampling time – conduct the survey at the same time of year.

Training required

See 'Passive scat counts'

DNA sampling

Sampling DNA may provide accurate identification of samples to the species and individual level (Piggott & Taylor 2003). DNA collection may be invasive using blood and tissue samples or non-invasive with faecal and hair samples collected. Samples of faecal matter and hair are simpler to collect as the species does not need to be handled or observed. This type of sampling can be used for population and home range estimation, and can provide information on the sex ratio and source of the population.

DNA sampling may provide a guide to distinguish between wild dogs and native dingoes and determine the level of hybridisation. This may have important consequences in conservation areas where the protection of dingoes from hybridisation is desired. Another application of DNA sampling is to determine the source of predation on livestock or endangered native animals. In a National Park in central Queensland it was determined that a pack of dingoes had preyed upon the highly endangered northern hairy-nosed wombat (*Lasiorhinus krefftii*), prompting the erection of a dog-proof fence (Banks *et al.* 2003).

The development of methods of extraction of the 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 using a large sample of coyote scats (651) collected from roads; these scats were positively identified from diagnostic sections of mitochondrial DNA (Kohn *et al.* 1999). The scats were then genotyped to determine individual animals, and the cumulative number of unique microsatellites was expressed as a proportion of the number of scats sampled. The asymptote or flatten top of this curve was determined as an estimate of local population size.

Capture–recapture models may be used with this type of data. A population of endangered wolverines (*Gulo gulo*) in Norway was monitored 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 grizzly bears (*Ursus arctos*) (Mowat & Strobeck 2000; Poole *et al.* 2001). Bears were sampled by removing hair at bait sites surrounded by a single strand of barbed wire. Microsatellite profiling of the root portion of the hair was then used to identify individuals. Subsequent sampling provided recaptures. Other types of monitoring tools that can be used are catch per unit effort (Romain-Bondi *et al.* 2004) and presence and absence studies.

Molecular studies of scats can be used to correct scat counts by accurately identifying scats to the species level. During North American scat surveys, scats correctly assigned to species by observation occurs in only 50% to 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, however have since been found to incorrectly distinguish pine marten scats from those of red foxes (Davison *et al.* 2002). In Australia all of the larger mammalian carnivorous species (wild dogs, foxes, cats and quolls) produce scats that could potentially be mistakenly identified from their morphology alone.

One of the main limitations is the high cost of extraction of DNA from scats and hairs owing to the low quantity and quality of DNA typically recovered from these samples (Harrison *et al.* 2002; Davison *et al.* 2002; Piggott & Taylor 2003). DNA degrades over time and fresh samples are required and must be stored correctly to preserve the sample. Storage methods suitable for DNA analysis include rapid freezing at –20°C, dehydration by air-drying or alcohol treatment, or saturation in a buffer containing high concentrations of salts or other chemicals that will interfere with enzymes (Foran *et al.* 1997; Kohn *et al.* 1999; Piggott & Taylor 2003). Piggot and Taylor (2003) investigated faecal preservation and DNA extraction methods for mammals found in Australia and developed a protocol that was found to be optimal for five different species, including the wild dog. This method involved air-drying the fresh scats in paper bags, ideal for field collection, followed by a surface wash 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), and this error may lead to 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. It has been recommended that a minimum of three PCR replicates be used for genotyping wild dog scats in summer and eight replicates for winter samples (Piggott 2004). These methods, when used for population estimation, rely on defaecation rates being equal among sexes and age classes and independent of social class. They also rely on the non-violation of capture–recapture assumptions (Kohn *et al.* 1999; Mowat & Strobeck 2000).

In spite of these problems, DNA sampling will be an effective and efficient way of monitoring a species that is difficult to observe, exists at low densities or has a large home range (Piggott & Taylor 2003). Collecting scats is a relatively easy way to obtain DNA samples, with the additional benefit of dietary information. It may be easy to obtain hair samples by using synthetic fermented egg as an attractant for wild dogs (Jolly & Jolly 1992). Chemicals such as these elicit a scent-marking behavioural response in foxes where they rub or roll themselves on the source of the odour (G. Saunders pers. comm.) and it may be that wild dogs would show a similar response. Simple hair snares, such as carpet squares with protruding nails to snag hairs together with an appropriate attractant sprayed on them could 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 scent station, where instead of footprints, hair is left behind to indicate a visit. The advantage of this technique over traditional scent stations is that the DNA sampling may give a population estimation.

Track counts

Footprints of animals are often one of 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 wild dogs (Fleming *et al.* 2001) and foxes (Saunders *et al.* 1995). There is a relationship assumed between the number of tracks and the actual abundance of the wild dog, but there have been few validations against known populations (Wilson & Delahy 2001; Fleming *et al.* 2001). Nevertheless, track counts are considered to produce reliable indices of abundance that can be used to detect changes in animal populations (Bider 1968; Newsome *et al.* 1975; Newsome & Catling 1979; Allen *et al.* 1996; Catling & Burt 1997; Stander 1998; Engeman *et al.* 2000; Wilson & Delahy 2001; Schauster *et al.* 2002).

Counting tracks is passive and animal behaviour is not altered by detection. It is done by using either track stations also known as sand plots and 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 the road is used as a transect and the number of sets of tracks on it are counted (Mahon *et al.* 1998; Edwards *et al.* 2000; Edwards *et al.* 2002; Burrows *et al.* 2003).

Strong rain and winds may reduce the clarity of, or remove, footprints, making accurate identification difficult or impossible. There is variation in the ability to detect footprints along a given transect due to soil type, colour, moisture content and shadows. This can be accounted for by correcting for the relative 'detectability' of footprints (Fleming *et al.* 1996).

The use of roads and tracks as sampling units is common, however it may create bias by unrepresentative sampling of the study area (Anderson 2001; McKelvey & Pearson 2001). The relationship between track counts and animal density is usually unknown and while track counts may measure change in species activity, it may or may not be related to actual abundance. In many cases activity is likely to change with seasons or annual cycles, independent of density. For example, dingo activity increases during the breeding season (Thomson 1992), or movements of animals vary in response to food resources (Thomson *et al.* 1992; Corbett 2001).

Caution should be excercised when relying on track counts to measure changes in abundance until the techniques can be validated against other known populations in an area.

Stratified sampling across the survey area or intensely sampling more smaller areas may overcome some bias, but would significantly increase the time and cost of monitoring. Furthermore, even though they may be simple to use, passive track sampling indices require 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 must match the likely home range size of the target species. If this is not achieved, the survey will measure the activity of only those few animals within the survey area. Therefore, track counts are unsuitable for small-scale surveys (Sargeant *et al.* 2003).

To account for the variation in detection of footprints, and thus be able to make more valid comparisons between sites, a measure of 'imprintability' needs to be taken (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 the resulting imprints on a scale of 0 to 3 (Van Dyke *et al.* 1986): where 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 detail of the sole visible. The resulting point value for each location will vary between 0 and 30 and allow the allocation of 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. Note that these are arbitrary cut-off points and may need to be expanded on a site-by-site basis, for example a score of (1) may need to include scores of 1–10 depending on site characteristics.

Track stations

Materials required

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

Count sheet

Map and GPS

Diagrams of animal tracks (Triggs 1996)

How to do the count

- Select sites to be monitored, use roads with low usage. At least 25 usable track stations are required or 26 plots at 1 km intervals equals 25 km of track.
- Set routes and mark out the transects on a map and record plots on GPS so that future surveys can follow the same track. To compare surveys each transect should be fixed.
- When establishing track stations, avoid situating them where overhanging foliage may cause dew to drip and obscure the footprints.
- Place a thin layer of sand approximately 1 m wide and 1 to 3 cm deep, covering the road from side to side and rake or sweep it smooth.
- Create a unique name for each track station and mark the position using a GPS.

- Create track stations every 1 km for the length of the transect.
- Count and record all sets of wild dog tracks and tracks of other species the following morning.
- Determine the imprint value and then sweep the track station clean of footprints.
- Repeat the count for at least three consecutive mornings or more than 78 track-station nights.
- Convert to indices via the average number of animal tracks per transect per day (Allen index) or the percentage of station nights with animal tracks (Catling index). Remember to remove track stations that have 'imprintability' scores of 1.

Standards

Route – use the same transect for each count.

Sampling time – always conduct the survey at the identical season and day so that light conditions are similar and during similar weather conditions.

Training required

Identification of tracks

Use of GPS

4WD

Worked example (Tables 3 and 4)

Fifty track stations were established to monitor wild dogs and foxes 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 Tables 3 and 4.

Table 3. 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 WILD DOG TRACKS	CATLING INDEX VALUE
50 (late summer)	150	0	150	22	$= 22 \div 150 \times 100$ $= 14.67$
50 (late winter)	150	32	118	17	$= 17 \div 118 \times 100$ $= 14.41$

Table 4. 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	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	0	0	**33**	0	0	0
9	0	0	0	**34**	0	0	0
10	0	0	0	**35**	0	0	0
11	0	0	0	**36**	0	0	0
12	1	1	0	**37**	0	0	0
13	0	1	0	**38**	0	0	0
14	0	0	0	**39**	0	0	1
15	0	0	1	**40**	0	0	1
16	0	0	0	**41**	0	0	0
17	0	0	0	**42**	0	0	0
18	2	0	1	**43**	0	0	0
19	0	1	0	**44**	0	0	0
20	0	0	0	**45**	0	0	0
21	0	0	0	**46**	0	0	0
22	0	0	0	**47**	0	0	0
23	0	0	0	**48**	0	0	0
24	0	0	0	**49**	0	0	0
25	0	0	0	**50**	0	0	0
No stations had an imprintability score of 1				**TOTAL**	9	6	7
				MEAN	9 ÷ 50 = 0.18	6 ÷ 50 = 0.12	7 ÷ 50 = 0.14
				ALLEN INDEX	= (0.18 + 0.12 + 0.14) ÷ 3 = 0.15		

Road counts

As above

How to do the count

- Select roads or tracks to be monitored
- Set routes and mark out each transect so that future surveys can follow the same path recommended length 25 km.
- Establish each track survey transect by putting down a thin layer of sand approximately 2–3 m wide or approximately the width of the road and 1–3 cm deep along the length of the road. If transect is naturally sandy/dusty, the area may need to be tilled. Sweep smooth with a drag towed behind a vehicle to remove existing tracks and make the surface suitable for footprints. Alternatively sand plots 5–10 m long (this length to be constant) could be established at 1 km intervals along the transect.
- Mark the location of each transect on a map using a GPS.
- Return the following morning. Count and record all sets of individual wild dog footprints and prints of other species. Individual footprints are defined as sets of footprints occurring not less than 1 km since the last occurrence of that species on the road.
- Determine the imprint-ability value every 1 km of each transect.
- Sweep the transect clean 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 kilometre or number of sand plots with footprints (Catling Index: see 'Track stations') and use the average as the index.

Standards

Route – use the same transect for each count.

Sampling time – always conduct the survey at the same time each year and during similar weather conditions.

Training required

Identification of tracks

Use of GPS

Worked example (Tables 5 and 6)

Aerial baiting for wild dog control 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 2 km in length, 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 an 82% reduction in wild dog abundance.

Table 5. 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	9	0.41	5	0.23
TRANSECT 2 (19 km)	11	0.58	10	0.53	16	0.84
TRANSECT 3 (20 km)	4	0.20	7	0.35	8	0.40
TRANSECT 4 (25 km)	9	0.36	3	0.12	10	0.40
TRANSECT 5 (17 km)	2	0.12	6	0.35	7	0.41
MEAN		0.31		0.34		0.35
INDEX VALUE	$= (0.31 + 0.34 + 0.35) \div 3 = 0.33$ tracks km^{-1}					

Table 6. 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)	1	0.05	1	0.05	0	0.00
TRANSECT 2 (19 km)	2	0.11	3	0.16	3	0.16
TRANSECT 3 (20 km)	0	0.00	0	0.00	0	0.00
TRANSECT 4 (25 km)	1	0.04	3	0.12	2	0.08
TRANSECT 5 (17 km)	0	0.00	0	0.00	1	0.06
MEAN		0.04		0.07		0.06
INDEX VALUE	$= (0.04 + 0.07 + 0.06) \div 3 = 0.06$ tracks km^{-1}					

% CHANGE	= (pre bait index value – post bait index value) $\div$ pre bait index value $\times 100$ $= (0.33 - 0.06) \div 0.33 \times 100 = 82\%$ reduction in wild dog abundance

Capture–recapture: trapping and telemetry

Capture–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 or recaptured and unmarked animals, that are marked and released. Animals are continually captured and released until the monitoring is finished. The resulting capture history is then used to produce an estimate of the population. Various capture–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). Assumptions common to all mark and recapture models are (Southwood 1989; Krebs 1999):

1. All animals have equal catchability, marked animals at any given sampling time have the same chances of capture as unmarked animals.
2. The behaviour or life expectancy of marked animals is not affected by recapturing.
3. All previously marked animals can be distinguished from unmarked animals.

The most common monitoring techniques that utilise capture–recapture methodology are trapping and radio-telemetry. Trapping of canids in Australia has been used as a control measure and has been useful to capture animals for research (Fleming *et al.* 1998; Fleming *et al.* 2001). Successful and humane trapping requires extensive training and should be carried out by experienced 'trappers or doggers', as trapping by inexperienced operators may make animals 'trap-shy'.

Steel-jawed traps are not approved by animal welfare agencies. Toothed and steel-jawed traps traditionally used by trappers in Australia should be replaced with padded leg-hold traps or treadle snares to reduce the incidence and severity of foot injuries sustained by both target and non-target animals (Fleming *et al.* 2001). Capture efficiency (CE) of traps varies with trap type, and Fleming *et al.* (1998), in a review of trap performance for wild dogs and foxes, found ranges from 1.56 to 2.45 (CE = number of trapped target animals/100 trap nights). Padded Lane's and Soft Catch® traps were the most efficient, followed by toothed Lane's and then treadle snares (Fleming *et al.* 1998). This range is equivalent to 41 to 64 trap nights per target animal, but capture rates for wild dogs can involve up to 172 trap nights per animal (Newsome *et al.* 1983). Trapping is time-consuming and labour intensive and is only suitable for small areas.

Trapping can be used as an index of abundance by comparing trapping events using catch-per-unit of trapping effort. Trapping can also be used in capture–recapture studies when combined with radio-telemetry. This involves trapping the target animals, but instead of being removed these animals have a radio-collar attached to them and are released at the point of capture after measurements such as sex, weight, reproductive condition and age are taken. The movements of radio-collared animals are measured by signals received by handheld directional antennae and portable receivers or from aircraft fitted with directional antennae. Alternatively, fixed receiver stations using immobile towers with

A capture pole is used to hold a wild dog

Wild dogs can be anesthetised, secured to a board and measurements recorded. Hair samples may be taken at this stage for DNA or faecal samples for analysis of parasites.

greater range than hand-held receivers, can be used to determine animal locations. A large study in the west Pilbara region of Western Australia utilised radio-telemetry from aircraft to monitor dingo activity and estimate home range and population density. (Thomson *et al*. 1992). It is possible to use a Petersen estimate or derivations of this estimate using radio located animals as a recapture and animals seen with them as unmarked captures (White & Garrott 1990; Kenward 2001). Radio-telemetry is useful for home range estimation and for determining areas of high activity. Radio-collared animals are sometimes used as 'Judas' animals to locate areas of wild dog activity. The Judas technique has been used successfully to locate and eradicate goats (Henzell 1987; Taylor & Katahira 1988; Keegan *et al.* 1994) and pigs (McIlroy & Gifford 1997).

Radio-telemetry

Materials required

Radio transmitters and receivers

GPS

Data sheets

Vehicle for tracking where appropriate

Aircraft if using aerial tracking

How to do it

- Capture wild dogs using an experienced trapper(s).
- If necessary, sedate captured animal with appropriate dosage of anaesthetic injection.
- Record physical condition, sex, weight, reproductive condition, approximate age and colour.
- Clean capture injuries and treat with an antiseptic solution.
- Attach radio-collar with unique operating frequency around neck of wild dog.
- Record details of radio-collar frequency and double check that transmitter is functioning correctly and well fitted.
- Allow the animal to recover from anaesthetic and release at point of capture.
- Start tracking after several days to allow the animals to acclimatise 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, causing minimal disturbance to the behaviour of the animal.
- Once the animal is located, record the position using a GPS.
- Record time, habitat type and animal behaviour.
- Obtain radio fixes every hour for duration of a tracking session.

Vehicle radio-tracking

- Use 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, as discussed above.

Aerial radio-tracking

- Track during periods of optimal wild dog activity at dawn and dusk.
- Locate radio-collared animals by scanning the appropriate radio frequencies while systematically flying over the study area.
- Once a radio signal is detected use the relative strength of the signal to direct the aircraft to the animal.
- If in open country, visual locations may be possible and records of association with other animals may be made.
- If visual location is not possible, locate the animal by flying completely around it while keeping the strongest radio signal on the side of the plane facing the circle, or make repeated passes near the animal from different directions.
- Record location with a GPS and on a map.
- Maintain surveillance of animals for 30 mins.
- Repeat tracking for 3 days every 2–3 weeks until there are 20 or more locations over a period of more than 100 days.

Fixed-tower tracking

- Establish two or more fixed location radio-tracking towers in elevated positions approximately 3–4 km apart.
- Take radio fixes every 15 min during a tracking session to assess 24-hour movements over 2–3 days.
- Use triangulation to determine the animal's position (see White & Garrott 1990; Kenward 2001).

Wild dog fitted with radio transmitter collar

Standards

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

Training required

Animal handling

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

Satellite and Global Positioning System (GPS) telemetry

A further development of telemetry techniques is the utilisation of satellites and GPS to monitor the movement of appropriately radio-collared animals. GPS telemetry utilises receivers, attached to the animals and signals received from satellites to determine the location on earth. Two main methods of data storage and retrieval are available, on board storage and remote downloading to a portable receiver (Mech & Barber 2002). On board storage relies on the retrieval of the collar and downloading the data. Retrieval can be via recapture of the collared animal or by triggering an automatic or remote drop-off mechanism to release the collar. The GPS unit is then located by VHF signal. Remote downloading units utilise VHF signals to send data to a portable receiver. The receiver must be within 5 to 10 km using on ground stations or 15 to 20 km using ground to air stations, These allow data to be retrieved daily and minimise data loss.

The great advantages of GPS telemetry are low fieldwork requirements, a high number of locations per animal, the ability to be used in all weather conditions and little disturbance of the target species. Animals need only to be captured to attach the collar and recaptured to retrieve the transmitter, with no other fieldwork required. Disadvantages include high cost, with prices varying with the type and size of package required. The battery life of GPS collars (determined by the rate of sampling) are low when compared with those of VHF systems.

The accuracy of GPS telemetry may suffer from interference from habitat and topography such as canopy cover impeding satellite signals. Frequent movement in steep terrain by GPS radio-collared animals may influence positional error (Di Orio *et al.* 2003). When evaluating the performance of GPS collars in different habitat types in California, Di Orio *et al.* (2003) found that almost 90% of fixes were within 25 m of the true location but noted that as canopy cover and density increased the corresponding positional error increased. GPS collar testing and monitoring of moose movements (*Alces alces*) in North America have found that canopy cover influences the proportion of successful locations and this may introduce bias into habitat-use studies with more accurate readings when the animal is in open canopy (Moen *et al.* 1996; Dussault *et al.* 1999; D'Eon *et al.* 2002). In spite of these effects GPS telemetry is the most accurate currently available method of tracking animals.

The weight of GPS collars has made their use with wild dogs limited, in general, collars weighing more than about 3% of body mass tend to have adverse effects on the target species (Kenward 2001). However, the smallest GPS collars currently available weigh about 300 g (K. Lay, Sirtrack, pers. comm.) and would probably not alter the foraging ability of the average wild dog that weighs about 15 kg. Therefore, GPS telemetry has become a valuable monitoring tool for wild dogs.

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

Satellite telemetry has similar advantages to GPS telemetry, with a large reduction in travel and fieldwork. Animals need only to be captured to attach the transmitter and recaptured to retrieve it, with no other fieldwork required. Recaptures can be facilitated by the installation of a VHF transmitter into the transmitter. The disadvantages of this technique are high cost and variable accuracy. The cost of a single transmitter unit varies, depending on the number ordered, the manufacturer, and the size of the study animal. (Mech & Barber 2002). Added to this are costs associated with data retrieval, which are based on kilobytes of information. The accuracy of satellite telemetry can vary from within 150 m to greater than 1000 m. Locations are categorised by accuracy, such that location class (LC) 3 has an accuracy of ± 150 m, LC2 ± 350 m, LC1 ± 1000 m and LC0 ± > 1000 m. Mills & Gorman (1997), while tracking African wild dogs, found that 9% of locations were LC3, 63% were LC2 and 28% were LC1. This degree of accuracy is acceptable for wide-ranging species such as African wild dogs, that can have home ranges up to 900 km^2 (Mills & Gorman 1997) or for caribou (*Rangifer tarandus granti*), that may move about 5000 km in a migration year (Fancy *et al.* 1989). However, if the target species utilises a small area, VHF or GPS telemetry techniques are more appropriate.

Auditory indexes

Social carnivores use long-range vocalisations, such as roars, howls or whoops, to communicate. By eliciting a response from these animals it may be possible to estimate territory and relative abundance. Auditory surveys have been used for wolves (Harrington & Mech 1982; Crête & Messier 1987; Fuller & Sampson 1988), coyotes (Wenger & Cringan 1978; Pyrah 1984; Okoniwski & Chambers 1984), lions (*Panthera leo*), spotted hyenas (*Crocuta crocuta*) (Ogutu & Dublin

1998; Mills *et al.* 2001), and African wild dogs (Robbins & McCreery 2003), with varying degrees of success. The basic premise of this technique is to playback recorded sounds of the species at night, although imitation of these vocalisations or use of an artificial stimulus may be useful. Roads or trails can be used as transects, with the observers stopping at set intervals and listening for a response to the playbacks (Gese 2001). Alternatively, randomly selected sites within a study area can be used as points (Fuller & Sampson 1988). Estimates of population size are based on the number of individual responses or the composition of replies from the pack (Wilson & Delahy 2001).

The advantage of auditory indices over other monitoring techniques is that they are quick and simple to use. However, there are many drawbacks to the technique that have led many authors to caution its use, especially over large areas. Mills *et al.* (2001) noted that spotted hyenas quickly became habituated to the sounds, limiting the repeatability of the survey. Differentiation of the sounds made by one individual from those made by the pack as a whole may prove difficult, even with the aid of sound recording equipment, and wind and rain can affect the sound transmission. (Harrington & Mech 1982). Fuller and Sampson (1988) suggest that auditory techniques may be useful for locating canid packs in small areas and is unsuitable for regional scale surveys. Conversely, Robbins & McCreery (2003) indicated that the technique was effective for monitoring African wild dogs over an area of 2200 km^2.

It would seem that the efficacy of auditory indices depends largely on the target species. Dingoes use howling to communicate but may respond to only 50% of howling sessions. When grouped in packs, they will consistently use chorus replies (Corbett 2001). This makes estimating dingo numbers using this technique unsuitable unless the dingoes are not pack bound. Howling surveys may be of some use in presence or absence studies, to locate packs and estimate trends in dingo activity, but are probably of limited use in monitoring these animals.

Remote photography

Remote photography involves using one or more cameras set up to trigger by animals tripping a line, passing through an infrared beam, activating a pressure sensitive plate, or heat sensors (Gese 2001). This technique has been used to identify predators at bait stations or nests, examine feeding ecology and, to detect the presence of a species (Foresman & Pearson 1998; Cutler & Swann 1999; Gese 2001). The use of bait stations relies on the tracks left behind by visiting species to determine bait uptake. Using remote camera traps, the identity of the species taking the bait can be accurately established and this reduces the likelihood of poor results when more than one species has visited a bait station or the tracks have been destroyed by rainfall (Belcher 1998; Glen & Dickman 2003a). In recent times, remote camera traps have been used to estimate target species abundance via mark and recapture methodology. It has proved useful in studying species that are secretive or aggressive and difficult to observe such as tigers (*Panthera tigris*) and grizzly bears (*Ursos arctos*) (Minta & Mangel 1989; Karanth 1995; Karanth & Nichols 1998; Gese 2001). The unique stripe patterns of tigers were used to distinguish between individuals and the population size, and densities were estimated from photographs taken by remote-trip cameras set up on transects (Karanth 1995; Karanth & Nichols 1998). Alternatively, artificial tags, as used in traditional mark and recapture studies, or radio-collars could be utilised to identify individuals.

The advantages of remote camera trapping are that it is less invasive, less time consuming and less costly than long-term direct observation of animals. It is ideally suited to the study of animals that are difficult to observe because of cryptic or aggressive behaviour (Cutler & Swann 1999; Wilson & Delahy 2001). Remote photography may limit observer bias and improve monitoring results (Gese 2001; Glen & Dickman 2003a). However, depending on complexity, the equipment involved with remote photography can be expensive (Glen & Dickman 2003a) and vulnerable to human interference, theft and damage (Wilson & Delahy 2001). Remote digital cameras require regular maintenance to replace batteries and some technical expertise to repair component failure, such as malfunctioning trigger systems (Cutler & Swann 1999). Care must also be taken to avoid leaving scent on the equipment as this may repel the target of the study (Wilson & Delahy 2001). There are problems with non-target animals triggering cameras. Other factors that may affect population estimates are: unequal capture probabilities of different age and sex classes; the need for a long monitoring period; and the number and spacing of cameras (Karanth 1995; Jacobson *et al.* 1997; Koerth *et al.* 1997; Cutler & Swann 1999).

Remote photography seems to have potential for wild dog population monitoring in Australia and it may be useful for accurately determining bait-take. This may be valuable in areas where quolls are present and there is concern over the effect of poison control programs on non target species. Detecting the presence of wild dogs may be more cost effectively undertaken with other methods such as track and scat counts.

MONITORING WILD DOG AND DINGO IMPACTS

This section discusses the different methods that can be used to monitor the impact caused by wild dogs. The tables at the end of this handbook summarise the methods of monitoring wild dog abundance.

Monitoring economic costs

Costs of control

The cost or effort involved in wild dog control can be used as an estimate in wild dog abundance. The average costs of fox control using 1080 baiting have been calculated for a 2000-ha property, assuming baiting by one person using a 4WD diesel utility and 60 bait mounds; these costs can easily be converted to wild dog control costing (Saunders *et al.* 1997). Records should be kept of the number of baits taken and, these should be allocated to the species responsible on the basis of the footprints found at the bait station. The cost of regional wild dog control strategies can be similarly monitored using the quantity of bait dispensed. Aerial baiting costs may be predicted from bait quantity (Thompson & Fleming 1991). It is important to remember that using these costs will be reliable if the spacing of bait placement and location of bait trails is constant.

Each year records may be kept to show changes in the control costs over time. This change in the amount of money spent may be an indicator of changes in the wild dog impact.

Example of costs of ground baiting

Miscellaneous costs such as travelling to collect baits and telephone calls to notify neighbours, have not been included (adapted from Saunders *et al.* 1997 with 2006 costings).

LABOUR	
Time taken to lay 60 baits	8 h
Time taken to check and replace bait line	5 h × 7 days
Total	43 h
Labour cost ($12.60/h + 15% on-costs)	$623.07
VEHICLE	
Average of 33 km per trip to lay and check baits	264 km
Total cost @ $0.798/km	$210.67
MATERIALS	
81 Doggone® baits used @ $1.15 each	$92.00
10 × 1080 warning signs @ $2.30 each	$23.00
Total cost	$115.00
AVERAGE TOTAL COST PER PROGRAM	**$948.74**
COST/ha (ONCE/YEAR BAITING)	**$0.47**

Example of costs of aerial baiting

Adapted from Thompson & Fleming (1991) with 2006 costings. The area baited covered nine RLPB districts in north-eastern NSW (24 323 ha).

LABOUR	
Bait preparation (purchase, poisoning and bagging)	610 h
Transport of baits and equipment to pick-up sites	554 h
Navigation and dropping of baits	165 h
Organisation and supervision of baiting	145 h
Other tasks	101 h
Total	1575 h
Labour cost ($12.60/h + 15% on-costs)	$22 821.75
VEHICLE	
18 vehicles travelling on average 1058 km	19 044 km
Total cost @ $0.798/km	$15 197.11
HELICOPTER	
89.2 h (baiting and ferrying time) @ $830/h	$74 036.00
MATERIALS	
24 285 kg of pre-butchered bait @ $1.50/kg	$36 427.50
TOTAL COST OF PROGRAM	**$148 482.36**
COST/kg OF BAIT USED	**$6.11**

Other costs

It is difficult to estimate accurately the agricultural costs attributable to wild dogs in Australia on a national, state or regional level (Bomford & Hart 2002). Conservative estimates of the annual cost impact of dogs have been put at a monetary value of $66.3 million (McLeod 2004). However, this value is based on limited information that has been extrapolated from sources such as government agency estimates and landholder surveys, and it has been acknowledged that there are many gaps in the knowledge (Bomford & Hart 2002; McLeod 2004). Individual landholders may therefore play a significant role in filling these gaps by calculating and monitoring all the costs attributable to wild dogs. These costs include control expenditure and shooting or trapping; checking, moving and sheltering livestock; stock losses (see Table 7); and fencing installation and maintenance. The inference that is made from cost monitoring is that a decline in costs is associated with a decline in wild dog abundance,

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

ACTIVITY	**LABOUR** …h @ $\$\ \mathrm{h}^{-1}$	**MATERIAL**	**COST $**
Shooting		Vehicle @ $\$\ \mathrm{km}^{-1}$ Ammunition Firearm maintenance	
Trapping		Vehicle @ $\$\ \mathrm{km}^{-1}$ Trap maintenance Ammunition Firearm maintenance	
Exclusion fence maintenance		Posts Wire	
Stock protection			
Stock losses		Ewe scanning @ $\$\ \mathrm{ewe}^{-1}$	

Monitoring livestock losses

There are two main approaches to obtaining information on stock predation. Loss surveys and reports from landholders across a regional scale and experimental studies comparing areas with and without predator control. Surveys or reports suffer from problems such as inaccurate estimates, variable response rates and variations in recognition of predation, but they still provide a relatively objective indication of areas with predation problems and trends over time (Fleming *et al.* 2001). This type of monitoring is limited to areas where intensive husbandry of livestock occurs; such monitoring could include the number of livestock killed, mauled, branded, lambing rates, sightings of wild dogs. Areas such as rangelands are problematic, because stock are regularly seen only at watering points or during musters. In suitable areas, such as eastern NSW, monthly surveys conducted over 4 years indicated that there were regional differences in the type of livestock killed, and there was evidence of seasonal patterns of predation (Fleming & Korn 1989). Sheep kills in a small area of south-eastern NSW were reduced from an average of 150 each year to 25, subsequent to the start of cooperative predator-management practices (Brindabella & Wee Jasper Valleys Wild Dog/Fox Working Group 2002). The proportion of calves mauled by wild dogs was recorded for 28 consecutive years by a landholder in north Queensland; the results indicated that after a change in canid management from localised ground baiting to regional aerial baiting, calf maulings declined from between 8% and 19% to zero for 2 years (Allen & Gonzalez 1998). Therefore, it has been recommended that surveys be collected as components of property inspection reports by staff from the relevant land management authorities (Fleming *et al.* 2001).

Comparing pastoral areas that have predator management with those that have not, over a number of years, is a more accurate measure of livestock losses. This is difficult to achieve, as few landholders would be prepared to leave productive areas of properties free of wild dog control. However, Allen and Gonzalez (1998) were able to evaluate the effectiveness of control in Queensland on three large properties, using two test herds of cattle per site. This study indicated that, where dingo populations recover after localised baiting, calf losses can be significantly higher than those found in unbaited areas. Potential causes of this are the creation of a 'dispersal sink' that promotes the dispersal of dingoes from surrounding unbaited areas (Thomson *et al.* 1992). Recolonising dingoes are generally younger animals that may have increased activity and poorer hunting ability than mature dingoes, predisposing them to attacking calves (Allen & Gonzalez 1998; Allen 2000).

Recognition and signs of predation

The following procedure is suggested for determining whether wild dogs have been responsible for predation.

If the soil surface is suitable, tracks may implicate wild dogs. The wild dog's footprint is larger and rounder than a fox and is often very deep at the site of attack because of the pressure exerted during killing. Pieces of wool with patches of skin attached and blood trails are good indicators of wild dog attacks. If adult

Wild dogs often attack sheep from behind as they run away

sheep or calves are the prey then wild dogs must be implicated, although the presence of wild dog footprints at the carcass does not necessarily mean predation was the cause of death.

Wild dogs often attack from behind as sheep or calves move away. If these animals survive they may have substantial tissue damage around the hindquarters, be lame, without tails or have skin hanging from them. Sometimes, ears are chewed off older cattle as wild dogs attack from the front. Surviving calves often only show teeth marks as evidence of wild dog attack, and the area around the bite becomes swollen through infection and flystrike. Skinning of the carcass will often reveal extensive bruising caused by wild dog attacks.

The age, body position and location of a sheep or calf carcass may give some idea of whether wild dogs were involved. Wild dogs will attack sheep of all ages but rarely attack cattle older than 12 months. Attacks can occur anywhere, whereas stock dying of natural causes generally die in a protected area. A carcass with 'paddling' signs would suggest predation was unlikely.

Monitoring indicator prey species

Predation of livestock may be greatest when alternative prey is scarce (Corbett 2001). As a result, in some circumstances it may be useful to monitor the abundance of the preferred prey of wild dogs such as kangaroos and wallabies, to indicate when livestock might be at risk. This may be especially useful in cattle areas. With sheep, damage seems to occur regardless of the abundance of the preferred prey. In other words, high kangaroo numbers would not imply a reduced likelihood of sheep losses. The possibility that low macropod population density could point to an increased likelihood of livestock losses has not been tested and is a monitoring tool that requires further research.

Wild dogs attack the back legs and kidney areas of sheep. Skinning carcasses shows extensive bruising along the body

Monitoring diversification of land use

Predation of livestock by wild dogs may become severe enough for landholders to diversify to other enterprises. Landholders who originally stocked sheep may change to cattle grazing. In Queensland between 1945 and 1996 the number of sheep stocked was negatively correlated with the number of cattle stocked, suggesting that cattle were being substituted for sheep (Allen & Sparkes 2001). The same study indicated that the number of bounty payments for dingo scalps increased as sheep numbers increased but decreased with the escalation in cattle numbers and subsequent decline in sheep production.

Monitoring vulnerable prey species

The predation impact of wild dogs on threatened or vulnerable native species may be estimated by monitoring the populations of these prey species. The densities of these prey species could be monitored before and after extensive control plans have reduced the density of wild dogs. 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 Kinnear *et al.* (2002) have shown that 11 medium-sized species have responded to fox control by first increasing population size and then expanding distribution. Twenty-six years of mammal monitoring in south-western Australian forests has also shown that native mammal abundance is related to the level of effort expended to control foxes (Burrows & Christensen 2002). Techniques for monitoring will vary with species and habitat and are thus situation specific. A combination of trapping and dung counts was used to monitor the response of black-footed rock-wallabies (*Petrogale lateralis*) to fox control in south-western Australia (Kinnear *et al.* 1988; Kinnear *et al.* 1998a,b). The apparent decline in fox population densities in the vicinity of rock-wallaby colonies led to population increases. However, some wallaby colonies also increased in the presence of unmanaged fox populations (Kinnear *et al.* 1988a,b), leading to cautions over the interpretation of these results (Hone 1999). Other monitoring of vulnerable prey species has included radio-tracking and counts of active nests of mallee fowl (*Leipoa ocellata*) (Priddell & Wheeler 1995; Priddell & Wheeler 1997), and track counts and small mammal trapping to compare native faunal species abundance between areas with high and low fox density (Catling & Burt 1994; Catling & Burt 1997).

In situations where wild dogs are being controlled for native species protection, it is important that foxes and cats be simultaneously controlled, as they will also pose a threat to some native species (Burbidge & McKenzie 1989). There is also the possibility that the population densities of these smaller predators may increase in the absence of wild dogs called the mesopredator release hypothesis (Soulé *et al.* 1988; Mitchell & Banks 2005). Control of other competitors of the species targeted for protection may also be necessary in conjunction with predator control. For example, in NSW the endangered malleefowl has shown little recovery after predator control (Priddell 1991), and competition for food with rabbits is a likely cause (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 wild dog damage and population density

Mapping the distribution of where wild dog problems occur and their population density over individual properties or regions facilitates the development and assessment of wild dog management plans. Regular updating of these management plans is necessary. These maps can range from simple hand-drawn property charts to more detailed and accurate topographic maps or computerised maps generated with GIS software. The choice of map type will depend largely on the scale of the area involved, the cost and availability of the technique, and the extent of the problem. These maps may include the location of wild dogs and poison baiting transects to indicate gaps in the coverage of control programs; the location of areas of rabbit infestation, which may indicate areas for wild dog control and refuge habitat and the preferred habitat of endangered species. These maps can be used as part of the overall property management plan and to assess progress over the years. At a larger scale, the NSW Department of Primary Industries has surveyed NSW Rural Lands Protection Boards and NSW National Parks and Wildlife Rangers to develop State-wide maps of pest species distribution and abundance (West & Saunders 2003). Information to include on maps includes:

- scale and north (magnetic/grid)
- name and location of property
- size of property
- property boundaries, permanent fences, gates, and roads
- topographic features such as watercourses, hill contours, rock outcrops
- refuge habitat – vegetation such as woodland or shrubland
- lambing paddocks
- wild dog abundance estimates
- areas of wild dog damage with a scale of damage
- areas of rabbit infestation or concentrations of other prey
- type of agricultural or other activities on this and adjoining properties
- location of sightings or signs
- It is important to make new maps with each new assessment. In this way the new map can be compared with the previous map to evaluate the current management.

SUMMARY OF WILD DOG AND DINGO MONITORING TECHNIQUES

The various wild dog 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
Bait stations	• quick and simple • inexpensive – can be part of a control program • control of wild dogs at the same time as monitoring (toxic baits) is quick and simple • target animal doesn't need to be sighted	• unreliable method in wet and windy conditions • may alter normal behaviour of target species • bait-shy animals undetected • road-based sampling: *non-representative coverage of area* • potential for interference (e.g. trampling from vehicles or humans)
Scat counts	• inexpensive • target animal doesn't need to be sighted • can be used in difficult terrain • sampling schedule flexible	• inappropriate for monitoring short-term changes • road-based sampling: *non-representative coverage of area* • identification of scats prone to error • defaecation rates will vary with season and diet
DNA sampling	• target animal doesn't need to be sighted • improved accuracy of scat counts • density estimates possible	• expensive • correct storage important • time consuming
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 • road-based sampling: *non-representative coverage of area* • potential for interference (e.g. trampling from vehicles, humans and stock)
Capture–recapture	• accurate estimate of abundance • other information may be collected at the same time (e.g. home range)	• expensive • labour intensive • time consuming • difficulty of capture
Satellite and 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
Auditory indexes	• wild dogs don't need to be sighted • can cover a lot of ground quickly	• untested • variable wild dog response • hard to tell individual from whole-pack responses
Remote photography	• accurate identification of species taking bait • allows interpretation when more than one species has visited a bait station or tracks have been destroyed by weather • less invasive, less time consuming, and less costly than long-term direct observation of animals	• vulnerable to human interference, theft and damage • requires regular maintenance and some technical expertise to repair component failure
Costs of control	• inexpensive – part of control program • can be incorporated into existing economic management	• unreliable if degree of effort or methodology changes • costs increase each year – need to account for inflation

MONITORING TECHNIQUE	ADVANTAGES	DISADVANTAGES
Other cost monitoring	• inexpensive • can be incorporated into existing economic management	• assumed relationship with wild dog abundance
Livestock losses: landholder survey	• simple	• variable response rate • identification of predation—are wild dogs causing the losses?
Livestock losses: experimental study	• accurate determination of losses	• expensive and time consuming
Indicator prey species	• prey species may be easier to monitor than wild dogs • may indicate when livestock predation is likely	• untested • wild dogs can still attack livestock when other prey is abundant
Diversification of land use	• may indicate regional trends in wild dog impact	• need to identify why land use has hanged • does not indicate current predation impact
Vulnerable prey species	• prey species may be easier to monitor than wild dogs	• difficulties in determining whether abundance is related to wild dog predation

Table 9. Wild dog and dingo monitoring techniques ranking table

	LABOUR	START-UP COST	EXPERTISE AND TRAINING	SPECIALISED EQUIPMENT	HUMANE	OH&S RISK
Non-toxic bait stations	Moderate	Low	Low	Low	High	Low
Toxic bait stations	Moderate	Low	Low	Low	Moderate	Low
Passive scat count	High	Low	Low	Low	High	Low
Active scat count	High	Low	Low	Low	High	Low
DNA sampling	Moderate	High	Low	High	High	Low
Track stations	Moderate	Moderate	Low	Low	High	Low
Road counts	Moderate	Moderate	Low	Low	High	Low
Mark and recapture (trapping)	High	Moderate	High	Moderate	Moderate	Moderate
Mark and recapture (radio-telemetry)	High	High	High	High	Moderate	Moderate
Satellite and GPS telemetry	High	High	High	High	Moderate	Moderate
Auditory indexes	Moderate	Low	Low	Low	High	Low
Remote photography	Low	High	Low	High	High	Low

GLOSSARY

Allen Index

The mean number of animal tracks per transect per day.

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.

Canid

Member of the Canidae family of carnivorous animals. Includes wolves, jackals, foxes, coyotes, domestic dogs and dingoes.

Catling Index

The percentage of station nights with animal tracks.

Corvid

Member of the Family Corvidae, including crows, ravens and magpies.

Dispersal

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

Index of abundance

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

Mesopredator

A predator that is also the prey of another predator.

Microsatellite

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

Polymerase chain reaction (PCR)

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

Presence/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.

Sink

A population or subpopulation in which the finite rate of increase is less than one, and which would become extinct if it were isolated from source populations.

Stratified random sampling (also called proportional or quota random sampling)

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

Track-station night

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

Transect

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

Trap night

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

Treadle snare

A trap that consists of a hole covered by sticks, over which a loop of cord attached to a bent stick is placed. When the animal steps on the sticks it falls into the hole and its foot is snared by the noose.

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