MONITORING TECHNIQUES FOR VERTEBRATE PESTS

FERAL PIGS

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NSW DEPARTMENT OF PRIMARY INDUSTRIES

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Australian Government
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WHY MONITOR VERTEBRATE PESTS?

The purpose of this manual is to provide details of the techniques available to monitor vertebrate pests 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 (Goldsmith 1991, 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 and 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 any management program, should be done before, during and after control, especially for long-term programs:

- Monitoring **before** a control program should establish a benchmark or index 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 aimed at reducing vertebrate pest abundance. In an ideal world, monitoring should compare treated sites, where control occurs, with untreated sites, where no control is done and accurately measure damage and abundance

before, during and after control. As already stated, measurements of damage are often not available, so assessments of abundance alone are used. However, estimates of the absolute abundance of wild animals are expensive to obtain and may be unnecessary for many pest management decisions (Caughley 1980). Furthermore, complete counts of all pest animals in an area are rarely practical, and more often than not, sample counts are done to provide an *index of abundance*.

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

Humane Pest Animal Control

This manual is to be read in conjunction with the relevant codes of practice and standard operating procedures for the humane control of pest animals (Saunders and Sharpe 2005).

Humane pest animal control, PIGCOP model code of practice for the humane control of feral pigs (Sharp and Saunders 2005)

PIG001 *Trapping of Feral Pigs*
(Sharp and Saunders 2005b)

PIG003 *Ground Shooting of Feral Pigs*
(Sharp and Saunders 2005c)

PIG004 *Use of Judas Pigs*
(Sharp and Saunders 2005d)

RES005 *Measurement and Sampling of Pest Animals used in Research*
(Sharp and Saunders for Department of Environment and Heritage)

RES001 *Live Capture of Pest Animals used in Research*
(Sharp and Saunders for Department of Environment and Heritage)

RES002 *Restraint and Handling of Pest Animals used in Research*
(Sharp and Saunders for Department of Environment and Heritage)

RES004 *Marking of Pest Animals used in Research*
(Sharp and Saunders for Department of Environment and Heritage)

RES005 *Measurement and Sampling of Pest Animals used in Research*
(Sharp and Saunders for Department of Environment and Heritage)

GEN001 *Methods of Euthanasia*
(Sharp and Saunders 2005a)

THE FERAL PIG

History

The feral pig in Australia is a descendant of various breeds of *Sus scrofa*, the domestic pig. There has been speculation that a number of other species of pigs, including *Sus celebensis* and *Sus papuensis*, were brought to northern Australia, but DNA evidence so far does not support this possibility. Records indicate the presence of domestic pigs immediately following the arrival of the First Fleet (Rolls 1969). Pigs were kept by settlements and were often unrestrained. They could readily escape and wander, and by the 1880s pigs had run wild in New South Wales. Their distribution followed watercourses, but where pigs occur in isolated populations the founding animals were probably deliberately released by hunters rather than a product of natural dispersal (Wilson *et al.* 1992). Feral pigs are still colonising parts of Australia (Twigg 2003).

Impacts

Feral pigs prey on newborn lambs and also reduce yields in grain, sugarcane, and fruit and vegetable crops by consuming or trampling plants. Fences and water sources can be damaged, and dams and waterholes fouled through wallowing and defecation. Feral pigs also compete with livestock for pasture and damage pasture by up-rooting vegetation (Tisdell 1982; Choquenot *et al.* 1996).

Feral pigs disturb natural environments through rooting up soils, grasslands and forest litter and by consuming a range of native plants (Pavlov 1995). There is some evidence that they may also help spread rootrot fungus (*Phytophthora cinnamomi*), which is responsible for dieback disease in native vegetation (Choquenot *et al.* 1996). Feral pigs also eat a range of live native animals, including earthworms, beetles, centipedes, snails, frogs, lizards, snakes, turtles and their eggs, and small ground-nesting birds and their eggs.

Distribution

Feral pigs are widely distributed in NSW, Queensland, the Northern Territory and the Australian Capital Territory (Choquenot *et al.* 1996). Isolated populations also occur in Victoria and Western Australia, on Flinders Island in Bass Strait and on Kangaroo Island in South Australia. Tasmania occasionally has temporary populations because of accidental releases. In western NSW and Queensland, pig distribution is closely related to the locations of inland watercourses and flood plains (Wilson *et al.* 1992). Increasingly, populations are appearing in the tablelands and coastal areas of eastern NSW and in other states, probably because of the deliberate release of animals (Hone and Waithman 1979).

Habitat

Feral pigs need to live in moist areas that can provide adequate food and water and enough shelter to protect against extremes of temperature (Pavlov 1995). In Australia, feral pigs are found in a variety of habitats that can provide these requirements, including rainforest areas, monsoon forest patches, paperbark swamps, open floodplains, marsh areas, semi-arid floodplains, dry woodlands and subalpine grasslands and forests.

Figure 1: Typical soil damage caused by pigs

Figure 2: Trees ringbarked by feral pigs

Biology

Diet

Feral pigs are opportunistic omnivores. They prefer succulent green vegetation, fruit, grain, and a wide variety of animal materials such as frogs, fish, reptiles, birds and small mammals (Choquenot *et al.* 1996). They will also eat underground plant materials such as roots, bulbs, corms and fungi. Their requirement for protein and energy is high, particularly for breeding, successful lactation and growth of young.

Reproduction

Feral pigs are able to breed throughout the year, but there are usually peaks in births coinciding with the seasonal abundance and quality of food in different habitats (Giles 1980; Saunders 1988; Caley 1993b). The gestation period lasts for 112 to 114 days, with an average litter size of 5 or 6 piglets (Choquenot *et al.* 1996). Litters are weaned after 2 or 3 months, and mating can occur again shortly after. Under favourable conditions two litters can be weaned in a period of 12 months. Female feral pigs reach sexual maturity once they reach a weight of 25 to 30 kg, which normally occurs between 7 and 12 months, whereas males become sexually mature at around 18 months old. This breeding capability gives feral pigs the capacity to quickly recover from a population setback and to quickly increase their populations in periods of favourable conditions.

Mortality

Mortality of juvenile feral pigs is highly variable and is determined by the prevailing conditions (eg 10% to 15% when food availability and weather are favourable; approaching 100% in drought) (Choquenot *et al.* 1996). Mortality is due to factors such as loss of foetuses, adverse weather conditions, accidental suffocation by sows, loss of contact, predation from feral dogs, and starvation. Starvation can affect feral pigs of all ages: lactation of sows can cease if protein levels are not adequate, and excessive tooth wear in older feral pigs can interfere with eating. Lack of appropriate nutrients also leaves feral pigs more susceptible to parasites and diseases.

Feral pigs can be hosts or vectors of a number of endemic parasites and diseases, some of which can affect other animals or people. Livestock health can be significantly affected by leptospirosis, porcine brucellosis, melioidosis, tuberculosis, sparganosis, porcine parvovirus, Murray Valley encephalitis, and other arboviruses. A number of worm species also carried by feral pigs can affect livestock (Choquenot *et al.* 1996). Human health can be affected by leptospirosis (through contact with the urine of affected feral pigs), porcine brucellosis (through handling of raw feral pig meat), and tuberculosis and sparganosis (through eating inadequately cooked

Figure 3: Access to water based habitat is preferred for pigs to maintain body temperate regulation

Figure 4: Disturbed banks along water courses show signs of pig activity

feral pig meat). Feral pigs would also be capable of carrying and spreading a number of exotic diseases and parasites if these were to enter Australia. These include foot-and-mouth disease, swine vesicular disease, African swine fever, Aujeszky's disease, trichinosis, and classical swine fever.

Social structure

Sows and piglets generally run together as a group. Immature males and females may also stay with the group until they reach maturity, or they may run as a juvenile group until they mate (Pavlov 1995). At about 18 months, males become more solitary, only rejoining a group for mating or to feed on localised food sources. Group sizes vary depending on the season, habitat and conditions, and range from 1 to about 100 (Choquenot *et al.* 1996), but up to 700 in North Queeensland.

Movements and home range

Feral pigs restrict their activity to cooler parts of the day (i.e. dawn and dusk), and in hot weather they are primarily nocturnal (Choquenot *et al.* 1996). Even in cooler weather they tend not to be active during the middle of the day. Feral pigs consistently use trails from one area of use to another, such as from shelter to food supply or water (Saunders 1988). Weather conditions and food availability affect the movement of feral pigs. In hot weather days may be spent in one area and nights spent feeding in another (Giles 1980; Dexter 1995). In many habitats there is a seasonal trend of movement between specific areas, depending on the current food supply. Feral pigs will readily swap between food sources so that excessive movement is not required. Even if disturbed, feral pigs will not move far and will readily return to their home ranges (Choquenot *et al.* 1996).

Home range is determined by habitat type, food supply, the size of individual animals, and population density. On a daily basis feral pig ranges are quite small, although the seasonal or overall home ranges may be much larger (Choquenot *et al.* 1996). Mature males tend to have larger home ranges than sows and these ranges can vary from 1 to 43 km^2.

Aerial surveys

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

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

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

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

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

Figure 5: Helicopters provide a fast and accurate means of monitoring pig populations in the wild

Standardisation can alleviate many of these problems, and correction factors for visibility bias can be developed to further improve the accuracy of population density estimates (Caughley 1974, 1980).

Aerial surveys are commonly used to monitor feral pigs in Australia, with helicopters now generally preferred to fixed-wing aircraft (Choquenot *et al.* 1996). This is mainly because of their ability to be flown at lower altitudes and speeds. This provides better visibility, thus improving the precision and accuracy of counts (Wilson *et al.* 1987; Clancy *et al.* 1997). However, the size of the survey area will determine the type of aircraft used, as fixed-wing aircraft have much lower running costs than helicopters, and over large areas this will outweigh the benefits (Clancy *et al.* 1997; Pople *et al.* 1998). A test of the accuracy of aerial surveys for feral pigs, using helicopters and a known number of feral pig carcasses shot as part of a control program, indicated that they provided reasonably accurate population estimates (Hone 1988a). Helicopter surveys have been used to evaluate the success of control programs (Saunders and Bryant 1988; Hone 1990b; Choquenot *et al.* 1993; Choquenot 1995; Choquenot *et al.* 1999b). However if helicopters are used during the control campaign this form of evaluation may be biased, because feral pigs may modify their behaviour to avoid detection (Saunders and Bryant 1988; Choquenot *et al.* 1990; Hone 1990; Choquenot *et al.* 1999).

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

Materials required

Chartered helicopter – wet, fuel supplied by charter company or *dry*, purchased separately

Trained and experienced observers

Count sheet or stereo tape/minidisk recorder, appropriate microphones and power supply (a manual counter is useful as a backup)

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

GIS software is highly desirable, as it can show flight lines to gauge accuracy, true flight distances and timing.

Vehicle to get the survey team in the general survey location or to supply fuel if appropriate

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

Figure 6: Counting numbers within strip transects (photo Peter Fleming)

How to do the count

- Select the survey area.
- Divide the area into potential sampling units or transects. Transects can be stratified into habitat types with correction factors for each type. The number or area of transects can be allocated to habitats on the basis of their habitat to total area ratio.
- Randomly or systematically select transects to sample.
- Conduct surveys in the first and last 3 hours of daylight.
- Fly along the transect at a constant speed and altitude. Factors such as topography and height of vegetation will limit the survey height. There are trade-offs to be made with height in terms of sightability and flushing the target species. Suggested limits are: speed, 85 km h^{-1}, survey altitude, 30 to 100 m subject to safety and the factors discussed above.

Line transects:

- Count all animals and record the distance interval on a count sheet or notebook, or record onto constantly running tape recorders; this allows observers to give their full attention to the search for feral pigs, and to the observations along the transect if the distribution of the population is to be mapped. The recording technique will depend on the density of the target species – the count sheet version is suitable only for low-density species.
- Once the survey is completed, count sheets/tapes are transposed onto data sheets. Record the number of feral pigs, the distance from the transect, and the habitat the pigs were seen in for each transect. Combine the observations made by the two observers counting on either side of the helicopter.
- To estimate the number of feral pigs in each transect, independently derived correction factors are used. For example, the number of sighting entities in each habitat is corrected for the effects of that habitat on sightability. However, other correction factors may be more appropriate, such as feral pig group size, observer skill, or interval between sampling periods.
- These totals are then multiplied by the average sighting entity size to get a corrected estimate of the total number of feral pigs in each transect.

Strip transects:

- Count all animals seen within a 100 m strip on a count sheet or notebook, or record onto constantly running tape recorders; this allows observers to give their full attention to searching for feral pigs, and estimating the position of observations along the transect if the distribution of the population is to be mapped. The recording technique chosen depends on the density of the target species – the count sheet version is suitable only for low-density species. Transect width can

vary according to vegetation cover or height. Some observers use transects that range between 50 m in woodlands and 400 m in open savannah.

- - At the conclusion of the survey, tapes are transposed onto data sheets. For each transect, the number of feral pigs in each sighting entity and the habitat they were seen in are recorded, that is, the observations made by the two observers counting on either side of the helicopter are combined into counts for a single transect.

- - To estimate the number of feral pigs in each transect, the number of sighting entities in each habitat is corrected for the effects of that habitat on sightability by using independently derived correction factors. This gives a corrected number of sighting entities on a transect-by-transect basis.

- - These totals are then multiplied by the average sighting entity size to get a corrected estimate of the total number of feral pigs in each transect.

Standards

Speed – conduct counts while flying at a constant speed of between 45 and 70 knots.

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

Time of day – conduct counts during the first and last 3 hours of daylight.

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

Observers – use the same (experienced) observers for each count.

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

Animal welfare considerations

Impact on target animals – altered behaviour caused by fleeing

Impact on non-target animals – altered behaviour caused by fleeing

Health and safety considerations

A pilot should not be asked to fly at an unsafe altitude, too close to steeply rising terrain, trees or structures, or in weather conditions that they consider unsafe for flying.

The length of sorties flown should be sufficiently short and with breaks between, to prevent fatigue in both the pilot and observers.

There are standardised policy documents for helicopters, including information on the use of trip sheets, communication protocols and emergency procedures.

Training required

Observer training

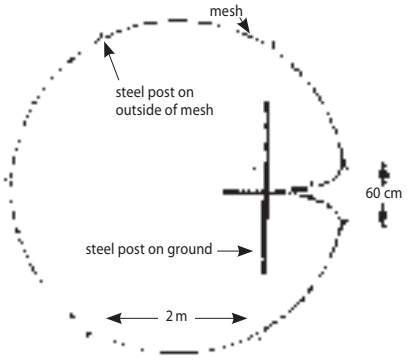

Figure 7: Heart shape or silo pig trap

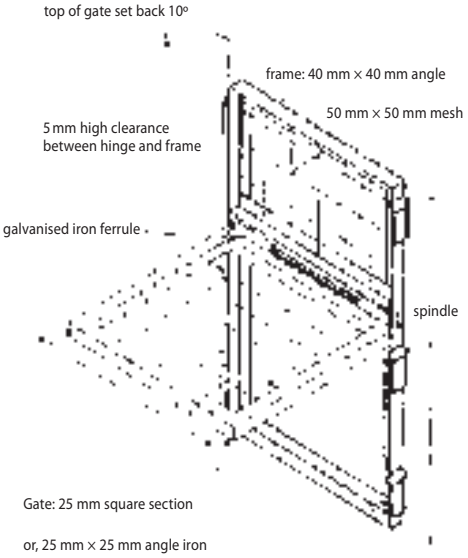

Figure 8: Drop gate for use in pig traps

Trapping

Trapping of feral pigs in Australia has long been used as a control measure and has been useful to capture animals for research and for the game meat export industry (Saunders *et al.* 1993; Caley 1994). There are two main live trap designs that are useful for capturing feral pigs: panel and silo traps. Both types of trap are made of steel mesh and incorporate a one-way entrance. Details on the design and construction of these traps are available from the NSW Vertebrate Pest Control Manual. The selection of trap design will depend, in part, on the resources available for the project. Silo traps are cheaper to construct, but panel traps are often preferred, owing to their transportability (Saunders 1988; Caley 1999). Successful trapping of feral pigs involves initial free-feeding at sites likely to have feral pig activity or near watering points. The most commonly accepted baits are fermented cereal grains or animal carcasses (Saunders 1988; Caley 1999), but this varies with the availability of natural foods and the familiarity with the food source, for example, bananas may be used in North Queensland or wheat in grain-growing areas. Note that the use of animal carcasses is illegal in Queensland and should not be encouraged in other states because of the risk of disease transmission.

Once bait is being consumed by feral pigs, bait trails up to 100 m long are used to lure feral pigs to a chosen trap site, with the largest proportion of the trail being placed at the trap site (Saunders 1988; Lukins 1989). Traps are constructed and left open, and the bait trail is resupplied to allow the feral pigs to become accustomed to the trap. After a fixed time period the trap is set; it must then be checked daily for the duration of the trapping period, as feral pigs are highly susceptible to heat stress (Dexter 1995). Checking also enables non-target captures to be released, although doors can now be designed to be reliably target-specific. Trapping usually continues until no new feral pigs have been trapped for some predetermined period, usually 5 to 7 nights.

Trapping alone can be used as an index of abundance by comparing trapping events via catch per unit of trapping effort. It can also be used to mark feral pigs for capture–recapture studies or radio-telemetry studies to determine population density or areas of activity and home range.

Consideration must be given as to whether trapping is representative of the population. For example, some feral pigs are trap-shy, and targeting preferred locations for traps may introduce biases. In capture–recapture trials some pigs may continually return to the trap for food.

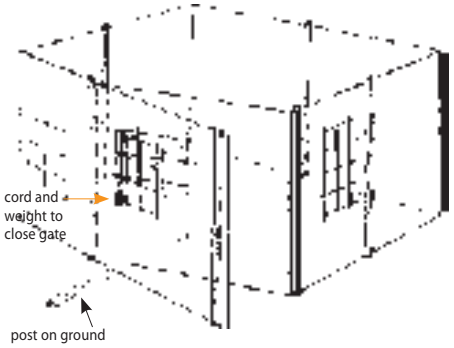

Figure 9: Enclosed feral pig trap

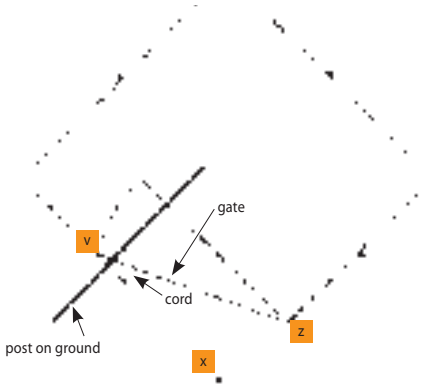

Figure 10: Panel pig gate

Materials required

Traps – several trap designs exist, differing mainly in their gate construction. It is best to use steel mesh with a grid no greater than 100×100 mm. A grid larger than this will damage the feral pigs' snouts if they charge the mesh. The minimum height needs to be 1.5 m. Entrance to the trap can be by a funnel entrance, a tripped gate, or a feral pig-specific trigger. Choice of trap design will depend upon habitat, materials available and accessibility to site.

Bait – bait preferences can vary from area to area, with feral pigs more attracted to bait with a strong odour. Baits can include grain, fermented grain (for example, wheat, oats, barley or triticale that has been soaked in water with molasses added), commercial pig or poultry pellets, vegetables, fruit, meat or carcasses. 10–20 kg of bait may be required each time the trap is set. Some people add meatmeal to the grain before fermentation; this is legal and makes a strong smell. The meat can be placed in PVC pipes (with airholes drilled in them) and the pipes tied to the trap mesh. The smell is very strong and lasts a long time, as the meat cannot be consumed.

GPS – position and locate traps in the field.

Count sheet – to record information in a logical format.

How to trap

- - Select trap sites by determining areas of recent feral pig activity (see section on 'Sign counts' page 40) near watering points, holes in fences, wallow areas or old carcasses that feral pigs are feeding on.
- - Undertake free-feeding by placing feed on well-used pads where feral pigs will find it. Leave 3 to 10 kg of bait at each selected site. If feral pigs are using several pads a trail of bait can be used to lure the pigs to a chosen trap site.
- - Mark the location of trap sites with a GPS.
- - Once feral pigs are taking bait regularly at a site, construct a trap.
- - Leave the trap open and place fresh feed at the entrance to direct the feral pigs inwards; make sure the majority of the feed is inside the trap.
- - Once the feral pigs are regularly feeding inside it, set the trap. This may take about 7 days.
- - Leave a small amount of bait in the entrance and ensure that the bait inside is well away from the entrance so that feral pigs must fully enter the trap to feed.
- - Set the trap each evening and check the following day, preferably in the morning.

Figure 11: Silo pig trap (photo Peter Fleming)

Figure 12: Panel pig trap in use (photo David Croft)

- - *Setting gate entrances* – use a short stick to prop the gate entrance open approximately 30 cm. Feral pigs entering push the gate open and knock the stick down, thereby shutting the gate behind them. Trip lines may also be used. A feral pig-specific gate trip has been developed: a rigid bar, attached by one end to the trap wall, holds a spring-loaded side-swinging door open via a notch. The bait is placed beneath the bar and when feral pigs feed under it they lift the bar, releasing the door.

- - *Setting funnel entrances* – tie the two sides together at the top with wire and make sure that both sides spring freely without dragging on the ground. The funnel must be easy for feral pigs to push through, but it must also spring closed completely once the feral pigs have entered, as they will try to push their way out if a small gap exists.

- - Some baits such as grain, may attract birds. If this happens, lightly cover the bait with soil or vegetation or dye the grain green to help deter consumption by birds.

Standards

Trap design – use the same type of trap, gate and trip mechanism.

Bait – use the same type of bait.

Site – use the same sites for each monitoring effort.

Time – monitor at the same time each year.

Animal welfare considerations

Impact on target animals – traps should be set up at sites where vegetation can provide shade and shelter, with shadecloth or hessian used for protection during extremes of weather. Ensure that trap construction will not cause injury from loose wire, sharp edges or malfunctioning gates. Dispatch feral pigs humanely.

Impact on non-target animals – to minimise the risk of catching non-target species use feral pig-specific gate trip mechanisms. If you are using silo traps, place a steel post across the funnel entrance approximately 1 m above the ground to prevent cattle from entering. If a trap continually catches non-target animals, use an alternative bait attractant or move the trap to another site.

Health and safety considerations

During construction of traps, operators should be wary of the risks of injury from lifting heavy items. Wear leather gloves and eye protection to prevent injuries from wire, steel panels and hammers. Never enter a trap with a captured adult feral pig – feral pigs can be aggressive and will attack, especially in situations when they or their dependent piglets are distressed or threatened. Feral pigs may carry parasites and diseases; wear gloves and wash your hands and other skin surfaces when handling carcasses. Carcasses can be very heavy (> 200 kg), use approved techniques to reduce back injuries when lifting.

Figure 13: Pig traps using fermented grain as bait

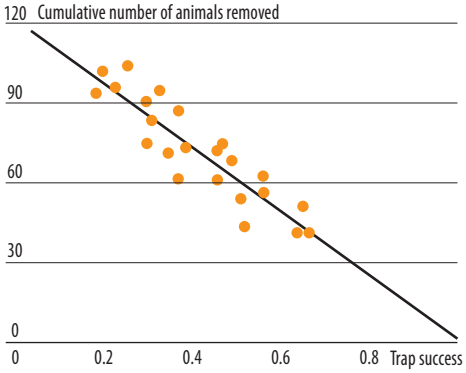

Figure 14: Hypothetical data demonstrating how CPUE can estimate population size. The line of best fit projects the population size at the start of trapping to be approaching 120.

Training required

Recognition of feral pig activity

Setting up of traps

Handling of feral pigs

Catch per unit effort

Catch per unit effort (CPUE) techniques are based on the idea that the effort expended to catch animals is proportional to the number of animals in the population. For example, during a control operation the effort required to capture and remove animals should increase over time, because fewer animals will be available to be caught (Lancia *et al.* 1994; Thompson *et al.* 1998). If all animals could be removed the expected catch would be zero, and the total number of animals removed would be equivalent to the initial population size (Lancia *et al.* 1994). Thus, the cumulative number of animals removed may be used to estimate the initial population (see Figure 14). This is a special case of CPUE, the cumulative catch or Leslie's technique (Leslie and Davis 1939). The CPUE method assumes that there is a linear relationship between the cumulative number removed and the repeated observations. Other assumptions of CPUE indexes are that the population is closed except for those individuals removed, all removals are known, each individual has an equal probability of being caught or killed, and the methods of removal are standardised (Caughley 1980; Thompson *et al.* 1998).

Advantages of CPUE are that live feral pigs do not need to be handled and are removed from the population. Consequently, this technique can be integrated into control programs. However, the assumptions of CPUE methods will not always be met, leading to biased estimates. For example, not all feral pigs will enter traps, they may be trap-shy or not find bait trails, resulting in underestimates of up to 20% (Choquenot *et al.* 1993). Therefore, CPUE methods may be used as indexes of abundance, but their use as population estimators should be treated with caution.

Materials required

As outlined on page 12.

How to do the count

See background information on how to trap on page 12, plus:

- - Check traps each morning.
- - All feral pigs captured should be humanely shot inside the trap.
- - Record the details of captured feral pigs (e.g. sex, weight, age, reproductive condition).
- - Continue trapping until no more feral pigs are being trapped.
- - Use the cumulative kill of feral pigs and the change in trap success or bait consumption to project the initial feral pig population estimate.

Standards

As outlined on page 13.

Animal welfare considerations

Impact on target animals – traps should be set up at sites where vegetation can provide shade and shelter, with shadecloth or hessian used for protection during extremes of weather. Ensure that trap construction will not cause injury from loose wire, sharp edges or malfunctioning gates. Dispatch the target animal humanely. Operators must have appropriate firearm training and certification. Humane destruction is part of firearms training.

Impact on non-target animals – to minimise the risk of catching non-target species, use feral pig-specific gate-trip mechanisms. If using silo traps, place a steel post across the funnel entrance approximately 1 m above the ground to prevent cattle from entering. If a trap continually catches non-target animals, use an alternative bait attractant or move the trap to another site.

Health and safety considerations

As outlined on page 13.

Training required

See standard operating procedures as outlined on page 2.

Figure 15: Collared animals can be easily tracked using radio telemetry

Figure 16: Tracking feral pigs using radio telemetry

Capture – recapture 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 recaptures marked animals and unmarked animals, which are then marked and released, and so on, until the monitoring has finished. The resultant 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 and Seber 1999; Buckland *et al.* 2000). All these methods make assumptions that should be satisfied in order to produce unbiased estimates. Assumptions common to mark – recapture models are (Southwood 1989; Krebs 1999):

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

Because feral pigs are relatively trappable, capture – recapture studies can work well for these animals and have been used in a variety of habitats. These locations have included semi-arid rangelands (Choquenot *et al.* 1990) and riverine areas (Dexter 1995), mountain forests (Saunders 1988; McIlroy *et al.* 1989), and tropical riverine habitat (Caley 1993a). Trapping is carried out as discussed earlier, with trapped feral pigs physically restrained, ear-tagged and released. Once all active bait trails have been trapped, recapture rates are used to estimate the number of feral pigs within the sampled area.

A variation on capture – recapture methodology is to use resightings as recaptures (Krebs 1999). This can be achieved by aerial double-counting, ground observations, DNA sampling, radio-telemetry or remote photography. Remote camera trapping involves using one or more cameras that are set up to be triggered by an animal tripping a line, passing through an infrared beam, activating pressure-sensitive plates or motion or heat sensors (Gese 2001). This technique has mostly been used to identify predators at bait stations or nests, examine feeding ecology and, to a lesser extent, detect the presence of a species (Cutler and Swann 1999; Gese 2001). It has also proved useful in estimating feral pig density in North America (Sweitzer *et al.* 2000). This technique has not been utilised in Australia.

Remote camera trapping of feral pigs has the advantages of reducing field effort and being cheaper than long-term direct observation of animals (Minta and Mangel 1989). However, the equipment needed for remote photography may be expensive, and is vulnerable to human interference, theft and damage (Wilson *et al.* 1987). Remote cameras require regular maintenance and some technical expertise to repair component failure, such as leaking batteries and malfunctioning trigger systems, and batteries and film must be replaced (Cutler and Swann 1999). Small cheap digital cameras have improved remote monitoring.

Capture and release

Materials required

See 'Trapping' as outlined on page 12, plus:

Anaesthetic

Ear tags

How to do the count

See 'Trapping' as outlined on page 15, plus:

- - Capture feral pigs as per trapping guidelines.
- - All feral pigs captured should be immobilised with the appropriate dosage of an intramuscular injection; however, some operators restrain pigs for ear tagging using a crush or ropes. This can be done humanely if done quickly . It may be possible to use a Stockstill® animal immobiliser. Drugs can be expensive, also the operator needs to have a veterinary licence, and effectiveness of drugs may be variable. Individual animals within a trap may need to be isolated and drugs administered according to liveweight. It may take up to 10 minutes for each pig, and heat-stressed animals may die while waiting. Using a rope noose and eartagging through the mesh of the trap, one researcher tagged and released 178 pigs in one project without any ill effects to any pigs (J. Mitchell, pers. comm.).
- - Record details of captured feral pigs (e.g. sex, weight, age, reproductive condition).
- - Tag the ear of the feral pig with a commercial tag.
- - Allow the animal to recover from anaesthetic and release at point of capture.
- - Continue trapping for 1 week.
- - Calculate population estimate based on the number of marked and unmarked animals captured.

Standards

See 'Trapping' as outlined on page 13.

Animal welfare considerations

Impact on target animals – traps should be set up at sites where vegetation can provide shade and shelter, with shadecloth or hessian used for protection during extremes of weather. Ensure that trap construction will not cause injury from loose wire, sharp edges or malfunctioning gates. Dispatch target animal humanely.

Impact on non-target animals – to minimise the risk of catching non-target species use feral pig-specific gate-trip mechanisms. If using silo traps, place a steel post across the funnel entrance approximately 1 m above the ground to prevent cattle from entering. If a trap continually catches non-target animals, use an alternative bait attractant or move the trap to another site.

Health and safety considerations

As outlined on page 13.

Sows may attack to defend offspring. If a group of small suckling piglets are caught in a trap, take time to observe where the sow is. Never enter a trap with captured feral pigs except when all animals are small piglets, the sow is under close observation or sedated and the trap is well secured by ropes or all adults are anaesthetised. Have a clear exit strategy. Never work trapped animals alone; at least two people must be present at all times to handle captured feral pigs. Use gloves and protective clothing, and wash hands thoroughly after handling animals. Allow captured animals to disperse unhindered when released. Keep dogs away when handling feral pigs for research.

Training required

See standard operating procedures as outlined on page 2.

Radio-telemetry

The movements of feral pigs can be monitored after initial capture using radio telemetry. Signals may be received by hand-held directional antennae and portable scanner/receivers, or from aircraft fitted with directional antennae. Alternatively, fixed receiver stations, immobile towers with greater range than hand-held receivers, can be used to determine animal locations. It is possible to use a Petersen estimate or derivations of this estimate, using radio-located animals as a recapture or resight, and animals seen with them as unmarked captures (White and Garrott 1990; Kenward 2001; Focardi *et al.* 2002). Radio-telemetry is useful for home range estimation and for determining areas of high activity; collared animals are used as 'Judas' animals to help locate other animals. This technique has been used successfully to locate and eradicate goats (Henzell 1987; Taylor and Katahira 1988; Keegan *et al.* 1994) and feral pigs (McIlroy and Gifford 1997).

Materials required

See 'Trapping' as outlined on page 12, plus:

People – two or more depends; on whether walked, vehicle or aerial tracking.

Radio transmitters and receivers – check batteries and discharge then recharge fully if possible.

Data sheets

Vehicle for tracking if appropriate.

How to do the count

- - Capture feral pigs as outlined on page 12.
- - Immobilise all captured feral pigs with the appropriate dosage of an anaesthetic injection.
- - Record details of captured feral pigs such as sex, weight, age, reproductive and physical condition.
- - Attach radio-collar with unique operating frequency around the neck of the feral pig. Alternatively, ear tag transmitters are available. With these the operator does not need drugs for immobilisation. They are more humane and can be used on growing animals. Collars can only be used on mature animals or for short periods.
- - Record details of radio-collar frequency and double-check that transmitter is functioning correctly.
- - Allow the animal to recover from anaesthetic and release at point of capture.
- - Continue trapping for 1 week.
- - Start tracking after several days, to allow animals to get used to the radio-collars and exhibit normal behaviour.

Walked radio tracking:

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

Vehicle radio tracking:

- - Use antenna attached to vehicle roof.
- - Locate radio-collared animals by scanning appropriate radio frequencies while driving on roads in study area.
- - Once a radio signal is detected, use the relative strength of the signal to direct the vehicle to the animal. Triangulation is needed for accuracy and to derive an error estimate.
- - Once located, track the animal on foot as discussed above.

Fixed-tower tracking:

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

Standards

As outlined on page 13, plus:

Radio-collars – use the same radio collar weight and attachment.

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

Animal welfare considerations

Impact on target animals – as outlined on page 13. Attaching transmitters to animals can affect their behaviour, ability to move and survivability. To limit the impact of radio transmitters on feral pigs some general recommendations can be made (White and Garrott 1990):

- Allow several days for the animals to get used to the transmitter before you collect data that will be regarded as indicative of normal behaviour
- - Avoid capturing and attaching transmitters during the animals' reproductive cycle.

Impact on non-target animals

As outlined on page 13.

Health and safety considerations

As outlined on pages 13 and 18.

At least two people must be present when fitting a transmitter, with one to restrain the animal and one to fit the transmitter. Take no unnecessary risks when handling wild animals, as given an opportunity they can react very quickly and unpredictably and cause an accidental injury. Before the process starts, all participants should be made familiar with the procedure and made certain of their individual roles and responsibilities.

Unforeseen events can happen during animal handling. Participants should be ready for a possible change of plan during the operation at short notice (e.g. in the event of an animal partly escaping restraint or proving too difficult to fully restrain safely). On-the-job training, by an experienced operator, must be given to a person before they fit a transmitter to a particular species of animal. Before the animal is released, all persons in the restraining team must agree on the procedure to release the animal, and they must verbally communicate to ensure that they all release the animal simultaneously. Wearing protective clothing, footwear and gloves may lessen the chances of injury or infection when handling wild animals. Wash your hands thoroughly after handling animals.

Training required

As outlined on page 14.

Animal handling

Firearms training

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

Satellite and GPS telemetry

A further development of telemetry techniques is the utilisation of satellites and Global Positioning Systems (GPS) to monitor the movement of appropriately collared animals. *GPS telemetry* is a useful technique for monitoring animal movements. It utilises GPS receivers, attached to animals, that use signals received from satellites to determine the animals' location. The two main methods of data storage and retrieval are onboard storage and remote downloading to a portable receiver (Mech and Barber 2002). Onboard storage relies on the retrieval of the collar and downloading the data all at once. Retrieval can be via recapture of the collared animal or by automatic or remote triggering mechanism to release the collar. The GPS unit is then located by VHF signal. Remote downloading GPS units utilise VHF signals to send data to a portable receiver. The receiver must be within VHF receiving range (5 to 10 km ground-to-ground or 15 to 20 km air-to-ground), allowing data to be retrieved daily and minimising data loss.

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 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 also 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 mean more successful locations when the animal is in the open. This could bias results in habitat-use studies (Moen *et al.* 1996; Dussault *et al.* 1999; D'Eon *et al.* 2002). The performance of GPS collars needs to be examined in Australian habitats, to assess areas of potential bias and error. In spite of these effects, GPS telemetry is the most accurate currently-available method of tracking animals.

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. A typical package for a single animal utilising remote data downloading, should include a collar with drop-off mechanism and VHF transmitter. A single download interface is required. The lifespans of GPS collars are low when compared with those of VHF systems, but this is determined by the sample rate used.

Satellite telemetry works on signals sent from a platform transmitter terminal (PTT) attached to an animal. The signals are uploaded to an Argos Data Collection and Location System (Service Argos, Inc., USA) aboard orbiting National Oceanic and Atmospheric Administration (NOAA, USA) weather satellites. These signals are then downloaded to Argos ground stations, where the data are able to be retrieved by the wildlife researcher, often within 20 minutes of transmission and from anywhere in the world, via public data networks. The best use of satellite telemetry is for tracking far-ranging species such as migratory birds and marine mammals (Mech and 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 and Gorman 1997), and wolves (Merrill and 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 PTT and recaptured to retrieve the transmitter, with no other fieldwork required. Recaptures can be facilitated by the installation of a VHF transmitter into the PTT. The disadvantages of this technique are high cost and variable accuracy (Mech and Barber 2002). Added to this are costs associated with data retrieval, which are based on kilobytes of information. The accuracy of satellite telemetry can vary from within 150 m to greater than 1000 m. Locations are categorised by accuracy, such that location class (LC) 3 has an accuracy of ± 150 m, LC2 ± 350 m, LC1 ± 1000 m and LC0 ± > 1000 m. Mills and Gorman (1997), while tracking African wild dogs, found that 9% of locations were LC3, 63% were LC2 and 28% were LC1. This degree of accuracy is acceptable for wide-ranging species such as African wild dogs, which can have home ranges up to 900 km^2 (Mills and Gorman 1997) or for caribou (*Rangifer tarandus granti*), which may move as far as 5055 km in a year (Fancy *et al.* 1989). However, if the target feral pig population utilises a small area, VHF or GPS telemetry techniques will be more appropriate.

Index-removal-index

An estimate of population size can be made from an index of density measured before and after a known number of animals are removed from a population (Caughley 1980; Eberhardt 1982). This index-removal-index method assumes that the population is closed for the duration of the survey. As a result, the measurement of pre- and post-removal indexes should be kept within as short a time as possible to minimise possible bias introduced by natural births and deaths. The pre- and post-removal population estimates are determined by using the following formulae:

Pre removal population estimate (N_1)

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

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

Post removal population estimate (N_2)

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

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

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

Worked example for feral pigs

Pre removal maximum percentage bait take (MPBT) – 0.83
Post removal MPBT – 0.07
Number of animals removed by aerial shooting – 122

$$N_1 = \frac{0.83 \times (-122)}{0.07 - 0.83}$$

$N_1 =$ 133 pigs pre removal

$$N_2 = \frac{0.07 \times (-122)}{0.07 - 0.83}$$

$N_2 =$ 11 pigs post removal

Bait-take

The proportion of bait consumed each night may be used as an index of feral pig abundance. Initially the amount of bait consumed increases steeply, then 'levels out' after approximately 3 days of free-feeding. This level of bait-take can be used to compare feral pig abundance over time or between sites (Saunders 1988). However, it may take up to 13 days or more to level out.

Bait trails are distributed across the survey area along tracks and trails, near watering points and feral pig sign and at locations where feral pigs will probably find them with a minimum distance of 1 km between trail locations (Choquenot and Lukins 1996). The bait trails are inspected daily and freshened or replaced until the percentage of bait-trails being consumed reaches a stable maximum. More than three consecutive days of the same proportional bait trail consumption can be used to indicate that the maximum percentage bait take (MPBT) has been reached (Choquenot and Lukins 1996). This measure can be transformed from frequencies to indexes of density to allow comparison over time at the same site (Caughley 1980; Choquenot *et al.* 1990).

The key assumption of this technique is that the association between bait trail consumption and feral pig abundance is constant over time and space. However, this assumption is most often violated, as the seasonal availability of alternative food resources affects the tendency of feral pigs to consume bait (McIlroy *et al.* 1993; Saunders *et al.* 1993; Choquenot and Lukins 1996), and the location of bait trails will probably influence the relationship between bait-trail consumption and feral pig density (Saunders *et al.* 1993; Caley 1994). Therefore, indexes derived from bait-trail consumption must be considered as site-specific and should not be used to compare relative feral pig abundance between sites. They can be useful for comparing relative abundance over time at the same site.

Materials required

Bait – the most commonly used bait is fermented wheat, oats, or barley grain soaked in water with molasses added for at least 24 hours – preferably 3 days – before use; 10 kg of bait is initially required for each bait trail.

GPS

Count sheet

How to do the count

- - Select bait trail sites. A reasonable guide is to use one bait trail for every 3 km^2 of the study area. This will be governed by available resources and accessibility to the area, with tracks and trails typically used in forested/rugged terrain.
- - The minimum distance between bait trail locations should be 1 km.
- - Bait trails should be 70 to 100 m long, with about 1 kg piles of bait spread over the length of the trail.
- - Bait trails may be placed along pads leading away from tracks or fire trails, on the track or fire trail, or a suitable distance away from the track or fire trail.
- - Mark the location of the bait trails with a GPS.
- - Check the bait trails each day. If grain piles begin to germinate or degrade, add fresh bait. Replace bait as necessary, ensuring that 10 kg of grain is always available to be found by the feral pigs.
- - Record bait trails as either taken or not taken. 'Taken' includes partial or complete consumption, as indicated by feral pig sign and/or total bait consumption.
- - Continue bait trail maintenance until at least 3 days after the maximum percentage bait-take (MPBT) has been reached (i.e. no further increase in bait uptake).
- - Transform the frequency into a density index using the following formula (Caughley 1980; Choquenot and Lukins 1996):

$$MPBT_1 = -1n\left[1 - \frac{MPBT}{100}\right] \times 100$$

Standards

Bait – use the same type and amount of bait.

Site – use the same sites for each monitoring effort.

Time – monitor at the same time each year.

Animal welfare considerations

Impact on target animals – nil

Impact on non-target animals – nil

Health and safety considerations

Care in handling baits

Training required

Bait handling

Figure 17: Dung counts are simple to use to detect an animal's presence

Dung counts

The faeces (dung) of feral pigs is often more conspicuous than the animals themselves and therefore provides a good method of detecting the animals' presence or absence (Sutherland 1996). Dung may be used to monitor populations, using two main approaches: calculating the total amount of dung in a given area, or determining the rate of accumulation of dung in fixed sample plots that are regularly cleared (Putman 1984). Calculation of the standing crop is most likely beyond the resources of most studies, but measurement of the rates of faecal accumulation has been successfully used to monitor feral pig abundance (Ralph and Maxwell 1984; Hone 1988b; Hone 2002; Rouys and Theuerkauf 2003; Cahill *et al.* 2003). An assumption of this method is that it is a linear index of feral pig abundance. This has been supported by a significantly positive correlation between the frequency of dung on plots and the observed population density of feral pigs (Hone 1995).

The advantages of dung counts are that it is simple to collect and little training is required. However, there are numerous factors associated with dung counts that can confound their use as a monitoring technique: the persistence of dung will vary with diet and weather conditions, high sampling effort is required to obtain acceptable levels of precision, defaecation rates will be variable, and small changes in abundance may not be detected. Consequently, dung counts are best used to provide indexes of abundance. Hone (2002) demonstrated a decline of feral pig abundance over a 6 year period using dung counts that recorded the percentage of plots with feral pig dung. This methodology was shown to save more than half the time taken to count the dung per plot (Hone 1988b).

Determining indexes from dung deposition or accumulation rates involves inspecting a number of small permanent plots to initially clear the plot of any dung, and then inspecting the plot again after a given time and counting the amount of dung deposited. The rate of accumulation is used as an index of feral pig abundance. Interpretation of dung counts is made less complicated when plots are cleared every month so the age of the dung does not need to be estimated (Hone and Martin 1998). A simpler index is to use the presence or absence of dung from plots. If the indexes created from dung counts need to be converted to total counts, there needs to be a correction for decay, which will vary in different months (Hone 1988b; Hone and Martin 1998).

Materials required

Vehicle

Count sheet

Map and GPS

30 m tape measure

Numbered pegs for marking plots – two required per plot

Small sledge hammer

Dung diagrams – suggested text: Triggs, B. (1996) *Tracks, Scats and Other Traces: a Field Guide to Australian mammals*. Oxford University Press, South Melbourne.