Pest Animal Control CRC

REPORT FOR THE AUSTRALIAN GOVERNMENT DEPARTMENT OF THE ENVIRONMENT AND HERITAGE

A project that investigates current options for managing feral pigs in Australia and assesses the need for the development of more effective and humane techniques and strategies.

Stage 4 Report. A list of key recommendations that land managers and owners should consider in relation to effectively and humanely managing the impact of feral pigs on native wildlife, especially nationally listed threatened species and ecological communities.

Published January 2005

Brendan Cowled[1], John Parkes[2] and Steven Lapidge[1]

[1]Pest Animal Control Cooperative Research Centre, GPO Box 284, Canberra, ACT 2601, Australia.
[2]Landcare Research, Canterbury Agricultural and Science Centre, PO Box 69, Lincoln., New Zealand.

This report should be cited as: Cowled, B., Parkes, J. and Lapidge, S. (2004). A project that investigates current options for managing feral pigs in Australia and assesses the need for the development of more effective and humane techniques and strategies – Stage 4 Report. Pest Animal Control Cooperative Research Centre, Canberra, Australia.

This project (ID number: 44380) was funded by the Australian Government Department of the Environment and Heritage through the national threat abatement component of the Natural Heritage Trust.

Natural Heritage Trust
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An Australian Government Initiative

Australian Government
Department of the Environment and Heritage

Acknowledgements
Sincere thanks to Dr Laurie Twigg, Dr Cheryl O'Connor and Dr Penny Fisher for assistance with this report.

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EXECUTIVE SUMMARY

1) The purpose of this report is to provide a list of key recommendations that land managers and owners should consider in relation to effectively and humanely managing the impact of feral pigs on native ecosystems, especially nationally listed threatened species and ecological communities. After consultation with the DEH, a summary of Stages 1 to 3 was compiled to meet these requirements. A variety of sources of information were used to provide additional information including Standard Operating Procedures from NSW Agriculture. For complete information, refer to Stages 1 to 3.
2) Methods available to control the impacts of feral pigs in Australia include ground baiting (warfarin, 1080, yellow phosphorus), aerial baiting (1080), trapping, exclusion fencing, hunting and harvesting, aerial shooting, ground shooting, habitat modification and the Judas pig technique. Other methods such as snaring and ground baiting with zinc phosphide are used overseas.
3) No recommended control method can be offered that suits every situation since the best tool will vary depending upon the unique requirements of each control program.
4) Generally, the effectiveness of a feral pig control tools can be assessed by establishing the effectiveness , cost effectiveness, safety to non-targets and practicality of the method.
5) When feral pig control is planned, managers need to know how much control (effort per unit area which varies depending on the efficiency of the method utilised and feral pig density) to apply to achieve the required level of damage mitigation. In an ideal world, a manager would have calibrated the relationships between control effort or cost and the change in pig densities this would achieve and the resulting changes in the condition or numbers of the valued resources being impacted by the pigs. However, this information is rarely available a priori for managers, who are left with the difficult decision on how much to spend to monitor their success or failure. If they spend too much of their budget to achieve certainty, they restrict their ability to do more pig control. But, if they spend nothing or too little on monitoring they run the risk that they did not achieve the goals of the operation, the impacts remain unacceptable but they are unaware of this. The approach to gain certainty depends on the scale and context of the pig control program, but inadequately designed monitoring is usually money wasted. For most ‘conservation’ programs run by government agencies that cover many control operations about 15% of the total budget appears to be the appropriate proportion to invest in monitoring. Whether all sites need the same level of monitoring depends on how confidently managers can extrapolate between sites and the quality of monitoring at priority or representative sites. Research to understand the relationships between control effort/cost, pig densities and impacts should be supplemented by planned adaptive management experiments using differences in control operations to identify better management. When eradication is the aim the only critical measure of success is the absence of pigs.
6) Aerial shooting, ground baiting (warfarin and 1080), trapping and aerial baiting are all highly effective control tools where appropriately used in suitable habitats.
7) Other control tools such as fencing and the Judas pig technique can be effective but can also be expensive and have high logistical requirements. Habitat modification and the effects of hunting and harvesting on conservation values have not been researched to any extent in Australia. Aerial baiting with single-dose meat baits may have high non-target impacts in some circumstances.
8) The humaneness of a control tool is an important consideration to avoid suffering of feral pigs.

9) Many of the currently available, yet effective feral pig control tools, may potentially impact on feral pig welfare in some way (minor to marked). However, the management of feral pigs is an imperative due to the level of feral pig impacts on the welfare of other animals and humans, and on the sustainability of natural resources. Therefore it is the responsibility of land managers to minimise the suffering of feral pigs by utilising the most humane yet effective control tool in a given situation. Support of research into new tools which are demonstrably more humane and effective than some established methods should also be encouraged.

10) The assessment of the humaneness of a control tool can be assessed with the five step humaneness review framework developed by Littin & O'Connor (2002) to assess the humaneness of vertebrate pest control toxins in New Zealand. However, the data necessary to definitively assess the humaneness of most control tools is incomplete, and in most cases, data available are primarily concerned with efficacy.

11) The available evidence suggests that warfarin, yellow phosphorus and hunting with dogs may impact on feral pig welfare in a moderate or marked manner. However, the evidence is incomplete. It is recommended that warfarin and yellow phosphorus be phased out of use over the short to medium term.

12) The available evidence suggests that 1080 and the Judas pig technique may produce minor welfare compromises in feral pigs. However, the evidence is incomplete. It is recommended that these methods are retained for use. 1080 is not necessarily a substitute for warfarin since it kills a smaller proportion of pigs in pen and most field trials although bait type can affect the efficacy of different toxins.

13) The available evidence suggests that trapping, fencing, some forms of habitat modification, ground shooting and aerial shooting are humane means of controlling feral pigs where appropriately conducted, but these methods can be relatively costly.

14) Some methods used overseas, such as lethal wire snaring, are not acceptable in Australia.

1) CURRENT METHODS OF CONTROL

1. Poison Ground Baiting,
   - Sodium fluoroacetate (1080) (used for feral pig control in QLD, NSW, WA, Victoria),
   - Warfarin (where used, use occurs by special permit from the APVMA[1], currently used in NSW and ACT),
   - Yellow Phosphorus (registered for use in carcasses in cropping areas in NSW, Qld and NT),
   - Zinc Phosphide (not registered for use in Australia),
2. Aerial Baiting with 1080 (registered for use in Queensland),
3. Trapping,
4. Fencing,
5. Aerial shooting,
6. Judas pig technique,
7. Lethal wire snaring (used in the USA),
8. Non lethal foot snares are used in New Zealand and Niue Island,
9. Hunting and harvesting,
   - Recreational hunting,
   - Commercial harvesting (New South Wales and Queensland),
10. Ground Shooting,
11. Habitat modification.

2) POTENTIAL ADDITIONAL METHODS OF CONTROL

1. New trapping technology,
   - Shape recognition traps,
   - Commercial attractants for traps,
   - Radio-transmitters, food dumps, automatic feeders,
2. Fertility control,
3. Biological control (unlikely due to impacts on domestic pork industry),
4. New Toxins,
   - Cyanide,
   - Other Anticoagulants,
   - Cholecalciferol.

3) RECOMMENDATIONS TO EFFECTIVELY AND HUMANENLY MANAGE FERAL PIGS AND THEIR IMPACTS

3.1) ISSUES TO BE CONSIDERED TO EFFECTIVELY MANAGE FERAL PIGS

3.1.1) Feral pig impacts

'Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs' has been listed as a key threatening process under the Commonwealth EPBC Act. More specifically, native flora and fauna are damaged by feral pigs through their movement, rooting, wallowing, trampling, tusking or tree rubbing, and through consumption of water,

[1] Australian Pesticides and Veterinary Medicines Authority.

animals, plants and soil organisms. Ecological processes affected include species composition and abundance, succession, and nutrient and water cycles. Impact can be direct or indirect, acute or chronic, periodic or constant, and are seasonally influenced (Braysher 2004). Generally, the known impacts of feral pigs on resources are inconsistent and varied, and often extensive. However, these impacts are incompletely researched and much of the information on feral pig impacts is anecdotal. Nevertheless, this does not necessarily preclude pragmatic control efforts, since normal monitoring during feral pig control programs can allow the relationship between pest density and damage to be estimated. Improved knowledge of the impacts of feral pigs will increase the effectiveness and auditing of feral pig control programs.

Recommendation 1:
Feral pigs undoubtedly have conservation impacts on threatened species and ecological communities, and management of these impacts by feral pig control is justified. Generally the control of these impacts is most efficiently and effectively achieved through lethal control methods.

3.1.2) Management approach

Braysher (1993) reviewed the management of vertebrate pests in Australia and published numerous principles for the strategic management of vertebrate pests. The first step in feral pig control is to management is to determine a management objective by estimating (or preferably, measuring) the impact that feral pigs are having on valuable resources, such as an agricultural commodity or threatened ecological community or species. The next step is to develop an appropriate management strategy which can range from eradication, containment, sustained management, targeted management to no action at all. Finally an operational plan is required where the actual actions (where, what method, costs, monitoring results) taken by different organisations and individuals are described.

Where eradication or containment is the aim, the only critical monitoring is on the presence (failure) or absence (success) of pigs. However, where sustained control is the strategic option managers need to have some measurable targets (updated as information is gathered) to strive towards. There are a linked chain of potential targets from the control effort and money spent, the number of pigs killed, the number of pigs remaining, through to the change in the valued resource being impacted by the pigs. Of course the last is the key measure of success or failure, but it is often difficult or expensive to monitor in routine operations, and managers often use one of the earlier measures in the chain as an index of success. This has risks when the links are not calibrated.

In conservation situations, the impact of feral pigs can be difficult to define. In addition, complex trophic relationships between pests and conservation resources mean that the threshold point at which control costs are minimised and the viability of threatened populations are not affected are difficult to identify (Choquenot & Parkes 2001). A number of models can be used to determine at what pest thresholds control efforts should begin (Choquenot & Parkes 2001). Generally, when reliable data and complex modelling are not available, the goal of feral pig management should be to estimate when feral pig impacts are unacceptable, and then control feral pig numbers to reverse the situation. This requires an understanding of where problem pigs are residing and feeding. Whilst such control exercises are occurring, the resource that is estimated to be damaged by feral pigs can be monitored and the effects of control can be assessed to determine if damage is reduced. Then control effort can be intensified or reduced depending upon the acceptability of the remaining feral pig damage.

Additionally, a combination of control tools may be more effective in a given control program than the application of a single control tool, since some animals are unlikely to be equally susceptible to all tools (Braysher 1993; Olsen 1998). However the order that these control tools should be applied and the combinations have not been researched.

Recommendation 2:
Most control operations can easily collect the amount of effort or cost expended and many (depending on the control method used) can easily measure the number of pigs killed. This information is sufficient only when reliable information exists to link these measures to residual pig densities and their impacts. However, this is rarely available and managers need to calibrate the links by investing in research or adaptive management experiments. We recommend that this is especially required for conservation problems where uncertainty about pig impacts is often high, the impacts are often on several species or across habitats, and are often complicated by other pest species and different under different rainfall regimes.

In such cases a precautionary approach is recommended with appropriate non-treatment sites to provide reliable interpretation. The precautionary approach would kill as many pigs as possible and hold densities at low levels. Resource responses should then be measured and if acceptable, the control can be relaxed (less intensive or less often) until the condition or trend in the resource starts to decline again. Control effort or pig densities at this point can then be used to set targets.

3.1.3) Control or eradication?

There have been calls for the eradication of feral pigs periodically in Australia (Auty 2003; AVA 2003). Eradication is an attractive prospect since the continual impacts of feral pigs and the expenditure on control programs would no longer occur (Bomford and O'Brien 1995). However, it is very unlikely that this could be achieved with current knowledge, techniques and resources. The problem of deliberate, illegal movement/translocation of feral pigs by irresponsible individuals would also need to be overcome.

Recommendation 3:
Feral pigs cannot be eradicated from mainland Australia with current control tools, available resources and where escape from domestic stock is certain. Localised eradication of isolated populations may however be possible. Impact reduction through the use of appropriate control methods is possible and recommended.

3.1.4) Where and when to apply feral pig control for conservation

The resources to control the impacts of feral pigs are limited and control for conservation should be focused where conservation (biodiversity) outcomes are optimised. Where these areas are across large land tenures, coordination of control with all land managers or owners is important. Where the priority conservation areas are on a single tenure (e.g., a single park or reserve) managers have to deal with the fact that feral pigs can rapidly immigrate into the controlled area and negate feral pig impact control. In some cases this might be best dealt with by increasing the frequency and intensity of in situ control, but in others it might require

feral pig control on the surrounding tenures. The costs and benefits of the strategy selected should be transparent. Costs would include the costs of more frequent versus wider control, while benefits might include those for conservation values on the surrounding land and the social benefits inherent in neighbours controlling feral pigs which can impact on a larger area.

Generally identification of important areas for conservation may be indicated where feral pig distributions and densities coincide with susceptible threatened native species or communities, and this may be mapped with geographical information systems or through local knowledge or research.

Feral pig impacts are often highest during specific times or at particular places (acute impacts). Control can be most effectively targeted at these populations at these times. Control is also effectively targeted at feral pig populations when these populations are most susceptible to control, such as during times of low reproductive success, during droughts when pigs are concentrated around water-sources and when new populations are establishing.

Recommendation 4:
Feral pig impacts may be both chronic and acute. Ongoing control is required to reduce chronic impacts but control at local sites or at particular times may be best for acute impacts. To protect conservation values that occur at local sites, a cost/benefit analysis of the scale of control to include buffers versus the frequency of the control at the site alone needs to be considered, including the benefits of wider control to other values and to community support. Management units need to be based upon 'real' biological boundaries (e.g. river systems) rather than some artificially chosen boundary wherever possible.

3.1.5) Other Considerations

Community perceptions, community education, extension to stakeholders and stakeholder involvement are all important factors in feral pig control (Choquenot et al.. 1996), but beyond the scope of this document. Other factors to be considered when establishing control programs include, identifying triggers for control efforts, identifying the key coordinating group in a control program and breaking up a large management area into reasonable management units (Brasher & Saunders 2002).

3.1.6) What are effective control tools?

Research to investigate the effectiveness of various feral pig control tools for optimising conservation outcomes has generally not occurred. Therefore a number of parameters can be assessed to gauge the effectiveness of control tools with current knowledge.

3.1.6.1. Efficacy.

The efficacy of a feral pig control method is assessed here as the feral pig population reduction attained in past research through the use of the control method. The ability to assess the efficacy of control methods through damage reduction achieved by its use would be more useful but this is hampered by the practicality of such studies and hence a lack of research. The population reduction attributable to a control method is assessed based on the numbers of feral pigs present at a study site before and after a control program.

3.1.6.2. The control method efficiency (cost).

The efficiency (cost) of a control technique is an important determinant in the overall ability of land managers to deliver feral pig control. It is critical in determining the balance between the cost of action versus the benefit of control.

3.1.6.3. Target specificity.

The target specificity of a control method is the ability of the method to control feral pigs without adversely affecting other species. It can be defined as the number of feral pigs killed relative to the total number of all animals killed. This can indicate the potential risk to non-target species. Any potential non-target impacts need to be measured at the population level over a suitable time-frame (e.g. 6-24 months).

3.1.6.4. The logistical practicality of a control method.

Control methods that place the maximum number of feral pigs in a population at risk are the most efficacious. However, a control method can still be highly effective when a large proportion of the population is exposed to the control method. If a control method does not occur across an entire management unit, immigration from non-treated areas or residual populations can quickly recolonise an area. Unfortunately, the appropriate scale of management units is often not well understood although recent research has improved knowledge in this area (Hampton et al. 2004). The logistical practicality of a control method, in this context, is the ability to supply the needs of a control program so that control can reach the majority of the management unit. Such 'supplies' may be labour, transport and materials.

Recommendation 5:
In the absence of specific research to review the effectiveness of all feral pig control tools for conservation protection, individual methods should be assessed based on the efficacy, the control method efficiency (cost), the target specificity and the logistical practicality of a method.

3.2) ISSUES TO BE CONSIDERED TO HUMANELY MANAGE FERAL PIGS

Recommendation 6:
Despite their effectiveness, many of the currently available, feral pig control tools may potentially impact on feral pig welfare in a minor to marked way. However, the management of feral pigs is an imperative due to feral pig impacts on the welfare of other animals and humans, and on the sustainability of natural resources (both agricultural and environmental). Therefore, it is the responsibility of feral pig managers to minimise the suffering of feral pigs subject to control by utilising the most humane yet effective control tool in a given situation. Support for research into new tools and practices that are demonstrably more humane and effective than established tools should also be provided.

The humaneness of lethal feral pig control methods could be assessed by looking at what the RSPCA perceives as humane killing. This is defined as the instant death of an animal, or when an animal is instantly rendered insensible to pain with death following (RSPCA 2004). However, the only current method of feral pig control in this review that can achieve this outcome is a well directed gun shot to the brain (predominantly ground shooting that occurs where the shooter is close to a feral pig). Therefore, relative assessments of the humaneness of feral pig control methods are more important than an assessment of the ability of a control method to induce instant insensibility since these are not always practical control tools. This point is especially important when it is considered that the selection of a particular feral pig control tool will not only be affected by the humaneness of that tool, but also by the effectiveness of that control tool in reducing feral pig impacts. By providing humaneness information on the control tools, the selection of the most effective yet humane feral pig control tool can occur in any given situation.

Generally, consideration of the following factors may allow an assessment of the potential impact of a control method on the welfare of a feral pig.

1. The mode of action of the control method.
2. The clinical signs of animals exposed to the control method.
3. The time that potentially painful/distressing clinical symptoms or adverse effects are experienced after application of a control method.
4. The pathology caused by the control method.
5. Reports of humans that have been affected by the control method.
6. The likelihood that the control method will cause physical damage to a feral pig without resulting in the death of the animal.

These factors can be combined into the humaneness review framework developed by Littin & O'Connor (2002) to assess the humaneness of vertebrate pest control toxins in New Zealand. This framework utilises five steps to review the humaneness of a toxin. These steps were established through a synthesis of various publications on the humaneness of vertebrate pest or wildlife control methods (Rowsell et al.. 1979; FELASA 1994; Kirkwood et al.. 1994; Sainsbury et al.. 1995; Gregory 1998; Broom 1999; PSD 2001; Mason & Littin 2003). The five steps are:

1. Consider the capacity of the species to suffer.
2. Anticipate the likely effects of the poison.
3. Determine the type, intensity and duration of effects, and the percentage of feral pigs affected.
4. Determine the degree of welfare compromise caused by each effect.
5. Assess the humaneness of the poison.

Littin & O'Connor (2002) considered the best way to compile information from their humaneness review framework to provide recommendations of the relative humaneness of vertebrate pest control methods. A legitimate method was to tabulate the data in order to allow expert assessment, rather than producing a less valid numerical ranking score. Very few studies have occurred which can provide the necessary data to allow a full and accurate assessment of the humaneness of the feral pig control methods.

Recommendation 7:
That the humaneness of a control tool should be assessed by consideration of the factors that may indicate that a feral pig may suffer. These factors can be assessed in the five step process of Littin & O'Connor (2002) outlined above.
However complete data to definitively assess the humaneness of feral pig control tools is generally deficient.

Another factor to consider when maximising the humaneness of control programs is whether the action will sustainably reduce the feral pig population. This will prevent recovery of feral pig populations which would again be subject to repeated control and potential welfare compromises in the future. Control programs should occur when fewer dependant piglets are present in feral pig populations (e.g. most births occur in summer and autumn in southern NSW whilst in the monsoonal lowlands of Northern Territory there is a peak in births in the early dry season) since these piglets may die of exposure, predation or starvation following the death of lactating sows (Sharp & Saunders 2004). Looking at the 'bigger picture', an effective control tool which is not humane to individual feral pigs can still be considered humane in some situations, if the control tool is extremely effective, since many other animals may be freed from adverse welfare impacts caused by feral pig populations.

4) BRIEF REVIEW OF THE EFFECTIVENESS AND HUMANENESS OF EACH CONTROL TOOL

1. Poison Ground Baiting.

Poison ground baiting is widely accepted in rural areas and is one of the most viable and cost effective means of feral pig control in rural areas of Australia (McIlroy 2004). In some situations it is the only effective means of controlling feral pigs in these areas. Potential problems do however exist with ground baiting. These are the possibility for non-target mortalities through primary or secondary poisoning, and the sometimes poor humaneness of poisoning compared with other methods of control, such as shooting.

a. Sodium fluroacetate (1080),

- **Effectiveness**

1080 ground baiting can be very effective at reducing feral pig populations in the field (Hone 1983; Mitchell 2003), although pen trials and field trials indicate 1080 is less efficacious for feral pigs than some other toxins such as warfarin when both toxins are administered in wheat (e.g. O'Brien 1988; O'Brien & Lukins 1990). Recent field experience in northern Western Australia indicated that 1080 in various grains was however extremely efficacious at reducing feral pig populations with reductions of 89% recorded (L. Twigg, DAWA, Pers. Comm. November 2004). The difference in efficacy between trials may reflect differences in baiting strategies (e.g. different bait types, level of pre-feeding) and intensities rather than toxin qualities.

The efficacy of any baiting campaign can be reduced by a variety of factors ranging from plentiful food supplies in the treated area to unseasonably wet conditions, so poisoning is best conducted when pastures have dried off (e.g. autumn in south eastern Australia, dry season in northern Australia). Another effective time to bait is prior to the breeding season, which generally peaks between May and October (Sharp & Saunders 2004a). To increase the efficacy of baiting campaigns, pre-baiting (Choquenot et al. 1996) and follow up monitoring and control is required (Saunders et al. 1990). The efficiency of ground baiting with 1080 can be high when conducted over broad areas in coordinated campaigns (Bryant et al. 1984; Choquenot & Hone 2002). The logistics of all ground baiting campaigns are affected by the necessity of reaching all feral pig habitats across a landscape, although treatment around water holes during drought can improve the efficiency of baiting campaigns. Ground baiting is often the initial control tool used in the eastern Australian rangelands during a control program to allow a primary knockdown of feral pig numbers.

The main disadvantages of 1080 for feral pig control is that feral pigs require large doses of 1080 to cause death relative to the smaller doses required for death in many non-target species. This potentially places non-target species at risk of primary and potentially secondary poisoning (McIlroy 2004) during poorly managed baiting campaigns. Although the sensitivities of various groups of animals vary, most individual animals in south eastern Australia will be susceptible to 1080 poisoning if they consume feral pig baits due to the relatively high concentration of 1080 in these baits. Baiting is not allowed close to urban areas, where humans or companion animals can be placed at risk, or where an unacceptable risk to native wildlife or domestic stock occurs. Various baiting strategies such as fenced bait stations, buried or covered baits, observation of bait take during free feeding, use of special baits attractive to feral pigs and not non-target species (e.g. fermented grain or omnivorous baits), timing of baiting to occur at nightfall, collection of uneaten baits and placement of baits in areas of high feral pig concentration should occur where possible to reduce potential non-target impacts.

Primary poisoning risk is affected by the bait substrate, baiting strategies and the diet of, and body size of native species locally present during a baiting campaign. Secondary poisoning risks through consumption of poisoned feral pig carcasses or feral pig vomit during baiting campaigns can also occur. However, a limited amount of research looking at 1080 residues in feral pig carcasses (O'Brien et al. 1987) reveals that non-target scavengers need to consume many times there own body weight from poisoned pig carcasses to absorb a lethal dose. For example, using figures from McIlroy (1983) a wedge tailed eagle would need to consume 13-20 times its own body weight in muscle, and a spot tailed quoll 2-3 times its own body weight in one sitting to be poisoned by a feral pig carcass. Furthermore, recent research has shown that vomiting may be less common than previously thought in the field during grain-based 1080 baiting campaigns (L. Twigg, DAWA, Pers. Comm. November 2004). Further feral pig carcass residue research is currently occurring (Matt Gentle, Qld DNR& M pers. com. August 2004; L Twigg, DAWA, pers. com. January 2005). Initial findings from Western Australia indicate that carcasses rapidly degrade and are only a risk to non-target scavengers for 2-3 days (L Twigg, DAWA, pers. com. January 2005).

- **Humaneness**

During trials with penned feral pigs, 1080 has caused vomiting which may be relatively prolonged and frequent (O'Brien et al. 1987; O'Brien 1988). In addition, some feral pigs undergo convulsions (O'Brien 1988; Buddle 2000) and can sometimes temporarily recover (possibly with injuries), before again convulsing (Cowled 2004, unpublished data). These symptoms may cause some welfare compromises during intoxication. Other welfare compromises could occur if feral pigs are sub-optimally dosed and take an extended period of time to die. However, recent field trials reveal that 34/36 pigs died quickly from 1080 poisoning with the remaining two feral pigs taking greater than 12 hours to die (Cowled 2005, unpublished data). Apart from the points mentioned above, it is unlikely that 1080 compromises other aspects of a feral pigs welfare, and it is generally a fast acting toxin which means any welfare compromises should be short lived. Other factors to consider to reduce animal welfare impacts are the steps that can be taken to reduce non-target poisoning (see above). Complete data to make a definitive welfare assessment is lacking since this assessment is based on data from efficacy trials.

b. Warfarin (where used, this occurs under a special permit from the APVMA),

- **Effectiveness**

The use of warfarin can only occur with a special permit from the Australian Pesticides and Veterinary Medicines Authority. In the field, warfarin has proved to be highly efficacious in decreasing feral pig numbers (Hone 1987; Brookes et al.. 1988; McIlroy et al. 1989; Saunders et al.. 1990; Clarke 1993). As in all baiting campaigns, pre-feeding, and follow up monitoring and control is an important part of warfarin baiting campaigns (Saunders et al.. 1990). The cost efficiency of warfarin baiting campaigns can be high relative to some other control methods (Saunders et al.. 1990), detracting from the technique. However, the qualities of the toxin and the baiting strategies employed potentially reduce the primary poisoning risks to non-target populations. For example, in contrast to 1080 poisoned baits, a non-target species may be required to feed from a bait station for two days or more in a row to ingest a lethal dose which lowers the chance of a non-target species ingesting a lethal dose of toxin (see table 1 below). The secondary poisoning risks associated with warfarin poisoned feral pigs cannot be determined since the sensitivity of native species to warfarin has not been assessed. However, some native species are known to be sensitive to the closely related anticoagulant, pindone (Martin et al..; Twigg et. al. 2005). Tissue residues in field poisoned feral pig carcasses have been calculated and are much higher than levels of 1080 residues in poisoned feral pigs during pen trials (O'Brien et al.. 1987), although these tissue residues occurred with

higher warfarin bait concentrations than are currently used (0.2% compared with 0.13%). These residue levels only constitute a risk during chronic poisoning incidents where carnivores or scavengers feed for consecutive days, although this has occurred during warfarin poisoning campaigns (O'Brien et al.. 1987). The logistics of warfarin baiting campaigns are relatively high compared with other ground baiting methods such as 1080, because several consecutive doses of warfarin must be consumed by feral pigs (in its currently administered concentration in wheat) for baiting to be lethal. A 'one shot' warfarin bait may improve the logistics of warfarin baiting campaigns, but may increase the potential non-target impacts (Parker & Lee 1995).

- **Humaneness**

Warfarin intoxication in feral pigs leads to haemorrhage in various areas of the body, weakness, lethargy, decreased food consumption, lameness and urinary and gastrointestinal tract bleeding (Hone & Kleba 1984; O'Brien & Lukins 1990). Signs of illness can occur for several days before death occurs (Hone & Kleba 1984; O'Brien & Lukins 1990). Due to the length of time that general symptoms are experienced in feral pigs, the pathology associated with poisoning and the clinical signs displayed, it is likely that warfarin compromises welfare in feral pigs in a marked manner. However, complete data to make a definitive assessment is lacking, since the available data is drawn from efficacy trials in pens.

Table 1. Comparison of relative toxicity and non-target safety of warfarin and 1080 to feral pigs.

Toxin	Concentration of toxin used in baits	LD_{50} in wheat for feral pigs[2]	Poisoned wheat required to be consumed for 40kg feral pig LD_{50}	Notes for toxicity to feral pigs	Notes for potential non-target safety (assessed based only on toxin qualities and independently of protective baiting strategies)
Warfarin	130 $mgkg^{-1}$	20 $mgkg^{-1}$ 2.9 $mgkg^{-1}$ [3]	6.2 kg (greater than 5% bodyweight, 1kg grain piles used) 892 g (cumulative effect over 2 days)	Feral pigs are generally required to consume warfarin grain for two or more days of to absorb a lethal dose (and at least 2 grain piles).	Presumably the effect of warfarin is cumulative on non-target species as well. It could be assumed that non-target species also require two or more days of grain consumption in order to easily consume an LD_{50}. This may lead to reduced poisoning risk. However, research into sensitivity of native species to warfarin has not been conducted and is required to prove or disprove this assumption. Residue levels in field poisoned feral pigs may be high which constitutes a secondary poisoning risk to some native species.
1080	330 $mgkg^{-1}$ (NSW) 288 $mgkg^{-1}$ (meat, Qld)	4.11$mgkg^{-1}$	498g	Feral pigs can easily absorb a lethal 1080 dose during consumption of one bait.	Some species from eastern Australia (n=14) potentially at risk since granivorous and an LD_{50} represents 1080 grain consumption of less than 5% body weight[4].

c. Yellow Phosphorus.

- **Effectiveness**

Yellow Phosphorus has been effective at killing feral pigs in pen trials (O'Brien & Lukins 1990; Bryant 2004) and the ready availability of the toxin to land managers probably extends the area over which feral pigs are controlled. However, the use of yellow phosphorus is often not coordinated across management areas, as is often the case with 1080 and warfarin baiting programs. Non-target impacts on scavenging and carnivorous animals are also possibly high since no baiting strategy is used to reduce this impact, and toxin administration occurs in carcasses. The logistical requirements for using yellow phosphorus are relatively low compared with other ground based toxins, since no free feeding is carried out or required with this method. Yellow phosphorus is relatively inexpensive but has operator and storage hazards.

- **Humaneness**

Phosphorus poisoning produces abdominal pain and other unpleasant effects in humans (Burkhart 2001). In feral pigs, clinical signs and pathology are evident that indicate that feral pigs experience a marked welfare compromise (O'Brien & Lukins 1990; Buddle 2000). However, complete data to make a definitive assessment is lacking, since the available data is drawn only from efficacy trials. Due to the known welfare impacts and the potential non-target impacts, the use of yellow phosphorus should only occur where no other baiting options exist, for example in remote areas without access to trained government officers who can supply 1080.

d. Zinc Phosphide (not registered for use in feral pig control in Australia).

[2] O'Brien 1988; O'Brien & Lukins 1990
[3] 2 consecutive doses
[4] McIlroy 1986

- **Effectiveness**

Zinc phosphide has successfully been used to control feral pig numbers overseas (Khokhar and Rizvi 1998). However, it can be unpalatable to feral pigs due to its garlic odour (Brooks et al. 1988). It is not registered for feral pig control in Australia.

- **Humaneness**

The data necessary to conduct a review of the humaneness of zinc phosphide in feral pigs has not been generated. However, zinc phosphide causes pain and discomfort in humans and other vertebrate pests (Burkhart 2001; Mason & Littin 2003) and is likely to do the same in feral pigs. The duration of these effects are likely to be short lived since zinc phosphide is a relatively acute toxin.

Recommendation 8: Ground baiting.

Properly managed ground baiting campaigns with 1080 and warfarin can be cost effective, efficacious, logistically practical and relatively target specific control programs. The warfarin baiting campaign conducted by ACT Parks and Conservation and NSW National Parks and Wildlife Service in Namadgi and Kosciusko National Parks is an example of a well resourced and managed ground baiting campaign in Australia.

However, it is recommended that research to establish the target specificity of a particular baiting campaign in conservation areas should be conducted in each habitat and season where the baiting campaign occurs. Impact estimation can be conducted during the normal pre-feeding period, and a decision to move to the toxic baiting phase of a campaign can be taken after this period, provided potential non-target impacts are found to be low.

It is recommended that warfarin use be phased out over the short to medium term due to likely welfare impacts. This should ideally occur when toxins of equal efficacy and target specificity are available. 1080 may not be as effective as warfarin against feral pigs in pen or field trials. However, 1080 is assumed to produce less welfare compromise than warfarin, and is still very effective, so 1080 use should be supported.

Yellow phosphorus is registered for use throughout much of the range of feral pigs. The risks to non-target safety and poor welfare outcomes generally do not justify the continued use of yellow phosphorus. The main advantage of yellow phosphorus is its ready availability to remote land-managers.

Based on this summary, research into additional humane and target-specific toxins should be given a high priority in the future.

2. Aerial Baiting with 1080 (registered in Queensland).

- **Effectiveness**

Aerial baiting is a useful tool for controlling feral pigs in broad-acre and/or inaccessible regions. Areas of high pig activity can be easily seen from the air and targeted. Aerial baiting trials with meat baits have generally not achieved the same level of control as ground baiting campaigns (Mitchell 1998; Mitchell 2001; Fleming et al. 2000; Mitchell & Kanowski 2003), although some studies have reported a high bait uptake (Clarke 1992; Mitchell 2003). The reasons vary, but insufficient baiting intensities and high non-target takes of bait have possibly contributed to the low level of efficacy (Fleming et al. 2000). Non-target impacts of an aerial baiting campaign may also be high when meat baits areas are used (Fleming et al. 2000). Therefore, in order to be a widely accepted means of controlling feral pigs, non-target bait takes urgently need to be more fully documented, and if found to be unacceptably high, mechanisms to reduce such impacts put in place.

As baiting strategies are further refined and more target-specific baits or toxins are developed, aerial baiting does, however, show great promise as an effective method of broad-scale feral pig control. This is particularly so in more remote areas, where it may be the most cost effective means of feral pig control, or in the event of an exotic disease outbreak.

- **Humaneness**

It is anticipated that the effects on feral pig welfare of 1080 aerial baiting are very similar to the effects of 1080 ground baiting. The main difference is that 1080 aerial baiting with meat is likely to result in greater non-target poisoning (Fleming et al. 2000), but also greater control of feral pigs for the same resources in inaccessible areas. See 1080 ground baiting.

Recommendation 9: Aerial Baiting.
Aerial baiting can be a cost effective and logistically practical and relatively humane (subject to minimal non-target impacts) means of feral pig control in remote and widespread areas. The use of appropriate baiting strategies will increase its efficacy. However, the method may have some problems associated with potential non-target impacts (especially with meat baits). It is recommended that this issue requires further research, for verification of potential impacts and solutions before aerial baiting can be a widely accepted means of controlling feral pigs. This research should be a priority in remote areas where the method would be of most value.

3. Trapping.

- **Effectiveness**

Although labour intensive, trapping can produce large decreases in feral pig populations in some situations, especially in small localised areas (Choquenot et al. 1993; Saunders et al. 1993; Mitchell 1998; Mitchell & Kanowski 2003). The effectiveness of trapping is determined by the attractiveness of the trap bait material, the season (trapping success is increased during periods of low food availability) and the rate at which feral pigs encounter traps (Saunders et al. 1993). No assessment of the efficacy of trapping as a broad-scale method of feral pig control has occurred (Bryant 2004).

Trapping is generally an expensive and time consuming means of feral pig control (due to high labour requirements), with high logistical requirements meaning that it is best applied to small areas of high agricultural or conservation value rather than larger, remote areas (Mitchell and Kanowski 2003). However, once feral pig trapping materials are purchased and traps are established, the costs and time taken for subsequent trapping campaigns are reduced significantly. The practice has the advantage of being highly target specific (Choquenot et al. 1996). Generally trapping is recommended as a control method where non-target risks preclude the use of poisoning, where low densities of feral pigs are present, as a follow up tool after more efficient control tools have been applied, and where ample labour is available to service traps.

NSW Agricultures Standard Operating Procedures (SOP) for trapping of feral pigs provides useful recommendations for the procedures to be followed for successful trapping (Sharp & Saunders 2004b).

- **Humaneness**

The data necessary to conduct a review of the humaneness of trapping in feral pigs has not been generated. If undertaken correctly, the method is likely to be relatively humane

(although some welfare compromise may occur), based on the anticipated effects from step 2 of the framework.

A number of steps can be taken to reduce welfare compromises. Traps should be checked at least daily (to prevent hunger, thirst or exposure) and should be placed in sheltered locations. Shade cloth can be used to provide shelter where no natural shelter exists (Sharp & Saunders 2004b). Traps should be constructed to avoid injury to captured feral pigs and this includes the use of appropriately sized wire mesh (50 mm x 100 m maximum) to avoid snout injuries in feral pigs colliding with trap walls (Sharp & Saunders 2004b). Feral pigs should be quietly approached and euthanased by a head shot as described in Stage 3. An appropriate sized firearm over short distances is a .22 calibre (magnum) rimfire rifle with expanding bullets. Extra care must be taken to ascertain that feral pigs are dead after use of a rifle of small sizes. Larger calibre rifles (also with high velocity, expanding bullets) will be more reliable than smaller rifles but are more expensive to operate. A shot gun is the preferred firearm of the British veterinary association for close euthanasia of farmed pigs and this method has merit for trapped feral pigs (Blackburn 1996). The target specificity of trapping is generally high, although the design of target specific traps is required in some habitats to avoid captures of vulnerable non-target species such as cassowaries (Mitchell 1993).

Recommendation 10: Trapping.

Due to the expense of trapping it is recommended that the technique be conducted only where poison baiting is considered inappropriate due to potential non-target impacts (especially threatened native species), lack of poison availability or community perception reasons, since poison baiting is generally more cost effective, more logistically practical and has been found to have equal or greater efficacy, especially where high density pig populations occur.

Trapping is likely to be a humane means of feral pig control, although welfare compromises are possible due to thirst, exposure and fear. The proper execution of a trapping program, where traps are checked daily, constructed adequately and are located in sheltered positions, should minimise or prevent such problems.

4. Fencing.

- **Effectiveness**

Fencing can reduce the impacts of feral pigs on small, defined areas of natural or agricultural resources through exclusion (Mitchell 2000), and can increase the effectiveness of other control methods by preventing immigration (Anderson & Stone 1993; Katahira et al. 1993). Although the initial costs can be extremely high, fencing can be useful for localised eradication, especially on islands (Anderson & Stone 1993; Garcelon 2004). However, across broad areas, the technique may simply redirect feral pigs to other areas and is best used with an additional control method (Choquenot et al. 1996). Fencing is very expensive to establish and maintain, especially in remote areas (Hone & Atkinson 1983; Hone & Stone 1989) and should not be relied upon unless substantial resources are available to ensure its success. The non-target impacts are not quantified (Mitchell 2000) and the logistics of the method are difficult to meet.

- **Humaneness**

The data necessary to conduct a review of the humaneness of using fencing to exclude feral pigs has not been generated. However, the effects are likely to be minimal since fencing can only be conducted across small areas and thus feral pigs will be able to redirect attentions to new food, water and shelter sources. Fencing that excludes feral pigs from accessing the only available water, food or shelter is not considered humane unless mechanisms are in place to reduce any animal welfare concerns (e.g. shooting). Where electric fencing is used, intense

discomfort or pain may be experienced for a very short period of time. Fencing can also create problems for the dispersal of native animals, and this should be taken into account if employing the technique for threatened species conservation.

Recommendation 11: Fencing.
Although expensive with relatively high maintenance costs, fencing can be an effective means of protecting small areas of high conservation value and for the creation of management units which can be used for effective feral pig eradication in localised areas. However, the method should only be used where considerable resources are available, for example in protecting extremely valuable areas, since the method is very expensive and requires ongoing resources to maintain the fences. The welfare effects are likely to be minimal except where feral pig populations are removed from shelter, food and water and no alternative sources are available.

5. Aerial shooting.

- **Effectiveness**

When undertaken correctly by suitably trained personnel, aerial shooting is an efficient means of lowering pig populations when undertaken in suitable habitat, such as flat terrain without thick vegetation (e.g. wetlands and open rangelands), especially when feral pig densities are high (Saunders & Bryant 1988, Hone 1990, Saunders 1993; Mitchell & Kanowski 2003). Reductions of 80% or more are possible, with greater population declines rarely pursued for reasons of costs (Saunders 1993). Aerial shooting is especially useful to extend feral pig control to remote or inaccessible areas and is one of the most efficacious techniques available for use over broad areas in many parts of rural Australia when feral pig densities are high. Aerial shooting is often more efficacious if it is combined with another control method to prevent re-establishment of high-density populations after culling has occurred. However, aerial shooting is not efficacious in all habitats that feral pigs are found in, such as mountainous or heavily forested areas or during adverse weather. The target specificity of aerial shooting is extremely high (Choquenot et al. 1996; English & Chapple 2002) and the logistical requirements, besides cost, are relatively easily met. Costs can be further off-set by including pig control in aerial shooting programs for other species (e.g. feral donkeys).

Appropriately trained and accredited shooters and pilots should always be used during aerial shooting campaigns. It is most efficient to conduct aerial shooting during periods when feral pigs are congregating around water sources (in the dry season in Northern Australia or during drought) or when feral pigs are likely to be foraging away from dense cover (morning, and late afternoon). The NSW Agriculture Standard Operating Procedures (SOP) for aerial shooting feral pigs provides useful recommendations for the procedures to be followed for successful aerial shooting (Sharp & Saunders 2004c).

- **Humaneness**

The data necessary to conduct a review of the humaneness of aerial shooting in feral pigs has not been generated. There are no data on the proportion of pigs wounded or on the time until death of fatally shot animals. However, the method is likely to be relatively humane when programs are carried out by competent and accredited staff, based on the anticipated effects from step 2 of the framework (death is generally reliable and swift). Where inexperienced staff conducts aerial shooting campaigns, welfare compromises can occur.

The preferred target area during large mammal aerial shooting campaigns is the chest area (English 2000). Even though a well placed head shot will result in a more rapid death than chest shots, head shots should not be used since a proportion of animals may escape wounded

due to the unreliable nature (small size) of this target zone. Feral pigs should only be shot when good visualisation of the animal has occurred and an accurate shot is highly probable. All feral pigs should be killed before moving onto further animals when shooting, and the routine placement of a second shot in all animals should occur (Sharpe & Saunders 2004c) since this will decrease the chance of a feral pig escaping wounded. It is rarely practical to locate shot pigs (or dependant young) from the ground after aerial shooting to ascertain that all feral pigs are dead due to difficulties with access, expense and the time involved. Smaller pigs should be shot with a shot gun rather than a rifle (Sharp & Saunders 2004c).

Recommendation 12: Aerial shooting.

Aerial shooting is a recommended control tool for use across large management units for controlling high density feral pig populations in suitable landscapes (open, flat habitats). Although expensive, it can be cost effective, extremely target specific, efficacious and logistically practical in these situations. However, where feral pig numbers are low, or where the landscape is densely vegetated or mountainous (poor visibility or operator safety) the method should not always be supported.

In contrast to the perceptions of some special interest groups, the use of aerial shooting is a humane method of feral pig control where campaigns are conducted in an appropriate manner by qualified, experienced staff.

Data is required on the welfare parameters for aerial shooting, i.e., the proportion of pigs wounded but not killed and the time until death of fatally shot animals.

6. Judas pig technique.

- **Effectiveness**

The method allows the effectiveness of other methods of control, such as baiting, trapping or shooting, to be increased through the targeting of resources to localised feral pig populations (McIlroy & Gifford 1997). As such, it is likely to reduce the non-target impacts of the other methods of control. However, this method is costly and can have high logistical requirements, such as skilled operators, telemetry equipment and sometimes aircraft (McIlroy & Gifford 1997). The method is best used to eradicate establishing populations, small isolated populations, or to mop up remnant populations after other control methods have been used. The method is not useful where high densities of feral pigs are present.

It has been reported that local adult sows from the target area are the best feral pigs to use as Judas pigs (McIlroy & Gifford 1997). NSW Agricultures Standard Operating Procedures (SOP) for the use of Judas pigs provides useful recommendations for the successful adoption of the technique (Sharp & Saunders 2004d).

- **Humaneness**

The data necessary to conduct a review of the humaneness of the Judas pig technique in feral pigs has not been generated. However, the technique is likely to produce a welfare compromise (fear or distress and possible injuries) for a short period only if it is conducted by competent personnel.

When trapping feral pigs and fitting collars, care must be taken to minimise fear, distress and injury. The procedure should not occur during very hot weather due to the risk of hyperthermia. Anaesthetics (or sedatives) should be used to decrease any stress associated with fitting the collars. Due to legal requirements associated with the use of scheduled drugs this step will usually require the involvement or supervision of a veterinarian, although exemptions can exist in certain situations for suitably qualified people such as researchers. Collars should be correctly fitted and suitably sized in relation to the size or potential growth of the feral pig. Injured feral pigs will not behave normally following release and should be

euthanased for welfare reasons. Sows should be released in their previous home range since the method will be more successful (McIlroy & Gifford 1997), and because survivability of the released sow and therefore welfare is likely to be higher.

Recommendation 13: Judas Pig Technique

The Judas pig technique can increase the efficacy and target specificity of other feral pig control techniques. It is however relatively expensive and logistically impractical in some situations. Although the method is likely to result in a short period of welfare compromise, its use is acceptable and effective where experienced staff participate.

7. Snaring (used in the USA).

This method is likely to cause unacceptable welfare compromises and non-target impacts in Australia. The method is generally only used in the USA where feral pigs are the sole large terrestrial vertebrate species occurring in the area.

Recommendation 14: Snaring

Snaring would be expected to cause high non-target impacts in Australia. The method is time consuming and therefore expensive. The method is also potentially inhumane in many animals exposed to the method. Snaring is illegal in many jurisdictions in Australia and not recommended for use in Australia.

8. Hunting and harvesting (Recreational hunting/commercial harvesting).

- **Effectiveness**

The efficacy of hunting and harvesting feral pigs has not been determined (Choquenot et al. 1996; Bryant 2004; Forsyth & Parkes 2004). In some areas the methods have markedly reduced feral pig populations (Miller & Mullete 1985; O'Brien 1987, Clarke & Dzieciolowski 1991; Katahira et al. 1993; Waithman et al. 1999), however, the efficacy of the method is reduced by deliberate introductions (Waithman et al. 1999; Hampton 2003) and decreasing returns in hunted areas (Forsyth & Parkes 2004). The costs of this method are often low since individual land-managers often have volunteers or people who will pay to conduct hunting. However, the logistics of hunting in remote areas reduce the area of land covered by hunters. Although the non-target impacts of responsible hunting are likely to be low, they have not been quantified. Hunting may be useful to remove remnant populations of feral pigs.

- **Humaneness**
    - **Hunting with dogs.**

The data necessary to conduct a review of the humaneness of hunting with dogs in feral pigs has not been generated. It is likely that the method leads to severe welfare compromises in feral pigs and some hunting dogs for a relatively short period of time.

    - **Harvesting by trapping.**

This has the same welfare considerations as trapping (above).

Recommendation 15: Hunting and harvesting.

It is generally unknown whether feral pig hunting and harvesting can result in conservation benefits in mainland Australia, although there are a several cases around the world and in Australian territory where this method has improved conservation outcomes. In contrast to this, some unethical feral pig hunters have translocated feral pigs to new areas in Australia and overseas, resulting in welfare compromises of transported feral pigs and often a new threat to threatened species and ecological communities. In addition, concerns exist that hunting may achieve only a certain level of control which is limited by diminishing returns for hunters as feral pig densities decline, and that this level of

control may not produce conservation benefits. It is recommended that a case by case assessment be made as to the suitability of hunting in conservation areas.

Hunting with dogs may produce some severe welfare compromises such as fear, distress or pain, although these effects are generally short-lived. The humaneness of professional harvesting of feral pig traps is probably relatively high.

9. Ground Shooting.

- **Effectiveness**

The efficacy of ground shooting is low since feral pigs are a cryptic animal and difficult to locate. This method can also cause dispersal of feral pigs and has been found to be generally not suitable for controlling the species over large areas (Saunders & Bryant 1988). However, some anecdotal reports indicate that recreational shooters can sometimes kill large numbers of feral pigs (L.Twigg, DAWA, June 2004, pers.com.). Shooting often kills only solitary boars.

Although generally inefficient, the cost effectiveness of ground shooting for land managers can be high since recreational shooters will generally conduct ground shooting for free. The target specificity can be high when responsibly conducted. The NSW Game Council has an accreditation scheme for hunters which can allow land managers to access responsible and highly trained recreational hunters for conservation purposes (Tony English NSW Game Council, August 2004, pers.com.). Ground shooting can be used as a follow up control technique after high density feral pig populations have been reduced with more efficacious and efficient control methods. NSW Agricultures Standard Operating Procedures (SOP) for ground shooting of feral pigs provides useful recommendations for the procedures to be followed for successful ground shooting (Sharp & Saunders 2004e). Ground shooting may be useful during 'mopping up' procedures during a potential exotic disease outbreak.

- **Humaneness**

The data necessary to conduct a review of the humaneness of ground shooting in feral pigs has not been generated. However, it is likely that the method is relatively humane where appropriately skilled shooters are used. Where unskilled shooters are involved, wounded feral pigs could escape and suffer before death or recovery.

Shooting should only be carried out in areas where feral pigs can be visualised properly and in terrain where any possible wounded feral pigs can be located. Head shots are only preferred when an accurate shot can be assured in order to enable an instantaneous death. Chest shots may be recommended where the shooters skills are limited or the pigs are shot at extensive distances. Feral pigs should only be shot when they are stationary and with a rifle with a minimum calibre of .243. Occasionally a shot gun can be used over shorter distances. The optimal point of aim will therefore vary depending shooter distance and skill.

If dogs are used to flush out feral pigs, dogs should not be allowed to approach target animals since they can be wounded or shot (Sharp & Saunders 2004e). Radio-transmitter collars on dogs should be used in all areas to prevent the loss of dogs which can lead to non-target impacts (such as hybridisation with dingos or predation of native species) or the death of the dog through starvation or injury.

The death of shot animals should always be ascertained before moving onto the next animal. Death of shot animals can be confirmed by observing the following (Sharp & Saunders 2004e);

- o absence of rhythmic, respiratory movements;
- o absence of eye protection reflex (corneal reflex) or 'blink';

o a fixed, glazed expression in the eyes; and

o loss of colour in mucous membranes (become mottled and pale without refill after pressure is applied).

If death cannot be verified, a second shot to the head should be taken immediately.

Recommendation 16: Ground Shooting.

Although possibly the most widely employed control technique, ground shooting is generally an ineffective means of managing feral pig populations in the long term.

The humaneness of ground shooting is relatively high, except where inexperienced shooters are involved, where shooting over extreme distances occurs and where wounded feral pigs cannot be located after shooting. It is recommended that any shooter seek the appropriate training before attempting to shoot feral pigs.

10. Habitat alteration.

- **Effectiveness**

No research has assessed this as a method of feral pig control.

- **Humaneness**

To our knowledge, no research has been conducted into the humaneness of habitat modification as a control tool.

Recommendation 17: Habitat Modification.

The efficacy of habitat modification has not been established. Some forms of habitat modification (such as vegetation clearing) are unacceptable for various reasons. Other forms of habitat modification (such as the sudden removal of all food, water or shelter from feral pigs) are unacceptable on welfare grounds. Other forms of habitat modification, such as the closure of excess water points such as bore drains may be acceptable and effective.

4.2) Comparison of the average efficacy and average control method efficiency[5] of different feral pig control tools based on published data[6]

Method of Control	% Efficacy	Minutes pig^{-1}	\$ pig^{-1}
Ground Baiting	74 **(based on field trials of warfarin and 1080)**	161 **(includes forested mountainous areas)**	35
Aerial Baiting	65	3.8	37.2
Aerial Shooting	72	2.3	31 **(includes unfavourable trials in wooded areas and doesn't include shooter training costs)**
Trapping	73	283	77 **(includes trap costs)**
Snaring[7]	100% **(with fencing to prevent immigration)**	2580	731 **(based on labour only at \$17 hr^{-1} and excludes fencing costs)**

[5] All Australian dollar figures have been converted from the year of generation to 2003 costs using CPI data from the Australian Bureau of Statistics. This allows an easier comparison across years.

[6] Cowled & Lapidge 2004. This comparison is only a guide, since the original figures are generated across a wide variety of landforms, with different feral pig densities (density sometimes not listed in the original literature), in different seasons and using different methodologies and may not reflect a valid comparison.

Fencing	N.A.	-	-
Judas Pig Technique	N.A.	-	-
Biological Control	N.A.	-	-
Habitat Modification	?	?	?
Hunting and harvesting	?	?	?

Recommendation 18:
The relative effectiveness of the available control tools vary across time, habitat and situations. It is recommended that appropriate control tools should be selected after consideration of all relevant and unique factors in a particular area.

5) FUTURE CONTROL METHODS

1. Cyanide.

- **Effectiveness**

Currently cyanide is an ineffective feral pig control tool, with Australian and New Zealand trials showing that existing formulations are not capable of reliably killing feral pigs (Hendersen et al. 1993; Mitchell 2003). The availability of better delivery vehicles for cyanide, such as micro-encapsulation, may allow this toxin to be an effective control tool. The challenge for the adoption of cyanide for feral pig control will be in the occupational health and safety, and government regulation fields.

- **Humaneness**

Cyanide causes rapid onset of salivation, staggering and convulsions in feral pigs where it causes death or sub-lethal poisoning (Mitchell 2003). The short period of minor to moderate clinical signs indicate that this toxin may be a relatively humane control method should further research be able to develop an effective and target specific means of delivering the toxin to feral pigs. However, due care is required by pest control operators to ensure their own safety.

2. Cholecalciferol.

- **Effectiveness**

No research has investigated the effectiveness of cholecalciferol for feral pig control in Australia. Research in New Zealand revealed that pigs are relatively resistant to cholecalciferol with doses of 200mgkg^{-1} being required to cause death (P.Fisher, Landcare Research, Pers. Com. January 2005). However, cholecalciferol was withdrawn as a rodenticide in Australia due to unacceptably high levels of primary poisoning of domestic dogs.

- **Humaneness**

Human case reports demonstrate that the toxin causes pain and intense discomfort in people (Burkhart 2001; Mason & Littin 2003). Research in other vertebrate pests (e.g. possums) indicates that cholecalciferol causes some clinical signs that result in marked welfare

[7] Based on 1 study only (Anderson & Stone 1993) and converted from US$ to AUS$ in July 2004.

compromises for considerable periods of time (O'Connor et al. 2003). No research has occurred in feral pigs which precludes a definitive assessment of the humaneness of cholecalciferol in feral pigs. It is probable that effects in other species may be replicated in feral pigs.

3. Biological Control.

- **Effectiveness**

The effectiveness of biological control could be extremely high as demonstrated by myxoma virus in rabbits. However, the use of biological control is likely to be unacceptable due to impacts on domestic pigs and the subsequent loss of export markets.

- **Humaneness**

This means of feral pig control is unlikely to be ever contemplated in Australia due to adverse effects on the domestic pork industry. To our knowledge, no research has been conducted into the humaneness of Classical or African Swine Fever as a control tool. It is likely that the method would cause a welfare compromise in infected pigs.

4. New trapping technology.

- **Effectiveness**

Shape recognition trapping shows promise as a means of feral pig control (Neal Finch, Uni. Qld. August 2004 pers. com.). See appendix 3, Stage 3.

- **Humaneness**

No assessment is possible until these methods are developed.

5. Fertility control.

- **Effectiveness**

Injectable fertility control has reliably induced infertility in feral pigs for long periods of time (Miller et al. 2004a,b). The next stage is to develop an oral vaccine for use in feral pigs (Lowell Miller, USDA NWRC, pers. comm. March 2004). This vaccine may be trialled within several years. Manufactured feral pig baits being developed by the Pest Animal Control Cooperative Research Centre are currently earmarked to field deliver this contraceptive.

- **Humaneness**

The use of fertility control may be a humane means of feral pig control (Fagerstone et al. 2002).

Recommendation 19:
That new control methods that are effective (target specific, effective, cost effective and practical) and humane are actively sought and adopted as they become available. Some of these may include fertility control tools or additional target specific feral pig toxins. This support may consist of research assistance or legislative changes.

6) DISCUSSION

This report highlights several gaps in our knowledge regarding the development of best practice management programs for reducing the detrimental impacts of feral pigs, both for the

protection of livestock, and, particularly, threatened species and ecological communities. Targeted research to address the most obvious knowledge deficiencies should be regarded as having a high priority. For some threatened species this is potentially time sensitive. The appropriate extension of research findings to land managers is also critical, and it is important that these arrangements are in place at the outset of any new research projects.

This final report contains a list of key recommendations that land managers and owners should consider in relation to effectively and humanely managing the impact of feral pigs on native species and communities. It was generally not possible to gear these recommendations towards nationally listed threatened species and ecological communities due to deficient knowledge of the impacts of feral pigs on these species and communities. Consequently, the most effective tools to combat these impacts cannot be generally recommended. The scarce amount of available research and much of the 'on the ground' knowledge of the impacts of feral pigs on threatened species and ecological communities was compiled through literature searches and extensive phone and email surveys of conservation managers and was presented in Stage 2. This deficiency of knowledge should not result in no action being taken to protect threatened species and ecological communities from feral pigs, since clear and unequivocal evidence is available that feral pigs do impact on many other native species and natural resources, both in Australia and overseas.

Poison baiting is probably the feral pig management tool that can potentially deliver the greatest benefit to threatened species and ecological communities for the minimum cost. Although poison baiting can be made highly target specific using existing toxins if standard operating procedures, such as those established by New South Wales Agriculture are followed fully, it should be acknowledged that this is unfortunately often not the case in some campaigns. This is due mainly to logistical or financial problems. Because of this, some existing baiting campaigns can potentially produce undesirable non-target outcomes. The development of more target specific baits (including the use of attractants or repellents on existing baits), whether natural or manufactured, should consequently be seen as useful for existing toxins. Furthermore, research into finding additional toxins that have heightened target specificity, as well as a humane mode of action, is also critical if sustained, effective and broad-scale control of feral pigs for nature conservation is to occur, or continue to occur in sensitive areas. This is of higher priority in the south-eastern states of Australia where native fauna is more sensitive to 1080 poison than are their fluoroacetate (1080)-adapted counterparts in some other areas of Australia. 1080 is the most widely used toxin to control feral pigs. A review of feral pig physiological deficiencies or toxicological factors that may predispose them and not sympatric species to particular compounds is highly recommended.

Many recommended methods exist for feral pig control, far more than for some other threatening species such as feral cats. The appropriate combination of their use in any given situation should be guided by an adaptive management approach where possible. That is, use what is believed the most appropriate tool for a given impact situation, based on size, severity, sustainment and economics of the damage, and monitor the outcome. Should the desired result not be achieved, attempt another technique or combination of techniques until it is. An important step is to report the results to colleagues and literature. Although this process could be driven by a management cost versus commodity benefit relationship as is possible in agricultural situations, the same rule can not be readily applied to protection of threatened species and ecological communities. Conservation of native species and communities should not be based on solely on economics. As such, appropriate environmental funding will be the key to on-ground nature conservation.

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