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 3 Report.
Review the humaneness of the options identified in stage 1.
Identify and prioritise gaps in the existing knowledge concerning the humaneness of the options and provide recommendations for future research activity.

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EXECUTIVE SUMMARY

1. Feral pig control is ethically justified due to the impacts of feral pigs on conservation, agriculture, human welfare and animal welfare. The peak animal welfare body, the RSPCA recognises that feral animals may need to be reduced or eliminated in certain situations but states that the methods used should be humane.
2. Generally, consideration of a number of factors may allow an assessment of the potential impact of a control method on the welfare of a feral pig.
3. An assessment of the welfare of a control method can occur using these factors in the method established by Littin & O'Connor (2002). This method uses the following five steps to assess the humaneness of a control method.
    a. Consider the capacity of the species to suffer,
    b. Anticipate the likely effects of the poison,
    c. Determine the type, intensity and duration of effects, and the percentage of feral pigs affected,
    d. Determine the degree of welfare compromise caused by each effect,
    e. Assess the humaneness of the poison.
4. This assessment considers the effect of a control method on an individual feral pig and does not consider the effect that control methods can have on the welfare of other animals affected by feral pigs, the welfare of feral pig populations or the welfare of non-target populations.
5. Research data that could be used to conduct a humaneness review, for example using the five step process is incomplete. No control tool could be assessed completely during this review. All control methods could be assessed to step 2 and many could be partially assessed to step 3.
6. The conclusions that could be made in this review indicate the possible or likely impacts of a control method on an individual feral pig's welfare. Further research is needed to confirm these incomplete conclusions.
7. Some conclusions were made.
    a. Some control methods may produce a minor, moderate or marked welfare compromise to feral pigs. These methods are;
        i. *Snaring*,*
        ii. *Habitat modification (large scale habitat modification* where pig populations are suddenly excluded from water and shelter leaving feral pigs exposed to water deprivation etc). Moderate habitat modifications where excess watering points are gradually removed are not included in this list.*
        iii. *Yellow phosphorus baiting (CSSP)*,*
        iv. *Cholecalciferol baiting (no efficacy testing has occurred in feral pigs)*.*
        v. *Zinc phosphide baiting,*
        vi. *Hunting with dogs*.*
        vii. *Biological control would probably lead to reduced welfare in feral and domestic pigs. Other considerations will prevent its use in Australia (pork industry,*

viii. *Judas pig technique,*
ix. *Warfarin ground baiting*,*
x. *1080,*
xi. *Aerial baiting with 1080.*

** In the authors opinion, these control method cause a marked welfare compromise on feral pigs.*

b. Some control methods may produce minimal welfare compromises. These methods are;
   i. *Ground shooting,*
   ii. *Trapping,*
   iii. *Habitat modification,*
   iv. *Aerial shooting,*
   v. *Cyanide or other ultra-fast acting toxins (although these are not an effective control method yet),*
   vi. *Exclusion fencing. A full welfare assessment has not been conducted.*

8. Future research should be conducted to provide data to complete the assessment of the humaneness of effective, commonly used feral pig control tools and improve their humaneness where needed. Some of the most commonly used or effective methods include;
   a. 1080 ground poisoning,
   b. Warfarin ground poisoning,
   c. Aerial baiting,
   d. Aerial shooting,
   e. Trapping,
   f. Hunting and harvesting,
   g. Additional baiting strategies to reduce potential non-target risks and improve the welfare of existing methods where needed,

9. Future research should be conducted to provide data to investigate the humaneness of additional feral pig control tools. This may include;
   a. Ultra-short acting toxins such as cyanide,
   b. Additional target specific, humane and effective toxins,
   c. Fertility control,
   d. Improved trapping technology.

1) INTRODUCTION

The objectives of this document are to '*review the humaneness of the options identified in stage 1 and prioritise gaps in the existing knowledge concerning the humaneness of the options, and to provide recommendations for future research activity*'.

Humaneness is defined by the Webster's 1913 dictionary as; *'the quality of compassion or consideration for others (people or animals)'*. Therefore, to define the humaneness of methods for controlling feral pigs is to define the compassion or consideration we show to feral pigs when we use such methods. This is a very general statement and it does not provide a framework for assessing the relative 'humaneness' of the various control methods.

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 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. 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 information to allow a ranking of control tools, the selection of the most effective yet humane feral pig control tool can occur in any given situation.

In addition, less humane, but effective control methods that can allow sustained management of feral pig populations and may reduce the overall welfare compromise to a feral pig population. This is because the application of an effective control method can lead to a sustained reduction in feral pig numbers, thus minimising the number of feral pigs that are required to be exposed to control tools in the following years. Furthermore, the reduction of feral pig populations will reduce the number of feral pigs which undergo 'environmental' deaths each year. Feral pigs can undergo an extremely high rate of natural mortality annually in Australia, due mainly to adverse environmental conditions. For example, the average mortality of piglets can range from as low as 10% to as high as 100% each year (due to predation, starvation, dehydration, exposure and death from disease) (Choquenot et al 1996). These environmental deaths clearly cause welfare compromises in feral pig populations. It could be argued that controlling feral pig populations to low levels with effective control tools can result in improved welfare outcomes since large numbers of potential 'environmental' deaths of feral pig are avoided. However, the focus of this review will be to assess the humaneness of a method of control to an individual feral pig rather than the population or ecological effects.

Generally, a humane time to conduct lethal feral pig control activities are when they are fewer dependant piglets in the feral pig population (Sharp & Saunders 2004). The killing of sows with piglets less than 2-3 months of age can lead to the death of these dependant piglets through starvation, predation and exposure. Sows are more likely to have dependant piglets during summer and autumn in south eastern Australia, during the early dry season in monsoonal climates and following heavy rain or flooding in the semi-arid zone. When a lactating sow is killed during a control program it is important to attempt to locate and cull dependant offspring (Sharp & Saunders 2004).

Feral pig control operations should be managed to reduce impacts rather than to simply kill feral pigs and they should occur in a coordinated manner across the landscape. This will aid in the development of a sustained control program which will reduce feral pig impacts and subsequently reduce the number of feral pigs subject to feral pig control and potential welfare impacts.

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 and severity that potentially painful/distressing clinical symptoms or experiences are perceived 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.

Although this method is best suited to considering toxins, it can be applied to an assessment of the humaneness of other feral pig control methods, although very few

studies have occurred which can provide the necessary data to allow a full and accurate assessment of the humaneness of the control methods. Where possible an assessment of the humaneness will be made, but areas of knowledge deficiency will limit the conclusions that can be made.

2) THE RSPCA POSITION ON VERTEBRATE PEST CONTROL

The RSPCA is the main animal welfare body in Australia and is given statutory authority in some situations. The organisation believes that animal welfare should be considered in relation to the five freedoms. As such they have produced a series of policy documents to advance animal welfare, including Animal Welfare and the Environment.

The RSPCA recognizes that the health of a habitat is affected by complex interrelationship between species within a habitat. It also recognizes that the state of the environment has undergone massive changes since human settlement and requires remedial action. The organisation recognizes that the welfare of wild animals is linked to the sustainable functioning of the ecosystem. The RSPCA also encourages well researched management of conservation areas to preserve important habitats, and accepts that feral animals may adversely affect the native environment, endanger native plant and animal species, jeopardize agricultural production and may be carriers of pests and diseases. Therefore the RSPCA recognizes that feral animals must be reduced or eliminated in some situations, but this must occur in a humane manner under government control. The RSPCA opposes the use of inhumane control methods and only sanctions the killing of feral animals where no successful, humane non-lethal alternative method of control is available.

Jones (2003) summarized six guiding principles that underpins the RSPCA position on vertebrate pest control and states that vertebrate pest control is probably the area in Australia that impacts the most on animal welfare.

1. The control program must be justified by objective assessment of impacts.
2. The use of non-lethal control is preferred over lethal control.
3. The control campaign must have a reasonable chance of success.
4. The control program must be coordinated and strategically applied.
5. The target specificity of the control tool must be high.
6. The control method must be humane.

However, the RSPCA is pragmatic and accepts that what is possible depends upon the methods available (Jones 2003). The organisation has raised concerns over a number of techniques (Jones 2003), and in relation to feral pig control, these are the use of inhumane poisons and baiting strategies.

The RSPCA believes that it is unfortunate that most control techniques do not achieve a humane death (Jones 2003). To remedy this, they propose that a priority research and development area in government control programs should be development of humane alternatives. The RSPCA advocates fertility control of wild populations (Jones 2003). A general belief by the RSPCA is that the consideration of animal welfare should be

mandatory in vertebrate pest control programs (Jones 2003). This review provides the most up to date information to be able consider animal welfare in feral pig control.

3) HUMANENESS REVIEW FACTORS and FRAMEWORK

3.1) Factors

3.1.1) Mode of action of the control method

The mode of action of a control method refers to how it works and is most applicable to toxins, since the way in which an animal is killed with a method such as shooting is relatively obvious. For example, warfarin works by preventing blood coagulation (Green & Thomas 1995), and 1080 works predominantly by depriving the animal of energy (Twigg & King 1991; Williams 1996; Eason & Wickstrom 2002).

The mode of action potentially affects the humaneness of the method because it potentially causes an animal to suffer. Warfarin is a good example, where the mode of action causes bleeding into various joints which can be painful where this occurs (Green & Thomas 1995; Mason & Littin 2003). The method of control may appear to impinge on animal welfare when an animal is observed after the control method is applied, until the mode of action is considered. 1080 baiting, for example, can lead to convulsions, especially in carnivores. Feral pigs also experience convulsions (O'Brien 1988; Radostits et al 2000; Buddle 2000), which appears distressing to observers. However, the animal is believed to be unconscious during the convulsions due to energy deprivation of the central nervous system (Gregory 1996; Williams 1996). This means that during convulsions at least, 1080 poisoning is unlikely to lead to compromised animal welfare.

3.1.2) Reports of humans that have been affected by the control method

It is commonly accepted that many sensations that cause suffering in humans can also cause suffering in animals. For example, pain perception is believed to be similar in animals and people (Flecknell & Molony 1997). Therefore, by utilising the reports of people that have been affected by control methods, comparisons between humans and animals can be drawn (Mason & Littin 2003). This method does however have limitations. Some of these limitations are that human experience and self consciousness can change the perception of a potentially negative situation in comparison to animals. For example, pain has an emotional and subjective component which can increase the perception of pain to humans (Flecknell & Molony 1997).

3.1.3) The pathology[1] caused by the control method

This approach has been used by various authors to assess the welfare implications of vertebrate pest control techniques and disease (Curtis 1990, quoted in Hughes & Curtis 1997; Littin & O'Connor 2002; Mason & Littin 2003).

[1] Pathology is the study of the derangement of molecules, cells, tissues and function that occur in living organisms in response to injurious agents or deprivations (Jones & Hunt 1997).

Pathology is the study of the derangement of molecules, cells, tissues and function that occur in living organisms in response to injurious agents or deprivations (Anonymous 1997). These injurious agents can be chemicals, heat, radiation, mechanical forces and micro-organisms. After injury, the body reacts in a predictable, but variable way, and these changes can be manifest as clinical signs or specific gross (or microscopic) changes in the organs or tissues. One of the major changes that occur during inflammation is redness and swelling with heat and pain (Ringler 1997). Inflammation can cause pain, and the pain is probably caused by increased pressure on the nerve endings associated with swelling, and due to the effects of inflammatory mediators and toxic products (Ringler 1997). Prostaglandins (potent inflammatory mediators) are released during inflammation, and these products increase the sensitivity of the damaged tissue to painful sensations (Griffiths 1999). In addition, tissue damage directly leads to pain, independently of inflammation.

In other words, by measuring the severity of changes to the body (pathological changes) associated with a control method that causes tissue damage, some idea of the pain or distress that the control method causes can be estimated. For example, a large amount of tissue necrosis may indicate that a particular toxin such as CSSP may lead to pain and is therefore inhumane. Likewise an animal with bleeding into various spaces such as joints may be expected to feel pain, and therefore warfarin may be assessed as a toxin which can compromise welfare. On the other hand, a toxin such as cyanide or 1080 leaves little sign of pathology after a poisoning (Hone & Kleba 1984; Mason & Littin 2003).

3.1.4) The clinical signs[2] of animals exposed to the control method

When the body is damaged, during disease or other adverse events (such as pest control operations) various body dysfunctions can occur. This can lead to physical signs of this damage being evident (clinical signs). For example, the evidence of pain can indicate tissue damage. Signs of bleeding can indicate a coagulopathy[3]. Fear can also be a clinical sign. These signs can indicate that an animal may perceive various sensations that may be adverse to the welfare of the animal. Therefore, the relative humaneness of control techniques can best be determined through the clinical signs that the control technique can cause.

3.1.5) Time that clinical symptoms are evident until unconsciousness

The time that clinical signs of illness, injury or disease are displayed by a feral pig after a control technique is applied can demonstrate how long a feral pig can receive potentially welfare compromising experiences. The RSPCA considers a humane death to be one in which death or unconsciousness is immediate (RSPCA 2004). The use of shooting where a head shot or heart/lung shot is used generally leads to a relatively rapid, reliable death (English 2000). On the other hand, the use of warfarin in feral pigs can lead to clinical symptoms that are extended for an average of 6 days (range 4-31 days) (O'Brien & Lukins 1990).

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[2] Clinical Signs are the physical manifestations of disease or damage to the body that can be measured, usually in order to provide therapy.

[3] Coagulopathy is a dysfunction with the blood clotting process.

3.1.6) The likelihood that the control method may have sublethal effects or wound a feral pig

Some control methods can result in a feral pig which is subjected to a control method without being killed. For example, ground shooting can result in wounded animals escaping when the shot is not fatal. Although less likely to occur with aerial shooting in appropriate habitat, the same problem can occur during aerial shooting (English 2000). Likewise, feral pig baiting with toxins can also result in feral pigs not absorbing a lethal dose of toxin, which can result in a period of 'illness' during which time the pigs welfare is compromised. The frequency with which these events occur is also important. For example, during an aerial cull of feral pigs in the arid rangelands of Queensland, where 187 feral pigs were shot, no wounded feral pigs escaped (Lapidge & Cowled 2004, unpublished data). This implies that although a theoretical risk of welfare compromise is present due to the escape of a wounded animal during aerial culling, the actual risk is low in well planned and appropriate aerial feral pig shooting campaigns.

3.2) Humaneness review framework (from Littin & O'Connor 2002)

The following five steps were developed to establish the humaneness of vertebrate pest toxins in New Zealand. This framework will be used to partially assess the humaneness of feral pig control methods in Australia.

3.2.1) Step 1: Consider the capacity of the species to suffer

It is generally believed in animal welfare science literature that vertebrate animals are capable of perceiving pain and distress due to similar neuro-anatomical pathways, similar behavioural responses to pain and distress, and the evolutionary significance of pain and distress (Littin & O'Connor 2002). Other considerations that can affect a species ability to suffer are between species differences in metabolism, social behaviour, biology and food and water requirements (Littin & O'Connor 2002). An example where feral pigs are concerned is that pigs have an absolute requirement for water each day in hot climates. The immobilisation of feral pigs during a period of prolonged illness or injury after control techniques are applied could therefore lead to a severe welfare compromise through thirst or hyperthermia.

3.2.2) Step 2: Anticipate the likely effects of the poison

'Prior knowledge of the mode of action, cause of death, and effects in humans and other animals while designing experiments to assess the welfare impacts of a poison means that some of the effects can be anticipated. Likely effects can be anticipated from the literature and/or pilot studies.' (quoted from Littin & O'Connor 2002).

3.2.3) Step 3: Determine the type, intensity and duration of effects, and the percentage of feral pigs affected

'Experimental observations of caged or penned animals should be used to determine these. It is essential to record in each animal:

- the time of onset of the first sign of poisoning,
- the time of onset and duration of each sign of poisoning,
- and the time to loss of consciousness.

This provides information on the intensity and duration of each effect, and the overall duration of effects in each animal' (quoted from Littin & O'Connor 2002).

Unfortunately, many of these observations are not available for feral pigs. In addition, this method needs to be adapted to investigate the effects of feral pig control tools which are not toxins. For example, the time of onset to the first sign of poisoning could be changed to the time of onset to the first clinical sign for a control tool which was not a toxin.

3.2.4) Step 4: Determine the degree of welfare compromise caused by each effect

'The next step is to determine the degree of welfare compromise or level of suffering caused by each effect based on its type, intensity and duration. This evaluation is based on an interpretation of behaviour and pathology in terms of animal welfare, that is accomplished with a thorough knowledge of normal behaviour of the species concerned, the welfare compromise caused by similar effects or poisoning in other animals or humans (being aware of species differences in behaviour and physiology), the responses of animals to known stimuli (e.g., injury, disease, surgery, endotoxin injection) and their amelioration by analgesics (e.g., Sanford et al. 1986; Rutherford 2002).' (quoted from Littin & O'Connor 2002).

Unfortunately the generation of this step for each control method used on feral pigs is not possible since the type, intensity and duration of effects and the percentage of feral pigs affected (step above) have not been researched completely.

3.2.5) Step 5: Assess the humaneness of the poison

This can only be a partial assessment in some control methods since not all information (step 3 and therefore 4 above) is available.

4) THE FACTORS AFFECTING OR INDICATING THE HUMANENESS OF INDIVIDUAL FERAL PIG CONTROL METHODS

4.1) Ground Baiting Toxins

4.1.1) Warfarin Ground Baiting

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. Signs of illness can occur for several days before death occurs. 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. However, complete data to make a definitive assessment using Littin & O'Connor's (2002) assessment is lacking.

4.1.1.1) Mode of action of warfarin

Anticoagulants used for pest animal control are vitamin K antagonists (Green & Thomas 1995). Vitamin K is an essential part of the coagulation (clotting) cascade. In a healthy animal, only small amounts of vitamin K are required to maintain sufficient levels of

vitamin K-dependant coagulation factors in order to prevent bleeding (Green & Thomas 1995). Normally, routine activity can lead to small vascular injuries, which are repaired by the body's normal physiological activities such as the coagulation cascade. When an anticoagulant is ingested, the ability of an animal to utilize vitamin K to regenerate used clotting factors is prevented (Green & Thomas 1995). This mode of action leads to the inability to repair normal vascular injuries, resulting in widespread haemorrhage and death due to circulatory collapse or haemorrhage within vital organs. Thus, the mode of action can cause bleeding into cavities. Bleeding into enclosed body cavities is known to cause pain (Mason & Littin 2003). An advantage of warfarin is that the toxin has an antidote, which allows treatment of accidentally poisoned animals.

4.1.1.2) Reports of humans that have been affected by warfarin

Mason and Littin (2003) reviewed many cases of human anticoagulant poisoning and concluded that warfarin poisoning leads to bleeding into enclosed cavities within the body which is painful. They listed body areas where bleeding has occurred due to anticoagulants which has been reported to cause pain in humans. Bleeding into muscle, joints, peritoneum, mesentery, ovaries/testicles, lungs, kidneys, spinal cord and eyes has all caused pain. Burkhart (2001) reviewed the clinical signs in humans and stated that flank pain, abdominal pain and extremity pain all occurred with anticoagulant poisoning. Bleeding into the lungs and airways of people can result in a distressing experience by making breathing difficult (Mason & Littin 2003).

4.1.1.3) The pathology caused by warfarin

Bleeding into various organs within the body can result in a quick and rapid death in domestic animals (e.g. brain) (Green & Thomas 1995). However, generally bleeding is not isolated to a rapidly lethal area, and bleeding occurs throughout the body. Feral pigs have been shown to bleed into many potentially painful areas such as legs, lungs, mesentery, kidneys, ovaries and testes (Hone & Kleba 1984). Buddle (2000) reported that widespread hemorrhages occur throughout the carcass and viscera and these particularly occur in regions subject to motion (subcutis, diaphragm, joints and heart).

4.1.1.4) The clinical signs in animals that consume warfarin

The clinical signs of warfarin poisoning in feral pigs included reduced feed intake, lameness, lethargy, blood in the faeces and urine, and haemorrhage from the nostrils (O'Brien & Lukins 1990). Buddle (2000) reviewed warfarin poisoning clinical signs in pigs. He reported sudden death was possible, but that listlessness, lameness, swelling of legs, bruising, recumbence, melena, skin and mucous membrane pallor, weakness, epistaxis, dyspnoea and abortion could all occur before death.

4.1.1.5) Time that clinical signs are evident until death

Feral pigs during pen studies, showed clinical signs for an average of 6 days (O'Brien & Lukins 1990) or 3.8-6.4 days (Hone & Kleba 1984). However, death can take as long as 31 days (O'Brien & Lukins 1990).

4.1.1.6) The likelihood that warfarin will not kill feral pigs that consume it

Feral pigs need to consume several days of warfarin grain to absorb a consistently lethal dose (O'Brien & Lukins 1990). Trial results have shown that almost all pigs increase their warfarin grain consumption after the first day of consumption (McIlroy et al 1989; Saunders et al 1990) and that warfarin baiting campaigns are effective at reducing feral pig populations (e.g. Clarke 1993). Sub-lethal doses of warfarin have not been reported, but are theoretically possible.

4.1.2) 1080 Ground Baiting

1080 intoxication in penned feral pigs causes vomiting which may be relatively prolonged and frequent. However, this may not occur in a field situation. In addition, feral pigs that undergo convulsions can sometimes temporarily recover (possibly with injuries), before again convulsing. These symptoms may cause some welfare compromises during intoxication. However, it is unlikely that 1080 compromises other aspects of a feral pigs welfare, and it is a fast acting toxin which means any welfare compromises are generally short lived. Complete data to make a definitive assessment is lacking since this assessment is based on data from efficacy trials.

4.1.2.1) Mode of action of 1080

Generally, the action of 1080 is to inhibit the Krebs cycle which results in the inability of cells to utilise glucose, an essential compound for normal bodily function (Williams 1996). More specifically, Eason and Wickstrom (2002) and Twigg and King (1991) reviewed the pathogenesis of 1080. After absorption, fluoroacetate is converted to fluorocitrate, which inhibits a critical enzyme, aconitate hydratase, in the tricarboxylic acid cycle (TCA). The TCA is the main energy producing pathway within aerobic animals. The inhibition of the TCA results in the accumulation of citrate in the tissues and plasma, energy deprivation and ultimately death. Fluorocitrate is synthesized in the mitochondria, where the TCA is located. Some evidence also suggests that fluorocitrate can inhibit citrate transport into and out of mitochondria, and that fluorocitrate has an inhibitory effect on succinate dehydrogenase. The high levels of citrate during 1080 poisoning inhibit the glycolytic enzyme phosphofructokinase, and interferes with the ionic balance within cells (Twigg & King 1999). The systems of many species are affected, but the effects are more pronounced in the cardiac system of herbivores and the central nervous system (resulting in convulsions and respiratory compromise) in carnivores.

4.1.2.2) Reports of humans that have been affected by 1080

A doctor who treated a patient poisoned with 1080 reported the following clinical signs (Williams 1948);

'When first seen the patient was in typical grand mal type epileptiform convulsion with dilated pupils, foaming and frothing at the mouth, rolling of the eyeballs, muttering prior to and after seizures, and he was unable to distinguish words. Face, neck, chest and exposed skin portions markedly cyanotic, and beads of moisture on face, lips, and forehead. Carpal spasm was marked, of epileptic type, inverted thumbs and flexing of fingers into cone shape. Other symptoms were generalized jerking of legs and arms, and stertorous labored breathing with mucous in throat, clenching of teeth'

The patient, who was also a medical doctor, after recovery reported that he did not perceive pain throughout the entire onset of the poisoning. After this period he was

unconscious and convulsing and he was treated with opioids. He experienced mild abdominal discomfort when recovering after the poisoning.

Generally, in humans 1080 poisoning causes stimulation of the central nervous system, with clinical signs of anxiety, agitation, nausea and tonic-clonic convulsions. However, none of these affected humans have reported pain (Gregory 1996). Some medical authors state that abdominal pain can be felt by poisoned humans (e.g. Burkhart 2001), although other medical authors do not list this as a symptom (Anonymous 2002).

4.1.2.3) The pathology caused by 1080

Post mortem examinations of feral pigs poisoned with 1080 revealed no pathology associated with the toxin (Hone & Kleba 1984). Radostits et al (2000) states that no specific gross post mortem signs of 1080 poisoning exist, although elevated tissue citrate levels occur.

4.1.2.4) The clinical signs in animals that consume 1080

When captive feral pigs are poisoned with 1080, the earliest signs may be vomiting or increased lethargy (51 minutes after ingestion in O'Brien 1988), and a laboured respiration with or without a white froth around the nostrils or mouth. Following this, affected pigs usually lie quietly whilst breathing laboriously until death (McIlroy 1983). O'Brien (1988) found that during pen trials, all pigs poisoned with 1080 vomited (mean of 16 vomits per pig), and some pigs experienced convulsions and/or hind limb paralysis. However, recent field experience in northern Western Australia indicated that feral pigs did not vomit after poisoning with 1080, with 60 of 61 dead feral pigs undergoing a post mortem examination containing full stomachs (L. Twigg, DAWA, Pers. Comm. November 2004). Buddle (2000) reported that pigs poisoned with 1080 generally show a sudden onset of poisoning signs. These signs generally start with uncontrolled running and tonic-clonic convulsions with persistent intermittent vomiting. Radostits et al (2000) stated that pigs display the nervous form of the possible clinical signs, with hyperexcitability and violent tetanic convulsions after an initial delay of up to 2 hours after ingestion. Some feral pigs may recover between seizures, which can result in injury to feral pigs followed by consciousness (Cowled 2004, unpublished data).

Gregory (1996) reviewed research on the impact of 1080 on canid welfare. He stated that canids display an initial period of barking and aimless running and that this has been attributed to a state of unawareness by several authors (Chenoweth 1949; Peters 1973; Batchelor 1978). He concluded that death was relatively humane, since convulsions are the main symptom of 1080 poisoning in canids, and during convulsions, people and animals loose consciousness. In summary, he reported that there are similarities between epilepsy and hyperinsulinism, and 1080 poisoning. Since epilepsy and hyperinsulinism do not cause pain in humans due to unconsciousness, he believed that convulsions in dogs associated with 1080 poisoning are unlikely to cause pain. Williams (1996) reviewed 1080 poisoning in rabbits and concluded that a lethal dose of 1080 results in weakness followed by unconsciousness. Convulsions sometimes occur following unconsciousness. He believes the poisoning of rabbits with 1080 does not contravene the spirit of the Prevention of Cruelty to Animals Act 1986.

Gregory et al (1996; quoted in Littin & O'Connor 2002) stated that recovery to consciousness by poisoned possums following convulsions was not acceptable for welfare reasons. During pen studies with 1080 dosed feral pigs, feral pigs exhibited convulsions followed by periods of apparent recovery and consciousness where feral pigs walked around pens before again convulsing again (Cowled 2004 unpublished data). This indicates that although feral pigs may not perceive pain whilst convulsions are occurring, these convulsions can still result in welfare compromises, for example when animals recover consciousness having sustained injuries whilst convulsing.

Oogjes (1996) reviewed a number of publications that have assessed the effects of 1080 on animal welfare. She ascertained that the effect of 1080 on animal welfare was unknown, and that it was likely that severe pain would be experienced by some animals. She concluded that 1080 was not humane and stated:

> *'Considering the period such death takes, sometimes up to several days when sub-lethal amounts are ingested* (sic), *it is simply not logical to assume that some animals are not experiencing nausea, pain, a sense of disorientation, leading probably to fear and distress'*

Her conclusion was that pain studies of 1080-dosed animals were needed based on the recommendations of government reports and that research into alternative population control tools was required. She also reported the recommendation of the Australian Nature Conservation Foundation Agency workshop on fox control that proposed that incorporation of an analgesic into 1080 baits may be necessary. Marks et al (2000) investigated the use of a number of drugs in 1080 baits to reduce the possibility that pain was experienced by foxes. They found that the initial period of running and retching were the times when fox welfare was most likely to be compromised, and that diazepam (valium) may reduce the chances that fox welfare is compromised through its anxiolytic and analgesic effects. This drug did not affect the efficacy of the toxin.

The Animal Welfare Advisory Committee (1989) reviewed the humaneness of 1080 in various pest species and concluded that pain studies in animals have not occurred and are justified. They were unable to conclude whether 1080 was painful or not. They also concluded that the use of 1080 is essential. They advised that the use of 1080 should be reviewed at local level and that the use of 1080 should be integrated with other control tools to prevent re-infestation.

However, pain is only on facet of a welfare assessment and stress. Other factors are also important.

4.1.2.5) Time that clinical signs are evident until death

The time to death varies between doses and pigs, but was 244 minutes (median time) in an extensive pen study (O'Brien 1988). Some feral pigs (4) took longer to die (between 1-5 days), but this only occurred when low, experimental doses of 1080 were used. Generally, the majority of feral pigs poisoned in the field with cereal and grain baits received higher doses than these lower experimental doses (O'Brien & Lukins 1988).

4.1.2.6) The likelihood that 1080 will not kill feral pigs that consume it

McIlroy (2004) believes that some feral pig baiting campaigns using wheat, pellets or meat may result in sub-lethally dosed feral pigs. This potentially imposes a period of 'illness' and discomfort on feral pigs with no reduction in individual impacts by that feral pig.

4.1.3) Yellow Phosphorus (CSSP)

Phosphorus poisoning produces abdominal pain and other unpleasant effects in humans. In feral pigs, clinical signs and pathology indicate that feral pigs experience a welfare compromise. Data to show the length of time that clinical effects are experienced by feral pigs is lacking.

4.1.3.1) Mode of Action of Phosphorus

Phosphorus is absorbed from the respiratory and gastrointestinal tract, but the mode of action is still unknown. Phosphorus poisoning symptoms generally include abdominal pain and vomiting, and sometimes haematemesis (vomiting blood), followed by cyanosis, coma and death (Clarkson 1991; Beasley 1997; both quoted in O'Connor et al. 2003).

4.1.3.2) Reports of humans that have been affected by phosphorus

Poisoning in humans causes pain, cramps nausea and vomiting (Diaz-Rivera 1950, quoted in O'Brien and Lukins 1990). Burkhart (2001) stated that human signs of poisoning include gastrointestinal or central nervous system signs or both. These signs include oral burns, vomiting, abdominal pain, diarrhoea and bleeding. A delay of up to 2 weeks can occur before central nervous signs and these can include restlessness, irritability, drowsiness, lethargy, stupor and coma. Liver and kidney damage can also occur.

4.1.3.3) The pathology caused by phosphorus

In feral pigs, post mortem signs of poisoning included rectal and nasal haemorrhages, gastrointestinal pathology, which included haemorrhages in the stomach, intestine and rectum. Liver damage was common. Liver damage was characteristically rigid, granular and friable with petechial haemorrhages and thickened gall bladders in some cases. Histologically, livers showed areas of coagulative necrosis and replacement haemorrhage (O'Brien & Lukins 1990). Generally, obvious pathology was prevalent (liver pathology (20% of feral pigs), bleeding in stomach (24%), bleeding in small intestine (33%), bleeding in rectum (33%)) (O'Brien & Lukins 1990). Buddle (2000) recorded the pathology as icterus, catarrhal or haemorrhagic inflammation of the gastrointestinal tract, with an enlarged, mottled, yellowish liver.

4.1.3.4) The clinical signs in animals that consume phosphorus

Clinical signs in feral pigs included lethargy and depression, decreased food consumption, recumbency and paddling of feet and occasional vocalizations. O'Brien and Lukins (1990) reported that pigs rarely vomited from CSSP poisoning. Conversely, Buddle (2000) listed the signs as vomiting, diarrhoea (with or without blood) with an apparent recovery in some cases followed by abdominal pain, jaundice, convulsions, coma and death.

4.1.3.5) Time that clinical signs are evident until death

In a study of CSSP toxicity in feral pigs, O'Brien and Lukins (1990) found that some pigs that received high doses (17.3 mg kg^{-1}) of the toxin died relatively quickly (as quickly as 6 hours), probably from circulatory collapse. However, even at these high doses, most pigs typically took 2-4 days to die, with death probably associated with liver or myocardial toxicity. The use of high doses of CSSP in the field, in order to kill pigs more quickly is not feasible, since high doses were found to reduce the acceptability of baited grain.

4.1.3.6) The likelihood that phosphorus will not kill feral pigs that consume it

O'Brien and Lukins (1990) found that most feral pigs which consume CSSP are likely to be killed, when sufficient doses of CSSP are used.

4.1.4) Cyanide Ground Baiting

Cyanide causes rapid onset of salivation, staggering and convulsions in feral pigs where it causes death or sub-lethal poisoning. Currently cyanide is an ineffective feral pig control tool, with Australian and New Zealand trials showing that currently available formulations are not capable of reliably killing feral pigs. As such it should not be used in feral pig control programs. However, 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 means of delivering the toxin to feral pigs.

4.1.4.1) Mode of action of cyanide

Cyanide in humans is easily absorbed as cyanide vapour into the lungs (Klaason 2001). Cyanide is primarily a central acting toxin that inhibits the cytochrome oxidase system of all cells which suppresses central nervous system activity leading to respiratory suppression and cardiac arrest (Anonymous 2002; Mason & Littin 2003).

4.1.4.2) Reports of humans that have been affected by cyanide

Mason & Littin (2003) and others (Anonymous 2002) reviewed reports of cyanide poisoning in humans. Sub-lethal dosing causes dyspnoea[4], sharp headaches, salivation, weakness and convulsions. In addition nausea, giddiness, vomiting, breathlessness, anxiety, abdominal pain and burning tongue and irritation of mucous membranes can occur.

4.1.4.3) The pathology caused by cyanide

Some reddening of the eyes and respiratory tract (Mason & Littin 2003) and burning of the skin can occur (Anonymous 2002).

4.1.4.4) The clinical signs in animals that consume cyanide

Clinical signs of cyanide poisoning in various animals include; salivation, voiding of faeces and urine, gasping for breath and staggering, collapse and convulsions (Eason & Wickstrom 2001). Mason and Littin (2003) reviewed research on cyanide use in possums,

[4] Abnormal breathing.

rodents and rabbits and found that cyanide can cause a brief period of discomfort followed rapidly by unconsciousness and death. Mitchell (2003) reported the clinical signs observed in a feral pig that died of cyanide poisoning. He reported that signs included excessive salivation, un-coordination, convulsions, collapse and rapid death. Other feral pigs which did not die had no symptoms or salivated and staggered with some vomiting.

4.1.4.5) Time that clinical signs are evident until death

Cyanide is a rapidly acting, cellular toxin that generally causes death within minutes of the first onset of symptoms (Saunders et al 1995). Mason and Littin (2003) found that death in humans occurred in minutes, if not seconds. In other animals, death occurs within minutes (Mason & Littin 2003). A feral pig that died of cyanide (1 pig died from 20) poisoning took 7 minutes to die (Mitchell 2003). Others feral pigs which did not die showed symptoms for up to one hour.

4.1.4.6) The likelihood that cyanide will not kill feral pigs that consume it

Current cyanide delivery methods designed to increase operator safety, which are used for possum control in New Zealand, were found to be ineffective in pigs (Mitchell 2003). During field trials 55 cyanide tablet bait takes by feral pigs occurred and only one feral pig carcass was found. During pen trials, 10 feral pigs were fed cyanide tablets and only one death occurred after 7 minutes. This lack off efficacy was assumed to be caused because feral pigs did not bite and crack capsules to ensure release of cyanide into the oral cavity, and because the uncracked capsule was found to be indigestible in acid when they were swallowed. In addition, powdered cyanide was trialled during pen trials with 20 feral pigs. No feral pigs died although a number showed clinical signs (10). The use of cyanide tablets in pigs was found to be ineffective by New Zealand researchers as well (Hendersen et al 1993). The effectiveness of cyanide will likely be improved through using enhanced encapsulation techniques that reliably ensure that a dose of cyanide is absorbed through the mucous membranes (Mitchell 2003). Sub-lethal doses of cyanide have been shown to cause long term sequelae such as parkinsonism (Mason & Littin 2003).

4.1.5) Cholecalciferol

Human case reports demonstrate that the toxin causes pain and intense discomfort in people. Research in other vertebrate pests (e.g. possums) indicates that cholecalciferol causes some clinical signs that result in marked welfare compromises for considerable periods of time. No research has occurred in feral pigs which precludes a definitive assessment of the humaneness of cholecalciferol in feral pigs. It is possible/probable that effects in other species may be replicated in feral pigs.

4.1.5.1) Mode of action of cholecalciferol

Calciferol and Cholecalciferol use in rodents were reviewed by Mason and Littin (2003) and Burkhart (2001) who wrote that the toxin causes increased metabolism of bone calcium and increased uptake of calcium from the gut which results in hypercalcaemia, kidney failure and other side effects due to soft tissue calcification. O'Connor et al (2003) reviewed the welfare implications of Cholecalciferol use in possums. They wrote that

possums undergo a prolonged period of time where clinical signs are evident before death occurs (7 days). In addition, marked weight loss and tissue mineralisation can occur in many cases, and possums are conscious until close to death.

4.1.5.1) Reports of humans that have been affected by cholecalciferol

Burkhart (2001) and Mason and Littin (2003) reviewed a number of human cases and reported that human patients experienced clinical signs such as vomiting, anorexia, weight-loss, irritability, depression, severe and frequent headaches, nausea, pain and intense discomfort in various areas of the body.

4.1.5.3) The pathology caused by cholecalciferol

Poisoned domestic animals displayed gastrointestinal haemorrhages, myocardial necrosis, calcification of vascular walls, calcification of the kidneys and stomach (Mason & Littin 2003).

4.1.5.4) The clinical signs in animals that consume cholecalciferol

Toxic doses in domestic pigs produce signs of vitamin D poisoning. These signs include hypercalcaemia[5], mineralization of the soft tissues and clinical signs of depression, weakness, nausea, anorexia, polyuria[6] and polydipsia[7] (Buddle 2000).

Cholecalciferol generally induces various clinical signs including loss of appetite, lethargy and rapid, shallow breathing. The speed of onset of these symptoms and their severity are dose dependant. In dogs and cats, nausea, vomiting, diarrhoea, renal failure and gastrointestinal haemorrhage can occur (Eason & Wickstrom 2001). Harrington and Page (1993) reported that horses poisoned displayed leg stiffness, recumbancy, weakness, anorexia, weight loss and extensive mineralization. Moore et al (1988) stated that cats experienced pain (kidney pain) when they had been poisoned with cholecalciferol.

4.1.5.5) Time that clinical signs are evident until death

Eason and Wickstrom (2001) stated that death in animals takes 4-7 days. The toxin has not been used in feral pigs, although accidental poisoning case histories exist for domestic pigs (Buddle 2000). These signs include hypercalcaemia[8], mineralization of the soft tissues and clinical signs of depression, weakness, nausea, anorexia, polyuria[9] and polydipsia[10]

These case histories are not sufficient to assess cholecalciferol using Littin and O'Connor's (2002) welfare framework.

4.1.5.6) The likelihood that cholecalciferol will not kill feral pigs that consume it

No data is available.

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[8] Increased blood calcium

[9] Increased urination

[10] Increased drinking

4.1.6) Zinc phosphide

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. The duration of these effects are likely to be short lived since zinc phosphide is a relatively acute toxin.

4.1.6.1) Mode of action of zinc phosphide

Zinc Phosphide releases phosphine gas in the stomach which causes inhibition cytochrome oxidase and other cytotoxic effects. Organs with the greatest oxygen requirements (heart and brain) are therefore damaged the most (Mason & Littin 2003).

4.1.6.2) Reports of humans that have been affected by zinc phospide

Reviews of humans poisoning show that humans experience diarrhoea and vomiting, excitement and respiratory distress, nausea, headaches, vertigo and abdominal pain (Burkhart 2001).

4.1.6.3) The pathology caused by zinc phosphide

Congestion and haemorrhage in all organs, fatty degeneration of the liver and inflammation in the small intestine (Radostits et al 2000).

4.1.6.4) The clinical signs in animals that consume zinc phoshide

Respiratory distress, diarrhoea, excitation, depression, abdominal pain, convulsions and death all occur in rodents (Mason & Littin 2003). Large domestic animals have been reported to experience toxaemia with depression of appetite, dullness and some increase in respiration (Radostits et al 2000).

4.1.6.5) Time that clinical signs are evident until death

Zinc phosphide causes death in either a relatively short time (less than 1 day) or in the case of animals which die from liver failure, death may take several days (Mason & Littin 2003). Mitchell (2003) believed that pigs take a number of hours to die, and this opinion is supported by research in Pakistan that found dead pigs were only a short distance from where they were poisoned (Khokhar and Rizvi 1998).

4.1.6.6) The likelihood that zinc phosphide will not kill feral pigs that consume it

Zinc Phoshide has proven to be a potent toxicant of feral pigs (Khokhar and Rizvi 1998).

4.1.7) Strychnine and Fenathion ethyl.

Both of these toxins are illegal for feral pig control and will not be considered further.

4.2) Aerial baiting

Aerial baiting occurs in Queensland using 1080. The main differences between ground baiting with 1080 and aerial baiting is that aerial baiting often occurs with meat baits and this potentially exposes more non-target species (Fleming et al 2000), and that aerial baiting is potentially more effective in remote areas that are difficult to access, because it allows more area to be treated for feral pigs for the same resources. However, ground baiting can be extremely effective where access is

acceptable and has a number of facets such as free-feeding to increase its effectiveness and reduce non-target impacts.

4.3) Fencing

The data necessary to conduct a review of the humaneness of fencing in feral pigs has not been generated. However, the effects are likely to be minimal since fencing can only be generated 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. Where electric fencing was used, intense discomfort or pain may be experienced for a very short period of time.

4.3.1) Mode of action of fencing

Fencing physically excludes feral pigs from areas needing protection from the impacts of feral pigs. Electric fencing can be used in addition to non-electrified fences. Where electric fences are used, electric currents have a high voltage and a low current and therefore lasting injurious impacts on feral pigs are unlikely to occur. Electric fences would be likely to cause intense discomfort or pain for an extremely short period of time.

4.3.2) The effect of fencing on non-target animal welfare

Fences can have adverse consequences on non-target wildlife welfare. For example, macropods can become entangled in the top strands of wire and can die. Generally dispersal of populations plays an important role in the social structure of wildlife populations, genetic diversity and the robustness of a species response to catastrophic events (Mansergh & Scotts 1989; Cork et al 2000), and a fence can dramatically hinder this process (depending on species and fence design). However, considering that feral pig exclusion fences are applied over such small land areas, the non-target impacts are likely to be low.

4.4) Trapping

The data necessary to conduct a review of the humaneness of trapping in feral pigs has not been generated. Traps should be checked at least daily and should be placed in sheltered locations to reduce feral pig exposure (feral pigs have a poor thermoregulatory ability). However, the method is likely to be relatively humane, based on anticipated effects from step 2 of the framework.

4.4.1) Mode of action of trapping

Animals are attracted into a physically harmless trap with food and cannot escape. Traps are checked daily and feral pigs are shot within the trap. Recommendations for the humane slaughter of farmed feral pigs are relevant to the euthanasia of trapped feral pigs. When shooting a farmed pig that requires euthanasia, to optimize the humaneness, the aim is to hit the brain (Blackburn1996). The brain is located just dorsal[11] to the level of the eyes and rostral[12] to the base of the ear. A number of points of aim will potentially

[11] Above
[12] Towards the snout

result in a brain shot. For example, with a rifle, the aim should be from the front of the pig, one finger's breadth above the line of the eyes, in a direction horizontal to the snout (Blackburn1996). When shooting with a 12 bore shot gun, which is a gun recommended by the British Veterinary Association for slaughter when close to a pig, a frontal shot, or a shot through the ear or the eye is recommended (Blackburn1996). However, shooting feral pigs in the field (ground shooting) beyond about 40 meters will require the use of rifle, since the range of a shot gun is short. A 12G shotgun firing SG (buckshot) or rifled slug ammunition is suitable for shots out to 40 meters. Sharpe and Saunders (2004b) list a number of methods that can be used to euthanase feral pigs depending upon size, but suggest a frontal shot for smaller pigs and a temporal (aim should be midway between the eye and base of ear) or behind the ear approach (behind the ear towards the opposite eye) to shooting the brain.

Traps should be constructed so that injury due to protruding wire is unlikely. In addition, the minimum size of mesh should be 50 x 75mm or 50 x 100mm since this will prevent snout injuries if feral pigs charge into the walls of the trap (Sharp & Saunders 2004b).

4.4.2) The pathology caused by trapping

There are no reports of pathology causes by non lethal feral pig trapping. However, no research has been conducted to our knowledge.

4.4.3) The clinical signs in animals that are trapped

There are no reports in feral pig control of trapping causing clinical signs of disease or injury. However, it is likely that feral pigs experience fear and distress for a short period of time when they are approached when traps are checked. It is possible that feral pigs experience minor thirst, even when traps are checked daily.

4.4.4) Time that clinical signs are evident until death

Any negative consequences of trapping can occur for many hours after a feral pig is trapped, since feral pig traps are checked daily. Daily checking has been advocated by the RSPCA (RSPCA 2004).

4.5) Aerial shooting

The data necessary to conduct a review of the humaneness of aerial shooting in feral pigs has not been generated. However, it is likely that aerial shooting is a humane means of controlling feral pigs where suitable programs are carried out by accredited staff.

4.5.1) Mode of action of aerial shooting

When shooting from helicopters, a chest shot is recommended because this is the largest target area, which produces death reliably after shooting (English 2000). This is because the aerial helicopter and the animal are both moving and it is important to use a chest shot to ensure that the animal is killed reliably. If a head shot was used, the bullet may not strike the brain and death may not occur. However, chest shots do not produce death as rapidly as a well placed head shot.

During government aerial shooting programs only highly trained and accredited shooters are used, and this ensures that shooters are appropriately skilled to shoot feral pigs humanely. The requirements vary between the states but the Feral Animals Aerial Shooter Training Course (FAAST) program consists of practical and theoretical assessments and includes regular re-assessments (Tony English, NSW Game Council, Pers. Com.) Aerial shooting which occurs on privately managed lands by private individuals is not formally restricted except through normal animal welfare laws. In government aerial shooting programs, the pilot positions the helicopter to give the trained aerial marksman a clear view of feral pigs. The shooter uses an appropriate calibre weapon and feral pigs are shot. A second shot is used where any doubt exists as to the lethality of the first shot, before moving on to the next animal. Aerial shooting is not recommended where mountainous terrain or vegetation makes visualising animals difficult.

Some authors have written that aerial shooting is more haphazard than ground shooting since both the shooting platform and animal are moving (e.g. Gregory 2003). In contrast to this statement, during aerial shooting, highly trained, registered government shooters are used with a high degree of skill, responsibility and accountability. Ground shooting operations are unlikely to achieve the same degree of accuracy due to the much greater shooting distances normally associated with the technique, and varying skill levels of shooters. In addition, aerial shooting allows rapid and accurate detection of almost all animals that are not immediately killed, compared with ground shooting (English 2000).

4.5.1) Reports of humans that have been affected by aerial shooting

In humans, gun shots can result in devastating injuries which can obviously cause pain. However, the pain experienced is likely to be minimal when death occurs quickly.

4.5.3) The pathology caused by aerial shooting

Most frequently, a well placed gun shot will result in a rapid death regardless of the pathology that a gunshot may cause. Only when gunshots are poorly placed, and feral pigs are not immediately killed is the pathology important in assessing the welfare of shooting.

Pavletic (1995) reviewed the effects of gunshots in animals. Three theories have been used to explain the wounding capacity of bullets and the kinetic energy theory is probably the most accurate. This theory explains that the energy of the bullet (determined by the mass and velocity of the bullet) affects the damage that occurs in a gun shot wound. Thus, high velocity bullets cause a very high degree of damage. Other factors that can affect the wound are;

- The projectile calibre,
- The bullet design. Jacketed, non expanding bullets cause less damage than soft nose or hollow point bullets which disintegrate, expand and cause massive damage to tissue upon impact.
- Ballistics is the science of projectile motion and terminal ballistics (the motion of a projectile into a target) affects the seriousness of a bullet wound. The amount of

tumble, bullet instability the secondary projectiles (bone and bullet fragments) can affect the wound as well.

Generally tissue damage occurs through crushing, stretching and cavitation. Stretching of tissues occurs due to the transmission of a shock wave to the tissue. Stretching can result in minor damage to tissues (lungs) or major damage (bone) due mainly to the ability of the tissue to absorb shock waves. The ability of the tissue to absorb shock wave is determined by its density. The shock wave travels out from the actual path of the bullet, so that significant energy transfer to adjacent structures can occur with high velocity bullets. The motion of the bullet and distortion and fragmentation causes crushing injuries. Cavitation occurs when a temporary cavity is created along the path of the bullet (up to 30 times the size of the bullet itself). This causes associated tissue damage such as bowel perforations, blood vessel ruptures and mesenteric rupturing.

Generally tissue damage that occurs can include the following (Gregory 2003).

- Muscle can be damaged by splitting or ripping.
- Veins can be burst at a distance from the injury.
- Nerves may show failure in transmission due to compression or stretching.
- Gas filled organs can be ruptured, even without direct bullet passage.
- Bone fractures can occur at a distance from the bullet passage.
- In animals that are not killed immediately, gas gangrene, peritonitis, and death, recovery or disability can all occur. Bullet fragments will often be left in the wound, especially with an expanding bullet.

The sensations that a feral pig perceives after being shot are dependant on nerve function. After an area of an animal's body is shot, nerves can function in a number of ways, depending upon the position of the nerve and damage to the nerve (Gregory 2003). Nerves that are severed show increased activity for up to four seconds, followed by an inability to transmit stimuli. Other nerves that are stretched or damaged generally show increased activity for several minutes, and this results in a feeling of tissue disturbance or paraesthesias. The position of pain receptors in and around the injury will affect whether pain is perceived. Generally however, the immediate feeling after being shot is probably a feeling of gross disturbance that can include an electric shock like feeling and pain, or can include a gross disturbance only, where pain is diluted or overridden by the barrage of sensory impulses (Gregory 2003). After an animal is shot, but not killed, the haemorrahge, oedema and inflammation causes persistent pain (Gregory 2003). Other sequalea to a non-lethal shot are wound infection and prolonged injury or sickness.

4.5.4) The clinical signs in animals that are affected by aerial shooting

Clinical signs include an entry wound, and an exit wound, with death generally occurring rapidly with well placed shots. Wounds caused by expanding bullets are much larger and more traumatic than by jacketed bullets (Gregory 2003), and therefore expanding bullets are often more likely to cause the death of an animal. If the animal is not killed immediately, the clinical signs will depend upon where the bullet strikes the animal. Pain associated with peritonitis, lameness, lethargy and depression associated with sepsis and

fat emboli to the central nervous system (CNS) can result in CNS disturbance and chronic pain (Gregory 2003).

4.5.5) Time that clinical signs are evident until death

Gregory (2003) reviewed a number of studies and anecdotal reports in different animal species which examined the time to death when the animal was shot in different areas of the body. Ground based thoracic shots in 42 deer resulted in a reliable death that occurred after deer had run an average of 32 meters (Bradshaw & Bateson 1999). This distance implies that death would have occurred quickly. The study reported that when head shots were used, misadventure sometimes occurred. One deer, after being pursued on ground for 4 hours escaped when a head shot missed the brain. An attempt to euthanase the wounded animal resulted in a considerable chase (15 minutes). However, head shots normally resulted in a rapid death.

4.5.6) The likelihood that aerial shooting will not kill feral pigs

Little data is available on the number of feral pigs that are shot and then escape wounded. However, the available data demonstrates that the chances are low. A review of an aerial shooting program in feral horses reported that one horse from 607 was not killed humanely and quickly during the aerial shooting program in difficult conditions (0.002% failure rate) (English 2000). In an aerial shoot of 187 feral pigs in the semi-arid rangelands of Queensland, no feral pigs escaped in a wounded state (Lapidge & Cowled 2004, unpublished data).

4.6) Judas pig technique

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 and distress) for a short period only.

4.6.1) Mode of action of the Judas pig technique

Feral pigs are trapped, physically restrained and a radio-collar is fitted. The feral pig is then released, and several days are allowed to pass so that the animal can rejoin other pigs. Other control techniques such as poisoning or shooting are then targeted to defined areas where the collared feral pig is subsequently located (McIlroy & Gifford 1997). Thus the humaneness of the Judas pig technique is more heavily influenced by the lethal control method that is used after the collared feral pigs have been released. Occasionally feral pigs are located with dogs and physically restrained before fitting a collar (see hunting with dogs).

Feral pigs are likely to experience fear and distress in the trap when they are approached by people, restrained and collared. Currently, the use of anaesthetics does not generally occur, since these are restricted drugs and must be administered under the close supervision of a veterinary surgeon. Exemptions exist for some researchers. The establishment of a working relationship with a veterinarian may allow the use of anaesthetics or sedatives in this situation and this may improve the welfare of the Judas pig technique the occupational health and safety point of the method. However, this may increase the expense and decrease the logistical practicality of a Judas pig operation.

4.6.2) The pathology caused by the Judas pig technique

Some physical injury is potentially possible during trapping, and fitting of radio-collars, but the potential for this is likely to be low. Otherwise, the method is relatively benign, as it is important to ensure that a healthy feral pig is released after collaring to ensure normal behaviour. However, experienced operators are required to ensure that collars are fitted correctly. Small feral pigs may not be able to carry a heavy collar. In addition, traps should be free of obstructions which can cause physical injuries.

4.6.3) Time that clinical signs are evident until death

This method is unlikely to cause clinical signs that are consistent with injury or disease.

4.7) Snaring

The data necessary to conduct a review of the humaneness of snaring in feral pigs has not been generated. However, it is likely that the method would lead to severe welfare compromises in an unknown percentage of cases.

4.7.1) Mode of action of snaring

Wire snares capture and strangle feral pigs due to the tightening of the snare. Gregory (2003) reviewed neck snares in a number of animal species and stated that the aim is to rapidly kill the animal by strangulation, due to the tightening of the snare on an animal's neck which causes occlusion of the trachea or carotid arteries. However, frequently the animal is trapped by another part of the body and death does not ensue by strangulation. Snaring is outlawed in much of Australia.

4.7.2) The pathology caused by snaring

In many cases, the pathology will be associated with strangulation. However, the pathology may vary depending upon where the snare catches the feral pig.

4.7.3) The clinical signs in animals that are snared

Animals that have been snared and not killed by strangulation have had signs of lameness (from missing feet), are sometimes moribund, can have vascular spasms which may lead to further vascular compromise, undergo renal failure and display shock (Gregory 2003).

4.7.4) Time that clinical signs are evident until death

If the snare is able to strangle the feral pig, death will occur relatively quickly. However, in a study of coyotes Guthery and Beason (1978) found that 48% of snared animals were still alive after being snared the night before. Presumably these animals would have gradually died over an extended period of time due exposure, shock or injuries. Some experienced field staff report that feral pigs do not always die quickly due to strangulation (Cody Stemler, District Field Assistant USDA APHIS, pers. comm. March 2004).

4.7.6) The likelihood that snaring will not kill feral pigs

No specific data exists for feral pigs, however up to 48% of coyotes may not be killed immediately by snares (Guthery & Beason 1978). Gregory (2003) also reported that a number of animals can escape from snares, often with severe injuries.

4.8) Hunting and harvesting

Hunting and harvesting of feral pigs can occur using ground shooting, trapping and by hunting with dogs. Studies have compared ground shooting of deer and hunting of deer with dogs. Although the methods used are not exactly the same between hunting with dogs in deer (where the deer are pursued until the deer can be approached to be shot with a pistol), and hunting with dogs for feral pigs (feral pigs are physically forced to stop running by dogs holding the pig), the comparison may yield some useful information that can allow a comparison between ground shooting and hunting with dogs in feral pigs. Hunting deer with dogs was found to cause greater welfare compromises than hunting deer by ground shooting (Bradshaw & Bateson 1999).

4.8.1) 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 some feral pigs for a relatively short period of time.

4.8.1.1) Mode of action of hunting with dogs

Hunting with dogs involves using ‘pig dogs’ to locate and catch feral pigs so that hunters can then kill the animal. A dog can ‘catch’ the pig through physically biting and holding (‘pinning’), or by causing the pig to turn and hold it’s ground facing the dog (‘baling’). The feral pig is then killed by shooting or by cutting the throat or stabbing the heart of the captured animal.

4.8.1.2) The pathology caused by hunting with dogs

Dogs can bite a feral pigs ears, snout, scrotum or legs (Gregory 2003). Biting can cause severe wounds which are similar to gunshot wounds in their potential for causing tissue destruction (Crane 1993). Bite wounds cause crushing, tearing and avulsion wounds and can appear to be relatively minor due to small skin puncture wounds but can have large, severe tissue injuries underneath the skin. Bite wounds have a high potential for infection. Animals are then shot (pathology reviewed above) or are stabbed or have their throat cut. The pathology associated with stab wounds are generally associated with cutting injuries along the blade of the knife and with stretching injuries of surrounding tissues. Pathology is generally limited to the path of the knife, unlike gunshot injuries (Crane 1993). Dogs can be severely wounded or killed during hunting operations, which may compromise the welfare of hunting dogs.

4.8.1.3) The clinical signs in animals that are hunted with dogs

Clinical signs in animals which are pursued can include signs of exertion, fatigue, respiratory distress and exhaustion (Gregory 2003). Signs of pain and fear are evident due to biting and wounding during the chase. However, feral pig hunts are usually short and intense, in contrast to other chase hunting such as fox hunting from horse back in the United Kingdom.

4.8.1.4) Time that clinical signs are evident until death

It is estimated that the time taken between locating and bailing the feral pig so that it can be killed is more often than not relatively short (a number of minutes rather than hours). This implies that the time that clinical signs are evident is short. However, to our knowledge, no trial data exists to the time spent pursuing feral pigs.

4.8.1.5) The likelihood that hunting with dogs will not kill feral pigs

During a number of studies (McIlroy & Salliard 1989; Caley & Ottley 1995) hunting with dogs was found to result in the escape of many feral pigs, especially when large groups of feral pigs were encountered. It is unknown how many of the escaping feral pigs were wounded. Solitary pigs were unlikely to escape during hunting campaigns (Caley & Ottley 1995).

4.8.2) Ground shooting

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.

Ground shooting of feral pigs is similar to aerial shooting. Feral pigs that are ground shot cannot always be shot in the head, and a chest shot is generally the most reliable means of ensuring a rapid and reliable death. The main difference between aerial shooting and ground shooting are;

- It can be less readily verified from a helicopter that feral pigs have been killed when shot.
- It may be possible during ground shooting, where feral pigs are close enough, to shoot them in the head, which causes a more rapid death than a chest shot.
- It can be more difficult to pursue wounded animals during ground shooting than it is during aerial shooting. Therefore shooting should only occur where wounded animals can be pursued.
- During government aerial shooting operations, the standard and skill of the shooters would often be higher than during ground shooting by non-government hunters.
- Aerial shooting can produce a more sustained and effective population reduction (in appropriate habitat).

4.8.2.1) Mode of action of ground shooting

During ground shooting, animals are stalked, or shot as they are observed. Shooting an animal in the head at close range is one of the most humane killing methods (Gregory 2003). Generally, when ground shooting, an animal is shot in the head, neck or chest, and the method of choice depends upon the distance of the shooter from the animal (Gregory 2003). Recommendations have been generated for ground shooting deer, and these recommendations may be applicable to ground shooting feral pigs. If a deer is within 20 m a head shot is appropriate, if the animal is between 20 and 40 m a neck shot is used, and if the animal is between 40 and 100m from the shooter, a chest shot has been

recommended (Farm Animal Welfare Council 1985). It is however possible that highly skilled shooters can produce an accurate head shot from extensive distances. Given the difficulty of hitting the brain in feral pigs, a chest shot will often be required for longer distance shooting or where the skill of the shooter is marginal.

4.8.2.2) Reports of humans that have been affected by shooting
See aerial shooting.

4.8.2.3) The pathology caused by ground shooting
See aerial shooting.

4.8.2.4) The clinical signs in animals affected by ground shooting
See aerial shooting.

4.8.2.5) Time that clinical signs are evident until death
Ground shooting probably allows a rapid and humane death of feral pigs although no specific research has occurred to validate this statement. Gregory (2003) reviewed the time taken for various species that were ground shot to die, and the accuracy of shooting. This review may be relevant to the humaneness of ground shooting in other large, hunted species such as feral pigs.

He found that in several studies the time taken to die was minimal. For example deer shot in the head or neck ran an average of 3 m after being shot (Bradshaw & Bateson 1999). Deer shot in the chest were able to run 32 m on average (Bradshaw & Bateson 1999). However, the study by Bradshaw and Bateson (1999) showed that 3% (± 1.5%) of deer that were shot by professional shooters escaped wounded, and could not be located. This would imply that an extensive period of time could occur before death in a small proportion of cases in feral pigs that are ground shot. These findings indicate that head shots kill deer (and possibly other large hunted mammals) extremely quickly, and that chest shots also kill deer relatively quickly. However, the study also shows that there is a small but significant risk of hunted deer (and possibly feral pigs) escaping after being shot, even by skilled hunters.

4.8.2.8) The likelihood that ground shooting will not kill feral pigs
No studies have researched the number of feral pigs that escape after wounding. However, the study by Bradshaw and Bateson (1999) showed that 3% (+/- 1.5%) of deer that were shot by professional shooters escaped wounded.

The death of shot animals should always be confirmed by observing at least 3 of the following (Sharpe & Saunders 2004b).

- Absence of rhythmic, respiratory movements;
- Absence of eye protection reflex (corneal reflex) or ‘blink’;
- A fixed, glazed expression in the eyes; and
- Loss of colour in mucous membranes (become mottled and pale without refill after pressure is applied).

4.9) Biological control

Biological control has been used successfully in the management of other vertebrate pests in Australia (e.g. myxoma virus in rabbits).

No data is available on the use of biological control in feral pigs in Australia. However, Choquenot et al (1996) reviewed published information to discuss the use of African Swine Fever (ASF) and Classical Swine Fever (CSF) as biological control agents. They raised a number of concerns regarding disease epidemiology and the domestic pork industry. CSF has had an increasing prevalence of sub-clinical strains (Van Oirschot 1999), and these may preclude its potential use as a feral pig population control tool in this country. The Pest Animal Control Cooperative Research Centre (PAC CRC) has conducted initial biological control research (using fertility control) for feral pigs and also reviewed the practicalities of using this method for feral pig control. The PAC CRC assessed that virus delivered immuno-contraception would be technically difficult and would be unacceptable due to adverse impacts on the domestic pork industry (Peacock 2003).

Biological control using an infective organism is unlikely to be ever used in Australia due to the risk of spread of any organism to the domestic pork industry or difficulties in gaining access to the export pork market following release of a biological control tool in Australia. The review below is a theoretical assessment.

4.10) African Swine Fever is reviewed as an example of biological control

4.10.1) Mode of action of ASF

Infected and carrier pigs transmit the infection to susceptible pigs through oral and nasal routes, although soft ticks have served as vectors and reservoirs in the other countries (Sanchez-Vizcaino 1999). Virus particles replicate in the white blood cells of a number of lymph nodes and then spread to the blood where they infect a number of target organs (lymph nodes, bone marrow, spleen, lung, liver and kidney). The damage that this replication causes is dependant upon the virulence of the virus. In sub-acute and acute forms, the disease causes extensive haemorrhages and lymphoid tissue destruction. In the chronic or sub clinical forms, death may not occur. Important for biological control would be an acute virus.

4.10.2) Reports of humans that have been affected by ASF

The disease does not infect humans.

4.10.3) The pathology caused by ASF

Haemorrhages and organ damage of the spleen, lymph nodes, kidneys and heart are common. Abdominal fluid, gastrointestinal damage, liver damage, pleural damage and brain damage can occur (Sanchez-Vizcaino 1999).

4.10.4) The clinical signs in animals affected by ASF

In virulent strains, the virus can cause sudden death or numerous haemorhagic lesions, loss of appetite, fever and high mortality (Sanchez-Vizcaino 1999).

4.10.5) Time that clinical signs are evident until death

The viraemia in ASF starts between 6-8 days after infection and lasts ‘for a long time’ (Sanchez-Vizcaino 1999).

4.10.6) The likelihood that ASF will not kill feral pigs

Sub-clinical shedders allow the spread of the virus (Sanchez-Vizcaino 1999). Some animals may recover after infection, and will likely have no signs of disease following this.

4.11) Habitat modification

To our knowledge, no research has been conducted into the humaneness of habitat modification as a control tool. However, it is likely that the method would produce welfare compromise where large scale habitat change occurred where feral pigs had no access to alternative water and shelter. However, other habitat modifications (such as capping bore drains etc) are likely to be relatively humane.

5) HUMANENESS REVIEW FRAMEWORK FOR FERAL PIGS

Data for reviewing the humaneness of the various control tools is lacking in feral pigs. The trial data that can be used in the framework of Littin and O'Connor (2002) is mostly drawn from efficacy trials, which do not provide all the information required to make a complete and thorough assessment of the humaneness of the control methods. The framework can generally be used to assess the humaneness of a control method to step 2 (anticipate the likely effects of the control method), and often a partial assessment of step 3 (determine the type, intensity and duration of effects). Frequently, the efficacy trials list clinical signs and other effects, but not the duration, prevalence or intensity of these signs. Therefore a final assessment cannot be made in many cases. Sometimes the control tool has never been trialled in feral pigs (e.g. cholecalciferol).
The humaneness review has been included as appendix 4, with summaries of this review being included in bold print in each of the individual methods listed above.

6) RECOMMENDATIONS AND RESEARCH FOCUS TO ADDRESS THE GAPS IN OUR KNOWLEDGE.

Unfortunately, further research is required before the relative humaneness of the available control tools can be definitively determined.

6.1.1) General Recommendations

- In the authors opinion, feral pig control is ethically justified based upon the impacts of feral pigs on agriculture, the environment and on other animals welfare. Improvements in animal welfare during feral pig control programs can be made, by increasing the efficacy of current control methods, reducing the use of inhumane methods, refining marginally acceptable control methods and researching additional humane and effective control methods.

- That this review of the humaneness of feral pig control methods should be assessed by utilising the humaneness review framework of Littin & O'Connor (2002).

These steps are;

1. Consider the capacity of the species to suffer
2. Anticipate 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

The research that has occurred into the control tools used in feral pigs has assessed the efficacy of the control method, not the humaneness of the control method. This means that

only a limited amount of partially suitable data is available to assess the humaneness of the control tools. All control tools could be assessed to step 2. Some control tools (particularly toxins such as 1080, warfarin and yellow phosphorus) could be partially assessed to step 3.

- Public education to distinguish between extremist animal rights views and animal welfare advocacy should occur. This education should include; the impacts of feral pigs on the welfare of other animals, the impacts of the environment on the welfare of an unmanaged feral pig population, the necessity for feral pig control, the control tools currently available for controlling feral pigs, and the need to improve the welfare of feral pig control as new methods become available.

- In order to minimize the animal suffering that occurs in vertebrate pest control, 3 steps must be taken (Mellor & Littin 2003).

1. The humaneness of all methods should be assessed and the most humane should be employed. This will potentially increase the humaneness of control programs immediately. However, the method must be useable in a given situation.
2. The humaneness of the methods remaining after the first step should be maximized. This results in intermediate welfare improvements.
3. An active research program to develop additional or more humane methods must be employed. This results in long term improvements to welfare.

This framework formulates the means to improve the humaneness of vertebrate pest control operations and should be used to refine feral pig control programs and methods. The framework has been applied to feral pigs below.

6.1.2) The humaneness of all methods should be assessed and the most humane should be employed.

This will potentially increase the humaneness of control programs immediately. However, the methods must be practical and effective in a given situation (Mellor & Littin 2003).

Following are summaries of the assessment of the humaneness of individual control tools. These are partial assessments and the level of steps completed in the five step assessment framework (Littin & O'Connor 2002) are stated with each summary (see appendix 4).

- Warfarin

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. Signs of illness can occur for several days before death occurs. In people and other animals warfarin causes pain and discomfort. 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. However, complete data to make a definitive assessment is lacking.

- 1080

Humans sub-lethally poisoned with 1080 have generally stated that the toxin did not cause pain. 1080 intoxication in penned feral pigs causes vomiting in a large proportion of feral pigs which may be relatively prolonged and frequent. However, recent field experience in northern Western Australia indicated that feral pigs did not vomit after poisoning with 1080, with 60 of 61 feral pigs undergoing post mortem containing full stomachs (L. Twigg, DAWA, Pers. Comm. November 2004). Feral pigs that undergo convulsions can sometimes temporarily recover (possibly with injuries), before again convulsing, although this data is unpublished. These symptoms may cause some welfare compromises during intoxication. However, these conclusions are based on pen trials and may not reflect a field situation. 1080 in penned feral

pigs is a relatively fast acting toxin, which means any welfare compromises are generally short lived. Complete data to make a definitive assessment is lacking since this assessment is based on data from efficacy trials.

- Phosphorus

Phosphorus poisoning produces abdominal pain and other unpleasant effects in humans. In feral pigs, clinical signs and pathology indicate that feral pigs experience a welfare compromise. Data to show the length of time and intensity of clinical effects experienced by feral pigs is lacking.

- Cyanide

When it causes death or sub-lethal poisoning, cyanide causes rapid onset of salivation, staggering and convulsions in feral pigs. Currently cyanide is an ineffective feral pig control tool, with Australian and New Zealand trials showing that currently available formulations are not capable of reliably killing feral pigs. As such it should not be used in feral pig control programs. However, the short period of relatively minor clinical signs indicate that this toxin may be a relatively humane control method should further research be able to develop an effective means of delivering the toxin to feral pigs.

- Cholecalciferol

Human case reports state that the toxin causes pain and intense discomfort in people. Research in other vertebrate pests (e.g. possums) indicates that cholecalciferol causes some clinical signs that result in marked a welfare compromises for considerable periods of time. No research has occurred in feral pigs which precludes a definitive assessment of the humaneness of 1080 in feral pigs. It is possible that effects in other species may be replicated in feral pigs.

- Zinc phosphide

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 some vertebrate pests. The duration of these effects are likely to be short lived since zinc phosphide is a relatively acute toxin.

- Fencing

The data necessary to conduct a review of the humaneness of fencing in feral pigs has not been generated. However, the effects are likely to be minimal since fencing can only be generated across small areas (fencing is extremely expensive) and this will leave resident pigs with access to alternative water and shelter. Where electric fencing is used it is possible that intense discomfort or pain may be felt for a very short period of time.

- Trapping

The data necessary to conduct a review of the humaneness of trapping in feral pigs has not been generated. However, the method is likely to be relatively humane, based on anticipated effects and suitable trapping procedures. Possible welfare effects are thirst, fear and distress or exposure.

- Aerial shooting

The data necessary to conduct a review of the humaneness of aerial shooting in feral pigs has not been generated. However, it is likely that aerial shooting is a humane means of controlling feral pigs where suitable programs are carried out by trained and accredited staff. Possible welfare compromises may occur where wounded pigs are left after a shooting program.

- Judas pig

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 and distress) for a short period only, provided collars are fitted correctly.

- Snaring

The data necessary to conduct a review of the humaneness of snaring in feral pigs has not been generated. However, research in other species indicates that it is likely that the method would lead to severe welfare compromises in a large percentage of feral pigs.

- 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 (fear and pain) in feral pigs for a relatively short period of time.

- Ground shooting

The data necessary to conduct a review of the humaneness of in feral pigs has not been generated. However, it is likely that the method is relatively humane where appropriately skilled shooters are used. Risks to welfare are where wounded feral pigs escape or if shots are not rapidly fatal.

- ASF

To our knowledge, no research has been conducted into the humaneness of ASF as a control tool. It is likely that the method would cause welfare compromise in infected pigs and the method would be unacceptable in Australia due to impacts on the domestic pork industry.

- Habitat modification

To our knowledge, no research has been conducted into the humaneness of habitat modification as a control tool. However, it is likely that the method would produce welfare compromise where large scale habitat change occurred where feral pigs had no access to alternative water and shelter. Other more moderate habitat modifications (removal of excess watering points) would not be likely to affect welfare.

Conclusions;

Consideration of a number of control methods based on pathology, mode of action, clinical signs in feral pigs, humans and other animals or the expected effects of a control method can indicate that a number of control methods compromise feral pig welfare in minor, moderate or marked ways. Future research may or may not validate this finding. Future research may also indicate which methods are not acceptable, or do compromise animal welfare but are acceptable where justification for use exists. These control methods are;

1. *Snaring*,*
2. *Habitat modification (large scale habitat modification* where pig populations are suddenly excluded from water and shelter leaving feral pigs exposed to water deprivation etc). Moderate habitat modifications where excess watering points are gradually removed are not included in this list.*
3. *Yellow phosphorus baiting (CSSP)*,*
4. *Cholecalciferol baiting (no efficacy testing has occurred in feral pigs)*,*
5. *Zinc phosphide baiting,*
6. *Hunting with dogs*,*
7. *Biological control would probably lead to reduced welfare in feral and domestic pigs. Other considerations will prevent its use in Australia (pork industry,*
8. *Judas pig technique,*

9. Warfarin ground baiting,*
10. 1080,
11. Aerial baiting with 1080.

In the authors opinion, these control methods (*) *lead to a marked welfare compromise in feral pigs.*

A similar consideration of a number of control methods can indicate that a number are relatively humane and only produce minor welfare compromises. Research may or may not validate this finding. These are;

1. *Ground shooting,*
2. *Trapping,*
3. *Habitat modification,*
4. *Aerial shooting,*
5. *Cyanide or other ultra-fast acting toxins (although these are not an effective control method yet),*
6. *Exclusion fencing. A welfare assessment has not been conducted.*

6.1.3) The humaneness of the methods remaining after the first step should be maximised.

This results in intermediate welfare improvements (Mellor & Littin 2003).

A number of methods should be researched to determine whether improvement is needed or possible, and this may improve the humaneness of some feral pig control methods. This research should be focused on control methods which are the most effective and widely used.

- All commonly used but effective methods should undergo a welfare assessment to justify their use and improve humaneness where needed. Many of the common control tools are partially researched for humaneness, and this recommended research should complete the five step welfare assessment (appendix 4). Where research indicates a marked welfare compromise, strong justification should be available to use these methods.
- Although not assessed in the humaneness assessment, the non-target impacts of commonly used control methods may impact on the welfare of non-target animals. Research should occur to address this knowledge gap.

Specifically;

- Warfarin Ground Baiting
  1. *The actual non-target impact of warfarin baiting campaigns is important to assess potential welfare compromises to non-target species*. Research should focus on populations of susceptible species that occupy habitat in which warfarin grain baiting occurs (e.g. native bird species and macropods)
  2. *The knowledge of how long feral pigs actually take to die in the field is unknown*. Currently the time taken to die after clinical signs appear is assessed as several days based on pen trials in feral pigs. However, penned feral pigs are generally healthy and fed a certain toxic dose. In the field, feral pigs can often eat larger amounts of warfarin grain over several days (by feeding at bait stations for more than the 2-3 days that occurred in pen trials) and can be under considerable environmental stresses. This may increase the speed at which feral pigs succumb to warfarin baiting campaigns and therefore imply that warfarin baiting of feral pigs is more humane than currently thought. Alternatively increased activity of feral pigs in free living situation may lead

to greater haemorrhage in more sites, which could increase the welfare impacts of warfarin.

3. *The prevalence, intensity and time of major effects (effects already published) should be recorded during pen trials*.

- 1080 Ground Baiting

1. *The actual impact of 1080 on feral pig welfare*. 1080 probably doesn't result in pain in feral pigs whilst convulsing, but is likely to impact on the welfare of poisoned feral pigs in some ways (especially if sub-optimal dosing occurs, and if convulsions are intermittent with recovery and perception of possible injuries between convulsions). Vomiting is likely to impact on the welfare of feral pigs if this occurs, but recent research indicates this may be rare in a field situation. Research to investigate the welfare of feral pigs that have been poisoned with 1080 in the field is warranted.
2. *The mean time to death of feral pigs is based on pen data*. During pen trials median times to death is 4 hours, or 5 hours at an LD_{50} dose (O'Brien 1988). In the field, it is possible that feral pigs may receive sub-optimal doses of 1080 (McIlroy 2004). This may cause prolonged periods of clinical signs until death occurs, through a combination of environmental stress and 1080 (Jim Mitchell Qld DNRME pers. comm. July 2004). Deaths of this nature may compromise feral pig welfare. Research to investigate the actual times taken for feral pigs to die in the field is warranted. Appropriate changes in concentrations of 1080 should be used in baits if deaths of this nature occur. However, this will increase potential non-target risks.
3. *The addition of anxiolytics/analgesics to feral animal baits may result in improved animal welfare during baiting campaigns* (Marks et al 2003). Research to investigate the incorporation of analgesics into 1080 baits should occur in feral pigs, and this should include a cost-benefit analysis. The addition of analgesics to warfarin or yellow phosphorus is unlikely to be effective since the analgesic may be metabolised and excreted before the toxic effect occurred or finished.
4. *The effect off current baiting strategies on the animal welfare of 1080 ground baiting.* This may include researching pre-feeding periods, bait substrates and toxin concentrations with regard to non-target impacts and feral pig welfare. This may allow development of more humane baiting strategies.
5. *The actual non-target impacts of 1080 ground baiting campaigns on non-target species.*

- 1080 Aerial Baiting

1080 is potentially a potent tool to allow management of feral pigs across broad and inaccessible management units. This would promote the adoption of sustained feral pig control programs which would reduce the number of feral pigs subject to control in the future, and further reduce the impacts of feral pigs upon the welfare of native animals. However, a number of inadequacies in our knowledge of welfare issues associated with aerial baiting exist.

1. *The non-target impacts*. Research into the non-target impacts of aerial baiting campaigns should occur.
2. *The best baiting strategies that will allow reduced non-target impacts and high effectiveness*. Research to develop these strategies may include the development of species specific baits (or research to show that current baits are species specific) and effective baiting intensities and strategies that may increase the humaneness of aerial baiting.
3. *The fate of feral pigs that consume aerial baits*. Currently 72mg of 1080 is registered for use in aerial baiting in Queensland. It is unknown how many baits are actually consumed by a feral pig, or the dose that is needed to be consumed to produce a rapid death in feral pigs in the field. It is possible that aerial baits are causing illness in feral pigs and adverse

environmental conditions cause the death of these feral pigs sub-optimally poisoned feral pigs.

- *Trapping may be a relatively humane method of feral pig control*. However, research to confirm this is required to justify the method. This research should focus on the behaviour of feral pigs in traps during the extended period of time that feral pigs are in the traps before euthanasia.

- *Aerial Shooting.* Aerial shooting may be a useful, humane and target specific means of controlling feral pigs in appropriate conditions. However, public disquiet exists due to adverse publicity in the past. Research to investigate the humaneness of helicopter shooting should occur. This research would be relatively simple to conduct and could entail post mortems of feral pigs following aerial shooting. This may allow deductions of the time taken for feral pigs to die following aerial shooting, based on pathology. Direct observation of times to death and accurate recording of the number of animals killed or wounded during aerial shooting could be part of this research.

- *Cyanide or similar ultra-fast acting toxins should be refined and researched in order to develop a relatively humane and safe method of poison baiting.*

- *Hunting and harvesting are commonly used means of feral pig control across wide areas of feral pig habitat.* The welfare impacts should be assessed.

6.1.4) An active research program to develop additional humane, or more humane methods where control methods are shown to be inhumane must be employed.

This results in long term improvements to welfare (Mellor & Littin 2003).

A number of priorities have been developed by prior research. Fleming et al (2000) and McIlroy (2004) wrote that additional toxins are required to improve the management of feral pigs, especially with aerial baiting. O'Brien (1986) also wrote that an additional feral bait package was needed. Additional toxin research has occurred at the Qld DNRME (Mitchell 2003). However, no additional feral pig toxins have currently been produced. Fertility control is an attractive means of feral pig control since the individual welfare of feral pigs could be expected to be high with this method of control. Improved trapping techniques may also improve the sustainability of feral pig control programs. These methods are assessed in the appendices. However, recommendations include.

- Research to isolate additional feral pig toxins should be supported. These toxins should be effective, humane and target specific where possible. See appendix 1.

- Research to support additional feral pig baiting packages should occur. This research should concentrate on target specificity and efficacy for controlling feral pigs. See Appendix 1.

- Research to investigate alternative baiting strategies using current toxins and substrates may reduce potential non-target impacts.

- Aerial baiting is potentially a potent feral pig control tool and research into additional baiting packages should support aerial application of toxins.

- Fertility control is generally a more humane method of control than lethal control methods. Currently the USDA has developed a mammalian anti-fertility vaccine, which is likely to be available as an orally active compound within 2-3 years (Lowell Miller, USDA pers. comm. March 2004). Research in Australia should occur to validate this immuno-contraceptive in Australian conditions. This research should include proof of concept trials using the currently available injection, oral liquid delivery trials and modelling to determine the effectiveness of this vaccine to control feral pig populations in Australian conditions. See Appendix 2. However, the use of fertility control could never replace lethal control and should be considered as an adjunct method of control. Target specific bait delivery packages will be required.

- Improved feral pig traps could potentially improve feral pig management in the semi-arid rangelands (Neal Finch, Uni. of Queensland. pers. comm. March 2004). This may increase the humaneness of feral pig management since large, sustained reductions in feral pig populations may be possible. See appendix 3.

- Research to investigate the impacts of feral pigs on ecosystems will allow the ethical justification of vertebrate pest control. This research will also increase the welfare of vertebrate pest control programs because it will allow auditing of programs for effectiveness. Auditing will allow refinement of control programs to allow the maximum benefit to be obtained for the lowest feral pig welfare compromise.

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8) Appendix 1. *The research and development of alternative toxins and bait packages for use in feral pig baiting programs.*

8.1) Future feral pig toxins

Future research to investigate the use of alternative toxins and baiting methods for feral pig control is warranted to increase the target specificity, humaneness and cost effectiveness of feral pig baits (McIlroy 2004). The development of a readily accessible feral pig bait package that land managers can use was identified as a priority at the recent Feral Pig Action Agenda (Lapidge 2003). McIlroy (2004) was also recently sub-contracted under the Meat and Livestock Australia Ltd-funded PAC CRC feral pig bait project contract to review the desirable traits that future feral pig toxins should have.

Desired attributes of a toxin for feral pig control (not in order of importance) (From McIlroy 2004).

a) Specificity. An ideal feral pig toxin is only toxic to feral pigs (is target specific).
b) Humaneness. A humane toxin kills quickly and produces minimal clinical signs that indicate that the feral pig is suffering.
c) Effectiveness. To be effective a feral pig toxin must kill at least 70% of treated individuals. This number has been determined to be the minimum proportion of the population that must be killed for a baiting campaign to be successful (Giles 1980).
d) Applicability. A bait will be more applicable if it can be delivered as a broad-scale control method, and if it can be distributed as a take home local control for use by land-managers. This is in comparison to some toxins that are only distributed by registered government workers.
e) Low cost.
f) High human safety in handling and the existence of antidotes. Some toxins can have human safety issues (cyanide) and do not have an antidote in the event of accidental poisoning (1080).
g) Low risk to non-target species. The risk to non-target species that may potentially consume feral pig baits should be minimal. This means they must have difficulty accessing baits or have a low probability of being affected by a toxin.
h) Lack of subsequent problems such as aversion/bait shyness. Many toxins can cause baits to be unpalatable, or can lead to sub-lethal dosing which will reduce the uptake of baits containing the toxin. This will reduce the proportion of the population that is killed in a poisoning campaign.
i) Lack of persistence and good environmental degradation. A good toxin is one that is quickly degraded in the environment and does not persist in the 'food chain'.

A number of poisons have the potential to be used as future feral pig control toxins. These include one-shot warfarin (compared to the multiple doses currently required), other anticoagulants, cyanide, zinc phosphide and cholecalciferol (McIlroy 2004). The Queensland Department of Natural Resources, Mines and Energy is currently researching the use of cyanide, zinc phosphide and 'one-shot' warfarin for feral pig control (Mitchell 2003). Although alternative toxin research is currently occurring, the applicability of such poisons for feral pig control is mostly yet to be determined.

The PAC CRC is planning an 'Achilles Heel' review of feral pig physiology in order to identify potential lethal agents or approaches for trialing on feral pigs in 2005/2006. However, new agents will not be easily identify. McIlroy's criteria listed above will be utilized in assessing any new lethal feral pig agents.

8.2) Future feral pig bait packages

Currently feral pig packages contain different toxins and bait substrates in different areas (McIlroy 2004). Anecdotal evidence suggests that feral pigs in different areas are attracted to different bait substrates (Bryant 2004). Fresh meat (Queensland), various grains (NSW), fresh fruit and vegetables (especially bananas in north Queensland), pollard pellet baits and carcasses are used to deliver toxins to feral pigs around Australia (Bryant 2004). However, many of these substrates are also attractive to other native and domestic animals.

Improved baiting strategies, underpinned by research undertaken by New South Wales Agriculture in the past, have reduced the negative consequences of feral pig baiting (Bryant 2004). An additional method that could improve the efficacy of feral pig control programs is the development of a tough, manufactured, quality-controlled bait if it is proven to be highly attractive and target-specific for feral pigs (O'Brien 1986).

As suggested by McIlroy (2004), a manufactured bait substrate suitable for feral pig control could:

a) Eliminate the labour intensive preparation of current baits,
b) Provide a bait which is available in all seasons,
c) Increase the quality control of toxin concentrations in baits,
d) Possibly be available as a 'take home' bait, rather than (as at present) graziers and other land holders requiring government land protection officers to supply 1080, and supervise it's mixing with the bait,
e) Be used for aerial application, and
f) Reduce the risk of poisoning non-target animals.

O'Brien (1986) reviewed design attributes of a feral pig bait package (and baiting strategies) which would aid in increasing the specificity of feral pig baiting methods. Specifically, O'Brien suggested:

a) Since the feral pig is a large powerful animal, the bait can be made available only to large animals by placing it in tough packaging.
b) Since feral pigs have highly sensitive olfaction, use odourants to increase the attractiveness of baits.
c) Pigs are relatively less sensitive to visual stimuli in relation to a number of non-target species; therefore use green dye to mask visual signals.
d) Feral pigs are omnivores, therefore use meat and vegetable components, such as grain and rotten meat attractants.
e) Feral pigs exhibit fossorial foraging, therefore bury baits.
f) Feral pigs have very large, nearly completely overlapping home ranges. Therefore, place baiting stations well apart to minimize non-target impacts, yet retain good contact with feral pigs.
g) Feral pigs have a nocturnal or crepuscular lifestyle, therefore place baits in late afternoon to reduce non-target impacts.

The PAC CRC, in collaboration with Animal Control Technologies Australia Pty Ltd, has begun the research and development phase of a new feral pig bait package. Feral pig pen trials of non-toxic bait substrates occurred in January 2004 to isolate promising substrates. Field trials to determine uptake by feral pigs and non-target animals began in February 2004 and are currently ongoing. The initial registration of bait packages will be attempted with 1080. The new bait package takes advantage of many of O'Brien's design attributes, for example, the green dye, the use of grain and the use of attractants. Other attributes which will increase the specificity of bait packages for feral pigs are the use of a large, toughened bait substrate and a novel toxin delivery system which will lower the ability of smaller animals (for example birds

and rodents) to access the toxin. Initial field trials of non-toxic manufactured baits has revealed that they are more efficacious (Lapidge & Cowled 2004 unpublished data) and target-specific (Cowled and Lapidge 2004 unpublished data) than the current used bait substrates of grain and meat.

The Forest Research Institute (NZ) conducted research to develop attractants and a bait which was suitable for wet conditions. Polymer baits were water resistant and their attractiveness to feral pigs was increased with the use of petrolatum, fish oil and synthetic fermented egg (Eason and Henderson 1991). Landcare research also investigated the use of a number of commercial baits, available in New Zealand for pig control (Henderson et al 1993). They found that Du-Pont and ACP baits were acceptable to feral pigs, and that synthetic fermented egg acted as a powerful attractant. They recommended the adoption of all the baits tested, rather than 1, since the stability of different baits under different climatic conditions varied, meaning that all were useful in different regions.

Landcare Research Ltd has continued research into the development of baits and baiting strategies for feral pigs in New Zealand. They investigated the use of non-toxic polymer baits with fish oil to aid in the eradication of feral pigs on Auckland Island (Clark 1991). It was found that these baits were palatable to pigs, sea lions and penguins. An alternative baiting strategy was proposed that would avoid non-target kills through limiting bait stations to areas greater than 800m from the coast. The uptake of this bait, when aerially distributed by a helicopter, was assessed by uptake of Rhodamine B (Clarke 1992). Baits were found to be successful with 100% of pigs assessed consuming baits. It was concluded to be a cost effective method of bait delivery to feral pigs.

Thomas and Young (1998 and 1999) also developed water resistant bait for use in pig control in New Zealand, in areas where hunting could not be practiced due to ground nesting birds and giant land snails. They estimated that this bait would be effective at reducing pig damage. The bait was developed for use in pig feeders or for burying to reduce non-target take.

Whilst some of the New Zealand information is usefully extrapolated to the Australian situation (such as attractants), much of the research needs to be repeated in Australia. This is because a different suite of non-target animals are present in Australia, and the different feral pig habitats between the two countries may require different bait substrates.

The Queensland Department of Natural Resources and Mines has recently trialled creosote on meat baits to increase the target specificity of these meat baits. Creosote was found to increase the target specificity of meat baits (Jim Mitchell Qld DNRM, Pers. Com. September 2004).

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9) Appendix 2. *Fertility control for feral pigs. Future prospects and current research.*

Summary

Feral pig populations in Australia are traditionally controlled through lethal methods such as shooting, trapping and poisoning. Some special interest groups in Australia are becoming increasingly vocal in their condemnation of control techniques, which they perceive as inhumane. This process has already occurred in America and the United Kingdom. In addition, lethal control techniques are not always appropriate in some sensitive areas and are frequently compromised by the high fecundity of feral pigs. As many people consider the use of fertility control to be a humane alternative to lethal control methods, since population control is achieved through reduced birth rates rather than by increased mortality rates, fertility control techniques for feral pigs would be a desirable addition to the tools available for feral pig management. The technique has previously been investigated in Australia and is currently being pursued in America.

9.1) Criteria necessary to make fertility control a viable option in feral pig management.

Many authors have reviewed the feasibility of fertility control for managing wildlife populations. Bomford and O'Brien (1997) reviewed the applicability of wildlife fertility control to the Australian situation. Fagerstone et al (2002) concentrated on the technical feasibility, economic reality, regulatory framework and public perception of wildlife management using fertility control in the USA. Bomford and O'Brien (1997) listed a number of criteria that must be satisfied for contraception to be successful in managing wildlife populations in Australia.

1. *An available drug or technique must exist to reduce fertility.* This is unlikely to be a barrier in the long term since a number of compounds exist that induce infertility.
2. *An effective delivery system must be developed to treat wild animals.* The development of a long acting, single dose anti-fertility agent that can be effectively delivered to wild animals would reduce the costs of applying regular lethal control measures across a wild population.
3. *End result of contraception must be reduced animal damage.* The reduction of a wild animal's fertility is not a valid reason to apply contraception to wild animal populations. The goal should be to reduce the fertility of the targeted animal populations, to a level that will result in reduced animal damage (Braysher 1993). Since no studies have occurred exploring this issue, Bomford and O'Brien (1997) compared the effect of fertility control and lethal control on animal populations using population modelling. They found that expanding populations of animals that exist in an environment with plentiful resources are more effectively controlled using lethal control means. However, these populations could potentially be more effectively controlled if fertility control was applied following some other factor, such as drought, shooting or poisoning. This is because the recovery of such populations will be slowed. This model reflects the situation with feral pig populations in Australia. Feral pigs can respond to favourable seasons with a rapid population growth, but populations are limited in drought (Choquenot et al 1996).
4. *The contraceptive must be humane and non-toxic.* Although some side effects exist with some contraceptive techniques, these techniques are in general superior to lethal control techniques in terms of humaneness.

5. *The contraceptive, or delivery system, must be target specificity.* Many contraceptive drugs are not target specific, but this is also true of many lethal control methods. Target-specificity of a general contraceptive can be greatly enhanced through species-targeted delivery vehicles. The use of genetically engineered organisms to spread immunological fertility control agents can also be target specific.
6. *The contraceptive must be environmentally acceptable.* Most fertility control agents do not leave harmful residues in the environment.
7. *The contraceptive must be cost effective.* Pest control benefits must exceed costs. However, this assessment must include non-economic factors such as animal welfare and morality, and biodiversity protection.
8. *The contraceptive must be applicable to Australian conditions.* Bomford and O'Brien (1997) concluded that the contraception of pest animal populations in Australia was not feasible since effective tools do not exist to date. This statement still holds today. However, they concluded that virally-vectored immunocontraception may be a possibility in the future, which could allow improved management of feral animal populations. They also concluded that small-scale control of pest animals could be possible in the future.

A number of other factors are important when considering the future success of contraception in feral pigs. Since fertility control can only be achieved through an understanding of the reproductive behaviour and biology of an animal (Fagerstone et al 2002), a thorough understanding of feral pig behaviour and biology must exist before instigating fertility control. Fortunately, information is available on reproduction in both domestic and feral pigs (Giles 1980; Saunders 1988; Choquenot et al 1996).

Fertility control methods must be biologically feasible for the target species (Dolbeer 1998 quoted in Fagerstone et al 2002). Dolbeer (1998) reviewed the theoretical effectiveness of fertility control as a sole population control tool. He recommended that fertility control as a sole means of population management be limited to smaller species such as rodents, which have short lifecycles and high reproductive rates. Larger species are likely to be less effectively controlled with reproductive control.

In a separate theoretical example, Knipling and McGuire (1972) showed that rat population reduction using fertility control was far more effective than using bait delivered toxin. This is due to the high reproductive potential of rats allowing a fast recovery of the population following baiting campaigns. However, the fertility control had to be applied to both males and females, and males had to exhibit normal reproductive behaviour. Feral pig populations however do not have the same reproductive rate and are longer lived. Furthermore, immigration from surrounding, non-controlled areas will reduce the effectiveness of a fertility control approach more than a lethal control approach.

Public involvement in the decision making process in vertebrate pest management is essential to the successful implementation of control programs (English and Chapple 2002). In some countries, such as the United Kingdom, fertility control may be the only publicly acceptable form of feral pig population management (Giovanna Massei, Central Science Laboratory UK, pers. comm., March 2004)

9.2) Methods of fertility control

9.2.1) Immuno-contraceptive vaccines

This technique relies on utilizing the animals own immune system to generate antibodies against various parts of the animals own reproductive system, such as gamete proteins, reproductive hormones and other proteins essential for reproduction (Fagerstone et al 2002). Such antibodies then interfere with the normal physiological functioning of the reproductive agents (Talwar and Gaur 1987 quoted in Fagerstone et al 2002). This method is applicable to many species.

- GonaCon (Gonadotrophin releasing hormone vaccine)

The United States Department of Agriculture's National Wildlife Research Centre has been researching and developing a Gonadotrophin Releasing Hormone (GnRH) vaccine for almost 10 years. It has been trialed in deer, horses and pigs. The agricultural industry has also been researching a GnRH vaccine for a considerable length of time (Moelen et al 1994; Oonk et al 1998). The vaccine is now at the stage where many species can have infertility induced for several years following vaccination (Miller and Fagerstone 2000). The most recent development is that of a single injection that can be used to induce long-term infertility in pigs (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).

Previously developed GnRH vaccines have been short acting and variable in their effect (Adams and Adams 1992; Ladd et al 1994; Meloen et al. 1994; Oonk et al. 1998; Schanbacher 1998 quoted in Miller 2004). However, the application of a new molecule for conjugating synthetic GnRH peptides and keyhole limpet hemocyanin (a mollusc protein), and the use of a new adjuvant (AdjuVac®) which is a modified Johnnes vaccine combined with small amounts of Mycobacterium avium, has lead to a sustained period of immunocontraception following a single injection in feral pigs (Miller et al 2004b).

Miller et al (2004a) described the mechanism of action of the GnRH vaccine;
"GnRH is a small peptide hormone sometimes called the "Master Hormone" because it is responsible for controlling the reproductive processes in both males and females. The GnRH peptide is identical in all mammals and is not immunogenic, both because of its small size and because it is considered "self" to the immune system. However, GnRH can be made immunogenic by coupling it to a carrier such as keyhole limpet hemocyanin. The coupled GnRH peptide is called a GnRH conjugate, which then is combined with an adjuvant to create a vaccine."

In a many mammals, GnRH is released from the hypothalamus and then circulates in the hypophyseal portal blood to the anterior pituitary where it stimulates the release of Follicular Stimulating Hormone (FSH) and Lutenising Hormone (LH). These hormones then stimulate the production of testosterone in the male and progesterone and oestrogen in the female. In an animal vaccinated with GonaCon, anti-GnRH antibodies in the hypophyseal portal blood complex to the newly released GnRH from the hypothalamus, preventing GnRH from binding to the FSH and LH receptors (Miller et al 2004a&b). In all the species tested, immunization with resulting antibody titre to GnRH leads to an inhibition of breeding behaviour and contraception. Effective contraception continues as long as antibody titres remain sufficiently high (Miller et al 2004a&b).

In pen trials with captive feral pigs, vaccination with 2000 µg of GonaCon induced infertility in 100% of pigs tested after 36 weeks. In contrast 100% of non-vaccinated females became pregnant during the same time period (Killian et al 2003). The infertility has continued for 3

years in 50% of treated females, and this infertility may be permanent as white tailed deer exhibiting long term infertility following GonaCon injection showed permanent abnormalities of the reproductive tract as determined through histopathology (Lowell Miller pers. comm.).

As stated, the vaccine is currently available as a single injection. The USDA is currently working on the production of an oral GonaCon vaccine. It is hoped that an oral vaccine will be developed within 2-3 years for field testing in feral pigs. Initial trial results have been promising, with trials in rodents reducing fertility by 50% when administered as a lipophyllic solution in water. However, problems still remain in the uptake of the vaccine across the small intestine following oral delivery, due to interference from ingested food stuffs (Lowell Miller, USDA NWRC, pers comm., March 2004).

Other methods of oral delivery, such as the use of recombinant brewers yeast as a delivery system are being researched in rodents (Paul Nash, USDA NWRC, pers. comm., March 2004). This would have the advantage of increasing uptake of the vaccine, since brewers yeast should allow easier presentation of the antigenic GnRH to the small intestine following delivery in a bait matrix. The yeast is modified to be killed in the environment through an inability to manufacture essential amino acids.

The application of an oral GnRH vaccine could have a number of applications in Australia. These are;

1. *In the management of small isolated populations in sensitive areas where lethal control is not an option.*

   This method of control would most likely be perceived by the public as acceptable form of feral pig control in areas close to urban settlements. In these areas, public safety and perception precludes the use of shooting and poisoning. In addition, non-target impacts on domestic animals can be perceived to be significant.

   A number of disadvantages exist with this potential method of control. The use of contraception as a sole method of control, as discussed above, is generally most effective for smaller mammals with high fecundity and short lives. The continued impacts that feral pigs cause in areas of solely contraceptive control would only be slowly reduced. This is because pigs could live for up to 5 years before they died from natural causes and would continue to impact on the environment until they died. This contrasts with lethal means that generally cause a rapid cessation of impact. Furthermore, it has also been suggested that fertility control of animal populations could increase adult survivorship due to decreased pregnancies (Sinclair 1997), and at this stage the GnRH vaccine is only partially effective (50%) for long periods as an injection. It is unclear how long the effect will last when orally delivered.

2. *Potentially as a follow up management tool in broad-scale population control following an initial population knockdown with a lethal control technique or a drought.*

   The ability of feral pigs to breed prolifically, and quickly repopulate to previous levels has hampered control operations in the past (Choquenot et al 1996). Thus, integrated pest management programs have been recommended to allow improved control of feral animal populations (Braysher 1993; Choquenot et al 1996).

Aerial shooting or poisoning of feral pigs has been demonstrated to be effective in reducing pig populations, but over subsequent years numbers have been shown to rebound quickly

(Saunders 1993). Through using fertility control in an integrated pest management program it is theoretically possible to extended by several years the initial period of population knockdown after lethal control measures have been undertaken. The ability to reduce the fecundity of feral pigs would slow the recovery of populations, provided immigration was limited, thus prolonging the advantages of lethal control measures. Fertility control may also offer an advantage over follow up poisoning since a GnRH vaccine could reduce the frequency of required follow up control operations to every few years.

At this stage, the potential costs of an orally delivered field vaccine are unknown. However, an aerial delivered, oral rabies vaccine used in the USA costs around $3 (US) per dose. It is stable in the field for several weeks after delivery (Susan Jojola, USDA NWRC, pers comm., March 2004). It is planned that any registered, commercial oral GnRH vaccine developed by the USDA would not be marketed for profit (Lowell Miller, USDA NWRC, pers. comm., March 2004).

A major disadvantage of this technology is that the GnRH vaccines are not target specific. GnRH vaccines have proved effective in reducing fertility in most mammals on which they were trialed, for example pets, cattle, horses, sheep swine, Norway rats and white tailed deer (Miller and Fagerstone 2000). Therefore, any vaccine delivery system must be target specific for feral pigs if the vaccine is to be utilized in the field. However, the same applies to toxic baits packages which are used frequently in feral pig control.

- *Zone pellucida vaccines*

Zona pellucida (ZP) is an acellular glycoprotein layer between the oocyte and granulosa cells. Antibodies generated against the ZP generate infertility by blocking penetration of the sperm (and therefore preventing fertilization) or by disrupting oocyte maturation (Fagerstone et al 2002). Porcine ZP is available in the US for research as SpeyVac® and has been used for fertility control in a number of species, including deer (Miller and Killian 2000), Norway rats (Miller et al 1997) and wild horses (Killian et al 2004). Using a new formulation of Porcine Zona Pellucida (PZP) vaccine, infertility in the horse is expected to last for 3-4 years following vaccination (Killian et al 2004).

Since the use of SpeyVac® leads to infertility through reduced oocyte implantations or reduced fertilization repeat cycling occurs. This can lead to changed behaviour (eg aggression in some species such as deer and increased car accidents) and adverse welfare outcomes (eg fawns born out of season and poor survivability). SpeyVac® has also been shown to be less successful than GonaCon in rodents (Miller et al 1997). However, SpeyVac® has been demonstrated to be effective when used in pigs (Killian et al 2003). Regardless, the use of SpeyVac® or other ZP vaccines is unlikely to be useful in the Australian situation if injections are required to deliver the vaccine. The development of SpeyVac® as an oral vaccine is not currently being investigated, and the use of virally vectored ZP vaccine is considered to be an unlikely prospect (see below).

- *Virally-vectored immunocontraception.*

The Pest Animal Control Cooperative Research Centre (PAC CRC) has made considerable progress towards the development of virally-vectored immunocontraception (VVIC) in the house mouse, European rabbit and European red fox. This work has focused on two areas, searching for an antigen that stimulates an immune response against the target animal's reproductive system (ZP) and delivering this antigen to the target animal (Peacock 2003). A recombinant mouse-specific virus (murine cytomegally virus and mouse ZP) has induced long-term sterility in laboratory and captive wild mice (Peacock 2003). Short-term infertility

has also been induced in rabbits using recombinant myxoma virus and the system is yet to be tested in foxes (Peacock 2003).

VVIC has an advantage that it is possible that long-term fertility control can be attained without the need for re-administering the immunocontraceptive. This is because the virus may persist in the population and continually re-infect new individuals. However, although VVIC looks to be technically possible, widespread public discussion and debate will be required before the release of a genetically altered virus (Peacock 2003).

Unfortunately, the use of VVIC in feral pigs is unlikely to be feasible for a number of reasons (Peacock 2003);

1. the negative effects of virally-vectored anti-fertility vaccines on Australian pork producers, overseas pork producers and the potential loss of international pork market access,
2. if a virus cannot be used, a baiting strategy must be used and a humane lethal method of control is far preferable to an immunocontraceptive one,
3. feral pigs are poor candidates for immunocontraception since they are long-lived,
4. the prohibitive costs of research and development (The PAC CRC estimates that the cost of developing a mouse VVIC virus to be about $12-20 M), with Australian investors unlikely to spend this amount on such a high-risk venture (Peacock 2003), and
5. public disquiet when considering the release of genetically modified viruses.

9.2.2) Other methods of immunocontraception

1. Sperm antibodies. This method creates a vaccine out of sperm head glyco proteins which causes antibody production in the female. These antibodies then prevent the sperm from binding to the ZP, which prevents fertilization (Bradley 1997 quoted in Fagerstone et al 2002)

2. Gonadotrophin releasing hormone agonists. Pituitary gonadotrophs can be made unresponsive to GnRH by administering an agonist of GnRH in a continuous manner. This leads to loss of gonadal function (Clayton et al 1979 quoted in Fagerstone et al 2002). However, this effect requires a continuous release of agonist, which is achieved through an implant and is therefore not practical in the Australian situation.

3. Gonadotrophin releasing hormone toxin. Linking synthetic analogues of GnRH and cytotoxins and targeting these conjugates to Luteinizing hormone (LH) and Follicular Stimulating Hormone (FSH) secreting cells in the anterior pituitary (Hobbs et al quoted in Fagerstone et al 2002). This will prevent the production of LH and FSH thus inhibiting ovulation and testosterone production in a non-immunologic and non-steroidal approach (Fagerstone et al 2002). However, this method is not specific to one species since GnRH is highly conserved across numerous species, which means non-target impacts could be high. In addition due to the large number of GnRH receptors in numerous parts of the body the potential for toxicity is high (Fagerstone et al). However, clinical trials are proceeding (Baker et al 1999 quoted in Fagerstone et al 2002).

4. Natural Plant Compounds. A number of naturally occurring plant compounds can induce infertility in animals, however whilst some show promise, extensive research will still be needed to explore these possibilities (Fagerstone et al 2002). Some of these include phytooestrogens, endophyte infested tall fescue and bromocryptine.

5. Steroids/Hormones. These are impractical in wildlife management since they require repeat and regular oral dosing or surgical implantion, and can lead to deleterious side

effects in both treated animals and predators or humans which consume treated animals (Fagerstone et al 2002).

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10) Appendix 3. *New Technology to Improve the Effectiveness of Trapping*

10.1) Shape recognition feral pig trapping

There are a number of existing methods for controlling animals at watering points, some of which are widespread and recommended by government agencies throughout Australia (Neal Finch, University of Queensland, pers. comm., April 2004). Essentially all current trap systems rely on mechanical or physical one-way barriers. Such systems generally cannot discriminate between target and non-target species.

Shape recognition technology is currently being developed at the University of Queensland for use in the rangelands as a control tool for all large vertebrates (native, domestic and feral) hopefully on the landscape scale. It is anticipated that it will also have application as a pig specific control method in the rangelands and other parts of Australia (Neal Finch, University of Queensland, pers. comm. April 2004). The system uses an enclosure design which directs animals down a lane way towards water where an intelligent camera operates an automated boom gate to 'siphon off' feral pigs to a holding yard. Proof of concept trials have progressed successfully and field trials are planned for this year in southern Queensland. It is anticipated that a unit will cost around $2000.

The system relies on the ability to accurately identify any large animal accessing a watering point through the use of machine vision technology. Using this ability together with specifically designed fencing and gates any large animal can be excluded, trapped or allowed to access water freely. The parts of the system comprise an intelligent camera, using machine vision technology, with enclosure design to successfully classify animals on a small scale. The system is initially planned to recognize and trap feral pigs, but any wild animal or domestic stock could potentially be identified and trapped this way. Field trials of enclosure designs have been successfully at directing animals down an access lane to water, and the shape recognition system will be placed at this point. The next stage in development is to place the complete system (enclosure, automated gate and intelligent camera) in national parks and pastoral land within the rangelands (Finch et al 2004, in press).

The system will only be applicable during seasons where pigs are concentrated around waterholes. During seasons of high rainfall the method may be ineffective. Provided the traps are checked daily and shelter is available, the method is likely to be a humane. The specificity of the method should also be high.

10.2) Commercial attractants for trapping

As stated, the ability to trap pigs depends on the desire of animals to enter the trap, after detecting the food or attractants in the trap. A problem with this is that fermented grain, grain and carcasses need to be used to attract pigs. Some commercial interest has been shown by land managers in purchasing commercially prepared bait attractants for feral pig traps. Such baits are being considered for development by private industry for use in the field (M. Smith, Animal Control Technologies Australia, pers. comm., March 2004).

10.3) Radio-transmitter, automatic feeders and food dumps in traps

Some novel uses of technology have also been used in the US to increase the efficiency of trapping operations (Garcelon 2004). Trapping operations in remote areas are often planned around a central point with radio transmitters attached to cage trap doors to assess daily trap

success. This allows the trap to be checked each day remotely, thus reducing the time for all traps to be checked and minimising disturbance in the trapping area. Automatic feeders are also used in traps so that during the pre-baiting period when traps are opened daily re-baiting is not required by staff. Some national parks services in Australia are reported to also use satellite surveillance and automated feeders to increase the efficiency of trapping operations (Braysher 2004).

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11) Appendix 4. *Humaneness Review Framework*

Table 1 Degree of welfare compromise caused by □ or indicated by ■ several clinical signs of control methods observed in feral pigs (adapted from table in Littin & O'Connor 2002).

Feature	**Minor**	**Moderate**	**Marked**
Convulsions/ seizures[13]		Recovery from intermittent/ short tonic or tonic-clonic convulsions[1]	Recovery from regular/ prolonged tonic or tonic/clonic convulsions
Tremors/ spasms	Occasional twitching (clonic spasm)	Prolonged twitching	
Vomiting/ retching	Occasional (e.g., 1–2 bouts) of retching	Vomiting or high frequency of bouts with many in each bout, with or without vomiting	
Pathology associated with toxicosis	Lesions/changes in 1–2 areas, or causing/ indicating short-term minor–moderate pain/discomfort or long-term minor discomfort	Lesions/changes in 3–4 areas, or causing/indicating short-term severe pain, or long-term discomfort	Lesions/changes in 5 areas, or causing/indicating long-term moderate–severe pain
Pathology associated with injuries	Minor lacerations or bruising	Moderate lacerations, bites, wounds	Major lacerations, bruising, broken bones, infections, gun wounds etc
Incoordination	Able to move freely but may be wobbly	Not able to move freely; may fall over	
Breathing	Occasional abnormal breathing pattern	Prolonged abnormal breathing, or short–medium periods of laboured breathing (dyspnoea)	Prolonged laboured breathing
Inactivity/ lethargy/ listlessness	Mostly inactive with reduced awareness	Mostly prostrate or lying with reduced awareness	
Feed/ water intake	Reduction in food intake can indicate pain perception (Bollen et al 2000). For feral pigs water consumption generally required daily in hot climates.	Zero for prolonged time	
Body weight	Minor weight loss	Moderate weight loss	Large weight loss
Voiding	Minor permanent change in faecal/ urine output (e.g., altered	Substantial or prolonged moderate change (e.g.,	Extreme prolonged diarrhoea

[13] There is no effect on welfare if consciousness is never regained after seizures. Hence these categories only occur if the animal recovers from these types of seizures.

	consistency), or substantial short-lived change	cessation, blood, diarrhoea)	
Abnormal posture	Occasional abnormal posture	Mostly abnormal posture	
Temperament		Irritable or aggressive temperament can indicate pain in pigs (Underwood 2002)	
Normal behaviour = interest in surroundings (including staff), willingness to move around, explorative behaviour, tail wagging, vocalization when fed (Bollen et al 2000).	Loss of normal behaviour, e.g., loss of feeding behaviour, sternal recumbency with reluctance to rise		
Vocalisation, may squeal or bark when in pain (Underwood 2002)		Occasional vocalisation	Prolonged vocalisation
Signs of 'fear'	Minor (small amount of escape behaviour such as avoidance behaviour)	Moderate (running etc)	Marked (extreme escape behaviour)

11.1.1) Humaneness Review Framework for Warfarin use in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of the poison	Causes pain in humans (Burkhart 2001), causes pathology and clinical signs in feral pigs and other species (Hone & Kleba 1984; Buddle 2000; Mason & Littin 2003) that indicate suffering may occur	Likely that warfarin causes suffering in animals, including feral pigs.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected with warfarin.

Reported effects in feral pigs (Hone & Kleba 1984; O'Brien & Lukins 1990)	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**
Onset of first signs (decreased food intake)	First sign at 2-3 days (Hone & Kleba 1984; O'Brien and Lukins 1990).	??	
Mean time to death/permanent unconsciousness	5.8-8.4 days depending upon sex and days of warfarin feeding (Hone & Kleba 1984)[14]	??	
Duration of effects	Mean approximately 3.8 -6.4 days (Hone & Kleba 1984). Up to 31 days (O'Brien & Lukins 1990)	Most animals within 3.8-6.4 days	The length of time that clinical signs are evident implies any welfare compromise can be experienced for several days, but up to 31 days.
Frank blood in faeces/urine	??	??	Minor to moderate welfare compromise depending upon prevalence, intensity, duration.
Lameness/stiffness	??	??	Demonstrates pain, moderate to marked welfare compromise depending upon prevalence, intensity, duration.
Lethargy/ progressive weakness	??	??	Minor to moderate welfare compromise depending upon

[14] Note that clinical signs were of 2 forms, sudden death due to massive haemorrhage or gradual onset. Data assessed for this study includes data from high concentration warfarin trials given over 2-3 days (similar to current field situation).

			prevalence, intensity, duration and physiological cause.
Recumbency	??	??	Minor to moderate welfare compromise depending upon prevalence, intensity, duration and physiological cause.
Haemorrhage	??	High proportion (Hone & Kleba 1984). Approximately 60-75% of limbs of poisoned feral pig contained haemorrhages. Haemorrhages in other areas of the body were also common.	Minor to marked welfare compromise depending upon prevalence, intensity, duration and site/s.
Depression	??	??	Minor to moderate welfare compromise depending upon prevalence, intensity, duration.
Moribund	??	??	Suggests pain or weakness which may indicate welfare compromise depending upon duration, prevalence and intensity.
Decreased food consumption	??	??	Minor to moderate welfare compromise depending upon site, prevalence, intensity, duration and the amount of weight loss.

5) Warfarin	**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. Signs of illness can occur for several days before death occurs. 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. However, complete data to make a definitive assessment using Littin & O'Connor's (2002) assessment is lacking.**

11.1.2) Humaneness Review Framework for 1080 use in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of the poison	In humans, 1080 poisoning has generally not resulted in pain, although nausea and abdominal pain have been reported by some authors. In feral pigs 1080 leads to prolonged and sometimes severe vomiting and intermittent convulsions with periods of consciousness, but death is relatively rapid.	Possible that 1080 can lead to some welfare compromises due to vomiting, and temporary recovery from convulsions, however, death is usually rapid.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected with 1080.

Reported effects in feral pigs (McIlroy 1983; Hone & Kleba 1984; O'Brien 1988, Buddle 2000)[15]	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**
Onset of first signs (vomiting)	51 minutes (vomiting). 4.34 $mgkg^{-1}$ of 1080 (O'Brien 1988)	Recent field experience reveals that the prevalence in wild feral pigs may be low (L.Twigg, DAWA, pers. com. November 2004).	Low?
Mean time to death/permanent unconsciousness	5 hours (4.34 $mgkg^{-1}$ dose of 1080) (O'Brien 1988)		
Duration of effects	4 hours (up to 5 days) (O'Brien 1988)		Generally a fast acting toxin, so duration of welfare compromise short
Vomiting/retching	4 hours	100% at 4.34$mgkg^{-1}$, mean number of vomits was 16 times per pig (O'Brien 1988)	Minor to moderate distress from abdominal pain after repeat bouts.
Dyspnoea	**??**	**??**	Minor to marked distress depending upon, duration, intensity or prevalence
Hyperexcitability and convulsions (tonic-clonic)	**??**	**??**	Minor to marked depending upon prevalence of recovery after convulsions, degree of possible injury, degree of CNS disturbance etc
Lethargy	**??**	??	Could indicate pain, weakness or disorientation. Minor to moderate distress depend upon, intensity, duration or prevalence?
Hind limb paralysis	**??**	A small proportion (figures not reported)	Distress could lead to minor or moderate welfare compromise but low prevalence

5) 1080	**1080 intoxication in feral pigs causes vomiting which may be relatively prolonged and frequent. In addition, feral pigs that undergo convulsions can sometimes temporarily recover (possibly with injuries), before again convulsing. These symptoms may cause some welfare compromises during intoxication. However, it is unlikely that 1080 compromises other aspects of a feral pigs welfare, and it is a fast acting toxin which means any welfare compromises are generally short lived. Complete data to make a definitive assessment is lacking since this assessment is based on data from efficacy trials.**

11.1.3) Humaneness Review Framework for Yellow Phosphorus use in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of the poison	In humans phosphorus leads to abdominal pain, vomiting, organ damage and death. In some instances death follows several days or weeks after ingestion due to organ failure. In	Phosphorus potentially causes welfare compromise in feral pigs

[15] These studies and reports were generally to establish the efficacy of 1080 in feral pigs and as such the data generated is only partially useful for a humaneness review.

	pigs phosphorus leads to clinical signs and pathology that indicates that pain may be experienced.	

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected with Phosphorus.

Reported effects in feral pigs (O'Brien & Lukins 1990; Buddle 2000).	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**
Onset of first signs	??		
Mean time to death/permanent unconsciousness	2-4 days using an LD_{50} dose of 5.3mgkg^{-1} (O'Brien & Lukins 1990)		This indicates that any welfare compromise is experienced for several days.
Duration of effects	2-3 days assuming signs start within 1 day of ingestion?		No data in O'Brien & Lukins (1990) to answer this question definitively. An assumption was made that signs started within 1 day of ingestion
Gastro-intestinal pathology (inflammation/bleeding), liver damage,	??	liver pathology (20%), bleeding in stomach (24%), bleeding in small intestine (33%), bleeding in rectum (33%) (O'Brien & Lukins 1990)	Indicates moderate to marked welfare compromise
Lethargy and depression	**??**	Most pigs (O'Brien & Lukins 1990)	Indicates possible minor to moderate welfare compromise depending upon intensity and duration.
Decreased food consumption	**??**	Most pigs (O'Brien & Lukins 1990)	Indicates possible minor to moderate welfare compromise depending upon intensity and duration
Recumbency	**??**	??	Minor to moderate distress depending upon, intensity, duration or prevalence?
External haemorrhage obvious (rectum and nasal)	**??**	38% (O'Brien & Lukins 1990)	Minor to moderate distress depending upon, intensity, duration
Paddling of feet/convulsions	**??**	??	Minor to marked distress depending upon, intensity, duration or prevalence or possible recoveries?
Vocalisations	**??**	Small number of pigs (O'Brien & Lukins 1990)	Indicates moderate to marked distress depending upon, intensity, duration?
Vomiting and diarrhoea	**??**	13% of pigs vomited (O'brien & Lukins 1990), Diarrhoea ??	Low prevalence, indicates minor welfare compromise but duration and intensity affects this
Abdominal pain	**??**	??	Moderate to marked welfare compromise depending upon prevalence, intensity or time of occurrence

5) Phosphorus	**Phosphorus poisoning produces abdominal pain and other unpleasant effects in humans. In feral pigs, clinical signs and pathology indicate that feral pigs experience a welfare compromise. Data to show the length of time that clinical effects are experienced by feral pigs is lacking.**

11.1.4) Humaneness Review Framework for cyanide use in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of cyanide	In humans, sub-lethal dosing with cyanide causes dyspnoea, sharp headaches, salivation, weakness and convulsions. In addition nausea, giddiness, vomiting, breathlessness, anxiety, abdominal pain and burning tongue and irritation of mucous membranes can occur. However, these effects are generally short lived and death is often rapid in vertebrate pests.	Can cause unpleasant symptoms that could compromise welfare in animals but these symptoms are very short lived. Currently the toxin is not effective in feral pigs. A good prospect for humane control of feral pigs in the future.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected with cyanide.

Reported effects in feral pigs (Mitchell 2003)	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**
Onset of first signs	Almost immediate		
Mean time to death/permanent unconsciousness	7 minutes (Mitchell 2003)	1/20 pig	
Duration of effects	1 hour (Mitchell 2003)	10 Sub-lethally dosed feral pigs (50% of trial pigs)	Indicates any welfare compromise for up to 1 hour in sub lethally dosed feral pigs
Salivation	??	??	Illustrates possible nausea. Minor distress depending upon, intensity, duration or prevalence?
Vomiting	**??**	**??**	Minor –moderate distress depending upon, intensity, duration or prevalence?
Staggering	**??**	**??**	Minor-moderate distress depending upon, intensity, duration or prevalence?
Convulsions	**??**	??	Minor-marked distress depending upon, intensity, duration or prevalence and the presence or absence of temporary recovery?

5) Cyanide	**Cyanide causes rapid onset of salivation, staggering and convulsions in feral pigs where it causes death or sub-lethal poisoning. Currently cyanide is an ineffective feral pig control tool, with Australian and New Zealand trials showing that currently available formulations are not capable of reliably killing feral pigs. As such it should not be used in feral pig control programs. However, 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 means of delivering the toxin to feral pigs.**

11.1.5) Humaneness Review Framework for use of cholecalciferol in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of cholecalciferol	Cholecalciferol causes pain and intense discomfort in humans. In other vertebrate pests some clinical signs indicate marked welfare compromises that can occur for many days	Cholecalciferol is likely to be a toxin which produces clinical signs and pathology indicative of marked welfare compromise in humans and some vertebrate pests. These welfare compromises are likely to persist for long periods of time before death. No research has occurred in feral pigs but it could be anticipated that these effects could also occur in feral pigs

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected with cholecalciferol.			
Reported effects in feral pigs **To the authors knowledge, no research has been conducted into cholecalciferol effects in feral pigs, although sporadic cases have been reported (Buddle 2000).**	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**

5) Cholecalciferol	**Human case reports demonstrate that the toxin causes pain and intense discomfort in people. Research in other vertebrate pests (e.g. possums) indicates that cholecalciferol causes some clinical signs that result in marked welfare compromises for considerable periods of time. No research has occurred in feral pigs which precludes a definitive assessment of the humaneness of cholecalciferol in feral pigs. It is possible/probable that effects in other species may be replicated in feral pigs.**

11.1.6) Humaneness Review Framework for use zinc phosphide in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of zinc phosphide	Zinc phosphide causes diarrhoea and vomiting, excitement and respiratory distress, nausea, headaches, vertigo and abdominal pain in humans. In animals, such as rodents, respiratory distress, diarrhoea, excitation, depression, abdominal pain, and convulsions occur. In larger domestic animals toxaemia with depression of appetite, dullness and some increase in respiration have been reported. Pathology associated with zinc phosphide in large domestic animals includes congestion and haemorrhage in all organs, fatty degeneration of the liver and inflammation in the small intestine. The toxin can be relatively rapidly fatal or it may take several days to be lethal.	Zinc phosphide has proved to be an effective toxicant in feral pigs, but to our knowledge, no research to assess its humaneness has occurred. It is likely that zinc phosphide does cause some welfare compromises in feral pigs, similar to its effect in rodents and humans (e.g. abdominal pain). However, these effects may be short lived in feral pigs due to the relatively acute nature of the toxin.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected with zinc phosphide.			
Reported effects in feral pigs **To our knowledge, no research has been conducted which can provide data for a humaneness review in feral pigs.**	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**

5) Zinc Phosphide	**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. The duration of these effects are likely to be short lived since zinc phosphide is a relatively acute toxin.

11.1.7) Humaneness Review Framework for aerial baiting use in feral pigs

1) Capacity to suffer	Present

2) Anticipate the likely effects of aerial baiting	It is anticipated that the effects 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, and greater control of feral pigs for the same resources. See 1080 ground baiting.	

11.1.8) Humaneness Review Framework for fencing in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of fencing	Fencing physically excludes feral pigs from small valuable areas. As such its effects on feral pig welfare may be limited to hunger, thirst or discomfort if feral pigs are excluded from areas they rely upon for shelter and food. However, feral pigs are generally mobile and fencing cannot exclude feral pigs from all areas due to its expense limiting its use. Therefore, feral pigs will often simply re-direct their attention to new areas (Choquenot et al 1996) and the welfare impact of fencing will be reduced.	The welfare impacts of fencing are likely to be low since feral pigs will redirect foraging and shelter needs to another area. However, if fencing excludes feral pigs from the only water or shelter source available, the method could be considered to cause severe welfare impacts. In this case another control method may be needed to cause a knockdown in feral pig numbers before fencing occurs to minimise deaths by dehydration. However, no research has been conducted into the humaneness of fencing on feral pigs.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by fencing.			
Reported effects in feral pigs **To our knowledge, no research has been conducted which can provide data for a humaneness review in feral pigs.**	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**

5) Fencing	**The data necessary to conduct a review of the humaneness of fencing in feral pigs has not been generated. However, the effects are likely to be minimal since fencing can only be generated 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. Where electric fencing was used, intense discomfort or pain may be experienced for a very short period of time.**

11.1.9) Humaneness Review Framework for trapping in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of trapping	Trapping feral pigs occurs by enticing feral pigs into a trap with food, and holding	Trapping is anticipated to be a relatively humane means of feral pig control provided

	trapped feral pigs until they are shot. Traps are checked daily and should be placed in sheltered locations. Feral pigs may experience a short period of fear and distress when traps are checked. They may experience minor thirst or hunger since pigs may be held for 24 hours. Feral pigs could experience discomfort if traps are not located in sheltered areas. Injuries occur in traps due to escape attempts but feral pigs generally lie quietly when trapped. Provided shooters are experienced, euthanasia would be humane.	traps are in sheltered locations, checked at least daily and that trapped feral pigs are euthanased by skilled shooters. No research has occurred to investigate the humaneness of trapping.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by trapping			
Reported effects in feral pigs **To our knowledge, no research has been conducted which can provide data for a humaneness review in feral pigs.**	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**

5) Trapping	**The data necessary to conduct a review of the humaneness of trapping in feral pigs has not been generated. Traps should be checked at least daily and should be placed in sheltered locations to reduce feral pig exposure. However, the method is likely to be relatively humane, based on anticipated effects from step 2 of the framework.**

11.1.10) Humaneness Review Framework for aerial shooting in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of aerial shooting	During government accredited feral animal aerial shooting campaigns, feral animals are shot in the thoracic cavity by trained and skilled government shooters. This results in the rapid death of virtually all animals through massive heart/lung/major vessel damage. Where doubt exists as to the lethality of a shot, a second shot is placed. Possible welfare compromises occur when animals are not killed outright and a second shot is inadvertently not placed. In addition, a short period of time (estimated to be seconds or minutes) may occur before animals loose consciousness or die.	Aerial shooting in feral pigs in appropriate habitats by trained and accredited staff is likely to be a humane control method due to the reliable and rapid death of feral pigs shot with this method.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by aerial shooting			
Reported effects in feral pigs **To our knowledge, no research has been published which can provide data for a humaneness review in feral pigs.**	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**

5) Aerial Shooting	**The data necessary to conduct a review of the humaneness of aerial shooting in feral pigs has not been generated. However, it is likely that aerial shooting is a humane means of controlling feral pigs where suitable programs are carried out by accredited staff.**

11.1.11) Humaneness Review Framework for the Judas pig technique.

1) Capacity to suffer	Present

2) Anticipate likely effects the Judas pig technique	The Judas pig technique occurs after trapping of feral pigs and consists of the physical restraint of a feral pig which allows the fitting of a collar, followed by the release of the feral pig. The technique probably causes fear and distress in feral pigs, but only for a short period of time. This fear and distress could be reduced with the use of sedatives or anaesthetics but these may be costly. Provided experienced handlers are conducting operations, and collars are fitted correctly, the chances of injury are low. The humaneness of the method is affected by the humaneness of trapping and the humanness of the control method used following the release of the collared feral pig.	The method potentially produces fear and distress in feral pigs for a short period of time. However, the welfare impacts are likely to be minimal, although these potential impacts could be reduced by animal restraint drugs.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by the Judas pig technique.

Reported effects in feral pigs	Mean Time	Prevalence	4) Degree of welfare compromise
To our knowledge, no research has been published which can provide data for a humaneness review in feral pigs.			

5) Judas Pig technique	**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 and distress) for a short period only.**

11.1.12) Humaneness Review Framework for snaring in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of snaring	In theory snaring is designed to capture a feral pigs head and neck within a snare leading to a rapid death by occlusion of the trachea or carotid arteries. In practice, studies in other animals (coyotes), and field experience reveals that a large proportion of snared animals may be snared inefficiently. This can lead to an animals escape with severe injuries or potentially a slow death whilst still snared.	Snaring is likely to result in the rapid death of an unknown percentage of feral pigs. However, the escape of wounded pigs or the slow death of inappropriately snared feral pigs is probable in a high percentage of cases. In addition, the method is likely to result in similar signs in a high percentage of non-target animals in Australia.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by snaring.

Reported effects in feral pigs	Mean Time	Prevalence	4) Degree of welfare compromise
To our knowledge, no research has been published which can provide data for a humaneness review in feral pigs.			

5) Snaring	**The data necessary to conduct a review of the humaneness of**

	snaring in feral pigs has not been generated. However, it is likely that the method would lead to severe welfare compromises in an unknown percentage of cases.

11.1.13) Humaneness Review Framework for hunting with dogs in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of hunting with dogs	When hunting with dogs, feral pigs are generally pursued for a relatively short time (compared with chase hunting in the United Kingdom). Feral pigs are held stationary by baling or pinning and during this time feral pigs can be bitten which causes pain and injuries in feral pigs. Feral pigs are then stabbed, shot or have their throat cut, which causes pain for a short period of time. Fear and distress are probably experienced by feral pigs at this time. A large proportion of feral pigs escape when large mobs are hunted. However, it is unknown whether feral pigs which escape have been wounded.	Hunting feral pigs with dogs almost certainly causes fear and distress. Pain and injury are probably experienced where dogs restrain feral pigs by physically biting them and when feral pigs are stabbed or cut. However, this fear, distress and pain is likely to occur for short periods of time. Therefore it is likely that hunting with dogs causes welfare compromises in feral pigs, at least for a short period of time. Without specifically generated data it is impossible to state the relative humaneness of the method against other means of controlling feral pigs.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by hunting with dogs			
Reported effects in feral pigs **To our knowledge, no research has been published which can provide data for a humaneness review in feral pigs**	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**

5) 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 some feral pigs for a relatively short period of time.**

11.1.14) Humaneness Review Framework for ground shooting in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of ground shooting	Shooting the head of feral pigs from the ground can lead to the rapid death of feral pigs. However, experience in other species suggests the use of head shots which can result in instantaneous death is not appropriate in all situations and a chest shot is recommended in many situations to ensure the rapid death of feral pigs. Generally, the use of appropriate calibre, high velocity rifles with expanding bullets in skilled hands can lead to the rapid death of a feral pig due to massive and extensive tissue damage. Exceptions to this are where an animal can be shot by inexperienced shooters or by shooters at extreme range or where a ballistic 'freak' can lead to a non-lethal shot. It is possible that these pigs could escape wounded due to the difficulties of pursuing feral pigs on the ground.	Ground shooting with skilled shooters can generally lead to the rapid death of a feral pig. Where inappropriately skilled shooters or inappropriately placed shots are used, feral pigs can escape wounded, with severe injuries which can obviously cause welfare compromises. However, it is likely that ground shooting is generally a humane method of feral pig control.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by ground shooting.			
Reported effects in feral pigs **To our knowledge, no research has been published which can provide data for a humaneness review in feral pigs**	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**

5) Ground shooting	**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.**

11.1.15) Humaneness Review Framework for biological control with ASF in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of ASF	ASF leads to multi-systemic organ pathology, and clinical signs of severe illness. It can lead to rapid death or death after several days.	It is likely that ASF causes a welfare compromise in infected feral pigs. However, the tool is unlikely to be ever used in Australia due to non-target impacts on the domestic pork impacts.

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by ASF.			
Reported effects in feral pigs	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**
In virulent strains, the virus can cause sudden death or numerous haemorhagic lesions, loss of appetite, fever and high mortality (Sanchez-Vizcaino 1999).	**??**	**??**	Moderate to marked welfare compromise depending upon prevalence, duration and intensity
Haemorrhages and organ damage of the spleen, lymph nodes, kidneys and heart are common. Abdominal fluid, gastrointestinal damage, liver damage, pleural damage and brain damage can occur (Sanchez-Vizcaino 1999).	**??**	**??**	Moderate to marked welfare compromise depending upon prevalence and the number of these changes seen in each animal

5) ASF	**To our knowledge, no research has been conducted into the humaneness of ASF as a control tool. It is likely that the method would cause welfare compromise in infected pigs.**

11.1.16) Humaneness Review Framework for habitat modification in feral pigs

1) Capacity to suffer	Present

2) Anticipate likely effects of habitat modification.	Habitat modification (such as removal of water sources or harbourage) may affect feral pig welfare by causing thirst or discomfort if feral pigs are no longer have shelter and water available. However, feral pigs are generally mobile and would be expected to migrate to other areas. Therefore, feral pigs may simply re-direct their attention to new areas and the welfare impact of habitat modification may be reduced. However, the sudden application of habitat modification across large areas may	The welfare impacts of habitat modification are likely to be low since feral pigs will redirect water and shelter needs to another area. However, if habitat modification is extensive enough or suddenly applied with no other form of population knock down, the method could be considered to cause severe welfare impacts. However, no research has been conducted into the humaneness of habitat modification on feral pigs.

	lead to welfare impact on feral pigs where migration to alternative habitat cannot occur.	

3) Determine the type, intensity and duration of effects, and the percentage of feral pigs affected by habitat modification.			
Reported effects in feral pigs **To our knowledge, no research has been published which can provide data for a humaneness review in feral pigs**	**Mean Time**	**Prevalence**	**4) Degree of welfare compromise**

5) Habitat modification	**To our knowledge, no research has been conducted into the humaneness of habitat modification as a control tool. However, it is likely that the method would produce welfare compromise where large scale habitat change occurred where feral pigs had no access to alternative water and shelter. However, other habitat modifications are likely to be relatively humane.**

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