Evaluation of Attractants and Toxins for Improved Target Specificity in the Control of Feral Pigs

Report to the National Feral Animal Control Program

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Table of Contents

Summary

Feral pigs (*Sus scrofa*) are an environmental and economic pest across Queensland. Current baiting programs primarily use meat baits poisoned with fluoroacetate (1080). Current concerns surrounding the use of fluoroacetate has propagated the need to examine additional toxins and improved bait packages.

Three bait substrates; meat, fermented coarse grain and banana were examined to aid in providing baits specific to pigs in regions with different dietary uptake. Attractants were tested to assess their palatability and uptake by feral pigs and uptake by non-target species. While no additive was found to significantly affect the consumption of bait by pigs, the trials highlighted the potential of creosote as a potential deterrent to non-target species. Field trials showed no uptake of non-toxic, creosote-covered baits by non-target species compared to total removal (100% uptake) of blank meat and grain controls. Cattle were the only non-target species to remove bananas, indicating that non-target animals do not perceive banana as a food source in the trial area.

Warfarin and cyanide were examined as potential toxins for the control of feral pigs. Warfarin is an anticoagulant that causes death by preventing blood from clotting. Paddock trials with multiple pigs using one-shot warfarin (440 mg) in meat and banana baits showed 100% bait uptake in the first night. Seven out of fifteen pigs died from the fifteen baits presented, but it was unknown if each pig got a bait. Deaths occurred between 11 and 25 days after consumption of the baits. Cyanide is a fast acting poison potentially suitable for the control of many vertebrate pests. Trials testing cyanide were initially hampered by supply delays. However, those trials undertaken showed signs typical of delivery problems. Cyanide tablets that were consumed whole did not dissolve to release the cyanide powder, and the pigs show no signs of poisoning. If the tablet was broken and some of the powder ingested it made the pigs ill, they then vomited and recovered. Those that died appeared to intake most of the powder and did not vomit at all.

While this project has identified creosote as a potential additive to meat, grain and banana baits to deter non-target species, further work is required in other regions to determine if it is a successful deterrent for other likely non-target animals. The results suggest that warfarin may be a potential toxin for feral pigs, but more research is needed to improve the delivery and/or the formulation. Similarly, cyanide is promising but more work is needed to find an effective delivery method.

Introduction

Feral pigs (*Sus scrofa*) are a major economic and environmental pest throughout Queensland. It has been estimated that national loss to agriculture caused by feral pigs may be around $100 million (Choquenot *et al*., 1996; McLeod, 2004). In 1996, losses to crop production in Queensland were estimated at $11.9 million (McGaw and Mitchell, 1998). The likely damage is much higher considering the estimate does not include the damage to the fruit and sugar industry and losses to lamb predation, and competition with stock.

Feral pigs cause direct damage to the environment by degrading habitats through rooting, trampling, tusking and rubbing vegetation and spreading weeds (McGaw and Mitchell, 1998). . Feral pigs prey on native animals and their eggs (Tisdell, 1984; Mitchell, 1993) and may directly compete with such animals as the cassowary (Choquenot *et al*., 1996) and brolga (Tisdell, 1984). Feral pigs pose a threat in the spread of endemic and exotic diseases; it has been estimated that an outbreak of Foot and Mouth Disease could cost more than $3 billion nationally (Choquenot *et al*., 1996).

Considerable effort and expense is undertaken to control feral pigs. For example, $1.1 million was spent on feral pig control in Queensland in 1984 (Choquenot *et al*., 1996) equating to about $2.2 million in today’s dollar values (McGaw and Mitchell, 1998). Feral pig control is undertaken using poisoning, shooting and hunting, trapping and fencing. Of these, baiting with poisons is the most widely used.

Current baiting techniques

A baiting package requires integration of several elements: the bait substrate, attractant, toxin, presentation and delivery. Successful integration of these elements will ensure that feral pigs will find and consume the bait, and die as a result of bait consumption. Additionally, such elements should be modified to reduce the susceptibility of non-target species. All of these elements must be considered to create a baiting package designed to target the specific pest and reduce impacts to potential non-target animals.

Bait Substrate
Feral pigs are omnivorous, opportunistic feeders that can eat a variety of animal (e.g. invertebrates, amphibians, reptiles, eggs of birds and reptiles, small/young mammals and carrion) and plant material (e.g. seeds, roots, bulbs, tubers, fruits, vegetables and fungi) (Choquenot *et al.*, 1996). Anecdotal evidence suggests that feral pigs prefer to eat food to which they are accustomed (Parker and Lee, 1995). This suggests that bait types should be based on what foods are locally available and therefore familiar to the feral pigs. As a result, three bait substrates are favoured for use in Queensland: meat, grain and fruits (usually banana). These are representative of the foods likely to be encountered in the pastoral zone (meat from carrion), agricultural zone (grain from crops) and wet tropics (fruit from plantations and rainforest

plants). These substrates will all be tested with different attractants to find a pig-specific bait package.

Bait Attractants

Ideally, attractants that are added to bait substrates should attract pigs to the bait while deterring non-target animals. Previous trials (Mitchell, 1992) have highlighted possible attractants for incorporation into a bait complex. These include molasses, vanilla, cadaverine, fishmeal, creosote and synthetic fermented egg (SFE). The more promising of these attractants will be assessed in pen and field trials for their ability to increase attractiveness and palatability of presented baits.

Toxins

Currently, two toxins are registered for use in Queensland: phosphorus and sodium fluoroacetate (1080). Phosphorus is available to landholders but is not recommended due to welfare considerations and potential non-target impacts (Choquenot *et al.*, 1986; McGaw and Mitchell, 1998). Fluoroacetate occurs naturally in some Australian native vegetation (Twigg and King, 1991; Twigg, 1994); with some native animals developing a high resistance to 1080 poison (Olsen, 1998; Twigg, 1994; King *et al.*, 1981). Fluoroacetate works by disrupting the Krebs citric acid cycle (Peters *et al.,* 1953; Sullivan *et al*., 1979) resulting in energy loss and a build-up of citrate to toxic levels (as referred to in Cremasco, 2002). Fluoroacetate also impairs the central nervous system (Waniewski and Martin, 1998) and may explain why no pain is perceived in cases of humans exposed to sub-lethal dosing (Reigart *et al*., 1975; Gregory, 1991). Death results from cardiac arrest or respiratory failure (McIlroy, 1981; Eisler, 1995).

Although fluoroacetate is widely used for the control of feral pigs it has some disadvantages (Choquenot *et al*., 1996). Feral pigs are large, robust animals that are not highly susceptible to fluoroacetate poisoning. Susceptibility varies considerably between individuals, with some feral pigs surviving ingestion of very high doses (McIlroy, 1983). Vomiting is frequently reported (McIlroy, 1983; Sheehan, 1984; Hone and Kleba, 1984) which leads to reduced absorption of 1080 and may expose non-target species to highly-toxic vomitus (O'Brien *et al*., 1986). There is the potential to kill non-target species through primary poisoning, due to the high levels of fluoroacetate required for pig control (McIlroy 1983; McIlroy, 1986). Finally, there is no antidote for 1080 poisoning (McIlroy, 1983; Twigg, 1986; Feldwick *et al*., 1994; Parker and Lee, 1995; Olsen 1998; Cremasco, 2002).

With these considerations in mind, warfarin and cyanide were presented as potential additional toxins for the control of feral pigs. Warfarin is an anticoagulant that has been shown to kill feral pigs in field baiting programs (McIlroy *et al*., 1989; Choquenot *et al*., 1990; Saunders *et al*., 1990) and in pen trials (Hone and Kleba, 1984; O'Brien and Lukins, 1990; Parker and Lee, 1995). Unlike fluoroacetate, it is more toxic to pigs than most other species (Buck *et al*., 1976), does not induce vomiting (Hone and Kleba, 1984) and has an antidote (vitamin K) (McIlroy *et al*., 1989; Choquenot *et al*., 1990; Saunders *et al*., 1990, Parker and Lee, 1995).

Cyanide is a fast acting toxin that can kill pigs (Hone and Mulligan, 1982) as well as other vertebrates, although little work has been done using cyanide as a control poison for feral pigs. Mitchell (2003) showed in pen trials that, with an effective delivery system cyanide could be a successful toxin to target pigs. However, most of the delivery systems tested only caused symptoms rather than death in pigs. There are antidotes available for cyanide poisoning, although their use is controversial (Eason and Wickstrom, 2001). However, it causes vomiting (Mitchell, 2003) and requires an effective delivery system.

This project will tested warfarin in an encapsulated formulation (AF-WRF750) in prototype bait packages determined from the substrate and attractant trial. This formulation has been specifically developed for this purpose by the Queensland Department of Natural Resources and Mines. Feratox® cyanide capsules were supplied by Feral-Control (Auckland New Zealand, registered in Australia as Etox Australia Pty Ltd. Address is PO Box 38443, Howick, 1705, Auckland, New Zealand) and tested on penned feral pigs. It was originally intended to test additional delivery systems for cyanide, however time constraints prohibited this. Zinc phosphide was also identified as a potential toxin, but due to problems obtaining the toxin, priority was given to the warfarin and cyanide testing.

Delivery

Baits may be distributed from the ground or the air. Both methods are used in feral pig control programs in Queensland. Aerial baiting is more efficient where baits are to be spread over large areas or into less accessible areas. Aerial baiting requires a robust bait package to enable it to withstand aerial application. This effectively limits the type of bait substrate, attractant, and toxin delivery system that may be used. For example, liquid warfarin that is used in some grain baits is unsuitable for use in meat baits (Mitchell, 2003) and therefore for aerial delivery. Ground baiting allows much more control over the baiting program since the location of baits is known, and their removal can be readily accomplished. It also allows for greater flexibility in the bait substrates and toxins available for delivery.

Behavioural differences

Identifying behavioural differences between the target and non-target animals may provide ‘strengths’ and ‘weaknesses’ for a baiting package to be developed that will reduce potential non-target risks. The first stage in this process is to identify the potential non-target species and arrange them into guilds of similar behavioural traits. The second stage is to develop a classification for comparing the target species to the non-target guilds using criteria including such things as foraging behaviour, habitat selection and seasonal effects (O’Brien, 1986). Differences can then be identified for suitability to incorporate into a baiting strategy.

The potential non-target species impacted by a feral pig bait can be placed into the following guilds: raptors, granivorous birds and small omnivorous mammals (Table 1). Raptors may be threatened when using meat baits, granivorous birds when using grain baits and small mammals for meat, grain and vegetable baits. O'Brien (1986) used these guilds to make comparisons to feral pigs (Table 2) and identified that a toxic bait needed to:

1. be available only to large animals,
2. incorporate odourants to increase attractiveness to pigs,
3. include visual stimuli to make it unattractive to non-targets
4. present a substrate/attractant that is unattractive to non-targets,
5. be buried; and
6. be distributed at low densities at night.

Table 1. Potential non-target species to feral pig baits grouped by guilds.

Guild		
Raptors	Granivorous Birds	Omnivorous Small Mammals
Eagles	Galah	Dunnarts
Kites	Cockatoos	Quolls
Falcons	Parrots	Bandicoots
	Pigeons	Rodents
	Brolga	Southern Cassowary*
	Quails	Australian Brush Turkey*
	Macropods#	Domestic Pets
	Domestic Stock	

Macropods, while not birds eat grain, * cassowaries and brush turkeys while not mammals are omnivorous.

Table 2. A qualitative comparison of feral pigs with three potential nontarget guilds. The relative position of target and non-target is indicated by the letters: P = feral pig; R = raptor guild; G = granivorous bird guild; M = omnivorous small mammal guild. (from O'Brien, 1986).

Body Size	small	MG R P	large
Olfaction	insensitive	GR MP	sensitive
Vision	poor	PM GR	good
	monochromatic	PM RG	polychromatic
Diet	herbivore	G M P R	carnivore
Digging Ability	nil	RG M P	significant
Home Range Size	small	M G RP	large
Home Range Overlap	nil	M R GP	complete
Activity Pattern	diurnal	GR PM	nocturnal

Current baiting packages in Queensland use strategies involving the bait type, colour, size, presentation and distribution to make baits more specific to feral pigs and less specific to non-target animals. Bait substrates are based on the most widely available food source for feral pigs in that region, to increase the chance of pigs recognising and therefore consuming it. For example, bananas and meat are used in the wet and dry tropics respectively, grain in cropping areas, and meat in arid and semi-arid zones. Grain is fermented to make it attractive to pigs and dyed green to reduce visibility to granivorous birds. Large pieces of meat baits (500 g) are used to reduce the likelihood of non-target consumption. Baits are presented after pre-feeding, late in the afternoon and can be buried, to take advantage of feeding habits and diurnal activity of pigs. Baits are distributed at low density over a wide range to target the large, overlapping home ranges of feral pigs.

This project aims to examine pig-specific attractants, and creosote as a deterrent to non-target species to reduce the likelihood of non-target impacts. It also examines warfarin as a toxin that is less susceptible to non-target species, and a cyanide ‘tablet’ that may reduce the opportunity for non-target animals to access the toxin.

Methods

Animal Ethics
All trials were performed under Pest Animal Ethics Approval Number 030606.

Animal care and maintenance
Approximately 60 feral pigs (*Sus scrofa*) were trapped from private properties around Gatton, Inglewood and Talwood, Queensland and housed at Robert Wicks Pest Animal Research Centre, Inglewood. Animals were housed in large pens (12 m x 6 m) in groups of up to 10 individuals of mixed sex and size. The pens had dirt floors to allow digging and wallowing, and a wooden hutch for shelter. All animals were fed daily at a rate of 500 g per pig per day. Food consisted of commercial grower pellets, coarse grain, and occasionally kangaroo meat. Water was provided *ad libitum*. All animals were checked daily for signs of stress and injury, and treated accordingly.

A Target Specific Pig Bait

Attractants trial
Five feral pigs (3 males, 2 females) were randomly chosen from the resident population and housed individually in large pens (12 m x 6 m). All trials were conducted in a small paddock (50 m x 50 m) attached to the housing pens. The trial paddock was divided into 5 m x 5 m grids, with a bait station (clear plastic, 175 x 120 mm food dish lid) placed at each intersection of the grids, making 72 bait stations. No bait stations were placed within 5 m of the boundary, or 10 m of the entrance. The two baits consisted of a control substrate (kangaroo meat, banana, fermented coarse grain) with no attractant added, and a treatment (of the same substrate) with an attractant (creosote, fish stock, meatmeal, molasses, vanilla) added. The weight of each substrate was kept constant for each trial (meat = 200 $\pm$ 10 g, banana = 180 $\pm$ 25 g, grain = 200 $\pm$ 10 g). Attractant was added to the substrate in a bucket and mixed until it covered all the bait, at constant rates (creosote = 15 mg/kg, fish stock = 50 mg/kg, meatmeal = 50 mg/kg, molasses = 50 mg/kg, vanilla = 10 mg/kg. For each trial, two baits were placed randomly on bait stations in the trial paddock. Each pig was then released one at a time into the trial paddock and allowed fifteen minutes to locate and consume the baits. The order of pigs was randomised for each trial, and each pig ran two trials per day. The first bait found, the time taken to find each bait, and the time spent at each bait was observed and recorded. The percentage of baits found first was analysed using Chi-square distributions and time to find baits and time spent at baits were analysed using generalised linear models.

No-choice trial
Fifteen pigs were randomly chosen from the resident population and housed individually in small pens (3.9 m x 1.3 m). Each pig was presented with a single bait for up to 1 hour. Recordings were made of whether the bait was consumed or not. Baits consisted of 50 g of meat, banana or grain covered in 15, 40, 80 or 100 ml of creosote. Each pig was offered all combinations of baits in a random order.

Choice trial

Thirty pigs were selected based on family groups or mobs from the resident population and housed in five groups in large pens (12 m x 6 m):
Group 1 – Adult male x 1, adult female x 1, young male x 2, young female x 2.
Group 2 – Adult male x 2, adult female x 1, young female x 3.
Group 3 – Adult male x 1, adult female x 3, young male x 1.
Group 4 – Adult male x 2, adult female x 2.
Group 5 – Adult male x 2, adult female x 2, young male x 2, young female x2.

Each group of pigs was released into a small paddock (80 m x 70 m) and allowed 20 minutes to complete a trial before being returned to the pens. Each trial consisted of two baits being randomly placed equi-distant from the entrance to the paddock and least 10 m apart. The baits consisted of a test bait (15, 40 or 80 ml of creosote on 500 g of meat, grain or banana) and 500 g of a control of the same substrate. Each combination of baits was tested twice and each group of pigs ran two trials per day. The first bait found, the time taken to find each bait, the time spent at each bait, and the amount of bait remaining was recorded. The percentage of baits found first was analysed using Chi-square distributions and time to find baits and time spent at baits were analysed using generalised linear models.

Non-target trial

Non-toxic baits were placed on private properties close to water sources (<100 m). One property was known to have feral pig activity from spotlighting and track evidence. The other property had little or no pig activity. At each site, seven circular sand plots (2 m diameter) were placed 30 metres apart. For each of the three trials, plots were monitored daily for three days and the amount of bait removed was recorded, as well as tracks seen on the sand plot. Plots were swept each day to remove tracks from the previous day. After three days, all remaining bait was removed and the sand plots replenished. Where creosote had soaked into the sand, that sand was replaced. For the first trial, each plot was randomly assigned one of the following bait types: meat control, meat 15 ml creosote, grain control, grain + 15 ml creosote, banana control, banana + 15 ml creosote, or no bait. For the second trial, each plot was randomly assigned one of the following bait types: meat control, meat + 40 ml creosote, grain control, grain + 40 ml creosote, banana control, banana + 40 ml creosote, or no bait. For the third trial, an eighth plot was added to each site. Each plot was randomly assigned one of the following bait types: meat control, meat control, meat + 15 ml, meat + 40 ml, grain control, grain control, grain + 15 ml creosote, grain + 40 ml creosote. For trials one and two, the meat bait consisted of 500 g of kangaroo meat cut in 100-g pieces, the grain bait was 500 g of fermented coarse grain, the banana bait was 500 g of banana cut into 50-g pieces. For the third trial, the meat bait was one 500-g piece of kangaroo meat. Creosote was added to the baits in a bucket and mixed until it covered the bait completely.

Additional Toxins

Warfarin paddock trial

Fifteen pigs were randomly chosen from the resident population and randomly placed into four groups:

Group 1- five pigs in a large pen (12 m x 6 m);
Group 2 - five pigs in a large paddock (40 acres);
Group 3 – two pigs in a medium paddock (20 acres);
Group 4 – three pigs in a small paddock (80 m x 70 m).

One-shot warfarin tablets were placed into the middle of meat or banana baits. Group 1 were presented with five baits consisting of a 440 mg warfarin pellet (400 mg/kg warfarin) in a piece of banana coated with 40 ml/kg of creosote. The group was observed while consuming the baits and the individuals that ate the baits were recorded. Three pigs consumed one bait each, one pig consumed two baits and one pig did not eat any bait.

Group 2 was presented with five baits consisting of a warfarin pellet placed in a 500 g piece of kangaroo meat coated with 40 ml/kg of creosote. Baits were placed between 100 and 300 meters of a water source on sand plots (Figure 1). All baits were removed on the first night, with pig tracks being the only signs of animal activity on the sand plots.

Figure 1. Bait presentation for pigs in the large paddock. Baits were a 500 g piece of kangaroo meat with warfarin tablet placed inside.

Group 3 was presented with two baits consisting of a warfarin pellet placed in a 500 g piece of kangaroo meat, coated with 15 ml/kg of creosote. Baits were placed between 100 and 300 meters of a water source on sand plots. Both baits were removed on the first night, with pig tracks being the only signs of animal activity on the sand plots. Group 4 was presented with three baits consisting of a warfarin pellet placed in a 500 g piece of kangaroo meat, coated with 40 ml/kg of creosote. The group was observed while consuming the baits and a record of which individuals ate the baits made. One pig ate two baits, one pig at one bait and one pig ate no bait. All animals were monitored daily and records made of deaths.

Cyanide pen trial

Fifteen pigs were randomly chosen from the resident population and housed in groups of three in large pens (12 m x 6 m). Feratox® cyanide pellets (supplied by Feral-Control Auckland New Zealand, registered in Australia as Etox Australia Pty Ltd. Address is PO Box 38443, Howick, 1705, Auckland, New Zealand) were presented as a single pellet; amongst commercial dog biscuits; amongst commercial pig grower pellets or concealed in kangaroo meat. The delivery method depended on the pigs' willingness to consume the cyanide pellet. Once the pellet was consumed, animals were observed and recordings taken of poisoning signs until the animal succumbed or recovered.

Results

Attractants Trial

Across the three bait substrates, no attractants offered were significantly preferred by the pigs. The entire bait was consumed in all but two of the occasions that baits were found. One occasion was a meat with fish stock bait, the other a banana control bait. Tables 3, 4 and 5, show the percentage of times that each attractant was found first, the average time to find each bait type, and the amount of time spent consuming each bait for meat, banana and grain substrate baits respectively. The percentage of times that each bait and attractant was found first was not significantly different (χ^2 = 4.10, d.f. = 10, p = 0.943). Although, for each substrate tested, the control was found first on more occasions than the baits with attractants. Molasses covered meat baits were found in the shortest amount of time on meat baits, meatmeal was found quickest on banana baits and fish stock for grain baits. However, the time taken to find baits with each attractant was not significant for meat baits (F = 1.42, d.f. = 5, p = 0.250), banana baits (F = 0.82, d.f. = 5, p = 0.551) or grain baits (F = 0.49, d.f. = 5, p = 0.781). Similarly, the time spent at each type of attractant was not significantly different for meat baits (F = 2.07, d.f. = 5, p = 0.102), banana baits (F = 1.13, d.f. = 5, p = 0.370) or grain baits (F = 0.50, d.f. = 5, p = 0.776).

Table 3. Preference shown by feral pigs for each attractant tested on meat baits. Values for baits found first are expressed as a percentage of all occasions, not including 20 percent of occasions when neither bait in a trial was found. Values of time to find and time spent at baits are means ± SE.

Attractant	Percent Found First	Time to Find Bait (sec)	Time Spent at Bait (sec)
Meat Control	44	216 ± 69	132 ± 37
Creosote	8	417 ± 168	219 ± 47
Fish Stock	12	451 ± 98	108 ± 22
Meatmeal	4	207 ± 89	60 ± 15
Molasses	8	72 ± 41	96 ± 31
Vanilla	4	442 ± 379	329 ± 123

Table 4. Preference shown by feral pigs for each attractant tested on banana baits. Values for baits found first are expressed as a percentage of all occasions, not including 8 percent of occasions when neither bait in a trial was found. Values of time to find and time spent at baits are means ± SE.

Attractant	Percent Found First	Time to Find Bait (sec)	Time Spent at Bait (sec)
Banana Control	32	247 ± 72	80 ± 11
Creosote	8	390 ± 264	117 ± 4
Fish Stock	12	126 ± 43	105 ± 41
Meatmeal	12	89 ± 40	110 ± 26
Molasses	12	149 ± 110	209 ± 130
Vanilla	16	169 ± 40	107 ± 32

Table 5. Preference shown by feral pigs for each attractant tested on grain baits. Values for baits found first are expressed as a percentage of all occasions, not including 4 percent of occasions when neither bait in a trial was found. Values of time to find and time spent at baits are means ± SE.

Attractant	Percent Found First	Time to Find Bait (sec)	Time Spent at Bait (sec)
Grain Control	52	255 ± 60	221 ± 19
Creosote	8	217 ± 71	163 ± 79
Fish Stock	12	112 ± 54	168 ± 13
Meatmeal	8	289 ± 87	243 ± 65
Molasses	8	377 ± 213	212 ± 44
Vanilla	8	312 ± 111	218 ± 32

As none of the attractants was significantly preferred over any other, or even the blank controls, it was decided to take creosote into further trials as this seemed the most likely to deter non-target animals.

No-choice Trial

In all trials, the bait was consumed within the one-hour period.

Choice Trial

In total, 180 paired trials were run, making 360 baits placed for consumption by the five groups of pigs. Of these, 198 were completely consumed, 101 partially consumed and 61 not consumed at all (Table 6). Table 7 shows the percentage of times each bait was found first, the time to find each bait and the time spent at each for all bait substrates. There was no difference between the percentage of times that each level of creosote was found first for any of the bait substrate (meat: χ^2 = 1.27, d.f. = 3, p = 0.737; grain: χ^2 = 2.37, d.f. = 3, p = 0.500; banana: χ^2 = 0.865, d.f. = 3, p = 0.834). The time taken to find baits was not significantly different for any level of creosote on the meat baits (F = 1.59, d.f. = 3, p = 0.197), grain baits (F = 1.27, d.f. = 3, p = 0.289) and banana baits (F = 0.264, d.f. = 3, p =0.851). The time spent at each level of creosote was not significant for meat baits (F = 1.91, d.f. = 3, p = 0.134) or grain baits (F = 1.25 d.f. = 3, p = 0.295). There was a significant difference between the creosote levels in the time spent at banana baits (F = 3.40, d.f. = 3, p = 0.021). Pigs spent less time at the banana baits with 15 ml/kg and 80 ml/kg than at the baits with none or 40 ml/kg of creosote.

Table 6. The amount of bait remaining for each substrate and level of creosote. Values are percentage of total baits of that type offered.

	Amount of Bait Consumed			
Bait	All	Half or More	Less than Half	None
Meat Control	80.0	3.3	3.3	13.3
Meat + 15 ml Creosote	80.0	10.0	3.3	6.7
Meat + 40 ml Creosote	50.0	23.3	6.7	20.0
Meat + 80 ml Creosote	50.0	23.3	20.0	6.7
Grain Control	70.0	6.7	3.3	20.0
Grain + 15 ml Creosote	43.3	26.7	13.3	13.3
Grain + 40 ml Creosote	30.0	36.7	16.7	20.0
Grain + 80 ml Creosote	43.3	23.3	13.3	16.7
Banana Control	66.7	3.3	3.3	26.7
Banana + 15 ml Creosote	53.3	20. 0	3.3	23.3
Banana + 40 ml Creosote	46.7	16.7	13.3	23.3
Banana + 80 ml Creosote	46.7	26.7	13.3	13.3

Table 7. Preference shown by feral pigs for each level of creosote tested on all bait substrates. Values for baits found first are expressed as a percentage of all occasions. Values of time to find and time spent at baits are means ± SE. Values with different letters are significantly different ($p < 0.05$) for the time spent at banana baits, all other values are not significantly different.

Bait	Percent Found First	Time to Find Bait (sec)	Time Spent at Bait (sec)
Meat Control	40.00	195.90 ± 48.04	177.81 ± 25.29
Meat + 15 ml Creosote	43.33	245.27 ± 56.14	279.27 ± 58.15
Meat + 40 ml Creosote	56.67	264.00 ± 34.29	156.18 ± 54.98
Meat + 80 ml Creosote	36.67	117.19 ± 34.29	149.19 ± 28.89
Grain Control	36.97	227.46 ± 58.22	351.96 ± 48.23
Grain + 15 ml Creosote	53.33	268.19 ± 64.26	444.32 ± 80.92
Grain + 40 ml Creosote	50.00	155.60 ± 44.58	432.08 ± 109.59
Grain + 80 ml Creosote	56.67	316.36 ± 67.74	255.82 ± 67.72
Banana Control	50.00	192.26 ± 52.80	110.78 ± 10.95[a]
Banana + 15 ml Creosote	46.67	227.26 ± 50.24	66.21 ± 14.48[b]
Banana + 40 ml Creosote	40.00	274.13 ± 88.44	98.46 ± 17.81[a]
Banana + 80 ml Creosote	40.00	217.32 ± 70.86	59.00 ± 11.17[b]

Non-target Trial

Bait plots at each site were visited by a variety of animals. Table 8 shows the occasions that an animal's tracks were found on a sand plot, the type of bait present and the number of occasions that any bait material was removed. Despite a low number of observations, the results suggest that baits with creosote were less preferred by most of the non-target species that visited the plot sites. Wild dogs, crows, goannas, foxes (Figure 2) and feral cats approached the meat baits with creosote but the only occasions that baits were removed were either where feral pigs were present, or by crows and goannas at 15 ml/kg when the meat was small pieces (Figure 3). One feral cat removed pieces of meat with 40 ml/kg creosote from the plot but dropped them within five metres of the original location. Small birds did remove grain that contained creosote, but they never removed the entire amount (Figure 4). The results are clearer when the amount of bait removed is compared for baits with creosote to the controls. Figure 5, shows the cumulative amount of baits removed over the three days. This shows that controls for meat and grain were readily removed. Only the meat with 15 ml/kg of creosote that was in pieces was completely removed. Only cattle and small birds removed banana baits. The cattle completely ate one banana control bait but did not eat any creosote covered baits that were visited. The small birds pecked at the flesh of bananas but an entire piece was never consumed.

Table 8. Animal visitations and bait removal from sand plots. Bait taken does not necessarily mean that the entire bait was removed.

	Bait Type																	
	Meat Control		Meat+ 15 ml		Meat+ 40 ml		Grain Control		Grain+ 15 ml		Grain+ 40 ml		Banana Control		Banana + 15 ml		Banana + 40 ml	
Animal	# of visits	Bait taken	# of visits	Bait taken	# of visits	Bait taken	# of visits	Bait taken	# of visits	Bait taken	# of visits	Bait taken	# of visits	Bait taken	# of visits	Bait taken	# of visits	Bait taken
Feral Pig (*Sus scrofa*)					1	1[f]	2	2[bb]	1	1								
Wild Dog (*Canis familiaris*)	1	1[c]	1	0	2[c]	0					1	0	1	0	1	0		
Fox (*Vulpes vulpes*)	5	5[ccc]	3[b]	1[g]	2[c]	1[h]	2	1[b]	2	2[bb]	1	0	1[b]	0				
Feral Cat (*Felis catus*)					2	0	1[b]	0			1[e]	0						
Kangaroo (*Macropus giganteus*)	2	0									1[a]	0						
Domestic Cattle (*Bos taurus*)									1[b]	0	1	0	1	1	1	0		
Crow (*Corvus orru*)	10	10[dfffg]	3	0	7[df]	0												
Small birds (unknown spp.)	1	0	2[f]	0	1	0	21[a]	20[fhh]	10[f]	5[ff]	6	0	2[f]	1	3	1	1	
Goanna (*Varanus varius*)	2	2[c]	2	2[f]														

Also present on the plot: a = feral cat, b = bird, c = crow, d = wild dog, e = kangaroo, f = fox, g = goanna, h = feral pig, i = cattle

Plots that had no bait were used in trials one and two to see if animals were actively approaching the baits or visitation was just by chance. The blank plots were visited only twice: once by cattle that also ate a banana control bait, and visited grain + 15 ml/kg creosote and banana + 40 ml/kg creosote; and once by a rabbit (*Oryctolagus cuniculus*). No other prints or signs of rabbits were seen on any of the plots.

Figure 2. A bait plot visited by a fox that removed the control (**a**) but not the meat covered in 40 ml/kg of creosote (**b**).

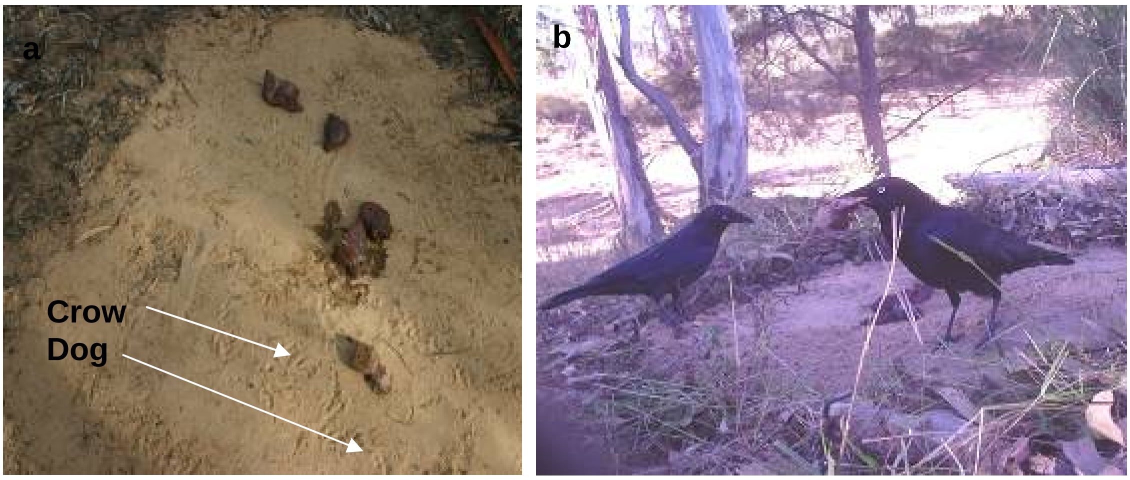

Figure 3. a. A bait plot containing meat pieces covered in 40 ml/kg of creosote that was visited by a wild dog and crows but was not removed. **b.** Crows removing bait from a plot containing meat pieces covered in 15 ml/kg of creosote.

Figure 4. A bait plot containing soaked grain covered in 15 ml/kg of creosote. Tracks of small birds can be seen, and some grain has been removed from the edge of the pile.

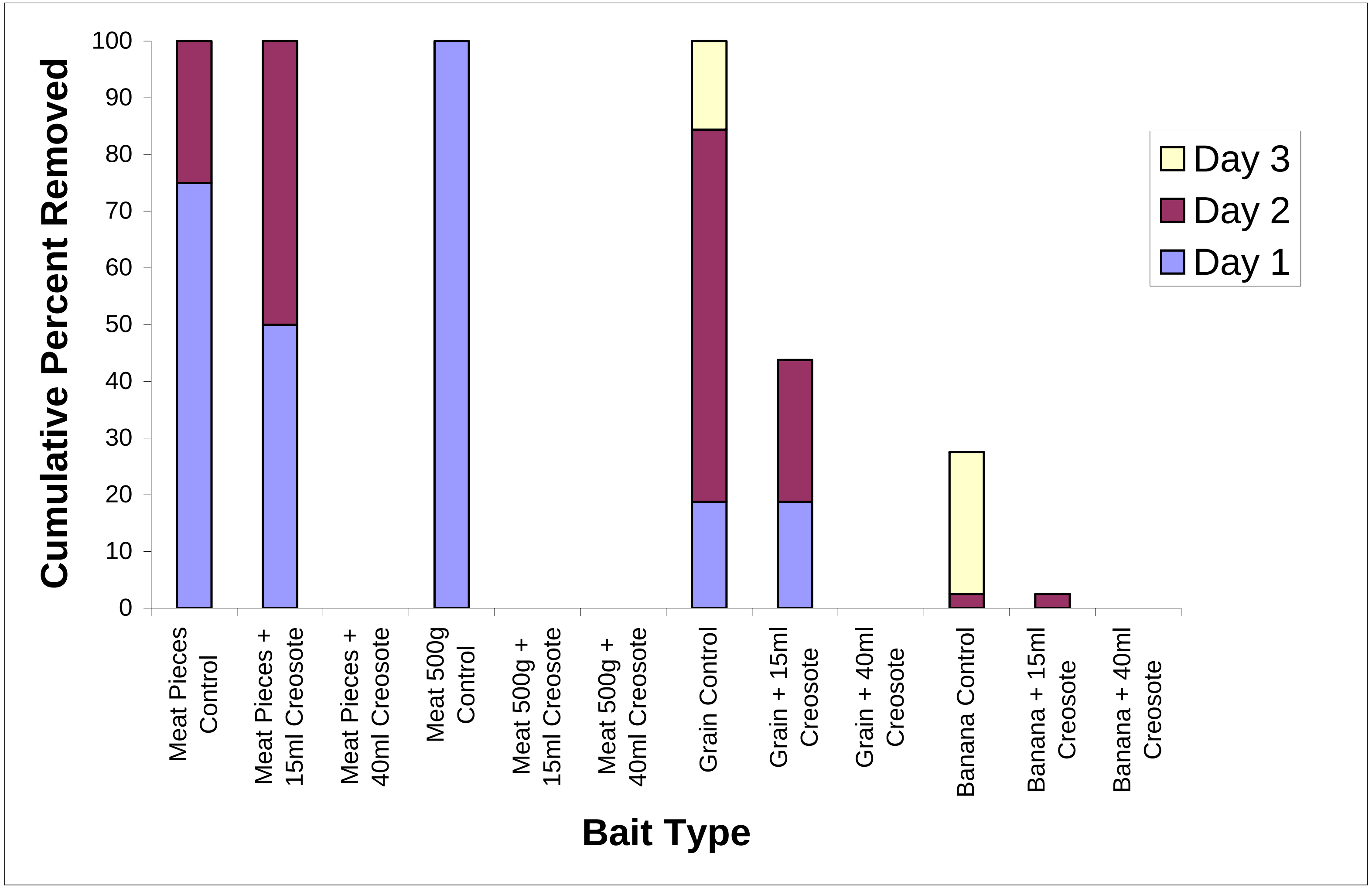

Figure 5. The amount of bait removed by non-target species over the three days that baits were available.

Warfarin Paddock Trial

All of the baits presented were consumed by the pigs either within 30 minutes of presentation (Figure 6), or during the first night after presentation. Of these, the consumption of eight baits was observed directly. Two pigs consumed two baits each, four pigs consumed one bait each, and two pigs did not consume any baits. Of these, both pigs that consumed two baits died, while two of the four that consumed one bait died. Consumption could not be directly observed for seven of the baits. From the two groups that could not be observed, three pigs died and four survived. All deaths showed signs of warfarin poisoning and occurred between 11 and 45 days after baits were consumed.

Figure 6. A feral pig consuming a meat bait containing a warfarin tablet.

Cyanide Pen Trial

Of the fifteen pigs that were exposed to cyanide pellets, four died, eight showed signs of illness and three showed no obvious ill effects. Signs of illness included: staggering, falling down, vomiting and convulsions. Table 9, shows the times to first sign of illness, whether the animal vomited, and survival. The first signs of illness were seen as early as 1 minute and 30 seconds after taking the pellet, but as long as 17 minutes after. The time to death of the four that died was between 12 minutes and 40 minutes. The pigs did not always ingest the entire contents of the pellet, some just broke the pellet in their mouth and spat it back out. Of the pigs that died, two ingested the pellet, two broke the pellet and spat some of it back out, and none of them vomited. It was unclear whether the pigs that ingested the entire tablet broke it their mouth or swallowed it whole. All of the pigs that showed signs of illness but recovered vomited at least once, and five of them more than once. All of the survivors showed no long-term adverse effects from having taken the cyanide. Four ate again that day, and all of them ate the next morning. Four of the survivors went into convulsions about 20 minutes after taking the pellet with recovery varying from a further 20 minutes to 2.5 hours. The three pigs that showed no signs of illness broke the pellet in their mouth then dropped it out. Therefore they probably did not receive any, or very little of the cyanide. Figures 7, shows the remains of pellets that were broken and dropped by a pig that died and a pig that survived.

Table 9. Pellet uptake, signs of illness and survival of pigs that consumed a cyanide pellet.

Pig No.	Sex	Age (piglet, sub-adult, adult)	Pellet Uptake	Time (min) to First Sign of Illness	Vomit?	Died/ Survived
1	M	Adult	Ingested	5:00	Many	Survived
2	F	Adult	Broke and Drop	5:00	No	Died
3	F	Piglet	Broke and Drop	Na*	No	Survived
4	M	Adult	Ingested	4:00	No	Died
5	M	Adult	Ingested	1:30	Once	Survived
6	M	Adult	Broke and Drop	16:30	Twice	Survived
7	M	Sub-adult	Broke and Drop	Na*	No	Survived
8	M	Adult	Ingested	Na*	No	Survived
9	M	Adult	Broke and Drop	2:40	No	Died
10	F	Adult	Ingested	5:00	Once	Survived
11	M	Adult	Ingested	4:30	No	Died
12	F	Adult	Broke and Drop	4:00	Many	Survived
13	M	Sub-adult	Broke and Drop	3:00	Many	Survived
14	F	Sub-adult	Broke and Drop	4:50	Many	Survived
15	F	Piglet	Ingested	13:00	Once	Survived

*Na – Not applicable as no symptoms were evident.

Figure 7. Cyanide pellets that were taken by pigs and then spat out. The pig that took capsule **a,** died after 15 minutes and 20 seconds. The pig that took capsule **b**, showed signs of illness after 1 minute and 30 seconds, vomited once and survived.

Discussion

Three bait substrates are used for feral pig baits in Queensland: meat baits for dry tropic and arid/semi-arid areas, grain baits for cropping areas and fruit baits for the wet tropics. All of these substrates appear equally palatable to penned pigs, but wild pigs are more likely to consume material with which they are familiar (Parker and Lee, 1995). The addition of attractants had no effect on the uptake of baits by penned feral pigs. None of the additives, however, proved to be more attractive than any other, or the blank controls. As a result, creosote was chosen as the most likely to deter non-target species.

There was no difference between the attractiveness or removal of creosote covered baits and the controls by feral pigs at all levels tested. However, creosote-covered baits may be promising as a deterrent to uptake by non-target species. Only goannas and crows completely removed creosote-covered meat baits, and only when the meat was in pieces. No non-target species removed creosote-treated grain, banana or 500-g meat baits. Nevertheless, this study was limited to grazing properties around Inglewood in southern Queensland and therefore to the species present there. Preliminary reports from a similar study in the wet tropics indicate that some species are removing creosote-covered grain and fruit baits (W. Dorney *pers. comm.*). More testing should be undertaken in a wider variety of habitats and species diversities to establish if creosote will be an effective non-target deterrent.

Warfarin has been shown in the past to be as affective as fluoroacetate in the control of feral pigs (McIlroy *et al*., 1989; Mitchell, 2003). Our results showed a 66% kill of pigs known to take baits; these results are similar to those seen in field trials by Mitchell (2003). Of the unknown uptake of warfarin baits, we saw a kill of 43%. This is probably a result of the same pigs monopolising baits as a result of baits being too close together and/or only small mobs having access to them.

The presentation of cyanide to penned pigs saw similar problems to those encountered by Mitchell (2003). Pigs that ingested the tablets whole, or broke the tablet and spat most of the powder out, showed signs of illness but recovered. In all cases, they became unsteady and vomited and in some cases collapsed, showed laboured breathing and convulsions which lasted from 20 minutes to, in one case, three hours. All these pigs recovered with no signs of ill effects. The pigs that did die broke the tablet in the mouth and ingested or inhaled some of the powder. These pigs did not vomit, showed other signs of poisoning after 2 - 4 minutes and died between 12 and 40 minutes after consuming the tablet. More work is needed in developing a method of delivering the cyanide powder into the mouth of the pig so that it is then inhaled.

The results from the cyanide trials suggest that the delivery method is inefficient. The capsules tested contained large quantities of cyanide, more than enough to kill large pigs, and all animals appeared to be susceptible as confirmed by the presence of symptoms in pigs that partially consumed the pellet. However, when the capsule failed to be broken in the mouth or were cracked in the mouth and spat out, the contents were regurgitated or ejected, resulting in an insufficient dose uptake. More work is needed to ensure that tablets are cracked in the mouth and cannot be spat out.

Cyanide is hygroscopic and will readily absorb available moisture. Mechanical ejectors rely on ejecting a fine cyanide powder into the mouth of a canid. Instructions for use direct that, any cyanide capsules showing signs of water penetration, such as caking of the powder, should not be used. The use of such capsules means that the animal will have more chance of spitting out the cyanide ‘bits’ that are caked together, whereas the powder itself could not be spat out. The powder in several of the pellets was observed to be ‘caked’, either a result of moisture contamination of the pellet during storage or by saliva after being cracked. Perhaps this is another indication that an alternative delivery mechanism is required, to ensure that caking and hence ejecting of at least some of the cyanide does not occur.

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