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# Dying to be clean: pen trials of novel cat and fox control devices

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Predation by feral cats (*Felis catus*) and red foxes (*Vulpes vulpes*) are key threatening processes for many endangered wildlife species. Toxin delivery through compulsive oral grooming is a potential mechanism to supplement existing control techniques for feral cats and red foxes, particularly when high prey densities reduce the uptake of toxic food baits by cats. We investigated the efficacy of different grooming traps by applying a gel containing toxic para-aminopropiophenone (PAPP) to the fur of feral cats and red foxes in experimental pens. Grooming behaviour and signs of poisoning in these animals were recorded by video. More cats interacted with "walk past" grooming traps triggered by sensor beams than with trap models that required the cat to enter a pipe or baited cage. After triggering a trap that had applied PAPP gel to their fur, 14 of 16 feral cats showed symptoms of anoxia, and 8 of these cats were dead by the following morning without exhibiting signs of distress. Seven of 12 foxes were observed to groom fur to which toxic gel had been applied and 3 of these ingested a lethal quantity of PAPP as a result. Our successful proof-of-concept trials support further development of grooming trap sensors and toxin delivery mechanisms to provide humane and targeted feral cat control, although this technique is unlikely to be as successful for fox control, given that foxes appear to not groom as fastidiously as cats.

**Keywords:** feline control; *Felis catus*; grooming trap; lethal control; PAPP; red fox; *Vulpes vulpes*; wildlife management

## 1. Introduction

Effective control of introduced feral cats (*Felis catus*) and red foxes (*Vulpes vulpes*) is a priority for the conservation of many small to medium sized mammals and ground-nesting birds (Smith and Quin 1996; Risbey et al. 2000), and is integral to the successful reintroductions of a range of threatened species both in Australasia and other regions (Short et al. 1992; Gibson et al. 1994; Priddel and Wheeler 2004; Moseby et al. 2011).

Broadscale poison baiting has proven successful in limiting fox numbers to the point where some medium-sized threatened species have demonstrated significant short-term or sometimes sustained increases in abundance and distribution (Dexter et al. 2007; Dexter and Murray 2009; Sharp et al. 2010; Kinnear et al. 2010; Dexter et al. 2013). Although poison baiting can be successful for controlling feral cats when they are food-stressed (Burrows et al. 2003; Johnston et al. 2011), this control method has limited efficacy when prey are abundant (Risbey et al. 1997; Algar et al. 2007; Moseby et al. 2009; Christensen et al. 2013). Indeed evidence suggests that an increase in cat predation following successful fox baiting may be implicated in subsequent declines in wildlife vulnerable to cat predation (Christensen and Burrows 1995; Risbey et al. 2000; Johnson 2006; Read and Ward 2011). Therefore, management programmes that can significantly reduce populations of both foxes and cats will likely be integral to the sustainable recovery of species threatened by both predators.

Development of felid-specific toxin delivery systems was a key recommendation of a review of cat management strategies in Australia (Denny and Dickman 2010). Oral grooming has been trialled or used as a technique for delivering toxins for the control of rabbits (Hale and Myers 1970) and rodents (Morris et al. 1983). Read (2010) also demonstrated the potential to deliver poison to feral cats through compulsive grooming, which circumvents their frequent aversion to consuming baits and other challenges of bait delivery of toxins including palatability and bait degradation issues. Avoiding a food-based delivery also improves target specificity by reducing significant non-target uptake (Algar et al. 2007; Moseby et al. 2011), a key requirement of acceptable pest animal control techniques (Sanders and Maloney 2002; King et al. 2007). A novel automated device that sprays poison onto the coat of an animal of a specific size or shape, hereby coined "grooming trap," will restrict exposure of most non-target species to toxins. Grooming traps also negate injury to non-target species that can sometimes be the by-catch of foot-hold (Meek et al. 1995; Fleming et al. 1998; Read et al. 2011a; Robinson and Copson 2014) and cage traps.

Use of sodium fluoroacetate (Compound 1080) as the principal toxin for fox and cat control in Australasia is limited in some circumstances by risks of inadvertent and

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irreversible poisoning of native wildlife and domestic pets. As an alternative toxin to 1080, para-aminopropiophenone (PAPP) offers demonstrably improved welfare outcomes for cats and foxes (Marks et al. 2004; Murphy et al. 2007), which is becoming an increasingly important criterion in the selection of pest control methods, including toxins (Littin et al. 2004; Sherley 2007; Bengsen et al. 2008). PAPP was originally investigated as a prophylactic and antidote against cyanide poisoning in humans (Rose et al. 1947). Ingestion of PAPP causes methaemoglobinaemia, the oxidation of the red blood cells so that they cannot carry oxygen (Marks et al. 2004). The rapid depletion of oxygen to the brain causes central nervous system failure followed by lethargy. Where the dose is sufficient, these symptoms are followed by unconsciousness and cardiac arrest, within approximately 60 minutes for foxes (Marks et al. 2004) and an average of 100 minutes for cats (Murphy et al. 2007). Foxes ingesting sublethal doses metabolise the toxin and emerge unharmed from their drowsy or unconscious state with no persistent effects (Marks et al. 2004).

The oral lethal dose $(LD)_{50}$ of PAPP for cats has been measured at 5.6–34 mg/kg and for dogs/foxes at 7.5–43 mg/kg, depending on whether experimental animals had been fasted or not (Murphy et al. 2007; Fisher et al. 2008). PAPP is selective for mammalian carnivores, with cats and foxes over 15 times more sensitive than dama wallabies and brush-tailed possums (*Trichosurus vulpecula*) (Savarie et al. 1983; Murphy et al. 2007; Fisher et al. 2008), so the toxin carries a reduced non-target risk compared with broad-spectrum 1080. Furthermore, the toxic effects of PAPP can be readily reversed by an antidote, methylene blue, allowing treatment of non-target wildlife or domestic animals that are inadvertently poisoned (Eason et al. 2010). The antidote is most successful if administered intravenously once symptoms of toxicoses are observed.

This study documents pen trials of four different grooming traps designed to deliver a lethal dose of PAPP gel onto the fur of cats and foxes. As distinct from the tray- or wick-style passive applicators previously used for grooming delivery of toxins (Hale and Myers 1970), these grooming traps are the first active toxin dispensers designed specifically for controlling feral cats. The devices are based on the propensity of cats to instinctively groom foreign substances from their fur. Our hypothesis was that humane death would result from ingestion of PAPP gel administered to the coats of feral cats and foxes. This novel approach to killing feral cats, and possibly foxes, could provide an additional humane and target-specific technique to reduce the impact of both exotic species on biodiversity and production values in Australia.

## 2. Methods

### 2.1. Delivery mechanisms

We assessed the behavioural responses of cats to four grooming trap designs:

(1) "Large pipe" was a pipe of 270 mm internal diameter and 850 mm long, fitted with a Highlander automated liquid soap dispenser (BL-0504A) positioned midway along the top of the pipe, which was triggered by a vertical 50-mm infrared (IR) proximity sensor whose beam was broken when the cat entered the pipe.

(2) "Small pipe" was a smaller diameter pipe (180 mm) using the same soap dispenser as above.

(3) "Walk past" grooming devices (Plate 1) were an array of sensors built into a box or post designed to target animals with rump and shoulder height intercepting passive infrared beams from midline sensors at 23 cm above ground level and a separation of 14 cm. In order to block firing at taller non-target animals, an upper centrally-located blocking sensor was positioned 40 cm above ground level and the unit did not activate if the IR beam from this sensor was broken. Similarly, non-target animals without a clearance between their belly and the ground of greater than 4 cm intercepted a lower blocking IR beam that also deactivated the unit (Plate 1). The instant that the two midline sensor beams were broken, and the upper and lower sensors remained unbroken within their detection range of approximately 600 mm, a solenoid triggered a pressurised canister to deliver the toxin through an external nozzle.

(4) "Baited cage" was a modification of the Connovation "Spitfire" design that employed a similar trigger and delivery mechanism to the "walk past" grooming devices but used food bait and a wire cage, open at one end and the top, to direct cats within range of the PAPP dispensing nozzle.

Foxes were only tested with the walk past traps that proved optimal for cats.

### 2.2 Poison formulation

A 100-mg dose of PAPP, which is lethal to cats (Murphy et al. 2007), can be delivered in 0.25 mL of a 40% gel formulation or 1 mL of a 10% formulation. Marks et al. (2004) reported that 226 mg of PAPP was lethal to foxes up to 8 kg in weight with a mean time to death of 43 minutes following ingestion. Rapid adsorption of ingested PAPP-containing gel through self-grooming was estimated to deliver doses of around 30 mg/kg to cats and around 40 mg/kg to dogs or foxes (Marks et al. 2004; Murphy et al. 2007). We used a 700-mg dose of 280 mg (40%) of PAPP held in suspension in viscous gel made from green-dyed food grade oil. The 280 mg dose of PAPP was predicted to be sufficient to kill the largest cats and foxes that were trialled, which weighed less than 8 kg, whilst allowing for incomplete grooming of gel delivered onto fur.

### 2.3. Experimental design

Wild-caught cats and foxes were housed separately in roofed netting pens 15 m × 10 m equipped with continuous video footage capabilities at the Department of Environment and Primary Industries Keith Turnbull Research

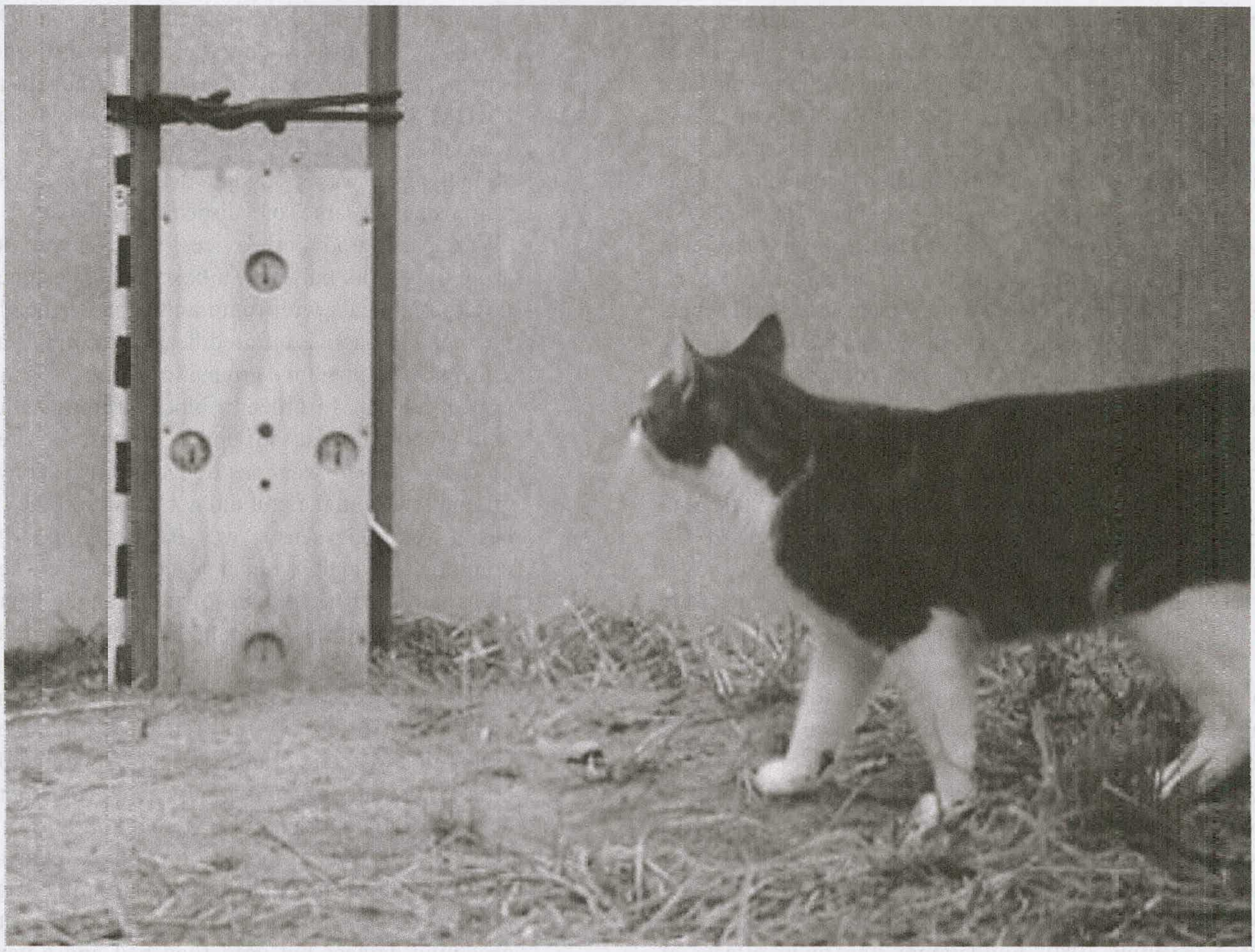

Plate 1. Feral cat approaching the “walk past” grooming trap prototype. *Source*: John Read.

Institute facilities at Frankston, Victoria. Foxes and cats were acclimatised for at least 24 hours in holding pens prior to entering the test pens. All pens contained water, food and a covered shelter site and all husbandry and experimental procedures were covered by Ethics permit 10/11, issued by the Victorian Department of Primary Industries Wildlife and Small Institutions Animal Ethics Committee.

Individual cats were put through a series of pens in sequence over a 4-night period. On the first night of the trial, cats were free to explore all four grooming trap designs in a deactivated state in the same pen to desensitise themselves to the objects. On the second night animals were moved, by enclosing them in their day shelter, to an adjacent pen that contained the same four activated trap types without PAPP gel (“dry fire”). Interactions with each trap type were recorded by counting light flashes attached to each grooming trap on video and still photo footage from cameras mounted side-on (video) and above (still) the traps. Both the video counts and analyses of the still footage was used to document animal interactions with the “dry fire” grooming traps for the first 6 hours after the animals left the day shelter. On nights 3 and 4 the cats were then exposed to either “live fire” walk-past or baited-cage grooming traps.

Only two foxes could be tested using the walk-past trap due to operating inefficiencies. In the remaining 10 fox trials the animals were restrained using a catch pole and 700 mg of PAPP gel was squirted onto the flank of the animal by hand syringe. To evaluate the effect of paste palatability on grooming rates in foxes, which appeared from initial trial animals to be less fastidious groomers than cats, the hand-syringed PAPP gel was flavoured with Vegemite® or sweetened condensed milk on five occasions each.

Video and still footage was examined to determine animal activity around devices and the times of activation, grooming, onset of visible symptoms of poisoning and last detectable movements. All experimental animals were inspected between 0700 h and 0800 h the following morning. Dead animals were examined for evidence of anoxia (pale grey gums and tongue) and any residual green PAPP gel on their fur before being weighed and measured. Animals surviving after two nights were euthanased by intracranial shot at close range with a .22 calibre rifle. All carcasses were laid on their side to simulate the morphology of a standing animal and the heights at shoulder and rump, and length from nose to rump, were measured.

## 3. Results

### *3.1. Behavioural trials*

There was a significant difference between the number of cat interactions with different grooming traps ($F = 4.34$, *d.f.* = 3, $P = 0.0096$), with pairwise comparisons

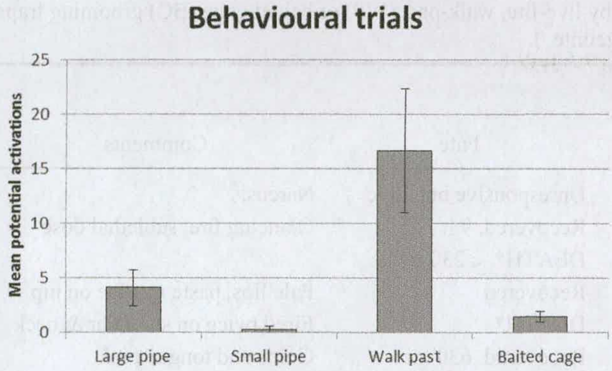

Figure 1. Potential activations (+ 1 SE) of different grooming trap designs assessed by mean number of cat interactions within firing range of each device in the "dry fire" trial.

confirming that the walk past design scored significantly more interactions than either the baited cage ($P = 0.015$) or small pipe ($P = 0.04$) (Figure 1). This pattern was confirmed in the subsequent dry-fire trials when the walk-past design was activated over four times and significantly more frequently ($T = 2.57$, $d.f. = 12$, $P = 0.02$) than the baited cage design (Figure 2). Cats were especially reluctant to enter the small diameter pipe, which was also the pipe most likely to restrict access by non-target medium-sized animals.

### 3.2 *Live-fire trial*

Fifteen of the 16 cats dosed with PAPP gel by activation of a grooming trap were observed grooming and 14 of these cats exhibited symptoms of anoxia, typically within 27 to 168 minutes (Table 1). Eight of the cats were dead the following morning (Table 1), with time from grooming to death estimated at 2.5 to 4 hours on three occasions. All poisoned cats captured on video were initially lethargic, then had difficulty walking (ataxia) before lying down and remaining largely motionless before either dying or waking from their sleep. The weights of cats that were poisoned (mean 3.4 kg, range 2.8–4.2 kg) were within the range of cats that recovered from partial doses (mean 3.3 kg, range 1.9–4.5 kg, Table 2). The most likely causes of sublethal doses were a partially blocked nozzle resulting in dispensing of a sublethal dose, or incomplete grooming – sometimes attributed to the poison gel being fired onto the neck where it was difficult to access. A kitten (1.9 kg and 21 cm shoulder height) passed under the midline sensors on 5 occasions without triggering the unit.

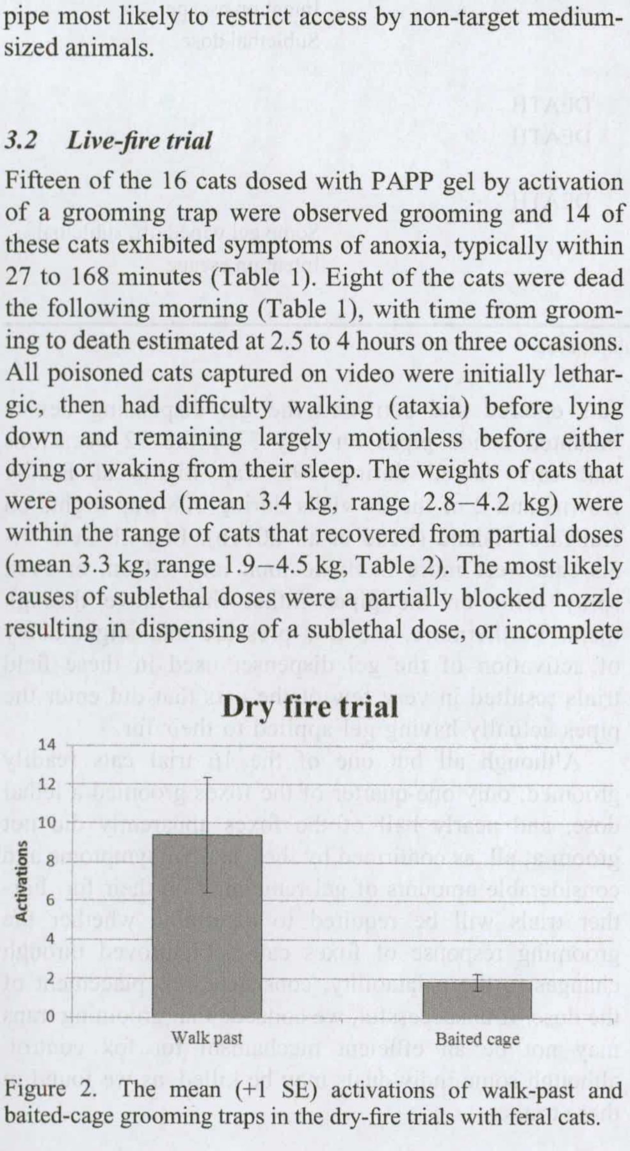

Figure 2. The mean (+1 SE) activations of walk-past and baited-cage grooming traps in the dry-fire trials with feral cats.

Seven of the 10 trial foxes that were manually dosed with PAPP gel exhibited grooming behaviour or symptoms of poisoning, with 3 of these animals ingesting a lethal dose (Table 1). Two of the lethal doses were with Vegemite® flavoured gel and once with condensed milk flavoured gel (Table 1). Despite use of flavoured gel, 5 foxes were not observed or suspected of grooming and 4 only partially groomed and received sublethal doses (Table 1). The mean weight of the 3 foxes that received lethal doses was 5.7 kg, which was slightly heavier than the mean weight of 5.2 kg for the 4 foxes that groomed yet received a sublethal dose. There were no signs of retching or convulsions during toxicosis, although mild distress was evident in some cases prior to collapse due to incapacitation.

Despite the reliable initial operation of some test units, live-fire pen trials for 6 cats and 7 foxes were thwarted by the units not firing when the target animal should have activated them. Likely causes of these issues included sensors that were dirty, misted due to rain or exhibited variable sensitivity, a blocked nozzle, or insufficient gas pressure. On a further three occasions the dose missed the target when foxes ran past the units before they activated.

Fifteen of the 16 inferred shoulder heights derived from measuring cat carcasses used in the trials ranged from 23 to 31 cm, with the shoulder height of one kitten only measuring 21 cm (Table 2). The lowest belly clearance of any of these cats was 6 cm, whereas the belly clearance of foxes ranged from 19 to 26 cm. The maximum inferred shoulder height of 19 of the 20 foxes ranged from 31 to 38 cm, with one tall fox measuring 41 cm at shoulder height (Table 1).

## 4. Discussion

Poisoning by PAPP in eight cats during these grooming trap pen trials was the first demonstration of the automated delivery of toxin to cat's fur, followed by its ingestion through grooming and subsequent death. As predicted, poisoning and subsequent death appeared humane in all cases, without obvious sign of pain. We demonstrated that the success of the grooming-induced poisoning was unrelated to the size of the trial cats but rather likely reflected differences with the placement or dose of the toxin on the cat and subsequent grooming behaviour. Both of these issues should be readily resolved by modifications to the type and positioning of the sensors and the delivery mechanism as discussed below. Incomplete grooming, which was suspected in four cases where cats recovered from a sublethal dose and retained some gel on their coat, may be remedied by improving the palatability of gel. Very little or no residue was apparent on the coats of cats that succumbed to the dose.

The 50% death rate of cats from this grooming trap trial is a lower percentage than the 18 of 20 cats (0.9–3.9 kg)

Table 1. Details of cats (C) and foxes (F) and their response to dosing by live-fire, walk-past (WP) or baited-cage (BC) grooming traps or syringe application (sweet = sweetened condensed milk; yeast = Vegemite®).

| Animal | M/F | Weight (kg) | Trial | Time to grooming (min) | Time to symptoms (min) | Fate | Comments |
|---|---|---|---|---|---|---|---|
| C1 | M | 3.1 | BC | 8 | < 622 | Unresponsive but alive | Narcosis |
| C2 | M | 3.3 | WP | 16 | 61 | Recovered, 9 h | Glancing fire, sublethal dose |
| C2 | M | 3.3 | WP | | | DEATH* < 230 min | |
| C3 | F | 2.3 | WP | 19 | 27 | Recovered | Pale lips, paste residue on hip |
| C4 | M | 4.0 | WP | 20 | 102 | DEATH* | Fired twice on shoulder & neck |
| C5 | M | 3.9 | WP | 80 | 171 | Recovered, 630 min | Gums and tongue pink |
| C6 | M | 3.9 | WP | 2 | nil | No symptoms | Partial grooming |
| C7 | M | 3.3 | BC | | | Unaffected | Paste on RH shoulder |
| C8 | F | 3.1 | WP | 3 | | DEATH* | Dosed twice |
| C9 | F | 3.3 | BC | 57 | 131 | DEATH > 189 min | |
| C10 | M | 4.5 | WP | 4 | 186 | Recovered* | Paste on right neck |
| C12 | M | 4.2 | WP | | | DEATH* | |
| C14 | M | 3.2 | WP | 1 | 29 | DEATH > 154 min | |
| C15 | F | 2.8 | WP | 6 | 95 | DEATH | |
| C16 | F | 2.7 | WP | | | DEATH | |
| C17 | F | 2.2 | WP | | < 316 | Recovered | |
| F1 | M | 6.1 | WP | 3 | 186 | Recovered | Pale gums, nozzle blocked |
| F4 | F | 4.3 | WP | | | Recovered | Sublethal dose |
| F31 | M | 4.7 | sweet | DNG | | | Intent on escape |
| F32 | M | 6.5 | yeast | yes | | | Sublethal dose |
| F33 | F | 5.5 | sweet | DNG | | | |
| F34 | M | 5.5 | yeast | yes | 19 | DEATH | |
| F35 | M | 6.3 | yeast | yes | < 27 | DEATH | |
| F36 | F | 5.5 | sweet | DNG | | | |
| F41 | F | 5.2 | sweet | yes | 35 | DEATH | |
| F42 | F | 3.8 | yeast | yes | no | | Some gel wiped off, sublethal |
| F43 | M | 6.9 | yeast | DNG | | | Intent on escape |
| F45 | F | 6.2 | sweet | DNG | | | |

DNG indicates grooming was not observed or evident. *Possibly affected by multiple dose.

that died consuming PAPP in a meat bait, where death occurred between 37 min and 4 h (Murphy et al. 2007). Ten of 14 dogs (14–30 kg) died from PAPP poisoned meat bait consumption in 71 min to 3.5 h (Murphy et al. 2007) and the mean time to death of foxes from a PAPP trial delivered by another oral delivery device, an M-44 ejector, was 43 min (Marks et al. 2004). As such, the time to death was similar in the current study, although the frequency of death was reduced, probably due to the current inconsistency of dose presentation on the animal and grooming ingestion being less efficient in some cases than direct ingestion of baits or toxins. Although delivery of lethal doses was on occasions compromised by suboptimal doses or grooming efficiency, we are confident that grooming traps present a novel and useful technique to poison cats that are not hungry or are otherwise reluctant to consume meat baits.

Significantly greater activation rates of walk-past grooming trap prototypes than piped or caged prototypes is probably explained by an aversion of feral cats to enter confined spaces. Low inferred activation rates of the pipe devices in pen trials reported here concurred with limited entries in two non-toxic field experiments in South Australia. In these trials, wild cats entered and activated the gel dispensing device mounted inside pipes on only 3 of the 72 occasions that cats visited during 393 trap nights at Roxby Downs and 2 of the 26 visits during 208 trap nights on Kangaroo Island (Read et al. 2011b). In both field trials cats were more likely to look into, sit on, or even spray urine on the pipes rather than move through them. Furthermore, the low pressure and slight delay of activation of the gel dispenser used in these field trials resulted in very few of the cats that did enter the pipes actually having gel applied to their fur.

Although all but one of the 16 trial cats readily groomed, only one-quarter of the foxes groomed a lethal dose, and nearly half of the foxes apparently did not groom at all, as confirmed by their lack of symptoms and considerable amounts of gel remaining on their fur. Further trials will be required to determine whether the grooming response of foxes can be improved through changes to the palatability, consistency or placement of the dose. If unsuccessful, we concede that grooming traps may not be an efficient mechanism for fox control, although some individuals may be killed, as we found in these trials.

Table 2. Gender and morphometrics of cats (C) and foxes (F) used in this trial.

| Animal number | M/F | Weight (kg) | Shoulder height (cm) | Belly clearance (cm) |
|---|---|---|---|---|
| C1 | M | 3.1 | 28 | 15 |
| C2 | M | 3.3 | 28 | 15 |
| C3 | F | 2.3 | 24 | 11 |
| C4 | M | 4.0 | 26 | 9 |
| C5 | M | 3.9 | 26 | 13 |
| C6 | M | 3.9 | 30 | 14 |
| C7 | M | 3.3 | 26 | 10 |
| C8 | F | 3.1 | 26 | 10 |
| C9 | F | 3.3 | 25 | 12 |
| C10 | M | 4.5 | 31 | 15 |
| C12 | M | 4.2 | 28 | 15 |
| C13 | M | 1.9 | 21 | 8 |
| C14 | M | 3.2 | 30 | 14 |
| C15 | F | 2.8 | 26 | 12 |
| C16 | F | 2.7 | 23 | 12.5 |
| C17 | F | 2.2 | 23 | 12 |
| F1 | M | 6.1 | 37 | 21 |
| F2 | M | 6.1 | 41 | 22 |
| F3 | F | 4 | 32 | 20 |
| F4 | F | 4.3 | 31 | 20 |
| F5 | M | 5.6 | 38 | 23 |
| F8 | F | 5.4 | 35 | 21 |
| F10 | M | 6.4 | 35 | 24 |
| F13 | M | 5.4 | 37 | 26 |
| F27 | M | 3.7 | 32 | 19 |
| F28 | M | 3.4 | 34 | 21 |
| F31 | M | 4.7 | 31 | 18 |
| F32 | M | 6.5 | 34 | 20 |
| F33 | F | 5.5 | 34 | 20 |
| F34 | M | 5.5 | 35 | 21 |
| F35 | M | 6.3 | 36 | 23 |
| F36 | F | 5.5 | 32 | 19 |
| F41 | F | 5.2 | 32 | 20 |
| F42 | F | 3.8 | 33 | 20 |
| F43 | M | 6.9 | 36 | 21 |
| F45 | F | 6.2 | 35 | 22 |

Although the walk-past grooming trap was the most successful design, several modifications to the sensors and delivery mechanisms are required to improve the efficiency of this control technique. First of all, should subsequent designs continue to use sensor arrays as a trigger, the midline "activation" sensors need to be separated further to ensure that target animals are side-on when approaching the grooming trap. Initial trials with closely spaced midline sensors resulted in the toxic gel glancing the cats and hence falling off their fur, or hitting their neck where thorough grooming proved difficult. We found that the lower "disabling" sensor was readily dirtied by dust or rain splash that unintentionally deactivated the unit. Providing a skirt at ground level and an adjustable sensor array that could be tailored for local conditions and non-targets, including removing this lower sensor in locations where low-slung non-target species are not present, would alleviate this problem. Second, the delivery mechanism needs to ensure that gel is not able to dry or solidify in the nozzle and thus produce a lower than specified dose.

We have demonstrated that the novel concept of grooming traps has the potential to be a valuable, humane and targeted technique for delivering toxins to feral cats; however, we were unable to support the value of grooming traps for foxes. Key advantages of the walk-past grooming traps over conventional cat control techniques include:

(1) No physical barrier to deter access by cats;
(2) Ability to use non food-based lures to dose target animals when they are not hungry;
(3) Improved target specificity by preventing smaller and larger non-target species from being sprayed;
(4) An adjustable sensor array to allow tailoring for local conditions and non-target species;
(5) Instantaneous administration of a measured dose of a humane poison; and
(6) Potential to deliver multiple lethal doses over extended periods without intervention or disturbance.

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