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Efficacy of lethal-trap devices to improve the welfare of trapped wild dogs

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Abstract

Context. Wildlife and pest managers and stakeholders should constantly aim to improve animal-welfare outcomes when foot-hold trapping pest animals. To minimise stress and trauma to trapped animals, traps should be checked at least once every 24 h, normally as soon after sunrise as possible. If distance, time, environmental or geographical constraints prevent this, toxins such as strychnine can be fitted to trap jaws to induce euthanasia. However, strychnine is considered to have undesirable animal-welfare outcomes because animals are conscious while clinical signs of intoxication are present. A toxin considered more humane, para-aminopropiophenone (PAPP), is available to induce euthanasia in trapped animals but is untested for presentation and efficacy.

Aim. We tested the efficacy of two types of lethal trap device (LTD's), each using a paste formulation of PAPP as the active toxin to replace the use of strychnine on foot-hold jaw traps.

Methods. Elastomer LTDs and PAPP-cloths were fitted to jaw traps set to capture wild dogs (*Canis familiaris*). Camera-trap data was used to record animal behaviours after capture and to determine the efficacy of both modalities.

Key results. Every trapped wild dog ($n = 117$) gnawed at the elastomer LTD's or PAPP-cloth attached to the trap jaws that restrained them; one dog failed to liberate the toxin. From the dogs caught in the main trial ($n = 56$), a mortality rate of 84% and 87% was reported respectively. The mean time from trap-to-death for elastomer LTDs was 64 min and 68 min for PAPP-cloths.

Conclusions. Elastomer LTDs and PAPP cloths combined caused the mortality of 85% of captured dogs. This efficacy could be improved by adopting the recommendations discussed in the present study for deploying PAPP-based LTDs during trap deployment.

Implications. PAPP-based LTDs offer an alternative option to the use of strychnine and improve the welfare outcomes for trapped predators, especially where traps are not checked within the recommended 24-h period.

Additional keywords: canids, trapping, pest management, control, humaneness, predator, LTD.

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Introduction

Introduced predators are regularly trapped throughout Australia using soft jaw traps (hereafter known as foot-hold traps) for the purposes of agricultural protection and conservation. Animal-welfare concerns associated with trapping include direct impacts from the trap and issues associated with the amount of time an animal is restrained before euthanasia. To address the former, steel jaw traps are being superseded by more humane alternatives, with padded foot-hold traps (Meek *et al*. 1995). Victor Soft Catch® #3, along with padded Jake™ and Bridger traps (Minnesota Trapline Products, Inc.) being now commonly used in Australia (Meek *et al*. 2018) to minimise pain and suffering caused to trapped animals. To minimise the amount of time that animals are held in traps, most jurisdictions require daily trap checking, but even this can be too long in extreme conditions; hence, the ongoing practice of wrapping strychnine-impregnated cloths (hereafter referred to as 'strychnine cloths') around trap jaws to quickly kill trapped animals (Fleming *et al*. 2001).

In 1977, the New South Wales Health Commission gave permission to dog trappers in the Western Division to use strychnine impregnated cloths on the jaws of traps, although the technique had already been used unsanctioned for decades. Fleming *et al*. (2001) reported that this practice was also used in Western Australia, South Australia and Queensland, and recommended that a more humane poison should be developed as an alternative to strychnine. Similarly, Sharp and Saunders (2008), in developing Codes of Practice for pest animal control, recommended that strychnine was an unacceptable toxin on animal-welfare grounds. Further, they recommended that it should be phased out as soon as a suitable alternative was available. Most predator traps set throughout Australia do not have strychnine cloths fitted (Meek *et al*. 2018).

International research (e.g. Fagerstone and Keirn 2012) has focussed almost exclusively on tranquiliser-trap devices (TTD) rather than lethal-trap devices (LTDs). Whereas Australia was using strychnine cloths in trapping programs for control purposes, other countries, e.g. the United States of America developed TTD to ensure that captured animals were relatively uninjured when released for research purposes (Balser 1965). Originally TTDs were formulated as cloth tablets (Balser 1965); however, Linhart *et al*. (1981) subsequently tested a moulded rubber nipple containing the active chemical, e.g. diazepam or propiopromazine hydrochloride. After that, use of cloth-style TTD's in North America largely gave way to rubber structures (Sahr 1997; Sahr and Knowlton 2000; Marks *et al*. 2004*a*). Use of TTD's was eventually encouraged on animal-welfare grounds and to protect the ongoing use of carnivore traps in the USA (Zemlicka and Bruce 1991).

A key cross-over between Australia's use of LTD's and international development of TTD's occurred when Marks *et al*. (2004*a*) evaluated the efficacy of TTD's on traps used for controlling European red foxes (*Vulpes vulpes*) and wild dogs (*Canis familiaris*). In response to this, and to the growing concern over the use of strychnine for invasive-species management in Australia, a project originally conceptualised by Dr Clive Marks was commenced to evaluate LTD's that contained fast-acting toxins, such as hydrogen cyanide in paste formulation, to improve welfare outcomes for trapped invasive predators. Initial LTD designs included plastic tubes cable-tied or wired to jaws designed by Dr Lee Allen and Mark Goullet; however, these ruptured too easily or leaked in hot conditions, so the development of an LTD design continued. In 2013–14, one of the authors (PM) imported some McBride TTDs from the USA and tested whether they would be an effective delivery system for para-aminopropiophenone (PAPP) in a gel or paste-based toxin formulation.

Para-aminopropiophenone is approved for use in manufacturing predator baits that are available throughout Australia and is considered to be relatively humane (APVMA 2015) because of its mode of action, i.e. inducement of methaemoglobinaemia. PAPP essentially reduces the oxygen-carrying capacity of blood, leading to a lethal deficit of oxygen in the heart and brain, with death achieved relatively quickly (see McLeod and Saunders 2013 for summary). Typically, the reported time to death for a toxic dose of PAPP for *C. familiaris* is 30–120 min (Vandenbelt *et al*. 1944; Dall and Spencer 2006) and for *V. Vulpes*, the mean times of 43 min (Marks *et al*. 2004*b*) and 53.8 min (Dall 2006) have been reported. Incorporation of PAPP into LTD's was a logical extension (Marks *et al*. 2004*b*) of the approval of this product as a predacide active constituent.

In 2014–16, in collaboration with Connovation Ltd and Siltech Ltd in New Zealand, we developed and refined a new LTD design that contained a PAPP formulation that could be safely secured to trap jaws by trappers. The objectives of the present study were to pilot and field test this new PAPP-based LTD design and a PAPP-based cloth system on traps set to catch wild dogs.

Materials and methods

The study site was the Moomba Gas Fields in the Cooper Basin, 28°07′25.91″S, 140°11′45.65″E, Australia. The Cooper Basin is located in north-eastern South Australia, north of Lyndhurst and south of Innamincka. The climate is hot and dry, with an annual rainfall of 200–300 mm, and temperatures ranging from 0 to 60°C throughout the year (www.bom.gov.au/climate/dwo/IDCJDW5038.latest.shtml, accessed 5 January 2019). Soils are predominately clay-rich vertosols and kandosols, with dune systems and low-lying wetlands. Vegetation comprises sparse shrubland and scattered grasslands. The toxic LTD trials were conducted around a waste-management facility where the abundance and density of wild dogs was very high.

Pilot trials

Two pilot trials were conducted at Moomba in 2015–16, for the purpose of refining both the LTD design and PAPP toxicology. The trials tested elastomer LTD strength and design, and PAPP-delivery efficacy. The trials led to a stronger and better-designed elastomer LTD, stronger cable ties and attachment and changes to the PAPP paste to improve uptake. The subsequent elastomer LTD design was used in the main trial and is reported hereafter.

Field trials

Following pilot trials to refine the elastomer and PAPP paste, the elastomer matrix of the LTD was changed to a stronger-quality elastomer (see *Elastomer lethal-trap devices*, below), so that dogs could not unintentionally liberate the contents before ingestion. The PAPP concentration was increased and mixed with both dimethyl sulfoxide (DMSO) and a sweet carrier to optimise uptake. For continuity with current practice of affixing cloths containing strychnine to trap jaws, PAPP-cloths (see below) were included in the field trials.

PAPP toxicology

The toxin PAPP (para-aminopropiophenone; 1-(4-aminophenyl)-1-propanone) is registered as an approved agricultural chemical that is used to make predator baits, such as, for example, Dogabait® wild-dog bait and Foxecute® fox bait (APVMA 2015). These baits are restricted chemical products (RCPs) under Section 93 of the Australian Agvet Code (www.apvma.gov.au/node/988, accessed 5 January 2019).

In both LTD and cloth applications, the PAPP (100% weight) was mixed with DMSO to optimise transport of PAPP across the oral and buccal mucous membranes, and with an inert carrier (1.8 g PAPP : 0.25 g DMSO : 0.45 g carrier). The specific product details of the PAPP paste used in both modalities are commercial in confidence and belong to the manufacturer and supplier, Connovation Ltd, Auckland, New Zealand. A colourless liquid, DMSO is an organosulfur compound (CH_3) used in medical and veterinary fields as a solvent or to reduce inflammation. It is an important polar aprotic solvent that dissolves both polar and non-polar compounds and is miscible in a wide range of organic solvents as well as water (Lide and Milne 1994). Those properties were expected to dramatically increase the absorption of a chemical such as PAPP, which is highly insoluble in water (Yalkowsky and He 2003). DMSO is an approved chemical for inclusion in veterinary medicines (accessed 5/1/19, www.tga.gov.au/book-page/22-dimethyl-sulfoxide-dmso, accessed 5 January 2019).

Basic temperature-stability tests were undertaken on the PAPP formulation in the Connovation Laboratory, (Auckland, New Zealand) in 2016. The PAPP formulation was applied to calico cloth and placed in a freezer (−30°C) for 24 h and a kiln (55°C) for 24 h, to evaluate the potential effects of temperature on the formulation. The formulation did not change under either condition and the PAPP-paste integrity remained consistent. Further stability trials are being conducted at the time of writing to conform to APVMA guidelines (APVMA 2015).

Animal trapping and handling

Five models of foot-hold traps were used in the trial (Victor Soft Catch® #3, Bridger #5, Jake™ and MB650 (Minnesota Trapline Products, Inc., MN, USA.), and New Lanes (Stockbrands Co P/L, Perth, Australia)), although the main model used were Victors. In accordance with best practice, each trap had off-set jaws lined with rubber padding to minimise injuries to captured animals. Traps were all fitted with after-market T-bar springs and crunch-proof swivels attached to chain less than 0.3 m in length. All traps were double-staked to the ground to prevent animal escape. Traps were set at holes in fences without lures and along tracks with lures. A variety of lures were used, including urine, synthetic manufactured lures and rotting food lures. Traps were checked early each morning and multiple times throughout the day, until early evening.

When a live, trapped dog was detected during the day, it was left for 2–3 h so as to determine whether PAPP had been ingested and to permit visual evaluation of toxicosis. If no signs of toxicoses were evident after 3 h, it was deemed unlikely that a lethal dose had been ingested. Any trapped animal not exhibiting acute methaemoglobinemia was euthanised in accordance with our animal ethics approval.

Elastomer lethal-trap devices

Elastomer LTD's each contained 2.5 mL of PAPP paste and were manufactured to the author specifications (Fig. 1) by Siltech Industries Ltd, Auckland, New Zealand. The authors all contributed to refinement of the final design, which was developed with key consideration given to how LTD's could be attached to jaws, and how the PAPP matrix could be contained with a suitably robust elastomer selected for field deployment. Ultimately, the elastomer used in the LTD's had the following properties: specific gravity = 1.15, tensile strength = 10.6 MPa, tear strength = 51 kN m^{-1} and brittle point = 73°C. The particular strength of the elastomer (Elongation 785%) was chosen to force dogs to chew at the nipple over some time to increase the probability of exposure to, or consumption of, a lethal dose. In each elastomer LTD, the PAPP paste was contained in the nipple by a small steel disc that was plugged and then sealed using an elastomer sealant. When the LTD was fitted to the trap, the disc side sat flat against the jaw surface, thereby preventing the LTD from moving laterally and liberating the paste.

Electronic cable ties (200 × 7 mm) were used to affix each LTD to a trap jaw such that the nipple faced into the ground until the trap was triggered (Fig. 2). Post-triggering, the nipple was easily accessible to the trapped animal and, by facing side-ways, reduced PAPP spillage once the nipple was punctured. This positioning also resulted in a smaller LTD surface area being exposed to trap bedding material (soil) when setting the trap,

Fig. 1. Two elastomer lethal-trap devices (LTDs), each showing a nipple filled with a para-aminopropiophenone (PAPP) formulation.

Fig. 2. A Victor® soft catch trap (see text), with the nipple from an elastomer lethal-trap device (LTD) successfully removed by a trapped wild dog. Note the LTD is fitted to the lazy jaw (not the jaw attached to the springs) so that it faces down when the trap is set.

reducing the chance of the LTD slowing trap-closure time (Meek *et al*. 2018).

PAPP cloths

The PAPP cloths comprised a piece of calico cloth (~6 cm × ~20 cm) that had PAPP paste applied onto half of one surface. The mass of PAPP paste applied to the cloth was ~3 g. The cloth was then wrapped around the jaw of the trap, such that the PAPP-impregnated section was covered by one layer of cloth that was free of the PAPP paste (Fig. 3).

Camera trapping

Camera traps (Table 1) were used at all trap sites to record data on the process of capture, toxin exposure and/or ingestion, toxicosis and mortality, so that the time from capture to PAPP ingestion to death could be quantified. Camera-trap settings used are reported in accordance with (Meek *et al*. 2014; Table 1).

Camera traps were located on a tripod secured to the ground, with pegs at ~0.5 m above the ground level and ~5–6 m from the foot-hold trap set. All images and videos from camera traps were reviewed by PM and the time of capture, probable time of consumption (determined by observed tearing of the LTD nipple or cloth and visual confirmation of chewing and licking of the trap jaw), visual and vocal evidence (where this function was available on the camera trap model) of ataxia, prostration, salivation and death or recovery were recorded. Visual evidence of ataxia (defined by Vandenbelt *et al*. (1944) as occurring when dogs reach ~60% methaemoglobin saturation) included involuntary body movements and was sometimes accompanied by vocalisations. Salivation and prostration (defined by Vandenbelt *et al.* 1944 as occurring when dogs reach ~75% methaemoglobin saturation) were easily observed in footage. The time between loss of responsiveness (>80% methaemoglobin saturation) and death (>90% methaemoglobin saturation) was sometimes difficult to determine from the camera-trap footage.

Fig. 3. A Victor ® soft catch trap (see text) fitted with a para-aminopropiophenone (PAPP)-cloth.

Table 1. Description of the camera traps used in the trials at Moomba 2015–17
H, high; N, yes; N, no

Brand	Model	Still (S)/ video (V)	Number of photos	Video length	Delay	Sensitivity	Sound
Reconyx	HC600	S	10	–	Nil	H	N
Reconyx	HC500	S	10	–	Nil	H	N
Reconyx	XR6	V	–	30s	Nil	H	Y
Uovision	565	V	–	60s	Nil	H	Y

Camera traps detect animals by comparing the background temperature signature compared with a moving subject's heat signature (Meek *et al*. 2015). When an animal reached the prostration-loss of responsiveness and/or consciousness stage of methaemoglobinemia, it was challenging to estimate time of death because the diaphragm moments were too shallow for the camera trap to detect and no image was triggered. When this occurred, we calculated the most probable time of death on the basis of subsequent triggers (sequences of images) of the camera by other dogs walking past the trap site. Using 10 photos per trigger allowed a near-video inspection of the dog's chest to detect movement caused by breathing.

Evaluating LTD efficacy

The following two metrics were used to evaluate both the elastomer LTD's and PAPP-cloths:

(1) trap-to-death = the time in minutes from capture until mortality. Where PAPP ingestion was discernible, the time from ingestion until death was recorded.
(2) percentage efficacy = the proportion of the trapped population that ingested PAPP from an LTD or PAPP-cloth and subsequently died

Trap-to-death time was measured by reviewing camera-trap data and recording the time stamps at capture and death automatically embedded on the camera-trap image data (EXIF file data). In cases where camera traps did not trigger again for some time after an animal was initially recorded as captured, time of death could be estimated only from the next time an animal triggered the camera trap, e.g. when another dog walked past the trapped animal.

Observations of behaviour associated with ataxia were recorded to enable estimation of time from ingestion until external signs of methaemoglobinemia were apparent. We also documented behaviours observed immediately before death.

Because captured animals were sexed and weighed, a permutation ANOVA (Anderson 2001) (n permutations = 999) was performed on a standardised Euclidean-distance matrix of mass (kg) and trap-to-death duration (min), to assess interactions between sex and mode of delivery (LTD vs PAPP-cloth), irrespective of the sampling period.

Animal metrics

Mass, sex, coat colour and an estimate of probable age class were recorded for all captured wild dogs. Each trapped animal was also appraised for visible injuries to the trapped limb, which was palpated for obvious fractures and dislocations. Trapping-related injuries were scored according to the five-category method in Fleming *et al*. (1998).

Results

Animal metrics

In total, 117 dogs were captured and poisoned during four trapping periods from 2015 to 2017. They weighed between 9 and 24.5 kg ($\bar{x}$ = 15.9 kg, s.d. = 3.3), with males being slightly heavier (mean = 17.6 kg, s.d. = 2.7, Range = 11.5–24.5, n = 63) than females (mean = 15.9 kg, s.d. = 2.8, Range = 9–20, n = 56,) (t = 6.82, d.f. = 104, $P < 0.01$). In total, 61% of captures were on front feet (Table 2) and 98% of animals exhibited no injuries of Category 1 (minor) injuries, with two Category 3 injuries and one Category 2 injury occurring after capture.

Pilot trials: prototype elastomer LTD

During the first pilot trial, only 10 of 30 trapped dogs received a lethal dose of PAPP via elastomer LTD's. In the second pilot trial, 25% of 32 dogs received a lethal dose of PAPP via elastomer LTD's.

Field trial 2016–17: evaluation of efficacy

In total, 56 dogs were trapped during the main trials with the elastomer nipple described above, although we excluded three dogs in the final analysis (see below). Every trapped dog (100%) chewed the elastomer LTDs or PAPP-cloth affixed to the trap holding them. Mortality rates were 84% for trapped dogs exposed to elastomer LTD's and 87% for trapped dogs exposed to a PAPP-cloth (Table 3).

One animal (MOODOG-98) captured during the final elastomer LTD trial was not included in the efficacy assessment because it was inadvertently exposed to free water *ad libitum* during capture, thereby constituting a treatment different from that of all other animals in the trial. Likewise, it was recorded in the PAPP-cloth assessment that the first two traps were wrapped with substantially more cloth covering the PAPP-paste than all other deployments, so these captures were also removed from the assessment of PAPP-cloth efficacy (Table 3).

During trap checking, two dogs (MOODOG-108 and MOODOG-117) captured in traps fitted with PAPP-cloths were detected in a prostrate state with shallow breathing. *In situ* review of camera-trap data showed that MOODOG-108 had chewed on the PAPP-cloth and, subsequently, been prostrate for more than 3 h. In accordance with agreed animal ethics procedures, the animal was killed. We recorded the event as a non-lethal dose of PAPP but note that it seemed highly unlikely that the animal would have recovered from PAPP intoxication (*sensu* Nocturnal Wildlife Solutions 2006).

MOODOG-117 was trapped in the late afternoon and left in the trap for 2 h to allow time for the PAPP uptake to occur. When we returned after sunset the animal was prostrate, unresponsive and was experiencing very shallow breathing. Because of a high volume of dog activity around the trap site, the animal was removed from the trap to allow it to die without the possibility of being cannibalised alive (Meek and Brown 2017). We returned later to find the animal had partially recovered and was seen wandering across the rubbish facility in an ataxic state and efforts were initiated to kill the dog. We hypothesised that if we had not interfered with the animal, it would have continued to struggle to escape the trap, causing additional exertion, possibly consumed more PAPP during this process, and would have succumb to toxicosis. However, given the animal did not die, we recorded this event as a non-lethal result.

Average time from capture to mortality was 68 min for LTDs (s.d. 40 min; range 30–185 min; n = 27) and 78 min for PAPP-cloths (s.d. 45 min; range 24–187 min; n = 12). Two dogs, one in each treatment, struggled to access the toxin in the first 120 min post-capture and, subsequently, died more than 180 min post-capture. With these outliers removed, mean time to mortality for elastomer LTD's was 64 min (s.d. 33) and 68 min (s.d. 30) for PAPP cloths. Median trap to death values were 60 min for both treatments.

There was no significant difference in mass nor trap to death times between modes of delivery when sexes were combined (pseudo-$F_{1,35} = 0.24$, $P_{perm} = 0.74$); however, the interaction between sex and mode of delivery was significant (pseudo-$F_{2,35} = 6.80$, $P_{perm} = 0.001$), with pairwise results showing a difference between sexes for elastomer LTDs ($t_{25} = 3.19$; $P_{perm} = 0.001$), but not for PAPP-cloths ($t_{10} = 1.84$; $P_{Perm} = 0.056$). Further analysis showed a significant interaction between sex and mode of delivery when accounting for mass (kg) only (pseudo-$F_{2,35} = 12.81$, $P_{perm} = 0.001$). The elastomer LTD's killed more larger males than larger females ($t_{25} = 4.53$, $P_{perm} = 0.001$), but there were no significant size × sex interactions among dogs that ingested the PAPP-cloth ($t_{10} = 1.75$, $P_{perm} = 0.126$). There was no interaction between sex

Table 2. Trapped-foot capture statistics

Double foot captures occurred when dogs were caught in a second trap placed on the other side of a pop-hole in a fence, to maximise chances of capture. This was unexpected and, to prevent further double catches, traps were separated further. F, front; B, back; L, left; R, right

Captured foot	Number of dogs	% of dogs
BL	23	19.7
BL/BR	1	0.9
BR	22	18.8
FL	29	24.8
FL/BL	1	0.9
FL/BR	1	0.9
FL/FR	4	3.4
FR	33	28.2
FR/BR	3	2.6
Total	117	

Table 3. Elastomer lethal-trap device (LTD) and para-aminopropiophenone (PAPP)-cloth efficacy-trial summary data

Some animals were removed from analysis for each modality because of different treatments, i.e. *ad libitum* water and excessive cloth wrapping; the total number caught is shown in parentheses

Metric	Value
Total dogs caught	53 (56)
Total efficacy of combined toxin trial (LTD + cloth) (%)	85
Total number of dogs caught with elastomer LTD attached	38 (39)
Elastomer LTD efficacy (%)	84
Total number of dogs caught with PAPP-cloth attached	15 (17)
PAPP-cloth efficacy (%)	87

Table 4. Trap-to-death time by sex and two modes of para-aminopropiophenone (PAPP) delivery

Data were available only for a subset of the population because camera trapping did not always record the start and finish times. LTD, lethal-trap device; F, female; M, male

Mode	Sex	Sample	Range (min)	Mean (min)	s.d.
LTD	F	14	30–146	59	33
LTD	M	13	32–185	79	44
PAPP-cloth	F	6	24–78	56	20
PAPP-cloth	M	6	50–187	100	54

and mode of delivery on trap-to-death time (pseudo-$F_{1,35} = 0.42$, $P_{perm} = 0.567$; Table 4).

Because dogs did not always access PAPP immediately on capture, and imagery from camera traps did not clearly show PAPP consumption, these values were an estimated capture time-to-death for the two treatments using a series of camera-trap imagery.

Discussion

The present study has reported on the efficacy of two LTD's containing a PAPP formulation, namely, an elastomer LTD (Figs 1, 2), and a PAPP-cloth system (Fig. 3.). Like that of Marks *et al*. (2004*a*), these trials found that 100% of the 56 LTDs fitted to foot-hold traps were accessed by trapped dogs. For the elastomer LTD's, 84% of trapped wild dogs reached fatal methaemoglobinemia, taking an average of 68 min to do so and as little as 30 min. For the PAPP-cloth treatment, 87% of trapped dogs succumbed to fatal methaemoglobinaemia, taking, on average, 78 min to do so, although death could occur within 24 min. The authors acknowledge that their trapping method involved staking traps to the site and did not deploy any drags. However, we do not expect a different efficacy result from traps using drags because the ultimate end point of using a drag is for the animal to become entangled and essentially unable to escape the trap. There may be a difference in time from capture to death depending on how far the dog drags the trap but we cannot comment further without additional testing.

Since only dogs were captured, no observations could be made regarding the impacts of elastomer LTD's or PAPP-cloths on non-target species.

General observations

The mean time from capture to death for both treatments generally conformed to values published in the literature (Marks *et al*. 2004*b*; Dall and Spencer 2006; Lapidge *et al*. 2007; Eason *et al*. 2010). However, in the present study, unlike in laboratory trials, recording the actual time of PAPP consumption was relatively difficult. It appeared that some animals did not find the LTD immediately after capture because the position of their foot in the trap, but not whether it was front or rear, made it difficult to quickly access the elastomer LTDs nipple. In these cases the trapped dogs still liberated PAPP from the LTDs but took more than an hour to do so.

Some dogs showed signs of late-stage toxicosis (i.e. prostrate with very shallow, slow breathing), although they recovered from toxicosis. According to the descriptions of Vandenbelt *et al*. (1944), these behaviours are symptomatic of >80% methaemoglobinemia. We propose two possible reasons why some animals may have recovered. In one case, access to water *ad libitum* may have changed the pharmacokinetics of the biotransformation of PAPP to metabolite N-hydroxylaminopropiophenone or enhancing its excretion via urine, the primary route of elimination. Second, during these trials we observed dogs vomiting when captured soon (less than 10 min) after feeding at a local waste facility. First, we hypothesised that PAPP was regurgitated with the food, thus reducing the dose received. Second, since these observations were made during the whelping–weaning season, it is unknown whether digestion processes are different during this time (when regurgitation may be utilised to feed dependent young), therefore affecting metabolisation of PAPP.

The first two dogs exposed to the PAPP-cloth showed some signs of PAPP consumption, but did not receive a lethal dose because we had applied too much cloth over the PAPP-paste. Subsequent applications used only one complete wrap of cloth before fixing and successful mortality confirmed that this application technique was effective. We recommend that, if this method is approved for use, that cloth is wrapped around the jaw twice, PAPP-paste applied and then one wrap of cloth is wired to the jaw to contain the paste. This will ensure that gnawing by the dog will liberate the paste readily onto the oral mucosa.

The use of camera traps to determine when an animal received a dose of PAPP, and the final time of death was constrained because the passive infrared sensor (PIR) was unable to detect shallow breathing by dogs in the last stages of toxicoses. This meant that the authors had to estimate the time to death on the basis of camera trap triggers by dogs walking past the camera trap (it was very common for dogs to investigate trapped animals). As a result, the time to death was a conservative estimate, albeit within acceptable time frames reported in the literature because of the high abundance of dogs at the site and the short intervals between camera-trap triggers by passing dogs.

Conclusions

Our results confirmed that elastomer LTDs and PAPP-cloths can be used to effectively euthanase wild dogs in foot-hold traps, thus providing an improvement in welfare outcomes over the use of strychnine cloths. As such, they may represent a valuable addition to the suite of tools available for invasive-species management, subject to additional work to ascertain possible impacts on non-target species. Field-based trials conducted in sites where non-target species may interact with traps, such as, for example, spotted-tailed quolls (*Dasyurus maculatus*), are needed to evaluate the level of risk to some native species. Although additional trials could likely improve mortality rates from PAPP ingestion, these devices should not be considered as a surrogate for checking traps at least daily. Likewise, the adoption of LTD's utilising PAPP should not absolve practitioners of their responsibility to ensure other aspects of trapping, such as, for example, appropriate equipment choice, trap placement and being suitably prepared to manually kill trapped animals, are given necessary attention.

It is the responsibility of all trappers to uphold the highest level of best practice to ensure the best welfare outcome for trapped animals.

Conflicts of Interest

The authors declare no conflicts of interest in this research.

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