*Short communication*

# Novel use for a predator scent: preliminary data suggest that wombats avoid recolonising collapsed burrows following application of dingo scent

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**Abstract.** Southern hairy-nosed wombats (*Lasiorhinus latifrons*) are fossorial marsupials that live in large burrow systems where their digging behaviour brings them into conflict with agriculture. In the absence of any available control options, non-selective culling is the primary mode of wombat management. This approach is contentious and has unknown implications for long-term wombat conservation. Predator scents, however, have been effective in altering behaviours of some herbivores and may offer a non-lethal alternative to culling if they discourage wombats from burrowing in perceived problem areas. Therefore, we trialled two dingo scents (faeces, urine) over 75 days to determine whether these scents would deter wombats from repopulating collapsed burrows. Ten inhabited single-entrance burrows were excavated over three days (to allow time for inhabitants to exit), collapsed and then filled in. Five burrows, separated by at least 200 m, were used for dingo scent treatments (three urine; two faeces) and three burrows, separated by the same distance, served as negative controls (unscented), along with two 'farmer-monitored' active controls (dog urine and a dingo carcass). We used a rank-sum score to assess wombat activity: scratching was scored with a value of (1), digging (2), and recolonisation (5), with each value reflecting total energy and time spent in the vicinity of the treatment. We fitted Generalised Estimating Equations (repeated-measures, Fisher Method) to explain variation within, and across, treatment and control burrows. Within 20 days, all 10 sites had signs of wombat activity that ranged from fresh digging, to fully functional burrows. Among the five treatment sites, scratching and tracks identified wombats as being present, but they did not dig. After 75 days, the five sites treated with dingo scents had minimal activity and no new burrows, while wombats recolonised all control burrows. Though we used only 10 burrows for this preliminary study, our findings suggest the need for further testing of dingo scents as a tool for dissuading wombats from digging and recolonisation of collapsed burrows. This represents a novel use for a predator scent, in that prey may remain in the vicinity near the deterrent, but curb problematic behaviours of economic consequence.

## Introduction

Wombats are nocturnal, herbivorous, endemic Australian marsupials, and the largest burrowing mammal in the world (family: Vombatidae). With over 75% of their time spent below ground, wombats depend on burrows to survive the harsh Australian environment, including protection from the elements and potential predators such as dingoes (*Canis dingo*) (Finlayson *et al*. 2005; Crowther *et al*. 2014).

We focussed on southern hairy-nosed wombats (*Lasiorhinus latofrons*), which are distributed predominantly in South Australia, and serve as the state's faunal emblem. Their large burrow systems and digging behaviour can, at times, create conflict with agricultural practices. Surveys with local farmers indicated that nearly 80% of participants found wombats caused damage on their property, and that wombat burrowing behaviour was a major management issue, with nearly 75% stating that wombats were a 'problem' (Sparrow *et al*. 2011; Sparrow 2012). This was of particular concern when burrowing occurred in cropping paddocks and under infrastructure such as fences and water tanks. In addition to safety concerns of farm machinery falling into collapsed burrows (Fig. 1), damage to equipment and reduction in crop quality (due to delays in harvest), both lead to serious financial loss. Tank collapse also leads to a loss of water for stock, and fence damage can result in stock escaping.

**Fig. 1.** (Top) Location for 10 burrows selected for wombat scent trials, 2 km west of Nundaroo, South Australia. Treatments: Burrows 1, 5 and 29 were treated with *Canis dingo* urine; Burrows 6 and 18 were treated with *C. l. dingo* faeces; Burrow 4 was the active control #1 (*C. l. dingo* carcass); Burrow 15 was the active control #2 (*C. domesticus* urine); Burrows 13, 14 and 17 were the neutral controls (no scents). (Bottom) Digging burrows in cropping paddocks; this can result in expensive farm machinery (e.g. combine harvester) or vehicles falling into collapsed wombat burrows. This is not only a safety concern, but also a financial issue as such equipment can cost up to US$100 000 to repair, and crop quality is reduced due to the extra time then required before harvest.

Many of these agricultural properties are large (>5000 ha) and isolated, so maintenance and regular monitoring is difficult and time consuming (Sparrow *et al*. 2011; Sparrow 2012).

Currently, the primary management tool to reduce wombat impacts on agricultural land is culling (destruction permit required: *National Parks and Wildlife Act 1972*). Culling is a contentious and emotional issue for all stakeholders (landholders, regional community, general public, government, and conservation groups) (Litkin 2010). Landholders are concerned about the sustainability of their properties, whereas the general public are concerned about the influence of culling on the future of wombats (Sparrow *et al*. 2011), because the species' long-term viability is unknown (Temby 1998). Furthermore, when a 'problem' wombat is removed, either lethally or non-lethally, recolonisation often occurs within a short time (Borchard and Wright 2010; Sparrow *et al*. 2011; Sparrow 2012). Often it is this constant removal/recolonisation process that frustrates the farmers (Stott 1998).

Despite concerns for the long-term future of the species, primarily due to climate change (D. A. Taggart, unpublished results) and human persecution, little effort has gone into researching alternative management measures such as microscale olfactory or tactile repellents (Sparrow *et al*. 2011; Sparrow 2012). The southern hairy-nosed wombats is distributed largely on agricultural land (Ostendorf *et al*. 2012), and wombat management by farmers will have an influence on its long-term survival. Therefore, it is essential to develop tools that promote coexistence between wombats and farmers.

Predator scents (urine, faeces, dander, skin glands) are used to influence or modify behaviours for a wide range of herbivores on nearly all continents (Apfelbach *et al*. 2005). When animals respond to scents, their behaviours may be context-dependent, or attenuate over time due to habituation (Murray *et al*. 2006; Cox *et al*. 2010) or chemical degradation of the signal, as old scents convey a different 'biological meaning' than newer scents (Peacor 2006; Hegab *et al*. 2014). Due to these challenges, the long-term efficacy of olfactory stimuli will likely depend on either mixing predator scents with other modalities (optical, auditory or contact repellents) into compound management tools (i.e. multimodal approach:

Munoz and Blumstein 2012), or in finding novel ways to deploy them.

In Australia, herbivore responses to predator cues have been mixed. Native Australian rodents (*Rattus fuscipes*, *R. lutreolus* and *Pseudomys gracilicaudatus*) avoid faecal odours from tiger quolls (*Dasyurus maculatus*) and introduced red foxes (*Vulpes vulpes*), although the native brown antechinus (*Antechinus stuartii*) did not respond (Russell and Banks 2007). Parma wallabies (*Macropus parma*) respond aversively to a synthetic predator scent, while the red-necked wallaby (*Thylogale thetis*) is attracted (Ramp *et al*. 2005). Long-nosed bandicoots (*Perameles nasuta*) and bush rats (*R. fuscipes*) respond to the body odour (sebaceous gland secretion) of domestic dogs (Carthey and Banks 2012, 2016). The authors presumed that experience with dingo predation had led to these animals responding to domestic dog scents.

Dingo scents, however, have previously been shown to be more evocative than dog scents. This may be because less vulnerable prey-animals (being larger or having more defences) may be able to discriminate between more, and less, threatening predators (Apfelbach *et al*. 2015). Individuals of several abundant native species, including western grey (*M. fuliginosus*) (Mella *et al*. 2014) and red kangaroos (*M. rufus*) (Parsons *et al*. 2007; Parsons and Blumstein 2010*a*), and possums (*Trichosurus vulpecula*) (Parsons and Blumstein 2010*b*), encountering dingo scents increase their vigilance, flight or avoidance behaviours.

Wombats comprise 11% of the diet of dingoes in south-eastern Victoria (Triggs *et al*. 1984), and a similar threat of predation would be expected historically in South Australia. Because of their life style, wombats may be particularly sensitive to olfactory predator cues: they venture above ground at night and must use scents for social communication and risk assessment. Indeed, wombats in captivity are known to modify their activity patterns when their enclosures are treated with faeces from non-related males and from predatory dingoes (Descovich *et al*. 2012). Therefore, we hypothesised that free-ranging southern hairy-nosed wombats would recolonise collapsed burrows treated with dingo scent less often than non-treated burrows.

## Study area

We carried out trials near Nundroo, South Australia (31°45′40″S, 132°3′30″E). This semiarid to arid region is mostly agricultural land used for cropping (predominantly wheat) and sheep grazing. Wombats were recorded in this region in the late 1800s; however, it was not until the 1970s that landholders began to note the encroachment of the species onto agricultural lands in the district (Stott 1998). Landholders in the region believe wombats present a 'significant' problem to them, due to the perception of an expanding population (Sparrow *et al*. 2011). This increase in local abundance is hypothesised to be partly due to the construction and subsequent electrification of the Dingo Fence, which bisects wombat habitat in the region, resulting in the removal of the species' only natural predator, and is also well known by locals as presenting a barrier to wombat dispersal north and west of the Fence (Sparrow, pers. obs.).

## Methods

Ten single-entrance burrows were selected on an agricultural property ~2 km west of Nundroo. Involved landholders were previous respondents to surveys carried out by Zoos SA (Sparrow *et al*. 2011). These burrows were in cropping paddocks and were chosen because they were representative of an area where the landholder, and neighbours, wished to explore alternative management options. The paddocks were also close to the highway and the farmer's residence, which meant there was easy access and an ability for continual monitoring.

Only one burrow within an average home range of a southern hairy-nosed wombat was treated. Home range for this species has been recorded as 1.3–4.8 ha through radio-tracking (Finlayson *et al*. 2005), and up to 7.8 ha through genetic analysis (Walker *et al*. 2006). Therefore, there was at least 200 m between treated burrows (Fig. 1), as a radius of 200 m is equivalent to a 12-ha area. Treatment burrows were also selected on the basis of the presence of other (untreated) burrows nearby – wombats use more than one burrow (Finlayson *et al*. 2005) – therefore ensuring there was an alternative burrow for the displaced animal to retreat to to minimise disturbance to the individuals.

In May 2013, all burrows were excavated and collapsed over three days to allow sufficient time for wombats to leave. The first day involved the use of an excavator to dig out the first 2–3 m of the tunnels, with clear exit points left for the animals overnight. On Day 2, the next few metres of the tunnels were dug up, and on the third day the remainder of the tunnels were completely excavated. Remote-sensor cameras were set up and monitored before, and during, the excavation process to ensure the departure of resident wombats. Once the burrows were confirmed to be empty, they were filled in. At three sites, 200 mL of dingo urine (a reasonable void in an arid adapted-canine) was sprayed evenly over the area immediately around the collapsed entrance because wombats commonly defaecate around the entrance to the burrow (Taylor 1993). At two sites, dingo faeces (~200 g) were raked evenly over the collapsed area. Three collapsed control burrows were left unscented. We controlled for the influence of human presence by routinely visiting both control and treatment sites and monitoring the site for varying levels of deterrence including: wombat presence (as evidenced by tracks and surface scratching), digging and reinhabiting burrows. Sites were visited every 1–2 weeks, for 75 days and wombat activity scored per a rank-sum method (Bennett *et al*. 2012) whereby tracks/scratching was scored as less invasive than digging, which in turn was less invasive than reinhabiting burrows.

Two additional burrows were excavated and collapsed (five total controls) to serve as 'farmer active controls'. One of these burrows was treated with 200 mL domestic dog (*Canis familiaris*) urine and the other with a dingo carcass laid within 2 m of the opening. Domestic dog urine was used separately from dingo urine because no studies have shown large marsupials to have any aversion to domestic dog urine (Apfelbach *et al*. 2015). Additionally, the physical characterisations of dog and dingo urines (fed on a similar diet) are different in turbidity, pH, specific gravity, and coloration (M. Parsons, unpubl. data), with urine from arid-adapted dingoes often appearing opaque (gas chromatography mass spectrometry (GCMS) has supported these differences; M. Parsons, unpubl. data). While dog body odour

(sebaceous gland secretion) has been shown to repel small marsupials (Carthey and Banks 2012), these exudates are highly volatile, and would not be present on a dried carcass. The two control burrows were directly observed and monitored by farmers; reoccupation of these burrows by wombats would be easily noticed. All work was performed under Wildlife Ethics Permit #7/2013; Permit to Undertake Scientific Research #M26161-1.

We obtained pooled dingo urine collected from a large pack of dingoes at the Australian Dingo Conservation Association in April 2013. Canines often urinate to mark territories (Pal 2003). A pooled sample is more likely to contain a greater range of semio-chemicals than samples collected from individual dingoes. Animals were of mixed sex and age and comprised 12 adult males, 18 adult females and 14 subadults of both sexes. All dingoes were fed chicken carcasses before collection. We collected the scents fresh because voids of fresh urine and faeces contain more information than older voids due to environmental degradation (Wyatt 2003; Bytheway *et al.* 2013). We elected not to freeze urine or faeces because the act of freezing scents can limit dispersal properties (Schultz *et al.* 2000). We were unable to maintain a fresh supply of scents due to the difficulty, time and expense of collecting pure-bred dingo scent.

### Statistics

The level of wombat activity was scored according to a rank-sum method of binary categorisations (no digging/digging: Bennett *et al.* 2012) with total time and energy spent in the area determining the magnitude of the score. Behaviours were scored as 0 (= no wombat activity), 1 (= wombats present but did not linger, as evidenced by tracks or scratching of top soil), 2 (= wombat digging below surface soil, indicative of more time lingering in the area because it takes longer to dig than scratch), and 5 (= recolonisation of burrow, which reflects substantial energetic investment associated with redigging the burrow

system). In the case of composite activity (more than one behaviour recorded concurrently), we added values together (e.g. one digging (2) plus one burrow (5) = activity score of 7). If a burrow became inactive, it was scored 0. If a burrow was always active, but no other behaviour recorded, the score remained at 5. We fitted Generalised Estimating Equations (repeated-measures, Fisher Method); IBM SPSS Statistics ver. 21 (Armonk, NY, USA) to explain variation within and across treatment and control burrows. We interpret *P*-values < 0.05 as significant.

## Results

Activity scores for three control burrows were significantly higher (mean = 2.5 ± 0.6) (Fig. 2) than for burrows treated with dingo urine (mean = 0.04 ± 0.03) (*P* = 0.006; *n* = 3) or faeces (mean = 0.13 ± 0.09) (*P* = 0.011; *n* = 2). The effects were prominent early in the trial and remained consistent throughout. Within the first 20 days after treatment, all five 'control sites' (controls, domestic dog urine and dingo carcass) had signs of wombat activity, from fresh diggings (below the surface soil) to fully functional burrows. However, the five sites treated with dingo scent had only minimal activity, i.e. surface scratching. At 75 days after treatment (Figs 2, 3), minimal activity (Category 1) continued to be observed at the five sites with dingo urine and faeces, indicating that animals were present but were not digging any new burrows.

## Discussion

Despite being in the vicinity throughout the 75-day trials, wombats elected not to dig around, or repopulate the five burrows treated with dingo scent. They did, however, recolonise all non-treated burrows including the two 'active farmer controls' (dog urine and dingo carcass). There was no difference in response between dingo urine and faeces.
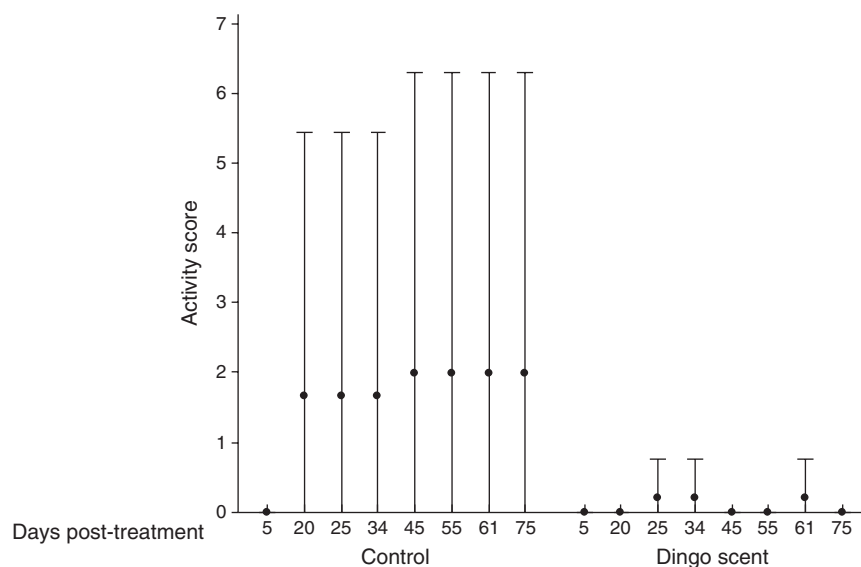


**Fig. 2.**    Interval plot of activity score against treatment and days after treatment (95% CI of the mean). Dingo scent notation includes both dingo urine (*P* = 0.006) and faeces (*P* = 0.011).
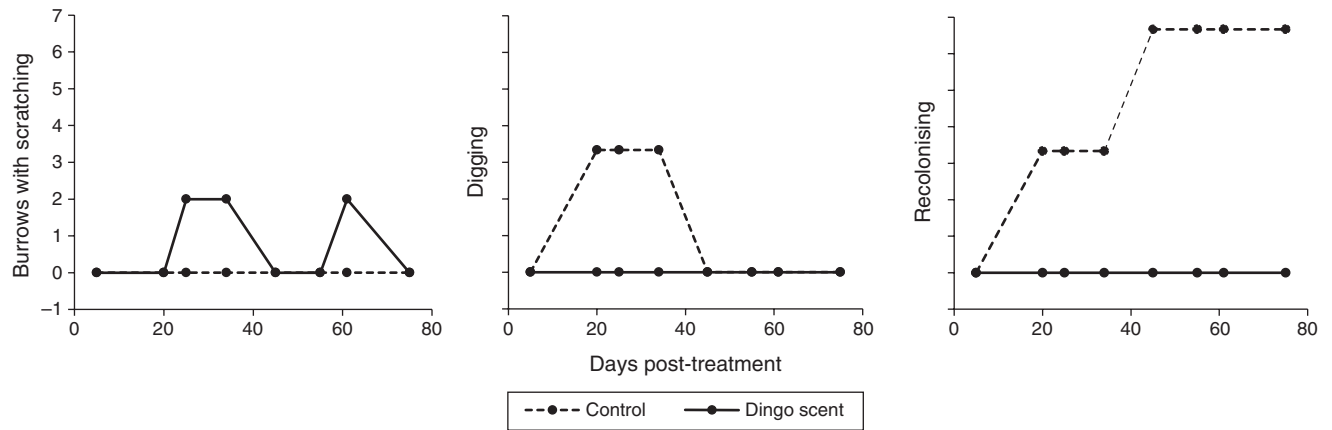
**Fig. 3.** Percentage of treatment and control burrows where each activity type was recorded throughout the 75-day period of scent presentation. The negative value is shown on the figure to clarify that treatment-burrow scores fall flat against the abscissa.

We expected wombats, a shy, fossorial species, to shift their behaviour around dingo scent. We did not, however, expect them to abandon digging or repopulating collapsed burrows, especially with their continued presence in the area. Descovich *et al.* (2012) also found that southern hairy-nosed wombats responded to dingo scents. Animals in enclosures investigated dingo scents nearly twice as often as the control scent, and followed with changes in foraging, walking and concealment. Importantly, Descovich et al. (2012) noted a residual, latent effect whereby wombats avoided conspecifics following presentation to dingo faeces. Our findings were also likely to have been influenced by residual effects, because the degradation of the most volatile chemical compounds in scent from predators (Ferrari *et al.* 2007) would have certainly dissipated in a period of weeks in the arid environment of Nundroo.

The regular scratchings on the burrows treated with dingo-scent indicate that the dingo scent did not repel the animals from the area, but instead shifted their digging and burrowing activity – the most important measure of an agricultural repellent. We expected animals to alter their behaviour, at least initially, when presented with a predator scent. We did not, however, expect evidence of the behavioural modification to be detected for an extended period (75 days). First, animals should learn that the scent was unaccompanied by tangible danger (habituation) (Murray *et al.* 2006; Cox *et al.* 2010). Additionally, aging scents rapidly break down in the environment based on the differential volatility of chemical constituents. Aged scents do not have the same chemical signature as a fresh scent, and ostensibly do not relay the same biologically meaningful information as a fresh scent (Peacor 2006; Hegab *et al.* 2014).

Several mechanisms may help explain our findings. First, a repellent will almost never work unless alternative resources are available. These animals had access to multiple burrows, and may have moved to another burrow, rather than staying around the scent long enough for habituation to occur. Our findings are similar to those of Descovich *et al.* (2012), though this response appears to be stronger. Descovich *et al.* (2012) experimented with wombats inside a protective enclosure, and animals in protected enclosures, including some marsupials, are less susceptible to predator cues (Parsons and Blumstein 2010*b*) than more vulnerable animals exposed to predation with reduced protection from cover.

Finally, we can only speculate as to the unexpected duration of the residual effect (75 days). We collected a pooled sample from 32 animals, many of those from adult males that marked and over-marked their voids, whereas the study of Descovich *et al.* (2012) collected urine from two individual dingoes. These three criteria – availability of alternative resources, level of immediate protective shelter, and the composite information available within the scent (over-marked voids by multiple individuals) – may be considered in future predator-scent research. Our preliminary results are encouraging, however, despite the small sample size, and justify fully replicated evaluations of this novel use of scent-based repellents.

## Management implications

Developing non-lethal tools for the management of southern hairy-nosed wombats in agriculture is important to promoting coexistence between farmers and this species. This study suggests that dingo scents could be a promising non-lethal repellent for wombats seeking to recolonise collapsed burrows. We recommend these scents be trialled on a larger scale to determine whether this could be a viable tool to thwart digging by southern hairy-nosed wombats on agricultural properties.

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