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Non-target species interaction with sodium fluoroacetate (1080) meat bait for controlling feral pigs (*Sus scrofa*)

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Abstract. Fresh meat baits containing sodium fluoroacetate (1080) are widely used for controlling feral pigs in Queensland, but there is a potential poisoning risk to non-target species. This study investigated the non-target species interactions with meat bait by comparing the time until first approach, investigation, sample and consumption, and whether dying bait green would reduce interactions. A trial assessing species interactions with undyed bait was completed at Culgoa Floodplain National Park, Queensland. Meat baits were monitored for 79 consecutive days with camera traps. Of 40 baits, 100% were approached, 35% investigated (moved) and 25% sampled, and 25% consumed. Monitors approached ($P < 0.05$) and investigated ($P < 0.05$) the bait more rapidly than pigs or birds, but the median time until first sampling was not significantly different ($P > 0.05$), and did not consume any entire bait. A trial was conducted at Whetstone State Forest, southern Queensland, with green-dyed and undyed baits monitored for eight consecutive days with cameras. Of 60 baits, 92% were approached and also investigated by one or more non-target species. Most (85%) were sampled and 57% were consumed, with monitors having slightly more interaction with undyed baits than with green-dyed baits. Mean time until first approach and sample differed significantly between species groups ($P = 0.038$ and 0.007 respectively) with birds approaching sooner ($P < 0.05$) and monitors sampling later ($P < 0.05$) than other (unknown) species ($P > 0.05$). Undyed bait was sampled earlier (mean 2.19 days) than green-dyed bait (2.7 days) ($P = 0.003$). Data from the two trials demonstrate that many non-target species regularly visit and sample baits. The use of green-dyed baits may help reduce non-target uptake, but testing is required to determine the effect on attractiveness to feral pigs. Further research is recommended to quantify the benefits of potential strategies to reduce the non-target uptake of meat baits to help improve the availability of bait to feral pigs.

Additional keyword: poison baiting.

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Introduction

Feral pigs (*Sus scrofa*) are a declared pest throughout Australia, causing extensive environmental and economic damage (Choquenot *et al.* 1996; Gong *et al.* 2009; Bengsen *et al.* 2014). Feral pig impacts on natural ecosystems are well recognised (see Bengsen *et al.* 2014 for review). Their widespread distribution, omnivorous diet (mostly plant matter, but also animal) and environmentally destructive habits (e.g. rooting, wallowing) suggest that feral pigs could potentially damage a range of ecological communities (Choquenot *et al.* 1996; Long 2003). Feral pig damage through predation, habitat loss, competition and disease transmission is listed in Australia as a key threatening process to biodiversity by the *Environment Protection and Biodiversity Conservation Act (1999)* (Department of the Environment 2013).

Land managers control feral pigs with a range of techniques such as aerial and ground shooting, trapping and commercial or recreational harvesting, and baiting (Gentle and Pople 2013). Effective broad-scale feral pig control relies heavily on sodium fluoroacetate (1080) bait (Bengsen *et al.* 2014), with application of 1080 fresh meat baits (often kangaroo) comprising ~75% of the bait material distributed per year in Queensland (Gentle *et al.* 2014).

Meat bait may pose a poisoning risk to non-target native species, given the large dosage of 1080 (72 mg) required for feral pigs and the sensitivity of non-target species (McIlroy 1983; Gentle *et al.* 2014). Raptors and monitor lizards (varanids) are thought to be most at risk due to their preference for meat and scavenging behaviours (McIlroy 1984). Non-target consumption of bait material may be reduced by dyeing bait green, particularly for birds (Hone *et al.* 1985; Kleba *et al.* 1985; Hartley *et al.* 2000) although any deterrence effects may be only short term (Jongman *et al.* 2000). The addition of dye to meat baits may be a potential strategy to deter non-target interactions but this has not been assessed for fresh meat baits used for feral pig control. Any differences in foraging behaviour between species groups may also offer means to reduce exposure to non-target species, and should be investigated.

We aim to assess whether the time until first approach, sample, investigation or consumption of large (500 g) fresh meat bait differs between species groups, and if dyeing the bait green will affect interactions. We briefly discuss implications of these findings for baiting campaigns.

Methods

Species–bait interaction trial

A species–bait interaction trial was conducted in the summer (November–January) of 2011–12 at Culgoa Floodplain National Park (hereafter Culgoa), south-western Queensland (28°55′20″S, 146°59′17″E). This coincided with the aerial baiting conducted biannually (usually April/May and October/November) at Culgoa Floodplain National Park for biodiversity protection. Fresh pieces of kangaroo meat (nominal weight = 500 g) were injected with 2 mL of 36 mg mL^{-1} 1080 solution (72 mg of 1080) as per standard for feral pig control in Queensland. Baits were distributed by aircraft on parallel east–west transects (at 2-km intervals), spaced at ~175–200 m to provide a bait density of ~1.7 baits km^{-2} (Gentle *et al.* 2014). Forty baits (mean weight = 538 g) were prepared by sewing a 5-g single-stage radio-transmitter (SirTrack©) inside each bait to allow baits that had been moved, but not consumed, to be located. Previous studies indicate that incorporation of transmitters does not significantly affect bait uptake (Saunders *et al.* 1999; Thomson and Kok 2002). On the same morning that aerial baits were deployed, these baits were laid on the ground by hand in four transect lines in habitats representative of those found within Culgoa. Baits were spaced at ~200-m intervals to simulate the spacing of the aerially distributed bait.

The baits were monitored for 79 consecutive days using 39 camera traps (BolyGuard©/ ScoutGuard© SG550 trail cameras) secured to trees, logs or star pickets. When triggered, cameras recorded a series of photographs that were used to identify species and interactions with bait. The baits were checked by staff each day and classified as: approached, investigated (approached and moved), sampled (approached, investigated, and sampled, i.e. chewed, pecked, torn apart or partially consumed), or consumed (approached, investigated and consumed). Categories were not mutually exclusive (e.g. consumed baits were also recorded as approached, investigated and sampled: Gentle *et al.* 2014).

Where bait was sampled, monitoring of the remaining bait material continued. The percentage of bait removed by sampling was visually estimated to the nearest 10%. Consumed baits were not replaced.

Species–bait–colour interaction trial

A species–bait–colour interaction trial was carried out at Whetstone State Forest (hereafter Whetstone), southern Queensland (28°19′51″S, 150°55′49″E) during November 2006. Sixty kangaroo meat baits were prepared using the same techniques as described for the species–bait trial. Twenty-eight of these baits were dyed green by adding a small amount of powdered food dye (Corella©, Australia). Green-dyed and undyed baits were laid alternately by hand adjacent to unmaintained dirt roads ~500 m apart. Thirty-nine camera traps (Pixcontroller, Export, PA, US) were used to monitor interactions with the bait, as described for the other trial except that baits were replaced with fresh bait upon consumption. Bait monitoring ceased after eight days, given the high rate of visitation and interaction with bait.

Statistical analysis

The time until first approach, sample, investigation, or consumption were compared for each species group to determine any differences in interactions with undyed or dyed meat baits. Data from Culgoa were not normally distributed so were analysed using the non-parametric Mood's Median test. Data from Whetstone were normally distributed so were analysed using a General Linear Model Analysis of Variance. The fitted model consisted of bait colour, bait location (i.e. bait point) and species groups. The bait location term was added to account for variance associated at the individual bait point (i.e. where bait was laid). Fisher's Least Significant Difference (l.s.d.) test was then used to identify significant differences (at the 5% significance level) in interaction between species groups.

Results

Species–bait interaction trial

The species recorded interacting with bait at Culgoa were feral pigs (*Sus scrofa*), feral cats (*Felis catus*), foxes (*Vulpes vulpes*), crows/ravens (*Corvus* spp.), Australian magpies (*Gymnorhina tibicen*), Australian magpie-larks (*Grallina cyanoleuca*), sand monitors (*Varanus gouldii*), black-tailed monitors (*V. tristis*), lace monitors (*V. varius*), shinglebacks (*Tiliqua rugosa*) and blue-tongue lizards (*Tiliqua scincoides scincoides*) (see Gentle *et al.* 2014 for detailed bait-uptake data on each species). We grouped these into monitors (sand, black-tailed and lace monitors), feral pigs and birds (crows/ravens, magpies and magpie-larks) for analysis. We excluded other species interactions from further analysis given the low sample size.

Of the 40 baits, 15% were approached only, 35% were moved, 25% were sampled only, and 25% were consumed. The median time until first approach ($\chi^2 = 8.48$, d.f. = 3, $P = 0.037$) and until first investigation ($\chi^2 = 10.15$, d.f. = 3, $P = 0.017$) differed significantly between the groups, with monitor lizards approaching ($P < 0.05$) and investigating ($P < 0.05$) bait more quickly than pigs and birds (Fig. 1). The median time until first sampling appeared to be less in the monitors than in pigs and birds (Fig. 1), although this was not statistically significant ($P > 0.05$).

Species–bait–colour interaction trial

Species interacting with bait at Whetstone were crows/ravens (*Corvus* spp.), a small raptor (*Falco* sp.), sand monitors (*Varanus gouldii*), and lace monitors (*Varanus varius*). Data were pooled into the following three groups for statistical analysis: monitors (sand and lace monitors), birds (crows/ravens, and small raptor species), and other (unknown species).

Sixty baits were used, comprising 28 green-dyed and 32 undyed baits. In total, 92% of baits (93% of green-dyed and 91% of plain respectively) were investigated. Bait monitoring ceased after eight days, given the high rate of visitation and interaction

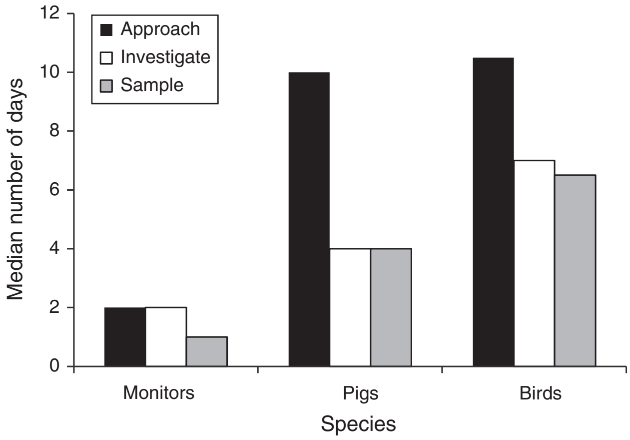

Fig. 1. Median time until baits were first approached, investigated and sampled by species at Culgoa Floodplain National Park.

Table 1. The percentage of dyed, undyed and total (shown in parentheses) baits that were approached, investigated, sampled and consumed by each species group at Whetstone State Forest

Group	Approach		Investigate		Sample		Consume	
	Dyed	Undyed	Dyed	Undyed	Dyed	Undyed	Dyed	Undyed
Monitors	42	58	42	58	41	59	43	57
	(60)		(60)		(53)		(38)	
Other	60	40	60	40	53	47	55	45
	(33)		(33)		(25)		(18)	
Birds	54	46	50	50	40	60	0	0
	(22)		(20)		(17)		(0)	

with bait. The percentage of bait interaction and the percentage of green-dyed and plain baits interacted with, by each group (i.e. monitor lizards, birds and other non-target species) are listed in Table 1. In all, 85% of baits were sampled. Of these, 45% were green-dyed and 55% plain. In total, 57% of baits were consumed, with again a slightly lower percentage of green-dyed bait consumed (47% versus 53%). Twenty-three baits were consumed by monitors. Camera malfunction (e.g. flat battery, not triggered) meant that the identification of species responsible for consuming 11 baits could not be determined.

The mean time until first approach differed significantly between species groups ($F_{2,12} = 4.33$, $P = 0.038$) (Fig. 2), but not between bait locations ($F_{53,12} = 1.77$, $P = 0.140$) or between bait colours ($F_{1,12} = 3.07$, $P = 0.105$). The mean time until first investigation did not differ significantly between species groups ($F_{2,11} = 3.0$, $P = 0.091$), bait locations ($F_{53,11} = 1.73$, $P = 0.163$), nor bait colours ($F_{1,11} = 2.99$, $P = 0.112$).

Species group ($F_{2,4} = 22.2$, $P = 0.007$) (Fig. 3), bait location ($F_{49,4} = 16.64$, $P = 0.007$) and bait colour ($F_{1,4} = 41.38$, $P = 0.003$) all significantly affected the mean time until first sampling, with undyed baits being sampled earlier (mean 2.19 days) than green-dyed bait (mean 2.70 days).

Discussion

The native species of most concern, based on the species sensitivity (i.e. toxicity) to 1080, include crows/ravens, magpies

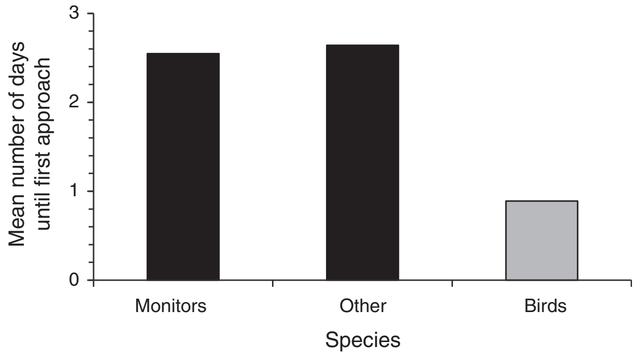

Fig. 2. Mean time until baits were first approached at Whetstone State Forest. Columns that do not share colour (grey and black) are significantly ($P < 0.05$) different from each other as determined by Fisher's Least Significant Difference Test.

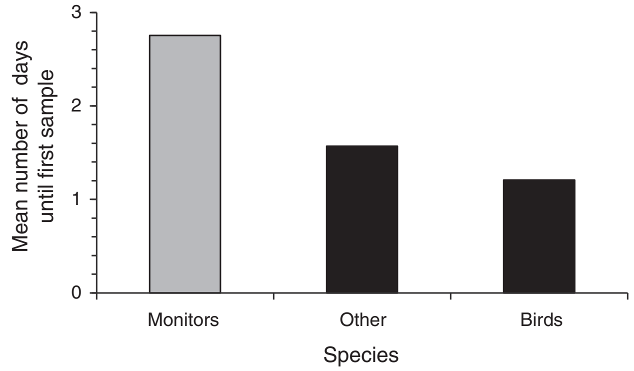

Fig. 3. Mean time until baits were first sampled at Whetstone State Forest. Columns that do not share colour (grey and black) are significantly ($P < 0.05$) different from each other as determined by Fisher's Least Significant Difference Test.

and varanids (see McIlroy 1983). However, despite many interactions with feral pig meat baits, few of these non-target species were recorded as sampling or consuming bait, with the exception of monitors at Whetstone. The lack of consumption by birds that approached, investigated or sampled the bait is possibly explained by the fact that the bait size (500 g) was originally chosen to be too large for most carnivorous birds to ingest in one sitting. The estimated percentage of bait consumed was used to (crudely) approximate the weight of bait, and hence the dose of toxin ingested. These estimates of consumption (visually compared to an uneaten, reference baits) suggest that these species typically appeared to consume less than 10% of their body weight, resulting in a non-lethal dose for most species (A. Millar, unpubl. data). On occasions, monitors may consume fresh meat baits (e.g. Woodford *et al.* 2012), and data from Whetstone support these findings. This is a concern for both the potential primary poisoning risk to monitors, and the reduction in availability of baits to feral pigs. The lack of bait consumption by monitors at Culgoa is intriguing, given that bait was readily consumed by monitors at Whetstone in this study and in other trials (A. Millar, unpubl. data). Site differences in the abundance of varanids may be one possible explanation: varanids appeared to be much more abundant at Whetstone (M. Gentle, pers. obs.), likely due to the favourable forest habitat at Whetstone (cypress pine–dominated forest) compared with the more open, diverse landscapes at Culgoa (see Gentle *et al.* 2014). Alternatively, the relatively few baits sampled by monitors at Culgoa may have been due to recent rainfall events increasing food supply to varanids. Food supply has been shown to be an important predictor of bait uptake by feral cats, with greater bait uptake occurring when alternative food is reduced (Christensen *et al.* 2013).

Our data may assist to understand or develop strategies to reduce bait interactions by non-target species. Our data show that monitors were quicker than pigs at interacting with bait at Culgoa, suggesting that there may be no advantage in limiting the period that baits would be presented in the field. Birds were quicker than monitors at Whetstone but not Culgoa, indicating that there may be some site differences in foraging strategies between species to consider. Feral pig baiting is conducted biannually at Culgoa, and only occasionally at Whetstone, which may result in some individuals being previously exposed to bait. Pre-exposure to bait may alter an individual's response in future bait encounters, dependent on the outcomes associated with the initial encounter (i.e. positive, neutral, or negative stimuli), although time since exposure and other factors are also important (Gentle *et al.* 2006). We cannot discount any potential effect on bait uptake from previous exposure, but acknowledge that it may contribute to the inconsistent species interactions between study sites. Our data suggest that the use of dyed bait may reduce non-target risk by delaying these species sampling bait, potentially allowing more time for feral pigs to locate and consume baits. The green-coloured PIGOUT® (Animal Control Technologies Australia) manufactured bait can be highly effective at reducing pig populations (Cowled *et al.* 2006*a*) and is reportedly target-specific in most Australian environs (Cowled *et al.* 2006*b*). Dyeing meat bait is unlikely to significantly affect consumption by pigs; grain remains highly palatable to pigs following addition of blue, green or black food dye (Hone *et al.* 1985; Kleba *et al.* 1985). However, we could not test this hypothesis in fresh meat baits; feral pig abundance was low at Whetstone and no feral pig activity was recorded at either green or undyed baits during the trial period. Additionally, dye may result in only a short-term reduction in feeding behaviour of some non-target species (Jongman *et al.* 2000), as evidenced in our study, further confusing the potential application of dye to meat baits. We recommend further testing to: (1) account for any site-specific differences in non-target species interactions to dye, and (2) ensure that the use of green dye in fresh meat baits does not reduce the attractiveness and palatability to feral pigs.

There may be other options to reduce the take of fresh meat baits by non-target species. These include laying baits in the late afternoon/evening or cooler months when varanids are less active, covering or burying baits, using feeding deterrents or pig-specific feeders, placing toxic baits in areas of high pig activity, when and where pigs are feeding, drying (i.e. reduce moisture content) baits to reduce palatability to varanids (see Twigg *et al.* 2001; Gentle *et al.* 2014). Strategies to delay the uptake of baits by non-target species may help to reduce primary poisoning risk. Fresh meat baits lose 1080 under field conditions (e.g. Fleming and Parker 1991; Twigg, *et al.* 2000) and delays in feeding may help reduce exposure of non-target species to the high initial doses of 1080 in pig meat baits. We recommend further research to examine and quantify the benefits of these potential strategies to reduce the non-target uptake of meat baits, and maximise the availability of bait to feral pigs.

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