

Fate of dried meat baits aimed at wild dog (*Canis familiaris*) control

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Abstract

Context. Livestock predation is a worldwide phenomenon, causing financial losses and emotional strain on producers. Wild dogs (*Canis familiaris*) cause millions of dollars of damage to cattle, sheep and goat production in Australia every year, and despite on-going control (baiting, trapping, shooting, and fencing), they remain a significant problem for livestock producers across many pastoral and agricultural regions of Australia.

Aims. We aimed to quantify the uptake of dried meat baits by wild dogs and determine whether an olfactory lure (fish oil) could increase uptake.

Methods. Camera traps and sand pads were used to monitor bait uptake for three baiting events on two pastoral properties in the southern rangelands of Western Australia in 2016 and 2017.

Key results. Of the 337 monitored baits with a known outcome, young wild dogs (<8 months old) removed only four, three of which were covered in a fish-oil lure. In warmer months, baits were largely consumed by varanids, and in cooler months, when baits were taken it was predominantly by corvids. Varanids and corvids took more baits than expected on the basis of activity indices. Kangaroos, feral cats and wild dogs consumed significantly fewer baits than expected from their activity on camera.

Conclusions. We have no evidence that adult wild dogs removed baits, despite many opportunities to do so (wild dogs passing cameras), and fewer wild dogs took baits than expected on the basis of activity events seen on camera. Olfactory lures may have the potential to increase bait uptake by naïve individuals (i.e. young dogs), but the sample size was small.

Implications. Increasing the number of baiting events per year, trialling novel baits, and baiting during low non-target activity are some of the recommended methods that may increase bait persistence and uptake by wild dogs.

Additional keywords: baiting, dingo, free-roaming dog, lure.

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Introduction

Predation of livestock is a common occurrence globally (Treves and Karanth 2003). In Italy (Cozza *et al.* 1996) and southern Europe (Meriggi and Lovari 1996), wolves (*Canis lupus*) predate on sheep, goats, cattle and juvenile equids. Sheep flocks in the United States of America are reduced as a result of coyote (*Canis latrans*) predation (Knowlton *et al.* 1999). The impacts of wild dogs (*Canis familiaris*; Jackson *et al.* 2017) on Australian livestock enterprises result in significant losses (reviewed by Fleming *et al.* 2014), making effective control of populations a priority for affected producers.

Wild dogs, defined as ‘free-living’ domestic dogs, dingoes or hybrids, cause significant damage to Australian livestock

enterprises (sheep, goat and cattle) through direct predation (killing or injuring livestock) and indirect impacts (such as stress to livestock), costing an estimated AU\$89 million per year (McLeod 2016). To reduce losses to pastoral and agricultural livelihoods, regular wild dog control is undertaken by producers. Methods of wild dog control can include baiting, trapping, fencing or shooting. Best-practice baiting includes deployment of meat-based baits by landholders in an integrated, coordinated, landscape-scale approach (Fleming *et al.* 2001).

Native Australian mammals, reptiles and bird species have developed a tolerance to sodium monofluoroacetate or ‘1080’, having evolved in the presence of naturally occurring plant species that contain the same toxin (Oliver *et al.* 1977;

Twigg and King 1991). This is particularly pronounced in Western Australia (Department of Parks and Wildlife 2013). Baiting programs using 1080 are, therefore, reasonably selective for less tolerant introduced species, including canids. Baiting programs usually occur at a landscape-scale to control entire wild dog populations, with previous research recording between 60% and 90% reductions in wild dog relative abundance (Thomson 1986; Fleming *et al.* 1996).

For baiting programs to be effective, target individuals must locate baits and consume them while the bait contains a lethal dose of the toxin (for a given individual). Several variables can affect the desired outcome of bait consumption, including bait type and/or presentation, the use of lures (Algar *et al.* 2007; Hunt *et al.* 2007), bait toxicity, season (Algar *et al.* 2007) and non-target bait consumption or 'interference' with bait (Eastman and Calver 1988).

Bait presentation can dramatically influence bait uptake by canids (Allen *et al.* 1989; Fleming 1996; Thomson and Algar 2000; Glen and Dickman 2003). The way in which baits are positioned or deployed (i.e. buried, hung on fence, ground laid or aerially deployed; Saunders *et al.* 1995; Fleming *et al.* 2001; Murray and Poore 2004) can influence the likelihood of discovery of the bait itself by the target species. Lures can also be used to increase discovery of baits by target species. Olfactory, visual and auditory-based lures have been investigated for their efficacy in increasing bait uptake by invasive pests and, therefore, baiting-program effectiveness (Mitchell and Kelly 1992; Hunt *et al.* 2007; Read *et al.* 2015). Furthermore, bait-application rate (1 bait/100 m is the standard practice; Twigg *et al.* 2009) can affect bait-take, with the deployment of more baits potentially increasing the opportunity for the target species to locate a bait (Thomson and Algar 2000; Algar *et al.* 2007). However, saturation of the landscape with baits has drawbacks, because some species (e.g. red foxes *Vulpes vulpes*) will cache excess food, and leaving baits exposed to the elements increases the risk of degradation of the toxin (reviewed by Allsop *et al.* 2017).

Loss of toxicity can occur as a result of rainfall, humidity and weather extremes, which can cause the microbial degradation of toxin in the baits, creating a bait with a sublethal dose of toxin (McIlroy *et al.* 1988; Fleming and Parker 1991; Körtner and Watson 2005; Allsop *et al.* 2017). If individuals consume a sublethal dose, they may experience sickness, potentially generating a 'negative' experience and a 'learned aversion' to 1080 baits (Allsop *et al.* 2017). This, in turn, may decrease bait uptake and reduce efficiency of baiting programs in the long term.

Effectiveness of baiting programs can also be influenced by non-target animals removing baits. Non-target interference with fox baits has been documented in Western Australia, where quokkas (*Setonix brachyurus*), kangaroos (*Macropus fuliginosus*) and ravens (*Corvus coronoides*) take baits (Dundas *et al.* 2014), in eastern Australia with spotted-tail quolls (*Dasyurus maculatus*; Körtner and Watson 2005) and urban areas with domestic dogs (Jackson *et al.* 2007). Although wild dog baiting programs are typically timed for periods of peak wild dog activity and low rainfall, they are not generally attuned to non-target species activity.

Wild dog predation on livestock must be almost non-existent for small stock enterprises (i.e. sheep and goats) to be financially

viable (Thomson 1986; Allen and Sparkes 2001; Fleming *et al.* 2001; Thomson and Rose 2006). In addition to direct predation, wild dogs increase stress levels for livestock, which can result in mis-mothering and/or reduced productivity because of a lack of access to water or food resources (e.g. Short *et al.* 2002; van Bommel and Johnson 2012). The southern rangelands of Western Australia were once a productive area for sheep and goat enterprises, but few properties now run small stock, in part because of predation pressure from wild dogs. Severe wild dog attacks were reported in this area from 2010 to 2014 more commonly than in any other area surveyed by Binks *et al.* (2015). As a consequence of this ongoing predation pressure, this area practices a program of biannual landscape-scale coordinated baiting. Here, we examine bait uptake by wild dogs in the southern rangelands of Western Australia. Our research aim was to determine whether bait uptake by wild dogs can be improved by addition of an olfactory lure.

Materials and methods

Site description

The study was conducted at two pastoral properties (Property A: 231 000 ha; and Property B: 75 000 ha) in the southern rangelands of Western Australia. The properties were separated by a distance of ~70 km, have a previous history of small stock production and have associated wild dog control. Neither property currently runs livestock commercially; however, both properties have feral goats and Property A has a small number of feral cattle. Property B functions as a tourist farm-stay operation. The area is typified by an arid environment, with a mean annual rainfall of 239.1 mm, and mean maximum temperatures in January reaching 38.2°C (Mount Magnet Station, 007057; Bureau of Meteorology 2017). The habitat is composed primarily of *Acacia* spp. woodlands.

Bait deployment

Dried meat baits contain 6 mg of 1080 and are made by air drying 100 g of fresh meat to a weight of 40 g (Thomson and Rose 2006). Baits were deployed on the two pastoral properties twice annually as part of a coordinated baiting program. Baiting for wild dogs is aimed at periods when food requirements by the dogs are high and movement is not restricted; generally, when pregnant bitches have not yet denned and pups are emerging (Thomson 1986). Producers therefore aim to deploy baits in autumn (generally in April) and spring (generally in September).

Three baiting events were monitored for each property in the present study (Table 1). Landholders whose livelihoods are imminently affected by livestock predation are 'risk-averse and responsible for the welfare of their livestock', and are consequently often unwilling to be a site that does not undergo wild dog control (Fleming *et al.* 2014, p. 107). Therefore, one property was baited during the coordinated baiting program, and bait deployment was delayed ~6 weeks for the other property, swapping the order of baiting between the two properties for successive bait-deployment events (see dates in Table 1). In the absence of a true experimental control, this allowed us to compare change in wild dog activity in response to baiting events between baited and unbaited sites

Table 1. This table shows the number of baits monitored at each property (with and without fish-oil lure), during each baiting event monitored by camera traps and on sand pads

All cameras monitoring a bait also had a sand pad in front of it, but not all sand pads had a camera. The number of baits monitored also include the baits laid by licenced pest-management technicians (LMPTs) in front of the camera. Camera traps were deployed at least 1 month before the first bait-uptake trials (92 cameras were deployed 3 March 2016 at Property A and 90 cameras were deployed 5 March 2016 at Property B). The cameras were not removed until 9 June 2017 at Property A and in 22 July 2017 at Property B. Although 182 cameras were deployed, we have included only the number of baits that were correctly placed in front of cameras, such that their fate could be determined (i.e. the bait was clearly visible); in some cases multiple baits were monitored for one baiting location where the bait was already removed. Sand pads were used to monitor bait uptake during each round at Property A but only once at Property B, in September 2016

Property	Baiting event	Baiting date	Bait deployment	Baits with fish-oil lure	Baits monitored		
					Camera	Sand pad	Total
A	1	Autumn 2016	8 April 2016 ^A	126	125	193	318
	2	Spring 2016	1 November 2016	49	79	64	143
	3	Autumn 2017	3 April 2017	42	89	64	153
B	1	Autumn 2016	9 June 2016	32	93	0	93
	2	Spring 2016	17 September 2016	61	63	92	155
	3	Autumn 2017	11 June 2017	14	74	0	74
Total				324	523	413	936

^AAn additional 13 Reconyx XR6 cameras were used in conjunction with the bait cameras. These cameras were removed on the 10 June 2016.

where baiting occurred non-simultaneously. Baits were laid by vehicle in the wheel ruts of tracks (1 bait per 100 m).

Monitoring bait uptake

Camera traps and sand pads were used to monitor bait uptake between March 2016 and July 2017. Camera traps were deployed at Properties A ($n=92$) and B ($n=90$) at least 1 month before the first bait-uptake trials and were not removed until a minimum of 40 days after the final bait deployment (Table 1).

Camera traps (Property A: 15 Scoutguards SG560 (Scoutguard, China) and 67 Reconyx™ Hyperfire™ HC500s (Reconyx, Holmen, WI); Property B: 11 Scoutguard SG560 and 79 Reconyx™ Hyperfire™ HC500s) were deployed at the side of property-access tracks. Camera traps were positioned at 1-km intervals, 30–50 cm above the ground, facing along the axis of the track. During bait deployment, baits were positioned ~5 m in front of cameras in the centre of their field of view.

Sand pads were created by smoothing a 2 × 2 m area with a broom across tracks; the same tracks were used for bait deployment and camera trap monitoring at ~1-km intervals (Allen *et al.* 1996). Sand pads were monitored for two consecutive days where possible. Sand pads were checked every morning for tracks, which were identified to species using a reference guide (Triggs 2004).

An olfactory lure was added to a proportion of baits monitored (see Table 1 for numbers). Once the baits had been laid, 10 mL of fish oil lure (Bait Mate Fish Oil Blend, Buckingham Drive, Wangara, WA, Australia) was poured over the baits *in situ*.

Because of a high proportion of baits being removed in the initial baiting event without triggering the cameras, we trialled tethering baits during the September and November 2016 baiting events, with the aim of increasing the time animals took to remove a bait, therefore increasing the likelihood of triggering the camera. A third of the baits were tethered by 1.8-kg monofilament fishing line (Maxima Fishing Line, Germany) to a 10-mm tent peg, 250 mm long, driven into the ground (below surface level) directly beneath each bait.

Images from camera traps were manually viewed as jpeg files in a simple image viewer program (Windows Live Photo Gallery,

Windows 7 Edition, Microsoft Corporation, Redmond, WA, USA). Estimating the date of bait uptake from camera photos was sometimes difficult, because the bait was present in one image and not the next, without an indication of the individual responsible for removing the bait. When this occurred, the first day the bait was not seen was taken as the bait-uptake date, and the bait was recorded as being taken by an unconfirmed species. A bait was recorded as removed at '0 days' if it was consumed on the day it was deployed. When a bait was partially eaten and individuals returned to consume it multiple times, the bait was recorded as removed on the first occasion. Individuals consuming the baits were recorded to species, and we recorded the time stamp and behaviour towards the bait for each individual. It was possible to identify individual wild dogs and feral cats (*Felis catus*), but individuals could not be distinguished for all other species. Activity events of each species [varanids (*Varanus gouldii*), corvids (*Corvus* spp.), kangaroos (*Macropus fuliginosus* and *M. robustus*), feral cats and wild dogs] were recorded as separate activity events. For individuals of the same species, a separate capture event was recorded if the images were captured at least 10 min apart. If two or more individuals of the same species were seen on camera at the same time, the individual was classified as multiple individuals (one capture event per individual). These activity events were standardised per camera per day (to account for the variations in camera set-up across the study sites).

Statistical analysis

The number of days for a bait to be removed (date bait removed minus the date bait deployed) was calculated for each camera-monitored bait. We compared the fate of baits (taken or not taken) with temperature (°C; average temperature for the month after bait deployment; Mount Magnet Airport station: 007600; Bureau of Meteorology 2017), presence of the fish oil lure (yes/no), and whether the bait was tethered (yes/no) using multiple-regression analysis with a binomial distribution and logit-link function. The length of time for camera-monitored baits to be removed (number of days) was examined in relation to

temperature, presence of the fish-oil lure, and whether the bait was tethered, using multiple-regression analysis with a Poisson distribution and log-link function.

We compared the length of time until bait uptake for the six bait events, and length of time until bait take by each species, using Kruskal–Wallis ANOVA by Ranks. We compared the proportion of baits taken by each species (camera-monitored baits only) with the average ambient temperature for the month following each baiting event using Spearman Rank-Order correlation.

We used Pearson's Chi-square tests to compare bait uptake ($n=523$ camera-monitored baits and $n=413$ sand pad-monitored baits separately) for those with ($n=324$) and without ($n=612$) fish-oil lure; expected values were calculated assuming that 35% of baits taken by each species had fish-oil lure. We used a Mann–Whitney U test to compare, for each species, the length of time until bait uptake (with and without fish-oil lure).

We used Pearson's Chi-square tests to compare bait uptake by each species ($n=523$ camera-monitored baits; sand pad monitored baits were not tethered) for those tethered ($n=142$) and not tethered ($n=381$). Expected values were calculated assuming that 27% of baits taken were tethered.

Bait uptake by corvids, varanids, kangaroos, feral cats and wild dogs were compared with the number of activity events of each species (instances of each species being captured on camera) by Pearson's Chi-square tests. Expected bait uptake for each species was calculated assuming that bait uptake was proportional to the number of activity events for each species.

We also recorded wild dog behaviour in front of the cameras (whether bait was or was not present), including removing bait, sniffing the bait (or where the bait was if already taken), urinating or defecating (on bait if present), rolling (on bait if present), mouthing bait, resting or playing, inspecting or interacting with camera, sniffing something else in the vicinity apart from the bait (if present), or moving past (without inspecting bait if present). The likelihood of a dog being seen on camera when a bait was present was calculated by a two-way chi-square test, comparing numbers of wild dog activity events in the presence or absence of a bait.

Most analyses were performed using Statistica 8.0 (Statsoft Inc. 2007). Pearson's Chi-square tests were performed in Excel (Microsoft). Values are shown as means \pm 1 s.d. throughout.

Results

Over 18 months of the study (Fig. 1), a total of 936 dried meat baits were monitored by camera traps ($n=523$; monitored for up to 110 days) and sand pads ($n=413$; each monitored for 1 or 2 days). Of the baits monitored, 337 baits or 36% of the total monitored had a known fate. Four (camera-monitored) baits were taken by wild dogs (<8 months old, deemed pups). Baits were removed by ants (sand pad: 17 baits consumed), corvids (camera: 35 baits taken; and sand pad: 2 baits taken), varanids (camera: 69 baits taken; and sand pad: 42 baits taken), kangaroos (camera: 29 baits taken; and sand pad: 1 bait taken) and feral cats (camera: 19 baits taken) (Figs 2, 3).

In total, 94 of the camera-monitored baits of known fate (18% of 474 baits) were not taken over all the baiting events. The fate (taken or not) of 474 camera-monitored baits was influenced by temperature (Wald statistic=41.77, $P<0.001$; Fig. 4a), with fewer baits being taken when temperatures were lower. The presence of the fish-oil lure (Wald statistic=0.11, $P=0.740$) or tethering (Wald statistic=3.21, $P=0.073$) did not influence bait uptake. The length of time (days) that 380 camera-monitored baits remained on the ground was negatively influenced by temperature (Wald statistic=423.91, $P<0.001$; Fig. 4b) and whether they were tethered (Wald statistic=116.31, $P<0.001$), but not the presence of the fish-oil lure (Wald statistic=1.86, $P=0.172$).

The length of time to bait uptake was significantly different among species (Kruskal–Wallis ANOVA by Ranks; $H_{7,n=379}=26.55$, $P<0.001$; Fig. 4c) and was different for the six bait deployments ($H_{5,n=379}=72.71$ $P<0.001$; Fig. 4b). Varanids were significantly more likely to take baits in warmer months ($R_{s5}=0.986$, $P<0.001$), whereas corvids were significantly more likely to take baits deployed during cooler months ($R_{s5}=-0.829$, $P=0.041$).

Corvids (35 baits taken; $\chi^2_1=4.40$, $P=0.036$) took significantly more camera-monitored baits with fish-oil lure than was predicted. Three of the four baits taken by wild dogs also had fish-oil lure (too few data to perform a statistical analysis). There were no significant differences in bait uptake between those with and without fish-oil lure for feral cats, kangaroos and varanids (Table 2). Significantly more baits without fish-oil lure were taken by animals that were not identified on camera (of 248 baits taken; $\chi^2_1=7.09$, $P=0.007$, Table 2). There were no significant differences for sand pad-monitored baits (monitored for 1–2 days) taken by varanids (Table 2). There was no difference in length of time to bait uptake between baits with and without fish-oil lure for any species (Mann–Whitney U tests; Table 2).

There was no effect of tethering on the proportion of baits that were recorded taken ($\chi^2_1=2.29$, $P=0.130$), and tethering did not serve to decrease the proportion of baits that were taken by unidentified species ($\chi^2_1=0.27$, $P=0.601$). However, tethering baits resulted in an increase in the numbers of varanids recorded on camera ($\chi^2_1=19.39$, $P\leq 0.001$). There was no effect of tethering on bait uptake by feral cats ($\chi^2_1=2.65$, $P=0.103$), kangaroos ($\chi^2_1=0.61$, $P=0.434$) or corvids ($\chi^2_1=1.77$, $P=0.183$).

Corvids ($\chi^2_1=15.55$, $P<0.001$) and varanids ($\chi^2_1=4253.31$, $P<0.001$) took more baits than was expected on the basis of the few activity events of these species seen on camera. Kangaroos ($\chi^2_1=91.31$, $P<0.001$), feral cats ($\chi^2_1=7.17$, $P=0.007$) and wild dogs ($\chi^2_1=18.75$, $P<0.001$) took fewer baits than was expected on the basis of their activity events observed on camera (Fig. 5).

In total, 1809 wild dog activity events were recorded on camera (wild dogs made up 10% of all activity events on camera). For 325 (18%) of these events, the bait was still present in the image (Table 3); this was less often than we predicted it should happen ($\chi^2_1=457.58$, $P<0.001$). In 8% of the instances where wild dogs and baits were simultaneously on camera, the wild dogs interacted with the bait, indicating behaviour that showed they were aware of the bait presence (e.g. sniffing or mouthing the

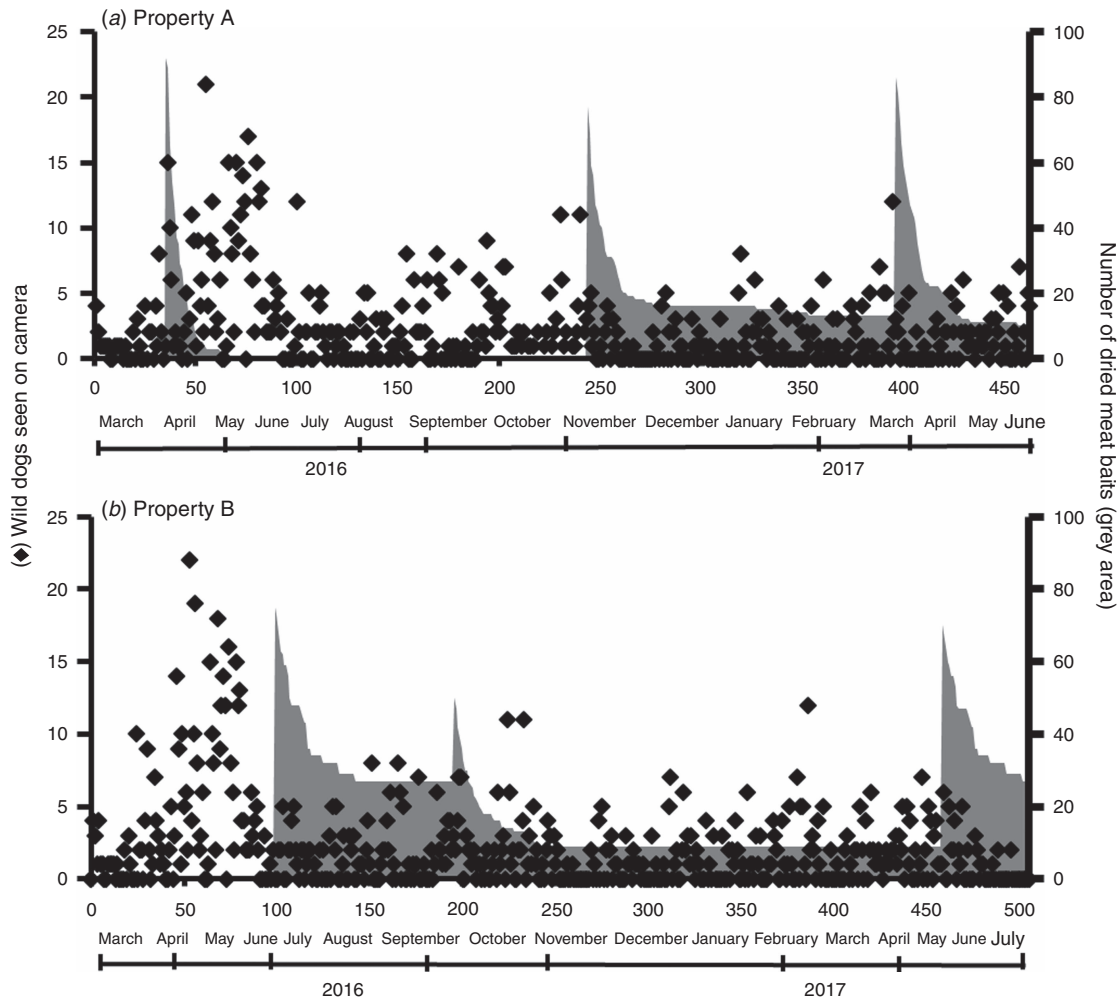


Fig. 1. The number of wild dogs (black dots) seen on camera and sand pads over the days of the study. The peaks for dried meat baits (the grey-shaded area) indicate the three baiting events at each property. The dashes on the black line below the months are camera-servicing events, although both properties are subject to regular landholder activities.

bait, rolling on the bait, urinating on the bait). One male adult individual was recorded interacting with 11 baits over two baiting events (but was later captured in a trap and was, therefore, not present for the last two baiting events). The baits that were taken by wild dogs were removed by young animals. Repeated observation of individuals over time allowed us to estimate the age of these animals; three individuals were estimated to be 2–3 months old, and the fourth dog was ~8 months old.

Discussion

Using a combination of camera traps and sand pads, we confirmed the fate of 337 of 936 dried meat baits targeting wild dogs in the southern rangelands of Western Australia. Bait uptake by wild dogs was low, with dogs removing only four baits (1.19% of the 337 baits of known fate). Three of the four baits taken by wild dog pups had fish-oil lure, which suggests that it is potentially effective as a novel lure for these dogs typically. Wild dogs left baits on the ground despite locating them and interacting with them (e.g. sniffing the bait,

rolling on the bait, urinating on the bait), and we also noted significantly fewer dogs on cameras when the baits were still present than we would have predicted. Several factors could have led to the low bait uptake by wild dogs, including interference by non-target species, low bait appeal, or learned aversion by wild dogs.

Interference by non-target species

We recorded substantial bait uptake by non-target species. Of the 337 baits with known fates, 71% were taken by non-target species, and 28% were not removed during our monitoring. Ants, corvids, varanids, kangaroos and feral cats removed baits, effectively reducing the number of baits available to wild dogs. We found significant species differences in bait uptake among our six bait events, which was likely to be a reflection of temperature differences. Varanids took more baits in warmer months. During the cooler months, corvids were more likely to take baits, and many baits were left on the ground unconsumed. Varanids and corvids took more baits than expected on the basis of the activity indices calculated

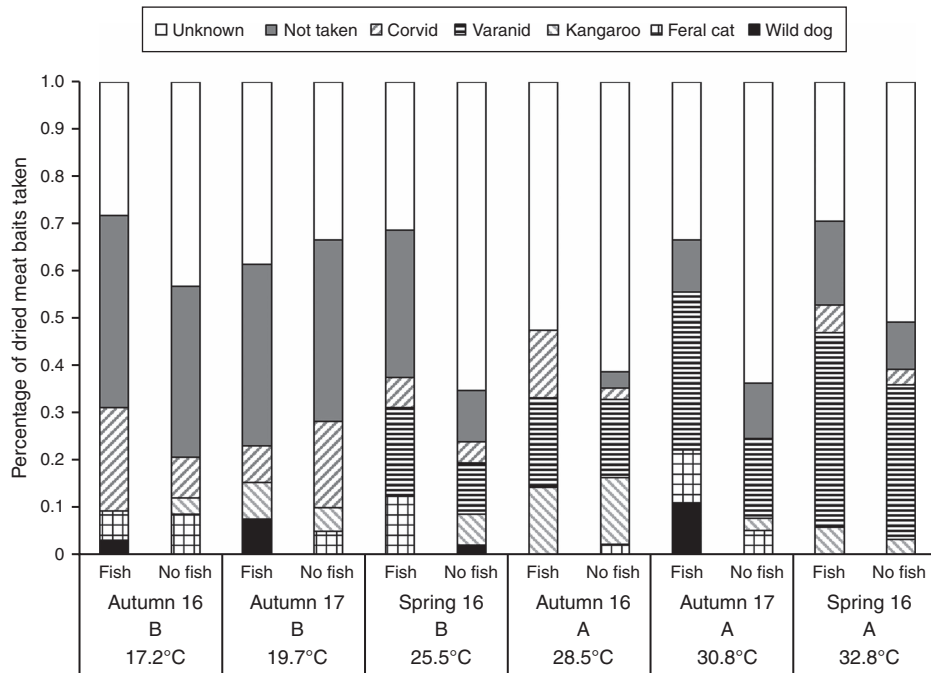


Fig. 2. Camera traps. Bar plot showing the percentage of baits with and without fish-oil lure removed by corvids, varanids, kangaroos, feral cats and wild dogs, or where the baits were not taken or taken by unconfirmed species. Data are shown for the six baiting events at Properties A and B. The columns are ordered from left to right by average maximum ambient temperature for the month following bait deployment.

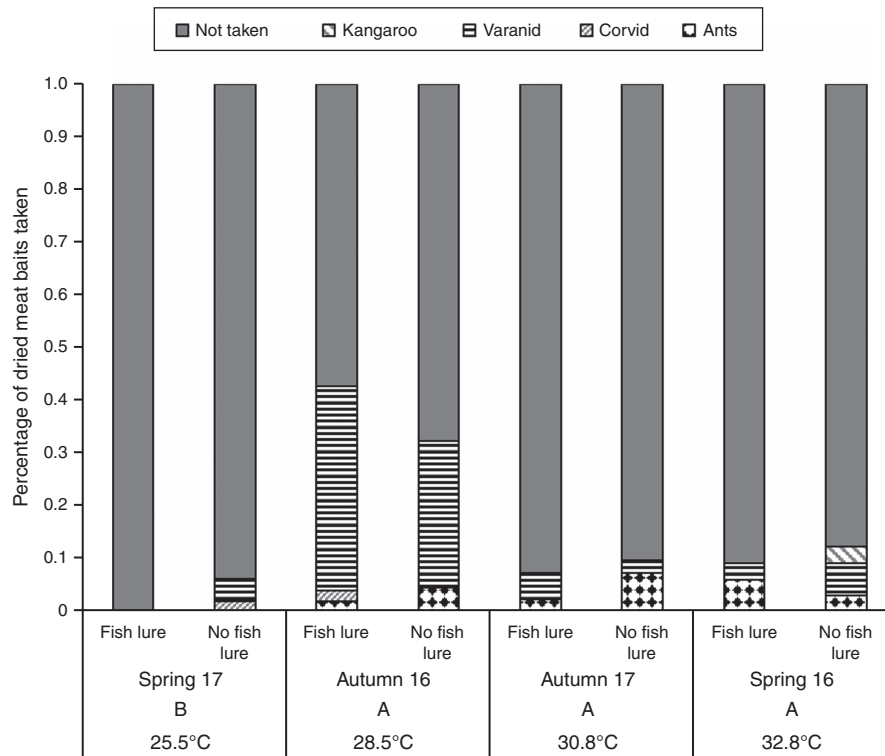


Fig. 3. Sandpads. Bar plot showing the percentage of baits with and without fish-oil lure removed by ants, corvids, varanids and kangaroos, or where baits were not taken. Data are shown for the three baiting events at Property A and one at Property B. The columns are ordered from left to right by average maximum ambient temperature for the month following bait deployment.

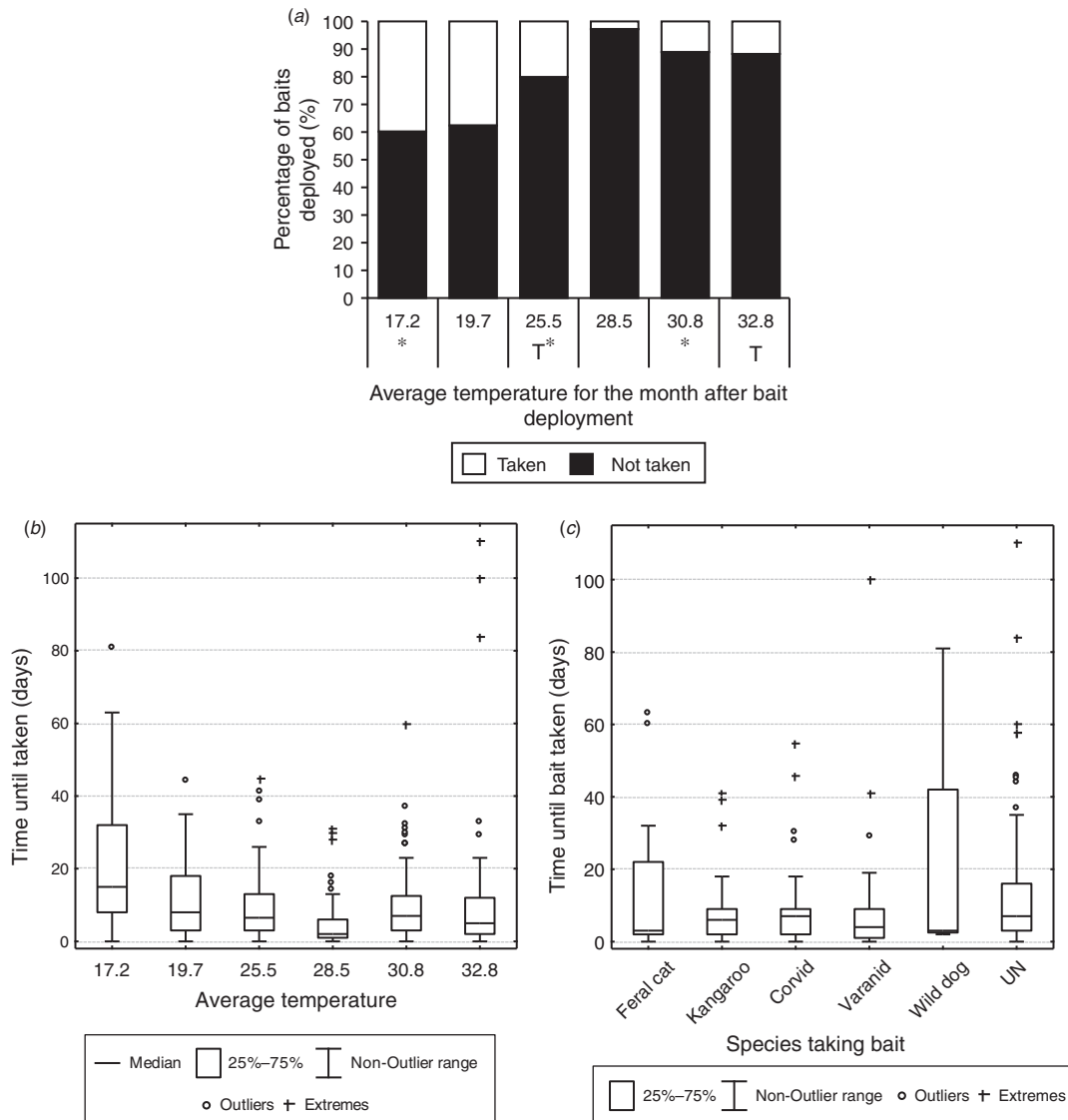


Fig. 4. (a) The percentage of camera-monitored baits deployed during each baiting event that were taken or not taken for each of six baiting events (three at each property). The average maximum ambient temperature for the month after bait deployment is indicated. T indicates sessions where a proportion of baits were tethered; asterisk denotes that baiting was performed outside normal baiting events. (b) Number of days for a bait to be taken for each of the six baiting events. (c) Number of days for a bait to be taken by each species and those baits taken by unknown species (UN). For (c), data are pooled for each baiting event and property by species. Values for (b) and (c) are the medians (horizontal lines) quartiles (boxes) and ranges (whiskers), circles represent outliers and asterisks extremes.

from the camera trap images, whereas feral cats and kangaroos (and wild dogs) took fewer baits than expected on the basis of their number of activity events recorded on camera.

Locating baits and bait appeal

Lures can be used to increase the uptake by invasive species, but the success of lures has varied in the literature (Hunt *et al.* 2007; Moseby *et al.* 2011). Corvids were significantly more likely to take baits with fish oil lure than was predicted. We also noted that three of the four baits taken by wild dogs had fish oil. Using fish oil (or other lures) could possibly increase the uptake of dried meat baits by wild dogs. Canids have

efficient olfactory senses (Gadbois and Reeve 2014) and the deployed baits, with and without a lure present, still had an obvious odour up to 2 months after deployment. Canid species in Australia (e.g. wild dogs and dingoes; Allen *et al.* 1996; van Bommel and Johnson 2017) and the USA (e.g. coyotes *Canis latrans*; Knowlton *et al.* 1999) can show neophobic behaviour, such that the addition of a piece of meat with a novel smell might induce avoidance by the canid. Alternatively, a novel bait might induce curiosity and increase bait discovery by the target animal. The fish-oil lure might possibly also mask an olfactory cue of the toxin itself (Atzert 1971), which the dog may come to negatively associate with baits (Allsop *et al.* 2017).

Table 2. Species observed removing baits monitored by remote-sensing cameras and on sand pads, broken down by the presence of the fish-oil lure, across all baiting events and properties

Also shown is the time taken by each taxon to remove baits (mean \pm 1 s.d.), as well as the effect of lure for baits to be removed by each species (Z_{adj} and P -value). Significant results are shown in bold

Parameter	Ants	Feral cat	Kangaroo	Corvid	Varanid	Wild dog	Unknown species	Not taken	Total
Camera-monitored baits									
Fish-oil lure		5	5	13	17	3	38	27	117
No lure		14	24	22	52	1	210	67	406
Total		19	29	35	69	4	248	94	523
Lure effect: χ^2_1		0.17	0.44	4.40	0.15	6.38	7.09	2.38	
P -value		0.680	0.507	0.036	0.701	0.012	0.008	0.123	
Time till taken (days) $\times \pm$ 1 s.d.		14.3 \pm 19.3	8.9 \pm 10.9	9.3 \pm 12.5	7.7 \pm 13.4	22.3 \pm 39.2	12.2 \pm 14.5		
Lure effect: Z_{adj}		0.79	0.02	0.61	-0.12	0	-0.12		
P -value		0.428	0.976	0.536	0.905	1	0.901		
Sand pad-monitored baits									
Fish-oil lure	5	0	0	1	24	0	0	177	207
No lure	12	0	1	1	18	0	1	174	206
Total	17	0	1	2	42	0	1	351	413
Lure effect: χ^2_1	2.92				0.83				
P -value	0.088				0.363				

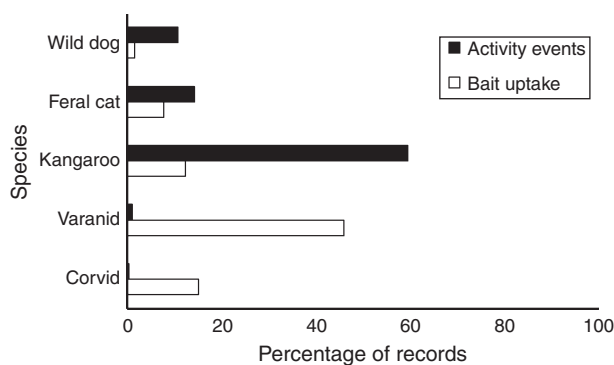


Fig. 5. Activity events and bait uptake over the entire monitoring period for five focal species. Each species' activity is a percentage of the total 16 885 activity events (by said species) seen on camera.

Changing the bait type (i.e. sausage, manufactured bait) or method of deployment (e.g. hung from a fence post, buried) could also encourage the individual dog's curiosity and potentially increase bait uptake. Bait placement within the landscape could also influence the ability of wild dogs to detect the baits. For example, baits for wild dogs are often placed along roads/tracks for convenience and ease of placement, but road use by dogs varies seasonally (Allen *et al.* 2014).

Learned aversion by wild dogs

The behaviour of wild dogs around our baits suggest that, given the long baiting history of the area, there has been increasing avoidance of baits. Of the 1809 wild dog activity events on camera, 18% of those also had a bait in the image, indicating that some wild dogs were locating baits. Often the behaviour of the individual wild dog on camera indicated that they knew the bait was present (i.e. sniffing or pawing the bait). A reasonable assumption is that some wild dogs in the present study have survived multiple baiting events and probably learnt

to not consume the dried meat baits. Several landholders surveyed by Binks *et al.* (2015) made the comment that baiting may be 'losing its effectiveness because dogs learn to not take baits'. Körtner and Watson (2005) also speculated that long-term baiting in an area may select for bait-shy individuals over time, and the highest knock-down effects have been recorded for bait-naïve populations (Thomson 1986; Fleming *et al.* 1996).

Canids will urinate or defecate on objects to mark them as 'aversion' for conspecifics. Following an encounter where coyotes were fed food items treated with an emetic, they were subsequently observed to urinate on the food when they were presented with it again (Gustavson *et al.* 1974, 1976). Foxes have also been reported urinating on baits (J. Kinnear, unpubl. data, cited by Kinnear *et al.* 2016). Finally, during learned aversion training where domestic dogs received a small electrical stimulus as a correction when they touched a non-toxic bait, some individuals urinated on the bait on subsequent presentations (Taylor 2017). This suggests that during our study, wild dogs demonstrated aversive behaviours towards dried meat baits.

All four baits that were taken, were taken by young animals (<8 months of age). These individuals are likely to be naïve to baits. Thomson (1986) recorded similar results in northern Western Australia, where no dingoes under 2 years of age survived aerially deployed baits compared with about half (7 of 13 survived) of adults (>2 years old) surviving. Interestingly, Thomson (1986) also noted that lone dingoes were more vulnerable and took more baits, probably because they did not have the pack size to take down larger prey and therefore scavenged more often. Three of the four dogs in our study seen taking baits were also alone. The fourth wild dog pup seen removing a bait was in the presence of an adult male and most likely a litter mate (on the basis of repeated identification over time). A wild dog male (most likely the pup's father) was recorded interacting with 11 baits over two baiting events, but did not take one and was later captured in a trap.

Table 3. Activities performed by wild dogs in the presence of a bait with and without fish oil, as recorded by the camera traps

Activity	Bait present		No bait present	
	Fish-oil lure	No fish oil	Fish-oil lure	No fish oil
Removing bait	3	1		
Sniffing the bait (or where bait was)	10	8	4	
Urinating/defecating (on bait if present)	1	1	3	1
Rolling (on the bait if present)	1		1	
Mouthing a bait	2			
Moving past (without inspecting the bait, if present)	124	155	118	1337
Resting or playing		2	2	
Inspecting and interacting with the camera trap	5	5	3	6
Sniffing something else in the vicinity (i.e. dead carcass or feral-cat faeces)	5	2	5	4
Total	151	174	136	1348
Total wild dog activity events: 1809				

Methodological issues: can tethering improve species identification?

Camera traps use contrasting surface temperature of the background and the animal moving across the camera's infrared sensors to trigger a photograph 'capture', otherwise known as 'heat in motion'. However, camera traps have different sensitivity to capturing ectotherms (such as varanids) and endotherms (Welbourne *et al.* 2016). Therefore, it is possible that more baits were removed by varanids than was recorded by the camera traps. This thermal issue may also bias species identification because of diurnal differences in temperature and species differences in activity patterns.

We recorded varanids taking 11% of the camera-monitored baits that were removed, but there was evidence that 68% of the sand pad-monitored baits were removed by varanids. Unpublished work in the southern rangelands of Western Australia has similarly noted that, over 10 days, 46% of sand pad-monitored baits (28 baits of 60) were removed by varanids (Blood 2008). We, therefore, believe that varanids accounted for a larger proportion of the camera-monitored bait uptake, with the failure of the camera to trigger and take an image preventing us from identifying the species taking the bait. We trialled tethering baits to improve our ability to identify species taking baits, and, subsequently, recorded more varanids on camera when baits were tethered. Tethering baits increased the length of time baits were on the ground, but there was no effect of tethering on bait-take by feral cats, kangaroos and corvids.

Another issue for the monitoring methods in the present study was the large number of baits taken on an unknown date because the animal did not trigger the camera traps. In future studies, we suggest the use of the time-lapse function of these camera traps so that an image of the bait is taken on a daily basis. This would allow more refinement of the bait-longevity calculations, and would increase the likelihood of being able to detect bait-take by ants (which cannot be determined by camera monitoring unless another animal triggers the camera).

Recommendations for management

Three baits were taken by wild dogs within days of deployment (2, 3 and 3 days post-deployment), but the fourth was taken 81 days post-deployment. Reducing uptake by non-targets,

therefore making baits more available to wild dogs, may increase uptake by wild dogs. Although this is also likely to increase the incidence of non-lethal baits (Fleming and Parker 1991; Kirkpatrick 1999), rendering them ineffective, or contributing to sublethal doses that increases the risk of individuals developing learned aversion (Allsop *et al.* 2017; Twigg *et al.* 2000). Baits can remain toxic in arid areas for more than 4 months, but rainfall shortens their life considerably (Kirkpatrick 1999; Twigg *et al.* 2000).

Baiting when non-target species are particularly active can substantially decrease bait availability for wild dogs. Baiting in spring (October) is programmed to coincide with pups emerging, but baiting efforts should ideally occur in periods of low non-target species activity; in the study sites we were working at, this means avoiding the warmer months. Ants (average ~2 days until bait removal) and varanids (average ~7 days) removed baits most rapidly in warmer months. Other studies have similarly noted that interference by non-target species can reduce bait longevity (Allen *et al.* 1989; Jackson *et al.* 2007; Dundas *et al.* 2014). Thomson (1986) did not comment on non-target interference, but instead discussed how prey availability may affect bait uptake by wild dogs; baits have to be more attractive than alternative food sources.

An option to avoid non-target interference with baits is to alter presentation. Fleming (1996) had only two buried baits removed by corvids. However, burying baits is generally not an option in landscape-scale baiting programs, especially where aerial deployment is required, and surface-laid baiting also reduces the leaching of 1080 (Allsop *et al.* 2017). Altering the type of bait used could increase bait-take, because it would reduce the likelihood of the target animals learning to associate negative experiences with a particular olfactory or visual cue. Fresh-meat baits are known to have a greater population knockdown than factory baits (e.g. Thomson 1986), but simply varying the bait type used at each round of control may have a greater long-term success.

Conclusions

The overall aim of a wild dog control programs is to reduce livestock and financial losses to producers. Interference by non-target species and wild dog aversive behaviour towards baits are hindrances to these programs. Given that wild dog

numbers are still sufficient to impose untenable stock losses, despite the long-term control programs, alternative control strategies may need to be incorporated into current landscape-scale baiting programs. Varying bait types frequently could minimise bait aversion and capitalise on curiosity for novel objects shown by many canids. Our work, while constrained by a low sample size, indicated novel lures may be a useful area for further work to increase bait-take by wild dogs (and increase bait appeal). Canid pest ejectors are an option to target wild dogs that reduces the issues of sublethal doses and the potential for learned avoidance, although they still rely on an attractive lure and minimal non-target interference (Kreplins *et al.* 2018). Finally, licenced pest-management technicians play an important role in managing wild dog population abundance at a regional scale, through an application of integrated wild dog control techniques including baiting, trapping and shooting (Thomson and Rose 2006). Having this range of options available will help landholders manage these wild dog impacts.

Conflicts of interest

The authors declare no conflicts of interest.

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