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Short Communication

Aerially deployed baits in the northern rangelands of Western Australia are available to wild dogs

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Abstract

Context. Aerial baiting using fixed-wing aircraft is an effective method of bait delivery for wild-dog control in remote locations. However, aerial baiting may result in loss of baits to positions that are inaccessible to wild dogs. Attempts, by landholders, to address such bait loss through compensatory baiting may increase baiting costs and potential risks to non-target species.

Aims. To assess bait drift under standard baiting conditions. To assess the availability of aerially deployed baits to wild dogs across several commonly baited landforms in the northern rangelands of Western Australia.

Methods. We determined drift characteristics of baits deployed under standard fixed-wing baiting conditions. We then determined the availability of aerially deployed baits by deploying baits with embedded radio-transmitters across four commonly baited landforms (riparian vegetation, tussock grassland, gorges and breakaways). We then visually assessed the availability of relocated baits (as 'high', 'moderate' or 'low').

Key results. Under standard fixed-wing baiting conditions, on average, baits fell 100.9 m forward, and 8.3 m laterally, from the point-of-release. Across all landforms, most baits (91.8%) were highly available, with a further 7.0% falling into the moderate category and 1.2% in the low category. There were significant differences in bait availability among landforms, with the proportion of moderate-low availability baits greatest in gorges and lowest on tussock grassland.

Conclusions. Within the northern rangelands of Western Australia, bait wastage owing to deployment in inaccessible locations is minimal.

Implications. Compensatory baiting for lost baits is unnecessary and increases costs to land managers.

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Introduction

Wild dogs (*Canis lupus familaris*, *Canis lupus dingo* and their hybrids) are important pests of livestock enterprises in Australian rangelands, resulting in lost productivity and significant control costs (Thomson 1984; Eldridge *et al*. 2002; Gong *et al*. 2009). Aerial baiting is recognised as the most cost-effective and efficient way of controlling wild dogs across large remote areas (Thomson 1986; Thompson and Fleming 1991; Fleming *et al*. 2001) and has been broadly adopted across Australian rangelands (Fleming *et al*. 2001).

To minimise baiting costs, baits must be delivered in a way that maximises bait uptake by target species and minimises the number of baits used (Thomson and Algar 2000). This approach is also consistent with a precautionary approach to minimising any potential non-target impacts of baiting (Glen *et al*. 2007).

Bait placement and bait distribution have been identified as potential factors affecting the efficacy of aerial baiting for 60 years (Tomlinson 1954; Thomson 1986; Thompson *et al*. 1990; Moseby *et al*. 2011; Robley 2011). Evaluation of aerial baiting rates for foxes has found that significant improvements in efficiency could be gained, without any loss of effectiveness, by reducing the baiting rate (Thomson and Algar 2000). However, baiting rate is only one factor capable of influencing aerial-baiting efficacy. Baiting efficacy is also likely to be affected by bait placement (Thomson 1986; Thompson *et al*. 1990).

Placement of aerially deployed baits may influence the availability of baits to wild dogs at several different spatial scales. Wild dogs use some habitats preferentially (Thomson 1992). Consequently, baits that are deployed, or land, in habitats not frequented by wild dogs are inaccessible to wild dogs at the habitat scale. Maximising availability of baits at the habitat scale can be achieved with knowledge of the ecology of the target species and by manipulating flight lines according to preferred habitat types (Thomson and Rose 2006; Moseby *et al*. 2011).

Baits may also be unavailable at the meso-scale. That is, baits are deployed in suitable habitat but are unavailable to dogs because they are not accurately delivered. Baits that are deployed on breakaways or ridges, but miss the target, fall into this category. At the fine scale, baits may be unavailable to wild dogs because they land in the target area but in inaccessible locations, such as within a spinifex (*Triodia* spp.) hummock or a crevice.

In areas of complex topography, helicopters are typically used for aerial baiting of wild dogs (Thompson *et al*. 1990; Fleming *et al*. 2006). In the rangelands, fixed-wing aircrafts are generally used because they are very accurate in landscapes of low relief and are less expensive than helicopters to operate (Thompson *et al*. 1990); however, the availability of baits deployed from fixed-wing aircraft to wild dogs has not been assessed. In absence of information, land managers may over- or under-estimate fine-scale bait availability. The former could result in baiting rates inadequate to control wild dogs, the latter in compensatory baiting to address perceived losses, resulting in increased financial cost to land managers and potential risks to non-target species.

Here, we assessed the drift of wild-dog baits from the point-of-release under standard fixed-wing baiting conditions, to assist in improving targeting accuracy of baiting using fixed-wing aircraft. We also determined the proportion of baits that are unavailable to wild dogs at the fine-scale across the following four commonly baited landforms in the northern rangelands: tussock grassland, breakaways, riparian vegetation and gorges.

Materials and methods

Study area

A trial ('bait-drift trial') to assess bait drift under standard fixed-wing baiting conditions was conducted at Carlton Hill Station (15°29′10″S, 128°32′E), ~35 km north of Kununurra in the East Kimberley, Western Australia (Fig. 1). The area used on Carlton Hill was the cleared, graded station airstrip (1 km by 50 m). The trial was conducted on 25–26 June 2012. Both days were fine, with minor gusts of wind (<20 kt).

The main experiment ('availability experiment') was conducted in the Pilbara (between latitudes 19°30′S and 24°00′S), in the northern rangelands of Western Australia. The west of the Pilbara is bound by the coast and it extends east to 121°30′E (Van Vreeswyk *et al*. 2004). The Pilbara includes two bioclimatic regions, namely, semi-desert – tropical, and desert – summer rain (Beard 1990). The rangelands of the Pilbara are mostly rugged, with prominent strike ridges and hills of outcropping rock separating deep valleys (Van Vreeswyk *et al*. 2004). Away from the coast, the vegetation is dominated by tree and shrub steppe (hummock grassland) with *Eucalyptus* spp. trees, *Acacia* spp. shrubs and *Triodia* spp. hummock grasses (Beard 1975; Van Vreeswyk *et al*. 2004).

There are four commonly baited landforms in the Western Australian northern rangelands, including riparian vegetation along river channels, flat tussock grassland, gorges in hummock grasslands, and breakaways in hummock grasslands.

Riparian vegetation along river channels ('riparian vegetation') is a major focus for aerial baiting in the Pilbara. River channels are typically flanked by a narrow (<30 m) strip of low woodland vegetation, typically up to 12 m height, and with canopy cover of between 10% and 30% and an understorey of tussock grass (Van Vreeswyk *et al*. 2004). Typically, during spring aerial baiting, river channels are dry, or have small, disconnected pools of water.

Flat tussock grasslands ('tussock grassland') comprise low, open grasslands, commonly dominated by *Aristida*, *Chrysopogon*, *Eriachne* and *Eragrostis* spp. These grasslands typically have a basal cover of between 1% and 10%, with grass tussocks below 0.5 m in height. Tussock grasslands occur mostly on alluvial plains and drainage tracts (Van Vreeswyk *et al*. 2004).

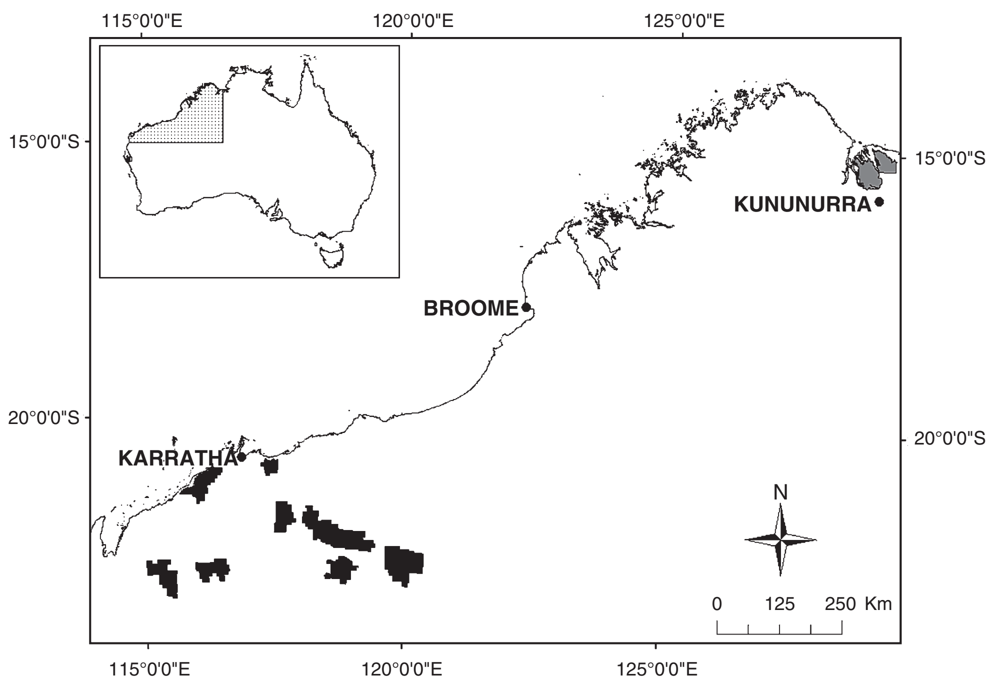

Fig. 1. Study locations. Bait-drift trial was conducted at Carlton Hill Station in the Kimberley (grey) and the availability experiment was conducted across nine properties in the Pilbara (black). Inset map shows location of northern rangelands in Western Australia (stippled).

Gorges in hummock grasslands ('gorges') are steeply incised valleys, with a drainage line at the base flanked by narrow (typically <10 m) strips of riparian vegetation. Gorges typically occur in hummock grasslands, with spinifex as the primary ground cover. Gorges differ from riparian vegetation in the gradient of the surrounding topography and the breadth of the riparian vegetation in the gorge.

Breakaways in hummock grasslands ('breakaways') are distinctive hills of relatively low relief (9–90 m), characterised by flat tops and steep eroded faces. Breakaways are distinctive in the landscape because of these characteristics. Breakaways generally have a mantle of loose rocks and are covered with open hummock grassland (Van Vreeswyk *et al*. 2004).

The availability experiment was conducted in conjunction with the annual Pilbara Recognised Biosecurity Group wild-dog baiting program, which is assisted by the Department of Agriculture and Food, Western Australia. The program includes aerial baiting on ~50 pastoral properties in the Pilbara each spring. Nine of these properties participated in the availability experiment (Fig. 1).

Bait-drift trial

Non-toxic dried meat baits (referred to as 'baits') were manufactured from 110 g of kangaroo meat (muscle block containing no skin, offal or bone) dried at ~50°C until they were 40% of the original weight (Thomson and Rose 2006). After an initial 12-h drying, a piece of 10-mm dowel was inserted into each bait to create a cavity for a radio-transmitter (as per Thomson and Kok 2002), before drying to target weight. Single stage radio-transmitters (Sirtrack, Havelock North, New Zealand) ~18 mm × 10 mm × 5 mm, weighing 2.4 g and with a 150-mm flexible whip antennae, were inserted into baits immediately before deployment. The antennae protruded from the bait ~80 mm. Transmitters were secured using toothpicks to block the cavity in the bait. Baits were individually weighed before deployment.

Three replicates of 36 baits with radio-transmitters and 75 baits without transmitters were deployed from a Cessna 206 aircraft. Radio-tagged baits were regularly interspersed with non-radio-tagged baits. All baits were sequentially numbered using a paint pen and were deployed in sequence. Baits were deployed from the aircraft flying at standard aerial baiting conditions, namely, ~300-ft altitude and a speed of 100 kt (Thomson 1986; Thomson and Rose 2006). A bombardier in the rear of the aircraft deployed baits through a chute at ~10 baits km^{-1} onto flat, cleared ground. An infrared sensor in the chute, connected to a GPS device fixed in the aircraft, recorded the point-of-release (latitude, longitude and altitude (accurate to 10 m)) for each bait as it was deployed.

Once deployed, baits were located on the ground by visual searching and telemetry. The GPS location (latitude, longitude and altitude) and accuracy of the GPS position were recorded with a handheld GPS device.

Availability experiment

Baits with embedded radio-transmitters were used to assess the availability of aerially deployed baits to wild dogs across commonly baited landforms in the Western Australian northern rangelands, including riparian vegetation, tussock grassland, gorges and breakaways.

Deployments of 30 transmitter baits were replicated three times in separate locations for each landform. In each case, aircraft altitude and velocity were as above and baits were dropped at ~10 baits km^{-1}. For two replicates, the number of baits used was less than 30 because the landform was shorter than the distance required for 30 baits; in one case, 20 baits were deployed on a breakaway and, in another, 23 were deployed in a gorge.

Baits were located using radio-telemetry within 3 h of deployment. The location (latitude and longitude) of each bait, and the accuracy of each GPS reading were recorded using a handheld GPS. For each located bait, the surface it came to rest on (vegetation, soil or rocks) and the distance from, type of, and height of the nearest vegetation were recorded. The availability of each bait to wild dogs was visually assessed, subjectively, as either 'high', 'moderate' or 'low'.

High availability referred to baits located in open ground, in a small grass tussock grass or on the very top surface of a spinifex hummock (<10 cm from the edge of the hummock). Moderate availability referred to baits located deep within a grass tussock (>30 cm), <5 cm deep in a spinifex hummock or on the top surface of a spinifex hummock but >10 cm from the side edge of the hummock. Low availability referred to baits located >5 cm deep in a spinifex hummock, >20 cm from the side edge of a spinifex hummock, or in one instance, in a large (2 m diameter), dense serrated leaf bush.

Statistical analyses

Drift of transmitter and non-transmitter baits was compared using ANOVA. Where there were no significant differences in drift metrics between transmitter and non-transmitter baits, the results were combined to provide descriptors of bait drift. The metrics calculated were the forward distance travelled from the point-of-release, the angle of departure from the aircraft and the lateral distance from the aircraft trajectory. These values were calculated using ArcMap 10.0 (ESRI, Redlands, California, USA) and the geographic modelling environment command 'pointdistances' (Beyer 2012). Weights of transmitter and non-transmitter baits were compared using Student's *t*-test. All data were assessed for normality. Where assumptions of normality were not met, appropriate transformations were performed.

Bait availability was assessed by calculating the proportion of baits in each availability category for each replicate. Because there were so few low-availability baits, to provide a conservative assessment of bait availability, the proportion of low- and moderate-availability baits was combined (square root transformed) and compared between landforms using ANOVA. Tukey's *post hoc* HSD test was used to determine the differences in availability of moderate–low-availability baits between landforms. All statistical analyses were performed in GENSTAT 15th edition (VSN International, Hemel Hempstead, UK).

Results

Bait drift

We located 96% of the baits deployed in the bait-drift trial, including all of those with transmitters. Despite the presence of the trailing aerial and a significant increase in bait weight

Table 1. Weight and drift characteristics of transmitter and non-transmitter baits from a fixed-wing aircraft under standard baiting conditions

Parameter	Transmitter baits	Non-transmitter baits	Analysis
Weight (g)	43.0 ± 0.9 (n = 75)	40.3 ± 0.6 (n = 155)	t = –2.65, P = 0.009
Distance from point-of-release to point-of-rest (m)	102.7 ± 2.9 (n = 88)	100.0 ± 2.3 (n = 181)	$F_{1,268}$ = 0.68, P = 0.409
Angle of departure from aircraft (°)	4.8 ± 0.5 (n = 88)	5.5 ± 0.3 (n = 181)	$F_{1,268}$ = 1.73, P = 0.189
Lateral distance from aircraft trajectory (m)	7.1 ± 0.6 (n = 88)	8.9 ± 0.5 (n = 181)	$F_{1,268}$ = 3.10, P = 0.080

owing to the addition of a transmitter, none of the variables of bait drift differed between transmitter and non-transmitter baits (Table 1). When deployed from a fixed-wing aircraft under standard baiting conditions, baits (transmitter and non-transmitter combined) typically fell 100.9 ± 1.8 m (mean ± s.e.) forward from the point-of-release, coming to rest at an angle of ~5.3 ± 0.3 degrees from the point-of-release and at a lateral distance from the aircraft trajectory of 8.3 ± 0.4 m.

Bait availability

Of the 342 radio-transmitter baits deployed, 341 were recovered. The one that was unrecoverable could be located but not retrieved. This bait was included in the low-availability category. Across all landforms, a high degree of bait availability was recorded. Most of all deployed baits (91.8%) fell in high-availability positions. A further 7.0% fell in moderate-availability locations and the remainder (1.2%) were classified as low availability. Of the four baits categorised as low availability, one fell into a large serrated bush and could not be retrieved. The remaining three were embedded in spinifex hummocks. Of the 24 baits that fell into the moderately available category, 19 were in, or on, spinifex, one was partially submerged in a creek line and two each fell into deep reeds or large tussocks.

The landform on which baits were deployed (n = 4) had a significant effect on the availability of baits in the combined lower categories (moderate and low) ($F_{3,11}$ = 78.64, P < 0.001, Fig. 2). All baits (n = 90) deployed on tussock grasslands were classified as highly available to wild dogs. The mean percentage of baits in high-availability locations decreased across landforms from riparian vegetation (94.4 ± 1.1%), breakaways (92.8 ± 1.5%) and gorges (79.5 ± 1.7%). Tukey's *post hoc* comparisons showed that gorges had a significantly (P < 0.05) higher proportion of baits in the combined lower-availability categories (moderate and low) than did all other landforms. Riparian vegetation and breakaway landforms did not differ from one another, but had a significantly fewer moderate–low-availability baits combined than did gorges, and more than did tussock grassland.

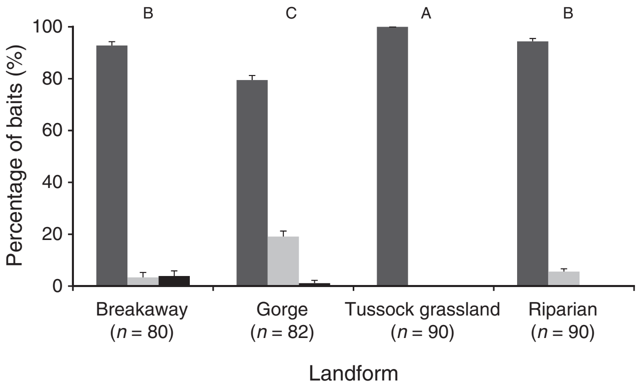

Fig. 2. Comparison of availability of aerially deployed baits across four landforms (mean ± s.e.). Dark grey columns indicate 'high' availability, light grey columns indicate 'moderate' and black columns 'low' availability. Different letters indicate significant differences between landforms in combined 'low' and 'moderate' categories using Tukey's *post hoc* test (P < 0.05).

Discussion

We have provided metrics to assist in the accurate deployment of wild-dog baits from fixed-wing aircraft. We have also addressed the need to evaluate the fine-scale availability of aerially deployed dried-meat baits to wild dogs in the northern rangelands of Western Australia.

Bait drift

The bait-drift trial allowed us to calculate the forward and lateral movement of dried-meat baits from a fixed-wing aircraft flying in a straight line at a standard baiting altitude (300 ft) and speed (100 kt). Fixed-wing aircraft pilots and bombardiers can work on the basis of dried-meat baits falling on average 100 m forward and ~8 m either side of the aircraft trajectory under standard baiting conditions. Allowance for greater variation is necessary when banking, flying at different speed or altitude, or in higher-wind speeds.

These metrics can assist in targeting baits at the meso-scale and are broadly consistent with previous work performed from fixed-wing aircraft with different bait sizes and flight conditions. Specifically, Thompson *et al.* (1990) recorded similar mean lateral movement (9.9 m) of baits nearly twice the weight of a dried-meat bait deployed at 300 ft and 80 kt.

Bait availability

A conservative interpretation of the bait-availability data showed that the overall availability of baits across all landforms was high (>90%). Further, if high- and moderate-availability baits were considered together, then the proportion of available baits exceeded 98%. Although high, the availability of baits deployed in the northern rangelands, did include variation between landforms over which baits were deployed.

Variation in bait availability between landforms may have been due, in part, to variation in topography. Declining availability from flat tussock grassland to gorge suggested a pattern of decreasing availability with increasing gradient and variability of terrain. Accuracy of baiting varies with terrain (Thompson *et al.* 1990; Robley 2011). Topography may affect accuracy of bait deployment and availability of deployed baits in a similar way, such that baits are more accurately deployed and more available on flat, open ground and less so in steeper, more variable terrain.

All but one low-availability bait, and the majority of moderate-availability baits, were located in, or on, spinifex hummocks. The presence of this landscape feature will therefore affect bait availability. Spinifex-dominated landscapes are by far the most extensive of the major structural plant communities in Australia, covering almost 1.4 million km^2 across the continent (Specht and Specht 2002; DEWR 2007). Spinifex can either increase or decrease the availability of baits to wild dogs. Although baits that become well embedded in spinifex fall into the low-availability category, the general structure of spinifex hummocks, namely dense, long, strong spiny leaves, may prevent ingress of objects into hummocks (Lazarides 1997), resulting in increased availability for those that do not become lodged in the leaves. Very dense mature spinifex is likely to contribute to reduced bait availability. However, as size and density of spinifex plants is affected by age and time since fire (Lazarides 1997; Armstrong and Legge 2011), these variables are likely play a role in determining bait availability in spinifex-dominated landscapes.

Implications for wild-dog management

Given the low loss of aerially deployed dried-meat baits to inaccessible locations in northern rangelands of Western Australia, there is no requirement to address bait loss through compensatory baiting. Where terrain is particularly steep and variable, as occurs in gorges, there is likely to be a slightly larger proportion of baits that are moderately available at the expense of those that are highly available. However, baits that fell into the low-availability category in these landforms still only account for a minor proportion of those deployed.

Costs of aerial baiting can be divided according to aircraft hire, bait and labour (Thomson 1986; Thompson and Fleming 1991). Cost-effective aerial baiting requires maximum wild-dog population reduction, or impact reduction, over the largest area for the lowest costs. However, in large remote aerial baiting programs accurately recording change in wild-dog density or impacts is extremely challenging. Under these circumstances, the area covered during a baiting program is generally considered as a surrogate for the operational effectiveness of the program.

As there is no requirement for compensatory baiting to offset losses of baits to inaccessible locations, omitting compensatory baiting means that landholders can increase coverage, improving operational effectiveness, or can use fewer baits, reducing overall costs. Further, omitting compensatory baiting is consistent with a precautionary approach to minimising potential risks to non-target species (Glen *et al*. 2007).

Success of baiting programs, in terms of bait uptake by target species, can be influenced by a suite of factors, including bait type, density of baits, size of the area baited, timing of baiting, durability of baits and the density of target species (Selhorst *et al*. 2001). Bait uptake will also be influenced by availability of baits to target animals. Here, we have investigated one aspect of the availability of aerially deployed baits to wild dogs, namely, access to the location of deployed baits. Bait availability to wild dogs will also be affected by uptake by non-target species (Allen *et al*. 1989; Thomson and Kok 2002; Moseby *et al*. 2011). Further investigation of the proportion of baits that can be accessed by wild dogs, but that are taken by non-target species, will further detail availability of aerially deployed baits to wild dogs.

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