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The use of poison baits to control feral cats and red foxes in arid South Australia II. Bait type, placement, lures and non-target uptake

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Abstract

Context. Poison baits are often used to control both foxes and feral cats but success varies considerably.

Aims. This study investigated the influence of bait type, placement and lures on bait uptake by the feral cat, red fox and non-target species to improve baiting success and reduce non-target uptake.

Methods. Six short field trials were implemented during autumn and winter over a five-year period in northern South Australia.

Key results. Results suggest that poison baiting with Eradicat or dried kangaroo meat baits was inefficient for feral cats due to both low rates of bait detection and poor ingestion rates for baits that were encountered. Cats consumed more baits on dunes than swales and uptake was higher under bushes than in open areas. The use of auditory or olfactory lures adjacent to baits did not increase ingestion rates. Foxes consumed more baits encountered than cats and exhibited no preference between Eradicat and kangaroo meat baits. Bait uptake by native non-target species averaged between 14 and 57% of baits during the six trials, accounting for up to 90% of total bait uptake. Corvid species were primarily responsible for non-target uptake. Threatened mammal species investigated and nibbled baits but rarely consumed them; however, corvids and some common rodent species ingested enough poison to potentially receive a lethal dose.

Conclusions. It is likely that several factors contributed to poor bait uptake by cats including the presence of alternative prey, a preference for live prey, an aversion to scavenging or eating unfamiliar foods and a stronger reliance on visual rather than olfactory cues for locating food.

Implications. Further trials for control of feral cats should concentrate on increasing ingestion rates without the requirement for hunger through either involuntary ingestion via grooming or development of a highly palatable bait.

Additional keywords: baiting, broadscale control, introduced, threatened species.

Introduction

Successful control of feral animals through poison baiting requires that target animals both find and ingest baits. The density of baits, non-target uptake and both fine-scale and habitat-scale bait placement can all influence whether a target animal successfully locates a poison bait. High bait uptake by non-target species can significantly reduce the number of baits available to target animals and bait density may have to be increased to compensate for non-target losses (Algar *et al.* 2007; Moseby *et al.* 2009). Alternatively, understanding the behavioural ecology of both target and non-target species may allow practitioners to optimise bait placement to reduce non-target uptake. Although aerial baiting prevents fine-scale bait placement, flight lines can be manipulated to target preferred habitat or exclude habitat favoured by non-target species.

Once a bait is encountered by a target animal, successful bait ingestion is required to effect a kill and this is primarily influenced by bait palatability and the hunger of the target animal. Some species, such as the red fox (*Vulpes vulpes*), are opportunistic feeders and will readily ingest a range of bait types including kangaroo, chicken, mice, egg and liver (MacDonald 1977; Short *et al.* 1997; van Polanen Petel *et al.* 2001). However, bait palatability has been found to influence ingestion rates with less palatable foods cached and highly palatable foods being more likely to be eaten or retrieved from a cache (MacDonald 1977; van Polanen Petel *et al.* 2001). Cats (*Felis catus*) are less likely to ingest poison baits than foxes (Risbey *et al.* 1997; Algar *et al.* 2007; Moseby *et al.* 2009) but have been found to consume kangaroo, chicken, fish and rabbit baits (Twyford *et al.* 2000; Algar *et al.* 2007). Specially formulated baits, such as Eradicat (WA Department for Environment and Conservation), can significantly reduce feral cat numbers (Algar *et al.* 2002*a*; Burrows *et al.* 2003) and have been used to eradicate cats from confined areas (Algar *et al.* 2002*b*). Unfortunately,

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successful bait ingestion by cats has been found to be highly variable (Algar *et al*. 2007) and it is widely believed that they will only voluntarily ingest poison baits when prey densities are low and cats are hungry.

This study aimed to investigate both bait detection and bait ingestion by feral cats in arid northern South Australia. First, the fine-scale accessibility of aerially-dropped baits was investigated to determine the proportion of baits accessible to cats. Uptake rates by target and non-target species were then compared in different habitats and accessibility classes. Non-target uptake was also investigated along baiting transects and in areas where threatened species were present. Different lures and bait types were then tested to determine their influence on detection and ingestion rates. Trials were conducted during the cooler months when baiting in the arid zone has been found to be most successful (Algar *et al*. 2007). Reptiles, significant prey items for feral cats in summer (Martin *et al*. 1996; Read and Bowen 2001; Paltridge 2002), and a potentially significant non-target group, are also less active during this time. Results were used to suggest improvements to baiting strategies.

Materials and methods

Study area

Arid Recovery is a joint conservation initiative centred around a fenced reserve in northern South Australia (30°29′S, 136°53′E) where introduced rabbits, cats and foxes have been excluded. Four locally extinct threatened species have been reintroduced; the greater stick-nest rat (*Leporillus conditor*), burrowing bettong (*Bettongia lesueur*), greater bilby (*Macrotis lagotis*) and western barred bandicoot (*Perameles bougainville*). The climate is arid with an average rainfall of only 166 mm a year. The dominant habitat types in the study area included mixed shrubland (*Acacia ligulata* and *Dodonaea viscosa*) on longitudinal dunes and low chenopod shrubland (*Maireana astrotricha* and *Atriplex vesicaria*) clay inter-dunal swales. Perennial dune vegetation averages one to three metres in height and inter-dunal swale vegetation is usually less than 80 cm. Projected vegetation cover varies considerably depending on seasonal conditions but averages 20–30% on dunes and 20% on swales. Drainage is endoreic with ephemeral swamps and claypans filling after exceptional rainfall events. Rabbit densities during the study period were estimated using spotlight counts, and averaged between 51 and 55 per km^2 (BHP Environmental Department, unpubl. data). Feral cat and fox densities in the study region fluctuate according to seasonal conditions but averaged ~0.8 and 0.6 per km^2 respectively over a 10-year period before the study (Read and Bowen 2001). Detection rates (percentage of independent track plots with spoor present) conducted between 2002 and 2006 averaged 18% for cats and 30% for foxes in unbaited areas and 19% and 16% in baited areas (Moseby and Hill 2011).

Poison baits

Two bait types were used in the trials: Eradicat sausages and dried kangaroo meat baits. Eradicat baits were developed by the Western Australian Department of Environment and Conservation and are a semi-dried meat product containing additives specifically attractive to cats. Eradicat sausages weighed 20 g net (dried to 15 g) and contained 4.5 mg of 1080 (sodium monofluoroacetate; Animal Control Technologies, Melbourne), a naturally occurring compound that is lethal to cats and foxes. Baits were used under an experimental licence held by the Western Australian Department for Environment and Conservation and the South Australian Department of Water, Land and Biodiversity Conservation. The baits were frozen until the morning of use when they were laid outside on mesh racks and sprayed with a Coopex solution (a residual insecticide; Bayer Environmental Science, Melbourne) to reduce insect attack. Once thawed, baits were left for 1–2 h on the mesh racks to ‘sweat’, where oils from within the sausages start to show on the surface and the outer skin. Dried meat baits were also used in one trial. These baits were 80–120 g pieces of kangaroo meat injected with 3 mg of 1080. Baits were dried to 50% of their mass, frozen and defrosted before use.

Six bait trials were conducted between 2002 and 2007 to investigate the influence of bait placement, lures and bait type on target and non-target uptake (Table 1).

Bait placement

In April 2002, 100 ‘cocktail frankfurts’ were dropped from a Cessna 172 aeroplane at a height of 150 m to investigate the proportion of aerially-dropped baits that would be accessible to feral cats. Commercially available frankfurts were used as a surrogate as they closely matched the Eradicat sausage baits in size and weight and this trial was conducted before the experimental licence was granted to Arid Recovery. Frankfurts were individually dropped in three passes over a 500-m section of representative dune that was vegetated with *A. ligulata* and *D. viscosa*. Flight speed matched that used in the broadscale aerial baiting events conducted around the Arid Recovery

Table 1. Characteristics of the six baiting trials conducted during the study including bait type, native non-target uptake, rainfall and whether the baits used were injected with 1080 poison

Average annual rainfall is 166 mm. *average of three sub-trials; E, Eradicat; M, dried meat baits

No.	Trial aim	Date	Bait type	Poison	Trial period (days)	Native non-target uptake (%)	Rainfall in 6 months prior (mm)
1	Influence of bait placement	May 2002	E	No	3	57*	11
2	Non-target uptake – general	June 2002	E	Yes	20	–	41
3	Non-target uptake – general	May 2003	E	Yes	26	25	72
4	Non-target uptake – threatened spp.	May 2003	E	No	3	16	72
5	Comparison of bait type	Aug 2002	E, M	Yes	3	21	16
6	Influence of lures	July 2007	E	Yes	12	14	35

Reserve between 2002 and 2006 (Moseby and Hill 2011). A piece of reflective adhesive tape was placed around the centre of each frankfurt to enable observers to locate the baits that night using torches. Located baits were categorised according to whether they landed 'in the open', 'under foliage' that did not extend to within 30 cm of ground level or 'within foliage' that extended to within 30 cm of ground level. Baits in the first two categories were considered to be highly accessible to cats while baits in the within foliage category were scored as high, medium or low accessibility. High accessibility was scored if the bait fell within 1 m of the edge of the foliage, medium between 1–2 m and low was more than 2 m into foliage.

In May 2002, unpoisoned Eradicat sausage baits were placed in both open and within foliage treatments in dune and swale habitats to test how bait accessibility and habitat affected bait uptake by target and non-target species (Table 1). We chose 3×1 km sites spaced more than 3.5 km apart with 25 bait stations and 100 baits per site. Within a site, bait stations were spaced 40 m apart and each bait station comprised a cluster of four 1×1 m bait plots. Bait plots included two sand dune and two swale bait plots with one plot in each habitat type placed in an open area and one within foliage. Plots were swept to remove tracks and a bait was placed in the centre of each plot. Those in the within foliage category (50 baits per site) were exposed to accessibility treatments (distance in from open) based on the same ratios found in the frankfurt trial drop. Plots were checked each morning for three days and bait removal and animal tracks were recorded. Strong wind or rain meant some plots were only checked for two nights. Chi-square tests were used to determine if there were differences in bait uptake between dune open, dune within foliage, swale open and swale within foliage treatments.

Target vs non-target uptake

In 2002 and 2003, pilot trials were conducted to investigate the uptake of Eradicat baits by native and exotic species. The trials were timed to coincide with aerial baiting events in June 2002 and May 2003 to replicate the seasonal conditions and non-target abundance at the time of baiting. In June 2002, a single transect of 20 poisonous baits was placed along the Arid Recovery Reserve fence line. In 2003, two transects each comprising 20 poisonous baits were situated 5 km apart, one along the Arid Recovery Reserve fence line and the other along the Borefield Road, a gravel dirt road located 5 km south of the Arid Recovery Reserve. Baits were placed on sand dunes at least 200 m apart. At each bait location along the Arid Recovery Reserve fence transects, a single bait was randomly thrown 1–5 m from a stationary vehicle. On the Borefield Road transect, the driver would walk off the road for 40 m before turning towards the car and throwing the bait over their shoulder for a distance of ~5–10 m. To mark the site but avoid attracting corvids and other species to the bait, flagging tape was placed only at the point of bait projection and an arrow was drawn in the sand towards the bait.

Baits were checked from the projection point each day for seven days and then every one to two days for up to 26 days. Where baits were missing, tracks were used to determine the species responsible for removing them.

A bait uptake trial was conducted also within the Arid Recovery Reserve in May 2003 to determine the response of three reintroduced threatened species, the greater bilby, burrowing bettong and greater stick-nest rat, to Eradicat baits. The sausages were not injected with 1080, but were otherwise prepared identically to those used in the aerial baiting trial. Eradicat uptake was investigated at 10 burrow or nest sites of each species. At each nest or burrow, 1 m^2 patches of sand were swept with the closest point being 50 cm away from each track runway, and one Eradicat bait was placed in the centre of each plot. The number of baits at each burrow or nest site ranged from three to seven, depending on the number of runways. The total number of baits at bettong, bilby and stick-nest rat burrow or nest sites was 37, 30 and 40 respectively, totalling 107 baits over 30 sites. The baits were checked each morning and tracks used to score each bait as: 'investigated', where the animal had diverted more than 50 cm off the runway towards the bait but not consumed the bait; 'nibbled', where a very small amount (<10%) of bait had been eaten; 'consumed', where more than 50% or all of the bait was eaten; or 'no response', where the bait was ignored or not found (with no tracks recorded within the 1-m^2 patches). There were no instances where between 10 and 50% of the bait was consumed. Baits were left for up to three nights and each bait received only one score. After a bait had been investigated, nibbled or consumed by a threatened species it was removed from the trial to ensure independence of replicates.

Comparison of bait type

In August 2002, uptake of buried and surface baits was compared in an area more than 40 km south of the Arid Recovery Reserve within the unbaited control area for aerial baiting trials. The study area was on Roxby Downs Pastoral Station located inside the dingo fence, where dingoes (*Canis lupus dingo*) are excluded for the protection of sheep. This trial was initiated after cats were thought to have died from consuming buried dried meat baits laid for foxes before the Eradicat aerial baiting trials in 2002 (Moseby and Hill 2011). One hundred bait sites were established 2 km apart on dunes along vehicle tracks. At each bait site, five plots were established 50 m apart and more than 10 m from the vehicle track. Three non-toxic 'bait' treatments and two controls were randomly assigned to each group of five plots. Bait treatments were Eradicat baits laid on the surface, fox baits laid on the surface and fox baits buried to a depth of 5–10 cm. All baits were placed in the centre of each 1×1 m plot, which was then raked and checked for animal tracks each morning for three days. Plots were scored as 'visited', where an animal had moved onto the plot but not ingested the bait, and 'removed', where the animal had moved onto the plot and ingested the bait. The two categories were mutually exclusive. The two control plots did not contain baits and one was a raked control and one an unraked control.

The use of lures

In July 2007, a trial was conducted to investigate whether bait uptake by cats could be improved by the addition of lures. Aerial baiting in the area had ceased in June 2006 and fox and cat spoor were regularly observed in the study area (see Moseby and Hill 2011). Twenty-one bait stations were established outside the Arid Recovery Reserve within 1 km of the fence line. Bait stations were more than 500 m apart and set in seven groups of three consecutive stations. Bait stations were set within 2 m of unsealed access tracks and consisted of a 1 m long and 0.5 m wide corral surrounded on three sides by vegetation and dead logs to a height of 0.8 m. A toxic Eradicat bait was placed on the ground surface at the open front of each corral. Each bait station within a group was randomly assigned to either (1) no lure, (2) olfactory lure (tuna oil) or (3) auditory lure (Feline Attracting Phonic-FAP, Westcare Electronics, Perth). Treatments were rotated within a group every four days allowing each bait station to receive all treatments over a 12-day period. The tuna oil was placed in an open-topped jar containing sphagnum moss to hold the scent and prevent any scent being left behind when the lure was rotated to another bait station. All lures were placed at the rear of the corral. Sand within 10 m of each bait station was swept to clear pre-existing animal tracks. Both the bait stations and vehicle track were checked each morning for tracks and categorised into either: 'visit', referring to an animal deviating from the road to within 20 cm of a corral but no bait taken; 'ignored', referring to an animal travelling along the road only; or 'removed', when a bait was missing. Any bait that was taken was replaced due to the assumption that multiple bait uptake from a corral would be different cat or fox individuals because of the use of toxic baits. Total bait nights (number of baits $\times$ number of nights) was 252. The number of baits ignored, visited or removed was compared between treatments using a 3×3 contingency table. The number of baits removed, ignored and visited was also compared between species to investigate the proportion of uptake from target and non-target species.

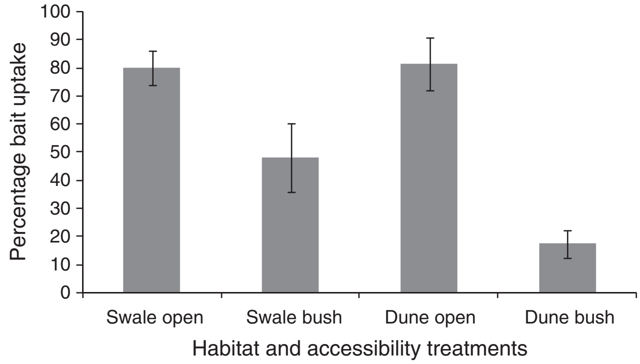

Fig. 1. Average percentage bait uptake per site by corvids in dune and swale habitat in both open and within vegetation accessibility treatments. Bars indicate 1 s.e.

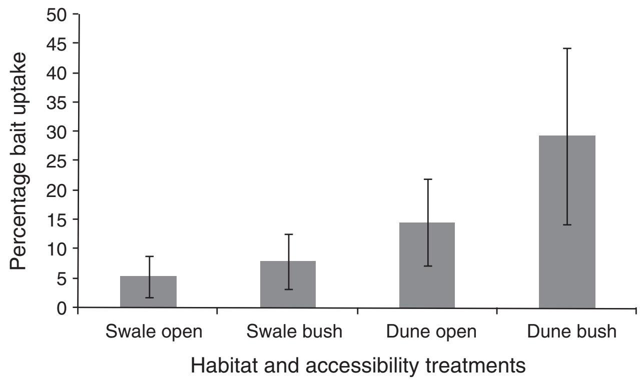

Fig. 2. Average percentage bait uptake per site by cats in dune and swale habitat in both open and within vegetation accessibility treatments. Bars indicate 1 s.e.

Results

Bait placement

All 100 frankfurts dropped from the plane were retrieved within two hours of aerial deployment. Fifty-one per cent of baits landed in the open, 19% under foliage greater than 30 cm from ground level and 30% in foliage less than 30 cm from ground level. When accessibility scores were allocated to the 49 baits that fell within foliage, the majority of them had high accessibility (75%), 22% had medium accessibility and only 3% of all baits were considered to have low accessibility.

When the influence of habitat type and accessibility was tested at three independent sites around the Arid Recovery Reserve there was a difference in bait uptake by both cats and corvids in the two habitat and two accessibility treatments (Figs 1, 2). Corvids removed 56% of the total baits at all three sites with an average site bait uptake of 80% in both the open dune and swale treatments. Differences in uptake between the four treatments were not due to chance ($\chi^2 = 36.7$, d.f. = 3, $P < 0.001$) with corvids taking more baits in the open and fewer baits within foliage, particularly in dune habitat (Fig. 1). Results from all three sites were combined to increase sample size for analysis.

Bait uptake by cats was low with only 14% of baits removed by cats during the trial. Chi-square analysis of combined site data revealed significant differences in bait uptake by cats ($\chi^2 = 18.1$, d.f. = 3, $P < 0.01$) with more baits taken from dune sites particularly within foliage (Fig. 2). To determine whether high corvid uptake in open sites influenced bait uptake by cats, available bait nights (number of total bait nights minus the number of baits taken by corvids) in each treatment were used to determine actual bait uptake figures for Chi-square expected values. Despite accounting for corvid uptake, cat bait uptake was still significantly different from that expected by chance ($\chi^2 = 10.4$, d.f. = 3, $P < 0.05$) with more baits taken from dunes within foliage than swale and open dune sites. Wedge-tailed eagles (*Aquila audax*) took four baits and rodents took one bait. An absence of sand goanna (*Varanus gouldi*) tracks at study sites suggested that they were not active during the trial. The uptake agent was unable to be determined for 20% of baits, usually those in the within foliage treatment where tracks were harder to observe.

Target vs non-target uptake

Bait uptake over time varied between the three baited transects outside the reserve but bait uptake was highest in the first three to 10 days after baiting (Fig. 3). Between 40 and 70% of baits were taken in the first 10 days with less than 20% taken in the following seven to 16 days. The species responsible for bait uptake was not recorded in 2002 but during the two 2003 trials six of the 40 available baits (15%) were taken by corvids, one by a small cat, three by sleepy lizards (*Tiliqua rugosa*), one by a babbler-sized bird and in nine cases the uptake agent was unknown as tracks were obscured by light rain recorded during the trial.

The non-toxic Eradicat bait trials conducted inside the Arid Recovery Reserve compared bait uptake by re-introduced and other native species. Ninety per cent of the baits were investigated by native animals, but only 16% (18 of 107 baits) were consumed (Fig. 4). Bettongs consumed 12 baits at five sites, bilbies consumed three baits at two sites, one goanna ate two baits at one site and a sleepy lizard consumed one bait (Fig. 4). Bettongs found more baits than all other species combined, and investigated, nibbled or consumed baits at 26 (87%) of the 30 shelter sites tested. Greater bilbies investigated baits at seven sites but consumed baits at only two of their own shelter sites. Stick-nest rats investigated or nibbled baits at 13 sites including eight of their shelter sites but did not fully consume any baits.

Comparison of bait type

When bait uptake was compared between Eradicat baits and surface and buried fox baits, in total, 48 (48%) surface Eradicat baits, 64 (64%) surface fox baits and 10 (10%) buried fox baits were removed over the three-day period (Table 2). Foxes and corvids removed the most baits (Fig. 5), with 19% and 18% of baits taken respectively. Fox and corvid ingestion rates for surface fox baits and surface Eradicat baits were similar. Cats only removed two Eradicat baits and one surface fox bait. The percentage of total baits encountered that were eaten was high in foxes (88%) and corvids (92%) but low in cats (25%) and other groups, such as rodents, lizards and other birds (Table 2). Higher visitation at surface bait sites (82 and 88 visits) compared with control (25 and 41 visits) and buried bait sites (18 visits) suggests that animals were attracted to the baits laid on the surface. Buried fox baits recorded the least non-target uptake but also the lowest uptake by foxes and cats. Visits to buried fox baits by cats and foxes were no greater than visits to control sites without baits. Although low sample sizes prevented statistical analyses, visitation at raked and unraked control sites was similar suggesting that raking was unlikely to have significantly affected visitation rates.

The use of lures

When auditory and olfactory lures were used in an attempt to improve bait uptake, 39 baits were removed over 252 bait nights yielding an overall uptake of 15.5%. Non-target species accounted for 90% of all bait uptake with only four baits removed by foxes and two by cats. The majority of non-target uptake was due to corvids (28 baits totalling 11% bait uptake) with four baits removed by the spinifex hopping mouse (*Notomys alexis*) and three by sleepy lizards.

Lures did not significantly increase bait uptake by cats and foxes. Cat and fox uptake data had to be combined due to the

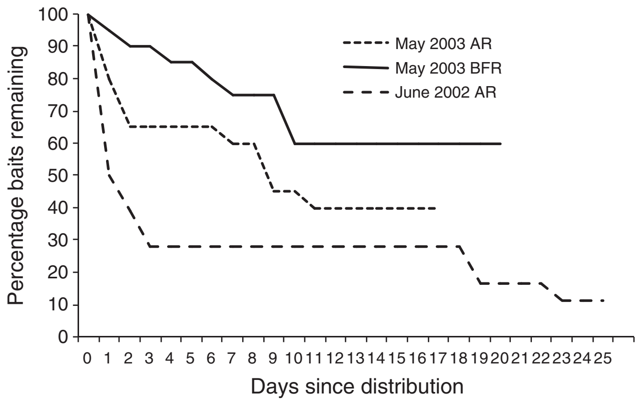

Fig. 3. The percentage of baits remaining each day along three baiting transects between 2002 and 2003. Twenty baits were placed along each transect. AR, Arid Recovery Reserve fence line; BFR, Borefield Road.

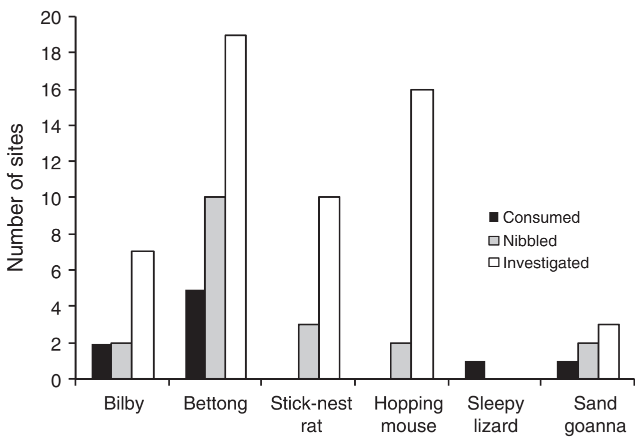

Fig. 4. The number of sites where baits were nibbled, consumed or investigated by each species during the trial: 107 baits were placed over 30 shelter sites including 10 bilby burrows, 10 bettong burrows and 10 rat nests.

Table 2. The number of baits that were visited and not removed, or visited and removed for each bait and control treatment
The two categories are mutually exclusive; $n = 100$ for each treatment

Species	Eradicat surface		Fox bait surface		Fox bait buried		Control raked	Control unraked
	Visit	Removed	Visit	Removed	Visit	Removed	Visit	Visit
Cat	2	2	5	1	2	0	0	2
Fox	2	22	2	26	4	8	16	24
Corvid	4	20	1	32	0	2	9	15
Other or unknown	26	4	16	5	2	0	–	–

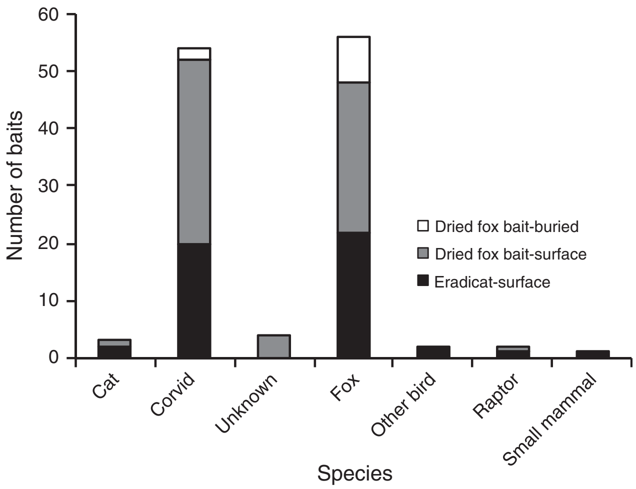

Fig. 5. A comparison of the number of poison baits taken by different animal groups in buried and surface bait treatments. The total number of available baits was 300.

small sample size (Table 3). There was no significant difference ($\chi^2 = 1.2$, d.f. = 2, $P > 0.05$) in the proportion of cats and foxes that visited, ignored and removed baits between the different lure types (auditory, olfactory or none). The three lure types were then combined and the proportion of baits visited, ignored and removed by cats and foxes compared with an expected equal probability in each category using Chi-square analysis. There was a significant difference in the proportion of cats and foxes in the three visit types ($\chi^2 = 8.9$, d.f. = 2, $P < 0.001$) with more baits ignored and fewer baits removed by cats and foxes. Cats walked past nearly half of the baits that were within 5 m despite two-thirds of them being associated with lures. Only 14% (2 out of 14) of baits that were encountered by cats were ingested. Foxes also either failed to notice or weren't interested in 60% of the baits that they walked past and only consumed 50% of the baits that they visited.

Discussion

Despite the presence of cats throughout the study area (see Moseby and Hill 2011) and trials being conducted during the cooler autumn and winter months, as suggested by Algar and Burrows (2004), bait uptake by feral cats at Roxby Downs was low with the majority of baits taken by non-target species. Cats failed to detect most baits used in the trials and recorded low ingestion rates for those baits that were encountered. Ingestion rates varied from as high as 50% to as low as 14%. Studies by Algar *et al*. (2007) and Moseby *et al*. (2009) found bait uptake rates to be highly variable (0–70%) and often lower than 20%. Risbey *et al*. (1997) also found that cats approached fishmeal and digest (an additive used by pet food companies to enhance cat food palatability) baits but rarely consumed them. Several studies have recorded higher bait uptake when using familiar foods (Short *et al*. 1997; Twyford *et al*. 2000; Mitchell *et al*. 2002) and Algar *et al*. (2007) suggest that cats only eat when they are hungry so encountering baits also needs to coincide with a period of hunger. The poor baiting success recorded in many poison baiting programs for feral cats is likely to be due to a combination of failure to locate baits (even when passing within a few metres), the presence of alternative live prey (Algar and Burrows 2004) and an aversion to scavenging or consuming unfamiliar foods (see Catling 1988; Short *et al*. 1999; Short *et al*. 2002).

Bait ingestion rates by foxes were much higher than those recorded for cats but they still varied and ranged from 50% to 93%. Although not directly comparable, these figures are similar to the rate of bait uptake by fox populations that have been reported in other Australian studies (58.3% Fleming 1997; 92% Marks and Bloomfield 1999). Foxes readily consumed Eradicat baits, as had been found by Algar and Burrows (2004).

Although limited by small sample sizes, the use of auditory and olfactory lures did not increase ingestion rates in our trial. Clapperton *et al*. (1994) found some olfactory lures, such as catnip and matatabi, attracted cats but did not determine their influence on bait uptake. Algar *et al*. (2007) found ingestion rates did not increase with auditory lures but several researchers have successfully increased bait uptake using visual lures (Friend and Algar 1995; Algar and Sinagra 1996; Algar *et al*. 2007). Cats are known to use visual and auditory stimuli more than olfactory stimuli when hunting for food (Commonwealth of Australia 2007). It is unlikely that these stimuli would be triggered by an inert, unfamiliar Eradicat bait, suggesting that bait presentation requires further research and ideally would closely match the appearance and behaviour of prey.

Bait uptake was highest on dunes, a result supported by local radio-tracking studies that found cats prefer this habitat type (Moseby *et al*. 2009). Interestingly, bait uptake was also higher when baits were placed within vegetation rather than out in the open, a result that was partly explained by lower bait uptake by non-targets in this habitat but was also significant when the influence of non-target uptake was removed. The hunting strategies employed by feral cats may include searching within vegetation for live prey, such as rodents and birds. Rodents are known to prefer to forage in areas with more cover (Parmenter and MacMahon 1983; Taraborelli *et al*. 2003) and birds and reptiles may be easier to stalk and catch within vegetation. Cats may also use cover as protection from predators, such as dingoes and wedge-tailed eagles.

Bait uptake by native non-target species ranged from 14 to 57% of baits in the six trials and often accounted for more than 90% of the total baits consumed. Corvids were the most significant non-target species, consuming or removing large numbers of both toxic and non-toxic baits. Both Australian ravens and little crows are common residents in the study

Table 3. The number of baits ignored, visited and not removed, or visited and removed by cats and foxes during the lure trial

Categories are mutually exclusive. 'Ignored' refers to the animal moving along the adjacent vehicle track without deviating towards the bait. Total number of bait nights was 252

Species	Visit	Removed	Ignored
Cat	12	2	10
Fox	4	4	12
Both	16	6	22

region (Read *et al*. 2000). No dead birds were observed during the trials and corvids remained common in the area, suggesting that few birds received a lethal dose of 1080. However, Australian ravens and little crows would only need to ingest one and two Eradicat baits respectively to reach their LD_{50} and potentially receive a lethal dose of toxin (McIlroy 1984).

Corvid uptake was highest in the unpoisoned bait placement trial that was conducted before aerial baiting with comparatively lower rates in later trials. This may have been partly due to corvids learning to avoid poison baits and also partly due to the method of bait deployment in earlier trials, where closely-spaced baits and quad bikes made it easier for birds to watch and follow observers. However, corvids also located and ingested baits that were away from human interference and even within vegetation. Corvids removed both Eradicat baits and unburied dried meat fox baits but rarely found buried fox baits. Algar *et al*. (2007) recorded an average non-target uptake of 22%, with corvids and varanids the most common species. All of our trials were conducted during the cooler months and it is likely that non-target uptake would be much higher during the summer months when more reptiles, particularly varanids, are active.

The impacts of high non-target uptake include both reduction in bait availability to target species, such as cats, and a possible decline in abundance of 1080-sensitive non-target species. Spinifex hopping mice were found to nibble baits inside the Arid Recovery Reserve and remove baits both in our lure trials and other baiting programs (Algar *et al*. 2007). In general, this species did not consume more than 10% of the bait and spinifex hopping mice are known to be moderately tolerant to 1080 ($LD_{50} = 32.7\ mg\ kg^{-1}$, King 1990) but the higher dose of 1080 in the sausage baits compared with standard fox baits means this species only has to ingest approximately one-quarter of a bait to receive the LD_{50} dose of the toxin. The other abundant rodent species in the study area, *Pseudomys bolami*, is closely related to species *P. hermansburgensis*, which needs to ingest as little as 8% of an Eradicat bait to receive its LD_{50} dose. Sleepy lizards regularly ingested baits during our trials and other lizards, such as varanids, have been found to ingest Eradicat baits, often in high numbers (K. E. M. pers. obs.; Algar *et al*. 2007). Although sleepy lizards and goannas are extremely tolerant to 1080 (McIlroy 1985) and would have to ingest ~21 and 7 Eradicat baits respectively to receive a potentially lethal dose, these species could significantly reduce bait encounter rates for target species. Encouragingly, most threatened species used in our trials nibbled or investigated baits rather than consumed them but this may have been partly related to the good seasonal conditions stimulated by 50 mm of rain recorded 3 months before the trial. Burrowing bettongs ingested the most baits within the Arid Recovery Reserve and are known to scavenge and consume a wide variety of food items (Robley *et al*. 2001; Bice and Moseby 2008). Some progress has been made on the development of a bait suspension device that may reduce uptake by varanids and rodents (Algar and Brazell 2008) but this is time consuming and not applicable to aerial baiting techniques.

One feral cat was found to remove a surface dried fox bait, supporting the suggestion by Moseby and Hill (2011) that cats will eat dried fox baits if they are hungry. Corvids and foxes did not show a preference for Eradicat or dried meat baits but consumed more baits on the surface than buried baits. Although fox bait uptake in buried bait plots was lower than surface baits, non-target uptake was only 20% compared with 50% for surface Eradicat baits and 62% for surface fox baits. The high reduction in non-target uptake may justify burying baits in fox control programs although it is likely to also reduce uptake by feral cats.

Trials ranged in duration from three to 26 days and results from some of the shorter trials may have been improved by extending the trial period. However, the high proportion of non-target uptake and poor bait ingestion rates recorded by cats in the shorter trials suggest that uptake rates by feral cats is unlikely to have significantly improved over time.

Conclusion

Despite the successful baiting of feral cats in some areas (Short *et al*. 1997; Algar and Burrows 2004), the high non-target uptake and risk to sensitive species coupled with the low bait detection rates and poor ingestion rates by cats suggests that Eradicat aerial baiting is an inefficient and ineffective broadscale control technique for feral cats in the Roxby Downs region. Reasons for poor bait uptake by cats may include high alternative prey, such as rabbits, an aversion to scavenging unless food resources are low, failure to recognise the bait as a food source, suspicion of unfamiliar foods and low reliance on olfactory senses to locate food. The main reason cited for poor bait uptake by feral cats is high numbers of alternative prey, such as rabbits (e.g. Short *et al*. 1997; Algar *et al*. 2007). However, even when rabbits were in low abundance, Algar *et al*. (2007) found average bait ingestion rates by feral cats of only 28%. Low ingestion rates suggest that significantly increasing bait density to offset high non-target uptake, as recommended by Algar *et al*. (2007), may improve bait detection but is unlikely to increase bait ingestion or efficiency and could lead to high non-target impacts. The highly variable results obtained from poison baiting trials (Algar and Burrows 2004; Algar *et al*. 2007; Moseby and Hill 2011), particularly in areas where rabbits are abundant, suggest that improvements in both detection and ingestion rates are required before poison baiting becomes an effective long-term control mechanism for feral cats. Detection rates could be improved through developing effective visual lures or more closely investigating the influence of bait placement. For example, placing baits under vegetation on dunes may improve detection by feral cats and reduce non-target uptake. However, improving ingestion rate is arguably easier and more important as it will minimise the number of baits required for successful control leading to higher bait efficacy, lower costs and lower non-target impacts. If bait ingestion could be assured for every incidence of bait detection then baiting could become a reliable, long-term method of cat control. Further trials should concentrate on increasing ingestion rates without the requirement for hunger. This could be done either through involuntary bait ingestion via grooming (see Read 2010) or through the development of a highly palatable bait that stimulates ingestion regardless of hunger.

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