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Sniffing out the stakes: hair-snares for wild cats in arid environments

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Abstract

Context. Wild cats (*Felis* spp.) are difficult to monitor because of their cryptic lifestyle and usually low numbers. Hair-snaring is a promising non-invasive method being used increasingly to estimate mammal populations.

Aims. Our aim was to carry out pilot trials of a simple hair-snare designed to capture hair from wild cats in arid environments.

Methods. Roughened wooden stakes were set at multiple sites on the crests of sand dunes and in swales in western Queensland, Australia, and in mostly sandy habitats of the Namib and Kalahari Deserts, Namibia. In Australia, stakes were sprayed with cat urine, extracts of catnip or valerian herbs as lures, or left untreated; in Namibia, alternate stakes were sprayed with a food lure of tuna emulsion oil. The stakes were checked for hair, usually daily, for 2–14 days, and the surrounding ground was inspected for tracks. Remote cameras also were used at some sites to confirm the identity of visitors to stakes.

Key results. In Australia, feral cats (*Felis catus*) were attracted to, and left hairs on, stakes sprayed with cat urine six times more frequently than to unsprayed stakes irrespective of whether snares were on dune crests or in swales, and showed no response to catnip or valerian. Tracks and photos showed that cats, dingoes or wild dogs (*Canis lupus* ssp.) and foxes (*Vulpes vulpes*) also approached and sniffed the stakes. In Namibia, *F. catus*, *F. lybica* and *F. nigripes* left hair on stakes, with deposition rates two and a half-fold higher at stakes with the food lure than without it. At least five other species of predators visited the hair-snare sites.

Conclusions. Simple wooden stakes provide a cheap and simple method of snaring hairs from wild cats, especially if used in conjunction with appropriate lures. Our results broadly support previous work, and extend the utility of the method to different *Felis* spp. in arid habitats.

Implications. Further research is needed on snares to investigate the seasonal efficiency of different lures. If DNA also is to be extracted to identify individuals, more work is needed to confirm that snares yield hair of sufficient quality to allow this.

Additional keywords: *Felis catus*, *F. lybica*, *F. nigripes*, *F. silvestris*, hair sampling, odour.

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Introduction

Cats (*Felis* spp.) occur on all continents except at the Poles, and occupy diverse habitats from arid desert to moist forest (Denny and Dickman 2010). Because of their cryptic lifestyle and usually low population densities (Kitchener 1991), cats are often difficult to monitor and manage, whether for conservation purposes (e.g. the threatened black-footed cat, *F. nigripes*) or for control of their predatory impacts (e.g. the feral house cat, *F. catus*). In Australia, feral cats have spread into all terrestrial habitats since their introduction by European settlers, and are considered a major threat to small and medium-sized (<3 kg) native vertebrates (Dickman 1996). Feral cats also have markedly negative effects on many native species in New Zealand (Gillies and Fitzgerald 2005) and on islands and mainland areas elsewhere in the world (Hess *et al*. 2009; Medina and Nogales 2009), leading to concerted efforts to control them. In contrast, threatened felids are provided with varying levels of protection in the wild, from the preservation of critical habitats to gaining respite from hunting (Nowell and Jackson 1996), and may be subject to captive management using assisted reproductive technologies (Herrick *et al*. 2010). In much of Europe, wild cats (*F. silvestris*) are protected in local ecosystems (Baumann *et al*. 2009), with conservation mandated by legislation (Macdonald *et al*. 2004).

Whatever the objectives of cat management, some form of monitoring is essential to ensure that targets are achieved. Direct monitoring by trapping is usually not feasible because of the large effort that is entailed, whereas indices such as spotlighting and counts of scats or tracks may not correlate well with the actual numbers or may be effective only at certain times or in suitable habitats (Mahon *et al*. 1998; Denny and Dickman 2010). Remote photography can provide longer-term monitoring and also the possibility of distinguishing individuals from characteristics of

their coats, and hence is being used increasingly in monitoring programs (Robley *et al*. 2008; Bengsen *et al*. 2011). However, a particularly promising method of detecting animals and gaining additional information on individual identity, sex, relationships to other individuals and demographic data such as population size and movements comes from capturing hairs and extracting DNA from the hair roots (Banks *et al*. 2003; Clevenger and Sawaya 2010; Kery *et al*. 2011). Hair-sampling requires the collection of sufficient hair to ensure that the rate of genotyping errors is minimised; material also should be stored soon after collection and subjected to efficient DNA-extraction (Piggott and Taylor 2003). As a first step in using this method, it is therefore crucial to use effective lures and hair-sampling devices.

German ecologists successfully use a non-invasive method of hair-sampling and DNA analysis to monitor populations of *F. silvestris* (Hupe and Simon 2007; Simon and Hupe 2008), whereby roughened wooden stakes are set in the field, sprayed with herbal lures such as extract of valerian (*Valerian officinalis*) and checked for hair after 5–14 days. Wild cats are attracted to the stakes and rub against the rough wood, especially during the breeding season, leaving enough hair for reliable collection and extraction of DNA (Steyer *et al*. 2013). This method does not preclude the sampling of hair from multiple animals, thereby complicating subsequent DNA analyses (Bremner-Harrison *et al*. 2006), and has the advantages of being cheap, easy to use and quick to deploy. Similar hair-capturing methods have been used to sample diverse species of mammals, for example pine martens in Switzerland (Burki *et al*. 2010), ocelots in the USA (Weaver *et al*. 2005), carnivores in Mexico (Castro-Arellano *et al*. 2008) and foxes (Vine *et al*. 2009; Berry *et al*. 2012) and spotted-tailed quolls in Australia (Ruibal *et al*. 2010). Lures generally may be based on the target species' preferred food or social odours, although both visual and auditory attractants may also be used (Molsher 2001; Moseby *et al*. 2004). Feral cats are variably responsive to different sensory stimuli, and appear to respond positively to some food odours, herbs such as catnip, or social odours derived from urine or faeces (Clapperton *et al*. 1994; Edwards *et al*. 1997; Short *et al*. 2002). Effective lures for other *Felis* spp. have been little studied, although *F. silvestris* seems attracted to extract of the root of valerian (Hupe and Simon 2007; Simon and Hupe 2008).

Despite the effectiveness of using lures and roughened wooden stakes for the capture of cat hairs in mesic forest habitats, such as in Germany (Hupe and Simon 2007; Steyer *et al*. 2013), it remains unclear whether such methods might work in arid habitats. Arid environments are often relatively open; hence, the provision of conspicuous wooden stakes may have attractive or repulsive effects on cats. In addition, olfactory lures may not last long in dry air. In the present study, we describe pilot trials aimed at testing whether cats leave hair samples on roughened wooden stakes (hair-snares) set in arid regions of central Australia and Namibia. We also explore whether deposition rates of hairs can be increased by using different olfactory lures and habitat locations. Because the trials were of a pilot nature, we did not attempt to extract DNA samples. However, we recorded whether captured hairs had roots or not, and thus whether subsequent extraction of DNA might be feasible (Kery *et al*. 2011; Steyer *et al*. 2013). Trials in Australia were undertaken to detect and sample hair from feral cats (*F. catus*), whereas those in Namibia were intended to detect *F. catus* and other felids such as *F. nigripes* and the African wild cat (*F. lybica*).

Materials and methods

Study sites

In Australia, trials were carried out on Mooraberrie Station (25.25°S, 140.98°E, by CRD) in the Channel Country of south-western Queensland and on Ethabuka Reserve (23.75°S, 138.47°E, by CRD and PUH) and Cravens Peak Reserve (23.36°S, 138.26°E, by PUH) in the Simpson Desert near the Queensland–Northern Territory border. Long, red sand dunes are the characteristic landform at each site, and vegetation is dominated by spinifex (*Triodia basedowii*), small groves of *Acacia* spp. and scattered *Grevillea* spp., *Eucalyptus* spp. and other shrubs. Detailed descriptions of the study sites are given, respectively, in Letnic *et al*. (2011), Dickman *et al*. (2011) and Haythornthwaite and Dickman (2006).

In Namibia, trials were carried out by CRD at 19 sites in three regional areas of the Namib and Kalahari Deserts. The Namib sites were set in sand dune, gravel and riparian habitats centred on the Desert Ecological Research Unit (now Desert Research Foundation of Namibia) facility at Gobabeb (23.57°S, 15.05°E). Riparian habitat occurs along the usually dry channel of the Kuiseb River and is dominated by *Acacia albida* and *A. erioloba*, with a patchy understorey of shrubs such as *Salvadora persica*, *Tamarix usneoides* and *Euclea pseudebenus.* The sand and gravel habitats are largely devoid of vegetation apart from very occasional shrubs or clumps of perennial grass. The Kalahari sites were set in the regions surrounding Otjiwarongo (20.48°S, 16.60°E) and Uhlenhorst (23.75°S, 17.92°E). The vegetation is a mix of thornbush savanna, tall shrubs and mixed woodland dominated by *Acacia* spp., *Boscia* spp. and *Grewia* spp., with a diverse but patchy cover of low shrubs and perennial grasses. More detailed descriptions of these sites are given, respectively, in Dickman *et al*. (1994, 1995) and Dickman (1995).

Hair sampling

At Mooraberrie, hair-snares were constructed from rough-sawn, untreated, softwood planks $8 \times 1.1 \times 90$ cm long, driven 15–20 cm into the soil, so that they stood 70–75 cm vertically above the ground surface. In November 1993, 22 planks were deployed, set individually at ~2-km intervals to maintain spatial independence (Mahon *et al*. 1998), with 10 on dune crests and 12 in swales within 50 m of dirt tracks. Vegetation cover on the dune crests was generally <15% and provided by shrubs such as *Grevillea* spp., whereas in the swales, ground cover exceeded 30% and was dominated by spinifex. The sand was swept in a radius of 1 m around each plank so that the tracks of visiting animals could be read. These crude hair-snares were checked for five consecutive mornings; hairs retained by the rough wood grain were placed in separate paper envelopes, and sand was reswept each morning. Sampling was repeated in November 1994, but with the following two modifications: 20 planks were established on dune crests and 20 in swales, with half of these selected at random in each dune position (i.e. crest and swale) and sprayed with ~4 mL of fresh cat urine. The spray covered the top 25–30 cm

of each stake. We used disposable latex gloves when setting these snares to reduce odour contamination. The urine, collected from two adult female feral cats shot elsewhere on Mooraberrie (T. Churches, pers. comm.), was reapplied after two nights.

On Ethabuka, two types of hair-snare were used. The first comprised rough-sawn pine stakes 6 × 0.6 × 65 cm long that stood ~50 cm high when driven into the soil. Twenty-four of these were set singly at intervals of 2–2.5 km, 12 on dune crests and 12 in dune swales, between 1 m and 10 m from sandy access tracks. Habitat cover was identical to that at Mooraberrie. Sand was again swept in a 1-m radius around each hair-snare, with the stakes checked for hairs and the smoothed sand checked for prints on four consecutive mornings. Collected hairs were again placed in separate envelopes. In different trials, cat urine (~4 mL) or tincture of valerian (~4 mL, Masterpet Australia, Sydney, NSW, Australia) was sprayed on six randomly selected stakes in each dune position on the evening of the first and third nights that the hair-snares were set. Three trials were carried out using this protocol. The first trial, in June 1993, used urine combined from three feral cats (1 adult ♀, 1 adult ♂, 1 unknown sex) shot near Ethabuka homestead (D. Smith, pers. comm.); the second, in November 1993, used tincture of valerian; the final trial, in November 1994, used urine from two adult male feral cats shot near bores on Ethabuka (D. Smith, pers. comm.). Different stakes were used in each trial to ensure that there was no carry-over of odours between times.

The second type of hair-snare used on Ethabuka comprised four sets of three 60-cm-high roughly-sawn wooden stakes that were spaced 1.5–5 m apart; two sets were established on dune crests and two on sandy access tracks in swales. As before, the sand around the stakes was smoothed to facilitate discovery of tracks. To further confirm the identity of visitors to these hair-snares, the two sets of stakes along tracks were set up within the field of view of Moultrie I40 Digital Game Cameras (Ebsco Industries Inc., East Birmingham, AL, USA). In each set, one stake was sprayed with valerian (Masterpet Australia), one with catnip (Rudducks Pty Ltd, Melbourne, Vic., Australia), and one remained untreated. The kind of treatment was marked on each stake. In erecting these stakes, we took care to set the untreated one first to avoid accidental contamination with the lures. After 2–14 days, the stakes were checked for potential hair and the ground for potential tracks, and camera images were downloaded. This protocol was used on Ethabuka in July and September 2011. An almost identical protocol was used on Cravens Peak Reserve in the same months. The only exception was that all stakes were established in dune swales, either near the edge of a swamp (Kunnamuka Swamp) or in the then-dry bed of a river running into the swamp.

In Namibia, the protocol at each study site followed that using the first type of hair-snare deployed at Ethabuka, with stakes comprising rough-sawn pine 6 × 0.6 × 65 cm long that stood ~50 cm high. However, only 10 were set per site, singly, at intervals of 1–1.5 km within 5 m of sandy access tracks. No attempt was made to position stakes on dune crests or in swales because these landforms were not conspicuous at all sites. Also, because our intention was to sample different species of *Felis*, we rejected the use of urine or other social odours derived from just one species, and instead sprayed alternate stakes with ~10 mL of tuna emulsion oil. Stakes were checked for five consecutive mornings, collected hairs placed in paper envelopes, and tuna oil refreshed on the evening of the third day. At several sites in Namibia, stakes were removed, knocked over or urinated on by large animals such as baboons (*Papio ursinus*) and unidentified artiodactyls; these were replaced immediately after these disturbances. All trials in Namibia were carried out in March and April 1992.

In pilot trials at Ethabuka and at M'Bela, near Uhlenhorst, we wound double-sided sticky tape, duct tape or fly strips (Aeroxon, Contech, Victoria, Canada) around small numbers of stakes to determine whether this improved their effectiveness in capturing hairs. Tapes were placed 10–30 cm above ground level and inspected at dawn, dusk, and once or twice during the day. Although sticky tapes have been used successfully in other studies (e.g. Vine *et al*. 2009; Berry *et al*. 2012), occasional feathers or small lizards found on the tapes suggested that they could be hazardous to small non-target fauna if used consistently. Hence, we did not pursue their use here.

Analyses

Hair samples were removed from their envelopes and placed into one of the following three classes according to the amount and quality of hair collected: Class 1 denoted loose hairs (usually <5) with no evidence of roots; Class 2 denoted samples where 1–5 hairs had obvious roots; Class 3 denoted samples containing many hairs with roots (>5, usually >30). Because our intention was primarily to identify an effective means of collecting *Felis* hair, we did not seek to extract DNA from any samples. However, we assumed that samples in Classes 2 and 3 would be suitable for this purpose because DNA potentially can be extracted even from single hairs that retain the root. Samples were washed in 70% ethanol and prepared for cross-sectioning and cuticular scale analysis using the techniques of Brunner and Coman (1974). We confirmed the identification of *F. catus* by comparing our sampled material with known reference hairs. For other species, identifications were made by reference to Brunner *et al*. (2002) or by comparison with reference specimens held at the University of Sydney, the Desert Ecological Research Unit, Gobabeb, and the State Museum, Windhoek.

Statistical analyses were carried out in three ways. First, we tallied the numbers of successful stake-visits (that is, the numbers of stakes with confirmed cat hairs) over all nights the stakes were set and compared these for association between habitats and lure types by using Fisher exact tests and between lure types and habitats separately by using chi-squared goodness-of-fit tests. Because the same individual cat may have deposited hair on the same stakes on different nights, we repeated analyses using only the frequencies of different stakes that had been visited. No qualitative differences were found in the results of these two analyses; hence, we present the results for stake-visits only. The same tests were used, second, to compare numbers of hair-snares with identified cat prints in the sand around the stakes. To increase sample sizes, we combined the results from identical trials carried out at the same site at different times and, with the Namibian results, combined data from different sites within each of the three study regions. Third, we used chi-squared contingency tests to compare numbers of hair-snares with prints versus those with deposited hairs between habitats and between lure types.

We also present the numbers of print or hair-deposition events counted as percentages of the stake-nights used to obtain them, where 1 stake-night = one stake set for one night. Photos taken by the remote cameras were inspected for the periods that stakes were in place, and numbers of visits by predators were tallied.

Results

In Australia, hairs of *F. catus* were deposited on 37 occasions on 33 stakes over 970 stake-nights, with a success rate of 3.8% (Table 1); in Namibia, hairs were deposited on 56 occasions on 48 stakes over 950 stake-nights, for a success rate of 5.9% (Table 2). Many hairs were usually deposited, with most left on the lower half of the stakes at or just below where lures had been applied. In Australia, 24 (64.9%) of 37 samples were scored as Class 3 and 11 (29.7%) were scored as Class 2, whereas in Namibia, 40 (71.4%) of 56 samples were scored as Class 3 and a further 12 (21.4%) were scored as Class 2. In both surveys, there were more incidences of cat prints on the sand surrounding the stakes than there were samples of hair on the stakes, with stakes capturing hair on 37 (56.9%) of 65 visits by cats in Australia and on 56 (83.6%) of 67 visits in Namibia (Tables 1, 2).

Exact tests revealed no association between lure and dune position at our Australian study sites with respect to frequencies of visits (Table 1), even after pooling data from the three trials using cat urine ($P = 0.285$ for deposited hairs, $P = 0.689$ for prints). However, goodness-of-fit tests using combined data from these three trials showed that cats left hairs six times more frequently at stakes with urine than they did at stakes without urine ($\chi^2_1 = 14.3$, $P < 0.001$), whereas hair deposition was similar on dune crests and swales ($\chi^2_1 = 0.57$, $P =$ n.s.). Similar results were obtained by repeating the analyses for cat prints (urine: $\chi^2_1 = 16.9$, $P < 0.001$; habitat: $\chi^2_1 = 0.1$, $P =$ n.s.). Results were too sparse to permit testing of the effects of catnip and valerian lures (Table 1). The tracks left near several stakes indicated that cats, wild dogs or dingoes (*Canis lupus dingo*) and foxes (*Vulpes vulpes*) had approached them. Photos taken by the remote cameras showed that, in at least four instances, a cat sniffed a stake but left no hair. No images were recorded of cats leaving hair. Additionally, there were three photos showing foxes sniffing stakes, and three photos depicting wild dogs.

Overall, cats left hairs on 20 (64.5%) of 31 visits to hair-snares on dune crests at our Australian study sites and at a similar rate on 17 (50%) of 34 visits to snares in swales (Table 1, $\chi^2_1 = 1.39$, $P =$ n.s.). In contrast, hairs were left on 24 (72.7%) of 33 visits where cat urine was used as a lure, a significantly higher frequency than the three (33.3%) of nine visits when catnip or valerian were used as lures (Table 1, $\chi^2_1 = 4.78$, $P = 0.029$).

Few cat samples were obtained in the region around Gobabeb, whereas both hair samples and prints were more likely to be found at hair-snares with lures in the other two regions (Table 2). Pooling data across all sites confirmed that cat hairs and cat prints were two and a half-fold more likely to be retained at snares with a lure than at those without a lure ($\chi^2_1 = 10.29$, $P = \sim 0.001$ and $\chi^2_1 = 16.25$, $P < 0.001$, respectively). In contrast to the Australian results, not all samples or visits by felids to snares represented *F. catus*. Hair samples ($n = 10$) and prints ($n = 12$) of the small and cryptic *F. nigripes* were detected at six of the eight study sites in the Uhlenhorst region, whereas prints ($n = 7$) attributable to *F. lybica* were detected in all three regions. It is likely that further prints and some hair samples were left by *F. lybica*, but these could not be distinguished from the signs of *F. catus* or hybrids of the two species. Small numbers of prints and hairs were left by other species of predators at the hair-snares, including the black-backed jackal (*Canis mesomelas*), Cape fox (*Vulpes chama*), bat-eared fox (*Otocyon megalotis*) and several species of viverrids. Leopard (*Panthera pardus*) prints were found at one site near rocky outcrops at Waterberg in the Otjiwarongo region.

Discussion

The simple wooden stakes that we used here proved capable of collecting hair samples from *Felis catus* and other small felids,

Table 1. Capture rates of hairs and prints of *Felis catus* at hair-snares in Australian study sites
Exact probability (*P*) results from Fisher exact tests are given; –, insufficient data to analyse

Study site	No. of trials	Lure type	No. of cat detections/stake-nights (% success)				*P*
			Dune crest		Dune swale		
			+Lure	–Lure	+Lure	–Lure	
Cat hairs							
Mooraberrie	1	None	2/50 (4)		3/60 (5)		–
	1	Cat urine	8/50 (16)	1/50 (2)	6/50 (12)	2/50 (4)	0.577
Ethabuka	2	Cat urine	7/48 (15)	0/48 (0)	3/48 (6)	1/48 (2)	0.364
	1	Valerian	2/24 (8)	0/24 (0)	1/24 (4)	1/24 (4)	–
	2	Catnip + valerian	0/114 (0)	0/57 (0)	0/92 (0)	0/46 (0)	–
Cravens Peak[A]	2	Catnip + valerian	0/22 (0)	0/11 (0)	0/20 (0)	0/10 (0)	–
Cat prints							
Mooraberrie	1	None	5/50 (10)		4/60 (7)		–
	1	Cat urine	11/50 (22)	1/50 (2)	9/50 (18)	3/50 (6)	0.590
Ethabuka	2	Cat urine	7/48 (15)	2/48 (4)	6/48 (13)	1/48 (2)	1.0
	1	Valerian	3/24 (13)	0/24 (0)	1/24 (4)	3/24 (13)	–
	2	Catnip + valerian	1/114 (9)	1/57 (2)	4/92 (4)	3/46 (7)	–
Cravens Peak[A]	2	Catnip + valerian	0/22 (0)	0/11 (0)	0/20 (0)	0/10 (0)	–

[A]All stakes were set in swales, either on the edge of a swamp or in a dry river bed between sand dunes.

Table 2. Capture rates of hairs and prints of *Felis* spp. at hair-snares in Namibian study sites

*$P < 0.05$; **$P < 0.01$; –, insufficient data to analyse

Study site	No. of trials	No. of cat detections/stake-nights (% success)		χ^2
		+Lure	–Lure	
Cat hairs				
Gobabeb	3	3/75 (4)	1/75 (1)	–
Otjiwarongo	8	16/200 (8)	7/200 (4)	3.52
Uhlenhorst	8	21/200 (11)	8/200 (4)	5.83*
Cat prints				
Gobabeb	3	4/75 (5)	1/75 (1)	–
Otjiwarongo	8	23/200 (12)	8/200 (4)	7.26**
Uhlenhorst	8	23/200 (12)	8/200 (4)	7.26**

confirming their utility in arid habitats. Some samples appeared to comprise mainly loose hairs, which suggested that animals had brushed lightly against the stakes; however, almost all contained at least a few hairs with roots. A few hair-snares yielded clumps of hair, which suggested that animals had actively rubbed against them. Although we did not attempt to extract DNA, the quantity of hair collected by the stakes was similar to the amounts that have been used to obtain DNA in other studies (Goossens *et al*. 1998; Broquet *et al*. 2007; Steyer *et al*. 2013).

Rates of hair collection were generally low, especially in Australia (success rate 3.8%), perhaps reflecting low levels of activity or abundance of cats in our study areas (e.g. Mahon *et al*. 1998). It is possible also that the presence of larger carnivores such as jackals, foxes and dingoes deterred cats from approaching the stakes, especially if cats arrived later than the other species and were alerted to their proximity by odour or other cues. However, evidence for this possibility is limited; cats frequently arrived the night after a visit by a larger carnivore, suggesting that deterrent effects, if present, were weak. The slightly higher rate of hair collection in Namibia (5.9%) may reflect differences in the methods used compared with the Australian trials, or greater felid activity at the time of study. Whatever the reasons for the observed hair-collection rates, the snares retrieved hair on 57–84% of visits by cats that came within a metre of the stakes, suggesting that collection efficiency once the stakes were encountered was reasonably high. Photographs showed that cats were generally interested in the stakes and would approach them to investigate by sniffing, even if they left no hairs.

In the Australian surveys, we found no evidence that habitat affected visitations or hair samples left on the hair-snares. Previous research has suggested that *F. catus* in arid Australia prefers dense vegetation on sand dunes, along creek lines and around water bodies (Edwards *et al*. 2002; Moseby *et al*. 2009), although Mahon *et al*. (1998) found a preference for open dune crests. Because most of our hair-snares were set near sandy tracks to facilitate access, it is possible that cats also used the tracks for movement and that this reduced any effect that habitat may have had. It is possible also that, if cats in our study sites do prefer dense vegetation for shelter, this can be found both near dune crests and in swales. Although cover generally on dune crests was <15%, isolated trees and small groves of mallee (*Eucalyptus gamophylla* and *E. pachyphylla*) occur short distances away down the dune sides, and patches of gidgee (*Acacia georginae*) occur on harder clay soils in the swales; we have seen feral cats resting above ground in all these species.

In contrast to the lack of any habitat effect, cats were more likely to visit hair-snares with lures than without them, and were likely to deposit hair if urine had been used rather than herbal attractants. Many scent lures have been used to attract *Felis* spp., including catnip, valerian, fish oil, fermented egg and cat urine (Clapperton *et al*. 1994; Edwards *et al*. 1997; Schlexer 2008), often yielding inconsistent results (Short *et al*. 2002). The positive response of feral cats to the odour of cat urine in our study contrasts with the findings of Clapperton *et al*. (1994), whereas it is broadly consistent with the work of Edwards *et al*. (1997) who documented attraction towards cat anal-gland preparations. Short *et al*. (2002) showed that social odours, such as urine, are most attractive to cats when they are breeding or defending territory during spring and early summer; indeed, two of our three trials with cat urine were carried out in November, when social odours were likely to have been especially attractive. Our clear results with cat urine may have arisen also because we added more urine to the snares to 'refresh' them after two nights. Moseby *et al*. (2004) recorded a non-significant tendency for cats to visit a mix of cat urine and faeces ('Pongo'), and noted that this lure desiccated rapidly during hot and dry conditions and had lost much of its smell over their 3-day trial period.

The strong attraction of cats to a food lure, tuna emulsion oil, is consistent with the findings of some studies (e.g. Veitch 1985; Dredge 1993; Edwards *et al*. 1997), but not others (e.g. Molsher 2001). Cats are more likely to be attracted to food lures if they are hungry or during periods of food shortage which, in some arid Australian habitats, are likely to occur between late summer and early winter (Short *et al*. 2002). We do not know when food shortages occur for *Felis* spp. in the Namibian desert habitats, owing to scant knowledge of both their diets and the breeding cycles of the potential prey species (Withers 1983; Griffin 1990; Skinner and Smithers 1990). However, patterns of rainfall and seasonal temperatures similar to those in arid Australia suggest that food shortages are most likely to occur in autumn, when our surveys took place. If *Felis* spp. during the present study were hungry, we would expect weaker responses to food lures at other times of year; however, this expectation remains to be tested.

Lures using catnip and valerian were ineffective in our trials. Both lures have been shown to be effective in attracting cats in other studies (Hupe and Simon 2007; Schlexer 2008; Simon and Hupe 2008) and may be attractive also to dogs and foxes (Schlexer 2008). These lures can produce a euphoric state (Grognet 1990). In domestic cats, the typical response to catnip consists of the following four stages: '(1) sniffing, (2) licking and chewing with head shaking, (3) chin and cheek rubbing, and (4) head-over rolling and body rubbing', lasting up to 15 min (Todd 1962, p. 56). For catnip, at least, susceptibility to its effects in cats is genetic and not all individuals may respond (Todd 1962; Tucker and Tucker 1988). In both pen and field trials in New Zealand, Clapperton *et al*. (1994) showed that feral and domestic cats responded positively to catnip and to another plant-based lure (matatabi, *Actinidia polygama*), with half of the subjects showing the full euphoria response. In Australian trials, however, neither the present study nor the studies of Molsher (2001) or Short *et al*. (2002) have shown any marked responses by cats to catnip. Cats, as well as foxes and dingoes, showed interest in stakes sprayed

with catnip and valerian, but not at rates greater than in control stakes; even when cat visits were documented via prints, hairs were retained on only three of nine occasions. There was no evidence from either prints in the sand or photographs that any predators showed euphoric responses, and it is possible that the autosomal dominant genes that encode for the catnip (and valerian) responses (Todd 1962) occur at low frequency in the Australian cat populations studied so far.

Rates of capture of feral cats are usually <5% and often closer to 1% (Molsher 2001; Short *et al*. 2002; Moseby *et al*. 2004); however, they can exceed 10% in unusual situations such as where cats are aggregated around rich and artificially subsidised food sources (Denny *et al*. 2002). Although capture rates of cats are not directly comparable to rates of capture of their hair, owing to factors such as greater wariness near traps, failure of trap mechanisms or escapes, and the possibility that individual cats can deposit hairs on multiple occasions, the rates of hair capture in both our Australian and Namibian study regions, although low, were still considerably greater than live captures are likely to have been. We conclude that the simple wooden stakes we used here can readily trap hairs from visiting cats, and that cat urine and food odours will enhance trapping efficiency, at least under conditions similar to those described. Future research might profitably investigate the efficiency of lures at different times of the year and the quality of DNA yielded by captured hairs.

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