Wildlife Research, 1997, **24**, 173–183

Field Evaluation of Olfactory Lures for Feral Cats (*Felis catus* L.) in Central Australia

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Abstract

Field trials were conducted in central Australia to evaluate the ability of various olfactory lures to attract feral cats (*Felis catus* L.). Ten food-based lures, one plant extract and two scent-based lures (anal-gland preparations from male and female cats) were evaluated on the basis of visitation rates and elicited behavioural responses. A visual lure composed of bird feathers was also tested in conjunction with the scent-based lures. One food-based lure (sun-rendered prawn) and both of the scent-based lures were found to attract feral cats. The visual lure did not enhance the attractiveness of the scent-based lures. The possible uses and relative advantages of these lures in control programmes and in ecological studies of cats are discussed.

Introduction

The house cat (*Felis catus* L.) has been introduced by humans to many parts of the world. In many instances, feral animals that interact little with humans and maintain self-perpetuating populations have become established in remote areas. Australia is no exception and feral cats occur in most mainland habitats, including the arid interior of the continent (Newsome 1995).

On islands, predation by introduced cats can have obvious and deleterious consequences for native populations of animals. Declines in island populations of birds because of cat predation are particularly well documented (Taylor 1979; Karl and Best 1982; van Aarde 1984; Fitzgerald and Veitch 1985; Berruti 1986). On larger land masses, the impacts of introduced predators are harder to discern from other factors (Clapperton *et al.* 1994*a*). In central Australia, for example, changes in burning patterns, increased competition for food, habitat modification due to the introduction of rabbits and domestic stock, and the spread of introduced predators tended to co-occur. As a result, it is difficult to determine which factors have mainly contributed to the dramatic extinctions and range contractions of native mammals within the region since European settlement (Morton 1990). Recent research has indicated that predation by feral cats may have been important. Predation by feral cats was the primary factor involved in the recent failure of a reintroduction programme for the rufous hare-wallaby (*Lagorchestes hirsutus*) in central Australia (Johnson 1991; Gibson *et al.* 1994). The future success of reintroduction programmes for this and other species on mainland Australia will depend upon the development of effective methods for the control of exotic predators.

Control programmes for feral cats have usually relied on ‘conventional’ methods including trapping, baiting and shooting (van Aarde 1984; Veitch 1985; Bloomer and Bester 1992). Cat diseases have not been used widely as biological control agents. Their use has been confined to offshore islands where there is little possibility of affecting domestic pets (e.g. van Aarde 1984). The effectiveness of control programmes based on conventional methods can be improved if

10.1071/WR96013 1035-3712/97/020173$05.00

suitable lures (attractants) are employed. In addition to bringing the target animal to a particular area (Turkowski *et al.* 1979; Veitch 1985; Jolly and Jolly 1992), lures can elicit investigative behaviour (Turkowski *et al.* 1979), which can increase capture rates and bait uptake. Also, if the lure is not attractive to other animals, impacts on non-target species can be mitigated.

Lures may be olfactory, visual or auditory stimuli, or a combination of these. Olfactory lures are the more popular (Linhart *et al.* 1977; Turkowski *et al.* 1979; Mitchell and Kelly 1992). Food-based lures are commonly used, typically in the form of an inert bait. Social odours or scents in urine and anal-gland secretions have also been used widely to attract canids and other carnivores (Conner *et al.* 1983; Clapperton *et al.* 1989, 1994*b*; Mitchell and Kelly 1992). Social odours have communicative value in many species of mammals, including cats (Bradshaw 1992). Synthetic lures derived from social odours have been developed for some species, including the coyote (*Canis latrans*) (Murphy *et al.* 1978) and the ferret (*Mustela furo*) (Crump 1980; Clapperton *et al.* 1989).

Food-based lures, particularly those based on fish and meat, have been the olfactory lures most often used for cats (Veitch 1985; Berruti 1986; Clapperton *et al.* 1994*a*). Only recently has the efficacy of scent-based lures in attracting cats been evaluated (Clapperton *et al.* 1994*a*). A group of plant-derived compounds known as lactones, which commonly elicit distinct behavioural responses in cats, also offer potential as olfactory lures (Clapperton *et al.* 1994*a*).

The primary aim of this study was to determine the effectiveness of various food-based and scent-based lures in attracting feral cats in central Australia. The effectiveness of a visual stimulus was also tested.

Methods

Field Trials

Experimental trials were conducted on free-living feral cats in semi-arid woodland dominated by mulga (*Acacia aneura*) 150 km north-west of Alice Springs from June to September 1994. The only other large mammalian predator present at the study site was the dingo (*Canis lupus dingo*).

Thirteen olfactory lures (see Appendix) and one visual lure were tested and evaluated on the basis of daily visitations and elicited behavioural responses. Ten of the olfactory lures were 'food-based' (nine seafood derivatives and one mammal derivative: commercially available blood and bone fertiliser). One olfactory lure was a plant derivative containing lactones (homogenised catnip: *Nepeta cataria*). The remaining two olfactory lures were social odours based on the anal-gland secretions of cats (Macdonald 1985). Preparation methods were similar for anal-gland preparations from males and females. The anal glands and about 4 cm of colon were removed from freshly killed cats. For each sex, material from several cats was pooled and allowed to decompose at room temperature for several weeks. Before use, the anal-gland preparations were mixed with urine from cats of the same sex. Urine was collected daily from cats held in wire-mesh cages and then stored at 4°C. Some of the urine used in the manufacture of the anal-gland lures was thus several days old. We did not record whether female cats used during urine collection were in oestrus. Glycerine was used as a solvent in some olfactory lures to keep the lure ingredient in suspension and to slow evaporation rates (Linhart *et al.* 1977).

Four olfactory lures plus a control (water) were presented during each trial. The lures were presented in 5-mL plastic vials containing sponge. The vials were loaded with 2 mL of lure in the laboratory, then capped and stored separately in plastic bags to avoid cross-contamination. In the field, the vial caps were replaced with similar ones with four perforations about 1·5 mm in diameter. Vials were then inserted in the top of hollow steel posts. Each post was buried in soil to a depth of about 8 cm leaving the vial exposed about 7 cm above the soil surface. The area around each post was then prepared by raking to register animal tracks.

Lure stations were situated at 500-m intervals along existing roads for a distance of 70 km. At each station the same treatment (= lure) was presented on paired sites located on either side of the road. Treatments were blocked and randomised every 2·5 km, giving 28 spatial replicates. Each trial was composed of two subtrials conducted in different weeks. In each subtrial, lures were exposed over four successive nights. Lure vials were not refreshed during the course of a subtrial. Thus, each lure was exposed at 28 stations over a total of eight nights during each trial. Each morning all animal tracks within 0·5 m of the vial at each site were recorded and then brushed out. The presence of one or more tracks of a particular species at either one of the paired sites at each station was scored as one visit by that species. The behaviour of cats and dingoes that had visited stations was assessed according to the following criteria: (i) to station—

tracks through plot but no obvious interest in vial; (ii) to vial—tracks leading up to vial; (iii) chew vial—vial chewed or pulled out of steel post. Missing vials were replaced each morning as were those vials where the sponge had been dissected and removed by ants.

The visual lure was designed to mimic a fluttering bird. This design was chosen because birds are an important prey item for feral cats in central Australia, occurring in about 10 and 20% of cat stomach contents in summer and winter, respectively (n = 392, Paltridge *et al*. 1997). The visual lure was made of two bird feathers (one black, one white–grey) each about 15 cm long wired together at an angle of 45°. These were attached with a length of light wire and a swivel to a branch overhanging the lure site, so that the feathers were suspended 1–1·5 m above the ground. The visual lure was tested once in conjunction with the scent-based lures by means of the experimental design described above.

During our second trial, there was a slight modification to the experimental design outlined above. Only three olfactory lures plus the water control were trialled over eight nights. A fourth olfactory lure based on valerian oil (*Valeriana* spp.) was tested during the first week but it could not be duplicated for the second week of the trial. As a consequence, another olfactory lure based on tuna oil was substituted in its place.

Data Analysis

Dingoes prey on feral cats (Corbett 1995) and there is a distinct possibility that cats may avoid areas recently visited by dingoes. Thus, before evaluating the effectiveness of lures with respect to cats, we examined whether dingo visitations and associated behaviour had an effect on the frequency of cat visits to lure stations. We assigned stations daily to one of the following groups: (i) ‘dingo negative’ stations—stations not visited by dingoes the previous night nor on any prior night during that week; (ii) ‘dingo single visit’ stations—stations where only one of the paired sites had been visited by a dingo during that week; (iii) ‘dingo double visit’ stations—stations where dingoes had previously visited both of the paired sites during that week, but not necessarily on the same night; and (iv) ‘dingo damaged’ stations—stations at which a dingo had disturbed the lure vials at both of the paired sites on the previous night (i.e. fresh dingo scent and vial damage at both sites). Cat visitations during the course of a week were assigned to the appropriate station group. Data for all lures and trials were pooled. The proportions of ‘dingo negative’, ‘dingo single visit’, ‘dingo double visit’ and ‘dingo damaged’ stations visited by cats were compared by means of a test equivalent to a chi-square test (Zar 1984, p. 400).

Lure effectiveness with respect to cats was examined by two methods. We analysed data for each trial separately and we excluded data for the two lures that were tested for only four nights. In Analysis 1, dingo visitations were ignored. Generalised linear models were fitted to cat visitation data by GLIM (NAG Ltd, Oxford, 1993). The dependent variable was the number of visitations each night for each lure (i.e. nights as replicates). The error function was specified as Poisson because the dependent variable was based on count data (Crawley 1993). Where ANOVA indicated that differences existed, the Tukey test was used to discriminate between the lures. In Analysis 2, dingo ‘affected’ stations were removed from the data set (see Results). For each lure, we calculated the proportion of stations visited by cats and this value was used to assess lure efficacy. Data for all eight nights of each trial were pooled. These data were analysed by means of a test equivalent to a chi-square test, as described above. Where significant differences were indicated, a Tukey multiple-comparison test of arcsine-transformed data was used to discriminate between lures.

For those lures that were effective in attracting feral cats, an assessment was made of their relative attractiveness to dingoes. This was achieved by dividing the number of dingo visitations to each lure by the number of dingo visitations to the water control during the same trial. A value approximating one indicated that the lure held no special attraction for dingoes above that of the water control.

The experimental protocol employed during this study was determined following a pilot study conducted in June 1994. Power analysis based on ANOVA was used to determine the appropriate number of lure stations and exposure nights. The goal was to achieve power greater than 0·7.

Results

Dingoes visited more lure stations than did feral cats. Overall, there were 478 separate dingo visitations over the total 4480 (140 stations × 8 nights × 4 trials) station-nights (i.e. 10·7% of stations visited). In about 50% of the dingo visitations, only one of the paired sites registered dingo tracks. In 42·7% of the dingo visitations, the lure vial at one site only was removed and chewed. In 32·8% of the dingo visitations, the lure vial at both sites was removed and chewed. Lure 8 (sun-rendered prawn) had the highest number of dingo visitations (38 visitations over 224 station-nights = 17·0%).

The percentages of ‘dingo negative’, ‘dingo single visit’, ‘dingo double visit’ and ‘dingo damaged’ stations visited by cats are shown in Fig. 1. No significant difference was found between any of the treatments, indicating that cats did not avoid stations recently visited by dingoes. However, the proportion of dingo-damaged stations visited by cats was much lower than that for any of the other treatments. This is because in many instances of dingo damage, the vials were removed and dropped away from the lure site, thwarting the possibility of subsequent cat visitation. This was reasonable justification for adjusting the number of replicate stations for dingo-damaged sites in Analysis 2 of lure efficacy with respect to cats.

Overall, 128 separate cat visitations were recorded over the total 4480 station-nights (i.e. 2·9% of stations visited). Sun-rendered prawn had the highest number of cat visitations (17 visitations over 224 station-nights = 7·6%; Table 1).

The results of Analyses 1 and 2, which examined the effectiveness of lures with respect to cats, were similar. Only results based on Analysis 2 are reported in detail here. Five of the lures were significantly different from the water control (Table 1): one food-based lure (sun-rendered prawn; χ^2 = 15·8, P < 0·005), the two scent-based lures (anal-gland preparations mixed with urine, for males and females; χ^2 = 17·0, P < 0·005) and the two scent-based lures combined with the visual lure (χ^2 = 17·0, P < 0·005). However, the visual lure did not enhance the attractiveness of the anal-gland preparations (i.e. there was no significant difference between the number of visitations to the gland preparation from males with and without the visual lure, nor between the gland preparation from females with and without the visual lure). The power of ANOVA tests as used in Analysis 1 ranged from 0·7 to 0·9.

In the majority of visits to the lures that had significantly more visitations than the control, cats investigated the vial containing the lure (Table 1). No cases were recorded of cats chewing the vial during any trial (Table 1).

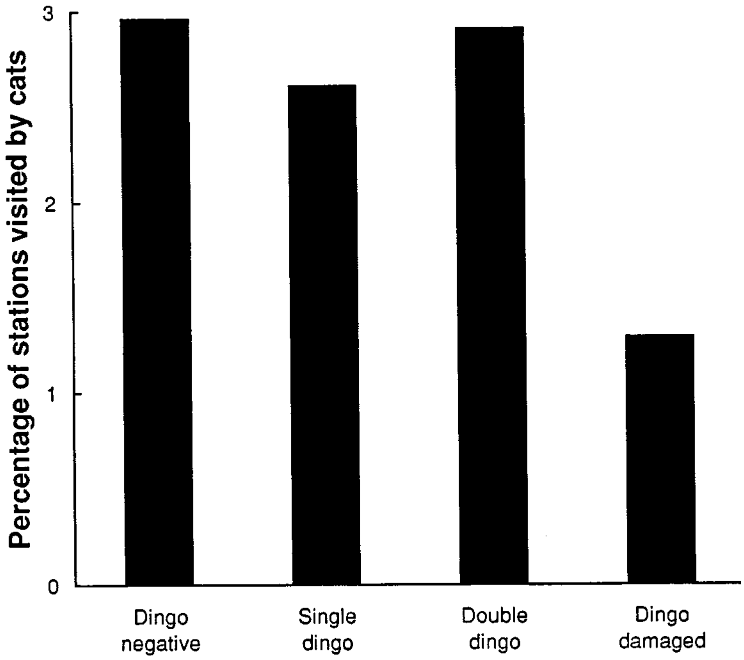

Fig. 1. The percentage of ‘dingo negative’, ‘dingo single visit’, ‘dingo double visit’ and ‘dingo damaged’ stations visited by cats.

Table 1. Results of the lure trials, showing visits of feral cats and behavioural responses

*, lures with significantly more visitations than control attractant 1 ($P < 0{\cdot}05$, test for comparing proportions). The number of dual visits is the number of times that both of the paired sites at one lure station registered cat tracks

Trial	Dates (1994)	Lure No.	No. of visits (No. of dual visits)	Stations visited (%)	Behavioural response (% of visits)		
					To station	To vial	Chew vial
1	21–24 June, 18–22 July	1	4 (1)	1·8	75	25	0
		7	11 (1)	4·9	45	55	0
		8	17 (1)*	7·6	29	71	0
		10	4 (1)	1·8	50	50	0
		4	8 (1)	3·6	38	62	0
2[A]	27 June–1 July, 25–29 July	1	2 (1)	0·9	33	66	0
		5	5	2·2	20	80	0
		12	2	0·9	50	50	0
		6	4	1·8	25	75	0
3	12–15 July, 9–12 August	1	4	1·8	50	50	0
		2	4	1·8	50	50	0
		3	1	0·5	0	100	0
		9	7	3·1	0	100	0
		11	7 (1)	3·1	29	71	0
4	15–19 August, 19–23 September	1	0	0	0	0	0
		13	14 (3)*	6·3	14	86	0
		14	7*	3·1	14	86	0
		15	14*	6·3	7	93	0
		16	8*	3·6	13	87	0

[A]Data for the two lures tested for only four days during Trial 2 are not shown.

The relative attractiveness of the five 'successful' lures to dingoes is shown in Fig. 2. Those based on cat scent (anal-gland preparations) were less attractive to dingoes than was the food-based lure (sun-rendered prawn).

The performance of the three 'successful' olfactory lures (based on the frequency of cat visitations) over the 4-day exposure period during subtrials is illustrated in Fig. 3. Clearly, there is no indication that the attractiveness of the lures declined over time.

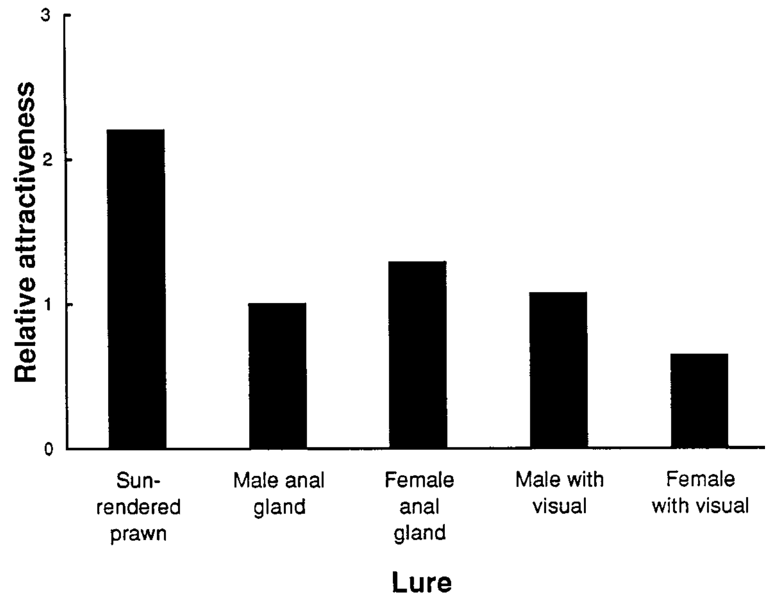

Fig. 2. The relative attractiveness (the number of visits to lure divided by the number of visits to control) of the five 'successful' lures to dingoes: sun-rendered prawn, anal-gland preparations from male cats, anal-gland preparations from female cats, and each of the latter two with a bird-feather visual lure.

Discussion

Our trials were conducted during winter under semi-drought conditions. In May 1994, prior to commencement of our trials, the density of feral cats based on spotlight counts at our study site was 0·52 km^{-2}. However, by the end of our trials (September 1994), cat density had declined by about 70% to approximately 0·16 km^{-2} (Edwards, unpublished data). Ten of 13 radio-collared feral cats died at the study site over this period, a mortality level of 77% (Edwards, unpublished data), indicating that the difference between spotlight counts was due to a population decline and not due to a change in detectability or behaviour of the feral cats.

Sun-rendered prawn and the anal-gland preparations from males and females were the only lures tested that elicited a cat response that was statistically higher than that recorded for the water control. Although our results are conclusive, a weakness in our experimental design precludes us from making broad generalities based upon them. The problem is that lures were not tested under the full gamut of seasonal and environmental conditions. Cost and time constraints precluded this option. It is possible that some lures work better at certain times of the year or in certain situations. For example, sun-rendered prawn attracted cats during semi-drought conditions when the cats were at relatively high densities. During non-drought periods or when cat density is lower, a food-based lure such as sun-rendered prawn may be less effective.

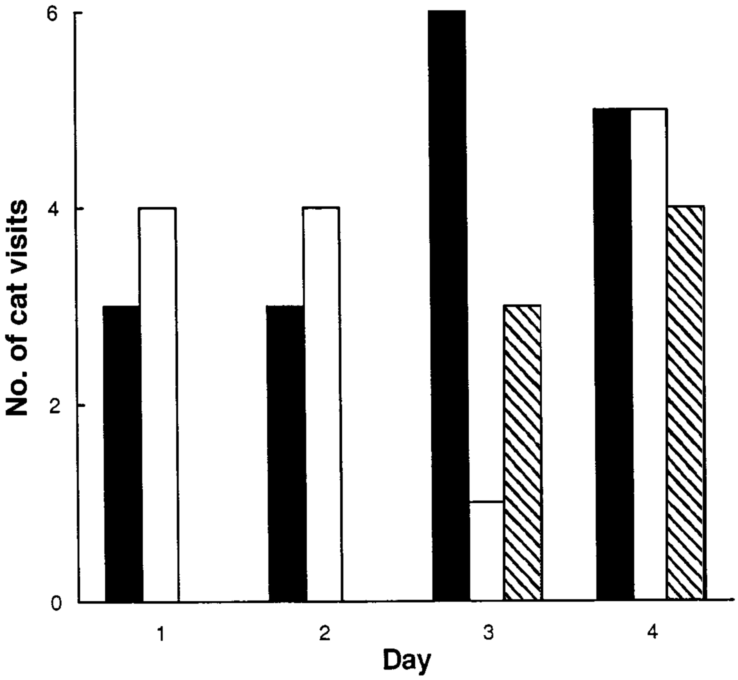

Fig. 3. Daily performance of the three 'successful' olfactory lures in terms of the frequency of cat visitations (data for 4-day subtrials combined). Solid bars, sun-rendered prawn; empty bars, anal-gland preparations from male cats; hatched bars, anal-gland preparations from female cats.

Similarly, the efficacy of scent-based lures may be strongly influenced by seasonal changes in reproductive behaviour. In eastern Australia, there is a peak in pregnancy rates in feral cats during September and October following a winter anoestrous period (Jones and Coman 1982). A similar pattern occurs in central Australia (Edwards, unpublished data). Thus, Trial 4 (scent-based lures) was conducted at the onset of the 'breeding' season. Scent-based lures may be less effective at other times of the year, particularly during the winter months when reproductive behaviour is relatively subdued.

During Trial 4, the lure derived from males attracted twice as many cats as did that from females, which raises speculation that the scent-based lures may be sex-specific. Unfortunately, we were unable to determine the sex of cats visiting the lure stations. However, 10 of 14 cats (71%) captured at our study site during 1994 were males. If male and female cats were equally trappable, this indicates that there was a bias towards males in our population during the trials. If so, a tendency for male cats to investigate male scent would explain the higher number of visitations to the male-scent lure. Sex-specific responses to scent-based odours have been reported in ferrets (Clapperton *et al.* 1988). However, ferrets are attracted more to the odours produced by the opposite sex than to those of their own sex (Clapperton *et al.* 1988).

In 8% of station visitations, cats visited both of the paired lure sites (Table 1). In most instances, it was not possible to ascertain whether the same cat visited both sites. If there were cases where different cats visited each of the paired sites, our method of recording multiple visits as one visit would have underestimated the attractiveness of some lures. However, only during Trial 4 did a lure receive more than one dual visitation. This lure was anal-gland preparation from males, which received significantly more visits than the water control in any case. Given this and the fact that the incidence of dual visitations was relatively low overall, dual visitations involving different cats are unlikely to have had a significant bearing on our results.

Although having paired sites can give rise to the problem of multiple visitations, the technique can have advantages. Where lure stations are placed along roads and the target animal tends to use roads, having paired sites can potentially enhance visitation rates under windy conditions. Also, having paired sites can mitigate the effects of damage by non-target animals. During our trials, for example, dingo damage to stations was confined to one of the paired sites in about 50% of cases. These stations remained functional despite the dingo damage, as the remaining site was unaffected.

An advantage that the anal-gland preparations appeared to have over food-based lures such as sun-rendered prawn is that they attracted relatively fewer dingoes. However, care must be taken in interpreting this result because dingo behaviour is strongly seasonal (Mitchell and Kelly 1992; Thompson 1992) and the food-based and scent-based lures were tested at different times of the year. These lures would need to be tested together to confirm whether dingoes respond differentially to them.

In more than 70% of the stations visited for the three 'successful' lures, cats investigated the vial containing the olfactory lure. This indicates that these lures could enhance the effectiveness of trapping programmes, particularly those employing buried foot-hold traps.

The olfactory lures tested in this study remained attractive to cats for at least four days under field conditions in central Australia during winter and spring. Maximum daily temperatures were probably about 25°C over the study period. Attractant odour was readily detectable to the human nose at the end of subtrials, which suggests that the lures may, in fact, have an active field life greater than four days under similar conditions. However, during summer, the active life of lures may be greatly reduced because of much higher maximum temperatures (*c*. 42°C) and resultant higher evaporation rates. The field life of lures used in control programmes can be greatly increased by using slow-release devices such as 'plastic rope' (Sullivan *et al.* 1990) or plaster discs (Roughton and Sweeney 1982). This approach reduces the frequency at which lures need to be replaced, an exercise that can be costly and time consuming (Clapperton *et al.* 1994*b*).

The distance over which these olfactory lures were effective is unclear and probably varied with prevailing conditions and habitat complexity. The distance that odour travels is affected by wind speed, relative humidity and temperature. In areas of dense plant growth, the effects of wind are greatly attenuated and odours probably travel less distance than in more open sites. In many cases of visitation, cats approached the lure from the scrub rather than from the road, which indicates that the cats may have been attracted from some distance.

These results show that feral cats can be attracted by odours in the wild. However, our results conflict with those of Clapperton *et al.* (1994*a*), who found that extracts from two plants that contain lactones, catnip and matatabi (*Actinidia polygama*), rather than social odours were most effective in attracting captive cats and urban strays. This raises some interesting questions. First, do cats from different areas respond differently to different olfactory stimuli? Second, is the behaviour of feral cats different from that of domestics and urban strays? The answer to both of these questions is probably yes. Some evidence exists that feral and domestic cats do respond differently to lures based on plant extracts and social odours, at least during pen trials (B. K. Clapperton, personal communication). Therefore, it is imperative that research into lures and other aspects of control be conducted on representative target populations.

Sight is believed to play a vital role in prey detection by cats (Turner and Meister 1988). The lack of impact of the visual lure during our trials is therefore a surprising result. However, we tested only one visual lure and in combination with a scent-based lure. It may be more appropriate to test visual lures that mimic prey, in conjunction with food-based rather than scent-based lures. Furthermore, visual lures may require a combination of visual form, movement, odour and sound in order to be effective on cats. More research is obviously needed in this area.

Lures can be used as a census tool in ecological studies. 'Scent' station lines have been widely used in USA to determine the relative abundance of coyotes (Linhart and Knowlton 1975; Roughton and Sweeny 1982), grey foxes and bobcats (Conner *et al.* 1983), and raccoons and other mammals (Smith *et al.* 1994). The technique could potentially be used to provide an index of population size for feral cats. However, because rates of visitation to 'scent' stations are not always directly related to density (Smith *et al*. 1994), the validity of the method for census of feral cats will need to be carefully assessed.

Acknowledgments

This study was jointly funded by the Parks and Wildlife Commission of the Northern Territory and the Australian Nature Conservation Agency (Feral Pests Unit). We thank Mike Fleming for helpful suggestions in regard to statistical analysis and the many volunteers who assisted with fieldwork, particularly the students of Centralian College. Nicki de Preu, Ken Johnson and Bill Freeland commented on drafts of this paper. We also thank Gary and Val Pryor for allowing us to work on their property. This manuscript was improved by helpful comments from Kay Clapperton and another anonymous reviewer.

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Appendix. List of lures showing formulations (all were blended)
The two lures tested for only four days during Trial 2 are not shown

Lure	Formulation
Control	
1	Water
Food-based	
2	10 mL blood and bone, 50 mL glycerine
3	Cod-liver oil
4	50 mL fish emulsion fertiliser, 10 mL glycerine
5	10 mL tinned sardines, 50 mL glycerine
6	10 mL tinned anchovies, 50 mL cod-liver oil
7	50 mL sun-rendered fresh fish, 10 mL glycerine
8	50 mL sun-rendered fresh prawns, 10 mL glycerine
9	50 mL sun-rendered fresh oysters, 10 mL glycerine
10	10 mL fresh prawns, 50 mL glycerine
11	10 mL fresh oysters, 50 mL glycerine
Plant-based	
12	10 mL catnip leaves, 50 mL glycerine
Scent-based	
13	100 mL anal-gland preparation from male cats, 85·5 mL urine from male cats
14	100 mL anal-gland preparation from female cats, 85·5 mL urine from female cats
Scent-based and visual	
15	Lure 13, bird feathers
16	Lure 14, bird feathers

Manuscript received 13 February 1996; revised 13 June 1996; revised and accepted 4 September 1996