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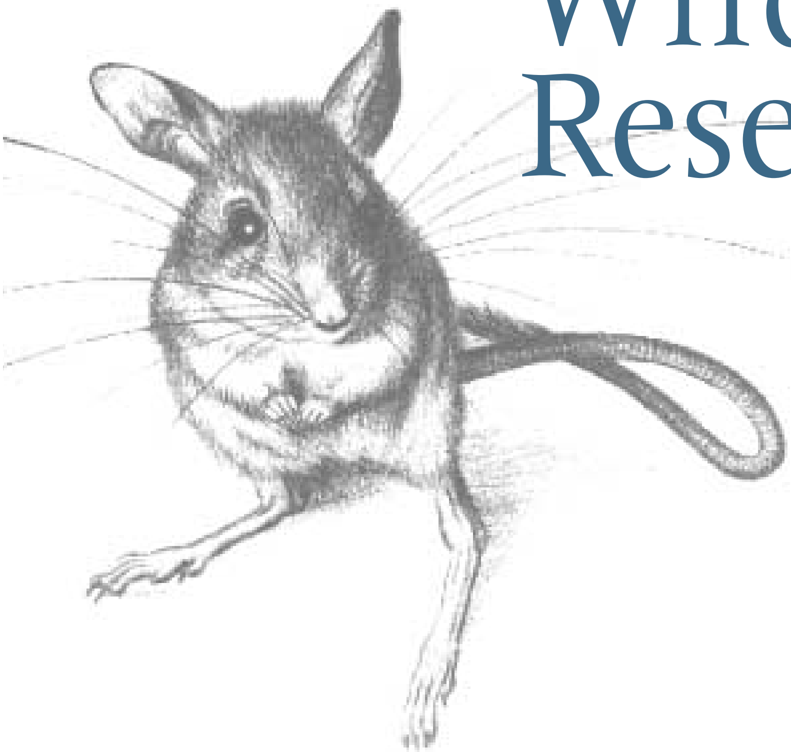

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Control of feral cats for nature conservation. III. Trapping

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Abstract. We present comparative success of various trapping methods trialed during control of feral cats at a site for the reintroduction of threatened mammals at Shark Bay, Western Australia. Our results come from 31 703 trap-nights that caught 263 cats (an average of 0.83 per 100 trap-nights). Cats differed markedly in their vulnerability to trapping depending on whether they primarily scavenged at rubbish tips or around human settlement or whether they hunted for their food in the bush. Cage traps were an effective means of controlling the former, with 9.4 cats captured per 100 trap-nights. Scavenging cats included a higher proportion of sub-adults and kittens and lower proportion of adult males than hunting cats. Variation between years in capture success for hunting cats was largely explained by the abundance of rabbits relative to that of cats and whether the rabbit population was increasing or decreasing. These factors accounted for a nine-fold difference in trap success. The number of cats caught in any particular trapping session could be explained by location (rubbish tip or town versus bush), trapping effort (typically greater effort yielded higher captures), abundance of cats at the site (captures were highest when cats were abundant), and season (captures were highest in the first half of the year when the young of the year were becoming independent). Concealed foot-hold traps, in a range of possible sets, provided effective methods for capturing cats that hunt, except where capture of non-target species was a critical limiting factor. Cage traps caught cats at a comparable rate to foot-hold traps for standard sets, but caught a significantly different cohort. Concealed foot-hold traps caught a higher percentage of adult cats, particularly males, than did cage traps. Mouse carcases and rabbit pieces were significantly more effective as lures when rabbits (the major food of cats at the site) were at low densities, whereas the success of commercial scent lures was unrelated to food availability. Significantly more cats than expected were caught using food as an attractant at times of food shortage (late summer, autumn and early winter) for both scavenging and hunting cats. In contrast, scent lures caught significantly more cats than expected in spring and summer when cats were defending access to mates and/or territory. Hence, no single trap type, trap set, or lure provided unequivocally superior performance over others. Control is likely to be best achieved by a variety of trapping methods and lure types used in combination, supplementing well timed poisoning efforts. Trap success is likely to be maximised by trapping at times when the dominant prey of cats are scarce relative to the number of cats and are decreasing in abundance.

Introduction

Feral cats, *Felis catus*, are a significant predator of native wildlife and have been implicated in the extinction of native species on offshore islands (Jones 1923-25; Burbidge 1971) and on continental Australia (Dickman *et al.* 1993). They have a predilection for prey less than 600 g when available, which often includes the young of larger mammals (Jones 1977; Catling 1988; Dufty 1991). Early historical losses of native Australian mammals weighing less than 350 g are thought to be due to the spread of feral cats in the early years of European settlement. For example, nearly 40% of mammal species weighing less than 350 g in the Western Australia wheatbelt were not recorded after 1860, compared with 11% of larger species (Short 1999). A similar trend was apparent in western New South Wales (Dickman *et al.* 1993). The substantial decline of small mammals in an area of semi-arid Western Australia, where feral cats had expanded in number following fox control (Risbey *et al.* 2000), suggests that feral cats are capable of causing such historical declines.

Feral cats have been implicated also in the failure or limited success of programs to re-establish native species in arid Australia (Christensen and Burrows 1994; Gibson *et al.* 1994) and in threatening remnant populations of endangered mammals (Spencer 1991; Horsup and Evans 1993): cats appeared to preferentially target the young of mammals that weighed more than 350 g, such as the allied rock-wallaby, *Petrogale assimilis*, the bridled nail-tail wallaby,

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Onychogalea fraenata, and the burrowing bettong, *Bettongia lesueur* (Spencer 1991; Horsup and Evans 1993; Short and Turner 2000).

Feral cats were trapped at Shark Bay in Western Australia as part of a program to reconstruct a community of mammal species extinct on mainland Australia but surviving on offshore islands (Short *et al.* 1994; Short and Turner 2000; Richards and Short, in press). We sought to eliminate cats and foxes, *Vulpes vulpes*, from a conservation reserve on Heirisson Prong at Shark Bay, and to reduce their numbers in an adjoining buffer zone. The conservation reserve is 12 km^2 of coastal heath and scrub on a peninsula fenced to exclude cats and foxes. The buffer zone is a 200-km^2 area where foxes are controlled. Cats were trapped throughout this zone, but with most effort focused in the third of the area closest to the barrier fence. Trapping, in conjunction with direct poisoning, secondary poisoning via rabbit baiting with 'one shot' oats, and spotlight shooting, was used to control cats in the conservation reserve (Short *et al.* 1994, 1997). This paper summarises the results of more than 30 000 trap-nights targeted at feral cats over the 10-year period 1992–2001. We evaluated a variety of trap types, trap sets, and lure types and assessed the key factors influencing trap success. Comparative data for foxes are presented where available.

Study area

Heirisson Prong is a long, narrow peninsula that juts into Shark Bay. A fence was constructed across a narrow neck in 1989 to exclude predators from a 12-km^2 core conservation area on the northern tip of the peninsula. The fence did not form a secure barrier so was supplemented by control efforts both within the reserve and within the buffer (Short and Turner 2000). Monthly baiting within the reserve (100 meat baits containing 4.5 mg of 1080 and laid from a vehicle at 100-m intervals along the track network) and biannual aerial baiting of the buffer with meat baits were used to control foxes. Cats have been managed by poisoning, trapping and shooting in the core area, and predominantly by trapping alone in the buffer (an exception being a major poisoning in 1995 detailed in Short *et al.* 1997). Trapping was particularly important in the northern one-third of the buffer zone as proximity to the town of Useless Loop precluded the use of poison baits and shooting for the control of predators.

Heirisson Prong receives an average annual rainfall of 230 mm with 70–80% falling over winter. The core is an area of low heath (*Thryptomene baekeaceae* and *Melaleuca cardiophylla*) and Acacia scrub (*Acacia tetragonophylla*, *A. ligulata*) on sand dunes and sand plain. It is used primarily for conservation. The area has reintroduced populations of western barred bandicoot, *Perameles bougainville*, burrowing bettong, *Bettongia lesueur*, and greater stick-nest rat, *Leporillus conditor*. Western barred bandicoots are classified as endangered and burrowing bettongs and greater stick-nest rats as vulnerable under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*. These populations of western barred bandicoot and burrowing bettong were the only wild populations on mainland Australia for much of the course of this study.

The adjoining buffer zone consists of extensive sand plains, sand dunes and occasional limestone rises. The vegetation is similar to that of the core, but also includes areas of *Triodia plurinervata* with scattered shrubs of *Acacia ligulata* and *Alyogyne cuneiformis*.

The density of European rabbits, *Oryctolagus cuniculus*, varied from year to year, with an index of density from spotlighting varying by 15-fold in the buffer and 30-fold in the core over a nine-year period (Short 1999). Rabbits were the dominant food item in the diet of feral cats at the site, contributing 88% by weight of the stomach contents of 106 cats sampled (Risbey *et al.* 1999). Several species of native rodents (*Pseudomys albocinereus*, *P. hermannsburgensis*, *Rattus tunneyi*) were common and widespread at the site, as were house mice, *Mus musculus*. The native carnivore *Sminthopsis dolichura* was present in low numbers. House mice were a common food item of cats at Heirisson Prong (ranked fourth after rabbits, *P. albocinereus* and birds: Risbey *et al.* 1999).

Heirisson Prong is part of Carrarang Pastoral Station (805 km^2), but only the southern 20% of the study area was grazed by sheep. The sheep station had four permanent residents and no domestic cats. The small mining community of Useless Loop sits within the study area. It had a population of about 100 people and three domestic cats. No new domestic cats have been allowed into the town since the early 1990s and all cats present at that time were neutered. The nearest town (400 residents) is 250 km away by road, hence is unlikely to be a major contributor to the feral cat population.

Methods

Trapping was conducted to eliminate cats from the core area and to reduce their numbers in the buffer zone with the aim of reducing reinvasion of the core. Effective cat control within the core area was seen as vital to the viability of reintroductions of threatened mammals. Trapping practices evolved with experience. Low and variable capture successes made controlled experimental comparisons difficult and required accumulation of results from many trips. Data on trapping effort (date, trap type and set, lure, location, trap-nights, trap success and non-target captures) were collated in one database and the characteristics of captured cats were compiled in another (date, location, trap type and set, sex, colour and weight of animal caught).

Field techniques

Cage and foot-hold traps were used to catch feral cats. Cage traps included both large (310 × 300 × 725 mm) and small (220 × 220 × 560) types. Both types had a swing door with the large traps activated by a pull hook and the small traps by a foot treadle. Cage traps were used exclusively in situations where trapping was visible to the general public (rubbish tip, town, and mine site workshops). They were also the trap of choice in areas where burrowing bettongs were present, as bettongs were a common non-target capture. Foot-hold traps potentially cause this species excessive injury due to their much smaller size relative to cats (adult weight of 1.2 kg cf. 4–6 kg). In this situation, cages were mounted on stilts to prevent access to bettongs. The bases of these traps were lined with carpet or linoleum and were set at approximately 45 cm above the ground.

Large cage traps were set regularly at the domestic rubbish tip, approximately 3 km from Useless Loop, to catch scavenging cats. Rubbish (from the collection of domestic rubbish bins) was dumped at this site and burnt weekly. Traps were baited with meat scraps. Usually 2–4 traps would be set for several nights at three-month intervals. They were opened at dusk and checked and closed at first light to reduce the likelihood of capturing seagulls, *Larus novaehollandiae*, or crows, *Corvus bennettii*. Trapping was conducted also within the town precinct and at the mine site workshop at irregular intervals, usually in response to a sighting of feral cats.

Foot-hold traps used were treadle snare traps, Lanes Ace rabbit traps, and Victor soft-catch traps. Treadle snare traps were an Australian trap (Bill Wall, RMB 6460, Yea, Victoria) designed to catch dingoes and used largely in south-eastern Australia (Meek *et al.* 1995). Lanes Ace traps (Lanes Hardware, PO Box 336, Gladesville, NSW, 2111, Australia) were designed for capture of rabbits and were modified for humane capture of cats using the methods of Jansen (1992). Victor Soft Catch 1½ traps (Woodstream Corp., Lititz, Pa., USA) have rubber inserts on the jaws of the trap to minimise injury and were designed for trapping animals the size of cats and foxes. Snare traps were used only in the early years of control (1991–92). Lanes Ace and Victor Soft Catch traps were compared for set off without capture or hold in a trial of 2560 trap-nights in June and July 1994. The numbers of traps of each type sprung by either a cat or fox without capture (as assessed by prints in the sand) were compared by Chi-square analysis. Subsequent to this trial, Lanes Ace traps were rapidly phased out of use as cats were far more likely to evade capture or pull their foot from this trap type.

Food lures included mice carcases, a portion of a rabbit carcase, liver, meat scraps, frozen fish, smoked fish, fishmeal, and tuna sausage. Social scents used were cat urine (soiled litter from cages in which cats were held by a local veterinary surgeon), Canine Call, Pro's Choice, Bobcat Anal Gland and Cat-man-do (all from Rocky Mountain Wildlife Products, La Porte, CO, USA), aniseed oil and fresh catnip. Food lures only were used with cage traps, whereas either food or scent was used with foot-hold traps. Several trials made use of tinsel as a visual stimuli to attract cats to foot-hold traps. Only a single lure was used at any trap site.

Victor Soft Catch and Lanes Ace foot-hold traps, treadle snares, and cage traps were typically set at 200-m intervals along sandy tracks. This set method allowed large numbers of traps to be quickly and efficiently checked from a vehicle. Lanes Ace traps were set either singly using the method described by Veitch (1985) or as pairs. The latter set was an attempt to overcome the possibility of cats or foxes pulling out of a single trap. It also doubled the plate area for the predator to step on, increasing the likelihood of capture. Trapping was conducted at 1–3-month intervals in the core area when cats were present, while individual trap routes in the buffer were typically trapped on a six-month rotation. Leg-hold traps were left in the same location for an average of eight days at a time (range 2–15 days).

Both Lanes Ace and Victor Soft Catch traps were set also at the base of feeders (McKinnon 1991) regularly baited with smoked fish or tuna sausage.

Another type of set made use of natural or man-made barriers or pathways likely to channel the movement of cats and foxes (funnel set). One common set of this type was along the barrier fence where several large, dense clumps of bushes grew close to the fence line. These gaps were further reduced to about 15–20 cm by strategic placement of sticks and branches. Victor Soft Catch or Lanes Ace traps were set in the gap. These sets were left unbaited and relied on the funnelling effect of fence, bushes, and barricade to direct the animal on to the plate of the trap.

Another technique used was to locate cat den sites by following a distinctive trail left by a cat dragging a rabbit (paw prints on either side of a drag mark): female cats appear to drag rabbits back to the den site to feed newly weaned kittens during October–March. Foot-hold traps were then set in obvious runways into the den and near carcases from previous hunts. Cage traps baited with food scraps were set in the area immediately around the den also. On other occasions, cage traps were set at sites where abundant kitten tracks indicated a nearby den.

Predator and rabbit numbers were monitored by spotlighting at approximate three-month intervals since December 1989. Surveys were conducted along standard routes (one in the core and one in the buffer) by two observers using 100-W spotlights while standing in the rear of a utility or traytop vehicle travelling at 10–15 km h^{-1}. Both routes were approximately 20 km in length for most of this period, apart from a brief period in the early 1990s when they were increased to approximately 30 km. Each route was surveyed for three nights per trip. Rabbit and cat sightings were converted to sightings per kilometre and averaged over the three nights of survey in each area.

Data analysis

Factors perceived as being likely to affect trap success included density of cats and rabbits and the likely availability of rabbits within the preferred size range of cats as well as the particulars of trapping such as trap type, trap set and lure type. Variations in annual catch of cats and trap success were evaluated against these factors. Data were collated across all trapping sessions for July to June of each year. This choice of year was to match the breeding cycle of cats (a peak in mating commencing in July following a period when many females are in anoestrous from late summer to early winter: Jones and Coman 1982*a*). Preliminary examination using simple linear correlation revealed key determinants of trap success. This suggested an initial partitioning of the data into two (trapping for scavenging cats at the rubbish tip, in town and at the workshop using cage traps versus trapping for hunting cats in the bush, largely using foot-hold traps).

Trap successes were compared between scavenging cats and hunting cats using the same trapping method (cages with food lure). Hunting cats (those with no direct or indirect reliance on man) were caught using cage traps set within a 20-km radius of Useless Loop but at a distance of more than 1 km from the rubbish tip or town. Chi-square analysis was used to test associations between the numbers of cats in particular sex/age categories caught in cage traps while hunting or scavenging.

Annual values for capture success of hunting cats were regressed against a range of variables: indices of rabbit and cat density as assessed by spotlighting during summer, the ratio of rabbits to cats sighted during spotlighting in summer (to reflect the relative availability of rabbits to cats as a prey item), and an assessment of whether the rabbit population at this time was increasing (+1), decreasing (–1), or stable (0), as assessed from spring and summer spotlighting counts.

Annual capture success (trap success per 100 trap-nights) was calculated for each 12-month period (July–June). Density indices for rabbits and cats showed strong seasonal fluctuations, with summer maxima and winter minima (a similar pattern is reported by Jones and Coman 1982*b*). Winter minima may have been due, in part, to cats being active for less time at night because of the ready availability of rabbit kittens as prey. Hence, only the summer maxima for each year were used to index overall abundance of cats for the year (i.e. July–June, with the summer value as its midpoint).

More detailed analysis was undertaken using individual trapping sessions as the basic unit of study and incorporating trap and lure type. The results for each trapping session were converted to a presence/absence result (i.e. a cat or cats were caught versus no cats caught) and transformed using a logit-transformation (Krebs 1998). The transformed values were regressed (using stepwise multiple regression) against the number of trap-nights per session, whether caught hunting or scavenging (dummy variable of value 1 or 2), cat density as assessed by spotlighting (both the summer density and the density at time of trapping), rabbit density as assessed by spotlighting at time of trapping, and whether rabbit numbers were increasing or decreasing over the past 3 months (given values of +1 or –1 respectively), the relative availability of rabbits to cats calculated as the ratio of rabbits to cats sighted during spotlight surveys with 0.01 added to cat spotlight index to ensure no division by zero, rainfall over the past 2 months, and 2 months lagged by a further 2 months, season (January–June = 1; July–December = 2), trap type (cage = 1, foot-hold = 2), and lure type (three dummy variables Lure/set 1, Lure/set 2, and Lure/set 3 were used to express four lure/set types: food = 0, 0, 0; scent = 0, 0, 1; funnel set (no lure) = 0, 1, 0; den set = 1, 0, 0). Factors showing a significant impact on the number of cats caught were investigated further.

Capture rates were compared for four seasons of the year (January–March, April–June, July–September, and October–December). Chi-square analyses were used to test the association

Table 1. Trap success and number of hunting and scavenging cats caught on Heirisson Prong over a 10-year period
Hunting cats are those caught more than 1 km from rubbish tip, town or mine site workshop; scavenging cats are those caught at the rubbish tip, town, or at the workshop. Data include all trap types

Year	Trap-nights	Trap success per 100 trap-nights	Hunting cats	Scavenging cats	Total	Scavenging as proportion of total
1991–92	1103	1.90	4	17	21	0.81
1992–93	1226	1.63	10	11	21	0.52
1993–94	9025	0.61	43	11	54	0.20
1994–95	5398	1.20	45	20	65	0.31
1995–96	4594	0.30	8	6	14	0.43
1996–97	2206	0.50	9	2	11	0.18
1997–98	1393	0.43	5	1	6	0.17
1998–99	2673	0.90	19	5	24	0.21
1999–2000	1332	1.58	8	13	21	0.62
2000–01	2753	0.94	18	8	26	0.31
Total	31703	0.83	169	94	263	0.36

Table 2. Trap success in capturing scavenging and hunting cats
Cages traps were baited with a food lure; foot-hold traps were baited with either a food or scent lure

Location	Trap-nights	Captures	Success per 100 trap-nights
Scavenging (cages only)	1001	94	9.39
Hunting (cages only)	3916	18	0.46
Hunting (foot-hold)	26786	151	0.56

between season of the year and the number of hunting cats caught with scent, hunting cats caught with food, and scavenging cats at the rubbish tip or in town.

Trap success was collated by lure type across all trap types and a range of densities of both cats and rabbits. Data from trapping sessions where two lures were alternated along a trap line were used to assess efficacy. In each case the performance of any lure was assessed against that of either Bobcat Anal Gland or Canine Call used in the same trials (the 'standard lure'). Hence, paired comparisons are standardised for cat density, season of year, and trap type. Probabilities were calculated from the binomial distribution, assuming that cats were equally likely to be caught in traps set with standard lure or test lure. Probability included that of a particular result and any equal or more extreme events using a one-tailed test.

The effect of rabbit density on the number of cats caught using either a food (mouse carcase or portion of rabbit carcase) or scent lure was assessed by Chi-square analysis.

Results

Factors affecting annual trap success

The number of cats caught per year varied between 65 in 1994–95 and 6 in 1997–98 (Table 1). The number captured in any year was positively correlated with trapping effort (i.e. trap-nights) ($r = 0.75$, $n = 10$, $P < 0.05$). Annual trap success varied six-fold (from 0.3 cats per 100 trap-nights in 1995–96 to 1.9 in 1991–92) and was highly correlated with the proportion of the annual total of cats that were caught as scavenging cats versus hunting cats ($r = 0.81$, $n = 10$, $P < 0.01$). This reflects the much greater effort required to catch hunting cats relative to scavenging cats.

Table 2 shows the difference in trap success to capture scavenging cats and hunting cats. Success in capture of scavenging cats at the tip, town, and workshop was nearly 20 times greater than that in the bush using the same capture method (cage traps with food lure). The age/sex composition of scavenging cats (Table 3) differed significantly from hunting cats ($\chi^2_2 = 13.9$, $P = 0.001$). Scavenging cats included a higher percentage of sub-adults and kittens than hunting cats (60% *vs* 40%) and a lower percentage of adult males (13% *vs* 33%). Males were disproportionately represented in the sub-adult and kitten class (70 *vs* 46). There were more males caught than females overall (1.15 : 1), but

Table 3. Sex and size of scavenging cats caught using cage traps compared with hunting cats caught using a variety of traps and sets
Adults include all males heavier than 3.8 kg and all females heavier than 2.5 kg (Jones and Coman 1982*a*). Note: weight measurements were not taken for some animals so numbers vary slightly from those in Table 1

Type of cat	Number by sex and size			Total
	Adult male	Adult female	Sub-adult or kitten	
Scavenging	11	24	52	87
Hunting	53	47	64	164
Total	64	71	116	251

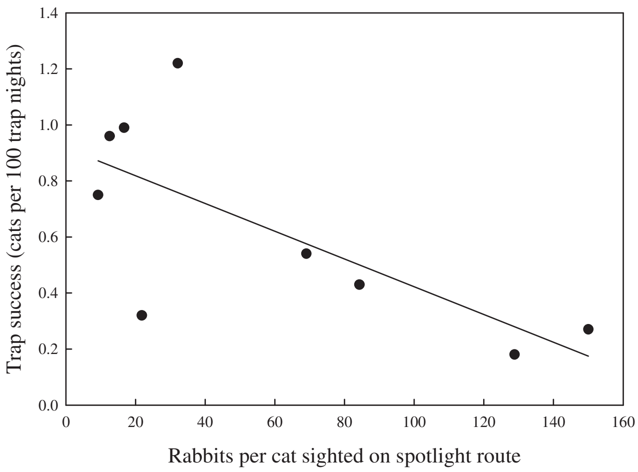

Fig. 1. The relationship between trap success for capture of hunting cats and the abundance of rabbits relative to cats, as assessed by summer spotlighting. A value of 20 on the *x*-axis refers to a rabbit : cat ratio of 20 : 1 as assessed by spotlight counts. The relationship is $y = 0.962 - 0.0055x$ ($r^2 = 0.64$, $F_{1,7} = 12.23$, $P = 0.010$).

this was not a significant departure from parity ($\chi^2_1 = 1.15$, $P < 0.25$).

Variation in annual trap success for hunting cats could be explained by the relative availability of rabbits. There was a strong negative relationship between annual trap success of hunting cats and the ratio of rabbits to cats as assessed from summer spotlighting (Fig. 1). The relationship was significant ($F_{1,7} = 12.23$, $P = 0.01$) and explained 64% of the variation in the data. Capture success declined nearly four-fold from ~0.91 captures per 100 trap-nights at a spotlighting sighting rate of ten rabbits per cat to 0.24 captures per 100 trap-nights at 130 rabbits per cat.

The variation explained increased to 77% if a dummy variable for whether the rabbit population was increasing or decreasing was added: trap success = 0.873 – 0.005(rabbit/cat ratio) – 0.138(rabbits increasing/ decreasing). When spotlight sightings of rabbits were low relative to cats (e.g. 10 rabbits per cat) and the rabbit population was on a declining trend then cat capture success was high (estimated at 0.96 cats per 100 trap-nights). Conversely, when spotlight sightings of rabbits were high relative to the number of cats sighted (e.g. 130 rabbits per cat) and the rabbit population was growing then trap success was far lower (0.11). The combination of these two factors accounted for an eight-fold difference in annual trap success.

Factors affecting the number of cats caught in a particular trapping session

A regression of the number of cats caught per trapping session on a range of variables using data from all trapping sessions over the 10-year period gave the equation $X' = -5.58$ + 10.6(cat summer spotlight index) + 3.87(hunt versus scavenge) + 0.0140(trap-nights) – 1.80(season) + 8.28(lure/set 1) + 1.54(lure/set 2) ($r^2 = 0.24$, $F_{6,375} = 19.4$, $P < 0.001$). The number of cats caught increased with higher cat density (as assessed for the year by spotlighting), increased when targeting scavenging cats at rubbish tip, town, and workshop (as compared with hunting cats in the bush), increased with increased trap-nights per trapping session, increased when trapping was in the first half of the year rather than the second, and was higher with use of den and funnel sets (as compared with track sets using either food or scent lures). Other trap types or sets, rabbit numbers, and prior rainfall did not add significantly to the predictive power of the regression.

The density of cats as assessed by spotlighting varied substantially between years (e.g. a 12-fold difference between years in indices of summer densities in the buffer zone) and between the two major trapping sites (core on average <30% of the buffer over the 10 years; yearly indices significantly different ($F_{1,18} = 9.4$, $P = 0.007$)). Cats were much more likely to be caught in any particular trapping session in years when their overall abundance was high and in the buffer zone rather than the core.

There was a significant association between the three classes of cats (hunting cats caught on scent, hunting cats caught on food, and scavenging cats caught on food) and the number of captures in any given season ($\chi^2_6 = 42.5$, $P < 0.001$). Overall, nearly twice the numbers of cats were caught during January–June than during July–December (151 cf. 78) (Table 4). This applied particularly to scavenging cats (64 cf. 30) and to hunting cats caught using a food lure (39 cf. 12). Food lures (particularly mice carcases) were most successful for capture of hunting cats in January–March. Sixteen of 21 cats caught in January–March

Table 4. Comparison of season of capture of hunting and scavenging cats using scent or food lure

Data are cats caught per 100 trap-nights with the number of cats captured given in parentheses. Trap-nights for hunting cats caught using scent: 18677; using food: 9955. Trap-nights for scavenging cats at rubbish tip, town and workshop using food: 1001. Excludes cats caught in funnel traps for which no lure used

Type of cat and lure	Season			
	Jan.–Mar.	Apr.–Jun.	Jul.–Sep.	Oct.–Dec.
Hunting – scent lure	0.60 (29)	0.32 (19)	0.18 (7)	0.70 (29)
Hunting – food lure	0.90 (23)	0.59 (16)	0.39 (7)	0.17 (5)
Scavenging – food lure	7.76 (18)	21.30 (46)	7.35 (20)	3.56 (10)

Table 5. Comparison of trap success of various trap types and trap sets in capturing hunting cats
Cage traps exclude those set for scavenging cats. VSC, Victor Soft Catch; LA, Lanes Ace

Trap set and type	Trap-nights	Cats caught	Trap success for cats	Foxes caught	Trap success for foxes
Den (VSC/cage)	28	8	28.57	0	0
Funnel (VSC)	1436	25	1.74	5	0.35
Feeder (VSC/LA)	580	5	0.86	0	0
Track (VSC)	21076	101	0.48	42	0.20
Track (large cage)	1537	7	0.46	0	0
Track (stilt cage)	447	2	0.45	0	0
Track (LA)	3016	13	0.43	6	0.20
Track (small cage)	1978	6	0.30	0	0
Track (treadle snare)	495	0	0.00	3	0.61
Total	30593	167	0.56	56	0.18

Table 6. Sex and size of hunting cats caught in funnel sets, at known den sites, or using cage or foot-hold traps set along tracks
Scavenging cats caught at rubbish tip, town and workshop are excluded. Adults include all males heavier than 3.8 kg and all females heavier than 2.5 kg (Jones and Coman 1982*a*). VSC, Victor Soft Catch; LA, Lanes Ace

Trap type	Number of cats	Number by sex and size		
		Adult male	Adult female	Sub-adult or kitten
Funnel set	23	8	1	14
Den set	10	0	3	7
Track set (cage)	15	3	5	7
Track set (VSC/LA)	112	40	39	33
Total	160	51	48	61

with food for which measurements are available were sub-adults or kittens compared with 12 of 28 for scent lures ($\chi^2_1 = 5.4$, $P = 0.02$). The peak in capture of scavenging cats using food lures was three months later than for hunting cats (April–June cf. January–March), perhaps reflecting the time taken for young, hungry animals to move from their natal range to the rubbish tip, town, or workshop. The trend of far higher captures in the first half of the year was not as marked for scent lures as for food (48 hunting cats caught by scent in the first half of the year compared with 36 in the second). Capture rates using scent lures were high from October to March and low in the remainder of the year.

Table 5 shows the relative effort and overall success of various trap types and sets at catching cats and foxes. However, these results are not standardised for density of cats or rabbits, season of trapping, or other variables. The prior regression analysis, which incorporated these variables, suggested a difference between den sets, funnel sets, and all other methods. Trapping at den sites, using a combination of foot-hold and cage traps, produced high capture success (28.6 per 100 trap-nights), but is a method that is difficult to apply widely because of the difficulty in locating dens. Funnel traps were a particularly useful method at Heirisson Prong and gave good capture success (1.74 per 100 trap-nights). Most captures were along the barrier fence. Foot-hold traps at feeders, foot-hold or cage traps set along tracks, and cages elevated on stilts returned similar capture rates of 0.43–0.86 cats per 100 trap-nights.

While no significant difference in trap success was demonstrated between trap types set along tracks, other factors contributed to our preference for some trap types. The incidence of predators, particularly cats, setting off a trap without capture (or escaping once caught) proved higher for Lanes Ace traps than for Victor Soft Catch traps (3.2% *vs* 0.6%) in a trial of 2560 trap-nights in June/July 1994. This difference was significant ($\chi^2_1 = 27.0$, $P < 0.001$). Lanes Ace traps were replaced entirely by Victor Soft Catch traps at Heirisson Prong following this trial. Treadle snares were abandoned early in the program because of difficulties in setting and traps being set off by cats without capture.

Different sets caught different ages and sexes of cats (Table 6). Track sets using foot-hold traps yielded a significantly different catch to that of the other three set types combined ($\chi^2_2 = 12.0$, $P = 0.003$), capturing a higher percentage of adult cats (71% *vs* 42%). Den and funnel sets caught high numbers of young cats (70% and 61% respectively). Funnel sets largely caught males (78% of total were male). While cage traps typically caught smaller, younger cats, a male weighing 5.85 kg was caught in a small cage trap. This was the second largest of 160 males caught on Heirisson Prong, the largest being 6.1 kg.

We made use of a wide range of scent and food lures to attract cats to traps. Table 7 collates this use, but comparisons of relative effectiveness are made difficult by the lack of standardisation for catching conditions such as density of cats and season of year that are known to influence capture

Table 7. Capture success using a variety of scent and food lures
Excludes data from scavenging cats and cats caught in funnel traps without lure

Lure	Trap-nights	Cats	Trap success for cats	Foxes	Trap success for foxes
Rabbit	404	4	0.99	0	0.00
Cat-man-do	824	6	0.73	1	0.12
Mice carcases	3614	22	0.61	0	0.00
Canine Call	7194	37	0.51	23	0.32
Catnip	1558	8	0.51	0	0.00
Bobcat Anal Gland	4882	20	0.41	14	0.29
Fish products	2735	11	0.40	7	0.26
Pro's Choice	3145	10	0.32	2	0.06
Aniseed	640	0	0.00	2	0.31

rates. Overall, freshly killed rabbit and the scent lure Cat-man-do gave the highest successes in capturing feral cats. House mouse carcases, Canine Call, and catnip were relatively successful also at attracting cats to traps (0.51–0.61 captures per 100 trap-nights). Less successful lures were Bobcat Anal Gland, Pro's Choice, various fish products (fishmeal, frozen fish or smoked fish), and aniseed. Canine Call, aniseed, Bobcat Anal Gland and various fish products achieved highest capture success for foxes.

Table 8 provides a comparison of a sub-set of lure types standardised for density of cats or foxes, seasonal factors, and trap type. Data were accumulated over a number of trapping sessions for each pair of lures. Seven of eight cats caught during seven trapping sessions that alternated Canine Call and Bobcat Anal Gland were caught on Canine Call (a significant difference at $P = 0.035$). Similarly, 17 of 24 cats caught during eleven trapping sessions that alternated mice carcases and Canine Call were caught on mice carcases. The first comparison suggests that Canine Call is a superior lure to Bobcat Anal Gland, and that Pro's Choice and fishmeal give similar capture rates. The second comparison suggests a significant difference between Canine Call and mice carcases (with mice performing better: $P = 0.032$), but no significant difference between Canine Call and catnip or Pro's Choice. Canine Call performed significantly better than anchovy and aniseed. Comparisons are made difficult by the extreme variability in capture rates between sessions. For example, 600 trap-nights in November 1994 using catnip yielded eight captures (all male), but six subsequent sessions over the next three years (958 trap-nights) yielded no captures.

Canine Call was most successful in the capture of foxes (Table 8). It was significantly more successful than mice carcases and catnip (capturing six of six foxes in each comparison). It caught more foxes than Bobcat Anal Gland, Pro's Choice and anchovy (five of six), and aniseed (five of seven), but these results were not significant. Bobcat Anal Gland performed significantly better than the visual lure of tinsel for the capture of foxes.

Mouse carcases and rabbit pieces performed better as lures for the capture of cats at low rabbit densities, while social scents were more effective at higher rabbit densities (Table 9: $\chi^2_2 = 17.7$, $P < 0.001$).

There were no physical injuries recorded for feral cats during this study, other than minor facial abrasions of some cats caught in cage traps. Most cats were shot at point blank range using a ·22 calibre rifle or pistol; a small number were radio-collared and released as part of other studies. Overall, 0.76% of traps caught non-target species, mostly rabbits (Table 10). Funnel sets and track sets using catnip accounted for half of all captures of rabbits, despite being just 10% of all trapping effort.

Discussion

Hunting versus scavenging cats

There was an approximately 20-fold difference in trap success for cage traps set at the rubbish tip, town, or workshop to catch scavenging cats compared with those set in the bush to catch hunting cats. Cats at these sites were derived from the feral population as all domestic cats in Useless Loop are desexed and wear an identification collar. We assume that the easy and reliable food at the tip attracted both young, dispersing cats and adult cats with home ranges including, or near to, the rubbish tip to scavenge. Cats have been observed to disperse long distances in times of food shortage (up to 230 km in central New South Wales), and to switch from a feral to commensal lifestyle when food is scarce (Newsome 1995). Presumably, our regular removal of cats encouraged others from nearby to replace them, thereby bolstering capture rates. The seasonal coincidence of weaning and independence with periods of natural food shortage in autumn would have increased the attractiveness of sites with a regular supply of food.

Cats and rabbits

Rabbits were the dominant food item of feral cats at Heirisson Prong (Risbey *et al.* 1999) and their availability to cats as prey seemed to strongly influence trap success. When rabbits were abundant relative to the number of cats and the population of rabbits was increasing (presumably indicating the presence of young rabbits in the population) then cats

Table 8. Comparison of performance of various lures.

Data are direct comparisons of trap success of a range of test lures against either Bobcat Anal Gland or Canine Call. Comparisons are standardised for cat density, season of year, and trap type. One standard lure and one test lure were alternated along trap lines. Probabilities were calculated from the binomial distribution assuming that cats were equally likely to be caught in traps set with standard lure or test lure. Probability includes that of particular result and any equal or more extreme events using a one-tailed test. Only comparisons where more than six cats or foxes were caught are presented. *, $P < 0.05$; **, $P < 0.01$

Test lures	Trap-nights	Sessions	Proportion cats caught by test lure	Probability of obtaining result for cats by chance	Proportion foxes caught by test lure	Probability of obtaining result for foxes by chance
Bobcat Anal Gland as standard lure						
Canine Call	2567	7	7/8	0.035*	5/6	0.109
Pro's Choice	2994	6	4/8	0.636	0/0	–
Fishmeal	2267	5	4/10	0.377	3/6	0.656
Tinsel	803	2	0/3	0.125	0/9	0.002**
Canine Call as standard lure						
Mice	4638	11	17/24	0.032*	0/6	0.016*
Catnip	3171	7	8/15	0.500	0/6	0.016*
Pro's Choice	2962	8	6/13	0.500	1/6	0.109
Anchovy	1280	4	1/8	0.035*	1/6	0.109
Aniseed	1280	4	0/7	0.008**	2/7	0.227

Table 9. The effect of rabbit density on trap success using food versus social scents as lures
Data are captures per 100 trap-nights with number of cats caught shown in parentheses. Food includes mice carcases and rabbit pieces only. Data for food lures include captures in foot-hold and cage traps; social scents were used only with foot-hold traps. Rabbit densities were assessed by spotlight counts: low, <1.2 km^{-1}; medium, 1.2 – 2.6 km^{-1}; high, >2.6 km^{-1}

Rabbit density	Lure	
	Food (mice/rabbit)	Social scents
Low	0.75 (16)	0.30 (18)
Medium	0.60 (6)	0.58 (35)
High	0.30 (2)	0.54 (29)

were difficult to trap. Conversely, when rabbits were scarce and declining and cats were numerous then cats were far easier to trap. There was an almost 10-fold difference in trap success between these two extremes.

This result is similar in kind to the bait uptake by cats observed by Short *et al.* (1997). They poisoned feral cats using the carcases of mice as a bait medium. Uptake of mouse carcases by cats was strongly influenced by the abundance of rabbits, varying between 23 and 74% of baits encountered. The uptake of baits was highest when rabbits were scarce (as assessed by spotlight counts).

Season of capture

Veitch (1991) discussed the importance of understanding the seasonal pattern of food availability to the cat and targeting a period of food shortage for intensive control operations.

Food lures were most effective during the first half of the year at Shark Bay when food sources were most likely to be in short supply, and when sub-adults were beginning to hunt independently. A period of food shortage typically occurs at Shark Bay in late summer and autumn during a non-breeding period for rabbits and when the population consists mostly of adult rabbits that fall outside the cat's preferred prey size. In addition, fewer reptiles are available in autumn due to falling ambient temperatures. Seasonal food shortage appeared to contribute to high trap success with food lures (three cats in 10 trap-nights) in a single night of trapping on 50-ha Althorpe Island in South Australia in June 1990 (Copley 1991). Similarly, Molsher (2001) recorded highest capture efficiencies in late autumn and early winter when the availability of rabbit kittens as food was low.

Jones (1977) found that rabbits weighing <600 g (about 10 weeks old) accounted for 81% of all rabbits eaten. Similarly, Catling (1988) found that cats in western New South Wales ate mainly small rabbit kittens (73% of all rabbits aged from 61 cat stomachs were kittens). Such small rabbits are increasingly less likely to be available as prey at Shark Bay as summer extends into autumn, unless significant cyclonic rain falls in the first 3–4 months of the year.

The density of cats, as assessed by spotlight counts, declined sharply from summer to winter, presumably as a result of the death or dispersal of many of the newly independent young of the year who were unable to find sufficient food. A similar pattern of summer maxima in abundance due to the presence of newly independent young and winter or spring minima resulting from nutritional stress acting particularly on subadults was observed by Jones and Coman (1982*b*) in north-western Victoria. They reported fluctuations from a mean of 2.4 km^{-2} in summer to 0.74 km^{-2} in winter.

However, concentration of trapping effort at times of food shortage may largely eliminate the young of the year (many of which may have died or dispersed anyway from food shortage), without making significant inroads into the adult populations. Hence, additional trapping during the breeding season using scent lures is likely to be vital to effective control or elimination. Spring and early summer are times when cats are defending access to mates and/or territory, when food is relatively abundant, and when few kittens have reached independence. At these times scent lures were most successful.

Comparison of success of various trap types for capturing hunting cats

We tested a range of trap types, settling on Victor Soft Catch traps in a range of sets for general trapping, and cage traps at rubbish tips and town or where capture of non-target species

Table 10. Comparison of non-target capture by various trap types and trap sets for capturing hunting cats
Data are from November 1993 to May 2001 only. Cage traps exclude those set for scavenging cats. VSC, Victor Soft Catch; LA, Lanes Ace

Trap set and type	Trap-nights	Rabbits caught	Bettongs caught	Goannas caught	Crows caught	Other birds caught	Overall capture rate per 100 trap-nights
Funnel (VSC)	1356	47	1	0	2	0	3.69
Feeder (VSC/LA)	238	2	0	2	0	0	1.68
Track (VSC/LA) – catnip as lure	1558	40	0	0	1	0	2.68
Track (VSC/LA) – all other lures	21820	75	1	6	3	5	0.41
Track (cage)	2111	0	12	1	5	0	0.85
Total	27083	164	14	11	11	5	0.76

was a problem. A range of practical issues determined these choices.

Treadle snares were expensive to purchase, bulky to transport, and difficult and time consuming to set compared with Victor Soft Catch traps, and appeared too slow to catch cats. They captured foxes but had no advantage over Victor Soft Catch traps. Skinner and Todd (1990) and Onderka *et al.* (1990) compared the efficiency and the level of injury sustained for foot-hold traps (including a larger version of the Victor Soft Catch trap that we used) and foot snares (different brands to that used in this study) for capturing coyotes and found that the capture efficiency of the foot-hold traps was three times that of the foot snares (Skinner and Todd 1990). The two brands of foot snare differed greatly in injury level to captured coyotes (Onderka *et al.* 1990). Neither reduced injuries below that of padded foot-hold traps.

Cage traps were excellent for catching scavenging cats because their high susceptibility to capture meant few traps were required. Rubbish tips and sites around buildings have road access so the bulkiness of traps was not an issue. They had the additional advantage over Victor Soft Catch traps of being more acceptable and safer to local people who might visit the area. However, for the capture of hunting cats in the bush they proved less useful, not so much because of poor trap success (they were effective at catching kittens and sub-adult cats), but rather because of their expense and bulk. They were expensive relative to Victor Soft Catch traps (currently \$A68 cf. \$A41), and were cumbersome and difficult to transport because of their size. They were also difficult to bait because of the need to put head and shoulders into the trap. Presumably, this also left much human scent on the trap. However, cage traps have a significant advantage over foot-hold traps if there is the potential for a by-catch of non-target species. For example, use of Victor Soft Catch traps had to be abandoned in our core site with the establishment of bettongs. Bettongs were difficult to exclude from these traps despite precautions such as the use of scent rather than food and fencing of traps.

Relatively high trap success has been obtained with cage traps at some sites but generally only in the early stages of campaigns to control cats when densities are high. For example, Seabrook (1990) caught 16 cats in 1438 trap-nights (1.1 cats per 100 trap-nights) on Aldabara Atoll in the Indian Ocean. Veitch (2001) used 3637 cage trap-nights baited with fresh fish on Little Barrier Island in New Zealand for the capture of 26 cats (0.71 per 100 trap-nights). Veitch (1991) considered their bulk to be a major disadvantage for use in eradication campaigns when several hundred may be required. Molsher (2001) caught 29 individual cats in 6027 trap-nights, using mostly large cage traps (81% of trap-nights), to give an overall trap success of 0.48 per 100 trap-nights. She found no difference in capture efficiency between cages and Victor Soft Catch traps.

Lanes Ace traps have been used in numerous successful campaigns to eradicate cats from islands (Veitch 1991, 2001; Grant and Page 1992). They are strongly recommended by those who have used them in the field. However, they are designed to catch a much smaller animal (1.5 kg rabbit) and cats commonly pull out of traps modified to soft catch (Risbey 2000) and may become trap shy. This can be partly overcome by setting traps in pairs. However, two traps per set is expensive relative to the use of a single Victor Soft Catch trap and paired traps are more time consuming to set than a single trap.

Feeders, which provide a continuous source of food, have been developed to provide a method of poisoning cats (McKinnon 1991). They can also be used to habituate cats to come to a particular spot to be trapped. Our success with feeders has been mainly along the barrier fence.

Victor Soft Catch traps are cheap, effective and humane (Olsen *et al.* 1986, 1988; Onderka *et al.* 1990; Linhart and Dasch 1992; Warburton 1992). We commonly trapped an area intensively by setting one trap per 200 m along the edge of sandy tracks, which enabled large numbers of traps to be set quickly. This method did not return the highest catch per trap but accounted for the highest number of cats caught. It did not require particular site characteristics, traps could be quickly and easily checked from a vehicle, and one person could manage a large number of traps (60–100 per day per person).

Trapping at funnel sets was particularly effective but was limited by site characteristics. Our best results have come from setting traps along the barrier fence. Cats and foxes dispersing into the area tend to move up and down the fence line to search for a way through. Nearly 80% of captures of feral cats were males colonising vacant habitat to the immediate south of the barrier fence separating the core and buffer zones. Another type of funnel set was to place traps in wheel ruts on roadways or a pathway that has been used previously by a cat. Natural barriers or portable fences can be used to channel movements over the trap. The last cat on Reevesby Island (344 ha) in South Australia was trapped using this method (Copley 1991). A disadvantage of using funnel sets on vehicle tracks is the problems it poses for checking traps from a vehicle, and possible problems with closing the road to other traffic. Funnel sets had a much higher catch of non-target species (predominantly rabbits) in our area.

Trapping at den sites is extremely efficient in terms of catch per set but is limited by the time and skill required to locate dens. We had most success in tracking cats by this method from November to March on dewy mornings within two hours of dawn. This season of the year is when females are weaning young and so dragging rabbit carcases back to the den. This method may be useful when attempting to eradicate cats from a limited area.

A comparison of trap success between studies is unlikely to be meaningful unless results are standardised for density of cats, density of prey, trap spacing, and trapping intensity at each site. Densities of cats are known to vary by a factor of over 100, depending on site and food availability. Densities of 1 ha^{-1} have been recorded on a densely vegetated sand cay with abundant nesting seabirds (Domm and Messersmith 1990). In comparison, sites in semi-arid Australia may have densities as low as 0.74 km^{-2} (Jones and Coman 1982*b*). Trap success is likely to decline with intensification of trapping effort at the one site (a higher frequency of trapping or a closer trap spacing). Trap success declines sharply in a given area when only a few experienced adult cats remain. For example, Veitch (1991, 2001) caught 151 cats in 75 406 trap-nights on Little Barrier Island (an average of 500 trap-nights per cat overall), but the last five cats took an average of 6500 trap-nights each.

Comparison of success of various lures

We found mouse carcases, fresh rabbit, and a number of commercial lures to be effective in attracting cats to traps. The effectiveness of food versus scent lures varied with season, the density of rabbits, and the age of the cat. A variety of food-based, scent-based, visual and auditory lures have been tested for feral cats elsewhere. However, results are inconsistent across studies.

Veitch (1985, 1991) tested a range of food lures and recommended the use of fresh fish. Dredge (1993) compared a range of bait types using cage traps set at refuse tips near Hobart, Tasmania. Fish meal proved the most attractive when compared with dried fish, anchovy sauce, fish sauce, and canned cat food.

Clapperton *et al.* (1994) tested a range of lures that included fish oils, catnip, matabi (silver vine, *Actinidia polygama*), a range of commercial lures (Pro's Choice, Bobcat Anal Gland, Cat Pack, Wildcat lure 1, and Wildcat lure 2), and cat's urine (male, non-oestrous female, and oestrus female). Catnip (freshly chopped leaves) performed best overall in both pen trials and trials at rubbish tips. Catnip sites were visited more often (12 times) than Pro's choice (7), Bobcat Anal Gland (5), or Cat Pack (11), but the result was not significant. Cat activity was significantly greater at catnip (i.e. more prints per chalk tile used to assess visitation at each lure). We obtained good capture success with freshly chopped catnip leaves in early trials but could not repeat these successes, perhaps due to removing the pool of susceptible individuals.

Edwards *et al.* (1997) tested a range of lures that included ten food-based lures (blood and bone, cod-liver oil, fish emulsion fertiliser, tinned sardines, tinned anchovies, sun-rendered fresh fish, sun-rendered fresh prawns, sun-rendered fresh oysters, fresh prawns and fresh oysters), catnip, cat anal gland plus urine, plus a visual lure. Trials were conducted on free-living cats in central Australia in early winter through to early spring. Sun-rendered prawns (a food), and anal gland (a scent) proved most attractive. The trial using prawns was conducted in early to mid-winter; the trial using anal gland was conducted in late winter and early spring (coinciding with a peak in breeding activity following a winter anoestrous period: Jones and Coman 1982*a*). Hence, the relative timing of successes with food and scent lures are broadly consistent with that found at Shark Bay.

An evaluation of the effectiveness of lures includes an assessment of their attractiveness to both target and non-target species, ease of use, availability, and cost. Some lures, such as fresh catnip, desiccate readily, need replacement daily, particularly in summer, and are very attractive to non-target species, such as rabbits. Many foods attract non-target species, or are susceptible to ant attack (e.g. dried fish, canned cat food and fish meal pellets: Dredge 1993).

Conclusions

Trapping provides a vital weapon in a broader arsenal for the eradication of feral cats from small areas where reinvasion can be effectively controlled. It is effective but labour intensive. In large and unbounded areas (such as our 200-km^2 buffer zone), the high reproductive capacity and dispersal ability of feral cats is likely to rapidly make up for trapping losses. The feral cat population can be thought of as two pools: a core of experienced adults and the young of the year. Concealed foot-hold traps, with mice carcases or portions of rabbit carcase, commercial scent lures, and catnip as lures, were most effective against experienced adults. Scent lures were used to maximum effect during the breeding season, a time (at least at Shark Bay) when food for cats was often abundant. Young, dispersing cats were vulnerable to such methods but could be caught also using cage traps (particularly in areas that offered opportunities for scavenging) and strategically placed funnel traps. Young cats were significantly more susceptible to capture in foot-hold traps baited with food than were adults at this time. Knowledge of the reproductive cycle of cats and the fluctuating availability of key food items to cats offers the opportunity to intensify trapping effort during periods when cats are most vulnerable to scent and food lures. Effective control of cats for nature conservation is likely to require a variety of methods, a variety of lures, and considerable effort. There is unlikely to be any single, easy method of control.

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