knowledge of all Australian government agencies would create a solid basis for any national biosecurity preparedness initiatives. The clear benefits of this approach, including the ability to rapidly assess the relative abundance of pest animals over large landscapes and thereby direct management decisions, should have broad appeal. We would, therefore, encourage a similar approach to be undertaken in other states (in addition to their current information management practices) to achieve a national standard for the cost-effective measurement of the relative abundance and distribution of vertebrate pest animals in Australia.

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Attraction of auditory and olfactory lures to Feral Cats, Red Foxes, European Rabbits and Burrowing Bettongs.

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Key words: *auditory and olfactory lures, European Fox, Feral Cat, trapping.*

Introduction. Predation by Feral Cats (*Felis catus*) and the Red Fox (*Vulpes vulpes*) has contributed to the extinction or decline of many native animals and is responsible for the failure of several threatened species reintroduction attempts in Australia (Gibson *et al*. 1994; Copley 1999). Control of cats and foxes is important for protecting extant wildlife populations and ensuring the success of reintroduction programs. Broadscale poison baiting has reduced fox numbers in many areas (Saunders *et al*. 1995) but cat control is generally acknowledged to be labour-intensive and expensive (Fisher *et al*. 2001). Although shooting, trapping and poisoning are used to control cats in Australia, there is currently no proven method for efficient broadscale cat control (Environment Australia Biodiversity Group 1999). Trapping is useful for eradicating or controlling cats in restricted areas, but relies on the use of effective attractants (Environment Australia Biodiversity Group 1999). Lures such as food, plant extracts and food and social odours (urine and anal gland preparations) are used to attract predators to baits or traps and many studies have compared their effectiveness (e.g. Turkowski *et al*. 1983; Clapperton *et al*. 1994; Edwards *et al*. 1997; Saunders & Harris 2000). Clapperton *et al*. (1994) reported catnip and matatabi to be the best lures for cats while Edwards *et al*. (1997) found sun-rendered prawn and social odours to be the most promising. Edwards *et al*. (1997) and Molsher (2001) found the addition of visual lures such as flagging tape, flashing lights and feathers made to mimic a fluttering bird to be ineffective at attracting cats.

Control of feral cats and foxes is an integral component of the Arid Recovery Project, an ecosystem restoration project based at Roxby Downs in arid South Australia. A vermin-proof fence has been erected around a 60 km^2 Reserve, all cats, foxes and European Rabbits (*Oryctolagus cuniculus*) have been removed, and locally-extinct threatened species have been reintroduced. Continued control of cats, foxes and rabbits is required around the Reserve to reduce the chance of cats and foxes breaching the fence and preying on the reintroduced species. For this purpose, 12 permanent leg-hold trap sites have been established immediately outside the Reserve. The aim of this study was to compare the effectiveness of different attractants for increasing trap success. Fenced lures were also trialed in an effort to reduce captures of non-target mammal species.

Methods. *Lure trials*: Field trials were conducted between December 2000 and February 2001 in the vicinity of Roxby Downs, 500 km north of Adelaide in arid South Australia. The habitat is dominated by longitundinal sand dunes spaced up to 1 km apart and separated by clay inter-dunal swales. Dominant dune vegetation includes Umbrella Wattle (*Acacia ligulata*) and Narrow-leafed Hopbush (*Dodonaea viscosa*) whilst swales are dominated by chenopod species such as Bladder Saltbush (*Atriplex vesicaria*) and Low Bluebush (*Maireana astrotricha*). The long-term annual average rainfall is 166 mm (Read 1995).

Two auditory lures and one olfactory lure were tested by recording daily visitations by cats, foxes and rabbits. Both auditory lures were commercially available devices, a Feline Attracting Phonic (FAP) obtained from the Department of Conservation and Land Management in Western Australia and a Potplant Watering Reminder (Bird) obtained from Dick Smith Electronics. The FAP emits a cat-like 'meow' while the Bird is the size and shape of a wren and emits

Table 1. The number of lure sites that successfully attracted cats, foxes and rabbits during each trial. The number of consecutive replicate transects used during each trial is in parentheses

Treatment	No. sites	Cats	Foxes	Rabbits
Trial 1 – individual (9)				
Pongo	28	2	3	6
Control	34	0	1	9
Bird	36	11	6	5
FAP	31	9	3	5
Trial 2 – combination (4)				
Bird/FAP	20	4	2	3
Bird/FAP + Pongo	20	10	1	9
Trial 3 – fences (7)				
Bird/FAP	26	5	2	8
Bird/FAP + fence	25	5	0	1
Total	220	46	18	46

a twittering bird call. The photo and moisture sensor in the Bird was altered so that it ‘sang’ continuously in 3-s bursts. The olfactory lure consisted of Pongo (D. Algar pers. comm, 2000), a mixture of cat urine and faeces collected from freshly killed cats that were shot or caught in softjaw leghold traps or cage traps in the region. Pongo from cats was pooled and stored in the refrigerator until required; sex and reproductive state of the cats was not recorded.

Trial 1 compared visitation by rabbits, cats and foxes at individual lure types and control (no lure) sites. Trial 2 compared a combination of Bird or FAP lures with and without the addition of Pongo and Trial 3 compared Bird and FAP lures with and without fences. During the trials, each lure, lure combination or control was tested at between 20 and 36 sites (Table 1). Each site comprised a ‘trapping channel’, a narrow single-entrance corridor made from bushes or dead plant material that the animal had to enter to investigate the lure closely. Lures were placed at the back of the 1 m long, 0.3 m wide channel. Pongo (2–5 ml) was poured onto absorbent sand at the back of the channel. Two softjaw leghold traps (Victor Soft Catch) are normally placed at the entrance, however, traps were not used during the lure trials and the presence or absence of tracks was used to determine if a cat, fox or rabbit had entered the trapping channel. All lure sites were placed on dunes and the sand in the channel and within a metre of the entrance was swept at the start of the trial to enable fresh tracks to be identified. Lure sites were checked early each morning for 3 days and the sand re-swept between visits. A lure was considered to have successfully attracted an animal if its tracks progressed past the entrance of the channel anytime over the 3-day period as this would lead to capture during normal trapping activity. Multiple visits by a species to a site over the 3-day period were not differentiated from single visits as they may have been made by the same animal and were not considered independent. Pongo was not refreshed during the 3-day trial. Fences used during Trial 3 were 30-cm high and made from 40-mm wire netting. The fence was placed across the entrance to the trapping channel and successful visitation was recorded if tracks were recorded inside the channel.

To ensure independence, lure sites were set more than 500 m apart along transects. Lure types were alternated so that like lures were not placed consecutively. Each trial consisted of a number of replicate transects tested consecutively to increase sample size. Replicate transects were situated more than 5 km apart and comprised similar numbers of each lure type. Results were analysed using contingency table (χ^2) analyses to test for differences in the proportion of sites visited between each lure type.

To investigate the response of Burrowing Bettongs to fences and lures, circles of fencing were also placed outside four Burrowing Bettong warrens within the Reserve. Fenced circles were 2-m diameter, 30-cm high and made from 40-mm wire netting. At each warren, Bird lures were placed in the centre of two fenced circles and two fenced circles were left empty. Bird lures were also placed in the centre of two un-fenced circles delineated by drawing a circle of 2-m radius in the sand using a stick. Two additional un-fenced circles were also used as controls and did not contain lures. Circles were established in the afternoon and the sand swept to remove any tracks. The presence or absence of Burrowing Bettong tracks within the circles was recorded once on the following morning and the lures and fences removed. The following week, food (peanut paste and rolled oats) was placed within two fenced and two un-fenced circles outside each warren in the late afternooon. Sand was again swept and the presence of tracks recorded the following morning.

Field trap success. Results from the lure trials were compared with actual captures of foxes and cats at permanent trap sites placed around the outside of the Arid Recovery Reserve fence. The configuration of permanent leghold trap sites was identical to lure sites but two softjaw leghold traps were placed at the entrance to the trapping channel. Between five and 12 permanent trap sites were set continually from April 2000 to December 2001. Each trap site contained a Bird or FAP lure, the ratio of lure types used at any one time varied considerably but Bird lures were always more abundant. Traps were checked within 2 h of sunrise and any captured foxes and cats were shot. The trap success of cats and foxes was compared between lure types using a contingency table (χ^2) analysis.

Results. Cats and foxes were both attracted to lures while rabbits showed no interest. During Trial 1, there was a significant difference in the proportion of sites visited between lure types for cats ($\chi^2 = 13.87$, DF = 3, $P < 0.001$) and foxes ($\chi^2 = 3.29$, DF = 3, $P < 0.05$) but not rabbits ($\chi^2 = 1.67$, DF = 3, $P > 0.05$). Control sites were not attractive to cats or foxes with only one fox recorded at a control site (Table 1). When controls were excluded there was a significant difference between visitation at Bird, FAP and Pongo sites for cats only ($\chi^2 = 5.74$, DF = 2, $P < 0.05$). Only 7% of Pongo sites attracted cats compared to 41% and 44% for FAP and Birds respectively (Table 1). When Birds and FAP were directly compared there were no significant differences in the proportion of lure sites visited by cats ($\chi^2 = 0.018$, DF = 1, $P > 0.05$) or foxes ($\chi^2 = 0.7$, DF = 1, $P > 0.05$). Cats or foxes were collectively recorded at 47% and 39% of Bird and FAP lure sites, respectively. FAP and Bird lure sites were then pooled to test for differences in Trials 2 and 3.

Table 2. The number and trap success of feral cats and foxes captured in permanent softjaw leghold traps set around the Arid Recovery Reserve from April 2000 to December 2001

Lure type	Trap nights	No. cats (trap success)	No. foxes (trap success)
Bird	3719	20 (0.54)	24 (0.65)
FAP	1901	8 (0.42)	15 (0.79)

Only three foxes were recorded during Trial 2 and one during Trial 3; so only cat data were analysed further (Table 1). During Trial 2, 14 cats were recorded at the 40 lure sites and the addition of Pongo did not have a significant effect on the proportion of FAP/Bird lure sites visited (Table 1; $\chi^2 = 3.96$, DF = 1, $P > 0.05$). In total, 10 cats were recorded at the 51 lure sites during Trial 3 and there was no significant difference in cat visitation between FAP/Bird lures with or without fences ($\chi^2 = 0.0048$, DF = 1, $P > 0.05$; one-tailed). However, rabbit visitation at lure sites was significantly reduced at sites with fences ($\chi^2 = 7.05$, DF = 1, $P < 0.05$, one-tailed).

Burrowing Bettongs breached fences to access food but not lures. There were no Burrowing Bettong tracks recorded within any of the eight fenced control circles or the eight that contained Bird lures. Burrowing Bettong tracks were recorded at four of the eight unfenced control circles and two of the eight unfenced lure circles. During the food trial, Burrowing Bettong tracks were recorded within four of the eight fenced circles containing food and all eight unfenced circles that contained food.

Both cats and foxes were captured in the permanent trap sites set around the Reserve but more foxes were captured than cats (39 vs 28; Table 2). The combined cat and fox trap success for the permanent trap sites was 1.2% and there was no significant difference in the proportion of captures from each lure type for foxes ($\chi^2 = 0.37$, DF = 1, $P > 0.05$) or cats ($\chi^2 = 0.35$, DF = 1, $P > 0.05$).

Discussion. Despite the different sounds produced, both Bird and FAP lures were equally successful at attracting cats and foxes. Cats and foxes in central Australia have a highly varied diet (Paltridge *et al*. 1997; Read & Bowen 2001). The different sounds made by prey species, together with the variety of prey eaten would suggest that a wide variety of sounds may be attractive to cats and foxes. During 2001, FAP lures ($35) were threefold as expensive as Bird lures ($12) and our results suggest that a range of cheaper auditory options may be equally successful. Lures would need to be tested under different seasonal conditions to determine if the effectiveness of each lure is seasonal as has been found for some fox bait attractants by Saunders and Harris (2000).

The addition of Pongo appeared to increase visitation by cats but this was not significant. Although some studies have found scent-based lures to attract cats (e.g. Edwards *et al*. 1997; Short *et al*. 2002), others found urine to be a poor attractant (e.g. Clapperton *et al*. 1994). The low sample size may have prevented a significant result for Pongo but the extremely hot and dry conditions at Roxby Downs also rapidly desiccated the Pongo causing it to quickly lose much of its smell. In central Australia, Edwards *et al*. (1997) found anal gland secretions placed in plastic vials kept their smell for at least 4 days in winter but suggested this may be greatly reduced during summer. Pongo may be more successful in cooler (winter) or moister periods and environments. Additionally, Pongo was mixed from male and female cats and it is possible that there were sex-specific responses that may have been affected by pooling. The attractiveness of scent-based lures may also vary depending on whether or not they are used during the breeding season (Short *et al*. 2002; Verbene & Ruardij 1982). Interestingly, foxes were attracted to the cat-derived Pongo lure more than controls as was the Dingo (*Canis lupus dingo*) in a study by Edwards *et al*. (1997).

Rabbits were not significantly attracted to any lure but often entered trapping channels incidentally. Rabbits are often captured in the 12 permanent leghold traps set around the Arid Recovery fence (K. Moseby pers. comm, 2003). The addition of short fences successfully deterred rabbits from accessing lures during the trial but did not significantly reduce the lures' attractiveness to cats. Although sample sizes were low, Burrowing Bettongs were not attracted to lures and only breached fences to access food. Further trials are needed but fences may be useful in deterring non-target species, and in the event of a cat or fox incursion may enable traps to be set inside the Reserve where threatened species are present.

Auditory lures have several advantages over olfactory or food lures; they are easier to transport and maintain, they provide a consistent output regardless of time and weather conditions, and they do not require continual refreshment. Pongo is not used at Arid Recovery and auditory lures have now been established at 12 permanent trap sites. Lure trap sites have been configured to include 12-month battery life and traps are checked remotely using a radio telemetry receiver. A radio transmitter is wired to the traps and automatically changes the speed of the transmitted pulse when the trap has been set off. Auditory lures now play an important role in cat and fox control at Roxby Downs and have contributed to the successful reintroduction of threatened species into the Arid Recovery Reserve.

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Size should matter: Distribution and genetic considerations for pest animal management. Peter B. S. Spencer[1] and Andrew P. Woolnough[2] ([1]School of Veterinary and Biomedical Sciences, Murdoch University, Western Australia, and [2]Vertebrate Pest Research Section, Department of Agriculture, 100 Bougainvillea Avenue, Forrestfield, Western Australia 6058, Austrlia. Email: P.Spencer@murdoch.edu.au).

Key words: *applied genetics, distribution and abundance, feral pig, GIS, Sus scrofa, vertebrate pest*.

Importance of understanding biological boundaries. Biological invasions by pest species constitute one of the leading threats to biodiversity and ecosystem health (Long 2003). However, in terms of reducing their abundance, and ultimately the restoration of damaged ecosystems, a species can not be effectively managed without understanding their demic structure or biological boundaries (Zenger *et al*. 2003). We consider that the ability to define biological boundaries of a population as an important ecological parameter for the effective control of feral and invasive species. This is particularly so where subpopulations may be acting as a source for re-invasion, and also in those areas that may act as net recipients of dispersing individuals.

Feral pigs: a 'triple threat species' (environment, agriculture and biosecurity). Feral pigs (*Sus scrofa*) are a significant vertebrate pest in Australia (Choquenot *et al*. 1996). There are estimated to be more than 23 million animals inhabiting approximately 40% of the continent, with numbers varying considerably depending on environmental conditions, and the level of control exerted (Hone 1990; Choquenot *et al*. 1996).

The south-west of Western Australia (WA) is under threat from a range of processes including vertebrate pests, changing fire regimes, logging and clearing. It also has been described as one of the 10 most biologically diverse regions in the world (Myers *et al*. 2000), so effective management of feral pig populations is essential. In this region, feral pigs occupy most suitable habitat from the Perth hills around to Albany in the lower south of the state. They are often associated with available water (e.g. dams, riparian ecosystems) and developing forest industries (Long 2003). Feral pigs are perceived as a major threat to the biodiversity (and agricultural) values of this region and present a biosecurity risk for endemic and exotic diseases (Choquenot *et al*. 1996). As such, they should be a high priority management issue for conservation and agricultural practitioners alike.

We suggest that utilizing a combination of genetic and distribution information will enhance our ability to define biological boundaries for feral pigs. This information is essential to develop and implement regional strategies necessary for the effective control of this highly destructive and invasive pest. Our approach combines GIS and genetic methodologies to estimate a minimum area occupied by feral pig populations at a landscape scale.

Location surveys and genetic sampling. Distribution and abundance information on feral pigs was obtained for every parcel of land (agricultural, conservation, forestry and unallocated crown land) greater than 10 ha in size using a detailed and robust survey process (see West & Saunders 2003; Woolnough *et al*. 2004). This survey process captured the detailed local knowledge of staff from the Departments of Agriculture (n = 73) and Conservation and Land Management (n = 31). Central to the survey process was a comprehensive two-part structured interview developed to minimize any perception bias. The first part of the interview was an interactive questionnaire specifically about pest animals. The second part of the interview was a mapping exercise which utilized specifically-developed maps (fine scale) for each local area to describe distributions of various pest animals and a set of standard definitions to describe the abundance of pest animals (see Woolnough *et al*. 2004). These key features of the survey process allow distribution and abundance data to be compared across local areas, regions and states (Woolnough *et al*. 2004). Moreover, we refer to distribution in terms of feral pigs being either present or absent from an area. This simplifies many of the assumptions that are associated with abundance and distribution estimates. Surveys were conducted from mid-2002 to mid-2003 with data incorporated into a Geographic Information System (GIS).

During the same period, we obtained samples for DNA analysis (at 14 microsatellite loci) from 276 adult feral pigs from the same areas. A Bayesian assignment approach of Pritchard *et al*. (2000) was used to identify genetic structure and, based on the sampling locations, feral pig populations were defined (see Hampton *et al*. 2004). The minimum polygon method (which is likely to overestimate total population area) was used to estimate the area occupied by each population and define the most likely biological boundaries of each population.

'Operational management unit' of feral pigs. Six genetically distinct populations have been defined for the south-west of WA and described by Hampton *et al*. (2004). These populations were found to be (significantly) genetically distinct, even between some populations that were only 25 km apart,