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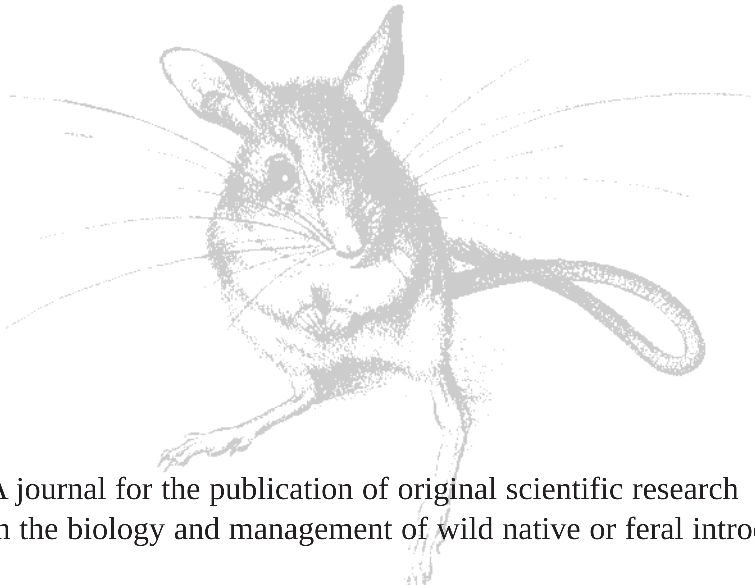

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The effectiveness of aerial baiting for control of feral pigs (*Sus scrofa*) in North Queensland

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Abstract

This study assessed the proportion of a feral pig population that consumed aerially distributed baits incorporating a non-toxic biomarker (iophenoxic acid). Baits were distributed at a rate of 18 baits km^{-2} over 70 km^2 of a seasonally inaccessible habitat. A total of 102 feral pigs were then captured by trapping and ground-shooting. Blood samples from 63 adult feral pigs were analysed for the presence of the biomarker; 40 (63%) were considered to have consumed at least one bait. Ground-shooting and trapping over 6 days resulted in 18% and 16% population reduction respectively.

Introduction

Feral pigs (*Sus scrofa*) are a significant problem in north Queensland, causing long-term ecological damage and economic losses to rural industries, and posing a threat in the event of an exotic disease outbreak (Johnstone 1982). Feral pigs are found in all habitat types throughout Queensland, often where access is limited because of topography, lack of roads or adverse environmental conditions (Allen 1984). Many Queensland habitats are seasonally inaccessible for varying periods during the wet season (November–March). Cape York Peninsula, particularly the coastal habitats, is difficult to traverse by vehicle in normal wet-season conditions. Consequently, ground-based control techniques are not possible for long periods in these areas.

In the event of an exotic disease outbreak (particularly for foot and mouth disease) the control and containment of feral pigs is an important consideration. Feral pigs are potentially significant hosts of foot and mouth disease not only because of their high susceptibility to the virus but also because they act as amplifiers of the disease (Pech and McIlroy 1990). Limited access because of adverse terrain or climatic conditions will restrict the level of population control achieved and impede the containment of feral pigs within the control area. Aerial shooting is the most practical technique in these situations; however, problems may occur if pigs disperse outside the containment area (Saunders and Bryant 1988). Dexter (1996) demonstrated no significant dispersal effect due to aerial shooting.

Poisoning is still considered the most appropriate technique for achieving large-scale control of feral pigs (O'Brien *et al*. 1986). Poisoning may be possible when accessibility is limited by utilising aircraft to distribute the poison baits. Increasing the availability of toxic baits (i.e. the opportunity to encounter baits) to a larger proportion of the feral pig population will achieve increased effectiveness of control (Hone 1986). Currently no information is available on the effectiveness of this technique to control feral pig populations.

The objective of this study, therefore, was to assess the effectiveness of aerial baiting by determining the proportion of a feral pig population that was marked after the aerial application of baits containing a biomarker. A biomarker technique was used because of the problem of accurately assessing population levels (to determine the degree of population reduction) and the inaccuracies associated with finding dead animals in the field (to determine death rate). Biomarkers have been used for a variety of species to evaluate bait uptake in field situations (Knowlton *et al*. 1986; Fletcher *et al.* 1990; Saunders *et al.* 1993). The technique relies on using non-lethal biomarker substances incorporated into bait material to identify or 'mark' the animals

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that consume the bait (Eason and Batcheler 1991; Saunders *et al.* 1993); the proportion of the population marked is assumed to represent the proportion that would have been killed if toxic baits had been distributed.

The study was conducted during the dry season because of the necessity of sampling the pig population using ground-based techniques. The intent was to illustrate the potential use of the technique during the wet season where ground-access is impractical.

Methods

Study area

The study was conducted in the Lakefield National Park situated near Princess Charlotte Bay, Cape York Peninsula, north Queensland (14°30′S, 140°10′E). Extensive marina plains surrounding 'Jane Table Hill' within the National Park were selected as the study site. Plant communities included salt marsh/salt flats *(Sporobolus virginicus)* grasslands mixed with sedge swamps of bulguru (*Eleocharis* spp.), small areas of eucalypt and melaleuca woodlands and groves of cabbage palms (*Corypha elata)*. This area is seasonally inaccessible to ground travel because flood waters from the Normanby and Bizant Rivers inundate the area during the wet season.

Approximately 70 km^2 were designated to be within the treatment area, bounded by the Normanby River to the east, the Bizant River in the west, Jane Table Hill to the north and Bizant cattle yards to the south. The study was conducted in July, the middle of the tropical dry season.

Baiting program

The biomarker selected for this project was iophenoxic acid (IA) (ethyl-3-hydroxy-2,4,6-triiodobenzenepropanoic acid), an organic chemical containing iodine used in medicine as a diagnostic X-ray contrast agent (Baer *et al.* 1985). IA binds to protein in blood plasma and elevates the level of protein-bound iodine.

Preliminary research showed meat to be the preferred bait material of feral pigs in this region. Three feral cattle were used to produce 312.5 kg of meat bait material which was cut into 1250 individual baits averaging 250 g, and air-dried for 2 days. Iophenoxic acid was dissolved in ethanol (absolute) at a concentration of 10 mg mL^{-1}. Each bait was then injected with 4 mL of solution (i.e. 40 mg IA $bait^{-1}$).

Four transect lines, approximately 10 km long, were established from topographical maps to enable flight paths to follow visual landmarks. The transects were established north–south and spaced 1 km apart. A fixed-wing plane fitted with specially designed baiting equipment was used for bait distribution The aircraft flew at 100 m altitude and 115 km h^{-1} air speed. Individual baits were dropped at 1-s intervals, i.e. approximately 32 m apart (312 baits per transect line). In total, 1250 baits were distributed over the study site (18 baits km^{-2}).

Population assessment

Helicopter surveys were conducted one day before baiting and 20 days after the sampling procedures ceased. Transects established for the baiting procedure were utilised; each transect was flown at 100 m altitude and 100 km h^{-1} airspeed. All pigs seen within a 500-m-wide transect by the observer were counted. Marks on the helicopter doorway provided reference points to define the 500-m width from an altitude of 100 m. The predominant grasslands allowed high visibility of feral pigs so the relatively wide counting transect could be used. Estimates of the population size were derived from the index–manipulation–index method (Caughley 1980), where density can be estimated before and after a known number of animals are removed from the population (Saunders and Bryant 1988; Saunders 1993).

Sampling procedure

Feral pigs were collected for sampling by ground-shooting and trapping. Sampling commenced 10 days after bait material was distributed to allow sufficient time for the feral pigs to find and consume baits.

Shooting was conducted by three teams of three members (driver, spotter and a shooter standing in the back of the vehicle). Shooting commenced at first light and terminated at approximately 1100 hours, when pig activity ceased due to high ambient temperatures. Shooting was conducted over 5 days (6 hours per team per day) for a total of 90 shooting hours. Teams were daily allocated to specific sites 5 km apart for safety reasons. Four traps were established for six nights (24 trap-nights) using feral cattle carcasses as the attractant.

Blood samples (50 mL) were collected from the brachial artery immediately after death. Samples were stored at ambient temperature overnight, plasma was decanted next morning and frozen. Juvenile pigs (<4 months) were not sampled because of the difficulty of determining whether piglets were unweaned so biasing the sample due to their possible reluctance to consume baits. Six blood samples were used to establish normal (baseline) plasma iodine concentrations. Two were collected within the study area seven days prior to bait distribution, and four more were collected 10 km outside the study area.

Blood sera samples were analysed to determine total iodine concentrations. Feral pigs that had consumed a bait were identified by the presence of significantly elevated blood plasma iodine concentrations from the baseline levels. The criterion for successful biomarking was based on the Shapiro–Wilk statistic (SAS 1985), with a value greater than the mean baseline iodine concentration value plus three standard deviations indicating that a bait had been consumed (Fletcher *et al.* 1990).

Results

During the 6-day sampling period 102 feral pigs were trapped or shot. Blood samples from 63 pigs that were older than 4 months of age (35 males, 28 females) were analysed for the level of plasma iodine. Adult pigs (32 males, 24 females) more than 18 months of age supplied 89% of the blood samples. Baseline iodine levels ranged from 9.96 to 27.3 μg L^{-1} (mean = 20.93 ± 6.85 s.d.) so samples with iodine values greater than 41.5 μg L^{-1} (mean + 3 s.d.) were considered marked (Table 1).

Table 1. Plasma concentrations of iophenoxic acid in sampled feral pigs

Mean (± s.d.) blood iodine values (μg L^{-1}). Samples are categorised into 4 iodine ranges and compared with control values. *N*, number of samples

Iodine range	*n*	Mean ± s.d.
Controls	6	20.93 ± 6.85
<41.5	23	19.30 ± 11.15
41.5–100	19	55.25 ± 10.66
101–1000	7	275.71 ± 271.43
> 1001	14	2083.57 ± 989.6

Plasma iodine values from the sample population ranged from 2 to 3830 μg L^{-1} (mean = 517 ± 965.8 s.d.). A total of 40 (63%) of the sample population [24 males (69%), 16 females (57%)] were considered to be marked, i.e. had consumed at least one bait (Table 2).

Shooting resulted in 49 feral pigs (28 males, 21 females) being killed (0.55 pig hr^{-1}); the shot sample contained 42 mature adults (>18 months), and seven subadults (12–18 months). Individual mature males accounted for 51% of the shot sample. In group situations mature boars, because of their size, were often targeted first. Small juveniles were difficult to spot in long

Table 2. Number of male and female feral pigs marked in the sample population

Sex	Number in sample	Number marked (%)
Males	35	24 (69%)
Females	28	16 (57%)
Total	63	40 (63%)

grass and more difficult to shoot because of their agility and small size. The average weight of the shot sample was 61.4 kg, compared with 20.2 kg in the trapping sample. Trapping captured 53 pigs (2.2 pigs per trap-night), comprising 31 males and 22 females (13 adults, 1 subadult and 39 juveniles under 4 months) (Table 3).

Table 3. The number (*n*) and average weight (av.wt., kg) of male and female feral pigs captured by trapping or shooting

Age class (months)	Sex	Capture Technique: Shooting *n*	Shooting av. wt.	Trapping *n*	Trapping av. wt.
<6	Male	–	–	24	9.2
	Female	–	–	15	8.9
6–12	Male	2	22.0	–	–
	Female	2	17.5	1	9.0
12–18	Male	1	37.0	–	–
	Female	2	34.5	–	–
>18	Male	25	77.0	7	64.3
	Female	17	52.6	6	43.2
Total		49	71.4	53	20.2

The aerial survey counted 87 feral pigs prior to baiting and 57 after the sampling was completed. Calculations indicated a feral pig population of 297 (4 km^{-2}) existed within the study area prior to the study.

Discussion

Aerial distribution of baits achieved a 63% bait take in this study. This level of theoretical population control is generally considered insufficient for effective population control (70% – Giles 1980; Hone and Robards 1980) or for exotic disease control (90–95% – Pech and Hone 1988). A superior control level may have been achieved by increasing the baiting density applied in this study (18 baits km^{-2}).

The approximately 300 feral pigs within this study areas were exposed to 1250 baits, equating to about four baits available per pig. Fletcher *et al*. (1990) ground-baited at a density of 490 baits km^{-2}, and calculated that 10 baits available per target animal delivered an oral vaccine to approximately 95% of the population. Hone and Pederson (1980) also ground-poisoned feral pigs at a density of 33 baits km^{-2}, and achieved a 58% reduction in feral pig numbers.

Fletcher *et al.* (1990) used iophenoxic acid for biomarking feral pigs in a field study and recorded a normal plasma iodine level of 26–120 µg L^{-1} (mean = 65 ± 30.4 s.d.). They incorporated 20 mg per bait (40 mg in this study), and found a criterion for successful biomarking was a value greater than 156.2 µg IA L^{-1}, which is approximately three times the level recorded in this study. The discrepancies between these two studies are difficult to explain; however, differences in environmental factors, food type, and soil nutrients may be responsible.

In this study more male feral pigs, 38% of the marked population, had consumed bait(s) than had females (25%). This differs from the findings of O'Brien and Lukins (1988), who demonstrated a significant bias towards females in their field-poisoning study but suggested that this effect is marginal and would not markedly influence the outcome of poisoning. Of the pigs that recorded iodine concentrations greater than 1000 µg L^{-1} (n =14), 13 were mature males (the last was a mature female). Predominantly adult pigs over 18 months old (89% of the sample population) had consumed a bait(s), 57% were adult males and 43% were adult females.

The five-day ground-shooting part of this study resulted in a population reduction of 16% (49 of the estimated 300 total population). Hone and Bryant (1981) suggest that eradication of feral pigs during an outbreak of foot and mouth disease would need to be achieved in 21 days. The extrapolation of the shooting rate for this study (0.55 pig h^{-1}) to eradication would have taken a theoretical 22.5 days to achieve. However, the shooting effort required increases as the population density decreases, so the time to eradication would be greatly extended. Aerial shooting programs have achieved a much higher kill rate, up to 92 pigs h^{-1} (Saunders 1993), but ground-shooting is generally regarded as a secondary control technique, to be used as a backup to primary techniques such as poisoning (Allen 1984).

Trapping for the six-day sampling period resulted in a population reduction of 18% (53 of the estimated 300 total population). The rate of capture in traps (2.2 pigs per trap-night) was higher than that reported by Saunders *et al*. (1993) in Kosciusko National Park (0.4 pigs per trap-night). However, Caley (personal communication) captured 2.5 pigs per trap-night in a tropical riverine habitat in the Northern Territory, a habitat more comparable to the one in which the present study was carried out. Trapping captured a predominance of juveniles in this study (74% were under 6 months of age) mainly due to capturing family groups. The trapping program was restricted to six days with only four traps in operation; trapping effectiveness would probably have been enhanced with more traps and a longer free-feeding period.

The determination of the number of baits consumed by individual marked pigs is dependent on the known level of iodine concentration in the baits. Because of possible leakage of the injected solution from the baits, the actual iodine levels in the baits was impossible to determine accurately. Thus, the iodine plasma levels could not be used to indicate the amount of bait material consumed by individual pigs. However, iodine levels greater than 1000 $\mu g\ L^{-1}$, 20 times the level considered to denote bait consumption, were recorded for 14 pigs (22%).

Further studies on other aspects of aerial bait application need to be considered. For example, this study applied a systematic bait distribution pattern – bait lines were spaced 1 km apart and no effort was made to target probable areas of high pig activity – which is not ideal for increasing the encounter rate of pigs with baits. For example, placement of baits on recent pig activity and at tree lines has been shown to influence the probability of bait being found and accepted (Saunders *et al.* 1993). Saunders *et al.* (1993) also suggested that all the pigs caught in their study were drawn from a catchment area (where pigs are likely to encounter baits during their normal range of movements) that extended 1820 m either side of the bait line. McIlroy *et al.* (1993) also discussed bait ‘catchment areas’ around bait lines; they suggested that baits need to be placed within 660 m of pigs to ensure the probability of the pigs encountering the bait material. The size of the catchment areas would influence bait placement and baiting density and so would need to be considered in aerial bait application.

O’Brien and Lukins (1988) and Saunders *et al.* (1993) emphasised the need for a sufficient free-feeding regime prior to a trapping or poisoning program; Saunders *et al.* (1993) recommended a minimum free-feeding period of at least 6 days. Aerial baiting is usually considered a one-off event with no prefeeding, as occurred in this study. The application of prefeeding in aerial baiting for pigs may have to be considered in plans for control of exotic diseases.

A limitation of any baiting program is that not all pigs will accept baits: Hone (1983) found that 23% of feral pigs failed to consume bait material, as did 37% in this study. Peregrine (1973) stated that low bait acceptance may be due to environmental (temperature, rainfall, season) or biotic (age, previous experience, nutritional state or sex) factors. Hone (1983) thought that wariness, insufficient free-feeding and lack of contact with the bait was responsible for this level of unacceptance of bait material. Hone (1990), Saunders *et al.* (1993) and Caley (1993) all suggested that seasonal parameters also influence bait acceptance; they found that acceptance was greatest when pigs were in the poorest body condition. In the present study site, seasonal food abundance is minimal during the late dry season (October–November) (Pavlov 1991), when the study was carried out; consequently, bait acceptance during the wet season, when food is plentiful, would be expected to be lower.

Aerial application of baits has advantages and disadvantages. The major advantage is that control programs can be implemented in adverse situations where ground-based techniques are impractical or cannot be fully implemented. For example, Saunders *et al*. (1993) found that access to conduct ground-based control operations (trapping and poisoning) in the Kosciusko region was dependent on the availability of fire trails traversing the site. Also, aerial baiting can cover large areas and is faster than conventional methods. Disadvantages include the lack of direct bait placement, usually no free feeding, and non-targeting of areas of high pig activity.

Further research is needed to determine the optimum baiting density required to achieve a control effectiveness consistent with practical population control or for containment of exotic diseases. The baiting density applied in this study appears to be a major influence on the level of bait-take achieved. Although this study was necessarily conducted during the dry season (for sampling purposes), this technique has potential for when ground-based control operations are not feasible in this area. Outbreaks of exotic diseases require that control of feral pigs must be implemented immediately, independent of season or access.

Additional studies are required to identify methods for optimising bait take, loss of baits to non-targets, consumption of multiple baits and the influence of seasonal, environmental and biotic factors on bait acceptability.

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