March 1980

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ABSTRACT: The changes in a feral pig population associated with 1080 poisoning were examined. There was a 58.1% reduction in population size after poisoning with no age-specific effect. The population size increased over 11.5 months after poisoning at an observed instantaneous rate of increase per year of 0.57. The results are discussed relative to feral pig control.

INTRODUCTION

Pigs (Sus scrofa) were introduced to New South Wales with white settlement. Subsequently some domestic pigs escaped or were released into the wild, forming feral (wild) pig colonies. By 1950, feral pigs were widespread in north-western New South Wales (Pullar 1950), and by 1977 throughout most of New South Wales (Hone and Waithman 1979).

Feral pigs are of agricultural concern in New South Wales because of their current impact on agriculture such as crop damage (Giles 1976, Pullar 1950), lamb predation (Plant et al. 1978), damage to pastures, fences and watering facilities (Pullar 1950), and the dissemination of diseases such as leptospirosis (Keast et al. 1963) and sparganosis (Appleton and Norton 1976). Feral pigs are of considerable concern also for their potential role as a reservoir of infection of several exotic diseases such as foot and mouth disease, swine fever, and African Swine Fever (Murray and Snowdon 1976). The main methods of controlling feral pig damage are poisoning, trapping, shooting, fencing, habitat changes and changes in agricultural management. These would also be the basic methods used to eradicate feral pigs if it was considered necessary in an exotic disease outbreak. The short-term effectiveness of the control methods is usually assessed by the percentage kill, and predictions of its long-term effects are based on knowledge of the remaining population's expected rate of increase.

This paper reports a study aimed at measuring the changes in a feral pig population following poisoning with sodium monofluoroacetate (1080). The observed instantaneous rate of increase per year is calculated, and the population examined for an effect of the poisoning on the age structure, sex ratio and social structure which may affect the rate of increase. Observations on bait taken by non-target species are also reported. The study was conducted over one year as field reports suggested that many feral pig populations returned to their pre-poisoning level of abundance in that time.

METHODS

The changes in the feral pig population sizes were monitored by counts of pigs for four nights at each of 5 watering points (1-5). The counts were assumed to be a relative measure or index of population size. Counting was conducted from 1930 hours to 2200 hours (Eastern Standard Time) with the aid of a spotlight or torch. Feral pigs may water more than once and could be counted more than once in the counting period so it was assumed that the frequency distribution of the number of times a pig is counted in a night is similar between nights and waters (sites). The time and observation and the size and composition of groups of pigs watering was recorded each night for each watering point.

The area covering the 5 watering points was 70 km^2. In the surrounding area of 330^2 km, poisoning was conducted at all watering points to overcome immigration effects on the counts after poisoning. As a result, no nearby area of similar habitat was available to be used as a non-treatment or null area. Hence no non-treatment indices of population size were obtained so the percentage reduction figures should be viewed with caution. The pre-poisoning counts were obtained from 6-13 January 1977 and the post-poisoning counts from 16-23 January, 14-19 February 1977 and 5-12 January 1978. Due to time limitations, the first post-poisoning counts were commenced after one of the three nights of poisoning.

POISONING

The bait used was meat from cattle and horses. The study was part of an investigation of different bait types for feral pig poisoning and meat could only be used for experimental purposes at the time. Meat is not used now as a bait for 1080 poisoning of feral pigs. The meat was cut to an average (± S.E.) weight of 190 (± 14) g (n = 17). After several hours drying in the sun, the baits were injected with 1080, so the concentration of 1080 in the poisoned bait was approximately 0.03%. Poisoned baits were distributed in the late afternoon and at dusk. The poisoned baits were placed on the ground either from the back of a vehicle in trails or by an operator on foot. The latter arranged the poisoned bait in heaps on tracks (pads) used by the pigs. Any baits remaining early next morning were picked up. Poisoned baits were distributed at each water for three consecutive nights, by which time some bait was always left and not taken by the feral pigs. Poisoning was conducted from 13 to 20 January 1977. The pigs were not free-fed with unpoisoned meat. The total number of baits distributed over the 400 km^2 site was 13,102. At the five watering points monitored 1756 baits were distributed.

NON-TARGET STUDY

The take of unpoisoned baits by non-target species was studied in the early morning to determine what species would take baits if they were not picked up by us. Several hundred unpoisoned baits were placed at intervals of 10 to 15 m apart along a boredrain. Baits were distributed and observed at dawn each morning for 3 days, the total time of observations being 14.5 hours. Observers watched the baits and recorded any species interfering with the baits, either as eating or taking the bait away. During the post-poisoning counts observations were also made of animals taking poisoned baits. It should be noted that the results obtained refer to the effects of poisoning on individuals, not populations of non-target species.

ANALYSIS

Differences in the number of pigs counted over time at different watering points were examined by random-factor analysis of variance (AOV), after transformation of the count to logarithms to base ten. Two degrees of freedom were subtracted from the total degrees of freedom to allow for missing data.

The observed instantaneous rate of increase per year, r, was measured by regressing the natural logarithm of the mean post-poisoning indices of population size on time (Caughley and Birch 1971). The observed rates of increase were tested for their statistical difference to zero, using a Students t test.

The effect of the poisoning on the age composition of the population was examined by trapping and shooting before and after poisoning. The pigs were grouped into five age classes and the relative frequencies examined by x^2 analysis. The before poisoning data were obtained at the time of pre-poison counts and are from Giles, Pedersen and Hone (unpublished data). The pigs were aged using the method of Matschke (1967), and foeti aged by the method of Henry (1968). Six months after the poisoning, in July 1977, a sample of pigs was collected by shooting to check on the reproductive status of the sows.

The effect of the poisoning on the social structure of the feral pig population was examined by x^2 analysis. A group was defined as the number of feral pigs within a two metre radius of any feral pig, when the animals were first sighted. The feral pigs were aged into three age classes; juvenile (0-5 months), sub-adult (6-12 months) and adults (>13 months).

STUDY SITE

The study area of approximately 400 km^2 was situated 160 km north-west of Bourke, New South Wales at 29° 20'S and 144° 40'E. The climate of the area is characterized by hot summers and mild winters, with an average annual rainfall of 29 cm, though this is quite variable. During the study in January 1977 the mean maximum and minimum temperatures (°C) for the pre- and post-poisoning periods were 38° and 21° and 34° and 20° respectively. The site is dominated by the floodplain of the Cuttaburra Creek, surrounded by higher red soil areas. The dominant vegetation of the floodplain is lignum (*Muehlenbeckia cunninghamii*) and grasses (*Aristida*, *Stipa*, *Sporobolus*, *Eragrostis*, *Chloris*, *Astrebla* and *Poa* spp.). In scattered channels were stands of *Acacia salicina* and *A. stenophylla*, Coolabah (*Eucalyptus microtheca*), Black Box (*E. largiflorens*) and Yapunyah (*E. ochrophloia*). The surrounding red soil areas were dominated by *Eucalyptus*-*Eremophila* associations including *Eucalyptus populnea*, *E. ochrophloia*, *Eremophila stuartii*, *Dodonaea attenuata*, *Casuarina cristata*, *Heterodendrum oleifolium*, *Atalaya hemiglauca*, *Flindersia maculata*, *Grevillea striata* and *Ventilago veminalis*. Saltbush *Atriplex vesicara* was common on some claypans.

Approximately twenty stock watering points are distributed over the site at intervals of two to five km. These include bore drains, ground tanks and troughs. There are no permanent natural waters in the area. The study was conducted on all or part of ten properties, which varied in area from 8,000 to 14,000 hectares. Nine of the properties carried sheep with some cattle, the tenth property had only cattle.

RESULTS

Reduction in Numbers Following Poisoning

Overall there was a 58.1% reduction in feral pig numbers immediately following the poisoning (Fig. 1). The percentage reduction varied between waters from 81.1% to a 40.3% increase in numbers (Table 1). There were significant differences in AOV, in the number of pigs counted between waters ($P<0.01$), times ($P<0.05$) and their interaction ($P<0.01$). Of the bait offered 93.1% was taken. The number of groups of feral pigs observed per watering point at different times showed similar trends to those of the population indices. The average number of feral pigs counted per half hour declined over the time of observation each night (fig. 2).

Rate of Increase

In 11.5 months after poisoning, the feral pig population nearly doubled and had almost returned to its pre-poisoning level. Over all watering points, the observed instantaneous rate of increase (± S.E.) per year was 0.57 (± 0.18) though there was considerable variation between the waters (Table 1). Each estimate of the observed rate of increase was quite imprecise. Only the rate of increase (1.09) at watering point 2 was significantly ($P<0.05$) different from zero.

Age Structure and Breeding

There were highly significant ($P<0.005$) differences in the age structure of the feral pig populations (Table 2) at the three times of sampling ($x^2 = 49.35$, df = 8). The significant difference was associated with the 1978 age structure data being significantly ($P<0.005$) different to the combined 1977 data ($x^2 = 42.739$, df = 4). The age structures immediately before and after poisoning were not significantly different. The difference in the age structures was associated with the 1.1-2.0 years

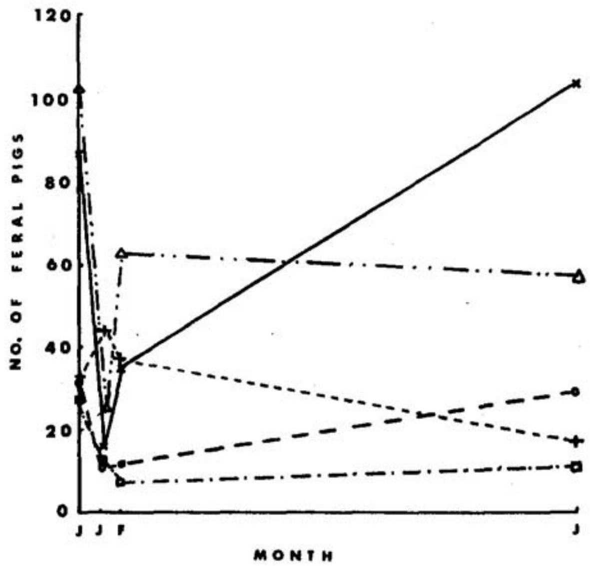

Fig. 1. The average number of feral pigs at the five watering points before and after poisoning. Watering point 1 x---------x; 2 o-------o; 3□------------□; 4Δ.......Δ; 5+ --------+.

Table 1. The percentage reduction in population size, observed instantaneous rates of increase (r) (± S.E.) per year and the finite rates of increase (λ) per year of feral pig populations at different watering points after poisoning.

Watering point	Percentage reduction	Observed rate of increase (± S.E.)/year	Finite rate of increase/year
	%	r	λ*
1	-81.1	1.64 ± 0.61	5.16
2	-67.6	1.09 ± 0.06	2.97
3	-58.2	0.29 ± 0.45	1.34
4	-65.3	0.25 ± 0.47	1.28
5	+40.3	-0.84 ± 0.10	0.43
Overall	-58.1	0.57 ± 0.18	1.77

* $\lambda = e^r$

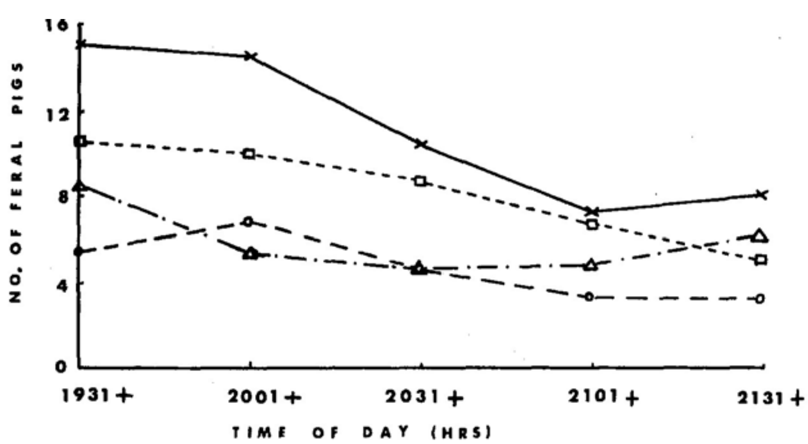

Fig. 2. The average number of feral pigs per half hour per watering point, before and after poisoning. Before poisoning x ---- x; after poisoning, Jan. 1977 o------o; Feb. 1977 Δ-.-.- Δ; Jan. 1978 □ ------ □.

Table 2. The age structure of a feral pig population before and after 1080 poisoning.

Age (years)	Before poisoning January 1977		After poisoning February 1977		After poisoning January 1978	
	n	%	n	%	n	%
0.1 - 1	107	56.6	39	56.5	53	63.1
1.1 - 2	1	0.5	1	1.5	12	14.3
2.1 - 3	17	9.0	12	17.4	3	3.6
3.1 - 4	40	21.2	12	17.4	9	10.7
4.1 +	24	12.7	5	7.2	7	8.3
Total	189	100.0	69	100.0	84	100.0

age class. In 1977 practically no pigs were of this age but in 1978, 14.3% of the pigs examined were aged 1.1-2.0 years old.

In July, six months after the poisoning, six adults (> 28 kg liveweight) sows were examined, and all were pregnant. The average age of the foeti was 82 days, corresponding to conception in mid-August, early September. In February 1977, of 13 adult sows examined only three were pregnant, and in January 1978 of 7 adult sows examined none were pregnant. The average in utero litter size overall was 7.6 (n = 9).

Sex Ratio

The numbers of male and female pigs counted in each of the four counting times were 184:231, 55:49, 118:76, 254:368. These differences were highly significant between times (x^2 = 26.25, df = 3, P<0.005).

Group Size and Composition

The average group size over all the watering points, before and after poisoning were 2.1, 2.0, 1.7 and 1.7. The frequency distribution of group sizes were highly skewed, with the modal size being 1.0 (Fig. 3), and were significantly (P< 0.005) different between times (x^2 = 48.769, df = 18).

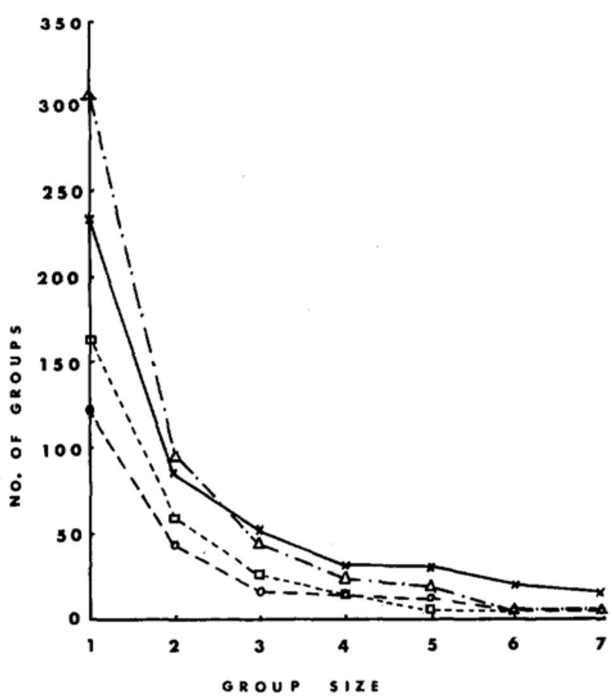

Fig. 3. Frequency distribution of group sizes of feral pigs before and after poisoning. Before poisoning x———x; after poisoning, Jan. 1977 o-------o; Feb. 1977 Δ --------Δ; Jan. 1978 □----------- □.

The composition of groups of feral pigs was similar between times though was not statistically tested. Single feral pigs were most commonly adult males (Table 3). Groups of size two and larger, that contained at least one adult, were most commonly adult sows and juveniles. Separate groups of sub-adults and juveniles were often seen, but mixed groups rarely.

Table 3. The demographic composition of groups of feral pigs before and after poisoning.

Group Size	Age	Sex of Adult	Before poisoning Jan. 1977	After poisoning Jan. 1977	Feb. 1977	Jan. 1978	Overall
1	A*	M	112	39	68	92	311
	A	F	50	15	29	76	170
	S§	-	21	29	20	37	107
	JΦ	-	11	7	20	26	64
2	AA	-	15	2	11	23	51
	AJ	F	15	3	4	6	28
	SS	-	16	16	13	17	62
	JJ	-	6	4	15	20	45
	Others	-	8	2	4	3	17
3	AAA	-	3	0	7	8	18
	AJJ	F	10	3	3	8	24
	SSS	-	13	7	6	7	33
	JJJ	-	6	5	10	8	29
	Others	-	7	1	0	3	11
4	AAAA	-	2	0	2	1	5
	AJJJ	F	4	4	1	8	17
	SSSS	-	9	2	3	1	15
	JJJJ	-	5	2	4	3	14
	Others	-	6	2	1	4	13
5+	Adults	-	3	0	0	0	3
	1A + J's	F	13	1	2	3	19
	S's	-	15	3	0	0	18
	J's	-	7	5	3	6	21
	Others	-	15	4	3	4	26
Number of nights of observation			20	20	17	20	77

*A = Adult
§S = Sub-adult
ΦJ = Juvenile

Unpoisoned Bait Take

The non-target species recorded as eating the unpoisoned meat baits were 3 foxes (*Vulpes yulpes*), 1 Whistling Kite (*Haliastur sphenurus*), 1 Little Eagle (*Haliaetus morphnoides*), 4 Black Kites (*Milvus migrans*), 4 Brown Falcons (*Falco berigora*), 3 Kestrels (*Falco cenchroides*), 1 Brown Goshawk (*Accipter fasciatus*), 5 Magpie-Larks (*Grallina cyanoleuca*) and 19 Corvids, of which three species occur in the area *Corvus coronoides*, *C. orru* and *C. bennetti*. Several species were observed to pick up a bait and carry it elsewhere, namely 2 foxes, 1 Corvid, 1 Brown Goshawk and 1 Brown Falcon.

Non-Target Effects of Poisoning

Two non-target species were observed to eat the poisoned baits, foxes and a Corvid. Non-target animals found dead after poisoning were one feral cat (*Felis catus*), three foxes, five Corvids, 2 Black Kites and one Magpie-Lark. These animals were found within 50 m of the watering points that had been baited. Beyond that distance the thick lignum growth decreased greatly the chance of finding any carcasses if they occurred there.

Cost

The estimated cost of the poisoning was $2,378 or nearly $6 per km^2. This cost included bait ($500), poison ($108), vehicle running costs and equipment ($510), and labor ($1,260). The cost does not include the cost of the evaluation.

DISCUSSION

The results reported suggest that poisoning may be a cheap and effective method of feral pig control, but that any effect of poisoning may soon be lost. In practical terms, these results mean firstly that feral pigs may not be eradicated by this poisoning method applied as a single exercise, and secondly if poisoning is used as a control technique ft must be used repeatedly or used in conjunction with other techniques such as trapping.

The poisoning resulted in a substantial drop in the feral pig population size. The reduction was apparently equal over all age groups though maybe not over both sexes. However, there was considerable variation in the effect of the poisoning between waters. At the water where the population increased after poisoning, small ephemeral waters were scattered in the area and were rapidly drying up at the time of the poisoning, so pigs may have moved to the watering points. The lack of non-poisoned populations forces caution however, in the interpretation of these results. The reasons for the overall percentage reduction being only 58% are unknown, but there are several possibilities. Some feral pigs may not have eaten the bait because of social interactions or they rejected it. Many factors have been suggested to affect bait acceptance by animals (Peregrine 1973). Some feral pigs may not have eaten enough 1080 bait to ingest a lethal dose. Research in Queensland has indicated that some feral pigs are not susceptible to very high doses of 1080 (Sheehan, pers. comm.).

The increase in the feral pig population size after poisoning was presumably due largely to breeding rather than immigration as the initial poisoning was conducted over a large surrounding area, specifically to overcome large immigration effects. In February, just after the poisoning, and in May heavy rain fell on the site, in total 35 cm. No other rain fell during the 11.5 months, however, much of the site was covered with floodwaters from March till September. The sows examined in July had conceived just after the heavy rain and had expected farrowing dates at the end of the flood when there was abundant growth of pasture, so the piglets born at that time would be expected, to have a high survival rate. Variation in the rate of increase between waters may have been associated with differing degrees of flooding and hence food supply. Movement of pigs between waters was probably not important as previous studies at the site suggested that there was little movement of feral pigs between watering points even after a flood (Giles, unpublished data).

The observed instantaneous rates of increase (r) and the finite rates of increase (λ) reported in this study are similar to those reported for wild pigs overseas. European wild boar in the USSR have been reported to increase from 478 to 1325 in one year (Bratton 1975 after Kozlo 1970) which is equal to an r = 1.02 per year and λ = 2.77 per year, and from 35 to 2100 over 10 years (Bratton 1975 after Kormilitsin and Dulitskii 1972), which is equal to r = 0.41 per year and λ = 1.51 per year. The rate of increase of feral pigs in New South Wales may be potentially higher than for European wild boar as the former breed continually throughout the year (Giles 1976), but the latter in the USSR have a distinct breeding season (Sludskii 1956). The New South Wales results are also similar to the results of a computer simulation model of wild pigs by Tipton (1977). He reported a finite rate of increase λ = 1.347 per year which is equal to an observed rate of increase of r = 0.298 per year of the computer population over 10 years. However, when the food supply to the pigs was varied between years, the increase was much lower. The maximum value of λ was 1.11 per year equivalent to r = 0.106 per year after 12 years.

The overall observed rate of increase (0.57) can be utilized to calculate the number of feral pigs that need to be killed to hold the population stable (r = 0). If the feral pigs are killed throughout the year, and N is the average population size throughout the year, the number required to be killed is 0.57 N (Caughley 1977). The variation in the observed rate of increase between waters in this study, and the expected variation in the average number of feral pigs between years, even without control, mean that the number of feral pigs required to be killed will vary between areas and years. Usually the average population size is not known, however, the approach can still be used if the actual kills and indices of population size are available (Caughley 1377). Tipton (1977) reported the effects of several harvesting and control schemes on his computer population. The optimum control strategy on the basis of many conditions, was to reduce the 0.5-1.0 year age class by 60%, and the 2.5 years and older class by 40%. The finite rate of increase λ was then 0.8508 per year, which is an observed rate of increase of r = -0.162.

The social structure observed in this study was similar to that reported for feral pigs in California (Barrett 1971) and Auckland Island, New Zealand (Challies 1975). The most commonly observed groups consisted of single adult males, then an adult female with juveniles, and groups of sub-adults and juveniles. Some of the larger groups, for example, those of seven or more feral pigs may not have reflected the social structure, but may have been coincident groups (Brown 1975) formed by attraction to a common resource, the watering points.

The social and age structures of a feral pig population may be very important in damage control. Large numbers of small groups arriving at a bait station as in this study may mean that some pigs for example adult males, can dominate the feeding behavior of others, and wholly or partly exclude them from eating the bait. Andrzejewski and Jezierski (1978) considered that the age and social structures of a wild boar population in Poland were more important in determining the amount of crop damage than the population size.

ACKNOWLEDGMENTS

We wish to acknowledge the technical assistance of J. 0'Grady during the conduct of this study. The work was financed by the Australian Meat Research Committee. The study owed much to the considerable assistance and cooperation of all the property owners, and personnel of the National Parks and Wildlife Service of N.S.W., the University of New England, CSIRO, Division of Wildlife Research and the N.S.W. Department of Agriculture.

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