CONTROL OF FERAL GOATS BY POISONING WITH COMPOUND 1080 ON NATURAL VEGETATION BAITS AND BY SHOOTING

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ABSTRACT

The effectiveness of poisoning feral goats (**Capra hircus** L.) with Compound 1080 on natural vegetation baits was tested and compared with a hunting campaign. Both control methods probably killed over 90% of the goats in treatment blocks of 1200 ha, but the poisoning method required less skill than hunting. **Melicytus ramiflorus** Forst., **Schefflera digitata** J.R. et G. Forst., **Coprosma lucida** J.R. et G. Forst. and **C. australis** (A. Rich.) Robinson proved to be useful bait species in terms of their palatability and durability. The Compound 1080 gel used in the trial was too acid, causing chlorosis and eventual abscission of treated leaves.

INTRODUCTION

Feral goats are a serious pest in many New Zealand indigenous forests (Atkinson 1964; Dale & James 1977; Sykes 1969) and the New Zealand Forest Service expends about 50 man-years of hunter effort and about 100 hours of helicopter time annually at a cost of $1.2 million, in attempts at control.

At present, control involves shooting the goats, either from helicopters or more usually on foot, with or without the assistance of hunting dogs. In some areas these methods have been successful in eliminating, or at least greatly reducing, goat populations but in other forests goat control is an apparently endless annual job that fully occupies the available resources of men and money merely to maintain the status quo. There are many large goat-infested areas – the Wanganui River catchment, eastern and northern Taranaki, and parts of the Raukumara Range, Great Barrier Island, Northland, north-west Nelson, and Westland, for example – where little or no control is attempted despite the obvious need to alleviate damage to the indigenous flora.

The use of the poison sodium fluoroacetate (Compound 1080) on natural vegetation baits may help to solve these control problems. The general method was first tried in New Zealand by Davison (1938) using a paste of strychnine and icing sugar smeared on natural vegetation in an unsuccessful attempt to poison goats on Raoul Island. More recent (and more successful) attempts using Compound 1080 suspended in various adhesive gels were made against wallabies (*Macropus rufogriseus fruticus*), red deer (*Cervus elaphus* L.) (N.Z. Forest Service 1977; also unpubl. data – *see* Acknowledgments), and white-tailed deer (*Odocoileus virginianus* (Boddaert)) (C. N. Challies, pers. comm.). This "one-hit" method has the potential of providing a substantial reduction or possibly extermination of the pest animal.

A trial was set up to determine what proportion of a feral goat population could be poisoned, to find the most suitable plant species for use as bait in terms of durability and palatability, and to compare the efficiency of the technique with that of a traditional hunting campaign conducted on a similar adjacent area.

METHODS

Trial Area

The trial took place in the lower part of the Mangakirikiri Stream, a second-order catchment of the Motu River in the Raukumara State Forest Park. The area chosen was typical of the steep, dissected hill country of the western Raukumara Range, rising from 250 m to 850 m above sea level. The complex forests are dominated by tawa (*Beilschmiedia tawa* (A. Cunn.) Kirk), kamahi (*Weinmannia racemosa* (L. f.)), and tawari (*Ixerba brexioides* A. Cunn.), with some red beech (*Nothofagus fusca* (Hook. f.) Oerst.) on the higher ridges. Seral forests of mahoe (*Melicytus ramiflorus)* or wineberry (*Aristotelia serrata* (Forst.) Oliver) are common and are preferred sites for goats.

Goats have been in the area for many decades (N.Z. Forest Service, unpubl. data) and have extensively browsed the vegetation so that little of their presumed preferred food remains within their reach. Feral pigs (*Sus scrofa* L.) and brush-tailed possums (*Trichosurus vulpecula* Kerr) are also present in the area, but red deer, which are present nearby, seem to avoid the goat-infested areas.

Three blocks, each of about 1200 ha, were selected. The two treatment blocks – poisoned and hunted – were set up on either side of the lower Mangakirikiri Stream, which was presumed to be an effective barrier to the goats' movements. The untreated control block was sited in another small catchment about 2 km from the edge of the treatment areas (Fig. 1).

Goat Population Estimates

Goat density in each block was measured before treatment in late February 1982, immediately after the treatments in mid-April 1982, and 11 weeks later in early July 1982, using two independent density indices.

Faecal pellet counts: In the poisoned, hunted, and control blocks respectively 376, 350, and 420 circular 0.0004-ha plots were established. These plots were spaced at 10-m intervals along transects through areas of high goat use, generally along ridges. The plot centres were marked with small flagged pegs. The density of faecal pellets was measured before the treatments by the point distance – nearest neighbour method (Batcheler 1973), with individual faecal pellets treated as entities as it was often difficult to distinguish discrete defecations. The plots were then cleared of all pellets.

The recruitment of new pellets on these plots was estimated, again by the point distance – nearest neighbour method, firstly immediately after the treatments (46 days after the initial measurements) and secondly, after a further 77 days.

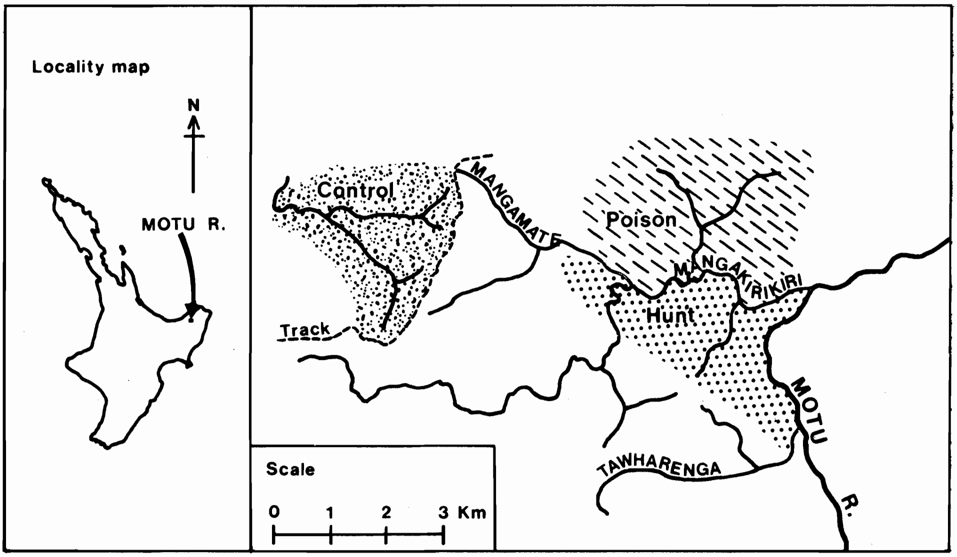

FIG. 1—Location of study area and the position of two treatment blocks (poisoned, hunted) and an untreated control block, Raukumara State Forest Park.

These recruitment densities were weighted to account for differences in the initial pellet densities between the three blocks.

Animal counts: The number of goats seen and the time spent observing in the three blocks were noted by all field parties each day during all phases of the trial. The number of goats seen per hour-worked was used as the second index of goat density.

Poisoning Method

The poison used was a carbopol-based gel loaded with 10% Compound 1080 and buffered with triethanolamine. This formulation was developed by J. A. Peters at the Forest Research Institute, manufactured by the Supplies factory of the Agricultural Pests Destruction Council at Wanganui, and is registered under the Provisional B section of the Agricultural Chemicals Act 1959 No. 2345.

Branches of putative palatable tree species were bent and tied down to within the goats' browse range. Twenty leaves on each branch (bait station) were each smeared with about 0.25 g of the toxic gel, squeezed from a plastic tube. With Compound 1080 a lethal dose for goats is about 0.0185 g (LD_{50} 0.5 mg/kg, McIlroy 1983) and so each leaf should have held enough to kill a goat.

Fifty-six man days were spent by up to six teams laying out the poison over about 1200 ha between 9 and 14 March 1982. A team, generally of two men, could lay about one tube of poison per day, each tube containing enough poison for about 100 bait stations at 20 leaves per station. In all, nearly 3000 stations were laid – an average density of about 2.5 stations/ha.

In the centre of the poisoned block, 68 bait stations on 11 putative food species were marked to test for goat preference. The fate of each of these stations was monitored daily over a period of 2 weeks.

The durability of the Compound 1080 gel itself was tested in a leaching trial in which a series of baits were laid out on leaves of *Melicytus ramiflorus, Hedycarya arborea* J.R. et G. Forst., *Ripogonum scandens* J.R. et G. Forst., and *Coprosma lucida,* all left out of goat reach. On the first day and on every second day thereafter for 8 days five such treated leaves from each species were collected, preserved in 10% formalin and later assayed for Compound 1080 using an alkali digestion specific ion electrode technique (C. L. Batcheler, pers. comm.).

Hunting

The hunting on the block adjacent to the poisoned block was carried out in two forays involving 61 man days. Five hunters shot in the area between 15 and 26 March and two from 14 to 18 April. No dogs were used, and the goats were shot with .22 calibre rifles.

RESULTS

Goats were observed feeding on poisoned leaves, many bait stations were eaten, and some carcasses were seen beside eaten bait stations. Although no tests were made to determine the cause of death, it was assumed that Compound 1080 poisoning was responsible. Searches of the poison block during poison laying and after revealed 53 dead goats. More were smelt but not found and doubtless other carcasses were not located in the difficult terrain.

In the hunted block, 112 goats were shot out of only 127 seen by the hunters (Table 1). An additional eight goats were shot during these periods in the hunted block on wet days or when no "official" hunting took place.

Goat Population Densities

Faecal pellet counts: The initial densities of faecal pellets varied between the three blocks, from 13.9 ± 5.2 pellets/m^2 in the poisoned block to 7.2 ± 2.9 pellets/m^2 in the hunted block and 6.2 ± 1.9 pellets/m^2 in the control block (Fig. 2a). The two sets of post-treatment pellet-recruitment measurements, made comparable by weighting by the initial densities in the poisoned block and expressed as pellets recruited per 100 days, showed decreases in the index in both treatment blocks compared with the untreated control block (Fig. 2b). The very large probable limits of error (Batcheler 1975) meant that the decrease in pellet density was significant ($p = 0.05$) only for the second of the post-treatment measurements. This measurement represented, on average, a 97% reduction in the poisoned block and a 95% reduction in the hunted block. The difference in pellet densities between the two blocks was not significant ($p = 0.05$).

TABLE 1—Goats killed and effort expended in two hunting forays

Date	No. goats seen	No. goats shot	Man hours	Goats shot/ hour
15.3.82	5	4	2	2.00
16.3.82	41	38	36	1.06
17.3.82	17	13	35	0.37
18.3.82	17	14	38	0.37
19.3.82	8	5	5	1.00
20.3.82	13	11	16	0.69
23.3.82	12	11	40	0.28
14.4.82	0	0	5	0.00
15.4.82	2	2	19	0.11
16.4.82	0	0	10	0.00
17.4.82	3	3	18	0.17
18.4.82	4	3	17	0.18

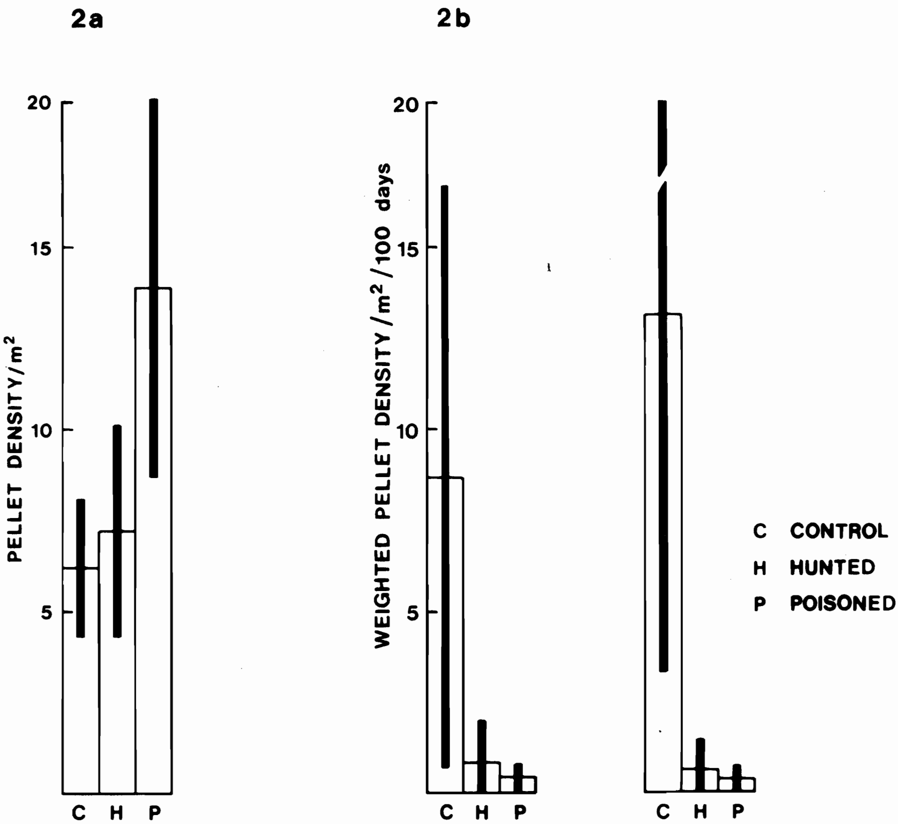

FIG. 2—Initial (late February) density of goat faecal pellets on control, hunted, and poisoned blocks (2a), and weighted density of faecal pellets recruited per 100 days on two post-treatment measurements on the same blocks in mid-April and early July (2b). Bars indicate 95% confidence limits.

The first weighted histogram in Fig. 2b is based on the pellet count 46 days after the first measurement – that is, it includes pellets recruited during the 10–16 days between the initial clearance and the beginning of the poisoning or hunting, as well as the much smaller recruitment during the post-treatment period.

Animal counts: The number of live goats seen per hour-worked each day over the periods before and after the treatments remained similar at averages of 0.44 goats/hour on 7 days before and 0.45 goats/hour on 2 days after the treatment periods in the control block. In the poisoned block, however, the number seen dropped from an average of 0.77 goats/hour on 6 days before the poison was laid, to an average of 0.04 goats/hour on 12 days after the treatment.

The hunted block showed a similar massive decline in the numbers of goats observed from an average of 0.41 goats/hour on 4 days prior to the hunting and 0.47 goats/hour on 11 days during the two hunting periods, down to 0.0 goats/hour on 3 days after hunting ended (Fig. 3).

Longer-term effect: In October 1982 the three blocks were inspected by four hunters and all goats seen were shot. The control block yielded 27 goats as the four hunters passed through on two occasions – no intensive hunting was carried out. The poisoned

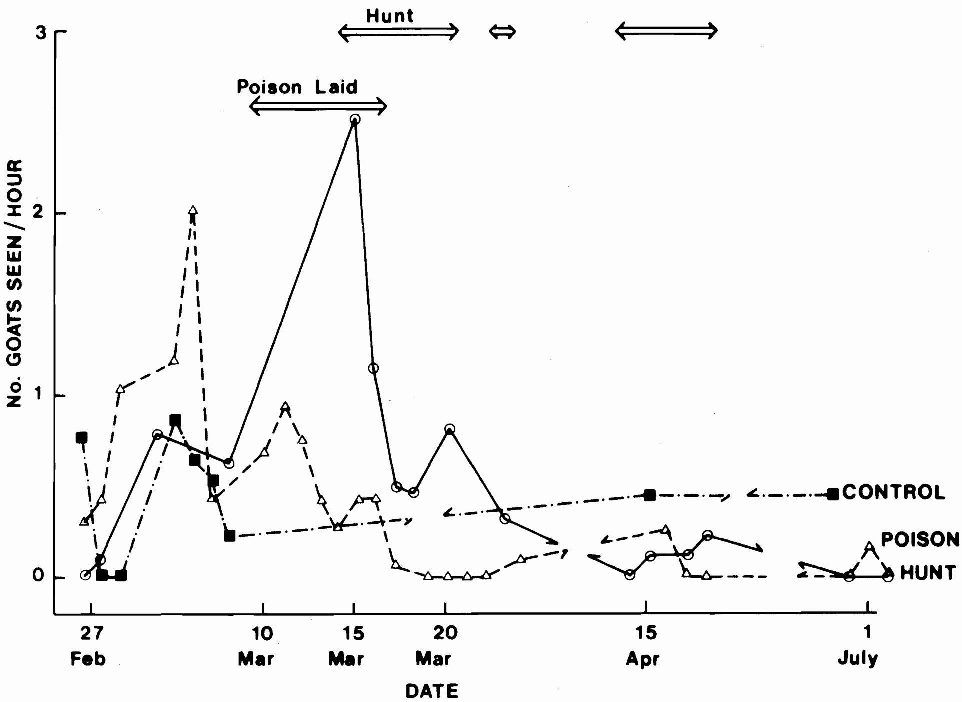

FIG. 3—Changes in the numbers of goats seen per hour each day on the untreated control block (–·–·–), the poisoned block (– – –), and the hunted block (———).

block was hunted by two men for 1 day and five goats were shot; four men in the hunted block for 2 days shot 10 goats.

Bait Acceptance and Durability

Of the 68 marked bait stations, 11% of stations were eaten to some extent on the first day and only another 6% of stations were eaten over the following 5 days. This initial high "take" was fortunate since the toxic gel was an effective phytotoxin, causing either withering and death of the baited leaves, or loss of chlorophyll, and/or abscission within 10 days (Table 2). The 1080 concentration in the toxic gel was checked and found to be 93 ± 1.6 mg/g, i.e., about the specified 10% loading. However, it is likely that the gel was not correctly buffered as laboratory tests on gel remaining in used tubes revealed a pH of only 5 instead of the ideal of between 7 and 8. This acid gel was also extremely viscous, making it difficult to apply, and it had a distinct acetic smell.

TABLE 2—Goat preferences on marked toxic bait stations, and durability for 11 common plant species

Species	No. bait stations	Stations with any leaves eaten after 14 days (%)	"Life" of baited leaves (days)
Melicytus ramiflorus	10	20	6
Schefflera digitata	8	37	6
Coprosma lucida	11	36	10
Coprosma australis	8	37	8
Weinmannia racemosa	7	0	7
Ripogonum scandens	4	0	8
Carpodetus serratus	3	0	6
Geniostoma ligustrifolium	7	0	2
Aristotelia serrata	2	50	9
Ixerba brexioides	6	17	10
Hedycarya arborea	2	0	8

The leaching trial showed that sufficient Compound 1080 remained in the baits to kill goats after 9 days, despite rain falling on days 4 and 5 (Table 3).

DISCUSSION

A high proportion of the goats were killed in both the poisoned and the hunted blocks. Because neither of the two density indices were capable of much precision, it was not possible to say which method was most effective. According to the pellet index poisoning was the best control method but according to the goat count index hunting

TABLE 3—Concentration of Compound 1080 per leaf over 9 days

Date collected	No. leaves*	Compound 1080/leaf (mg)
17.3.82 - day 0	20	27.7
19.3.82 - day 2	20	24.7
21.3.82 - day 4	20	19.9
23.3.82 - day 6	20	12.2
25.3.82 - day 8	15†	16.9

* Five from each of four tree species

† All the **Hedycarya arborea** leaves had dropped; the baited leaves of the other species had lost their chlorophyll.

was. Similar effort was required to lay the poison (56 man days) and to hunt the goats (61 man days), but greater skill is needed to hunt goats – especially as survivors learn the danger man can represent and become exceedingly cunning.

The cost-effectiveness of poisoning could be improved by concentrating on baiting tree species that are both palatable and durable. Much effort was wasted in baiting non-preferred plants (e.g., *Weinmannia racemosa* and *Hedycarya arborea*) or non-durable plants (e.g., *Geniostoma ligustrifolium* A. Cunn.). Concentration of the baits on goat-preferred seral sites would also improve the efficiency of the technique, although some baits may still be needed in other less-favourable forest types to ensure a high kill.

It is likely that areas where goats have severely depleted the vegetation within their browse range will prove the most suitable for this technique. Any highly favoured plants brought down to within goat range will be quickly discovered and devoured.

The tree species baited most successfully in this trial was *Melicytus ramiflorus* which was palatable, moderately durable, common on the more open, seral goat-preferred sites, and had suitable leaves for the application of the Compound 1080 gel.

The best estimate of goat density from the hunted block gave a minimum density of 1 goat/10 ha. An average of 2.5 bait stations/ha was laid in the poisoned block, giving an average of 25 bait stations for each goat, a ratio that may well be lowered with experience.

Neither method of measuring the changes in goat density was particularly satisfactory. The faecal pellet density index is imprecise and it is only because very large changes in density were achieved in this trial that valid conclusions could be drawn from the data. The index of goats seen per hour is also rather variable, partly because of the effects of weather on the observability of goats – they tend to take shelter in wet weather, for example (Riney & Caughley 1959) – and partly because of presumed differences in observer effort caused by the nature of their activity while goats were being noted. For example, field parties were on some days doing faecal pellet transects, on others were laying poison, and on others were actively seeking goats to shoot – the latter activity probably being the cause of the increase in the index in the hunted block during the hunting period.

This trial has demonstrated that several aspects of the poisoning method need improvement or should be noted when control campaigns are being planned. Firstly, the quality of the gel needs to be improved and standardised to ensure that it is not phytotoxic and that it is durable in wet weather. Secondly, the baits need to be distributed throughout the area to be treated and in sufficient numbers to ensure all the goats are potentially at risk. It should also be borne in mind that goats may show seasonal dietary preferences, with obvious consequences for the natural bait poisoning technique.

The technique is a useful alternative or addition to hunting as a goat control method in forested areas, especially in those areas where no control has been attempted and where non-target browsing animals (deer and domestic stock) are or should be absent. A control strategy in an undisturbed area might begin with a Compound 1080 natural bait poisoning campaign and end with a traditional hunting campaign to test the effect of the former and to eliminate as many of the surviving goats as possible.

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The unpublished reports referred to in this paper are N.Z. Forest Service internal reports available from the Forest Research Institute at the author's address. I wish to thank K. G. Tustin, M. L. J. Barnett, C. L. Batcheler, R. E. Lambert, J. L. Bathgate, and G. T. Jane for permission to quote their unpublished material

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