ORIGINAL ARTICLES—

THE USE OF SODIUM FLUOROACETATE (COMPOUND 1080) FOR THE CONTROL OF THE RABBIT IN TASMANIA

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Introduction

The European rabbit (*Oryctolagus cuniculus* (L.)) has been one of the most important single factors limiting agricultural production in Australia. The reduction in rabbit numbers by the virus disease, myxomatosis, which has swept south-eastern Australia since 1950, has demonstrated the increased production possible when rabbit populations are under control; and there is evidence that in one season alone the value of agricultural production has increased by many millions of pounds. There are, however, substantial areas where myxomatosis has not produced a satisfactory control; and furthermore even where its effects have been most pleasing it is necessary to employ conventional methods of destruction to consolidate the gains which have been made. This need has become particularly pressing in the light of the knowledge that the controlling value of myxomatosis is unlikely to be maintained indefinitely.

It is the considered opinion of the Tasmanian authorities that control of the rabbit by poisoning represents the cheapest, quickest and most efficient approach to the problem. If prime reliance was to be placed on poisoning in a State-wide rabbit control campaign, it was necessary to examine critically the methods and materials in current use.

Should an ideal poison exist it would, in the opinion of the authors, be reliable and constant in its effects, odourless and tasteless to the rabbit, and productive of as painless a death as possible and be slow in action so as to minimise bait shyness. It would be selectively toxic to the rabbit and relatively safe to humans, stock, and native fauna, and possess the property of remaining toxic only for a limited period.

No known poison fulfils all these criteria. Strychnine and phosphorus, the two in most common use, fall far short of them. Towards the end of 1950, however, preliminary experiments by the C.S.I.R.O. Wildlife Survey Section (Lazarus 1956) had indicated that sodium fluoroacetate, commonly known in the U.S.A. (where it was established as a valuable rodenticide) as Compound 1080, might prove superior to the "standard" poisons in certain important respects and be suitable for field use.

Work was therefore initiated, both in the laboratory and the field, to confirm and extend the available information on Compound 1080 and to develop practical procedures for its large-scale use under Tasmanian conditions. This paper summarises the results and experience obtained over a three-year period, the first year of which was entirely experimental. Over these three years (1952-54) approximately 320 lb of 1080 have been distributed in the field. At the concentration used, this represents the poisoning of about 16,560 miles of furrow, and the treatment of a substantial part of the rabbit infested country of the State. The work involved has been under the personal direction of officers of the Animal Health Service in the Department of Agriculture.

Properties and Pharmacology of Sodium Fluoroacetate

During the Second World War, as the Allied Armies became involved in areas where the danger of rat-borne diseases was great, research on rodenticides, particularly those which could be readily synthesised, was intensified. Among the substances examined were the fluoroacetates.

Since the synthesis of monofluoroacetic acid by Swarts (1896) little attention was paid to the group until, in the 1940's, Polish chemists reaching England reported the toxicity of the methyl ester of fluoroacetic acid. Under war-time security, work on the fluoroacetates progressed on both sides of the Atlantic and in

1945 Treichler and Ward introduced sodium fluoroacetate ("Compound 1080") as a rodenticide in the United States (Kalmbach 1945).

Marais (1944) in South Africa has established that the toxic principle of the plant "Gifblaar" (*Dichapetalum cymposum*) is monofluoroacetic acid; this is thought to be the first record of a naturally occurring organic fluoride (Chenoweth 1949). Gifblaar is a well recognised hazard of stock.

Commercial sodium monofluoroacetate is a fine white loose powder, odourless, tasteless and very freely soluble in water. It is highly toxic to rodents but much less so to humans and birds, and suffers the disadvantage of being highly toxic also to most domestic mammals—particularly dogs, cats, and sheep (see Table 1). As a safety precaution, the poison, in powder form, is frequently coloured with nigrosine.

Sodium fluoroacetate baits do not lose their toxicity quickly when left to weather in the field. In the absence of rain, baits can remain attractive to stock and dangerous for considerable periods, and even soft bait material such as carrot will withstand the leaching effect of up to half an inch of rain. Bait materials made from boiled whole grain are regarded as particularly dangerous because the poison is presumed to penetrate to the interior of the grain, where it is unlikely to be removed by the leaching effect of rain. The use of grain as bait can, however, be made safer by not boiling when incorporating the poison, as it will then germinate under suitable conditions and its toxicity will diminish.

Despite warnings, at least one fatality attributable to 1080 occurred in a citizen of the United States, and severe restrictions have been placed on its sale and use (National Research Council 1948). Under responsible supervision, however, it is used effectively in the control of rats, mice, prairie dogs, ground squirrels, and coyotes, in a variety of baits and in poisoned water (Ward 1946; Robinson 1948).

Although the poison is not selective in action, it is considered that with the intelligent use of bait material and selection of strengths of mixture, it is possible to employ 1080 for rabbit

TABLE 1.

Sodium Fluoroacetate—Lethal Doses Expressed in Milligrams per Kilo Bodyweight.

A. Minimum Lethal Dose (L.D 100)

Man	5.0 (a)	Horse	5.0 (b)
Rabbit	0.7 (c) 0.8 (d)	Domestic Fowl	14.0 (b)
Sheep	0.45 (c) 0.25-0.5 (g)	English Sparrow	2.7 (b)
Pig	1.0 (e)	Coyotes	0.2 (a)

B. Median Lethal Dose (L.D. 50)

Monkey	5.0-7.5 (b)	Dog	0.1-0.2 (b)
Rabbit	0.3 (f)	Cat	0.3 (b)
Goat	0.7 (b)	Housemouse	8.0-10.0 (b)
Pig	0.3 (b)	Albino Rat	5.0-7.0 (b)
Horse	1.0 (b)	Norway Rat	3.0-7.0 (b)
Fowl	6.0-7.0 (b)	Black Rat	1.0-4.0 (b)

(a) Ward and Spencer (1947).
(b) Insect Control Committee (1946).
(c) Authors.
(d) Lazarus (1956).
(e) Schwarte (1947).
(f) Ward (1946).
(g) Jensen *et al.* (1948).

control in a manner which represents very small risk to animals other than sheep (which must in any case be removed from the area being poisoned), to some native fauna, and to unrestrained dogs which might consume poisoned carcases.

The manner in which sodium fluoroacetate exerts its toxic effect has been thoroughly investigated by Peters (1952, 1954) whose work has shown that the reverse of the normal detoxication of harmful compounds takes place, and that a lethal synthesis occurs within the body. Peters (1952) summarised this as follows:—

> "Though fluoroacetate is not toxic itself to any enzyme it is converted in vivo by the synthetic action of tissue enzymes into a fluorocompound which has a marked enzymic toxicity in vivo as well as in vitro."

This enzymic inhibition affects the cellular metabolism of the animal poisoned. The relatively long delay period between the intake of fluoroacetate and the onset of symptoms is characteristic and probably results from the time required for cellular penetration and for the time necessary for individual cell damage to accumulate and affect the organ as a whole.

Apparently excretion from the body is slow, for over a period of a few days the accumulation of sub-lethal doses may become lethal; a three-day lapse between doses renders this ineffective (Foss 1948). Tolerance built up by sub-lethal doses is only short-lived (48 hours), and could not be produced in the rabbit (Chenoweth 1949).

Species vary widely in the symptoms exhibited. With some the heart is affected (rabbits) and with others the central nervous system (dogs); man, monkeys, cats, and pigs exhibit both symptoms. The symptomalogy recorded in three human cases of which details are available include tingling sensation in mucous membranes which had been in contact with the compound, numbness of the entire face in one case, salivation, spasmodic contractions of voluntary muscles, extreme lethargy, loss of speech, unconsciousness and epileptiform convulsions. No painful effects are recorded.

The poison is slower in its action than the more popularly used strychnine. It enjoys the advantage of not producing obviously painful effects in the rabbit, although immediately prior to death a proportion of poisoned rabbits will squeal. However, when dogs are poisoned with 1080, their behaviour is most distressing. They become extremely excited, frequently howl, and exhibit running fits.

Toxicity to the European Rabbit

As detailed in Table 2, the authors have determined the minimum lethal dose of commercial Compound 1080 for the European rabbit to be 0.7 mg per kilo body weight. This figure was arrived at by the experimental poisoning of wild rabbits which had been held in cages for not less than two weeks until accustomed to captivity. The rabbits were dosed with the appropriate quantity of a solution containing 0.2 mg of 1080 per ml and a stomach tube was utilised to ensure that the experimental animal received the full quantity of the poison. The sample of poison used was a commercial preparation containing 90% of sodium fluoroacetate. This figure of 0.7 mg per kilo as the L.D.100 agrees closely enough with that obtained by Lazarus, and is interesting in view of Ward's (1946) findings of 0.3 mg per kilo for the L.D.50 in the rabbit. The authors have been unable to poison any rabbit with that dosage, but it is possible that Ward was working with a domestic breed.

It will be noted that the time to death varies from one hour to 12½ hours. Massive doses have been observed to reduce this time to 45 minutes in caged rabbits, and field experience indicates

TABLE 2.

Sodium Fluoroacetate—Determination of the Minimum Lethal Dose in the Wild European Rabbit.

Dose rate in mg per kilo	Number of Rabbits	Percentage Mortality	Average time to die in hours
0.5	10	60	12.5
0.6	10	80	11.5
0.7	10	100	8+
0.8	10	100	7.5
0.9	2	100	4.5
1.0	4	100	4
1.1	2	100	4
1.2	2	100	5
2.0	2	100	2
2.5	2	100	2.3
3.0	2	100	2.3
4.0	2	100	2
6.0	2	100	1.5
8.0	2	100	1
10.0	2	100	2
12.0	2	100	1.3
14.0	2	100	1
30.0	1	100	1

that the minimum time may be even shorter than this. Some physiological condition in the rabbit such as alkalosis (Chenoweth *et al.* 1951) may explain this discrepancy.

In the majority of cases the poisoned rabbit was apparently normal up until a few minutes prior to death when it showed convulsive fits. Approximately 20% squealed during the convulsion and death ensued within 2-3 minutes. A small proportion of rabbits passed through a stage of marked lethargy and ataxia culminating in convulsive fits, and death. The authors feel that symptoms of lethargy and ataxia may be associated in the main with the small dose rates, though insufficient cases have been observed to make a conclusive statement.

On post-mortem examination the poisoned rabbit showed evidence of gastritis and generalised venous engorgement, findings which are not considered pathognomonic.

Toxicity to Sheep

Jensen *et al.* (1948) give the minimum lethal dose for sheep as 0.25-0.5 mg/kg. The authors' observations would indicate that the higher figure is the more accurate as doses of 0.4 mg/kg have not been fatal. Doses of 0.5 mg/kg and higher invariably proved fatal.

The symptoms were not diagnostic. A latent period, the duration of which varied with the dose rate, was followed by a state of apprehension during which the pulse rate usually rose to 200-300 per minute. Final recumbency was mainly quiet, but a few short periods of excitement occurred. Death usually occurred during a mild convulsive seizure.

Autopsy did not reveal any pathognomonic features. All gross changes appeared to be related to the increased venous pressure due to ventricular fibrillation. The carcase bloated rapidly and blue discoloration of the skin occurred within a few hours. The subcutaneous fat was pink to red. There was engorgement of the blood vessels in the skin, muscles, heart, stomach and duodenum. The pancreas was congested and pulpy, kidneys showed petechial haemorrhages and were pulpy. The pericardial sac, pleural and peritoneal cavities contained blood stained fluid. Histological examination did not add to this picture.

Shortly after the use of Compound 1080 became widespread in Tasmania there were some mortalities among sheep. As far as possible these mortalities were investigated, and in each case it was found that the losses were due to the owner having failed to carry out the simple precautions which had been recommended. The Department requires the landowner to leave a poisoned area free of stock until all baits have been picked up, covered with soil, or weathered away. The third alternative is adopted mainly in the summer grazing areas of the Central Plateau where the nature of the soil makes the ploughing of a good furrow very difficult and where it is the normal practice to spell the runs for long periods.

Secondary Poisoning

Cases of secondary poisoning of domestic animals have occurred, dogs being the most frequent victims. Deaths among cats and pigs are rarely encountered. It is felt that the risk of secondary poisoning of dogs is the only objection to the use of 1080 that need be seriously considered. Sheep and cattle dogs can be protected by suitable restraint when not working and by the simple expedient of muzzling, but the risk of working hunting dogs on a recently poisoned area is great enough to hamper seriously the "mopping-up" operations which should follow a successful poisoning.

While the risk of secondary poisoning of dogs is very real, in the case of humans it appears that it would be physically impossible to eat sufficient flesh from 1080 poisoned rabbits to ingest a dangerous dose of the poison. Something in the order of 40-50 rabbits, including their viscera, would contain the minimum fatal dose.

Some apprehension has been expressed by stock owners in phosphate deficient areas on the possibility of cattle with pica being poisoned by the consumption or chewing of rabbit carcases following a successful poisoning. Once again it is the authors' opinion that this would be most unlikely, as it would involve the beast consuming the full poison content of at least 20 rabbits if it is assumed that the M.L.D. for cattle is similar to sheep.

Poisoning of Native Fauna

No poisoning operation directed against the rabbit, whatever the poison used, can be free of some risk to native animals occurring in the locality and to which the baits may offer some attraction. However, fears that our wild fauna may suffer heavy casualties as the result of 1080 poisoning have not been substantiated by field observations, except in circumstances where the native animals are themselves present in pest proportions. Occasionally possums and small ground living marsupials, such as bandicoots, have been found dead or dying in the vicinity of rabbit furrows.

Birds in general show a marked tolerance to 1080, although appreciable numbers of both sparrows and starlings have been observed to die from the ingestion of baits prepared for rabbits; and where it is desired to poison either of these species a very effective control has been achieved using 1 oz 1080 to 25 lb of grain.

Wallabies appear to be highly susceptible to the poison, as has been amply demonstrated on Flinders Island where they constitute a pest. A poisoning campaign using bait compounded of 1 oz 1080 to 175 lb carrots, distributed in the conventional furrow after three free feeds, proved most successful.

The authors doubt whether the risk of killing fauna during rabbit control operations can be accepted as a valid objection to poisoning. In the main, areas where rabbits are present in numbers do not provide favourable habitats for native animals likely to be affected.

Accidental Poisoning of Man

Apart from the safeguards taken in handling the poison reference to the table of comparative toxicities and strength of mixture used, will suffice to show that the risk of accidental human poisoning is extremely remote. It is calculated that approximately 350 mg of 1080 would be required to kill an average man weighing 70 kilograms. This amount of poison is contained in approximately ⅓ oz of standard solution for field use or 2 lb of prepared bait. The risk of a person ingesting such quantities of solution or bait is negligible. Table 3 shows that in field preparations of rabbit poisons which are in common use in Australia the risk of accidental poisoning of humans is probably least with Compound 1080 as a much greater quantity of the bait would need to be consumed.

It is the opinion of the authors that accidental poisoning with 1080 is not a serious human hazard except at the stage where the powder is dissolved in water for distribution in the field. The powder is very light and could with insufficient care in handling contaminate the clothing, hands or utensils of the operators in quantities which could be lethal. It is therefore necessary that it be handled only by selected personnel to this stage, and then only in suitable premises.

Mertin (1951) records that over the 10 years in which sodium fluoroacetate has been produced commercially there have been only four recorded cases of poisoning in humans, and of these three recovered. All were associated with the poison in powder form. The first was a United States naval sanitation officer who ingested a quantity of the poison when a gust of wind blew the powder into his face. The accident happened during the preparation of rat baits in the field. He recovered after a period of extreme lethargy lasting six days. The second was a Negro child of five years who licked crystals of 1080 from the top of a bottle of rat poison. He made a clinical recovery over a period of six days. The third was also an American child whose recovery is recorded but no details were given as to the method of ingesting the poison nor clinical syndrome observed. The fourth victim was an American ex-Serviceman who successfully suicided by taking Compound 1080. He succumbed to the effect of the poison in 17 hours.

Method of Use in Field

It should be stated that all supplies of Compound 1080 in Tasmania have, up till the present, been under the control of the Department of Agriculture, and the Department has obtained the poison conditionally on its use being

TABLE 3.

Comparative Toxicity to Man of Rabbit Poisons.

	L.D.100 in mg/kilo	Usual Poison Content of 100 lb. bait	Quantity of Prepared Bait to Kill a Man
Strychnine Alkaloid*	1.0	2½ oz.	1.6 oz.
Arsenic Trioxide	1.5	4 lb.	.09 oz.
Yellow Phosphorus	1	4 oz.	1.0 oz.
Sodium Fluoroacetate	5	⅔ oz.	2 lb.

*These figures are based on Tasmanian practice; concentrations of Strychnine used on the mainland are considerably greater.

controlled and directed by officers of the Department. Similarly the agreement of purchase specified that the compound would not be resold. To enable the field use of the poison, the Department has built up an organization to meet these requirements. In brief, the procedure is that the landholder is required to prepare and free feed a furrow and the Departmental officer, at his request, will mix and lay the poisoned baits. Field officers are never permitted to handle the material in powder form.

In preparing the poison for issue to field officers, a standard solution is obtained by dissolving 1 oz of the poison in 30 oz of water. Specially trained personnel do the mixing for the whole State, and the solution is sent out in strong plastic 3-gallon containers. (Galvanised iron containers were used until it was seen that the solution was strongly corrosive to this material.) Three mixing centres are strategically sited in various parts of the State and these are, as far as possible, draught-proof; they have concrete floors and, of course, ample water is provided for washing purposes. Heavyweight rubber gloves are provided for the operators.

The strength of the mixture for field use was determined following consideration of the amount of water that the bait bases in common use would readily absorb, and the desired concentration of poison in the bait. It has been found in practice that 30 oz of water will be quickly absorbed into 150-175 lb of diced carrot or apple; and 1 oz of 1080 is considered on field experience to give the optimum concentration of poison in that quantity of bait base.

The standard solution simplifies the field officer's work, as his task is simply to sprinkle 4 oz of this solution over one 4-gallon tin of the bait material. In practice this procedure gives a concentration of 1080, ranging from 1 oz in 150 lb to 1 oz in 175 lb of bait base; a variation which does not appear to affect results in the field. The bait base and poison are mixed in galvanised iron vats, the required quantity of poison solution being sprinkled over the bait though a bottle cap of the type used for dampening clothes prior to ironing.

The operation of mixing is performed in a hole in the ground dug for the purpose and in dimension approximately 4 ft. by 3 ft. by 4 in. deep. This hole is subsequently used for the safe disposal of all unused bait, together with the water used for washing the equipment when the poisoning operations are completed.

All equipment used to hold or transport poison bait must be of non-absorbent material; cornsacks should not be used for this purpose.

The accepted method of poisoning is to free feed a furrow until free feed has been taken for three nights. One night without further feeding is allowed so that the remaining free feed is completely eaten; and the poison bait is then laid in the furrow in quantity depending upon the local rabbit population. In practice this varies from 20 lb to 50 lb of bait to the mile of furrow, and is always greater than the amount which would be used under similar conditions with strychnine baits.

Field Experiments

1080 is characteristically a slow-acting poison, and because of this many rabbits die far from the furrow, usually in cover and often in burrows. The difficulty of assessing the efficiency of the kill is thus obvious, since only a proportion of the carcases is viewed during the surface pick-up, and, as yet, there is no accurate method of assessing the pre-poisoning population. As a rough guide it was estimated that one-third of the kill was visible for surface pick-ups, but this obviously varied with the nature of the country, especially the proximity of cover and warrens to the furrow.

In order to obtain accurate figures for the efficiency of 1080, experiments were carried out under natural conditions on rabbit populations confined within netted boundaries. The plan was to poison the selected area using standard procedure and then to dig out all warrens and to account for every rabbit within the fences.

In November 1953, a suitable paddock for this purpose was found at Hollow Tree in Central Tasmania. Eighty-four acres in area, all boundaries were netted and the improved pasture was being well grazed by a substantial resident rabbit population. Most of the burrows were located in sandy alluvium on the western side of the creek, which, running approximately north and south, divided the paddock into two sections. The western portion was flatter and better watered, carrying a richer pasture than the eastern, which rose steeply to a rocky hill in the south-east corner and in the main retained a cover of native plants. The breeding season was at its height with an abundance of high quality green feed available, conditions which had hitherto deterred most people from poisoning at this time of year.

The furrow was not drawn until some days had been spent becoming familiar with the movement pattern of the rabbit population. This aided the siting of the furrow, and also enabled any gross changes in behaviour, due to the poisoning techniques, to be assessed. During this period several deep river bank and sub-fenceline warrens, which would have been difficult to dig out, were fumigated with chloropicrin: the rabbits in these were not included in the final assessment.

On the 15th November, 2.1 miles of furrow were drawn with a mouldboard plough, the average depth being 2½ inches. No bait was laid this night. After five nights' free feeding the furrow was left for one night so that all unpoisoned material would be eaten before the lethal bait was laid (see Table 4). The bait was available to the rabbits for three nights before it was picked up.

Carrot was used on the western section and on part of the eastern, the rest of the latter being baited with apple for comparative purposes. The take of apple was disappointing.

A total of 1,064 rabbits were recovered after three days' digging and dogging. Corpses were sexed and weighed as recovered. Fig. I shows the composition of the population and distribution of the kill. Six hundred and fifty-eight rabbits were recovered dead, which must be regarded as a very conservative indication of the kill, since only 21 of the 120 suckling kittens were dead when dug out, and 88% of the breeding does were poisoned. Many of the kittens were obviously unfed and would have died, so that a truer picture is obtained if the figure of 88% kill is applied to this wholly dependent age group. This increases the total kill from 63 to 70%.

The numbers of rabbits, dead and alive, recovered from the different warrens are set out in Table 5. Having regard to the rabbit's habit of avoiding unfamiliar burrows, and their restricted feeding movements at the time of the experiment, with a flush of pasture available, it seems reasonable to assume that both the dead and alive rabbits were normally inhabiting the warren in which they were found. Surface corpses were only attributed to a particular warren if picked up on or very close to it. It will be seen from the Table that the percentage kill varied markedly from warren to warren. This can be explained in part by variation in the warren-furrow relationship, and in part by the difference in age structure of the different warren colonies which would affect the pattern of feeding movements of their constituent individuals.

It is clear from Fig. I that the majority of survivors were in the lowest two weight groups, and using Southern's (1940) regression formula this gives their ages as 0-3, and 3-5 weeks respectively. Rabbits at this age are at least partially dependent on the maternal milk supply and have been observed to keep close to the burrow mouth, so that few would have reached the furrow as it was drawn. Besides this restricted feeding range, it is also possible that bait attractive to older rabbits is less so to kittens on a part milk diet and with juvenile dentition.

A second experiment was run at Tullochgorum, North-east Tasmania, in April 1954. The 50 acre paddock selected was chiefly sandy

TABLE 4.

Hollow Tree Experiment—Poisoning Procedure.

Date	Carrot lb.	Apple lb.	Remarks
Nov. 15	—	—	Furrow drawn—left empty
„ 16	47	28	Little free feed taken
„ 17	25	21	——
„ 18	36	26	Carrot-take excellent; Apple poor
„ 19	79	30	Carrot-take excellent
„ 20	123	48	Carrot-take excellent
„ 21	—	—	No additional free feed laid
„ 22-24	97	50	Poisoned with 1080

TABLE 5.

Hollow Tree Experiment—Warren Analysis.

Warren	Population	Dead				Per cent. Killed	Alive Total
		Location*			Total		
		1	2	3			
A	327	28	47	136	211	65%	116
B	74	2	8	31	41	55%	33
C_2	96	9	14	52	75	78%	21
C_3	35	—	4	27	31	89%	4
C_4	6	—	—	6	6	100%	—
D	10	—	—	9	9	90%	1
E_1	20	4	4	11	19	95%	1
E_2	17	1	2	7	10	59%	7
F	28	3	4	20	27	96%	1
G	27	—	2	15	17	63%	10
H	33	2	2	13	17	52%	16
I	51	2	6	21	29	57%	22
K	21	1	—	17	18	86%	3
L	75	4	7	27	38	51%	37
Total	820	51	93	392	548	—	272

*Locations: 1 = surface corpses.
2 = burrowmouth corpses.
3 = corpses deep in warren.
(Rabbits in locations 1 and 2 were retrieved with out digging.)

alluvium carrying improved pasture which was dry after the summer. Two and one half miles of furrow were drawn, covering the area thoroughly; and the bait was scattered around, rather than in, the furrow to avoid covering the sticky (apple) bait with sand. The poisoning procedure followed is set out in Table 6.

TABLE 6.
Tullochgorum Experiment—Poisoning Procedure.

Date	Weight of bait laid lb.	Remarks
April 1	81	Poor take
„ 2	81	Take still poor
„ 3	81	Take patchy and poor
„ 4	10	Cleaned up free feed
„ 5	108	Poisoned with 1080

Under conditions very much more favourable than those of the Hollow Tree Experiment a spectacularly good kill was achieved. Of the 203 rabbits recovered after thorough digging, only nine were alive. Four of the nine survivors were less than half grown and furthermore were the only rabbits of this weight in the population, which had just started breeding after the summer.

TABLE 7.

Location of Rabbit Corpses.

Place	Number of Rabbits			Per cent. picked up
	Picked up	Dug out	Total	
Hollow Tree	217	441	658	33%
Tullochgorum	107	87	194	55%

FIGURE 1

POPULATION COMPOSITION & DISTRIBUTION OF KILL IN TWO EXPERIMENTS

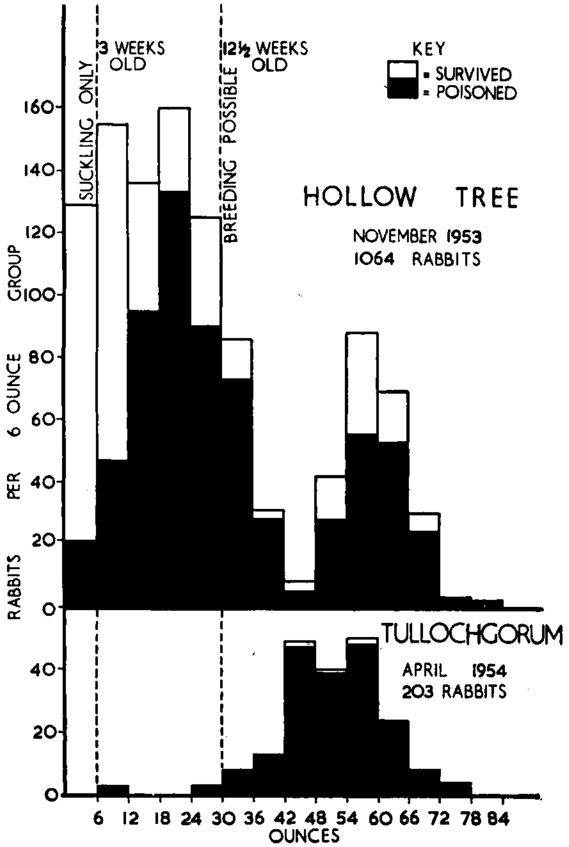

Fig. I gives the composition of the Hollow Tree and Tullochgorum populations for comparison. Table 7 shows the location of corpses in both experiments. The percentage that can be picked up from the surface or in burrow mouths after a 1080 poisoning clearly varies with the local conditions, as was to be expected.

The success of the kill at Tullochgorum was mainly attributable to the more mature population and to the available natural feed being so dry. The latter was reflected in the far greater weight of free feed and poisoned bait consumed (per capita) than at Hollow Tree. In both cases the amount laid was in relation to the previous day's "take," so that a surplus was always available, except on the night before poisoning.

The results of the experiments described show that kills of very high efficiency can be obtained at the optimum season providing sufficient care is given to furrow placement and free feeding. Furthermore, better kills than have previously been considered possible can be made at the most difficult time of the year, namely the breeding season, amidst ample feed.

Discussion

The work described in this paper suggests that 1080 will establish itself as the foremost rabbit poison in Australia; and recent developments in several States indicate that this may be brought about fairly rapidly. Although in general use in Tasmania for only three years, 1080 has already eclipsed all the older poisons. Strychnine and phosphorised pollard are now used only occasionally; and the once familiar poison cart is seldom seen, and if encountered it has generally been adapted to run furrows through the more difficult country of the central highlands in preparation for the laying of 1080 baits.

In contrast with the eastern mainland States, myxomatosis has not, until the last of the three seasons referred to in this paper, proved of any significance in Tasmania as a factor in rabbit control. The disease still continues to be ineffective in the highlands, though in areas of lesser altitude it has now established itself widely and is performing very satisfactorily, even where the rabbit population is very light. The effectiveness of the 1080 poisoning campaign was obvious before myxomatosis made its belated start, for rabbit numbers had been reduced to a lower level than they had ever been since the animal assumed pest proportions.

In the operation of a large-scale, practical poisoning scheme it is impossible to check, quantitatively, the results of individual trails as they are laid; but we were confident that anything of greater significance than the occasional incidental failure would soon become manifest. It can be stated quite definitely that the overall results of the 1080 campaign have fully confirmed the promise of the early experiments.

While there is no doubt that under most circumstances rabbit poisoning with 1080 is economically sound and justified, there are considerable areas in Tasmania (mostly represented by summer grazing country over 2,000 ft in altitude) where difficulties of terrain combined with low per-acre value increase the cost of running a furrow and raise doubt as to the economic justification of 1080 poisoning as at present practised. There is unquestionably a need for further work aimed at adapting poisoning techniques to this type of country.

One of the most difficult problems facing the authorities in Tasmania was to convince all those concerned that a prerequisite to success in any rabbit control scheme was an acceptance of the principle that the rabbit is a pest, and must be regarded only as a pest, and that any temporary or local relaxation of effort in consideration of the commercial value of rabbit products would weaken and endanger the campaign as a whole.

Since the inception of the Tasmanian Scheme, the attitude to rabbit control has altered very materially. The vermin inspector is now almost always welcomed on properties, and the administration no longer lacks the encouragement and co-operation so necessary to success. Before 1950 the average landholder's experience in the effectiveness of control measures was not encouraging due, in our opinion, mainly to an erroneous belief in the value of trapping, inefficient poisons and poisoning methods, a lack of simultaneous action throughout a district, and a lack of netting fences to minimise re-infestation. The widespread use of 1080 under departmental direction has very largely overcome these difficulties.

It was common practice for landholders in Tasmania to employ their staff on routine farm duties for part of the year only, and to allow them to trap rabbits and dispose of the carcases and skins on their own account during the balance of the year, a practice which in normal seasons was very remunerative. Such a procedure inevitably leads to the "farming" of rabbits and the conservation of the "breeding stock;" and the population is only seriously attacked during those months of the year when their skins are of greatest value and after they have made serious inroads into the feed needed by farm livestock during the winter.

Poisoning was also carried out mainly during the winter months, to take advantage of the higher skin values; though it must have been obvious that summer poisoning was more efficient and also desirable for the protection of the winter feed. Because of the importance, in the eyes of farm and station employees, of recovering the skins for subsequent sale, strychnine became established as the favoured poison even though there were increasing reports of its unreliability. Phosphorus, which might have provided a useful alternative to strychnine under certain conditions, was particularly unpopular with farm hands because it kills slowly and renders the picking up and skinning of carcases impracticable.

For a poisoning operation to be effective, the furrow must be carefully sited in relation to the rabbits' movement pattern and the free-feeding routine must be conscientiously followed. While many, if not the majority, of Tasmanian farmers needed no instruction on these matters, the availability of departmental staff to advise on, and if necessary supervise, the placement of furrows and free-feeding procedure undoubtedly raised the general level of poisoning efficiency to a uniformly high standard; and has probably constituted one of the most important factors in the success of the campaign.

The speed at which rabbits can re-colonise areas from which they have been cleared, unless prevented by netting fences, is well known. Unless there are sufficient netting fences in an area to deal with this problem, a control campaign to be effective must obviously be organised on a district basis, with the responsible authority closely supervising the work to ensure adequate co-ordination of operations. Effective control has been achieved in many districts of Tasmania in this way, using 1080 poisoning, without recourse to netting fencing. If it is found over the next few years that this situation can be maintained, relying mainly on the cheapest known method of control, namely poisoning, a substantial increase in the use of netting could be avoided. The cost of the erection and maintenance of rabbit-proof fences being what it is, the resultant saving to the community would be very substantial.

For an all-the-year-round poison like 1080, the provision of a rotation of bait bases can be quite a problem. The Department encourages the production of special crops for this purpose, and many landholders now grow carrots and turnips for rabbit bait. It is likely that apples will always be the main bait in Tasmania, but they are plentiful only from March until August, and the period of bait shortage can be reduced considerably by the use of turnips and carrots. For its own poisoning teams, the Department has been able to maintain a continuous supply of bait by using cool-stored carrots between October and January. Although carrot seems to be the most satisfactory bait under normal Tasmanian conditions, good results can be obtained with a wide variety of materials.

The success that has been attained under the Tasmanian scheme is basically attributable to the ability of the Department of Agriculture to provide an adequate team of officers competent to advise on the details of poisoning methods, and available to poison furrows with 1080 at landholders' requests. The Vermin Destruction Section of the Department is staffed with a senior inspector and 16 district inspectors. In addition three mobile teams each of two men are employed, their function being to destroy rabbits on crown lands, and on private properties when land holders seek official assistance, or when compulsory entry is necessary due to a failure on the part of the owner to comply with the provisions of the Vermin Destruction Act of 1950. These teams are virtually self-supporting.

The 16 district inspectors are responsible for a total area of approximately 6½ million acres, comprising over 11,000 holdings. In the early days of the campaign it was found that inspectors were often hard-pressed to meet the demands on their services in the distribution of 1080; but more recently, with the marked reduction in rabbit numbers, they have experienced little difficulty in covering their districts.

When the Tasmanian scheme first got under way, the inspectors' main duties were to determine the location of infested areas, and to instruct and encourage landholders to take effective action for the destruction of the pest. During the last two years of the period covered by this paper, the inspectors' time was mainly spent in supervising poisoning operations. At the time of writing it is considered that the balance between inspectorial duties and the active participation in poisoning is very satisfactory, except at the height of summer when some casual assistance is desirable to cover demands from landholders.

Rabbit control methods have been evolved over a long period mainly as a result of observation and experimentation by practical-minded landholders, and it is only in recent years that they have received any real measure of scientific scrutiny. This is rather remarkable when one considers the damage which the pest causes; and it is obvious that the progress attained in recent years with newer weapons should encourage a more detailed survey of the techniques involved. Ample opportunity exists for further work on all aspects of the problem in an endeavour to minimize the costs involved in attaining a reasonable measure of control; and no doubt, *inter alia*, the search for newer poisons and better poisoning methods will continue.

Fluoroacetamide, a compound closely related to 1080, has been given some preliminary tests in Tasmania, and the results indicate that it may prove to be a very useful poison. It is much slower in action than 1080, 30 mg/kilo of 1080 killing a rabbit in 45 minutes, whereas 40 mg/kilo of fluoroacetamide kills in approximately 2½ hours. This slow action should be a valuable characteristic, as a large number of rabbits will have time to feed on a furrow before symptoms develop among the first arrivals, producing a scaring effect. Recent trials appear to substantiate this hypothesis, as fluoroacetamide baits have been taken more readily than 1080 ones, although palatability tests have not shown any preference for one over the other.

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