EVALUATING OPOSSUM POISONING OPERATIONS BY INTERFERENCE WITH NON-TOXIC BAITS

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SUMMARY: From eight trials made during 1967–69 a technique was developed for estimating the reduction, by poisoning, of opossums (*Trichosurus vulpecula*) from the extent of interference with non-toxic flour-paste baits. The model assumes that opossums do not, through experience and learning, search for other baits close by.

The trial data showed that contagion, an increase in levels of bait interference from night to night and very high acceptance levels were a consequence of baits having been preferentially placed on open ridges and spaced too closely.

Manipulation of baits on randomly-located lines showed that if baits were spaced 40 yards apart and lines were at least 200 yards apart there was little evidence of contagion.

Procedures are given for using interference levels from poisoned areas and untreated control areas to estimate kills.

INTRODUCTION

Aerial sowing of bait poisoned with "1080" (*Sodium monofluoroacetate*) is widely accepted as the most efficient means of controlling Australian opossums (*Trichosurus vulpecula*) over large areas of forest.

The effects of this technique can be analysed into two parts: (a) the immediate reduction in population density following poisoning, and (b) the long-term effects of changes imposed on population dynamics. Successful analysis of the latter requires a knowledge of the rate of population increase at the time of poisoning and the subsequent effect of poisoning on fecundity and mortality rates. However, the relative merits of different control techniques can be judged more simply by the percentage reduction in animal density after poisoning.

Techniques for estimating the relative abundance of mammalian populations are numerous. Either they require field techniques which are too laborious or difficult for quick estimates, or they are too crude to detect anything but large changes in density.

Frequency of capture of opossums in traps has often been used in New Zealand as a means of estimating population trends in forest areas and assessing the relative decline in density obtained after poisoning. Batcheler, *et al.* (1967) have recently shown how trap counts of opossums may be used as estimators of density but concede that the technique induces changes by reducing the population. When successive estimates are made from the same trap-line in a relatively short period, the results may be viewed with some suspicion.

An alternative method which depends upon measurement of relative levels of interference with a series of non-toxic flour-paste baits is now suggested in this paper.

THE MODEL

It is not possible to tell how many opossums interfere with any one bait on any given night. The situation is analagous to the use of sample plots for estimating the density of entities by recording only their presence or absence.

Although the mean number of entities per plot cannot be found by counting, it is possible, provided they are randomly distributed, to estimate their density from the first term of the Poisson series:

$$m - c/m = e^{-x}$$

(Where m = number of plots,
c = number of plots containing entities,
x = mean number of entities per plot,
and e = base of Naperian logarithms.)

and

$$x = 1/\log_e (m - c/m)$$
$$= 1/\log_e (m - c) - \log_e m$$
$$= \log_{10} m - \log_{10} (m - c) \log_{10} e \quad \text{(i)}$$
$$= \log_e (m/m - c) \quad \text{(ii)}$$

Thus, by using the frequency of plots containing zero entities it possible to calculate the mean number of entities per plot encountered over the whole sample. Equation (i) is that presented by Dice (1952) and (ii) is that presented by Batcheler, *et al.* (1967) for estimating the relative density of opossums from trap counts.

The application of this model for the estimation of the mean number of interferences per bait requires the assumption that baits are being interfered with at random.

EARLY FIELD TRIALS

Trials using the level of interferences with non-toxic baits to obtain an index of density change were made during aerial poison campaigns against opossums organised by the N.Z. Forest Service in the Styx Valley in 1967 and the Taipo and Taramakau Valleys in 1968.

Heavy rain following the sowing of poisoned carrots in the Styx Valley made it necessary to repeat the operation a few weeks later. In 1968 the Taipo and Taramakau areas were each divided into three blocks: a control, one which was sown with poisoned carrots and one which was sown with a poisoned manufactured hard pellet.

In each poisoned area five bait lines were established, the location of those in the Styx Valley being chosen subjectively and those in the Taipo and Taramakau by stratified randomisation. To avoid the complications caused by changes in the levels of interference with baits resulting from differences in weather, unpoisoned control areas were also baited at the same time. Baits made from flour paste were placed directly on opossum runs at approximately 20-yard intervals along the

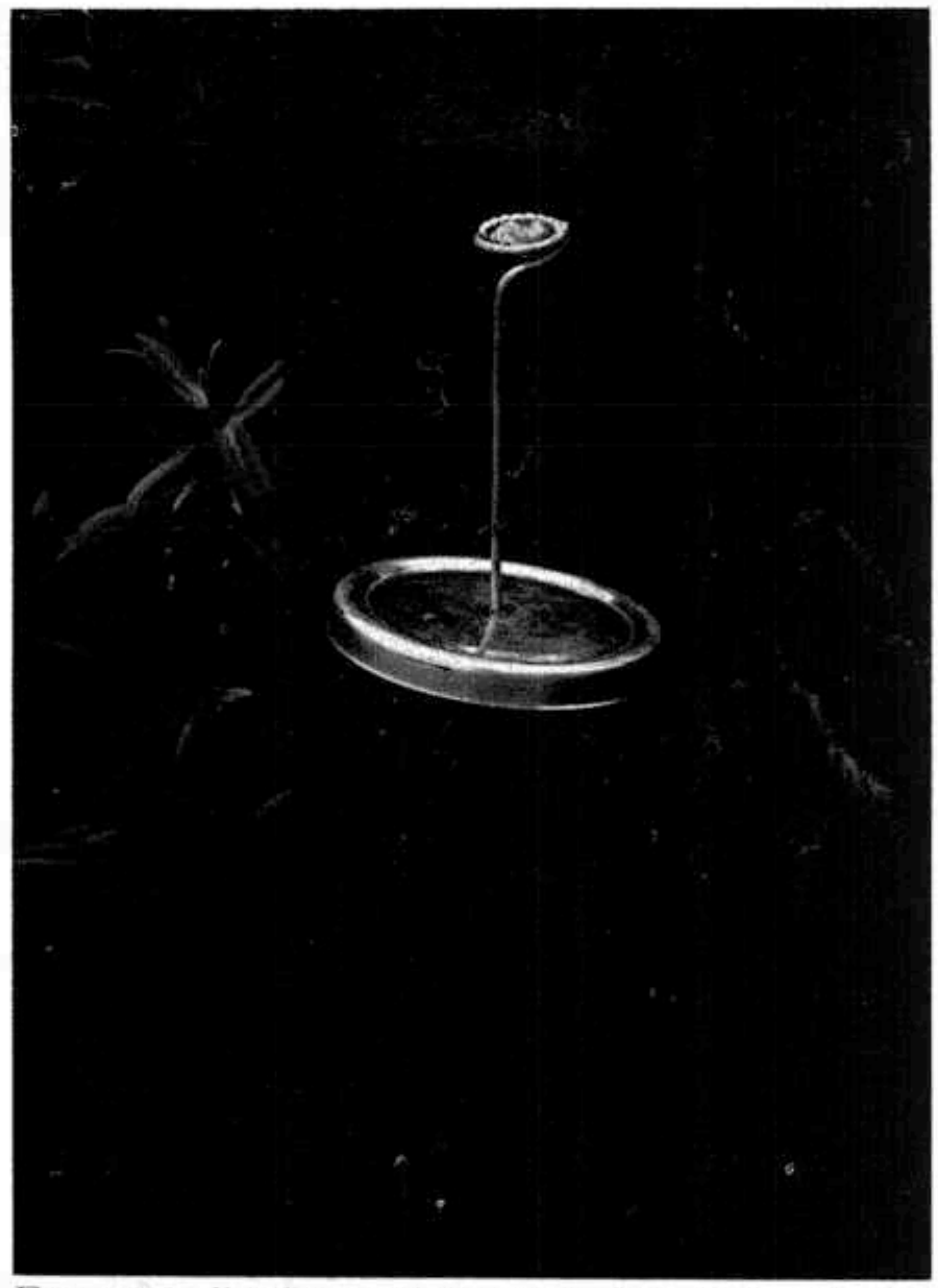

FIGURE 1. *Device used for excluding rats and mice from the flour-paste bait which is applied in the small cap at the top. Extensive trials with starved white rats proved the shield to be 100% effective.* [Photo: P. F. Boswell]

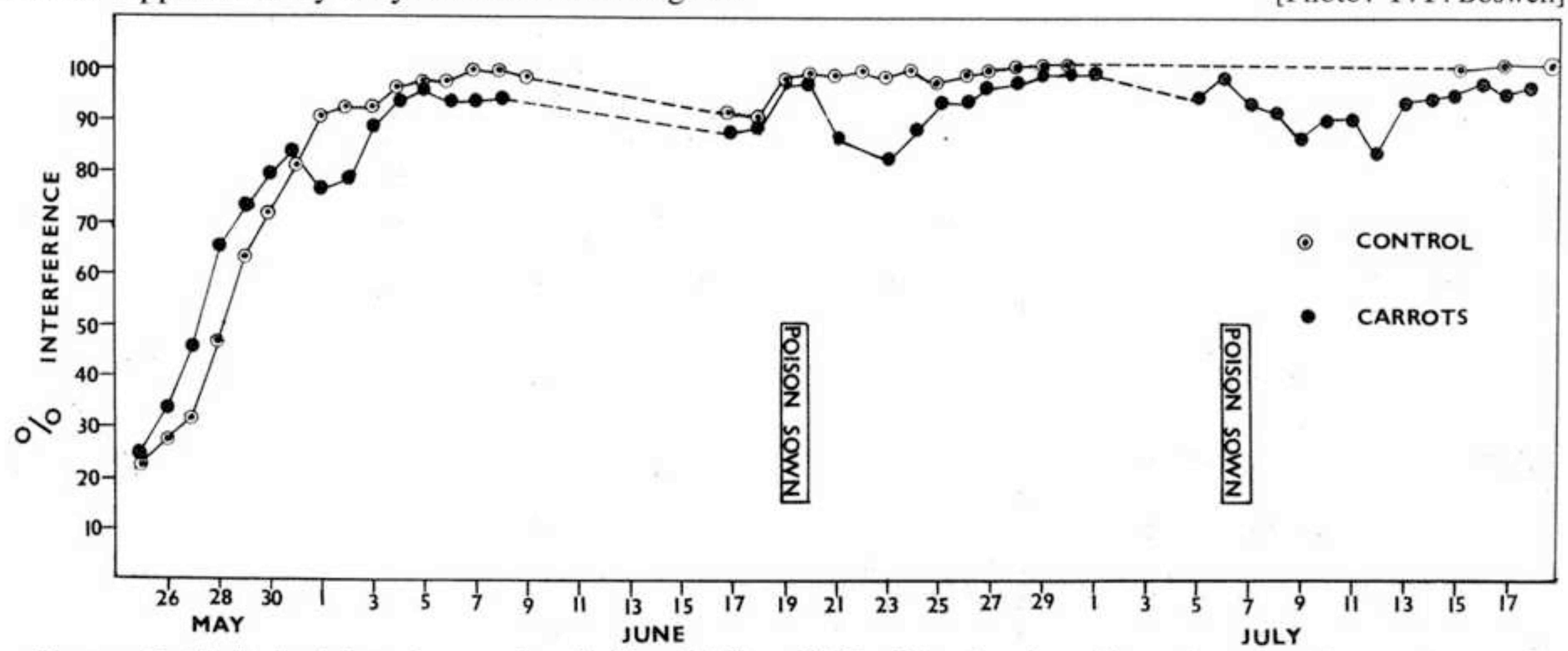

FIGURE 2. *Daily bait interference levels, Styx Valley 1967. The broken line denotes days when no baiting was carried out either because of heavy rain or manpower shortages.*

lines established in the Styx, but there were problems of interference by rats and mice. A device to exclude these animals was used in all subsequent trials (Fig. 1). Each line was visited daily to record interferences and to set fresh baits.

An immediate decline in the levels of interference from those which had been reached by baiting at least seven days previously was recorded in the poisoned areas. This was followed 3–5 days later by an increase which continued until the pre-poison level had been reached. As this pattern was consistent in all poisoned areas and did not occur in the controls it was assumed the drop in interference levels was attributable to death of some members of the populations (Figs. 2–4).

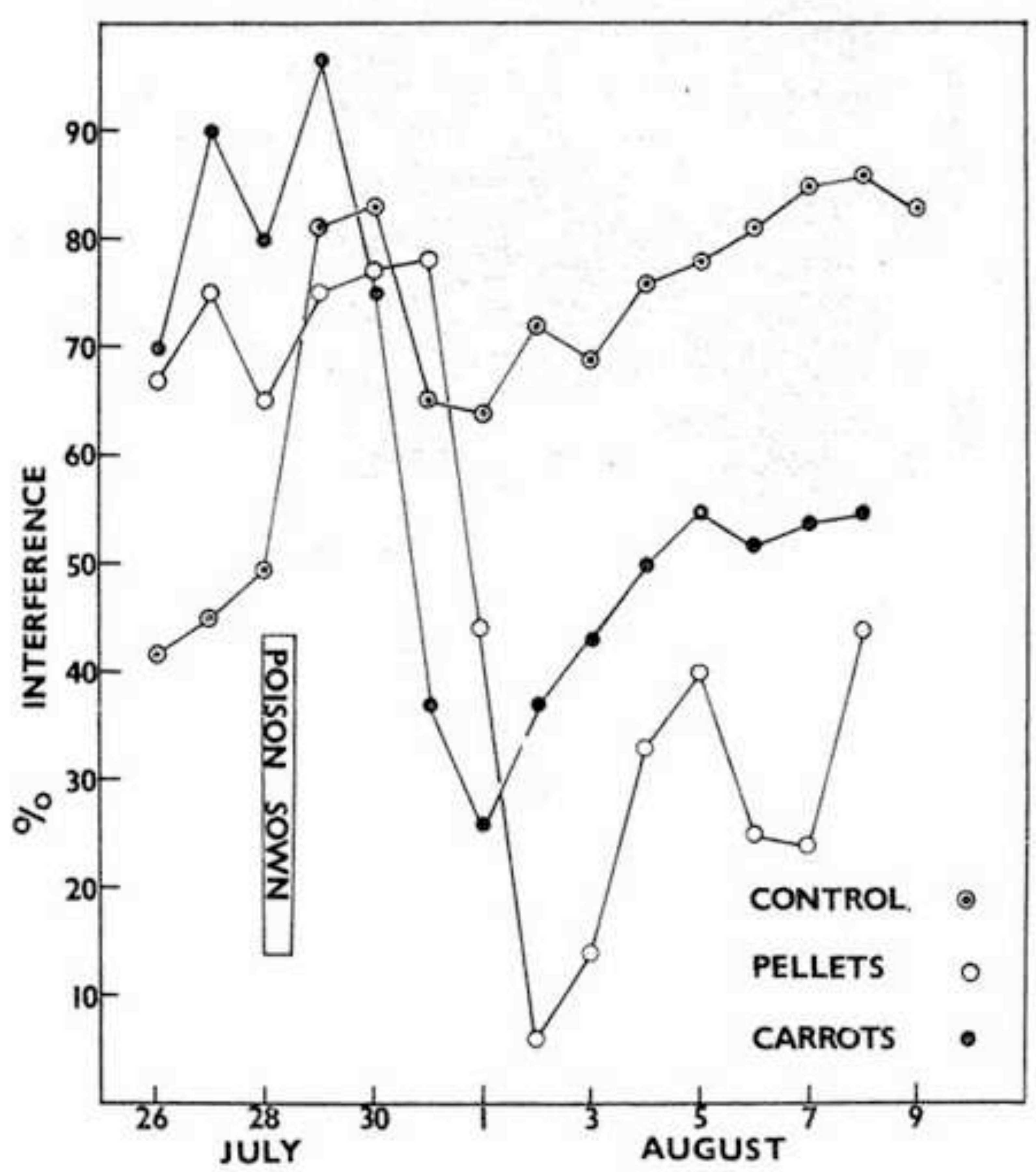

FIGURE 3. *Daily bait interference levels, Taramakau Valley, 1968.*

A model based on the maximum fall in interference levels appeared to be valid for determining declines in relative density, if it were assumed that poison killed the same proportion of animals interfering with baits as those distributed throughout the poisoned areas. To assess the proportion of animals which succumbed to each of the poisonings the following procedure was adopted.

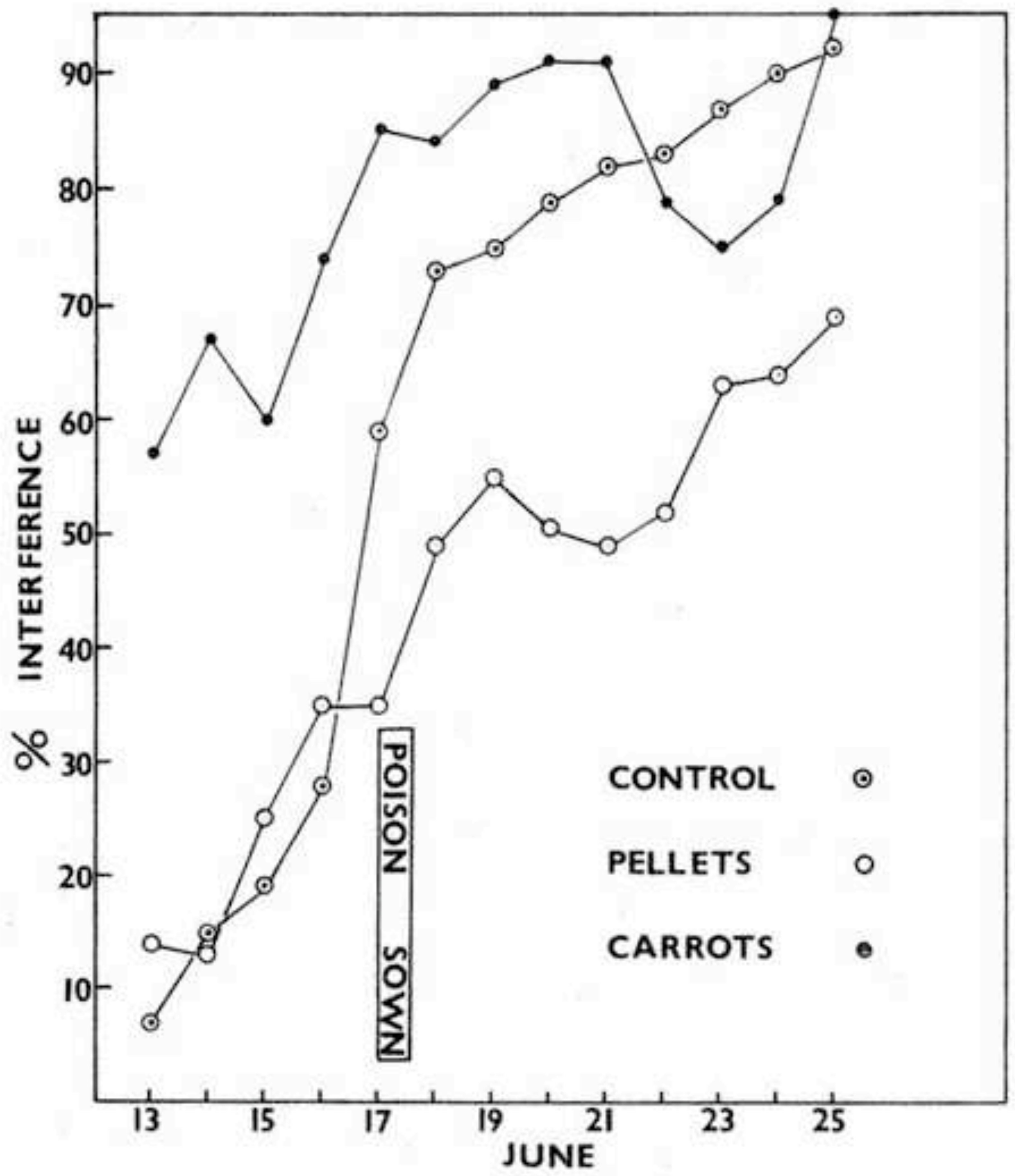

FIGURE 4. *Daily bait interference levels, Taipo Valley, 1968.*

From the day of poisoning all interference levels were treated with the transformation,

$$\log (m/m-c).$$

From the respective untreated controls the relative change in transformed interference levels was recorded from day to day and the change noted in these levels relative to the change on the day of poisoning. From these ratios the expected transformations were calculated on the supposition that there had been no poisoning. The differences between the expected values and those measured were presumed to be directly associated with the decline in the number of animals visiting baits from day to day.

In the Styx Valley the control area was not sampled at the time of the second poisoning because of shortage of staff and a constant value for the expected level of interference of 98% has been assumed.

This value was interpolated between the two successive sets of baiting conducted on the control area (See Fig. 2).

TABLE 1. *Transformation of interference levels, Styx Valley, first poisoning.*

	CONTROL			POISONED			
Date (i)	% Interference (ii)	Log (m/m–c) (iii)	Ratio of (iii) to that at 19th (iv)	% Interference (v)	Log (m/m–c) (vi)	Theoretical value assuming no poisoning from (iv) (vii)	Deviation from expected (vii–vi) (viii)
19 (June)	97	1.53	1.0	97	1.53	1.53	0
20	99	2.01	1.31	96	1.42	2.01	0.59
21	98	1.70	1.11	90	1.00	1.70	0.70
22	99	2.01	1.31	87	0.89	2.01	1.12
23	98	1.70	1.11	85	0.82	1.70	0.88
24	99	2.01	1.31	83	0.78	2.01	1.23*
25	97	1.53	1.0	91	1.05	1.53	0.48
26	98	1.70	1.11	95	1.31	1.70	0.39
27	99	2.01	1.31	93	1.16	2.01	0.85

* Denotes maximum deviation.

The maximum decline in interference with baits was accepted as indicating relative kill and was used to calculate the percentage reduction in density. In the Styx Valley its value for the first poisoning was 100 (1.23/2.01) = 61 and for the second poisoning, 100 (0.96/1.70) = 57. The overall reduction in density obtained in the Styx was therefore 83%. In the Taramakau Valley the reduction caused by poisoning with pellets was 100 (0.56/0.68) = 82% and by poisoning with carrots, 100 (1.45/1.80) = 75%. In the Taipo Valley poisoning success was not so marked, being 100 (0.08/0.36) = 21% with pellets and 100 (1.37/2.05) = 67% with carrots. Tables 1–4 summarise density determinations from relative levels of interference with bait.

Results obtained from the preliminary trial made in the Styx may be artificially high because bait-lines ran along well formed ridges where the vegetation was much more open and opossums tended to congregate. Furthermore, baits were placed directly on runs with no device to exclude the unknown number of rats and mice which were interfering with baits.

TABLE 2. *Transformation of interference levels, Styx Valley, second poisoning.*

Date (i)	% Interference poisoned area (ii)	Assumed control % interference (iii)	Log (m/m–c) of (ii) (iv)	Log (m/m–c) of (iii) (v)	Deviation from expected. (v–vi) (vi)
6 (July)	98	98	1.70	1.70	0
7	89	98	0.96	1.70	0.74
8	91	98	1.05	1.70	0.65
9	86	98	0.86	1.70	0.84
10	90	98	1.00	1.70	0.70
11	90	98	1.00	1.70	0.70
12	82	98	0.74	1.70	0.96*
13	94	98	1.23	1.70	0.47
14	93	98	1.16	1.70	0.54
15	95	98	1.31	1.70	0.39
16	97	98	1.53	1.70	0.17

* Denotes maximum deviation.

EVIDENCE OF CONTAGIOUS EFFECTS WITHIN BAIT-LINES

Because the level of interference with baits increased steadily from the time they were first placed, and because they increased again after the decline caused by poisoning, it was clear that opossums were learning the pattern of baiting

TABLE 3. *Transformation of interference levels, Taramakau Valley, 1968.*

	CONTROL			POISONED WITH PELLETS				POISONED WITH CARROTS			
Date (i)	% Interference (ii)	Log (m/m–c) (iii)	Ratio (iii) / that at 17th (iv)	% Interference (v)	Log (m/m–c) (vi)	Value assuming no poisoning from (iv) (vii)	Deviation (vii–vi) (viii)	% Interference (ix)	Log (m/m–c) (x)	Value assuming no poisoning from (iv) (xi)	Deviation (xi–x) (xii)
29 (July)	81	0.72	1.00	75	0.60	0.60	0	97	1.52	1.52	0
30	83	0.77	1.07	77	0.65	0.64	0.01	75	0.60	1.62	0.02
31	65	0.46	0.63	78	0.66	0.38	0.28	37	0.20	0.96	0.76
1 (Aug.)	64	0.44	0.61	44	0.25	0.37	0.12	26	0.13	0.94	0.81
2	72	0.55	0.77	6	0.03	0.46	0.43	37	0.20	1.17	0.97
3	69	0.51	0.71	14	0.07	0.42	0.35	43	0.24	1.07	0.83
4	76	0.62	0.86	33	0.18	0.51	0.33	50	0.70	1.31	0.61
5	78	0.66	0.91	40	0.22	0.55	0.33	55	0.35	1.39	1.04
6	81	0.72	1.00	25	0.13	0.60	0.47	52	0.32	1.52	1.20
7	85	0.82	1.14	24	0.12	0.68	0.56*	54	0.34	1.74	1.40
8	86	0.85	1.18	44	0.25	0.71	0.46	55	0.35	1.80	1.45*

* Denotes maximum deviation.

TABLE 4. *Transformation of interference levels, Taipo Valley, 1968.*

	CONTROL			POISONED WITH PELLETS				POISONED WITH CARROTS			
Date (i)	% Interference (ii)	Log (m/m–c) (iii)	Ratio (iii) / that at 29th (iv)	% Interference (v)	Log (m/m–c) (vi)	Value assuming no poisoning from (iv) (vii)	Deviation (vii–vi) (viii)	% Interference (ix)	Log (m/m–c) (x)	Value assuming no poisoning from (iv) (xi)	Deviation (xi–x) (xii)
17 (June)	59	0.39	1.00	35	0.19	0.19	0	85	0.80	0.80	0
18	73	0.57	1.47	49	0.29	0.27	0.02	84	0.79	1.17	0.38
19	75	0.60	1.56	55	0.35	0.29	0.06	89	0.96	1.24	0.28
20	79	0.68	1.75	51	0.31	0.33	0.02	91	1.05	1.39	0.34
21	82	0.74	1.92	49	0.28	0.36	0.08*	91	1.05	1.53	0.48
22	83	0.77	1.99	52	0.32	0.37	0.05	79	0.68	1.58	0.90
23	87	0.89	2.28	63	0.43	0.43	0	75	0.60	1.82	1.22
24	90	1.00	2.58	64	0.44	0.48	0.04	79	0.68	2.05	1.37*
25	92	1.10	2.83	69	0.51	0.53	0.02	95	1.31	2.24	0.93

* Denotes maximum deviation.

from day to day. The placing of bait-lines up open ridges contributed to this in the Styx trial by enabling opossums to be guided from station to station. In the Taramakau and Taipo trials, lines were located by stratified randomisation and ended along predetermined compass bearings to avoid the possibility of unconsciously choosing sites which would be favourable for opossums.

To identify whether baits were taken randomly or not, bait stations in the 1968 trials were set in groups of threes or twos or singly. The distance between baits in each group was five yards and between groups 20 yards (Fig. 5). A method similar to that adopted by Leslie and Davis (1939) was used to determine whether the frequency of interference in all groups of three stations followed a Poisson distribution, as this would indicate a random pattern of interference. Although it was known that levels of interference were increasing steadily from night to night, it was necessary to decide whether this arose from a summation of random encounters, each being remembered from previous nights, or whether the level of interference was increasing because animals were actively searching. The expected Poisson distribution was calculated for each of the trial areas in both the Taramakau and Taipo from night to night and the observed values tested by chi-square: The probability that the observed distribution differed from the expected Poisson distribution was derived from the tables of Fisher and Yates (1963). Results shown in Table 5 indicate clearly that, for the first 3–5 days of baiting, interference levels were the result of random encounters, but that after that time opossums began searching for baits and continued to do so until maximum levels were reached.

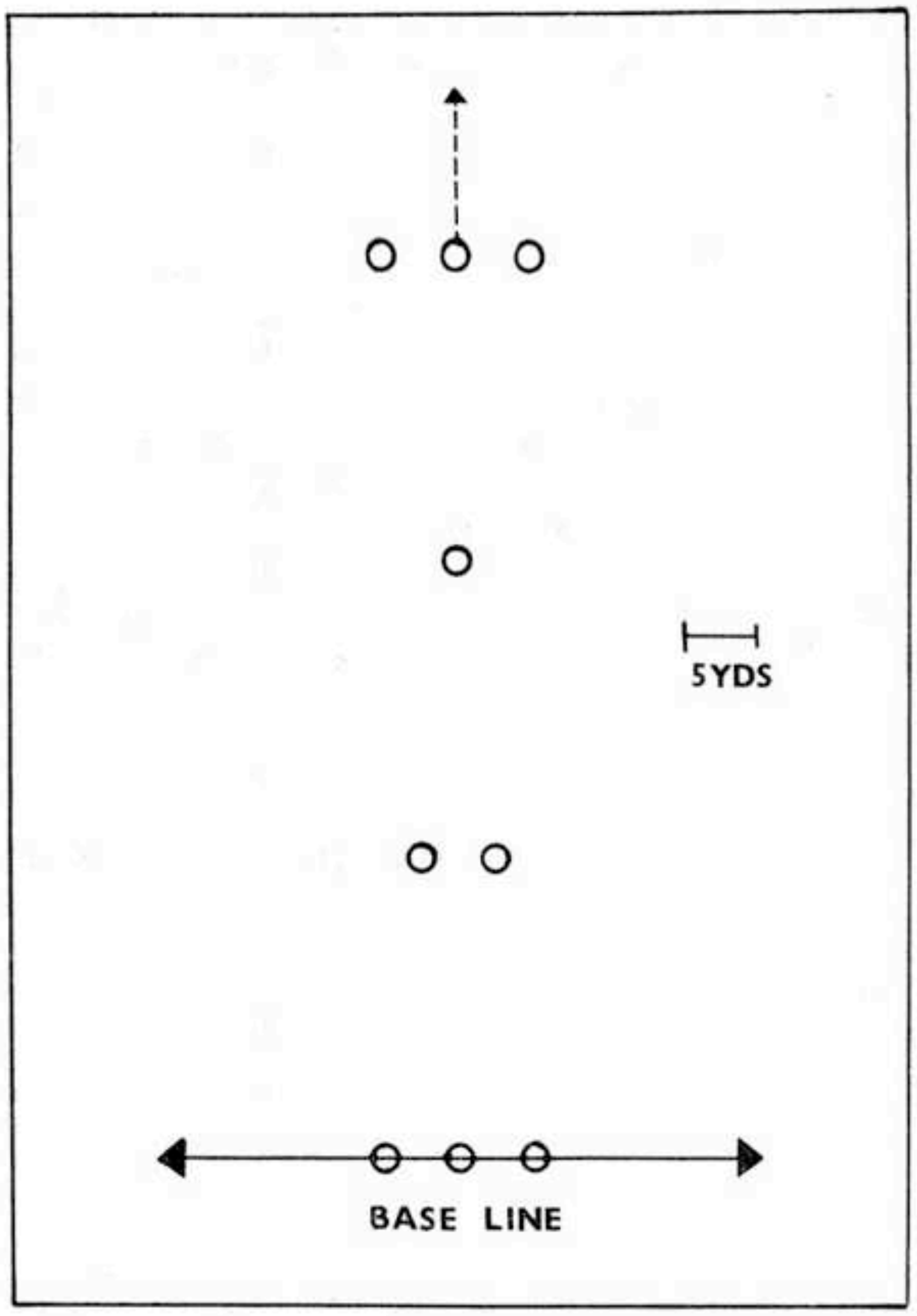

FIGURE 5. *Layout of bait stations during 1968 trials. In all, 30 bait stations were laid out on each line.*

TABLE 5. *Daily probability of interference levels being random.*

	Days of baiting																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Taramakau																					
Control (>)	.85	.80	.90	.80	.90	.90	.40	.40	.50	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Pellets (>)	.90	.95	.90	.90	.70	.70	.50	.40	.30	.30	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Carrots (>)	.80	.95	.70	.80	.90	.90	.85	.95	.40	.40	.50	.10	.20	.10	.10	.10	.10	.10	.10	.10	.10
Taipo																					
Control (>)	.90	.85	.90	.80	.90	.75	.80	.40	.50	.40	.50	.30	.10	.10	.10	.10	.10	.10	.10	.10	.10
Pellets (>)	.95	.90	.95	.80	.40	.30	.30	.30	.40	.30	.40	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Carrots (>)	.90	.90	.90	.70	.90	.40	.40	.30	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10

SPACING TRIALS, TARAMAKAU 1969

From the trials made in 1968 it was apparent that, despite randomisation of lines, contagious effects still influenced the nightly level of interference. For the model (ii) to estimate relative density changes efficiently it was necessary to ensure that these effects were removed.

In April 1969 trials were made in the Taramakau Valley to determine the most economic distances between baits and the interval of time between successive baitings that would avoid contagion.

Five bait-lines were established at least 200 yards apart and baits were spaced at intervals of 5, 20, 40, 70 or 100 yards. Initially, lines were baited for 10 days. At the end of this period the results were considered to be unaffected by contagion on lines where the overall level of interference had not increased significantly from the first day. Student's 't' was used to test the null hypothesis that the regression coefficient was not significantly different from zero ($P = <0.05$). The proportion of baits interfered with remained approximately the same from night to night when spaced 40, 70 and 100 yards apart. Interference was therefore inferred to be free from contagion; whereas with spacings of 5 and 20 yards, the level of interference increased significantly.

Two lines of baits spaced at 5 and 20 yards were subsequently established in an adjacent area and baited at intervals of two days on eight successive occasions. The proportion of baits taken again increased from night to night, which suggests that it was not possible to avoid the contagious effects of small distances by baiting at longer time intervals (Table 6).

TABLE 6. *Summary of spacing trials Taramakau Valley, 1968.*

Spacing (yards)	ONE DAY INTERVALS Coeff. regress.	't'	Sig.	TWO DAY INTERVALS Coeff. regress.	't'	Sig.
5	5.40	3.32	0.02*	4.80	3.13	0.05*
20	1.90	2.80	0.05*	2.32	2.95	0.05*
40	0.24	0.96	0.10	—	—	—
70	0.26	0.89	0.10	—	—	—
100	0.15	0.62	0.10	—	—	—

* Denotes spacing giving a daily rate of increase significantly different from 0.

HAUPIRI-TAIPO POISON TRIAL 1969

In the Haupiri and Taipo Valleys during September 1969 baits were spaced at 40-yard intervals in a trial using hard pellet bait.

The element of contagion was thought to have been removed by this interval and baits were set for a minimum period of seven days before, and seven days after, poisoning. Density changes were estimated by the difference in the mean levels of interference before and after poisoning. Unpoisoned control areas were used to ensure that any changes in levels of interference not attributable to poisoning were identified. The difference in the mean levels of interference obtained in each of the poisoned areas proved to be highly significant ($P = <0.01$), whereas the slight differences obtained on the untreated controls proved to be non-significant (Table 7).

By applying the formula: relative density = log $(m/m-c)$ to the difference between the mean level of interference and the mean level of interference obtained before poisoning in each poisoned area, estimates were obtained of relative decline in density. The result for the Taipo was:

$100 \log(100/100-8.6)/\log(100/100-19.8) = 40\%$;
$= 40\%$;

and for the Haupiri:

$100 \log(100/100-7.0)/\log(100/100-12.9) = 53\%$.

DISCUSSION

Contagion, progressively higher interferences with baits, was first encountered in the Styx Valley and identified in the 1968 trials as being caused by animals actively searching for bait. The use of randomly-located bait-lines instead of those laid along ridges did not remove contagion although it did reduce the overall level of takes.

The modifications adopted from the spacing trials have improved the accuracy of density estimations by reducing contagion to non-significant levels. The standard errors of the levels of interference in the 1969 poison trials were all

TABLE 7. *Tests of significance of differences in levels of acceptance between pre- and post-poison baiting; Haupiri and Taipo Valleys, 1969.*

	Pre-poison mean interf. level	S.E.	Post-poison mean interf. level	S.E.	Mean diff. interf. levels	't' diff. means	d.f.	Sig.
Haupiri								
Control	19.6%	1.61	19.5%	1.60	0.1%	0.22	13	N.S.
Poisoned	12.9%	1.66	5.9%	0.75	9.0%	3.72	13	<0.01
Taipo								
Control	14.4%	1.75	16.1%	2.04	1.7%	0.66	15	N.S.
Poisoned	19.8%	1.82	11.2%	1.51	8.6%	3.26	15	<0.01

within about 10% of the means (Table 7). Extending the number of days of baiting to anything over 10 days in future trials would achieve little. The model appears to be reasonably well justified for assessing opossum density by this method, provided all elements of contagion are removed. Therefore, baits should be spaced at least 40 yards apart and baited daily to ensure random encounter by opossums.

To ensure adequate coverage of areas to be assessed, at least five randomly-located lines, each of 20 bait stations, should be established for approximately every 500 acres of forest. No line should be closer than 200 yards from its neighbours.

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REFERENCES

BATCHELER, C. L., DARWIN, J. H., and PRACY, L. T. 1967. Estimation of opossum (*Trichosurus vulpecula*) populations and results of poison trials from trapping data. *N.Z. J. Sci.* 10: 97–114.

DICE, L. C. 1952. *Natural communities*. Univ. Michigan Press, Ann Arbor.

FISHER, R. A., and YATES, F. 1963. *Statistical tables for biological agricultural and medical research*. Oliver and Boyd, London.

LESLIE, P. H., and DAVIS, D. H. S. 1939. An attempt to determine the absolute number of rats on a given area. *J. Anim. Ecol.* 8: 94–113.