

## EVALUATION OF NON-TOXIC BAIT INTERFERENCE FOR INDEXING BRUSHTAIL POSSUM DENSITY

**Summary:** Percentage non-toxic bait interference is currently used by local authorities to monitor brushtail possum control operations but the validity of the method has not been established. Two models have been proposed to estimate an index of possum density (possums per bait) from a log-transformation of percentage bait interference. In two trials, percentage bait interference and the density index derived from percentage bait interference using the Bamford (1970) model usually increased from night to night. Variation in the number of possums per bait was reduced by dividing the Bamford index by the number of nights baits were put out, as proposed by Jane (1981). The spatial distribution of bait interference along lines of bait stations was random for the first night and usually for at least 5 nights. Rhodamine dye and cyanide poison, alternated at bait stations after at least 5 nights non-toxic baiting, showed that about 83% of possums in one trial and 29% of possums in the other trial interfered with more than one bait on the same night. Increasing the spacing between bait stations reduced the proportion of possums interfering with more than one bait. The number of possums per line killed by cyanide baits after at least 5 nights of non-toxic baiting was strongly correlated with percentage bait interference, with and without logarithmic transformation, on the first night. The possums' apparent ability to remember the location of bait stations from one night to the next means that, in the absence of better advice, the original Bamford (1970) model should be modified as proposed by Jane (1981) to estimate possum density and change in possum density (e.g., from pre- to post-poison).

**Keywords:** brushtail possums; *Trichosurus vulpecula*; population density.

### Introduction

The percentage of non-toxic baits interfered with by brushtail possums (*Trichosurus vulpecula* Kerr) is currently used by local authorities to monitor the effectiveness of control operations (Clarey *et al.*, 1992). The method typically involves recording the percentage of non-toxic baits interfered with per night for three consecutive fine nights. The same procedure is used before and after control operations, and the percentage reduction in possum numbers is estimated from the difference between the mean pre- and post-control interference divided by the mean pre-control interference multiplied by 100. However, this method has not been validated and is likely to under-estimate possum density when bait interference approaches 100% because more than one possum may interfere with each non-toxic bait. That is, there is unlikely to be a linear relationship between possum density and percentage non-toxic bait interference.

The original model of non-toxic bait interference, proposed by Bamford (1970), used the Poisson distribution to estimate the number of possums interfering with baits from the proportion of baits interfered with:

$$\text{possums/bait} = -\log_e (1-f)$$

where  $f$  = the proportion of baits interfered with. Thus, 10% of baits interfered with ( $f=0.1$ ) indicates 0.1 possums/bait, 50% ( $f=0.5$ ) indicates 0.7 possums/bait, and 90% ( $f=0.9$ ) indicates 2.3 possums/bait. When interference approaches 100% the logarithmic transformation becomes unreliable (Jane, 1979). Density estimates should be repeatable from day to day and under similar conditions such as weather. Bamford (1970) and later users of the technique (e.g., Jane, 1979, 1981; Clarey *et al.*, 1992) measured bait interference daily for several days (usually 3–5), presumably to average out the effects of weather.

The Poisson model assumes that possums interfere with baits at random. However, two observations appear to negate this assumption. First, with repeated baiting, the level of bait interference increases nightly (Bamford, 1970; Jane, 1979, 1981). Second, the sequential distribution of bait interferences along lines of bait stations often appears clumped, although this has not been proven statistically. The nightly increase in interferences could be caused by a combination of possums encountering new baits at random and possums returning to previously encountered (and remembered) bait stations, or by possums

increasingly moving along lines of bait stations searching for baits (so-called contagion). The clumped distribution of interferences, if proven, could be caused by patchy distribution of possums or by contagion.

Bamford (1970) claimed that with 20 yard (approx. 20 m) spacing between bait stations, possums interfered with baits at random for the first 3–5 nights of baiting, then began searching for baits and continued to do so until maximum bait interference levels were reached. He also claimed that by increasing the spacing between bait stations to 40 yards (approx. 40 m), the level of bait interference after 10 nights was not significantly higher than after the first night. However, other users of the technique (e.g., Jane, 1979, 1981) have found that bait interference increased from night to night, even with 40 m spacing between bait stations.

Jane (1981) proposed a modification to the mathematical model to account for the effect of possums remembering previously encountered baits:

$$\text{possums/bait} = (-\log_e (1-f))/i$$

where  $f$  = the proportion of baits interfered with, and  $i$  = the number of nights baits were put out. This modification assumes that the proportion of possums returning to previously encountered bait stations is constant from night to night (Jane, 1979, 1981).

The only previous attempt to validate the accuracy of non-toxic bait interference found a significant correlation between log-transformed bait interference and log-transformed trap catch (Jane, 1979). However, the relationship between non-toxic bait interference and absolute possum numbers has not been established.

In this paper, data collected from two trials in 1978 and 1979 are analysed to determine whether the Jane (1981) model reduced the nightly variation in the density index estimated from possum interference with baits, whether the spatial distribution of bait interference was random, whether individual possums interfered with more than one bait, whether spacing between bait stations influenced the proportion of possums interfering with more than one bait, and whether the level of possum interference with baits was correlated with possum numbers.

## Methods

Bait stations were made from pieces of wire approximately 600 mm long, with a 30 mm diameter bottle cap glued into a twist at one end to hold the bait, and a 130 mm diameter tin lid with a hole in the centre slipped up from the other end and suspended

by a rubber band about 150 mm below the bottle cap to prevent interference to the bait by rats (*Rattus* spp.) (after Bamford, 1970). The wire was inserted about 200 mm into the ground so that the bottle cap was about 400 mm above ground.

### Mt Thomas Forest

Bait stations were set at 40 m intervals on four lines, with at least 200 m between lines, running straight up and down hill in remnants of mountain beech (*Nothofagus solandri* var. *cliffortioides* Hook. f.), Mt Thomas Forest, Canterbury. Because of the limited area of forest there were only 12–16 stations per line.

The stations were baited with a flour/soya bean oil paste on 17 December 1978, and the number of baits interfered with was recorded the next day. Fresh bait was put out on 18 December, but rain interrupted the experiment the next day, so the stations were removed. They were replaced on 8 January 1979, then re-baited and checked daily for 3 days. On 10 January, the stations on each line were baited alternately with (a) flour/soya bean oil paste dyed with 0.1% Rhodamine B, a non-repellent marker (Evans and Griffith, 1973; Morgan, 1981), at even-numbered stations, or (b) flour/soya bean oil paste (not dyed) overlying unlured sodium cyanide at odd-numbered stations. The following day possum carcasses at the cyanide stations were inspected externally and internally for the presence of dye. Apparently unmarked possums were inspected under an ultra-violet light. Any dyed possums killed at cyanide stations must have eaten bait from at least one dye station and one cyanide station on the same night. The stations were removed for 21 days, then replaced on 31 January and re-baited and checked daily for three days to investigate the effect of removing a known number of possums on bait interference levels.

### Kaingaroo Forest

Bait stations were set on flat land in compartments of *Pinus radiata* D. Don, Kaingaroo Forest, Rotorua, to determine whether topography and forest type (*cf.* Mt Thomas Forest) influenced the distribution of bait interference. The stations were spaced at three intervals; 40 m apart in one compartment (92 bait stations), 100 m apart in two compartments (37 and 42 bait stations), and 200 m apart in two compartments (20 and 16 bait stations). There were two lines of stations, at least 200 m apart, in each compartment.

The stations were baited with a flour/soya bean oil paste on 7 March 1979, and checked and re-baited daily when weather permitted until bait

interference was 50% or greater. On 17 March, the stations were baited as before, but 0.1% Rhodamine B dye was added to baits at odd-numbered stations and unlured cyanide was placed under baits at even-numbered stations. On 18 March, carcasses at the cyanide stations were inspected for the presence of dye, as at Mt Thomas Forest. All bait stations were then re-baited with non-dyed flour/soya bean oil paste overlying unlured sodium cyanide. On 19 March, additional carcasses were inspected for the presence of dye. Any possums found dyed must have visited a dye station but not a cyanide station on the night of 17 March.

### Statistical analyses

The Wald-Wolfowitz runs test (Wilkinson, 1990) was used to assess whether the sequences of bait interferences along the lines of bait stations were random. Chi-square tests (on raw data), with Yates' correction for small sample sizes, were used to compare the percentage bait interference and proportion of possums dyed at different bait station spacings. The relationship between bait interference and number of possum carcasses was tested using regression and correlation techniques using individual bait interference lines as replicates (Wilkinson, 1990).

## Results

### Nightly variation in bait interference

Percentage bait interference and the number of possums per bait estimated using the Bamford (1970) model increased rapidly from night to night at both Mt Thomas (Fig. 1) and Kaingaroa Forest (Fig. 2), except when there was heavy rain (on 13 and 16 March at Kaingaroa) and when cyanide was added to every second bait (on 11 January at Mt Thomas and 18 March at Kaingaroa). By comparison, the density index estimated using the Jane (1981) model was more constant (Figs. 1 and 2), with a coefficient of variation (standard deviation/mean) about half that of the Bamford (1970) density index (Table 1). The removal of 68

possums from Mt Thomas on 11 January reduced percentage bait interference by 17.3% and the number of possums per bait by 41.8% estimated using the Bamford (1970) model and by 53.3% using the Jane (1981) model. On 1 February, after an interval of three weeks, percentage bait interference had decreased by 30.8% and the number of possums per bait by 61.0% estimated using the Bamford (1970) model and by 73.9% using the Jane (1981) model. Bait interference increased from 1–3 February at a similar rate to earlier assessments (Fig. 1). At Kaingaroa Forest, the removal of 12 possums on 18 March from the compartment where bait stations were 40 m apart reduced percentage bait interference by 36.9% and the number of possums per bait by 56.0% estimated using the Bamford (1970) model and by 60.1% using the Jane (1981) model (Fig. 2).

### Spatial distribution of bait interference along lines of bait stations

The spatial distribution of bait interference was random on the first night on all lines of stations

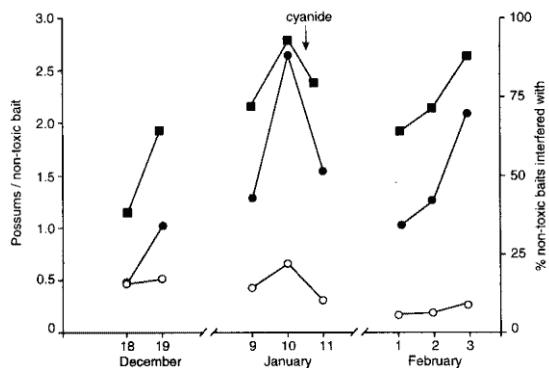


Figure 1: Percentage non-toxic bait interference (■) and number of possums/non-toxic bait estimated using the models of Bamford (1970) (●) and Jane (1981) (○), Mt Thomas Forest, December-February 1979: 40 m spacing between bait stations.

Table 1: Percentage bait interference and number of possums per bait estimated from the Bamford (1970) and Jane (1981) models (mean  $\pm$  standard deviation).

Locality and spacing between bait stations	Number of non-toxic bait stations	% bait interference first night	Bamford (1970) first night	Bamford (1970) mean $\pm$ SD all nights	Jane (1981) mean $\pm$ SD all nights
Mt Thomas 40 m	56	37.9	0.48	1.39 $\pm$ 0.80	0.52 $\pm$ 0.11
Kaingaroa 40 m	92	9.8	0.09	0.88 $\pm$ 0.57	0.15 $\pm$ 0.04
Kaingaroa 100 m	79	10.5	0.11	0.44 $\pm$ 0.29	0.06 $\pm$ 0.02
Kaingaroa 200 m	36	11.4	0.12	1.04 $\pm$ 0.58	0.16 $\pm$ 0.04

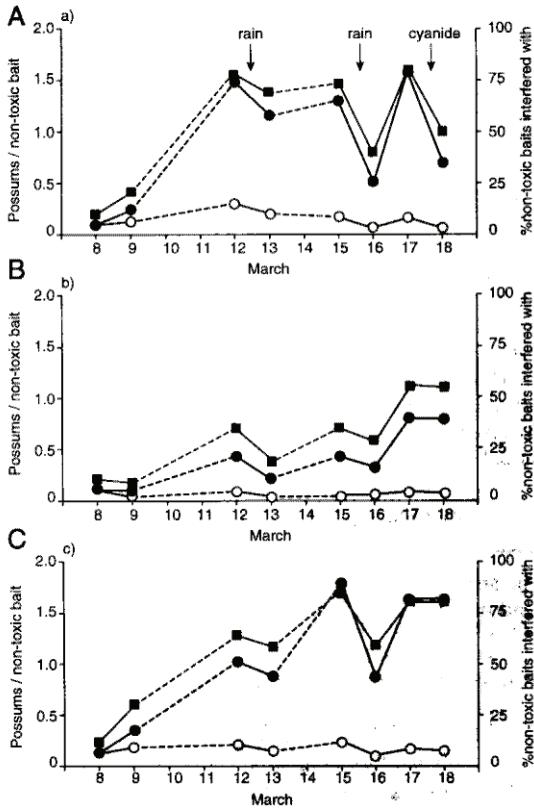


Figure 2: Percentage non-toxic bait interference (■) and number of possums/non-toxic bait estimated using the models of Bamford (1970) (●) and Jane (1981) (○), Kaingaroa Forest, March 1979: (A) 40 m spacing, (B) 100 m spacing, (C) 200 m spacing between bait stations.

where baits were interfered with, although there were two lines (I and J at Kaingaroa Forest) where no baits were interfered with on the first night (Table 2). Bait interference was also random on the second night on all lines except one (line A at Mt Thomas), where all baits were interfered with (Table 2, Fig. 3). Interference became non-random on some lines on subsequent nights for a variety of reasons. For example, non-randomness occurred when all except the first or last baits in a line were interfered with (e.g., Mt Thomas, line A, night 4; Table 2, Fig. 3). Although 11 out of the 12 baits on this line were interfered with on both nights 4 and 5, the spatial distribution of interferences on night 5 was not significantly different from random because the 11 interferences occurred in two runs, of one and 10, separated by one bait not interfered with, whereas on night 4 the 11 interferences all occurred in one run (Fig. 3). These differences probably result from a statistical artefact not possum behaviour. Non-randomness resulting from too many consecutive interferences or non-interferences, which may indicate contagion, occurred only after five nights (e.g., Kaingaroa Forest, line A, night 6) (Table 2, Fig. 3). The addition of cyanide to alternate bait stations on the last night resulted in catches of up to five possums per station at Mt Thomas and up to three possums per station at Kaingaroa Forest (Fig. 3), indicating that individual baits may be interfered with by more than one possum. The addition of cyanide to alternate bait stations also reduced percentage bait interference on the same night on lines where stations were 40 m apart by about 20–40% (Figs. 1 and 2), indicating that individual possums were interfering with more than one bait.

Table 2: Probability values for randomness of spatial distribution of bait interference along lines of bait stations. n=number of baits per line. ND = probability not determined.

Locality and spacing between bait stations			Night							
	n	1	2	3	4	5	6	7	8	
Mt Thomas	40 m A	12	0.210	0.000	0.637	0.025	0.655	ND	ND	ND
	40 m B	16	0.605	0.050	0.705	0.000	0.008	ND	ND	ND
	40 m C	12	0.692	0.603	0.250	0.692	0.676	ND	ND	ND
	40 m D	16	0.436	0.513	0.324	0.008	0.605	ND	ND	ND
Kaingaroa	40 m A	50	0.316	0.187	0.403	0.226	0.776	0.000	0.002	0.257
	40 m B	42	0.468	0.226	0.315	0.111	0.000	0.000	0.016	0.062
	100 m C	19	0.057	0.557	0.090	0.054	0.223	0.002	0.034	0.908
	100 m D	18	0.724	0.627	0.108	0.776	1.000	0.956	0.190	0.582
	100 m E	21	0.237	0.050	0.383	0.697	ND	ND	ND	ND
	100 m F	21	0.746	0.268	0.556	0.866	ND	ND	ND	ND
	200 m G	10	0.366	0.366	0.049	0.366	0.122	0.821	0.366	ND
	200 m H	6	0.724	0.480	0.077	0.000	0.157	0.000	0.000	ND
	200 m I	10	0.000	0.821	0.888	0.502	0.617	0.009	0.366	0.366
	200 m J	10	0.000	0.574	0.574	0.888	0.870	0.049	0.870	0.072



Table 3: Number of possum carcasses per cyanide bait station and percentage of possum carcasses dyed with Rhodamine B the day after cyanide was put in bait stations.

Locality and spacing between bait stations	Number of cyanide bait stations	Number of possum carcasses	Number of carcasses per station	% carcasses dyed
Mt Thomas 40 m	28	68	2.4	22.1
Kaingaroa 40 m	46	12	0.3	58.3
Kaingaroa 100 m	39	17	0.4	23.5
Kaingaroa 200 m	18	20	1.1	20.0

The proportion of the possum population (as distinct from the possums killed by cyanide) interfering with more than one bait ( $p$ ) was estimated from:

$$p = \frac{\text{number of dyed possums}}{\text{number of dyed baits eaten by possums}}$$

assuming each dyed bait was eaten by a different possum. At Mt Thomas, 18 dyed baits were eaten (i.e., 18 possums should have been dyed) and 15 dyed possums were found dead at cyanide bait stations the same night; i.e., 83.3% of possums visiting dyed bait stations also visited a cyanide bait station. In the compartment at Kaingaroa Forest where bait stations were 40 m apart, 24 dyed baits were eaten (i.e., 24 possums should have been dyed) and seven dyed possums were found dead at cyanide bait stations; i.e., 29.2% of possums visiting dyed bait stations also visited a cyanide bait station. However, it is likely that not all possums visiting cyanide bait stations in this compartment were killed because vomit was found at 15 stations without possum carcasses, indicating possums were “cyanide-shy” and received sub-lethal doses of cyanide. In the compartments at Kaingaroa Forest where bait stations were 100–200 m apart, 36 dyed baits were eaten (i.e., 36 possums should have been dyed) and eight dyed possums (22.2% of those dyed) were found dead at cyanide bait stations. About 7% of the possums visiting dyed bait stations did not visit a cyanide station the same night but visited one the following night.

### Correlation between bait interference and number of possums

At Mt Thomas Forest, 2.42 carcasses per cyanide bait (range 0-5) were found on 11 January, compared with 1.95 possums per cyanide bait estimated to be present the same night from interference to baits using the Bamford (1970) model. At Kaingaroa Forest, on 18 March, 0.48 possums/bait (range 0-3) were killed at cyanide bait stations compared to 0.78 possums/bait estimated to be present from bait interference. On 19 March (1 day later), 0.09 possums/bait were found at cyanide bait stations compared to 0.23 possums/bait

estimated to be present from bait interference.

However, as noted above, it is likely that possums in the compartment where bait stations were 40 m apart at Kaingaroa Forest were “cyanide-shy” and not all those visiting cyanide bait stations were killed.

There were significant correlations between the number of possums killed by cyanide baits and (a) percentage bait interference on the first night (18 December at Mt Thomas and 8 March at Kaingaroa Forest) ( $r = 0.891$ ,  $P = 0.001$ ) (Fig. 4), (b) number of possums/bait the first night estimated using the Bamford (1970) model ( $r = 0.874$ ,  $P = 0.001$ ) (Fig. 5), and (c) number of possums/bait averaged over all nights estimated using the Jane (1981) model ( $r = 0.958$ ,  $P < 0.001$ ) (Fig. 6). There was also a significant correlation between the number of possums killed by cyanide baits and the number of possums/bait on the night before cyanide was added to baits estimated using the Bamford (1970) model ( $r = 0.660$ ,  $P = 0.038$ ), but no significant correlation between the number of possums killed by cyanide baits and untransformed percentage bait interference on the night before cyanide was added to baits ( $r = 0.623$ ,  $P = 0.054$ ).

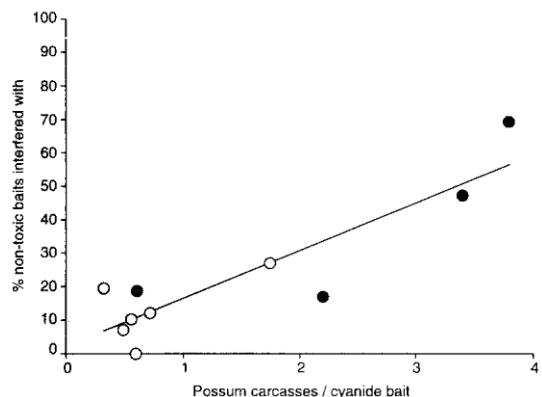
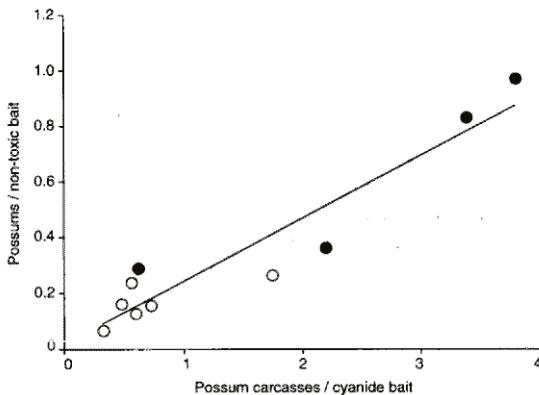
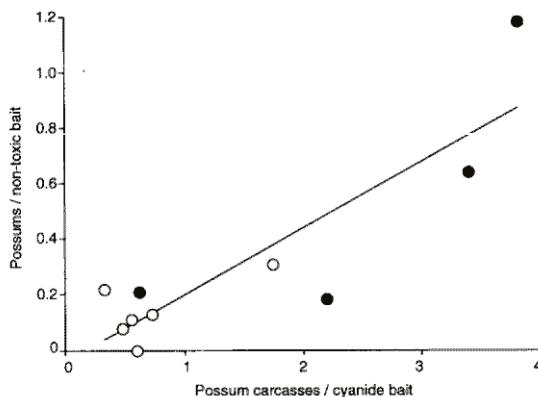


Figure 4: Comparison of percentage non-toxic bait interference on night 1 with the number of possum carcasses per cyanide bait on lines at Mt Thomas (●) and Kaingaroa Forest (○).



**Figure 5:** Comparison of number of possum interferences per non-toxic bait on night 1, estimated using the Bamford (1970) model, with number of possum carcasses per cyanide bait on lines at Mt Thomas (●) and Kaingaroo Forest (○).



**Figure 6:** Comparison of number of possum interferences per non-toxic bait averaged over all nights, estimated using the Jane (1981) model, with number of possum carcasses per cyanide bait on lines at Mt Thomas (●) and Kaingaroo Forest (○).

## Discussion

The finding that the spatial distribution of bait interference along lines of bait stations was random for at least the first night, and usually for at least five nights, supports the claim by Bamford (1970) and Jane (1981) that contagion is unlikely when bait stations are 40 m or more apart. However, possums have been recorded making nightly foraging movements of up to 1300 m (Green and Coleman, 1986). Thus, it is likely that several bait stations will

occur within the home range of individual possums, even when bait stations are at 200 m intervals, and that possums will encounter more than one bait station randomly as a result of normal nightly movements. Possums would be more likely to randomly encounter several bait stations at 40 m spacing than at 200 m spacing.

The proportion of possums killed that were dyed with Rhodomine was influenced by possum density, and under-estimated the proportion of the population that interfered with more than one bait. It is likely that only one possum would be dyed at each dye bait station because the first possum to visit would eat all the dyed bait, whereas more than one possum could be killed at each cyanide bait station because the first possum(s) to visit would die before all the bait was eaten. The higher density of possums at Mt Thomas meant that the ratio of dyed baits to the number of possums in the forest was lower there than at Kaingaroo Forest. Thus, a lower proportion of the possums killed was dyed in Mt Thomas than in Kaingaroo Forest. However, the proportion of the possum population interfering with more than one bait was estimated to be higher at Mt Thomas than at Kaingaroo Forest, although it is not clear whether this was related to topography (possums moving along lines going up and down hill at Mt Thomas) or to the cyanide-shyness of possums at Kaingaroo Forest.

The observation of up to five possums interfering with a single cyanide bait indicates that possum home ranges overlapped. The relationship between percentage of baits interfered with and the number of possums per bait interference needs to be better validated than in this study, but it is likely that without statistical transformation of some sort, percentage bait interference will under-estimate possum numbers at high density, and consequently under-estimate percentage kill when used before and after a control operation. Percentage bait interference, even with logarithmic transformation, is always likely to under-estimate percentage kill if the possums' apparent ability to remember the locations of bait stations is not taken into account. The increase in bait interference by possums from night to night, even after an interval of three weeks, means that first-night post-poison estimates theoretically will be higher than first-night pre-poison ones. Jane's (1981) modification of Bamford's (1970) model is an attempt to correct for this. An alternative (or additional) method of correction would be to use a non-treatment block (Bamford, 1970).

The number of possums killed by cyanide baits after at least five nights of non-toxic baiting was more strongly correlated with percentage bait

interference on the first night non-toxic baits were put out than with percentage bait interference on the night before cyanide was added to the baits, probably because possum interference increases to an asymptote over time (Bamford, 1970). Even where there are few possums, most baits are discovered eventually. Possum numbers were more strongly correlated with percentage bait interference over several nights, transformed and averaged using the Jane (1981) model, than with first-night percentage bait interference, with or without transformation using the Bamford (1970) model. Possum density is likely to be more accurately estimated from several nights' data than from a single night's data, although the validity of the Jane (1981) model for doing this has not been adequately established.

The high correlation between possum numbers killed on cyanide bait lines and percentage bait interference, with and without logarithmic transformation, supports the correlation between log-transformed trap catch and log-transformed bait interference found by Jane (1979). However, the relationship between 1-night cyanide catch or log-transformed trap catch and absolute possum numbers remains unknown. The validity of non-toxic bait interference as an index of possum density is currently being investigated by measuring non-toxic bait interference and then trapping possums to extinction over a range of possum densities (B. Warburton, *pers. comm.*). Jane's (1981) method of correcting for possums remembering the location of baits also needs validating in a replicated trial by relating percentage reduction in possum density estimated using his model to absolute reduction in possum numbers. In the meantime, pest control managers should transform percentage bait interference as recommended by Bamford (1970) and divide this by the number of nights baiting as recommended by Jane (1981) to more accurately estimate both possum density and change in possum density.

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