SCIENCE & RESEARCH INTERNAL REPORT NO.132

MONITORING POSSUM NUMBERS FOLLOWING 1080 POISON CONTROL AT MAPARA RESERVE

by

Theo Stephens

Published by
Head Office,
Department of Conservation,
P O Box 10-420,
Wellington
New Zealand

ISSN 0114-2798
ISBN 0-478-01430-9

Keywords: Possum, Trichosurus vulpecula, control, monitoring, Mapara Reserve, 1080 poison, sodium monofluoroacetate, kokako

CONTENTS

MONITORING POSSUM NUMBERS FOLLOWING 1080 POISON CONTROL AT MAPARA RESERVE

by

Theo Stevens
Conservancy Advisory Scientist, Waikato Conservancy, Department of Conservation, Private Bag 3072, Hamilton, New Zealand

ABSTRACT

1080 poisoned baits (Wanganui No. 7) were aerially spread throughout the three blocks of Mapara reserve in September 1990 and again in October 1991 to control possums. Changes in possum abundance were monitored by trapping, using a modified version of Seber's "removal method". A trapping method was chosen in preference to spotlight counts, bait take and pellet counts because a suitable control area, critical to these methods, was not available; traps were already in place on permanent sets; and trapping contributes to the control objective. The removal index was considered more suitable for monitoring than the simpler catch per unit effort index (number of possums caught per 3 trap-nights) because the latter is affected by variation in possum catchability, as well as possum abundance.

The removal method depends on obtaining declining catches on successive nights. There is a significant risk that the method will not give a meaningful result if trapping intensity is inadequate or if nightly variation in catchability is excessive. The catch per unit effort index is still available if an abundance index based on the removal method is unobtainable.

The 1990 poison operation reduced possum numbers to 21% of pre-poison abundance (95% Confidence Limits (CL) were 13.8% and 28.2%). During the following year, possum numbers built up to 39.5% (95% CL 28.7% and 50.3%) of pre-poison abundance and
1991 poison operation caused a non-significant reduction to 32.2% (95% CL 21.8% and 42.6%). Thus the September 1991 operation probably did not reduce possum densities to the level attained in October 1990. The reason for the poor kill following the 1991 poison drop is unknown, although several possibilities are identified.

1. INTRODUCTION

1.1 Study area

The Mapara Wildlife Management Reserve is one study area in an experimental programme designed to test the hypothesis that 'maximum practicable introduced mammal browser and predator control will (in the short term) increase kokako (*Callaeas cinerea*) chick output and (in the longer term) population density' (Innes 1992). At

Mapara, most mammals (possums, rats, mustelids, cats and ungulates) are intensively controlled. The aerial 1080 applications were for possum (*Trichosurus vulpecula*) control (Innes and Williams 1991). Incidental 1080 by-kill probably temporarily reduces ship rat (*Rattus rattus*), mice, and possibly hedgehogs. This report has two objectives. First, to describe the effect of two 1080 poison control operations on possum abundance and second, to comment on possum monitoring methods considered as options for other kokako study areas.

The Mapara possum control programme is unusual in that operations have been maintained annually for four years, and aerial 1080 applications have been repeated in consecutive winters. The effect on possum populations of repeated 1080 application has not been described.

1.2 History of possum control at Mapara

Commercial trappers had hunted Mapara reserve on an ad hoc basis until 1988. Possum control operations have taken place in one or more of the three blocks (North, Central and South) of the Mapara Reserve every year since 1988, starting with a contracted team of commercial trappers (all blocks, winter 1988), trapping by DOC staff (Central Block, summer 1989), aerial 1080 application (all blocks) in 1990, again in 1991 and a third application is planned for 1992. In September 1990 and October 1991, 1080 Wanganui No.7 poisoned baits (green dyed, cinnamon lured cereal pellets) were aerially spread throughout the three blocks of Mapara Reserve and some adjoining private bush (total area 1700 ha) at a nominal density of 8.0 $kg.ha^{-1}$. Rat control with Talon 50WB (1988 and 1989 only) in several kokako territories and possum by-catch on the stoat line also contributed to a reduction in possum numbers.

In 1988, prior to the control operation by contract trappers, possum density was thought to be about 4 $possums.ha^{-1}$ (Kelton 1989). The contract trappers removed 2.2 $possums.ha^{-1}$ over the three blocks and the 1989 DOC operation removed a further 2.1 $possums.ha^{-1}$ from the Central Block. Possum density in August 1990, before the first 1080 drop, was therefore quite low, probably about 2 $possums.ha^{-1}$ in the North and South blocks and probably less than 1 $possums.ha^{-1}$ in the Central Block.

2. MEASURES OF POSSUM ABUNDANCE

Methods available for monitoring possum abundance include spotlight counts, bait interference, trapping and pellet count indices. There are a number of design options possible within each of these methods to suit different situations. A non-destructive method which does not affect possum numbers would be most appropriate for the kokako study because the programme includes areas where possums are not controlled. Ideally, the same monitoring method should be used in all study areas so that possum ahundances can he compared in different areas.

2.1 Spotlight counts

Spotlight counts were rejected as being unsuitable for forested areas and logistically difficult. This method would indicate possum abundance on reserve margins but not within the forest. Seasonal variation in possum activity and movement patterns as well as nightly variability in possum activity due to weather and other unknown factors is likely to be considerable. Thus repeated counts would be required. If pre-and poison counts are likely to he more than a week or two apart, then simultaneous observations at one or more control blocks would also he required. This method was rejected, being too demanding logistically and unsuitable for forested areas.

2.2 Bait interference

Bait interference methods were rejected because:

1. The cost of acquisition and placement could not he justified when about 900 traps were already in position on permanent sets.

2. There was no suitable control block to correct for any natural changes (perhaps associated with weather, phase of the moon, availability of another food source etc). Mangapehi forest was also to receive 1080 application in 1990 for control of bovine tuberculosis.

3. The relationship between between bait take and possum abundance has yet to be established.

A bait take method could be appropriate for all kokako study areas where possums are not controlled because it does not alter possum numbers.

2.3 Pellet counts

Pellet counts were used to measure the impact of the 1988 trapping operation. However, this method could not he continued because the control, Mangapehi Forest, was to be the target of possum control. Other possible control blocks in Pureora Forest were also either receiving, or likely to receive, possum control for bovine TB reasons. A control block is essential for pellet count methods because defecation rates and pellet decay rates are known to fluctuate naturally, depending on weather and seasonal food resources. Without a control block, change in population numbers cannot be inferred from change in pellet densities. The change in pellet densities may be due to changes in food and/or weather affecting pellet production and/or changes in decay rates. Additional control blocks and replicate treatment blocks are needed to formally implicate the poison drop as the cause of change in population numbers.

A potential problem with the pellet count method is that a high proportion of plots yield zero pellet counts when possum densities are low and consequently the precision of the index will he low in relation to the effort required to obtain it. This could mean that the impact of a control operation on a low density population, such as at Mapara, may not be measurable.

2.4 Trapping methods

There were two points in favour of adopting a trapping procedure for monitoring possum abundance at Mapara.

1. Trapping contributes to the control objective. However this would be inappropriate in other kokako study areas where possum abundance should be monitored and not controlled.

2. Traps on sets were already in place in the southern and central blocks of Mapara Reserve having been used in earlier control operations (1988, 1989).

Given the absence of commitment to any particular possum monitoring method for all kokako study areas, use of existing equipment and infrastructure for monitoring seemed the most cost efficient option. However, trapping is not an ideal monitoring system in study areas where possum numbers are to be monitored but not controlled, because the monitoring method alters possum numbers. Furthermore, getting the permanent sets in place is laborious and logistically demanding.

Two monitoring methods based on trapping were considered: a simple catch per unit effort rate index (number of possums caught per 3 trap-nights) and the more demanding 'removal' method described by Seber (1973) and modified by Hickling (1989). The key advantage of the removal method is that between survey variation in catchability is accounted for in calculation of the index. This means that, firstly, kill rates can be estimated directly from the index and, secondly, controls are not required to correct for variation in behaviour. The assumptions on which the method depends are:

1. The population is closed. That is, loss from and gain to the population are negligible during the survey.

2. Probability of capture (P) is the same for each possum exposed to capture.

3. P remains constant over the nights within each survey.

Immigration and emigration from the reserve during the survey is probably of no significance during the three or four survey nights.

Mapara P was probably not the same for all possums exposed to capture because there was geographic variation in past trapping activities. This variation will reduce precision unless a stratified sampling procedure is possible.

Two sources of within survey variation in P should be considered. Firstly, P may decline during a prolonged survey because remaining possums may he more trap shy than those caught on the first few nights. If the survey extends over more than about five nights, P should be estimated between nights so that any change over the survey can be accounted for. Secondly, weather and other factors (e.g. mating, seasonal food resources) which influence possum activity will also affect P. Weather related variation in P is best minimised by trapping only on fine nights and other variation reduced by completing the survey as rapidly as weather conditions will allow.

3. METHODS

The 'removal' index of possum abundance was estimated four times, before and after each of the two poison operations. This method uses trap catches on three fine nights to calculate a measure of possum abundance. Absolute abundance (numbers per unit land area) cannot be estimated because the size of the area sampled by traps is unknown. It is therefore necessary to relate abundance to trapping effort, so that the measure is an index of abundance. The unit of effort chosen is arbitrary. In this study the unit is trappable possums per trap.

A mixture of Lanes Ace and Victor leghold traps were located on permanent sets, on a "best set" basis, along routes, mainly ridges, between points of access to the south and central blocks of the reserve (Figure 1). The traps were numbered and divided into consecutive lines of ten. Alternate lines were set on the pre-and post-poison surveys to minimise effects of reduced possum numbers caused by trapping, as distinct from the poison operation. The number of the trap in which a possum was caught as well as the sex and maturity (adult or juvenile) of the catch were recorded. Traps set off or catching animals other than possums were also recorded.

Since the sample unit for this method is a line of traps, not an individual trap, the number of traps per line was held at ten to the number of samples and the precision of the result. The total nightly catch (Appendix 1) was used to estimate P (as in Appendix 2) and the abundance index (N_i/trap) was calculated for each line (Appendix 1). The mean and variance of these samples were used to estimate survival and associated 95% confidence intervals. For comparison, a catch per unit effort index (number of possums caught per line over three nights) was also calculated.

Rain on the second night of the first pre-poisoning survey reduced trapping efficiency by about 65%. Trap data for this night (Appendix 1, data in brackets) were not used in the analysis and trapping was continued for a fourth night, to provide data for three fine nights. All other surveys were completed on three fine nights.

4. RESULTS

4.1 Spatial variation in possum abundance

There was significant variation in catches associated with previous trapping history (Table 1). Lines in the central block, which had been hunted by contract trappers in 1988 and intensively trapped by DOC staff in 1989, produced fewer possums (mean = 1.90) than the South Block (mean = 3.90; Student's t-test: $p < 0.05$), which was hunted only by contract trappers in 1988. Probability of capture (P) was lower in the Central Block (0.134) than in the South Block (0.277; $p < 0.05$) but the abundance indices (60.0 and 66.1 respectively) were similar ($P > 0.05$). Thus the difference in catches was probably more a consequence of variation in possum catchability, presumably associated with different previous trapping experience, than possum abundance.

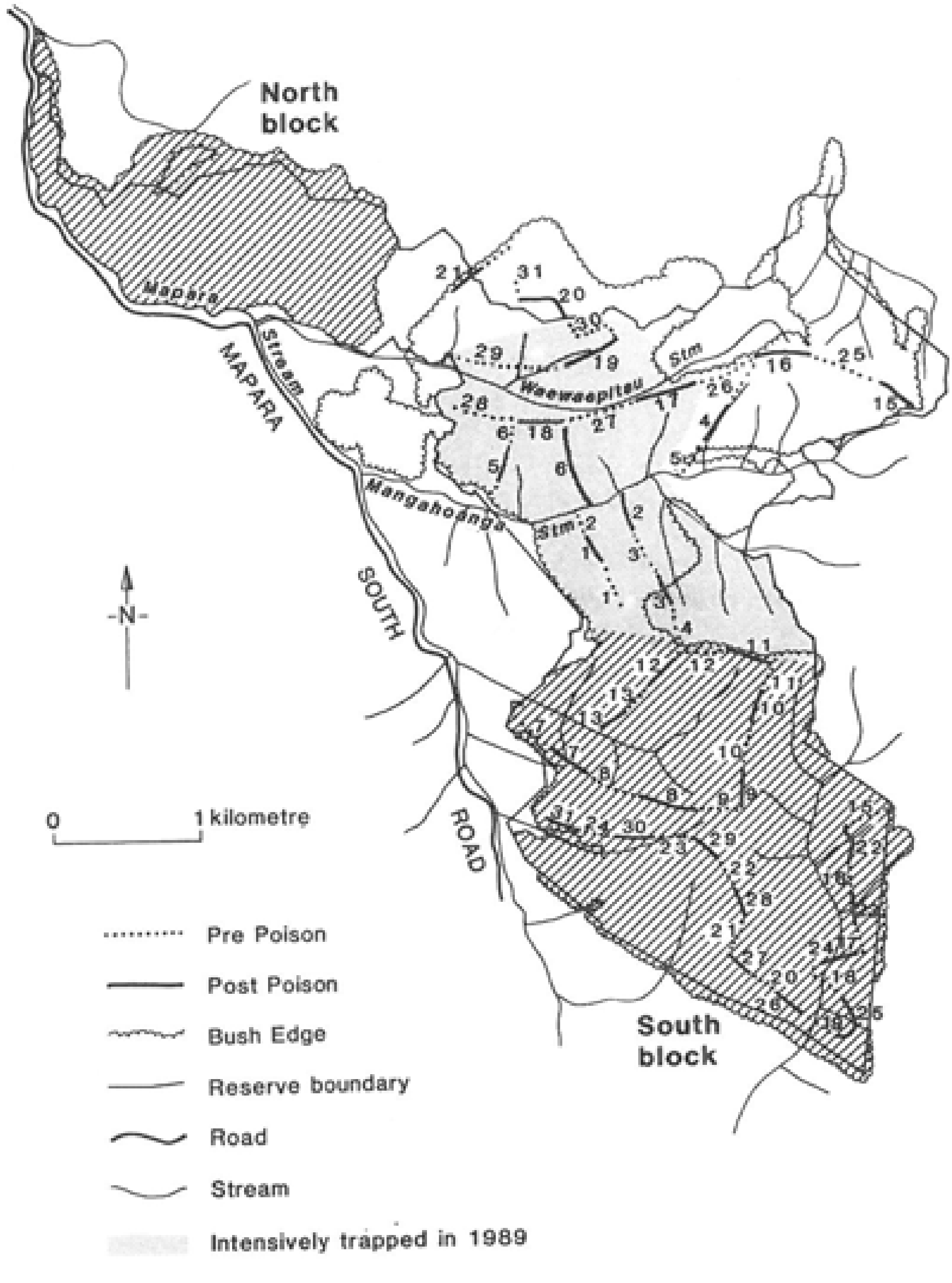

Figure 1 The Mapara Wildlife Management Reserve showing location of the possum trap lines used to monitor possum abundance in 1990 and 1991. The lines are numbered as in Appendix 1.

Table 1 Temporal and spatial variation in trapping parameters at Mapara Reserve

Year	1990						1991					
Status	PRE-POISON			POST-POISON			PRE-POISON			POST-POISON		
Control History	A	B	C	A	B	C	A	B	C	A	B	C
Mean catch.line^{-1}.3nights^{-1}	1.90	4.13	3.20	0.56	1.12	1.20	3.00	2.40	1.80	1.56	1.80	1.00
P	.134	.277	-	-	.275	.407	.149	.435	-	.566	.741	.263
N	0.60	0.661	-	-	0.179	0.150	0.809	0.287	-	0.171	0.182	0.167
Trapnights	300	480	141	270	489	150	270	432	150	270	450	150

A = Lines within the area trapped by contract trappers in 1988 and then intensively trapped by DOC staff in 1989 (shaded area in Fig 1)
B = Lines within areas only trapped by contract trappers in 1988
C = Lines within areas trapped by contract trappers in 1988 where incidental kills associated with ship rat control occured in 1988 and 1989

Lines located in the South Block where some incidental possum control had taken place in association with rat control efforts, caught similar numbers of possums (p 0.05) as other South Block lines. On two occasions, successive catches did not decline on the few lines located in these areas and so it was not possible to estimate P and the abundance index.

4.2 Variation in catchability

For all areas combined, P increased from 0.17 in August 1990 to 0.26 after the first 1080 drop, remained at a similar level (0.29) in August 1991 but increased to 0.44 in October after the second 1080 application. The total variation (temporal and spatial) was even greater, ranging from 0.13 in the intensively trapped area (August 1990) to 0.74 in areas covered only by contract trappers (October 1991). This many-fold variation in between areas over the period monitored, illustrates why the catch per unit effort indices, such as the trap-catch rate, are potentially misleading as indices of possum abundance. Catch per unit effort indices will tend to overestimate possum abundance in low density areas and will result in underestimation of kill following a control operation.

4.3 Demography

The possum catch was on all occasions dominated by adults, particularly adult males (Table 2). The scarcity of juveniles suggests that leghold traps may preferentially catch adult possums, causing juveniles to be under-represented in the catch. The increase in numbers between October 1990 and August 1991 was almost entirely of adults. Thus the increase seems to have been a result of immigration mature and maturing possums from surrounding areas with little, if any, contribution from-breeding within the Mapara Reserve.

Table 2 Sex and maturity of possums trapped at Mapara in 1990 and in 1991 before and after each poison operation.

	1990		1991	
	PRE-POISON	POST-POISON	PRE-POISON	POST-POISON
Adult Males	58	20	45	31
Adult Females	38	9	23	15
Juvenile Males	6	1	2	0
Juvenile Females	1	0	0	0

4.4 Effects of 1080 application

The pre-poisoning survey indicated a mean (±95% confidence limits) of 0.771 ± 0.192 trappable possums per trap (Figure 2). This estimate is biased low because the kills which occurred on the wet night could not be taken into account. The post-poisoning survey gave a mean of 0.162 ± 0.068 trappable possums per trap. The September 1990 poison drop reduced the index to 21.0% of the pre-poisoning level with a possible range (95% confidence limits) from 13.8% to 28.2%. This kill estimate is also biased low by the kills which occurred on the rainy night during the pre-poison trapping. The magnitude of the bias is probably in the range of 5 to 10%. Thus it is reasonable to conclude that the 1080 poison drop at Mapara reserve in September 1990 killed 80 to 85% of the possums.

Between October 1990 and August 1991 the index increased to 39.4% of the August 1990 (pre-poison) level, within a possible range of 28.7% to 50.3%. After the 1991 control operation, there was a small (and statistically non-significant) reduction to 32.2% of the August 1990 index, within a possible range of 21.8% to 42.6%. Thus the 1991 1080 poison control operation probably did not reduce possum densities to the level attained after the1990 operation. At best, most of the annual increment (immigration plus reproduction) may have been destroyed by the control operation.

5. DISCUSSION

5.1 Variation in effects of 1080 application

The 1990 poison drop caused a major reduction in the possum population whereas the 1991 operation had no significant impact. There were a number of factors which differed between the two operations:

1. The 1990 possum population had no previous experience with 1080, whereas those remaining in 1991 were probably experienced and therefore potentially bait shy;

2. The population was much smaller in 1991, so that there may have been relatively more highly preferred foods available and consequently, there may have been less incentive to take the baits;

3. There was an extended period of fine weather (8 dry days and little rain for 14 days) following the 1990 drop whereas there were only four fine nights following the 1991 operation.

4. Although the baits were stored in cool dry conditions, showed no physical sign of deterioration and actual toxic loading was within specifications (assays indicated 0.071% sodium monofluoroacetate), they were several weeks older for the 1991 operation.

Thus, while there are a number of possible reasons for the poor kill following the 1991 operation, there is no basis to ascribe any particular cause to this failure.

It would be interesting to know whether maintenance operations for TB control also have little effect on possum populations. Unfortunately, control maintenance operations in the Central North Island do not include rigorous monitoring of effects on possum populations, so the effect of control maintenance operations is unknown. The continued spread of bovine tuberculosis in domestic cattle (e.g., 11 new TB positive herds near Ngaroma in May 1992), despite full implementation of the control maintenance programme, should raise questions about the effectiveness of control maintenance and the need to establish the impact of these operations on possum populations.

5.2 Pitfalls in the catch per unit effort as an index of abundance

The index obtained from the removal method, in contrast to catch per unit effort indices, takes variation in catchability into account. It is therefore not as sensitive to factors other than possum abundance. Furthermore, estimation of the percentage kill via the removal method does not require the unrealistic assumption that an individual's catchability remains constant between surveys despite variation in possum abundance. In fact, catchability usually increases as density declines (Batcheler *et al.* 1967; Frampton pers. comm.). There are two reasons for this: (1) at high densities, another possum is more likely to get caught first,

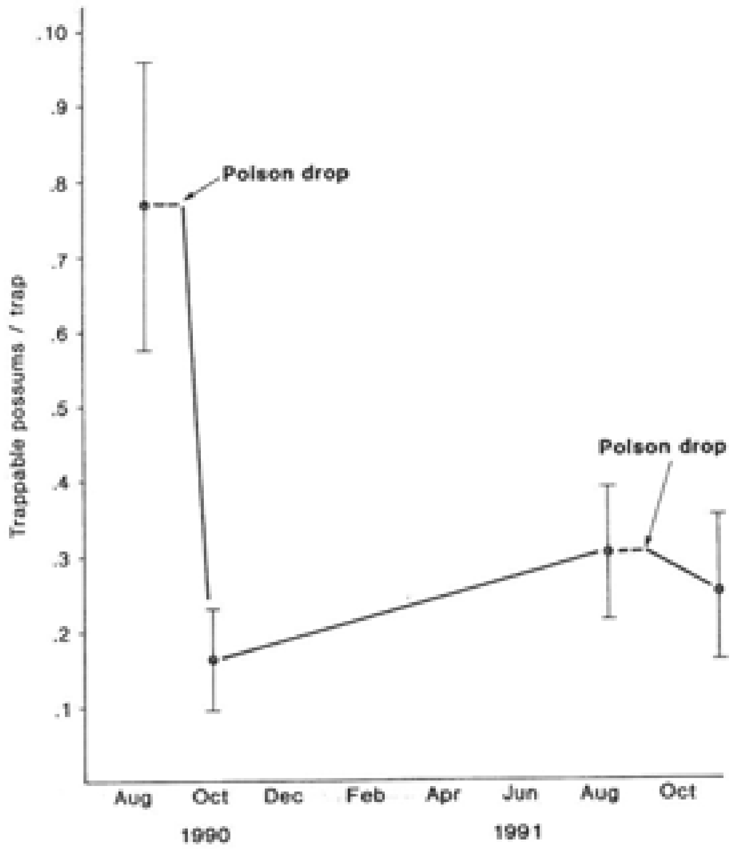

Figure 2 Variation in possum abundance at Mapara Wildlife Management Reserve between August 1990 and October 1991. Data are mean values and 95% confidence limits.

rendering the trap inactive, and (2) possums are thought to range further when their population density is low and so would be more likely to encounter a trap. Thus catch per unit effort is not usually proportional to possum density and this confounds estimation of survival following a control operation or comparison of possum abundances in different areas. For example, one cannot assume that a 70% kill was achieved because the catch fell from 10 to 3 possums per 100 trap-nights.

5.3 Pitfalls in the removal method as an index of abundance

Successful use of the removal method depends on obtaining declining catches on successive nights. Variation in the number caught on successive nights caused by removal must exceed nightly variation in catchability associated with factors unrelated to abundance. Trapping fine nights helps to reduce this night-to-night variation, but there are likely to be other, less understood sources of variation in catchability (e.g. phase of moon; temperature; cloud cover; wind). Thus the trapping effort must be sufficient to bring about a significant reduction in the number of possums present in the area trapped, otherwise a useful abundance index will be unobtainable. Frampton (pers. comm.) suggests that a 50% reduction after three nights is required. The problem arises when densities are low (e.g. Table 1) and also when possum densities are high (e.g. Speed 1992). Increasing trapping effort by using more traps, or by trapping more nights, will improve the likelihood of obtaining a useful abundance index. Increasing the number of nights trapped will reduce the variance in population estimates more efficiently than increasing the number of traps.

A clear decline in captures may not be apparent after very successful control operations. Increasing trapping effort may not solve this problem if captures are random encounters with survivors and immigrants.

When possum density is high, large numbers of traps will be required to cause a population reduction from which this abundance index can be calculated. For example, if possum density is quite high, at 20 ha^{-1}, about 12 ha^{-1} will have to be caught over the three nights to obtain a 95% confidence that is less than about 30% of the If about one third of the traps catch a possum, then at least 12 traps.ha^{-1} will be needed to obtain a useful abundance index estimate. Clearly, it is not logistically feasible to cover even a moderate sized forest area with this density of traps. However, at Mapara, possum densities were probably less than 2 ha^{-1} before the first 1080 drop and probably less than 0.5 ha^{-1} thereafter. Consequently the 300 traps spread over approximately 600 ha provided sufficient trapping effort to achieve the requisite 50% reduction over three nights on all occasions following the first 1080 operation.

The need to bring about a significant reduction in the number of possums present in the area trapped and the need for adequate coverage of the area to be monitored are competing objectives. There is a serious risk of spreading the traps to get good coverage of the area but at insufficient density to cause a significant reduction. If this happens, a useful abundance index will not be obtained, but a trap-catch index will be available. One way to resolve these competing objectives would be to trap a few areas of the block to be monitored, each area being a sample of the block. Within each area the trap lines could be run out from a central point, like spokes on a wheel. Either alternate lines or separate groups of traps along the same line could be used for pre and post-poison monitoring. Trapping should continue until a 50% or greater reduction is obtained. Calculations for estimating N, P and their variances when more than three nights are trapped are given by Blower *et al.* (1981).

5.4 Possum monitoring methods for kokako study areas

A single monitoring method for all kokako study areas is desirable so that possum abundance can be compared between areas. Any trapping method is not ideal in treatment areas where the study design requires that possum numbers are monitored but not altered. A non-destructive method such as pellet counts, bait take or spotlight counts is appropriate. Spotlight counts are unsuitable for fully forested areas typical of kokako habitats. Pellet counts can give imprecise results when possum densities are low, so that the effect of control operations may be immeasurable. Increasing the number of plots counted will reduce the problem. All three methods require a control and, as with Mapara, a suitable control may not be available, particularly for the full term of the kokako study.

6. CONCLUSIONS

1. The density of possums at Mapara was low before the poison operation.
2. The 1990 poison application caused a major reduction in the possum population but the 1991 application had little effect.
3. The increase in numbers after October 1990 was primarily from immigration, not reproduction.
4. Use of the trap-catch rate as an index of possum abundance is potentially misleading because of significant but unknown variation in catchability.
5. Use of the removal method for monitoring is logistically demanding and there is a real risk that the method will fail if trapping intensity is inadequate or if insufficient nights are trapped. However, the data can always be used to calculate the trap-catch rate which, whilst potentially misleading, may be adequate for some purposes as an index of possum abundance.
6. There is no possum monitoring method available for use in all kokako study areas to allow unbiased comparison of possum abundance over time and between study areas. Given the problem with maintaining control blocks, a monitoring programme based on trapping sample areas and applied in a standard manner is the most appropriate approach.

7. ACKNOWLEDGEMENTS

Special thanks go to Doug Taucher who pulled together the team who got the traps and sets in place, organised the 1080 poison drops, did the pre- and post-poison trapping and collated the data for me to write up. Elaine Murphy, Keith Broome, John Innes and Chris Frampton provided constructive comments on the manuscript. Chris was particularly helpful with advice on statistics and discussion about monitoring methods and his input substantially improved the quality of this report.

8. REFERENCES

Batcheler, C L, Darwin, H, and Pracy, L T 1967.

Estimation of opossum (*Trichosurus vulpecula*) populations and results of poison trials from trapping data. *New Zealand of Science* 10(1): 97-114.

Blower, G J, Cook, L M, and Bishop, J A 1981. Estimating the size of animal populations. Allen & Unwin, London. 128 pp.

Hickling, G J 1989. An index of possum numbers from large-scale survey trapping. Unpublished report, Forest Research Institute, PO Box 31-011, Christchurch.

Innes, J G 1992. N.I. Kokako research for 1992/93 - an outline. Unpublished report to the Kokako Recovery Group, Department of Conservation, Wellington.

Innes, J G and Williams, D 1991. The impact of aerial 1080 poisoning on ship-rat populations at Mapara and Kaharoa. FRI contract report for Department of Conservation, Wellington.

Kelton, S 1989. The possum control salvage operation summer 1989. Unpublished report, Waikato Region, Department of Conservation.

Seber, G A F 1973. The estimation of animal abundance and related parameters. Charles Griffin, London. 506pp.

Speed H 1992. Quarterly report (January - March 1992) to Tasman Forestry Ltd. Research by Management programme at Kaharoa Forest. Unpublished report #9.

APPENDIX 1

Trap catch data: August 1990 pre-poison trapping (21, 22, 29 and 30 August)

Line	No. of Traps Set	Possums Caught	Traps sprung	N_t.Trap^{-1}
1+	10 (10) 10 10	1 (0) 2 3	1 (0) 0 0	1.38
2+	10 (10) 10 10	1 (0) 1 1	0 (0) 0 0	0.69
3+	10 (10) 10 10	0 (1) 0 2	0 (0) 0 0	0.46
4+	10 (10) 10 10	0 (0) 0 0	0 (0) 0 0	0.0
5	10 (10) 10 10	2 (0) 0 1	1 (0) 2 0	0.69
6+	10 (10) 10 10	0 (0) 0 0	0 (0) 0 0	0.0
7*	10 (10) 10 10	0 (0) 0 0	0 (0) 0 1	0.0
8	10 (10) 10 10	1 (0) 1 0	1 (0) 0 0	0.46
9	10 (10) 10 10	4 (1) 0 0	0 (0) 0 1	0.92
10*	10 (10) 10 10	2 (0) 1 1	1 (0) 1 0	0.92
11*	10 (10) 10 10	0 (0) 2 3	0 (0) 0 0	1.15
12+	10 (10) 10 10	0 (0) 1 0	0 (0) 0 0	0.23
13*	07 (07) 07 07	0 (1) 1 1	0 (0) 0 0	0.657
14	10 (10) 10 10	0 (0) 1 0	0 (0) 0 0	0.23
15	10 (10) 10 10	2 (1) 3 1	1 (0) 0 0	1.38
16	10 (10) 10 10	3 (2) 1 1	0 (0) 1 1	1.15
17	10 (10) 10 10	2 (0) 2 0	0 (1) 1 0	0.92
18	10 (10) 10 10	3 (2) 2 1	1 (0) 0 0	1.38
19	10 (10) 10 10	1 (0) 2 0	0 (0) 0 0	0.69
20	10 (10) 10 10	2 (1) 1 2	1 (0) 0 0	1.15
21	10 (10) 10 10	1 (0) 1 1	0 (0) 0 0	0.69
22*	10 (10) 10 10	2 (1) 1 2	1 (1) 0 0	1.15
23	10 (10) 10 10	2 (1) 2 1	0 (0) 0 0	1.15
24	10 (10) 10 10	2 (0) 3 2	0 (0) 0 0	1.61
25	10 (10) 10 10	3 (0) 2 2	0 (0) 1 0	1.61
26	10 (10) 10 10	0 (0) 0 1	0 (0) 0 0	0.23
27+	10 (10) 10 10	0 (0) 0 0	0 (0) 0 0	0.0
28+	10 (10) 10 10	0 (0) 0 0	0 (0) 0 0	0.0
29+	10 (10) 10 10	5 (0) 1 1	0 (0) 0 0	1.61
30+	10 (10) 10 10	2 (1) 0 0	1 (0) 1 0	0.46
31	10 (10) 10 10	1 (0) 1 2	0 (0) 1 0	0.92
	TOTALS:	42 (13) 32 29	**MEAN:** **95% CI:**	0.7705 $\pm$.192

\+ indicates Central Block lines trapped both in 1988 by contract trappers and in 1989 by DOC staff.

* indicates lines within ship rat control areas where incidental possum kills occurred.

NB Data in brackets were not used as it rained on this night.

Trap catch data: October 1990 post-poison trapping (9, 10 and 11 October)

Line	No. of Traps set	Possums caught	Traps sprung	N_r.Trap^{-1}
1+	10 10 10	1 0 0	0 0 0	0.167
2+	10 10 10	0 0 1	0 0 0	0.167
3+	10 10 10	0 0 0	0 0 0	0.0
4	10 10 10	1 1 0	1 0 0	0.334
5+	10 10 10	0 0 0	0 0 0	0.0
6+	10 10 10	0 0 0	0 0 0	0.0
7*	10 10 10	0 1 0	0 0 0	0.167
8	10 10 10	0 0 0	0 0 0	0.0
9	10 10 10	0 1 1	0 0 0	0.334
10*	10 10 10	2 0 0	0 0 0	0.334
11+	10 10 10	0 0 0	0 0 0	0.0
12*	10 10 10	0 0 0	0 0 0	0.0
13*	10 10 10	0 0 0	0 0 0	0.0
14	03 03 03	0 0 0	0 0 0	0.0
15	10 10 10	0 1 0	0 0 0	0.167
16	10 10 10	0 0 0	0 0 0	0.0
17+	10 10 10	0 0 0	0 0 0	0.0
18+	10 10 10	0 0 0	0 0 0	0.0
19+	10 10 10	1 1 1	1 0 0	0.501
20	10 10 10	0 0 0	0 0 0	0.0
21	10 10 10	0 1 1	0 0 0	0.334
22	10 10 10	0 0 0	0 0 0	0.0
23	10 10 10	1 0 1	0 0 1	0.334
24	10 10 10	2 0 0	0 0 0	0.334
25	10 10 10	1 0 0	0 0 0	0.167
26	10 10 10	1 2 0	0 0 0	0.501
27	10 10 10	0 0 0	0 0 0	0.0
28*	10 10 10	1 1 1	0 0 0	0.501
29	10 10 10	0 0 0	0 0 0	0.0
30	10 10 10	2 1 0	0 0 0	0.501
31	10 10 10	0 0 1	1 0 0	0.167
TOTALS:		13 10 07	**MEAN:** **95% CI:**	0.162 $\pm$.068

+ indicates Central Block lines trapped both in 1988 by contract trappers and in 1989 by DOC staff.

* indicates lines within ship rat control areas where incidental possum kills occurred.

Trap catch data: **August 1991 pre-poison trapping** (26, 27 and 28 August)

Line	No. of Traps set	Possums caught	Traps sprung	$N_t.Trap^{-1}$
1+	10 10 10	2 2 1	0 0 0	0.604
2+	10 10 10	1 1 0	1 0 1	0.242
3+	10 10 10	0 2 2	0 0 0	0.484
4+	10 10 10	1 1 0	0 0 0	0.242
5	10 10 10	0 0 0	0 0 0	0.0
6+	10 10 10	0 0 0	0 0 0	0.0
7*	10 10 10	0 0 0	0 0 0	0.0
8	10 10 10	0 0 0	0 0 0	0.0
9	10 10 10	3 1 0	0 0 0	0.484
10*	10 10 10	0 0 0	0 1 0	0.0
11*	10 10 10	2 3 1	0 0 0	0.725
12+	10 10 10	2 1 0	0 0 0	0.363
13*	10 10 10	0 0 1	0 0 0	0.121
14	10 10 10	3 3 0	0 1 1	0.725
15	10 10 10	2 1 0	0 0 0	0.363
16	10 10 10	0 0 0	0 0 0	0.0
17	8 8 8	0 0 0	0 0 0	0.0
18	9 9 9	1 0 0	1 0 0	0.134
19	7 7 7	1 1 0	0 0 0	0.345
20	10 10 10	0 1 1	0 1 0	0.242
21	10 10 10	3 1 2	0 1 0	0.725
22*	10 10 10	0 1 1	2 1 0	0.242
23	10 10 10	2 2 1	0 0 0	0.604
24	10 10 10	1 2 1	1 0 0	0.484
25	10 10 10	1 1 0	0 0 0	0.242
26	10 10 10	1 0 0	0 0 0	0.121
27+	10 10 10	3 0 2	0 0 0	0.604
28+	10 10 10	1 2 0	0 1 1	0.363
29+	10 10 10	1 0 2	0 0 0	0.363
TOTALS:		31 26 15	MEAN: 95% CI:	0.304 ±.093

+ indicates Central Block lines trapped both in 1988 by contract trappers and in 1989 by DOC staff.
* indicates lines within ship rat control areas where incidental possum kills occurred.

Trap catch data: November 1991 post-poison trapping (26, 27 and 28 November)

Line	No. of Traps set	Possums caught	Traps sprung	$N_i.Trap^{-1}$
1+	10 10 10	0 0 0	1 0 0	0.0
2*	10 10 10	0 3 0	1 1 1	0.469
3*	10 10 10	1 0 0	0 1 0	0.157
4	10 10 10	0 1 0	0 0 0	0.157
5+	10 10 10	1 0 0	0 0 0	0.157
6+	10 10 10	2 0 0	0 0 0	0.313
7*	10 10 10	1 1 1	0 0 0	0.469
8	10 10 10	2 0 0	0 0 0	0.313
9	10 10 10	1 1 0	0 0 0	0.313
10*	10 10 10	0 0 0	0 0 0	0.0
11+	10 10 10	0 0 0	0 0 0	0.0
12*	10 10 10	0 0 0	0 0 0	0.0
13*	10 10 10	0 0 0	0 1 0	0.0
14	10 10 10	1 0 0	0 0 0	0.157
15	10 10 10	0 1 0	1 0 0	0.157
16	10 10 10	1 1 2	0 0 0	0.626
17+	10 10 10	2 0 1	0 0 0	0.469
18+	10 10 10	2 0 0	0 0 1	0.313
19+	10 10 10	0 2 0	1 0 0	0.313
20	10 10 10	0 0 0	0 0 0	0.0
21	10 10 10	2 2 0	1 1 0	0.626
22	10 10 10	0 0 1	0 0 0	0.157
23	10 10 10	1 0 0	0 1 0	0.157
24	10 10 10	3 3 1	0 0 0	1.095
25	10 10 10	2 1 0	0 1 0	0.469
26	10 10 10	0 0 0	0 0 0	0.0
27	10 10 10	0 0 0	0 0 0	0.0
28*	10 10 10	1 1 0	1 1 1	0.313
29	10 10 10	0 0 0	0 0 1	0.0
TOTALS:		23 17 6	MEAN:	0.248
			95% CI:	±.097

+ indicates Central Block lines trapped both in 1988 by contract trappers and in 1989 by DOC staff.
* indicates lines within ship rat control areas where incidental possum kills occurred.

APPENDIX 2
Calculations

From Seber (1981) equation 7.24, probability of capture (P) is calculated thus:

$$P = \frac{3X - Y - (Y^2 + 6XY - 3X^2)^{0.5}}{2X}$$

where X = 2n1 + n2 and Y = n1 + n2 + n3. n1, n2 and n3 are numbers of possums caught on the first, second and third nights respectively.

The variance associated with P is defined by:

$$\frac{[P(1-P)]^2[1-(1-P)^3]}{\bar{N}(1-P)[1-(1-P)^3]^2 - [(3P)^2(1-P)^3]}$$

where $\hat{N}$ is the mean index of abundance as defined below.

The trap catch index (N_i) is:

$$\frac{C_i}{t_i(1-(1-P)_3}$$

N_i is the number of trappable possums per trap on line i.
t_i is the number of traps on line i
C_i is the total catch on line i
P is the probability of capture as above

The index of abundance ($\hat{N}$) is the mean number of trappable possums per trap, defined by:

$$\frac{\sum N_i}{\mathrm{T}}$$

where T is the total number of traps used in the survey: $\sum t_i$

The variance of $\hat{N}$ is:

$$\frac{\sum N_i^2 - \frac{(\sum N_i)^2}{\mathrm{T}}}{\mathrm{T} - 1}$$

Survival between two surveys is defined by:

$$\hat{N}_{post}/\hat{N}_{pre}$$

The variance associated with this estimate of survival is:

$$(\mathrm{var}N_{post}/\hat{N}_{pre}) + \left(\mathrm{var}N_{pre}(\hat{N}^2{}_{post}/\hat{N}^4{}_{pre})\right)$$

Kill = 1 - Survival

PRE-POISON AUGUST 1990

$X = 2\ (42) + 32 \quad = 116$
$Y = 42 + 32 + 29 \quad = 103$

$$P = \frac{348 - 103 - (10609 + 71688 - 40368)^{0.5}}{232} = 0.1734$$

$\hat{N}_{i}$ (Mean $\pm$ 95% CI) = 0.771 $\pm$ 0.192

POST-POISON OCTOBER 1990

$X = 2\ (13) + 10 \quad = 36$
$Y = 13 + 10 + 7 \quad = 30$

$$P = \frac{108 - 30 - (900 + 6480 - 3888)^{0.5}}{72} = 0.2626$$

$\hat{N}_{i}$ (Mean $\pm$ 95% CI) = 0.162 $\pm$ 0.068

PRE-POISON AUGUST 1991

$X = 2(31) + 26 = 88$
$Y = 31 + 26 + 15 = 72$

$$P = \frac{264 - 72 - (5184 + 38016 - 23232)^{0.5}}{176} = 0.288$$

$\hat{N}_{i}$ (Mean $\pm$ 95% CI) = 0.304 $\pm$ 0.093

POST-POISON NOVEMBER 1991

$X = 2(23) + 17 = 63$
$Y = 23 + 17 + 6 = 46$

$$P = \frac{189 - 46 - (2116 + 17388 - 11907)^{0.5}}{126} = 0.443$$

$\hat{N}_{i}$ (Mean $\pm$ 95% CI) = 0.257 $\pm$ 0.097