A review of possum monitoring in Waikato Conservancy

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1. Introduction

Most of the possum control undertaken by Waikato Conservancy is to maintain or rehabilitate forest condition. Some is undertaken for the protection of particular species (e.g. kokako at Mapara). Forest condition is therefore the ultimate indicator of possum control needs and success. The proximate measure is possum abundance and this is currently the performance measure for ground based and aerial control operations. Furthermore, the relationship between possum abundance and vegetation condition is not well understood and there is enormous public demand for information about the effect of control operations on possum abundance. The public tend to grasp the effectiveness concept in terms of "how many did they kill", so effectiveness information is usually expressed as percent reduction following a control operation. Consequently, possum monitoring is done for one of two purposes:

1. To measure the operational effectiveness of possum control projects;
2. To gauge the relationship between vegetation condition and possum abundance (damage threshold) in order to set operational targets and identify priorities for control.

Until very recently, there were no national DoC standards or guidelines for either possum monitoring or vegetation condition monitoring. However, there is a national policy on use of leghold traps which has major implications for possum monitoring. Last year Land Protection and Protected Species divisions introduced policy requiring all leghold traps set in areas with flightless birds to be raised at least 70 cm above ground to eliminate trapping risk (File Ref ANI 0051; 11 October 1995). In Waikato Conservancy, this applies primarily to kiwi areas on the Coromandel and possibly also Pureora North Block if recent reports of kiwi calls are confirmed. Since we have largely phased out use of traps in favour of bait stations for possum control, policy implications are confined to the possum monitoring component of Conservancy possum control projects. Pressing questions are:

1. what are the cost implications of using kiwi-safe traps for the possum monitoring component of control operations?
2. what are the implications for comparing possum trap catch data collected before and after policy implementation?
3. what can be done to enhance the rigour and efficiency of possum monitoring?
4. what is a useful (for management purposes) precision standard for possum monitoring?
5. what proportion of possum control budgets is cost effectively allocated to possum monitoring?

The first question was addressed by reviewing potential approaches to possum monitoring and then using a field comparison of ground set traps and traps raised at least 70 cm on purpose built plastic ramps. The second and third were addressed by analysis of statistical features of trap catch data. The costs of obtaining precision, and wrong decisions made because of low precision, were examined to answer the last two questions.

2. Possum monitoring methods

Monitoring objectives limit the range of monitoring methods to those which provide measures suitable for repeated comparisons over time and between places. This requirement eliminates faecal pellet counts, bait take methods, bait interference methods, spotlight counts and cyanide lines, which all vary with time and place for reasons other than variation in possum abundance. Use of non-treatment control areas at the same time can alleviate some problems with these methods, but there are significant ethical issues associated with maintenance of such areas. Thus only direct capture methods are suitable for monitoring possum abundance.

2.1 APPROACHES TO TRAP CATCH POSSUM MONITORING

The most rigorous index of possum abundance is obtained by repeated removal (Seber 1973; Blower et al 1981). This approach takes variation in catchability into account and so produces a measure which is directly related (i.e. proportional) to possum abundance. However, this requires intensive trapping effort (e.g. Stephens 1992) so that the catch declines by at least 50% and may not work when possum densities are low (so that capture becomes a rare event) or very high (so that effort is insufficient for catches to decline). Furthermore, this method requires that capture probability for possums is constant. However, the capture probability for individual possums increases as the cumulative catch rises and so violates the key assumption upon which the method is based (Barker and Warburton in press). Repeated removal is simply too expensive to use except in special circumstances. The next best approach is to use catch per unit effort as an index of abundance.

2.2 METHODS FOR THE CATCH PER UNIT EFFORT APPROACH

Catch per unit effort, or catch rate, is usually expressed as a percentage reflecting the number of possums caught per 100 trap nights (e.g. 5%, meaning the catch rate is 5 possums per 100 trap nights). This measure is not proportional to possum abundance because possum catchability decreases with population density (and varies with many other factors). So, other things being equal, an area with a catch rate of 5% has less than half the possum density as another area with a 10% catch rate. The actual form of the relationship between catch rate and possum abundance is unknown. So, while there is a sound basis for identifying differences in possum abundance, changes in abundance are unlikely to be equivalent to the measured change in catch rate. This is why estimates of the percentage reduction of a possum population are best obtained from repeated removal data. Estimates based on the pre- vs. post-operation change in trap catch rates will underestimate the actual proportion of the population killed by a control operation. Batcheler et al. (1967) attempted to address this.

2.3 TRAPPING METHODS USING ELEVATED SETS

There are at least five ways to raise traps beyond easy reach of flightless birds. These include putting traps on:

1. low branches, stumps, fallen trees and other naturally elevated positions;
2. ramps made from fallen branches, punga logs and other such naturally occurring materials;
3. purpose built platforms fixed to tree trunks;
4. purpose built ramps made from wooden boards;
5. purpose built ramps moulded in plastic.

The first two approaches are not appropriate for monitoring purposes because of the variability in capture probability caused by the variety of sets used. Platforms, wooden or plastic ramps provide desirable standardisation and so have potential from a theoretical perspective. Platforms seem practical logistically and were briefly used by West Coast Conservancy for possum control purposes before being abandoned (due to efficiency problems) in favour of aerial 1080. Traps set on wooden ramps may have better catch efficiency but the labour costs of placement and retrieval in the field are not attractive. Plastic ramps can be moulded to stack in a pack so that field logistics become more feasible, but some possums may be averse to climbing on plastic. The plastic ramps seem likely to offer the best solution for possum monitoring using elevated sets, so the catch efficiency of traps set on plastic ramps was compared with ground set traps, the potential to calibrate the two methods examined and the effort needed to maintain monitoring precision determined.

3. Efficiency of ground set traps and traps set on plastic ramps

3.1 INTRODUCTION

The common and widely held opinion of possum trappers is that ground set traps are the most effective way to catch possums. Consequently, this method has been the basis for the design of our possum monitoring. Standard procedure in Waikato Conservancy (based on Frampton 1994) has been to choose the location and orientation of lines primarily on the basis of logistic and access constraints and secondarily, to represent the habitats and communities present in the operational area. The number of traps used depends on the size and diversity of communities present. Lines of traps are set for three fine nights, spacing them at 20 m intervals on a best set basis within 5 m radius of the 20 m mark. Half a trap-night is subtracted from total number of trap-nights for each "set-off" or non-target catch. With the introduction of DoC trapping requirements, it is necessary to compare catch rates from raised traps on plastic ramps with catch rates from ground set traps, firstly to calibrate the two measures, and secondly to determine the sampling effort needed to obtain comparable precision for the abundance index.

3.2 PLASTIC RAMP DESIGN

The plastic ramps (Appendix 1) are rotation moulded two-piece box-section boards designed by Phil Thomson and Keith Broome. The upper part of the board has a 60 mm offset to the left where the Victor No. 1 leghold trap is located between lugs. The offset is designed to ensure the trap is appropriately located to catch the right front leg of a possum climbing the ramp. The larger, lower part of the board is stackable to maximise the number of ramps that can be carried in the field.

3.3 STUDY AREA

The trial was undertaken in early December 1995 by Kyle Chalmers in the North Block of Pureora Forest near Ngaroma Road (Appendix 2). This area was selected because of its proximity to Pureora Field Centre, ease of access and high possum density. There has been no possum control within this area over the last five years.

3.4 METHOD

Two hundred traps were located along six lines on plastic ramps and on the ground in approximately equal numbers, the choice (plastic ramp vs. ground set) at each trap site being made using odd and even numbers from a random

Number table. The trial used the standard trap monitoring procedure, as in 3.1 above. A lure of mixed flour, sugar and cloves was used.

Transects were established using compass and hipchain. The plastic ramp was leant against the tree, roughly at an angle of 30-35^{0} with the top nailed to the trunk. Trap chains were nailed into the tree as close to the ground as possible so that a caught possum could still reach the ground.

If traps were closed during the monitoring (due to unsuitable weather), the plastic ramps were left on the ground until monitoring started again. This was to ensure the presence of the plastic set did not influence possum behaviour in the interim (e.g. so possums do not get used to running up the ramps when the traps are closed).

3.5 RESULTS

3.5.1 Comparative logistics

Plastic ramps, although lighter than wooden ramps, are still very bulky and heavy to carry. Each weighs approximately 1200 grams. This has major implications for the amount of effort required for trap monitoring. Two people can comfortably carry enough traps and equipment to set up one line using ground sets. Only 7 plastic ramps can be carried in heavy bush by one person, thereby requiring at least five people or multiple trips to set up a line of 33 traps. Kyle Chalmers estimated the increase in effort required was between 250% and 350%, depending on the terrain.

3.5.2 Catch rate comparison

Catches in traps set on plastic ramps and traps set on the ground were:

Line 1: 18 plastic sets - 9 possums, 5 traps knocked off
15 ground sets - 21 possums, 3 traps sprung, 1 rat.

Line 2: 18 plastic sets - 10 possums, 3 traps knocked off
15 ground sets - 8 possums, 3 rats, 2 traps sprung.

Line 3: 20 plastic sets - 13 possums, 1 trap sprung, 5 traps knocked off
13 ground sets - 14 possums, 1 trap sprung.

Line 4: 16 plastic sets - 3 possums, 1 trap knocked off, 2 traps sprung
18 ground sets - 15 possums, 2 traps sprung.

Line 5: 14 plastic sets - 5 possums, 7 traps knocked off
20 ground sets - 9 possums, 3 traps sprung, 1 rat.

Line 6: 14 plastic sets - 6 possums, 3 traps knocked off
19 ground sets - 14 possums, 2 rats, 1 trap sprung.

Ground Sets: 81 possums; 290.5 trap-nights; catch rate 27.9%; 18 sprung.

Plastic Sets: 46 possums; 286.5 trap-nights; catch rate 16.1%; 24 "knock-offs"; 3 sprung.

The data suggest that there is a lower possum and rat catch rate and more "knock-offs" of traps on plastic ramps than on the ground. The number of traps knocked off the plastic ramps implies a design problem, although this may be misleading because "knock-offs" are not a possible outcome for ground set traps.

There are at least two fundamentally different ways to determine the statistical significance of the apparent difference in catch rates. The best approach (Table 1) is to treat each of the six lines as sample units yielding paired estimates of the catch rate for two different set types and use Student's t to test the null hypothesis that the mean difference between the catch rates for the two set types is zero. This test indicated a significant but lesser difference (Student's t = 2.733; p = .021). The power of this test is constrained by small sample size (n=6) and large variability between lines.

Another approach is to compare the two catch rates in a binomial comparative trial using the Chi-square test (with Haber correction for continuity) in a 2 x 2 contingency table. This test indicates a substantial difference between the two catch rates (χ^2 = 11.67; p< .001). However, the assumptions associated with binomial data are probably not met by trap catch data and p is almost certainly underestimated because catches in traps spaced only 10 to 30 metres apart along the same line are unlikely to be independent.

It may be that the difference in catch rates is not a consequence of aversion to plastic or the trap being elevated but merely a design problem with the plastic ramp leading to more sprung traps manifesting as "knock-offs". This was tested by repeating the analysis above after adjusting the plastic ramp catches on the basis that the number of sprung traps should be the same for traps set on both plastic ramps and on the ground. Since there were 18 sprung traps on the ground and 27 (24 "knock-offs" plus three sprung) it seems reasonable to assume that 9 of the 27 (i.e. 27 minus 18) represent possums which would have been caught had some design problem been rectified. The estimated catch for the plastic ramp sets on each line was:

Estimated catch = Possums caught + 9/27 x (No. of "knock-offs").

add the number of effective trap-nights:

Estimated effective trap-nights = Trap-sets x nights - (9/27 x (No. of "knock-offs"/2)).

This leads to a correct catch of 55 possums over 291 trap-nights giving a catch rate of 18.9% with 18 sprung traps. The Chi-square test indicates that this is still significantly (χ^2 = 6.49; .025>p>.O1) less than the ground set catch rate (27.9%). However, Student's t test indicates no significant difference (t=1.855; .2>p>.1). Thus it is possible that the lower catch rate of traps set on plastic ramps is caused by a design problem with the ramp as opposed to elevation of the trap or aversion to plastic.

Table 1. Catch rates for traps set on the ground and on plastic ramps.

	G Ground Sets	P Plastic Sets	G/P Ratio G/P	G–P Difference
	0.488	0.175	2.789	0.313
	0.188	0.190	0.989	-0.002
	0.364	0.228	1.596	0.136
	0.283	0.065	4.354	0.218
	0.155	0.130	1.192	0.025
	0.252	0.148	1.703	0.104
Mean =	0.28	0.156	2.104	0.132
Std Dev =	0.122	0.056	1.267	0.119
Coeff Var =	0.424	0.359		
Ratio G/P =	1.848		2.104	
Correlation (G/P)	0.294			
Std Err (G/P)	0.406		0.517	
Student's t =				2.733

3.5.3 Calibration catch rate data from ground set traps and traps on plastic ramps

The correction factor for converting plastic set trap-catch data to ground set data can be calculated three ways:

1. the mean ground set catch rate divided by the mean plastic set catch rate (0.288/0.156 = 1.848)
2. the mean ratio of ground set catches and plastic set catches for each line (2.104)
3. the total ground set catch rate divided by the total plastic set catch rate (27.9/16.1= 1.733).

The standard error of the first estimate (± .406) is smaller than for the second estimate (± .517), and is not readily calculated for the third estimate, which suggests that it is preferable to use the first method to calculate the correction factor. The correlation between the catch rates of the two set types (Figure 1) was weak (r = 0.294), indicating that ground set catch rates cannot be estimated from catches from traps set on plastic ramps with useful precision and major changes in possum abundance will be undetectable if the comparison is between catches from ground set traps and traps set on plastic ramps.

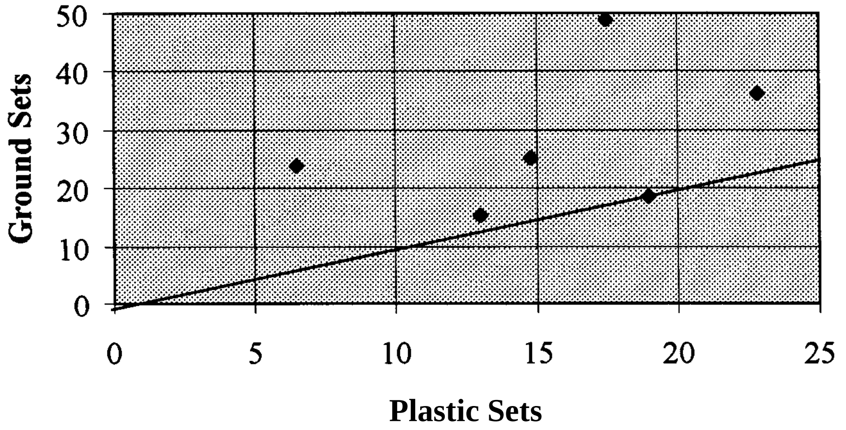

Figure 1. Catch rates along six trap-lines determined from ground set traps and traps set on plastic ramps. Equal catch efficiency is indicated by the sloping line.

4. Statistical features of trap-catch data

There are two possible outcomes for a trap: either a possum is caught or it is not. Therefore trap catch data is binary and may have a distribution akin to the binomial distribution. Binomial data come from trials which are:

1. independent (the outcome of any one trial is unrelated to the outcome of others), and
2. capture probabilities for each trial are the same.

Possum trap catch data are not entirely consistent with these two attributes of binomial data. Firstly, the outcome of a trap may not be independent of the outcome of other sets because a possum caught in one trap is not available to be caught in another, nor in the same trap on a subsequent night. Independence is also violated if the traps are arranged to form a line. Secondly, capture probabilities vary because possums are being removed and because possum density and activity is variable.

Alternative strategies to address this problem are to design the trapping protocols:

1. to minimise violation of assumptions required for binomial models.
2. to avoid assumptions required for binomial models.

Consideration of how to ensure trap data adequately represents the operational area is also needed.

4.1 STRATEGIES TO MINIMISE VIOLATION OF ASSUMPTIONS REQUIRED FOR BINOMIAL MODELS

Strategies to maintain the independence of trap outcomes include:

- space traps widely relative to possum density
- use many traps over few nights (not few traps for many nights)
- randomly locate individual traps rather than lines of traps
- express data in binary format (0 if no possums are captured and 1 if at least one is caught).

Strategies to minimise variation in the probability of capture include:

- standardising trap sets
- standardising weather conditions when traps are set
- standardising the seasonal timing of monitoring.

Even with these strategies in place, a key assumption needed for binomial statistics is violated: capture probabilities increase as the number of possums competing for traps declines as monitoring continues. In addition, patchily distributed possums will add to the heterogeneity of capture probabilities. Furthermore, the logistic difficulty of placing and servicing individual traps randomly located in the operational area render approaches based on binomial models highly impractical.

4.2 STRATEGY TO AVOID ASSUMPTIONS REQUIRED FOR BINOMIAL MODELS

If lines of traps are used as the sampling unit, the assumption is that catch rates of replicate lines randomly located in the operational area are normally distributed. Power to detect differences in catch rates depends on the number of trap lines and the variation between them. It is most efficient to use many lines of few traps and to standardise sets (as above) to minimise variation in capture probability unrelated to possum abundance. Further research is needed to determine the optimum number of lines, number of traps per line and spacing between traps to achieve specified precision. This is because precision depends on both within-line and between-line sources of variation as well as bias caused by trap saturation (Barker and Warburton in press). Maximum precision is therefore the optimum trade-off between traps per line, the number of lines and trap spacing. The optimum trade-off will vary with possum abundance and so will vary from place to place. Based on trap catch data given in Stephens (1992), the optimum number of traps per line is greater for low density possum populations than for moderate density populations. At least ten lines will be needed to achieve reasonable power to detect change in possum abundance.

4.3 SAMPLE REPRESENTATION

There is also opportunity to improve the extent to which monitoring represents the operational area. If the operational area has several distinct vegetation types, or altitudinal zones, then the trapping effort should be allocated to these in proportion to the area covered by each type. To achieve representation, it is more efficient to use more short lines (about 20 traps) than fewer but longer lines. More consideration could be given to formally randomising the location (start position) and orientation (compass bearing) of each line. The extent to which this is practical will depend on terrain and access. Best practice would probably be to first identify areas which are inaccessible and cannot be monitored and eliminate these at the outset. The monitoring then applies to the area which can be monitored and there is no claim that the whole area is being monitored. The second task is to choose line start locations (and possibly line orientation) at random (e.g. use random numbers to define first the start location and then the bearing).

4.4 WHAT LEVEL OF PRECISION IS REQUIRED FOR MANAGEMENT PURPOSES?

Selection of an appropriate standard of precision for management purposes is an important but difficult issue. The choice is first between a relative or absolute measure, then about the level of precision required. The precision of either type of measure depends upon the size of the proportion to which it will be applied. For example a relative confidence interval of ±50% of the estimate is much more precise in absolute terms for a 5% catch rate (i.e. 2.5% to 7.5%) than for a 50% catch rate (i.e. 25% to 75%). Conversely, for practical purposes, an absolute confidence interval of ±2% is more precise for a catch rate of 50% than for a catch rate of 5%.

Obvious ecological recovery from possum damage occurs at quite low catch rates (10% for moderately palatable plants; 5% for highly palatable indicator species; 1% for kokako; 0.5% for *Dactylanthus taylori*). Variation in possum abundance at these levels is therefore of significance for ecological management. Differences in the effects of abundant possum populations (catch rates >30%) are of little concern to conservation managers because they are all unacceptable. Therefore, high precision is important for management when catch rates are low (<10%) but not when catch rates are much greater. This has two important implications:

1. a relative standard for the desired level of precision is more useful than an absolute standard.
2. bias problems caused by trap saturation when possum abundance is high are not of concern from a management perspective.

The appropriate level of precision is a balance between the cost of obtaining precision and the cost of wrong decisions made because of low precision. In Waikato, most possum control is to enable palatable and particularly sensitive species to recover to a reasonably healthy state. Vegetation and species monitoring generally show that satisfactory canopy and emergent vegetation condition is associated with trap catch rates less than 10% and good condition is associated with trap catch rates less than 5%. Thus 5% is the target for most control operations and, ideally, payment for contractors would be based on achievement of the 5% trap catch rate. Thus monitoring should be designed to test the null hypothesis that the mean catch rate is >5%.

The cost of poor precision depends on the type of control operation (ground control methods or aerial 1080) and on whether the imprecision leads to wrongly identifying achievement or non-achievement of target. Because possum populations increase by up to 100% annually if immigration is significant, control programmes are on a 4 or 5 year cycle and an operation can be brought forward or delayed one or occasionally two years on the basis of possum numbers and vegetation condition. Bringing forward an operation is a cost, the amount being 20% or 25% of total operational cost for a one year shift in a 4 or 5 year operational cycle respectively.

For both ground control and aerial 1080, the cost of wrongly identifying achievement of target is ecological damage from excessive possum numbers because (without forest condition monitoring) there is no basis for identifying the need to bring the next operation forward to prevent this. Although the currency of the cost is ecological, and assuming there is no irretrievable biodiversity loss, then the dollar cost is probably the same: 20% or 25% of operational cost. The cost of wrongly identifying non-achievement of target for ground control operations is comparatively minor, being confined to an unnecessarily prolonged operation and repeated monitoring, which is unlikely to exceed 10% of operational cost. Furthermore, the cost of imprecision is carried by contractors if we assume the operation failed and test the null hypothesis that the catch rate is greater than the target. In contrast, for an aerial 1080 operation the cost is of needlessly bringing forward the next operation, and is carried by the Department.

The present failure rate (i.e. targets not achieved) of possum control operations is about 1 in 5. This suggests that for any operation, the risk of failure is about 20%.

A precision of ±50% of the 5% target (i.e. a confidence interval from 2.5% to 7.5%) should eliminate both ecological damage and the risk of having to bring the next control operation forward. Similarly, if possum control is to enable kokako to breed successfully, then the target for control would be a catch rate of 0.5% and the desired confidence interval for performance monitoring would be around 0.25% to 0.75% - also a precision of ±50% of the target.Thus a relative measure of precision (95% confidence interval) at around ±50% of the target is an appropriate precision standard for management purposes. Vegetation monitoring also contributes to the reduction of costs associated with wrong decisions. Therefore, investment in such possum monitoring precision is cost effective if this plus vegetation monitoring can eliminate the risk of wrong decisions for less than about 4% or 5% of the cost of the operation (i.e. 20% or 25% of cost times the 20% risk of failure).

4.5 ESTIMATION OF EFFORT REQUIRED TO ACHIEVE A GIVEN PRECISION STANDARD

Estimation of trapping effort needed for a particular level of precision using lines of traps as the primary sampling unit is confounded by the interaction of possum abundance, number of trap lines, the number of traps per line and the spacing of traps along the line. However, assuming, for the purposes of the argument which follows, that possum trap catch data has a binomial distribution, an optimistic estimate of the trapping effort required to achieve a given level of precision is given by:

$$n = (Z^2_{\alpha(2)}(p(1 - p)))/\delta^2.$$

Where n is the number of trap nights required
p is the proportion of traps which catch a possum
δ is the target error limit
$Z_{\alpha(2)}$ is the two-tailed normal deviate at probability level α

So, on the basis of the ±50% of target precision standard, 292 trap-nights will be needed for a target catch rate of around 5% with an approximate confidence interval from about 2.5% to 7.5%. However, if the target catch rate is only 2.5%, then 599 trap-nights are required to achieve the same level of precision (i.e. 95% confidence interval not more than ±50% of the estimate). This shows the importance of using efficient trapping methods to minimise the effort (= cost) needed to achieve a given precision.

A more precise estimate of the confidence limits (Zar 1996) around the catch rate estimate can be calculated from:

$$L_l = X/(X + ((n - X + 1)F_{\alpha(2),\nu 1,\nu 2}))$$

where L_l is the lower confidence limit
X is the number of traps which caught a possum
n is the total number of trap nights
F is the two-tailed value from the F distribution at probability a with numerator degrees of freedom (df) ν_1 and denominator df ν_2
$\nu_1 = 2(n - X + 1)$ and $\nu_2 = 2X$

$$L_u = (F_{\alpha(2),\nu' 1,\nu' 2}(X + 1))/(n - X + F_{\alpha(2),\nu' 1,\nu' 2}(X + 1))$$

where L_u is the upper confidence limit and X, n, and F are as above
$\nu'_1 = 2(X + 1)$ and $\nu'_2 = 2(n - X)$

The lower 95% confidence limit on a 5% catch rate from 300 trap-nights is 2.8% and the upper limit is 8.2%. Note that these limits are asymmetric, and that they represent a best case scenario because trap catch data are inadequately modelled using the binomial distribution.

4.6 INTERPRETATION OF DATA FROM GROUND SET TRAPS AND TRAPS SET ON PLASTIC RAMPS

Following a change of monitoring methods there will be a need to compare data obtained using both methods.This will require use of a conversion facfor obtained by calibration of the two methods as in section 3.5.3. The conversion factor is an estimated value and so will contribute error, further reducing the power of detection of difference between mean catch rates.

Consider the hypothetical situation, perhaps before and after a long term, low intensity bait station operation, where the first survey based on 300 ground set trap-nights gave a catch rate of 25% and a second 300 trap-night survey using plastic ramps, yielded a 5% catch rate, perhaps reflecting a more than five-fold change in possum abundance. Are the catch rates the same and can the monitoring procedure detect a change of this magnitude?

The 95% confidence interval for the first survey ranges from 20.7% to 30.3%, and for the second survey, after conversion to "ground set" catch rates (as in paragraph 3.5.3 above), ranges from 2.3% to 26.3%. The ranges overlap, so there is no basis for concluding that possum abundance has changed and it is clear that this monitoring procedure is not powerful enough to detect a five-fold change in possum abundance. However, had ground set traps been used for both surveys, the catch rate on the second survey would have been 9.2%, the 95% confidence interval from 6.3% to 13.0%. The ranges do not overlap (even at $p=0.001$) and so it is reasonable to conclude that possum abundance changed.

Thus a change from traps set on the ground to traps set on plastic ramps will mean that monitoring programmes designed (and budgeted) to detect a 50% change in catch rates will only be able to detect changes greater than about five-fold. This will not avoid wrong decisions about the planning and management of possum control operations.

This is a best case scenario because, as explained in sections 4.0 and 4.1, trap catch data are inadequately modelled by the binomial distribution. The effect of the violated assumptions is underestimation of both p and the size of the confidence interval around catch rate estimates.

5. Discussion

5.1 WHAT LEVEL OF INVESTMENT IN MONITORING IS APPROPRIATE?

Possum control is done to maintain or rehabilitate forest condition and/or the viability of species populations. Possum monitoring is needed to make short term, operational decisions about possum control operations. It has little relevance for determining the extent that objectives for possum control have been achieved. Achievement of control objectives is indicated by the condition of forest and/or the status of particular species populations. So, from an operational perspective, the cost effective level of investment in possum monitoring is determined by the cost of wrong decisions and the risk of making a wrong decision. This seems to be around 5% of the operational cost.

Possum monitoring is useful for other purposes and so has additional value. These other purposes include:

- Understanding the relationship between possum abundance and the condition or status of particular species. This information is needed to define operational targets and so is an "overhead" cost on control operations.

- Public information. The public and their representatives tend to be much more focused on the kill achieved by an operation than on the effects of the operation. There is public relations value in supplying the demand for this information which goes beyond the requirements of possum control objectives. However, precision is not as important for this purpose as it is for operational and understanding purposes.

- Improvement of operational effectiveness. Refinement of control operations is ongoing with development of navigational equipment, improved spreaders, baits, bait stations, lures, toxins, traps, novel killing devices, etc. Possum monitoring is needed to evaluate the effectiveness of these innovations and so is also an overhead cost on control operations.

How to value possum monitoring for these other purposes is unclear. On the basis of "willingness to pay", local staff feel comfortable with spending up to 15% of operational budget on monitoring, but balk at more than 20%. If the operational management value of monitoring is around 5%, then this implies that these other purposes are worth 10% but not more than 15% of operational cost.

5.2 GROUND SET TRAPS AND TRAPS SET ON PLASTIC RAMPS - COMPARING COSTS

Plastic ramps, although lighter than wooden ramps, are still very bulky (720 mm x 180 mm x 55 mm) and heavy (1.2 kg) to carry. On the basis of Kyle Chalmers' comments, the cost per trap of placing plastic ramps is about 3 times greater than for ground sets.

Since the catch efficiency of traps on plastic ramps is lower, more trapping effort is required to obtain a given level of precision. The 5% ground set catch rate is about equivalent to a 2.7% catch rate using plastic ramps:

$$5\ \%\ \text{ground set catch rate} / 1.848 = 2.7\%\ \text{plastic ramp catch rate}$$

To get precision of ±50% of the estimate, then 554 plastic ramp trap-nights will be required compared with 292 for ground set traps. The total increase in effort is:

$$3 \times 554/292 = 5.7$$

Maintenance of current precision for our possum abundance monitoring using plastic ramps will cost 5.7 times as much, without taking into account the one-off cost of plastic ramps. If plastic ramp catch rate data are to be compared with ground set baseline data, there will also be about a ten fold reduction in the ability of the monitoring procedure to detect change.

The approximate costs of trap monitoring are:

Ground Set Traps (300 trap nights required)

6 person days @ $150/day work = $900 x 1.3 (weather factor)	$1170
Materials (lure and tape etc.)	$30
1 person day (@ $150/day planning and write up)	$150
TOTAL	$1350

Traps Set on Plastic Ramps (600 trap nights required)

36 person days @ $150/day = $5400 x 1.3 (weather factor)	$7020
Materials (lure and tape etc.)	$60
1 person day (@ $150/day planning and write up)	$150
TOTAL	$7230

$150 per person/day covers costs of transport, leave, allowances etc.

The cost for plastic set monitoring does not include the actual cost of the plastic sets.

The change to plastic ramps will increase both the total cost of control operations and the proportion of the total budget used for the possum monitoring component. For example, the budgeted cost of the Moehau operation ($141,000) will have to increase to $170,400 to accommodate use of plastic ramps and the possum monitoring component of the budget will increase from 4.8% to 21.2% if the sensitivity of the monitoring programme is to be maintained. Similarly, the Papa Aroha operation ($52,100) will have to increase to $69,700 with the monitoring component of budget increasing from 7.8% to 31.1% and the Central Coromandel operation ($248,700) increases to $289,900 with monitoring increasing from 3.8% to 20.4%. In addition, the sensitivity of comparison with the ground set trap catch data gathered to date would not be recoverable. Note that in each case monitoring costs would exceed the 15% of budget threshold. It would therefore be more cost effective to carry the risk (and costs) of wrong management decisions and forego the other benefits than to do possum abundance monitoring.

5.3 RISKS, KIWI AND OPPORTUNITY COSTS

To date there have been about 564,065 ground set trap-nights (Leigh 1995) within the Coromandel and ten kiwi were reported (Conservancy file BIR 010) to have been caught (Table 2). That is 56,407 trap-nights per kiwi caught.

Table 2. Possum trapping effort on the Coromandel Peninsula and numbers of kiwi captured.

Area	Trap-nights	Reported Kiwi caught
Moehau 1989-93 (DOC hunters)	532,413*	7
Papa Aroha 1993-4 (Contract hunters)	17,450	3
Monitoring Kennedy Bay, Papa Aroha, Moehau and Central Coromandel 1993-6 (DOC hunters)	14,202	0
TOTAL	564,065	10

* Note: An additional 124,375 trap-nights of possum control by contract trappers in 1993-5 has been excluded. No kiwi captures were reported but there is no basis for confidence that none were caught.

Assuming an annual monitoring effort of 3000 trap-nights over Coromandel operational areas and that kiwi abundance remains constant, it will take 18.8 years to accumulate enough trapping effort to probably catch one kiwi and $253,800 will have been spent on ground set trap monitoring. If plastic ramps are used to avoid catching this one kiwi, the total cost would be $1,359,240, the additional cost being $1,105,440 (Table 3).

Table 3. Comparison of the costs and effort required to monitor possum abundance on the Coromandel Peninsula with a precision of ±50% of the estimate.

Set Type	Annual Trap-nights	Annual Cost	Cost over 18.8 years
Ground	3000	$13,500	$253,800
Plastic ramp	6000	$72,300	$1,259,240
		Difference	$1,105,440

Implementation of leghold trapping policy in kiwi areas will cost Waikato Conservancy $1.1 million ($58.8k annually) over nearly 19 years to prevent the death of one kiwi. It will also result in the loss of much of the intended use of the Conservancy's baseline possum catch rate data. Is this justifiable in terms of conservation output and the political focus on the Department's efficiency and accountability? Could kiwi gain greater benefits over a 18.8 year period if Waikato Conservancy spent around $55.8k annually on kiwi in some other way?

5.4 STRATEGIC DIRECTION: WHERE TO FROM HERE?

Possum control performance monitoring should address the question "To what extent have control objectives been met?" Forest condition or species monitoring - not possum monitoring - is required for this. Ideally, methods for assessment should be sufficiently rapid, precise and cost effective to also serve the needs of operational management and so obviate the need for possum monitoring. However, this is not the present situation. There are no national standards for forest condition monitoring. A high skill level is required, key methods are prohibitively expensive (e.g. exclosure plots) and affordable measures provide only an assessment (cf. measurement) of forest condition.

At present, with the public demand for reporting on the kill rates achieved by particular control operations, with the accelerating development of more effective ways to control possums and the lack of knowledge about operational targets, there is a real need for possum monitoring. However, in time the public focus should shift to reporting on achievement of control objectives, there should be a sound basis for identification of operational targets and enough confidence in control methods to render possum monitoring generally redundant.

An appropriate strategy would seem to be:

1. Improve the precision of possum monitoring within the limits of cost effectiveness.

2. Set national standards for possum monitoring.

3. Commission research to determine the sampling effort (i.e. number of lines; traps per line; trap spacing) needed to obtain a specified level of precision for catch rate estimates.

4. Do possum monitoring only for operations where risks and information needs require it.

5. Develop techniques for suitably precise, cost effective, reproducible forest condition measurement.

6. Set national standards for forest condition monitoring.

Encourage a shift from possum monitoring to forest condition monitoring as the need for the former diminishes and suitable techniques for the latter become available.

6. Summary and conclusions

A national policy requires all leghold traps set in areas with flightless birds to be raised 70 cm above the ground. This has major implications for possum monitoring.

Waikato Conservancy tested the use of plastic ramps to raise traps beyond easy reach of flightless birds. Plastic ramps can be moulded to stack in a pack so that field logistics become more feasible, but some possums may be averse to climbing on plastic. A purpose built plastic ramp merited evaluation as it may offer the best solution for possum monitoring using elevated sets.

The increase in effort required to use sets on plastic ramps was between 250% and 350%, depending on the terrain. The cost of obtaining precision on catch rate estimates falls with increasing efficiency of the trapping method. The catch efficiency of ground set traps is significantly greater than the efficiency of traps set on plastic ramps. Possible reasons for this include:

- aversion to the plastic ramp;
- elevation of the trap;
- design problems with the set causing "knock-offs".

It is possible that the lower catch rate of the sets on plastic ramps is caused by a design problem with the set as opposed to elevation of the trap or aversion to the plastic ramp.

Calibration of catch rates obtained using the two methods is too imprecise to be useful. The compounded errors of catch rate estimation and conversion result in 300 trap-night monitoring being insufficiently sensitive to detect changes in catch rate smaller than five-fold.

To maintain the present level of possum monitoring precision using sets on plastic ramps will cost 5.7 times as much, without taking into account the one-off cost of the ramps. If catch rate data from traps set on plastic ramps is to be compared with ground set baseline data, there will also be about a tenfold reduction in the ability of the monitoring procedure to detect change.

There is significant opportunity to improve standard possum monitoring practice to better represent the operational area and better match the design of possum trapping to the assumptions required by the statistical models used to detect differences.

High precision is important for management when catch rates are small but not when they are large. Therefore, a relative standard for the desired level of precision is more useful than an absolute standard. The appropriate level of precision is a balance between the cost of obtaining precision and the cost of wrong decisions made because of low precision. A relative measure of precision (95% confidence interval) at around ±50% of the estimated catch rate seems to be an appropriate precision standard for management purposes. This should eliminate both the risk of ecological damage and the risk of having to bring the next control operation forward. Investment in such monitoring precision as well as vegetation condition monitoring is cost effective for operational management as well as other purposes if together they can eliminate these risks for less than about 15% of the cost of the operation.

The change to traps set on plastic ramps will increase both the total cost of control operations and the proportion of the total budget used for the possum monitoring component. Investment in ground set trap monitoring is clearly cost effective at around 5% of total operational cost. If the leghold trap policy were implemented on the Coromandel, monitoring costs would exceed 20% of budget in all cases. It would be much more cost effective to carry the risk (and costs) of wrong management decisions than to do possum monitoring for the purpose of guiding management decisions.

If Waikato Conservancy were to implement the leghold trap policy using plastic sets then the Conservancy would spend $1.1 million ($58.8k annually) over 18.8 years to prevent the capture of one kiwi, as well as losing much of the intended use of its baseline possum catch rate data.

6.1 RECOMMENDATIONS

1. That the Department establish a threshold level of risk and cost at which the leghold trap policy comes into effect.
2. That the Department research and develop alternative kiwi-safe methods for monitoring possum abundance, and that these be calibrated with existing methods to enable comparison with historical data.
3. In the interim, the Department undertake a comparative trial to establish the relative costs and catch efficiencies of platform sets; sets on wooden ramps; sets on plastic ramps; ground sets and any other trap ping methods which might be appropriate for elimination of risk to flightless birds.
4. That the Department further develop standard procedures for possum monitoring that provide the precision required, and that minimise the violation of assumptions required for formal hypothesis testing procedures.
5. That the Department develop national standards for vegetation monitoring, addressing issues of reproducibility, precision and cost.
6. That the Department note, in the longer term, performance monitoring should be based on forest condition rather than possum abundance.

7. Acknowledgements

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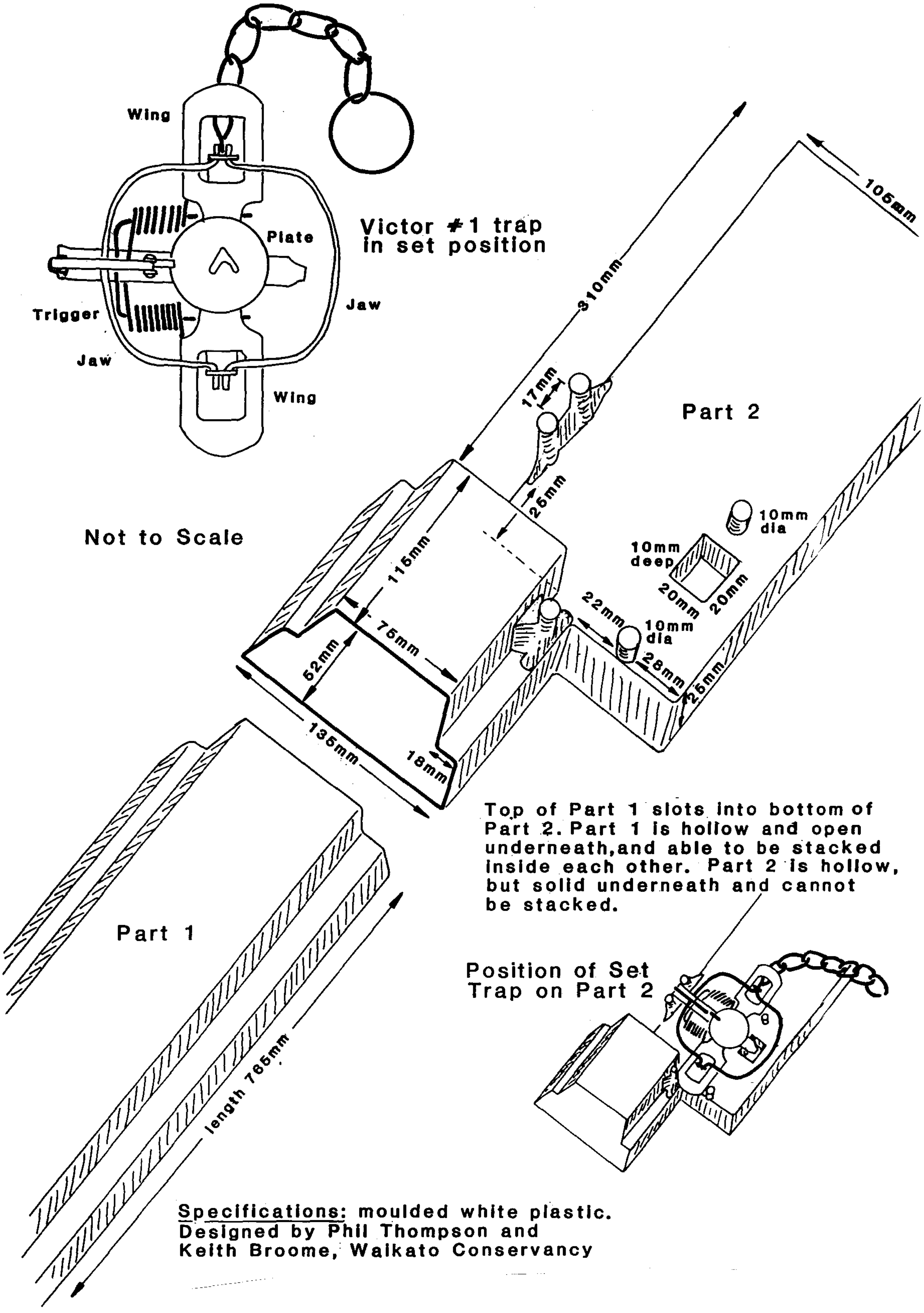
Appendix 1. Plastic ramp with leghold trap.



Top of Part 1 slots into bottom of Part 2. Part 1 is hollow and open underneath, and able to be stacked inside each other. Part 2 is hollow, but solid underneath and cannot be stacked.

Specifications: moulded white plastic.
Designed by Phil Thompson and
Keith Broome, Waikato Conservancy

Appendix 2. Location of trap monitoring lines, Pureora Forest Park.