Monitoring the impacts of vertebrate pest control operations on non-target wildlife species

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CONTENTS

Abstract

This publication gives protocols for determining bait quality, monitoring the impacts of pest control operations on populations of non-target species (birds, bats, reptiles, frogs, fish, and invertebrates), and collecting tissues from dead animals and samples of water for toxicity testing. Some of the protocols are still being developed (e.g. protocols for monitoring bats and frogs). Users of these protocols should consult with relevant experts before starting a monitoring programme. We recommend that the Department of Conservation call meetings of relevant experts to finalise the development of standard methods for monitoring the population trends of various wildlife species.

Keywords: pest control, 1080 poisoning, brodifacoum, monitoring, non-target species, birds, bats, reptiles, frogs, fish, invertebrates, water samples

1. Introduction

A recent review (Spurr & Powlesland 1997) highlighted the need for protocols for monitoring the impacts (costs and benefits) of aerial 1080-poisoning operations for control of the brushtail possum (*Trichosurus vulpecula*) on populations of non-target wildlife species. There is also a need for protocols for monitoring the impacts of other poisons for control of other pests (e.g. the impacts of brodifacoum-poisoning operations for eradication of rodents on non-target wildlife species on offshore islands), and for monitoring the impacts of ongoing pest control using a variety of methods in mainland islands. These protocols should be used in conjunction with the Vertebrate Pest Control Manual (Haydock & Eason 1997) and Best Current Practices in Sequential Use of Possum Baits (Henderson et al. 1998), which describe the properties of different poisons and protocols for carrying out pest control operations. The protocols will need reviewing and updating as methods develop.

2. Bait quality

Aspects of bait quality that affect non-target species include factors such as bait size, toxicant concentration, colour, cinnamon concentration, and hardness. For example, baits containing a lot of small pieces ('chaff' or 'dust') pose a risk to small forest birds (Harrison 1978; Powlesland et al. 1999). Baits containing 1080 are dyed green to reduce their attractiveness to birds (Caithness & Williams 1971). Cinnamon oil is added to baits partly to mask the smell and taste of 1080 to possums (Morgan 1990) and partly to repel birds (Udy and Pracy 1981). Specifications for these factors are given in the Vertebrate Pest Control Manual (Haydock & Eason 1997). Baits should be checked that they meet these specifications before they are applied in the field (see below). Toxicant concentration may also be checked at various times after the bait has been applied in the field (e.g. to determine whether the bait is still toxic to non-target species). When handling toxic baits follow the appropriate Health and Safety procedures for handling pesticides (e.g. wear gloves). When transporting toxic baits refer to the relevant Standard Operating Procedures (e.g. baits need to be securely held, not in the driver's cabin, attended to at all times, kept separate from food and drink, and accounted for). The following instructions were adapted from G.R.G. Wright (Landcare Research pers. comm.).

2.1 FRESH BAIT

2.1.1 Carrot bait

Carrot bait containing 1080 should be checked for size, toxicant concentration, colour, and cinnamon concentration. Samples of bait should be collected on the

day of the poisoning operation, before the bait is loaded into the aircraft. Collect 1 kg of bait at the beginning and after every 10 tonne of bait has been processed. Place the samples in plastic bags and either snap shut or tie with a plastic tie or rubber band. Do not knot the bag. Each sample should be labelled externally with at least bait type, location, date, and time of day. It is better to use an attached label than rely on marking the plastic bag directly. Use a waterproof label and waterproof marking pen. Pencil, though waterproof, should not be used because it is not easy to read if the labels become wet.

Samples of bait should be sent as soon as possible by door-to-door ground transport to the Toxicology Laboratory, Landcare Research, Gerald St, Lincoln, for analysis. Ground transport has less stringent packaging requirements and is cheaper than air transport. Note, however, that courier firms use air links and are subject to the International Air Transport Association (IATA) Dangerous Goods Regulations. Contact the Toxicology Laboratory well in advance so that preparations can be made for analysing your samples. When transporting 1080 bait samples by land, you are required to fill out a Dangerous Goods Declaration (Form NZS 5433:1988) (Table 1). If samples cannot be sent immediately, they should be frozen as soon as possible, and stored frozen until they can be sent. Specify which tests you require (e.g. bait size distribution, 1080 concentration, colour, and cinnamon concentration). Because baits are collected on the day of poisoning, the results will be an a posteriori analysis.

TABLE 1. INFORMATION NEEDED FOR FILLING OUT A DANGEROUS GOODS DECLARATION (FORM NZS 5433:1988).

HEADING	INFORMATION NEEDED
Proper Shipping Name	Pesticides, solid, n.o.s. (sodium monofluoroacetate, 0.15%)
Common Name	1080 bait, 0.15%
Hazard Class	6.1
UN No.	2588
Hazchem Code	2X
Packing Group	III
Other Information	Toxic

n.o.s. = 'not otherwise specified'

2.1.2   Cereal-based bait

Cereal-based baits containing 1080, procured from Animal Control Products Ltd by the Department of Conservation or the Animal Health Board, are audited in the factory by MAF Quality Management for bait size, dust content, and 1080 concentration, according to the 'Draft protocol for 1080 pellet audits of Animal Control Products—Issue 2, June 1995'. In addition, baits should be checked independently for colour, cinnamon concentration, and general condition (e.g. hardness and mouldiness). Recent research has shown that cinnamon concentration in cereal-based baits declines rapidly even in unopened bags (R.J. Henderson, Landcare Research pers. comm.). Hardness influences the amount of fragmentation of baits in the hopper or sowing bucket, or as they descend

through the forest canopy to the ground. Methods of measuring hardness are still being developed. Samples of 1 kg of bait should be collected from four bags selected at random, and sent to the Toxicology Laboratory, Landcare Research, Gerald St, Lincoln. Specify which tests you require (e.g. colour, cinnamon concentration). A Dangerous Goods Declaration (Form NZS 5433:1988) is required, as above, when transporting baits containing 1080.

Cereal-based baits containing brodifacoum, pindone, or cholecalciferol should also be checked to determine whether they meet specifications. This analysis can be done at the Toxicology Laboratory, Landcare Research, Gerald St, Lincoln. The Hazard Class, UN No.; Hazchem Code, and Packing Group for transportation of these baits have not been allocated.

2.2   WEATHERED BAIT

Samples of weathered baits (carrots and cereal-based baits) are sometimes collected from the field to assess residual concentrations of toxicants. A total of 10–50 g of bait is required for a single analysis. Each sample should be put into a separate plastic bag or container, and labelled with bait type, location, and date. The samples should be sent by the quickest method of ground transport to the Toxicology Laboratory, Landcare Research, Gerald St, Lincoln, using the same transport details as for fresh bait. If the samples cannot be sent immediately, they should be stored in a freezer until they can be sent. A Dangerous Goods Declaration (Form NZS 5433:1988) is required, as above, for any baits containing 1080.

2.3   INTERPRETATION OF RESULTS

The report from Landcare Research will state the mean and 95% confidence limits of the toxicant concentration in the baits, plus the limits of detection. If requested, the bait size distribution, cinnamon concentration, etc. will also be given. These data can be compared to the bait specifications given in the Vertebrate Pest Control Manual (Haydock & Eason 1997).

3. Monitoring impacts on non-target species

Issues to consider when planning to monitor the impacts of vertebrate pest control operations on non-target species include experimental design, replication, randomness, power, and methods of analysis. As a general rule, a biometrician should always be consulted when planning a monitoring programme.

3.1 EXPERIMENTAL DESIGN

The experimental design should be appropriate to the situation. The best design for monitoring the impacts of a treatment such as vertebrate pest control on non-target species is to measure the population density (or an index of population density) of the non-target species in treatment and non-treatment areas before and after treatment is applied in the treatment area (Green 1979). The sampling plots (or lines) should be randomly located within each area, or within strata within each area (i.e. stratified random sampling). If possible, measurements should be made at the same plots (or lines) after treatment as before treatment. This design assumes that the trends in non-target species populations in the two areas would, in the absence of treatment, change in a similar way with time. The design has been used extensively to monitor the effects of vertebrate pest control on bird populations in mainland forests (e.g. Spurr 1981, 1988, 1991; Powlesland et al. 1999).

An alternative design is to measure populations before and after treatment only in the treatment area (i.e. there is no non-treatment area). This assumes that there are no natural changes with time (e.g. no seasonal changes in behaviour and no differences in weather) that might affect population estimation (from counting or trapping animals). This design has been used to monitor the effects of vertebrate pest control on bird populations on offshore islands where it is difficult to establish non-treatment areas (e.g. Miller & Anderson 1992; Robertson et al. 1993; Towns et al. 1993; Empson & Miskelly 1999; Robertson & Colbourne in press).

Another design is to measure populations in treatment and non-treatment areas only after treatment has been applied (i.e. there is no before-treatment assessment). This design assumes that the populations in the two areas were similar before treatment. It has not been used yet to measure the impacts of vertebrate pest control on non-target species.

3.2 REPLICATION AND RANDOMNESS OF TREATMENT ALLOCATION

To be able to generalise the results, a minimum of two replicates is required (i.e. at least two treatment areas and/or two non-treatments areas). Plots (or lines) within treatment and non-treatment areas are not replicates but are sub-samples (or pseudo-replicates in the sense of Hurlbert 1984), and are used to obtain a more accurate population estimate in each area. True replicates are different pest control operations that occur at the same time and that use the same bait type, toxicant concentration, application rate, etc. However, this is usually not possible when assessing the impact of vertebrate pest control. There is usually only one control operation to assess at a time. Consequently, the results apply only to that control operation.

To be statistically valid, in addition to replication, the area(s) receiving treatment should be assigned at random. Again, this is not possible for vertebrate pest control. The areas receiving treatment are always 'selected' because of high pest numbers. Non-treatment areas usually have lower pest

numbers. This cannot be avoided. Nevertheless, non-treatment areas should be selected with habitat and wildlife as similar as possible to the treatment areas.

In the following sections, it is assumed that there is only one treatment and one non-treatment area, that the treatment area is not randomly selected, that plots (or lines) within areas are randomly located, and that both treatment and non-treatment areas are monitored before and after pest control.

3.3 POWER

If data are available from previous surveys using the same techniques, then a priori power analyses should be done to determine the power of the proposed survey to detect a given change in population abundance, should one occur, or to determine the number of samples required to detect a given change in population abundance for a given power (Green 1994). If previous data are not available, the new data obtained should be used to determine the sample sizes required (for a given power) to detect changes in population abundance in future surveys.

If the data are discrete (e.g. the number of animals observed alive before and after treatment), the power to detect a reduction in survival is related to the sample size. Thus, if 25 animals are observed alive before treatment, there is an 80% chance, at the 95% level of statistical probability, of discriminating a 30% reduction in survival, if a population difference exists (Table 2). The power to detect a difference in survival between treatment and non-treatment areas is also related to the sample size. Thus, if 25 animals are observed alive in each area before treatment, there is an 80% chance, at the 95% level of statistical probability, of discriminating a 30% difference between survival in the treatment area and the non-treatment area (e.g. between 90% survival and 60% survival), if a difference exists.

A problem with deciding what power (and sample size) is appropriate is that the population change that might affect long-term population survival is probably unknown for any species. The technical addenda being prepared for the kokako recovery plan considers this problem for kokako (J. Innes pers. comm.).

TABLE 2. PERCENT REDUCTION DETECTABLE, IN RELATION TO SAMPLE SIZE, AT THE 95% LEVEL OF STATISTICAL PROBABILITY AND GIVEN AN 80% CHANCE OF DETECTING A REDUCTION SHOULD ONE OCCUR (ELASHOFF 1997).

NUMBER OF ANIMALS IN SAMPLE	MINIMUM DETECTABLE % REDUCTION
10	60
12	50
16	40
23	30
37	20
77	10

3.4 STATISTICAL ANALYSIS

3.4.1 Comparison of population trends in treatment and non-treatment areas

Where there is replication of treatments, and random allocation of which areas are treatment areas and which are non-treatment areas, and where measurements of non-target species populations in the treatment and non-treatment areas are repeated at the same plots before and after treatment, the appropriate test to determine the impact of treatment is the repeated measures analysis of variance (Green 1993). The test can be done using a statistical package such as SYSTAT® (SPSS 1996). The data should be checked for normality and, if needed, transformed with square-root or $\log_e (x+1)$. If the data are transformed for analysis, the sample means and standard errors should be back-transformed for graphing. In the analysis, the effect of treatment is indicated by the treatment × time interaction term, for which the statistical package will produce an exact *P* value. As noted above, this requires at least two treatment areas and/or two non-treatment areas, measured at least once before and after treatment. However, most assessments of pest control operations are unreplicated, and treatments are not randomly allocated to treatment areas.

Without replication and random allocation of treatments, the population estimates before and after treatment in treatment and non-treatment areas can be compared by a repeated measures analysis of variance with the number of plots (or lines) in each area as the sample size, provided the plots (or lines) are independent and have been randomly located. Such an analysis will indicate whether there has been an area × time interaction (as distinct from a treatment × time interaction), but it cannot determine the cause of any interaction because there has been no replication. Without replication, treatment is only one of the possible explanations for any area × time interaction. If the plots (or lines) have not been randomly located, then they cannot represent the treatment area as a whole. Consequently, any analysis then refers only to the area around the plots (or lines), not to the whole treatment area.

If it is not possible to sample the same plots (or lines) after treatment as before treatment (e.g. where destructive sampling may influence population levels), then the appropriate statistical test is a two-factor analysis of variance, where area and time are the two factors, and the number of randomly located plots (or lines) in each area is the number of replicates. The analysis will indicate whether there has been an area × time interaction but, as above, it cannot determine the cause of any interaction because there has been no replication.

If the data are not normally distributed or the variances are unequal, even after transformation, then non-parametric methods of analysis may be used in place of the parametric two-factor analysis of variance (e.g. Friedman two-factor analysis of variance). This is best done using a statistical package such as SYSTAT® (SPSS 1996). There is currently no non-parametric alternative to the parametric repeated measures analysis of variance.

Various alternative methods of analysis have been proposed for assessment of unreplicated environmental impacts where measurements have been made before and after the impact (e.g. Stewart-Oaten et al. 1986; Carpenter et al. 1989; Carpenter 1990; Reckhow 1990; Skalski & Robson 1992) but none have

advantages over repeated measures analyses (Green 1993). However, if the data are discrete (e.g. the number of animals observed alive in treatment and non-treatment areas before treatment is applied and the number of these observed alive in each area after treatment), the proportion of animals alive in the two areas can be compared by a chi-square (χ^2) test, using Yate's correction for continuity:

$$\chi^2 = \Sigma((|O-E| - 0.5)^2/E)$$

where O is the number of animals observed after pest control, and E is the number of animals expected to be observed after pest control. The number of animals observed alive and the number of animals observed dead (or missing) **after** pest control should be entered in a contingency table, as follows:

	NUMBER ALIVE	NUMBER DEAD
Treatment area		
Non-treatment area		

The expected numbers for each cell can be calculated from the sum of the relevant row numbers, divided by the total number from all four cells, and multiplied by the sum of the relevant column numbers. The row totals are the numbers alive before the control operation. Calculation of the expected values and the resulting χ^2 value is best done using a statistical package such as SYSTAT® (SPSS 1996). Because there is only 1 degree of freedom, Yate's correction for continuity should be used. The statistical package will produce an exact *P* value. If the calculation is done using a calculator rather than a computer then the significance of the χ^2 value can be determined from a table of χ^2 probabilities with 1 degree of freedom. It must be remembered that the result applies only to the individual pest control operation, because there is no replication. If the sample size is small (e.g. less than 40), Fisher's exact test should be used instead of the chi-square test. This can be done easily using a statistical package such as SYSTAT® (SPSS 1996).

3.4.2 Comparison of population estimates before and after treatment when there is no non-treatment area

When there is no non-treatment area, and no replication of the treatment, the before and after population estimates can be compared using a paired t-test, with the number of plots (or lines) as the sample size (n) and the degrees of freedom as n–1, provided the plots (or lines) are independent, have been randomly located, and the same plots (or lines) sampled before and after treatment. This will determine whether there is a difference between the before and after population estimates, but without replication of treatment areas it is not possible to attribute a cause to any difference. If the plots (or lines) have not been randomly located, then the analysis refers only to the area around the plots (or lines), not to the treatment area as a whole. If the same plots (or lines) have not been sampled before and after treatment, then the appropriate statistical test is a standard t-test. These tests should be done using a statistical package such as SYSTAT® (SPSS 1996).

If the data are not normally distributed or the variances are unequal, even after transformation, then non-parametric methods of analysis may be used in place of the t-tests (e.g. Kruskal-Wallis or Mann-Whitney tests). Again, these tests should be done using a statistical package such as SYSTAT® (SPSS 1996).

If the data are discrete (e.g. the number of animals observed alive before treatment and the number of these observed alive after treatment), the proportion of animals surviving can be compared by a χ^2 test. If natural mortality is likely to be important (e.g. if the observations are made a year apart) then a correction for natural mortality should be made (e.g. see Robertson & Colbourne in press). The numbers of animals observed alive and dead (or missing) before and after the control operation should be entered in a contingency table, as follows:

	NUMBER ALIVE	NUMBER DEAD
Before		0
After		

Note that the number dead before treatment will always be zero. Calculation of the expected values, the χ^2 value, and the P value is best done using a statistical package such as SYSTAT® (SPSS 1996). Because there is only 1 degree of freedom, Yate's correction for continuity should be used. It must be remembered that the result applies only to the individual pest control operation, because there is no replication. If the sample size is small (e.g. less than 40), Fisher's exact test should be used instead of the chi-square test.

Some of the methods that have been used previously to compare two (or more) sets of population estimates (e.g. before and after treatment) when there is no non-treatment area have been invalid. For example, Dawson & Bull (1975) and Dawson et al. (1978) compared bird counts in different areas using chi-square tests on the accumulated counts from all stations and all days counted in each area. This is not valid because counts repeated at the same stations daily could be counts of the same birds each day. Such counts should be averaged not summed, making the chi-square test inappropriate.

4. Birds

4.1 FIVE-MINUTE COUNTS

The 5-minute count technique was developed for monitoring bird populations in New Zealand forests (Dawson & Bull 1975). It has been used extensively for monitoring the impacts of 1080-poisoning operations on bird populations (e.g. Spurr 1981, 1988, 1991, 1994a; Warren 1984; Calder & Deuss 1985; Miller & Anderson 1992; Pierce & Montgomery 1992; Roberston et al. 1993; Towns et al.

1993; Fanning 1994). The technique is most suitable for the more common forest birds such as the rifleman (*Acanthisitta chloris*), whitehead (*Mohoua albicilla*), brown creeper (*Mohoua novaeseelandiae*), grey warbler (*Gerygone igata*), fantail (*Rhipidura fuliginosa*), tomtit (*Petroica macrocephala*), robin (*Petroica australis*), silvereye (*Zosterops lateralis*), and bellbird (*Anthornis melanura*) (Table 3), but may also be used for less common species such as kereru (Mander et al. 1998) and kakariki (Elliott 1998). Point counts of various lengths are probably the most widely-used method internationally for monitoring bird population trends (Bibby et al. 1992; Ralph et al. 1995).

The number of birds counted is influenced not only by the number of birds present, but also by factors such as the species of bird, habitat structure,

TABLE 3. RECOMMENDED METHODS FOR MONITORING POPULATION LEVELS OF DIFFERENT BIRD SPECIES EXPOSED TO VERTEBRATE PEST CONTROL OPERATIONS.

SPECIES	FIVE-MINUTE COUNTS	TERRITORY MAPPING	MIST-NETTING	BANDING AND RESIGHTING	RADIO-TELEMETRY
Brown kiwi	–	+	–	+	+
Great spotted kiwi	–	+	–	+	+
Little spotted kiwi	–	+	–	+	+
Blue duck	–	+	–	+	+
Brown teal	–	?	–	+	+
Harrier	–	+	–	+	+
Falcon	–	+	–	+	+
Banded rail	–	+	–	+	+
Weka	+	+	–	+	+
Spotless crake	–	+	–	+	+
Marsh crake	–	+	–	+	+
Pukeko	–	+	–	+	+
Kereru	+	+	–	–	+
Kaka	?	+	–	–	+
Kea	?	+	–	+	+
Kakariki	+	–	–	–	+
Long-tailed cuckoo	?	–	–	–	+
Shining cuckoo	?	–	–	–	+
Morepork	–	+	–	–	+
Rifleman	+	+	+	+	?
Fernbird	+	+	+	+	?
Brown creeper	+	+	+	+	?
Whitehead	+	+	+	+	?
Yellowhead	+	+	+	+	?
Grey warbler	+	+	+	+	?
Fantail	+	+	+	+	?
Tomtit	+	+	+	+	?
Robin	+	+	+	+	?
Silvereye	+	+	+	+	?
Bellbird	+	+	+	+	?
Tui	+	+	+	+	+
Kokako	?	+	–	+	+
Saddleback	?	+	+	+	+

topography, weather, time of day, season, and ability of the observers. These influences must be standardised or eliminated if valid indices of density are to be made. The counts of different species are not comparable because each species has a different detectability (e.g. the bellbird is more likely to be detected than the rifleman because it has a more conspicuous call). Thus, each species must be recorded and analysed separately. Treatment and non-treatment areas should be similar in habitat and topography, and be counted on the same days (using two observers, one in each area at the same time) and an equal number of times by each observer (by observers swapping between areas on different days). Only observers able to accurately identify birds from their sounds (songs and calls) as well as by sight should participate in bird surveys. If differences between observers are great, they could reduce the power of monitoring to detect changes in bird populations. Observer differences may not be important if the same observers count in both areas before and after treatment. However, observer bias is important if different observers are used from year to year in long-term studies. Observers also need to be trained to estimate the distances to birds seen and/or heard (see below).

According to Dawson (1981), unless a bird species is very abundant (>1 per count) and large numbers of counts are made (>30), the technique has low power (i.e. can detect only large changes (>50%) in forest bird populations). For example, 48 counts are needed to detect a 40% change, 85 counts to detect a 30% change, 192 counts to detect a 20% change, and 770 counts to detect a 10% change in a species with an average of 1 bird per count.

We are aware of only one study that has attempted to relate the numbers detected by the 5-minute count technique to known numbers of a species in New Zealand. Gill (1980) found that 5-minute counts of grey warblers and robins varied in proportion to their true densities. This correlation has not been verified for other bird species. Cassey (1997) found that 5-minute point-distance counts (i.e. 5-minute counts with distances to birds estimated) over-estimated the true density of saddlebacks (*Philesturnus carunculatus*), but whether this was a result of the 5-minute count itself or the distance extrapolations used to convert the count to density is unclear.

Five-minute counts are not suitable for monitoring short-term impacts of pest control on individual birds because individual territory-holders that die from poisoning may be quickly replaced by 'floating' non-territorial birds. This replacement can only be detected by observations of individually marked (e.g. banded) birds (see below). In addition, the new territory-holders may establish their presence by calling and singing more frequently, making them more detectable in 5-minute counts. Some birds may also become unpaired as a result of pest control and, especially if males, may increase their rate of calling and singing. For example, the death of several territorial blackbirds (*Turdus merula*) as a result of an aerial 1080-poisoning operation in The Cone in September 1977 caused increased singing by both the replacement birds and the surrounding surviving birds, which caused an increase in the numbers counted in 5-minute counts made 2 weeks after poisoning (E.B. Spurr unpubl. data). Likewise, Empson & Miskelly (1999) found 5-minute counts of robins increased as a result of increased vocalisation after an aerial brodifacoum-poisoning operation on Kapiti Island in September–October 1996 although the

number of robins had decreased. Thus, 5-minute counts should not be done until several weeks or months after pest control operations, to allow any disruption to the behaviour of birds to stabilise.

4.1.1   Equipment

- map(s)
- notebook
- pen/pencil plus spare
- plastic tape
- wristwatch (digital or with a second hand)
- binoculars (e.g. 8×30 or 7×50, suitable for use in dim forest light)

- data recording cards
- hip-chain and cotton
- compass
- spirit marker pen

4.1.2   Method

Counting stations should be located randomly, stratified randomly, or systematically on randomly located transect lines, in treatment and non-treatment areas, if they are to represent the areas as a whole. If they are not located randomly (e.g. located on a circuit) they will not represent the area as a whole, only the circuit within the area. The stations should be at least 200 m from the edge of the survey area, and a minimum of 200 m apart. At this distance, there is little chance of counting the same bird at adjacent stations (Bibby et al. 1992; Ralph et al. 1995), especially in the breeding season for small forest passerines such as grey warblers, tomtits, and robins that have territories or home ranges of less than about 4 ha (200 m × 200 m). For these species the counting stations will be independent. However, the counting stations will not be independent for larger species such as kaka (*Nestor meridionalis*) and kereru (*Hemiphaga novaeseelandiae*) that have much larger territories or home ranges. For these species, data could be analysed from every second station (which would give a spacing of 400 m). In some previous studies, counting stations have been only 100 m apart, but at this spacing they are unlikely to be independent even for small forest passerines. When counting stations are on transect lines, a hip-chain should be used to locate them exactly 200 m apart, to avoid bias in 'selecting' the location. Counting stations and the route between them should be clearly marked (e.g. with plastic tape) in both directions so that they can be re-located. The hip-chain cotton must be removed afterwards to prevent birds becoming tangled in it and dying.

For statistical purposes, the number of counting stations (or lines of counting stations) should be as great as possible. From a practical point of view, the maximum number of stations that can be counted by one observer in 1 day is 20–40, depending upon the terrain and the distance between stations (or lines). If stations are located on transect lines, it is better to have 10 lines of four stations, for example, than 4 lines of ten stations.

Each observer needs to make only one count at each counting station before and after treatment. Repeat counts (e.g. two or more counts at the same counting station) by the same observer will improve the accuracy of the data for each counting station, and consequently for each area being surveyed. However, for statistical reasons, it is better to increase the number of counting stations than to repeat counts by the same observer at existing stations.

The treatment and non-treatment areas should be counted at the same time (e.g. by using two observers, one in each area at the same time) (Table 4). Both observers should count an equal number of times in both areas (by swapping between areas on different days). The number of days spent counting will depend upon the number of stations to be counted (e.g. 2 days if all stations in an area can be counted in 1 day, 4 days if only half the stations in an area can be counted in 1 day, 6 days if only a third of the stations in an area can be counted in one day, etc.). The same observers should count before and after treatment. If this is not possible, then new observers should be trained and checked by experienced observers previously involved in the survey, and their counts calibrated.

Counting should be started as soon as the observer has settled at the counting station (i.e. stopped breathing heavily, got field card ready, etc.), normally within 1–2 minutes of arriving. The observer records all birds heard and/or seen in exactly 5 minutes. According to Dawson & Bull (1975), 'Each count is treated as an entity so that, even if it is thought that an individual bird was included in a previous count, it is counted again'. However, we recommend following Bibby et al. (1992) and Ralph et al. (1995), who stated that individual birds should not be counted more than once. The counts should be independent for statistical analysis. As noted above, the spacing of counting stations 200 m apart ensures that the chance of double counting is low.

Within each count no bird is knowingly counted twice, nor are birds assumed to be present without some visual or auditory clue to their presence (e.g. a flock of silvereyes is noted as the number heard calling rather than the number the

TABLE 4. COUNTING ROUTINE USING TWO OBSERVERS, ONE IN THE TREATMENT AREA AND ONE IN THE NON-TREATMENT AREA, FOR A DIFFERENT NUMBER OF DAYS DEPENDING UPON THE NUMBER OF STATIONS TO BE COUNTED.

		TREATMENT AREA	NON-TREATMENT AREA
(a) All stations counted in 1 day	Day 1	Observer 1 (all stations)	Observer 2 (all stations)
	Day 2	Observer 2 (all stations)	Observer 1 (all stations)
(b) Half of the stations counted in 1 day	Day 1	Observer 1 (half of the stations)	Observer 2 (half of the stations)
	Day 2	Observer 1 (half of the stations)	Observer 2 (half of the stations)
	Day 3	Observer 2 (half of the stations)	Observer 1 (half of the stations)
	Day 4	Observer 2 (half of the stations)	Observer 1 (half of the stations)
(c) One-third of the stations counted in 1 day	Day 1	Observer 1 (one-third of the stations)	Observer 2 (one-third of the stations)
	Day 2	Observer 1 (one-third of the stations)	Observer 2 (one-third of the stations)
	Day 3	Observer 1 (one-third of the stations)	Observer 2 (one-third of the stations)
	Day 4	Observer 2 (one-third of the stations)	Observer 1 (one-third of the stations)
	Day 5	Observer 2 (one-third of the stations)	Observer 1 (one-third of the stations)
	Day 6	Observer 2 (one-third of the stations)	Observer 1 (one-third of the stations)

observer guesses such a frequency of calling would represent; if a bird calls in one place and later one of the same species calls some distance away, they are taken as two individuals unless there is evidence that the first bird moved to the second place) (Dawson & Bull 1975).

Do not count birds judged to be more than 200 m away (Dawson & Bull 1975). Ralph et al. (1995) recommended counting all birds detected (but not birds already counted) to maximise the amount of data recorded, but we do not recommend this. However, there is unlikely to be much difference between the two methods because most birds are detected within 200 m. Both methods excluded birds flying overhead and judged not to belong to the area being surveyed.

Ramsey & Scott (1979, 1981) and Reynolds et al. (1980) recommended recording the distances to birds that are detected and using these distances to estimate the area surveyed (see also Bibby et al. 1992). This allows estimates of species density to be made (Fancy 1997). Cassey (1997) used this technique to estimate the density of saddlebacks in two habitats on Tiritiri Matangi Island. However, the technique requires large sample sizes and relatively precise estimates of distances, and for this it is necessary to use highly trained observers. We are not in a position to recommend recording distances at present. Recording distances to birds does not prevent analysis of the data as if distances had not been recorded, for comparison with previous counts where distances were not recorded.

Counts should be made within the period from about 1.5 hours after sunrise to 1.5 hours before sunset, to avoid the changes in bird conspicuousness near dawn and dusk. In mid-winter, this means that counts should be made between 0930 and 1530 (NZ Standard Time). In mid-summer, the equivalent times are 0730 to 1930 (NZ Summer Time). Counts should be made throughout the day, centred around the solar noon (1230), rather than be made all in the morning or all in the afternoon. Counts should not be made during strong winds or heavy rain, because these conditions affect the behaviour of birds and the ability of observers to detect them.

The best time of year for making 5-minute counts is in the breeding season, in spring and early summer (September–December), when birds are relatively sedentary and dispersed on breeding territories. In the autumn and winter some species, such as silvereyes, form large mobile flocks, which means that counts of individuals will not be independent. Thus, for pest control operations in winter, pre-poison surveys should be made in the previous spring–early summer, and post-poison surveys in the following spring–early summer.

Counts are best recorded on specially prepared field cards (Fig. 1). The name of the survey area, the name of the observer, the date (D/M/Y), day of survey (1, 2, 3, etc.), and transect number should be recorded once on each card. The following information should be recorded for each count: station number, time at start of count, and codes for temperature, sun, wind, noise, and precipitation (see Table 5). Each bird observed should be recorded by a stroke in either the heard or seen columns on the field card. If a bird is first heard and later seen, the record in the heard column should be annotated with an 's'. Thus, in Fig. 1, station 1, two bellbirds were first heard then later both seen; one grey warbler was heard only and another seen (i.e. first seen); one blackbird was first heard

Five-Minute Bird Count Card									
Area Pureora				**Observer** J. Smith					
Transect	1		**Date** 28/08/97		**Day** 1				
Station	1		2		3		4		5
Time	0930		0943		0959		1015		1030
Temperature	2		2		3		3		3
Sun	5		5		5		5		5
Wind	0		0		1		1		0
Noise	0		1		0		0		0
Precipitation	0		0		0		0		0
Notes	1 kaka								
Species	H	S	H	S	H	S	H	S	H	S
Bellbird	Hⁱˢ		ll	ll	ll	l	lll	l	ll	l
Grey Warbler	l	l	lˢ		l		ll		l	
Blackbird	lˢ		ll			l	lˢ		l	
Fantail		l				l			l	
Chaffinch	l		ll	l	lˢ	l	l		ll	
Kereru				l				l		
Unknown			l						l	

Figure 1. An example of a field card used for recording 5-minute bird count data.

then later seen; one fantail was seen; and one chaffinch was heard only. If a bird is first seen then heard, the record in the seen column is not annotated. The distinction between heard and seen can be used to check the accuracy of the identification (if a bird is seen its identity is likely to be more accurate than if it was only heard?) and to assess conspicuousness (the higher the ratio of heard to seen the greater the conspicuousness?). Unidentified birds should be recorded as 'Unknown' or 'Unk' in the species column. If they are identified after the count, the record can be amended to the correct identity.

TABLE 5. CODES FOR ENVIRONMENTAL VARIABLES TO BE RECORDED FOR 5-MINUTE BIRD COUNTS (AFTER DAWSON & BULL 1975).

TEMPERATURE (on a 1-6 scale, or in °C)	SUN	WIND (Av. for each count on a modified Beaufort scale)	NOISE other than wind, (e.g. water, cicadas, traffic, chainsaws, etc.)	PRECIPITATION (Av. for each count) M = mist, R = rain, H = hail, S = snow
1 = freezing <0°C 2 = cold 0–5°C 3 = cool 5–11°C 4 = mild 11–16°C 5 = warm 16–22°C 6 = hot >22°C	0 to 5 minutes (To the nearest min., of bright sunlight on the canopy immed-iately overhead)	0 = leaves still or moving with-out noise (Beaufort 0 and 1) 1 = leaves rustle (Beaufort 2) 2 = leaves and branchlets in con-stant motion (Beaufort 3 and 4) 3 = branches or trees sway (Beaufort 5, 6, and 7)	(Av. for the 5 min.) 0 = not important 1 = moderate 2 = loud	0 = none 1 = dripping foliage 2 = drizzle 3 = light 4 = moderate 5 = heavy

4.1.3　Analysis of data

When counts have been made in one treatment area and one non-treatment area, before and after treatment, and the counting stations (or lines of counting stations) are independent, the data may be analysed by repeated-measures analysis of variance, using the number of counting stations (or lines) as the sample size (see section 3.4.1). If the counting stations (or lines) have been randomly located, the repeated-measures analysis of variance will indicate whether there has been an area × time interaction, but it cannot determine the cause of any interaction because the treatment was not randomly allocated to area and there was no replication of treatment. Without replication, treatment is only one of the possible explanations for any area × time interaction. If the counting stations (or lines) have not been randomly located, then the analysis refers only to the area around the counting stations (or lines), not to the treatment area as a whole.

When there is no non-treatment area, the before and after counts can be compared using a paired t-test with the number of counting stations (or lines of counting stations) as the sample size, provided the counting stations (or lines) have been randomly located (see section 3.4.2). This will determine whether there is a difference between the before and after counts, but without replication of treatments it cannot attribute a cause to any difference. If the data are not normal or cannot be normalised, then non-parametric methods of analysis should be used (see section 3.4.2).

4.2　TERRITORY-MAPPING (OR ROLL-CALLING)

Territory-mapping (or roll-calling) has been used in New Zealand for monitoring populations of bird species such as the little spotted kiwi (*Apteryx owenii*), New Zealand falcon (*Falco novaeseelandiae*), fernbird (*Bowdleria punctata*), and kokako (*Callaeas cinerea*) before and after vertebrate pest control operations (Calder & Deuss 1985; Innes & Williams 1990; Pierce & Montgomery

1992; Fanning 1994; Colbourne & Robertson 1997). It is suitable for any species that is highly territorial (Table 3). In general, territories of individual birds (or pairs) are first mapped in detail, and then resurveyed to determine whether they are still occupied. Birds are generally not individually recognisable. In the absence of information to the contrary, the technique assumes that, after the initial survey, birds recorded in territories during a subsequent survey are the same birds as recorded in the same territories previously. However, recent studies of banded kokako at Mapara Wildlife Management Reserve have indicated that individuals that die or leave a territory can be replaced within a few days without it being apparent that they are new birds (I. Flux, Department of Conservation, pers. comm.). Thus, territory-mapping, like 5-minute counting, is most suitable for monitoring long-term impacts at the population level rather than short-term impacts on individual birds. The power of territory-mapping to detect changes in population levels is related to the number of territories monitored (see section 3.3).

The methods used for territory-mapping in New Zealand differ considerably from those used in Europe (Williamson 1964; Williamson & Homes 1964; O'Connor 1990; Bibby et al. 1992). In Europe, observers do not know the territory boundaries of birds before the survey begins. In New Zealand, they do. In Europe, observers record the locations of all birds seen or heard during a visit to the survey area on copies of a large-scale map (1:2500), and note territorial or breeding behaviour (such as sex of bird, singing, fighting, carrying food, and the location of nests). Particular attention is paid to recording contemporaneous registrations of different birds of the same species and same sex because such registrations guarantee that at least two territories exist. The number of territories is then determined from clusters of bird observations after 8–12 visits to the survey area. In New Zealand, observers first identify the territory boundaries of birds and then determine the occupancy of identified territories on subsequent visits. This is possibly better called roll-calling than territory-mapping.

The following instructions were adapted from Rasch (1992) for kokako and Powlesland (1997) for robins.

4.2.1 Equipment

- map(s)
- compass
- hip-chain and cotton
- plastic tape
- binoculars (e.g. 8×30 or 7×50, suitable for use in dim forest light)
- spirit marker pen
- wristwatch
- notebook
- pen/pencil plus spare

4.2.2 Method

Randomly locate at least one plot within each treatment and non-treatment area to represent each area. If the plots are not randomly located, your observations will be representative of those plots only, not the areas as a whole. If you have only one plot in each area it should be large enough to contain at least 40 territories of each bird species to be monitored if you want to detect a 20% reduction (see section 3.3). Five plots of eight territories would be better. For

small birds (e.g. robins and tomtits) with territories of 2.5 ha, plots need to be at least 100 ha to contain 40 territories. To contain eight territories, plots should be at least 20 ha. For small birds in forest, grid each plot with taped lines at 100-m intervals, with each line being numbered at 50-m intervals so that observers can determine where they are when they hear or see a bird. For large birds (e.g. kaka, New Zealand falcons, and kokako), which have larger territories, the survey area needs to be much larger and plots do not need to be gridded. Draw large-scale maps of each survey area on which to record the locations of the bird territories.

Determine the boundaries of all bird territories by making repeat visits to each plot, mapping the location of all birds encountered and paying particular attention to simultaneous observations of different birds of the same species and sex because such observations indicate different territories. If possible, follow birds to obtain a clear picture of the extent of their territory. For kokako, it is recommended that routes taken by birds be recorded on a map or 'follow sheet' (Rasch 1992). All neighbouring birds should be clearly identified. More than one person is usually necessary to identify neighbours, the number of people depending upon the number of birds with adjacent territories. Initial determination of territory boundaries may take some time. For kokako, it may take as many as 12 visits per territory, or 5 person-weeks per territory, to map the territories in a dense population (Rasch 1992).

Decide what constitutes a survey for resighting (roll-calling) birds in your study. It may mean a single half-hour search of each identified territory, or it may mean an initial half- hour search of each territory and then going back to locate any known territorial birds that were missed on the initial search. Decide whether the survey must be completed within 1 day, 2 days, or 1 week. Whatever you decide must be adhered to for all surveys, before and after the control operation. For kokako, it may take from less than 1 hour to more than 4 hours to re-locate an individual on its territory (Rasch 1992).

On each survey, keep a record of the presence and absence of birds seen in each territory. Be specific about what you record. For example; 'heard bird calling in territory A but not seen', 'saw bird in territory A but unable to determine sex', or 'saw male in territory A'. If any birds are banded indicate this: e.g. 'saw banded bird in territory A but unable to determine sex or identity', or 'saw male M-Y/R in territory A'.

If the control operation is in spring or early summer, surveys should be repeated weekly for at least 4 weeks before the expected date of the control operation. Continue the weekly monitoring if the operation is delayed. After the control operation, monitor the presence/absence of birds in each known territory weekly for at least 4 weeks for 1080-poisoning operations and for at least 10 weeks for brodifacoum-poisoning operations, starting 1 week after poisoning. If the control operation is in autumn or winter, then for seasonally territorial species territory-mapping and roll-calling must be done in the spring before and after the operation because the method is restricted to the breeding season. For species that are territorial throughout the year, such as kokako, territory-mapping and roll-calling can be done at any time of the year. Only birds located on their territories at least once a week for 4 weeks before pest control should be included in the data analysis.

4.2.3　Analysis of data

The number of occupied territories in the treatment and non-treatment areas before and after pest control should be compared using the chi-square test or Fisher's exact test, to determine whether there is a significant difference in the survival of birds in the two areas (see section 3.4.1). If there is no non-treatment area, the chi-square test or Fisher's exact test can be used to compare the number of occupied territories in the treatment area before and after pest control (see section 3.4.2).

4.3　MIST-NETTING CAPTURE RATES

The capture rates of birds caught in mist nets have been used as indices for monitoring bird population trends overseas (Karr 1981; Ralph et al. 1993) and for comparing bird abundance in different forest types in New Zealand (Spurr et al. 1992), but have not yet been used for monitoring the impacts of vertebrate pest control on bird population trends. The method is most suitable for small passerines such as riflemen, whiteheads, brown creepers, grey warblers, fantails, tomtits, robins, silvereyes, and bellbirds that are relatively sedentary and have small home ranges (see Table 3). If standard mist nets are used the sampling will be restricted to birds flying below about 3 m. However, if necessary, nets can be raised into the forest canopy to sample birds there (Spurr et al. 1992; Dilks et al. 1995). The method can be used only by people experienced with using mist nets.

In addition to capture rates, survival rates of birds can be calculated (from recaptures) because birds that are captured are banded with numbered metal leg-bands. Thus, mist-netting, unlike 5-minute counting and territory-mapping, is potentially suitable for monitoring both short-term impacts on individual birds and long-term impacts on bird populations. The power of mist-netting to detect changes in bird population trends has not been determined.

4.3.1　Equipment

- banding permit
- mist nets
- poles for mist nets
- bands
- pen or pencil plus spare
- banding pliers
- cloth bags for holding birds
- scales
- notebook

Handling and banding permits, appropriate-sized metal bands, banding pliers, and mist nets can be obtained from the Banding Office, Department of Conservation, PO Box, 10420, Wellington. Animal Ethics Committee approval will also need to be obtained. Ensure all mist nets are the same size and have an appropriate mesh size for the target species. Poles for mist nets should be made from aluminium tubing (obtainable from hardware suppliers). For convenience, make the poles telescopic by using two sizes of aluminium tubing, so that one fits snugly inside the other (Dilks et al. 1995).

4.3.2 Method

Randomly locate at least five transects in both the treatment and non-treatment areas if you wish these transects to represent each area. If the transects are not randomly located, data collected from them will be representative of those transects only, not the areas as whole. The transects within each area should be far enough apart so that the same birds are not caught on different transects (i.e. at least 500 m apart). On each transect, erect three to five mist nets at sites where the vegetation is amenable to mist-netting. Some clearance of vegetation may be necessary to prevent snagging and tearing the mist nets. The mist nets can be in a line end to end or spaced further apart. Permanently mark the mist-net sites so that they can be relocated after pest control. Lures (e.g. tape recordings of bird calls) must not be used to attract birds to mist nets because capture rates should represent unmodified rates of net interception (Karr 1981).

All transects within an area do not have to be sampled on the same days, but the same number of transects should be sampled on the same days and at the same times of day in both treatment and non-treatment areas. Mist nets should be operated throughout the day, from about 0800 to 1800 hours, though capture rates are usually highest in the early morning and evening. Mist-netting should be done for no more than 2 days at each net site (otherwise birds may avoid recapture) then the nets shifted to a new site if necessary. Aim for 100 mist-net hours per transect. Mist-netting should be restricted to fine days or days with light rain only and checked every 15 to 30 minutes to minimise bird mortality. All birds captured should be banded with numbered metal leg-bands to enable recaptures to be identified. The data can be separated into first captures and recaptures.

The best time of year for obtaining mist-net capture rates is in the breeding season, in spring and early summer (September–December), when birds are relatively sedentary and dispersed on breeding territories. At this time of year, Spurr et al. (1992) caught about one bird of each of the more common small passerines per 100 mist-net hours in lowland podocarp forest. Thus, for pest control operations in winter, pre-poison surveys should be made in the previous spring–early summer, and post-poison surveys in the following spring–early summer. Mist-netting in autumn, after the breeding season, provides data on the relative abundance of young and adult birds.

4.3.3 Analysis of data

If there are treatment and non-treatment areas, the data (birds, by species, per 100 mist-net hours) should be analysed by repeated measures analysis of variance, to determine whether there has been an area × time interaction (see section 3.4.1). If there are no non-treatment areas, the capture rates before and after pest control can be compared using a paired t-test (see section 3.4.2). If the data are not normal or cannot be normalised, then non-parametric methods of analysis should be used (see section 3.4.2).

4.4 BANDING AND RECAPTURING OR RESIGHTING

Birds have been captured and banded with numbered metal bands and/or unique combinations of coloured plastic bands, and then recaptured or resighted several times before and after vertebrate pest control operations to

determine the impacts on individual birds of species such as fernbirds, tomtits, robins, and kokako (e.g. Pierce & Montgomery 1992; Ranum et al. 1994; Walker 1997a; Powlesland et al. 1998, 1999). This technique is suitable for any species that can be recaptured or resighted relatively frequently (see Table 3). It assumes that birds that disappear have died as a result of pest control (e.g. 1080-poisoning). Few dead banded birds have been found after pest control operations, but a large proportion of those that have been found have contained residues of poison. The technique can also provide information on the impacts of pest control on bird populations, but it requires more effort than with 5-minute counts. Only one or a few species can be monitored at a time. The method can be combined with territory-mapping. Banding birds is not restricted to the breeding season as is territory-mapping, but it may be easier in the breeding season because birds are more sedentary then and therefore are likely to be resighted more readily. The power of banding studies to detect changes in bird population levels is related to the number of birds banded (see section 3.3). The following instructions were adapted from Powlesland (1997).

4.4.1   Equipment

- banding permit
- mist nets
- poles for mist nets
- cassette tape recorder
- tape of bird calls
- pen or pencil plus spare
- binoculars (e.g. 8×30 or 7×50, suitable for use in dim forest light)

- bands
- banding pliers
- cloth bags for holding birds
- scales
- notebook

Handling and banding permits, appropriate-sized metal and colour bands, banding pliers, and mist nets can be obtained from the Banding Office, Department of Conservation, PO Box, 10420, Wellington. Animal Ethics Committee approval will also need to be obtained. Poles for mist nets should be aluminium tubing (obtainable from hardware suppliers). Use two sizes so that one will fit snugly inside the other to make the poles telescopic (Dilks et al. 1995). Obtain a portable cassette tape recorder, tapes, and taped calls of birds from Cognita (formerly Conservation Design Centre), Nelson, or preferably by taping calls in your study area. For robins, obtain a clap-trap and/or a hand-net, and a supply of mealworms or other readily available invertebrate food that the birds will eat.

4.4.2   Method

Randomly locate at least one plot within each treatment and non-treatment area (as for territory mapping). If you have only one plot it should be large enough to contain at least 40 birds of each species to be monitored. Five plots of eight birds would be better statistically but more difficult operationally. For small birds (such as robins and tomtits), plots need to be at least 100 ha to contain 40 birds. To contain eight birds, plots should be at least 20 ha. Grid each plot with taped lines at about 100-m intervals, with each line being numbered at 50-m intervals so that observers can determine where they are when they hear or see a bird. This will aid with re-locating birds. For large birds such as kaka, New Zealand falcons, and kokako, the survey area needs to be much larger than for

small birds, but will not need to be marked so intensively. Draw large-scale maps of each survey area on which to record the locations of the birds.

Erect mist nets or set up other capturing devices, such as clap-traps for robins, at strategically located sites, where the vegetation is amenable to mist-netting, within the randomly located plots. Capture and colour-band at least 30 birds in each area, so that at least 75% of the birds are banded before monitoring starts.

Decide what constitutes a survey for resighting birds in your study. It may mean a single day spent searching in each area, or it may mean an initial 1-day search and then going back for a second day (or longer) to locate any known banded birds missed on the initial search. Decide whether the survey must be completed within 1 day, 2 days, or more. Whatever you decide must be adhered to for all surveys, before and after the control operation.

On each survey, keep a record of the presence and absence of banded and unbanded birds seen in each area. Be specific about what you record. For example: 'heard bird in territory A but not seen', 'saw bird in territory A but unable to determine whether banded', 'saw banded bird in territory A but unable to determine identity', or 'saw M-Y/R in territory A'. Repeat surveys weekly for at least 4 weeks before the expected date of the control operation. Continue the weekly monitoring if the operation is delayed. After the control operation, monitor the presence/absence of banded birds weekly for at least 4 weeks for 1080-poisoning operations and for at least 10 weeks for brodifacoum-poisoning operations, starting 1 week after poisoning.

The effect of poisoning on the bird population can then be assessed from the minimum number of birds known to be alive (MNA) before pest control and the minimum number known to be alive at various time-intervals after pest control. The minimum number alive can be estimated by adding the number of individuals recorded in the survey under consideration and the number of banded individuals recorded in subsequent surveys but not during the survey under consideration. A disadvantage of this method is that estimates after pest control are based on fewer samples than estimates before pest control unless data from the last survey are excluded from calculation of the minimum number alive before pest control. If this is not done, the number alive after pest control may be underestimated.

4.4.3 Analysis of data

The number of banded birds in the treatment and non-treatment areas before and after pest control should be compared using the chi-square test or Fisher's exact test, to determine whether there is a significant difference in the survival of birds in the two areas (see section 3.4.1). If there is no non-treatment area, the chi-square test or Fisher's exact test can be used to compare the number of banded birds in the treatment area before and after pest control (see section 3.4.2).

4.5 RADIO-TELEMETRY

Radio-telemetry has been used to monitor the impacts of vertebrate pest control on some species of large birds, such as kiwi (*Apteryx* spp.), kaka, weka (*Gallirallus australis*), morepork (*Ninox novaeseelandiae*), and blue duck

(*Hymenolaimus malacorhynchos*) (Pierce & Montgomery 1992; Robertson et al. 1993; Greene 1995; Walker 1997a; Powlesland et al. 1998; Robertson et al. 1999a,b; Stephenson et al. 1999; Robertson & Colbourne in press). Radio-transmitters have also been used to monitor survival of kereru, though not in relation to vertebrate pest control (Clout et al. 1995; Pierce & Graham 1995), and could be used for other species (see Table 3). Radio-transmitters (with or without mortality sensors) enable individual birds to be located even after death. The power of radio-telemetry studies to detect changes in bird survival is related to the number of birds fitted with radio-transmitters (see section 3.3).

4.5.1 Equipment

- permits
- mist nets
- poles for mist nets
- cassette tape recorder
- tape of bird calls
- cloth bags for holding birds
- scales
- binoculars (e.g. 8×30 or 7×50, suitable for use in dim forest light)

- bands
- banding pliers
- radio-transmitters
- harness for radio-transmitters
- radio-receiver
- Yagi aerial

Obtain permits for capturing and handling birds, and for attaching radio-transmitters to them, from the Department of Conservation, PO Box, 10420, Wellington. Animal Ethics Committee approval will also need to be obtained. Radio-tagged birds should also be banded, so obtain permits and equipment as for banding birds (section 4.3.1).

Obtain mist nets, bands, and banding pliers (as in section 4.3.1). Obtain radio-transmitters (preferably with mortality sensors), radio-receiver, and Yagi aerial (e.g. from Sirtrack Ltd, PB 1403, Havelock North). Ensure that the weight of the transmitter package (including battery) does not exceed 5% of the body weight of the bird.

4.5.2 Method

Erect mist nets (see Dilks et al. 1995) or set up other capturing devices such as clap-traps in treatment and non-treatment areas. Capture and attach radio-transmitters to at least 40 birds in each area if you want the ability to detect a 20% reduction in numbers (see section 3.3).

Use a radio-receiver and Yagi aerial to locate individual birds (alive or dead) daily for at least 4 days or once weekly for at least 4 weeks before pest control. If the control operation is delayed, locate birds at least weekly until the operation occurs. Relocate birds weekly for at least 4 weeks after 1080-poisoning operations and for 10 weeks after brodifacoum-poisoning operations.

4.5.3 Analysis of data

A chi-square test or Fisher's exact test can be used to determine whether there is a significant difference in survival of birds in the treatment and non-treatment areas (see section 3.4.1).

4.6 OTHER TECHNIQUES

Various other techniques have been used to monitor populations of birds in specific situations: e.g. 1-hour or 2-hour night-time counts for kiwi (Robertson et al. 1993; Empson & Miskelly 1999; Robertson & Colbourne in press), display flight monitoring and census counts from vantage points for kereru (Mander et al. 1998), and transect counts for kokako (Hudson & King 1993). Techniques for monitoring birds of open country have not been specifically considered in this manual. Techniques for monitoring waterfowl populations have also not been considered in this manual. The choice of technique is influenced by individual preference, resources available, and suitability of the technique for the species (see Table 3).

5. Bats

Both short-tailed bats (*Mystacina tuberculata*) and long-tailed bats (*Chalinolobus tuberculatus*) live in areas where vertebrate pest control operations have been carried out, but there are no standard techniques for monitoring their populations. There have been only two assessments of the impacts of vertebrate pest control on bat populations: viz. the impacts of 1080-poisoning on the short-tailed bat population in Rangataua Forest in August 1997 (Lloyd & McQueen 1998) and the impacts of brodifacoum-poisoning for the eradication of rats on the short-tailed bat population on Codfish Island in August 1998 (P. McClelland, Department of Conservation, pers. comm.). Techniques that have been used to monitor bat populations include counts of bats leaving and/or entering daytime roosts, counts of echo-locations ('bat passes') using automatic bat detectors, and radio-telemetry of individual bats before and after treatment. The Bat Recovery Plan (Molloy 1995) lists the development of survey and monitoring techniques for bats as a top priority. The following instructions are adapted from C.F.J. O'Donnell and P. McClelland (Department of Conservation pers. comm.).

5.1 COUNTS OF BATS LEAVING AND/OR ENTERING DAYTIME ROOSTS

Counts of bats leaving and/or entering daytime roosts have been used to monitor short-tailed bat populations before and after 1080-poisoning for possum control in Rangataua Forest in August 1997 (Lloyd & McQueen 1998) and brodifacoum-poisoning for eradication of rodents on Codfish Island in August 1998 (P. McClelland, Department of Conservation pers. comm.). The exact methods have not yet been published.

5.1.1 Equipment

- video camera
- time-lapse video recorder
- video tapes
- monitor
- infrared light source
- battery

5.1.2 Method

The exact methods have not yet been published. Video recorders are set up at known roost sites. Video tapes are viewed and the total number of bats leaving and/or entering the roosts counted.

5.1.3 Analysis of data

No information obtained.

5.2 COUNTS OF 'BAT PASSES' RECORDED BY BAT DETECTORS

Bats emit ultrasonic sounds as they navigate, and these sounds are converted to audible clicks as bats pass by an electronic bat detector. Bat detectors have been used to determine the presence or absence of bats and could be used for monitoring population abundance once standard procedures have been developed (C.F.J. O'Donnell, Department of Conservation pers. comm.). O'Donnell & Sedgeley (1994) developed an automatic monitoring system that enables sampling the frequency of occurrence of bat calls all night, for several nights if necessary. When short-tailed bats fly within c. 22 m of the detector, or long-tailed bats within 50 m, the echo-location calls of the bats activate the recorder and the sounds are recorded on tape. A talking clock speaks the time every hour and is also recorded on tape.

The number of 'bat passes' per hour provides an index of bat activity (rather than the absolute number of bats). There is currently no information on how the number of 'bat passes' relates to the number of individual bats. A series of passes in an hour could equally be produced by one bat passing several times or several bats passing once. Bat activity is influenced by a number of factors, including temperature and abundance of flying invertebrates. These factors must be standardised or eliminated if valid indices of bat abundance are to be made.

5.2.1 Equipment

- Batbox III bat detectors (Stag Electronics, Sussex, UK)
- voice-activated tape recorder
- talking clock
- battery (e.g. alkaline 9V, or sealed gel 12 V with voltage regulator)
- waterproof container to hold the above (see O'Donnell & Sedgeley 1994)
- thermometer (mercury maximum/minimum)

5.2.2 Method

Automatic monitoring systems should be located at randomly selected points in treatment and non-treatment areas. The number and spacing of points have yet to be decided. Four bat detectors at least 500 m apart were used on Codfish Island (P. McClelland, Department of Conservation pers. comm.). The detectors should be set at 27–28 kHz for short-tailed bats (Parsons 1997) and 40 kHz for long-tailed bats (Parsons et al. 1997). The system should be left at the sample point all night. The number of nights of sampling has yet to be decided. Surveys should be made in summer when the weather is fine (clear, partly cloudy, or overcast, but no rain or strong winds) and the temperature is >7°C.

The presence and absence of 'bat passes' and 'bat pass' rate per hour should be tabulated after listening to the tapes. A 'bat pass' is defined as a sequence of greater than two echo-location calls as a bat flies past the microphone (Furlonger et al. 1987). A sequence of audible clicks followed by a pause delineates each 'bat pass'. A full description of the method is given by O'Donnell & Sedgeley (1994).

5.2.3 Analysis of data

No information obtained.

5.3 RADIO-TELEMETRY

Radio-transmitters can be successfully attached to bats, and daytime roosts checked for the presence of radio-tagged bats before and after vertebrate pest control operations. The power of radio-telemetry studies to detect changes in bat survival is related to the number of bats fitted with radio-transmitters (see section 3.3).

5.3.1 Equipment

- permits (handling, banding, Animal Ethics Committee)
- maps
- mist nets
- harp traps
- cloth bags for holding bats
- radio-transmitters
- radio-receiver
- aerial
- scales

5.3.2 Method

No information obtained.

5.3.3 Analysis of data

No information obtained.

6. Reptiles

Several species of lizards (skinks and geckos) live in areas where 1080-poisoning for possum control has been carried out, but the impact of poisoning on their populations has never been monitored. Lizards and tuatara (*Sphenodon punctatus*) also live on islands where brodifacoum-poisoning has been used for rodent eradication, and a variety of methods has been used there to monitor their population recovery.

Some population monitoring methods previously used, such as catch per unit effort (CPUE), based on area searching, are not recommended because they are inefficient, biased, and destroy lizard habitat (Towns 1991; Whitaker 1994). An appropriate population monitoring technique for lizards has not been published but the following instructions are adapted from Towns (1975, 1991, 1994), Whitaker (1994), and Towns & Elliott (1996).

6.1 PITFALL TRAPPING

Pitfall trapping has been used to estimate the relative abundance of lizards before and after brodifacoum-poisoning for rodents and on different islands (Towns 1991, 1994). The number of lizards caught in pitfall traps is influenced by population size as well as by a number of other factors (e.g. lizard species, sex, and activity). However, when pitfall traps are used in paired treatment and non-treatment areas, before and after application of a treatment, and analyses are restricted to within species, factors apart from population size cancel out unless there is an interaction between a factor such as lizard activity and treatment (see also section 4.1). The power of pitfall trapping to detect changes in population indices of lizards has not been determined.

6.1.1 Equipment

- maps
- calipers or ruler
- cloth bag (for holding lizards)
- spring balance (e.g. Pesola™ accurate to 0.1 g)
- pitfall traps (see below)
- field cards or notebook
- pen or pencil

Pitfall traps should be made from 4-litre paint tins with the interior lacquered to reduce rusting. The traps must have holes drilled in the bottom to drain water away and avoid drowning captured lizards. The traps must also have a lid supported 10–20 mm above them to protect captured lizards from the sun. Animal Ethics Committee approval will be needed to capture reptiles.

6.1.2 Method

Pitfall traps should be located at 20 m intervals on randomly located transect lines 100 m long (i.e. five traps per line). There should be at least five lines of pitfall traps per survey area. Alternatively, clusters of five pitfall traps 2 m apart may be located at five random points at least 20 m apart in the survey area.

The traps should be buried in the ground, with the rim flush or slightly below the ground surface, and substrate packed close around the rim. When the traps are set, the lids should be supported 10–20 mm above the rim of the traps. When the traps are closed, a stout stick just longer than the diagonal height of the trap should be placed inside each trap (Whitaker 1994). Do not use the lid to close the trap because it could get dislodged.

The bait that should be used in the traps depends upon the target species. The best baits are canned pears or canned fish-based cat-food (Whitaker 1994).

The traps should be checked daily for at least 4 days before and 4 days after a pest control operation. For 1080-poisoning operations, the post-treatment survey should be done at least 1 week after poisoning, and for brodifacoum-poisoning operations, at least 2 weeks after poisoning. If the objective is to determine if there are any long-term benefits of pest control, then annual monitoring at the same time of year will be necessary because most New Zealand lizards have low productivity.

Captured lizards should be identified to species and sex, and released alive beside the trap where they were caught. The average capture rate per night should be calculated for each trap, and the results expressed as the number of lizards caught per 100 trap nights per transect line. If non-treatment areas are surveyed, they should be surveyed on the same nights as the treatment areas (to standardise seasonal and weather variables).

6.1.3   Analysis of data

If there are treatment and non-treatment areas, the data (lizards per 100 trap-nights) should be analysed by repeated measures analysis of variance, to determine whether there has been an area × time interaction (see section 3.4.1). If there are no non-treatment areas, the capture rates before and after pest control can be compared by a paired t-test (see section 3.4.2). If the data are not normal or cannot be normalised, then non-parametric methods of analysis should be used (see section 3.4.2).

6.2   MINIMUM NUMBER ALIVE

If captured lizards are individually marked then recaptures can be used to estimate the minimum number alive (MNA) at different time points before and after pest control (see Towns 1991, 1994; Patterson 1992; Towns & Elliott 1996). The assumptions of a closed population are accepted: viz., that there is no large-scale movement of lizards into or out of the study areas between sampling, and that there are few deaths of lizards eligible to be caught but not caught (Towns 1994; Towns & Elliott 1996). The power of this technique to detect changes in lizard population levels is related to the number of lizards marked (see section 3.3).

6.2.1   Equipment

- maps
- scissors (sharp)
- pitfall traps (as above)
- calipers or ruler

- cloth bag (for holding lizards in) • field cards or notebook
- predetermined toe-clip combinations • pen or pencil
- spring balance (e.g. Pesola™ accurate to 0.1 g)

For predetermining toe-clip combinations, there are 150 individual combinations from clipping two toes and 625 from clipping three toes (Whitaker 1994). Animal Ethics Committee approval will need to be obtained to capture and toe-clip reptiles.

6.2.2 Method

Lizards should be captured by pitfall trapping (as above) for 4 nights before and at least two lots of 4 nights after pest control. Captured lizards should be identified to species and sex, weighed to the nearest 0.1 g, measured in millimetres from snout to vent, individually marked, and then released beside the trap. See Whitaker (1994) for methods of identifying sex. The only permanent method of marking is toe-clipping (Whitaker 1994). Remove toe(s) quickly and cleanly with a sharp pair of scissors. Temporary methods of marking include waterproof spirit-based felt pens, nail varnish, typists correction fluid, and acrylic paint.

The minimum number alive before pest control can be estimated by adding the following:

- The number of individuals caught on night 4 before pest control
- The number of previously marked individuals caught in subsequent trapping sessions after pest control but not on night 4 before pest control
- The number of unmarked individuals caught in subsequent trapping sessions after pest control but which were of sufficient snout–vent length (SVL) to suggest that they had been alive but not caught on night 4 before pest control.

The minimum number alive after pest control can be estimated by adding the following:

- The number of individuals marked before pest control that were caught in the 4 nights after pest control
- The number of unmarked individuals caught in the 4 nights after pest control but which were of sufficient size (SVL) to suggest that they had been alive but not caught before pest control
- The number of previously marked individuals caught in the second 4-night trapping session after pest control but not in the first 4 nights after pest control
- The number of unmarked individuals caught in the second 4-night trapping session after pest control but which were of sufficient size (SVL) to suggest that they had been alive but not caught before pest control.

A disadvantage of this method is that estimates after pest control are based on fewer samples than estimates before pest control unless data from the last 4-night trapping session are excluded from calculation of the minimum number alive before pest control. If this is not done, the number alive after pest control may be underestimated.

6.2.3　Analysis of data

The minimum number of lizards alive in the treatment and non-treatment areas before and after pest control should be compared using the chi-square test or Fisher's exact test (see section 3.4.1). If there are no non-treatment areas, the chi-square test or Fisher's exact test should be used to compare the minimum number of lizards alive before and after pest control (see section 3.4.2).

6.3　OTHER TECHNIQUES

Other techniques are required for lizards that are not easy to trap (e.g. the grand skink, *Oligosoma grande*, and the Otago skink, *O. otagense*), and for arboreal species (e.g. the forest gecko, *Hoplodactylus granulatus*, and the common green gecko, *Naultinus elegans*). Patterson (1992) suggested marking lizards with acrylic paint without capturing them, by using a long stick, and then using a mark-resighting technique to estimate abundance.

For tuatara, Cree et al. (1995) used the number of tuatara captured per person per hour searched as a measure of abundance. Searches were made at night using spotlights. Tuatara that were found were captured by hand and given a unique toe-clip so that no tuatara was counted twice. This allowed the minimum number alive to be estimated. Cassey (1997) used distance sampling on line transects to estimate the abundance of tuatara without capturing them. Transect lines were marked with fluorescent tape, and observations were made at night using a head-mounted spotlight. The perpendicular distance from the transect line to the initial location of each sighted tuatara was estimated and recorded. The program DISTANCE (Laake et al. 1994) was used to fit detection functions and estimate abundance. Abundance is likely to have been underestimated because some tuatara moved before they could be detected. Distance sampling needs to be further evaluated before it can be used to routinely monitor lizard populations.

7.　Frogs

Several methods have been used for surveying the population trends of native frogs (Bell 1996, Newman 1996). The Native Frog Recovery Plan recommended strip transect counts for long-term monitoring of both *Leiopelma archeyi* and *L. hochstetteri* (Newman 1996). However, Thorsen (1998, unpublished Department of Conservation report) noted that strip transects were of limited use for monitoring *L. hochstetteri*. The Recovery Plan identified the development of standardised monitoring techniques for each species of native frog as a high priority.

7.1   STRIP TRANSECT COUNTS

Strip transect counts have been used in a number of studies monitoring the impacts of 1080-poisoning operations on both *L. archeyi* and *L. hochstetteri* populations (McNaughton & Greene 1994; Greene et al. 1995; Bell 1996; Perfect 1996). However, they should be limited to *L. archeyi* and other terrestrial species. Perfect (1996) calculated that in her surveys, strip transects could detect decreases of 35% or greater for *L. archeyi* (with 80% power at the 95% level of significance) but could not confidently detect even a 35% decline in *L. hochstetteri* numbers. The following instructions are adapted from the above publications, Newman (1996), and Thorsen (1998, unpublished Department of Conservation report).

7.1.1   Equipment

- maps
- plastic tape
- hip-chain and cotton
- thermometer (wet and dry-bulb)
- notebook
- pen or pencil
- calipers or ruler
- camera and film

7.1.2   Method

The Recovery Plan recommended transects 2 m wide × 100 m long (Newman 1996), but Perfect (1996) found 50 m sufficient length for both *L. archeyi* and *L. hochstetteri*. Thorsen (1998, unpublished Department of Conservation report) stated that there should be at least 20 strip transects (preferably 50) in each treatment and non-treatment area. If, because of the risk of disturbance to frogs and the habitat, the same transects are not surveyed before and after control, there will need to be double this number of transects. The transects should be randomly located in areas of suitable frog habitat, and marked with coloured plastic tape so they can be relocated. Make a sketch map and physical description of the habitat, including a photograph from a photo-point, for each transect.

The best time of year for surveys is late January–February (Newman 1996). Thus, for pest control operations in winter, pre-poison surveys should be made in the previous January–February, and post-poison surveys in the following January–February.

Surveys should be made during the day, between 0900 and 1600 hours. If possible, sample on days which have had less than 8 mm of rain within the previous 3 days, and greater than 5°C minimum temperature the previous night (McNaughton & Greene 1994). Treatment and non-treatment areas should be surveyed on the same days, and individual transects should be surveyed at the same time of day each day they are surveyed. Record temperature, rainfall, and humidity.

Search in all suitable habitat along the transect in a non-destructive way. Keep search time and search effort as constant as possible. Lift the same rocks and logs each time a transect is searched. Rocks or logs should not be lifted if lifting would disturb the surrounding habitat. Replace rocks and logs carefully so as not to harm frogs or disturb their habitat. Search in crevices and, where

appropriate, in vegetation up to head height. Where counts (for *L. hochstetteri*) are made in streams, they should be made going upstream to avoid double-counting any frogs that swim downstream. Plot the locations of frogs on sketch maps of the transects, and record 'distance to frog' and 'time to frog' from the start of the transect. Express the results as the number of frogs per 50-m transect.

Counts should be made at weekly intervals for at least 3 weeks before and after pest control. The same observers should count the transects before and after pest control to counteract any observer bias (McNaughton & Greene 1994, Greene et al. 1995; Perfect 1996). Observers should be trained before undertaking a survey (Greene et al. 1995).

The size of frogs should be measured using calipers, measuring the snout to vent length in millimetres. This will enable population estimates to be stratified into size-classes. The calipers should be held as close as possible above the frog but without touching it, to avoid disturbing it any more than necessary.

7.1.3 Analysis of data

If there are treatment and non-treatment areas, and the same transects are monitored before and after pest control, the data (frogs per transect) should be analysed by repeated measures analysis of variance, to determine whether there has been an area × time interaction (see section 3.4.1). Perfect (1996) used analysis of deviance in a generalised lineal model (GLM) technique, which has less restrictive assumptions than analysis of variance. If different transects are monitored before and after treatment, the data should be analysed by two-factor analysis of variance (see section 3.4.1).

If there are no non-treatment areas, and the same transects are monitored before and after pest control, the before and after counts can be compared by a paired t-test (see section 3.4.2). If different transects are monitored before and after pest control, the data should be analysed by standard t-test. If the data are not normal or cannot be normalised, then non-parametric methods of analysis should be used (see section 3.4.2).

7.2   OTHER TECHNIQUES

Thorsen (1998, unpublished Department of Conservation report) recommended the use of presence/absence surveys over at least 12 streams per area for monitoring *L. hochstetteri* populations. Bell (1996) recommended that pitfall trapping should be investigated further for monitoring native frog populations, especially of terrestrial species, because it reduces observer bias and the risk of crushing frogs under stones or logs. Recently, the provision of artificial cover (e.g. large plastic pot plant saucers) has been tested as a method for monitoring populations of both species (C. Smuts-Kennedy, pers. comm.).

8. Fish

There are 47 species of freshwater fish, 27 native and 20 introduced, that live in the rivers and lakes of New Zealand (McDowall 1990), but it is not known how many of these live in areas where vertebrate pest control occurs. Although there have been concerns about contamination of freshwaters by poisons used for vertebrate pest control, especially 1080, there is no evidence of any contamination above the minimum acceptable value for human consumption of 5 ppb in 868 samples collected after 40 aerial 1080-poisoning operations around New Zealand (Eason et al. 1999). The highest concentration of 1080 detected was also well below the concentration shown to be toxic to fish such as rainbow trout (*Oncorhynchus mykiss*) (Fagerstone et al. 1994). To our knowledge there have been no surveys of freshwater fish populations in New Zealand in relation to the impacts of vertebrate pest control. Should anyone wish to do such a survey, suitable methods were outlined by Roxburgh (1996).

9. Invertebrates

Invertebrate populations have been monitored by a range of methods (Southwood 1978), but the only published methods used for monitoring the impacts of vertebrate pest control are pitfall trapping (Spurr 1994b), Malaise trapping (Hutcheson 1996), and the number of invertebrates feeding on baits (Sherley et al. 1999). Litter sampling (Moeed & Meads 1986) and some other techniques could be used. It is important when planning a monitoring programme to remember that many invertebrate populations are seasonal (Green 1996). The invertebrates present in winter when most poisoning operations for vertebrate pest control occur are likely to be different life stages and even different species to those present in summer. Some species may be pupating at the time of a control operation and only emerge and be caught in traps after the operation. This is most likely to occur in spring, but a knowledge of the life history and habits of different species is needed for a full analysis of the results of a monitoring programme. Another important consideration is the time taken to sort and identify invertebrate species (Green 1996). Only about half the insect fauna in New Zealand has been described, and identification of species is a job for experts. The New Zealand Arthropod reference collection is held by Landcare Research, Mt Albert, Auckland.

9.1 PITFALL TRAPPING

Pitfall trap catches are influenced by population size as well as by a number of other factors (e.g. invertebrate species, sex, and activity) (Topping & Sunderland 1992). However, when they are used in paired treatment and non-

treatment areas before and after application of a treatment, and analyses are restricted to within species, factors apart from population size cancel out unless there is an interaction between a factor, such as invertebrate activity, and treatment (Heneghan 1992). The power of the method to detect changes in population indices is low when there are only 10 pitfall traps per area (Spurr 1994b). The power when there are more traps has not been calculated. The following instructions are adapted from Moeed & Meads (1985) and Green (1996).

9.1.1 Equipment

- maps of study areas

- pitfall traps — should be constructed according to instructions in Moeed & Meads (1985) or Green (1996) (i.e. 110 mm deep and 73 mm in diameter). Small holes (<1-mm diameter) should be drilled 40 mm from the top of each trap to drain excess rainwater.

- cover for traps (e.g. wooden board)

- preservative (e.g. Galt's solution, 30 % ethylene glycol solution, or 25% common salt solution)

- auger or trowel (for digging holes for traps)

- collecting bottles and labels

9.1.2 Method

Traps should be placed at 10-m intervals on at least five randomly located transect lines in each habitat or vegetation type within each treatment and non-treatment area. There should be at least four traps per line (cf. Moeed & Meads 1985). If resources are limited only one habitat or vegetation type (the same type in both the treatment and non-treatment areas) should be monitored. The monitoring sites should be matched for factors such as altitude, slope, and aspect, to reduce variability in catch rates.

A tight-fitting hole should be dug in the ground, preferably using an auger, and traps inserted into the hole so that the rim is flush with the surface, and substrate is packed closely around the rim. Capture rates will be affected if the rim is not flush with the surface or if there is a gap between the rim and the surrounding ground. Avoid unnecessary disturbance around the trap site and ensure surplus earth is discarded well away from the trap site. Traps should be installed at least 1 month before trapping proper begins because some invertebrates are attracted and some deterred by fresh earth. The traps can be left open during this time by placing a stick just longer than the diagonal height of the trap inside each trap.

When in operation, the traps should be one-third filled with a preservative such as Galt's solution, ethylene glycol solution, or saline solution. They should be covered with a wooden board to prevent them filling up with leaves and other debris and to prevent the preservative from being diluted by rainfall. The covers should be at least 15–20 mm above the lip of the trap to allow invertebrates easy access to the trap. In areas where traps may be disturbed by possums or other wildlife, the covers may need to be held down by rocks, branches, nails, or some other form of attachment.

The traps should be emptied at least four times before and four times after the pest control operation. It is important to ensure that the rim of the trap is flush with the ground surface each time the trap is re-set (see above). The length of time that traps are left open depends upon the catch rate. If the control operation is in winter, catch rates may be quite low and it may be necessary to empty traps only monthly, or, if emptied weekly, it may be necessary to pool two or more weekly samples to avoid too many zero catches. If the control operation is in spring, catch rates after control could be much greater than before control as a result of emergence of adults from pupae. The experimental design assumes that this seasonal variation will be similar in the treatment and non-treatment areas. Invertebrates collected from traps should be sorted and identified to species wherever possible.

9.1.3 Analysis of data

If there are treatment and non-treatment areas, the data (e.g. counts of each invertebrate taxon per trap per week before and after treatment) should be analysed by repeated measures analysis of variance, using the number of randomly located traps (or trap-lines) as replicates, to determine whether there has been an area × time interaction (see section 3.4.1). If there are no non-treatment areas, the capture rates of invertebrates before and after pest control can be compared by a paired t-test (see section 3.4.2). If the data are not normal or cannot be normalised, then non-parametric methods of analysis should be used (see section 3.4.2).

9.2 LITTER SAMPLING

This technique estimates an index of abundance of the invertebrates living in the litter. The instructions below are adapted from Moeed & Meads (1986) and Green (1996). The technique has not yet been used to monitor invertebrate populations before and after vertebrate pest control operations, and the power of the technique to detect changes in invertebrate populations has not been calculated.

9.2.1 Equipment

- maps of study areas
- spade
- 70% ethanol
- Tullgren or Berlese funnels (including light/heat source and collecting jars)
- quadrat markers
- cloth collecting bags
- storage bottles

9.2.2 Method

At least five plots should be randomly located in both the treatment and non-treatment areas. Because sampling destroys the litter, plots should be large enough to contain two quadrats of similar litter type adjacent to each other (2 m apart), one to be collected before and one after pest control. All quadrats should be the same size (e.g. 200 mm × 200 mm) and litter should be collected to the same depth (e.g. 70 mm). When collected, the samples should be placed in

cloth bags and taken to a laboratory as soon as possible (and within 8 hours) for extraction of the invertebrates.

In the laboratory, the litter samples should be placed on 6-mm mesh brass netting in separate Tullgren (or Berlese) funnels. A low-wattage bulb is then suspended above each litter sample to dry out the litter. As the litter dries out from above the invertebrates move down through the litter and fall into a collecting jar containing 70% alcohol. The invertebrates collected should be sorted, identified to species if possible, and counted. The results should be expressed as the number of individuals of each taxa per area (e.g. 0.2 m^2) of litter.

9.2.3   Analysis of data

If there are treatment and non-treatment areas, and the same plots are measured before and after treatment (i.e. the pre and post-control sampling quadrats are paired within plots), the data (invertebrates per quadrat) should be analysed by repeated measures analysis of variance using the number of randomly located plots as replicates, to determine whether there has been an area × time interaction (see section 3.4.1). If different plots are measured before and after treatment, the data should be analysed by two-factor analysis of variance (see section 3.4.1).

If there are no non-treatment areas, and the same plots are measured before and after treatment, the number of invertebrates per quadrat before and after pest control can be compared by a paired t-test, using the number of randomly located plots as replicates (see section 3.4.2). If different plots are measured before and after treatment, the data should be analysed by a standard t-test. If the data are not normal or cannot be normalised, then non-parametric methods of analysis should be used (see section 3.4.2).

9.3   MALAISE TRAPPING

Malaise trapping was used by Hutcheson (1996) to monitor the impacts of a 1080-poisoning operation for possum control on beetle species composition and abundance. The traps are usually erected on the ground to catch invertebrates flying low to the ground, but they may also be raised into the sub-canopy or canopy to catch invertebrates flying there that may encounter baits lodged up in trees. The power of Malaise trapping to detect changes in invertebrate population levels has not been calculated. The following instructions are adapted from Green (1996) and Hutcheson (1996).

9.3.1   Equipment

- maps of study areas
- collecting jars
- Malaise traps
- collecting fluid (e.g. ethanol)

Hutcheson (1991) and Cresswell (1995) describe designs for attaching collecting jars to traps.

9.3.2   Method

Four Malaise traps should be randomly located in both treatment and non-treatment areas. Each trap requires a reasonably flat, log-free area of about 2 m² (Hutcheson 1996). The orientation of the traps should be standardised (e.g. all facing north). If you wish to raise traps into the canopy to sample flying invertebrates that may encounter baits there, you will need to construct a frame and floor for the traps. Faulds & Crabtree (1995) give instructions for doing this, and a mechanism for lifting traps into the canopy.

The traps should be emptied at least four times before and four times after the pest control operation. As with pitfall trapping, the length of time that traps are left open depends upon the catch rate. If the control operation is in winter, catch rates may be quite low and it may be necessary to empty traps only monthly, or, if emptied weekly, it may be necessary to pool two or more weekly samples to avoid too many zero catches. If the control operation is in spring, catch rates after control could be much greater than before control as a result of emergence of adults from pupae. The experimental design assumes that this seasonal variation will be similar in the treatment and non-treatment areas. According to Hutcheson (1996), Malaise trapping for beetles is best done in December. The same may be true for other taxa. If a control operation in winter affects larvae, this should be reflected in December capture rates of adults. Thus, as well as trapping immediately before and after pest control operations, pre-poison trapping could also be done in the previous December, and post-poison trapping in the following December. Invertebrates collected from traps should be sorted and identified to species wherever possible.

9.3.3   Analysis of data

If there are treatment and non-treatment areas, the data (counts of each invertebrate taxon per trap per week before and after treatment) should be analysed by repeated measures analysis of variance using the number of randomly located traps as replicates (see section 3.4.1). If there are no non-treatment areas, the capture rates before and after pest control can be compared by a paired t-test, using the number of randomly located traps as replicates (see section 3.4.2). If the data are not normal or cannot be normalised, then non-parametric methods of analysis should be used (see section 3.4.2).

9.4   COUNTS OF INVERTEBRATES FEEDING ON BAITS

Counts of the number of invertebrates feeding on non-toxic baits before and after application of toxic baits were used by Sherley et al. (1999) to monitor the impact of 1080-impregnated cereal-based baits on various invertebrate populations. A weakness of the technique is that mortality may be over-estimated because invertebrates may be 'trained' to eat toxic baits by being pre-fed non-toxic baits. Also, any decline in the number of invertebrates eating baits may be the result of repellency rather than mortality. This could be avoided by using different bait types for monitoring and for the control operation.

However, a disadvantage of this procedure is that different species of invertebrates may feed on the different bait types used for monitoring and for pest control. The power of the technique to detect changes in invertebrate population levels has not been calculated. The following instructions are adapted from Sherley et al. (1999) and Spurr & Drew (1999).

9.4.1 Equipment

- maps of study areas
- notebook
- low-wattage headlamp or torch
- collecting jars and labels (if collecting invertebrates)
- fluorescent plot markers
- pen or pencil plus spare
- pooter (if collecting invertebrates)

9.4.2 Method

Randomly locate at least five 18 m × 18 m plots in both the treatment and non-treatment areas. Mark each plot with fluorescent markers on a grid of 3 m × 3 m, and mark the route to each plot with fluorescent markers so that the plots can be found at night. Place one non-toxic bait at each intersection on the plot grids during the day (i.e. a total of 49 baits per plot). The baits should be a different bait type to that used for the control operation (see above). Inspect the baits that night, starting soon after dark, using a low-wattage headlamp or torch. Record the identity (family, genus, and species if possible) and the number of all invertebrates observed on or under baits. If the same plots are to be assessed before and after pest control, do not collect the invertebrates because this may affect the post-control assessment. If it is necessary to collect invertebrates for identification, the post-control plots should be located separately (at least 20 m away) from the pre-control plots. Plots in the treatment and non-treatment areas should be surveyed on the same night (using two observers). The number of plots that can be surveyed in one night will depend upon the accessibility of the plots. All plots do not have to be surveyed on the same night, but the same number of plots should be surveyed in each area on each night.

9.4.3 Analysis of data

If there are treatment and non-treatment areas, and the same plots are measured before and after treatment, the data (invertebrates per bait per plot) should be analysed by repeated measures analysis of variance using the number of randomly-located plots as replicates, to determine whether there has been an area × time interaction (see section 3.4.1). If different plots are measured before and after treatment (because invertebrates on baits were collected for identification), the data should be analysed by two-factor analysis of variance.

If there are no non-treatment areas, and the same plots are measured before and after treatment, the number of invertebrates per bait per plot before and after pest control can be compared by a paired t-test, using the number of randomly located plots as replicates (see section 3.4.2). If different plots are measured before and after treatment, the data should be analysed by a standard t-test. If the data are not normal or cannot be normalised, then non-parametric methods of analysis should be used (see section 3.4.2).

Green (1996) lists other techniques for monitoring invertebrate populations such as pan traps, light traps, trunk traps, emergence traps, and radio-telemetry. Most are more suitable for monitoring the abundance of canopy-dwelling invertebrates than of ground-dwelling invertebrates. Walker (1997b) described a technique for monitoring populations of *Powelliphanta* land snails. Artificial weta houses or 'condominiums' (Sherley 1998) have been used successfully to monitor the non-target impact of an aerial 1080-poisoning operation in Ryan Creek in April 1998 on tree weta (*Hemideina crassidens*) populations (C.A. Robertson, Department of Conservation, Hokitika pers. comm.). They could also be used to monitor cave weta and ground weta, and other invertebrates such as cockroaches. Harmonic radar (Lövei et al. 1997) could be used to re-locate invertebrates before and after pest control operations. Further research is required on these methods before they can be used routinely for monitoring invertebrate populations.

10. Dead animals

Confirmation of the presence of a pesticide, and by implication the cause of death, can be obtained by submitting carcasses or tissues from carcasses of dead animals for analysis of pesticide residues. When handling poisoned carcasses, follow the appropriate Health and Safety procedures for handling pesticides (e.g. wear gloves). When transporting poisoned carcases refer to the relevant Standard Operating Procedure (e.g. the toxic material needs to be secure, not in the driver's cabin, attended to at all times, kept separate from food and drink, and accounted for). The following instructions were adapted from Wright (1998a, unpublished Landcare Research report).

10.1   COLLECTION OF SAMPLES

It is helpful to know what pesticide you are looking for in order to collect appropriate samples. Wherever possible, animals should be dissected and the appropriate organs or tissues removed. If the pesticide involved is not known, samples appropriate to each possible pesticide should be collected (see below) and placed separately in bags or specimen containers before freezing. Small animals up to the size of stoats (*Mustela erminea*) may be frozen and sent whole if preferred. Contact the Toxicology Laboratory, Landcare Research, Lincoln, well in advance so that preparations can be made for analysing your samples. This will also ensure faster processing of your samples.

For all cases of poisoning, the stomach or intestine contents should be inspected because they may provide evidence of traces of bait material. If the animal is freshly dead, the stomach contents may also contain residues of pesticide. For small animals, collect the whole stomach (or the whole animal). For large animals (e.g. sheep and cattle) collect at least 100 g of stomach

contents. If the animal has been dead for some time, the active compound may no longer be detectable in the stomach and may be found only in appropriate organs and tissues in the body (Wickstrom & Eason 1997). The organs or tissues to collect depend upon the pesticide of interest (see below).

10.1.1 Sodium monofluoroacetate (1080)

For determining 1080 residues, collect at least 10 g of muscle tissue if possible (50 g is preferred) from the hindquarters of mammals or the breast of birds. For samples of less than 10 g (e.g. from small birds), the sensitivity of the analysis will be reduced. Avoid tough sinews that may be difficult to homogenise in the laboratory. Collect muscle tissue from large mammals before opening up the stomach to avoid cross-contamination. Small mammals, birds, and invertebrates should be sent whole. Individuals of small invertebrates (e.g. ants, beetles, or cockroaches) weighing less than 0.1 g can be pooled for analysis. Larger invertebrates can be analysed individually. At least 0.5 g of sample is required for analysis.

10.1.2 Anticoagulants

For determining residues of anticoagulants (e.g. brodifacoum, pindone, diphacinone, coumatetralyl, and flocoumafen) in vertebrates, collect the whole liver (or at least 100 g of the liver of larger animals). Collect the liver from large mammals before opening up the stomach to avoid cross-contamination. Small mammals, birds, and invertebrates should be sent whole. Individuals of small invertebrates (e.g. ants, beetles, or cockroaches) weighing less than 0.1 g can be pooled for analysis. Larger invertebrates can be analysed individually. At least 0.5 g of sample is required for analysis.

10.1.3 Other pesticides

If you suspect poisoning from cholecalciferol, cyanide, or phosphorus, please contact the Toxicology Laboratory, Landcare Research, Gerald Street, PO Box 69, Lincoln, attention Geoff Wright, telephone (03) 325 6701, extension 2265, or fax (03) 325 2418, for details of what to collect.

10.2 PACKAGING, STORAGE, AND TRANSPORT

10.2.1 Packaging

Snap-top plastic bags are the most appropriate packaging for the stomachs of small animals, and muscle, liver, and invertebrate samples. Small screw-top plastic jars are also suitable for small tissue samples, and larger screw-top plastic jars for stomach contents of large animals. Each sample should be labelled externally with at least name of collector, date, location, suspected pesticide, and animal species. It is better to use an attached waterproof label than to mark the container directly. Always use a waterproof marking pen. Do not use pencil which, though waterproof, is not easy to read after freezing and thawing. A separate sample form listing details required for the national Vertebrate

Pesticide Residue Database is given by Wright (1998a, unpublished Landcare Research report).

10.2.2 Storage

All samples should be frozen to below –10°C as soon as possible after collection, and certainly within 8 hours. A chilly bin packed with party ice is suitable for temporary storage in the field until the samples can be placed in a freezer.

10.2.3 Transport

Samples should be sent to the Toxicology Laboratory, Landcare Research, Gerald Street, Lincoln, for analysis. Landcare Research maintains a national database of vertebrate pesticide residues. Send samples frozen. To prevent thawing, samples should be packed in contact with freezer packs or water frozen in plastic soft-drink bottles, either in a chilly bin or thoroughly wrapped in insulating material or newspaper.

Samples should be sent door-to-door early in the week to avoid the possibility of being left out of a freezer over the weekend and thawing out. They should be marked 'URGENT—Tissue samples—Please keep frozen'. No special declaration is required unless the samples are likely to be infected (e.g. from animals with tuberculosis).

10.3 INTERPRETATION OF RESULTS

The report from Landcare Research will state the mean and 95% confidence limits of the pesticide concentration in the samples, plus the limits of detection. The limits of detection of various pesticides using current methods of analysis are as follows:

1080	0.0015 mg/kg in muscle tissue
brodifacoum	0.01 mg/kg in liver tissue
pindone	0.2 mg/kg in liver tissue.

The presence of pesticide residues in a dead animal is an indication of exposure, and must be considered as at least contributing to the cause of death. However, failure to detect a pesticide in a carcass does not necessarily imply an alternative cause of death. A number of variables affect the amount of pesticide present in a sample of animal tissue (e.g. age of the animal, condition, time between ingestion of the pesticide and death, age of the carcass, susceptibility of the tissue and pesticide to degradation, and ambient temperature). The ability to detect pesticide residues in animal tissue is also affected by the size and quality of the sample, so ensure that collection, packaging, storage, and transporting of samples is adequate.

11. Water samples

Aerial poisoning operations for vertebrate pest control cannot avoid dropping baits in freshwater creeks and streams, especially in forested areas. As a result of concerns about the contamination of freshwater by poisons used for vertebrate pest control, especially 1080, extensive monitoring of water for 1080 residues has been carried out since 1990. There was no evidence of any contamination above the minimum acceptable value for human consumption of 5 ppb in 868 samples collected after 40 aerial 1080-poisoning operations from 1990–1998 (Eason et al. 1999). A protocol for collecting water samples after 1080-poisoning operations has been developed by Wright (1998b, unpublished Landcare Research report), and is available on request.

12. Recommendations

Many of the methods described above are still being developed. As a consequence, this manual should be regarded more as a discussion document than as a finished product. Users should contact relevant experts before starting a monitoring programme. We recommend that the Department of Conservation call meetings of relevant experts to finalise the development of standard methods for monitoring the impacts of vertebrate pest control operations on non-target species populations.

13. Acknowledgements

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