Envirolink Medium Advice Grant ESRC205

Measurement of Impacts of Introduced Pest Animals on Indigenous Biodiversity Values in Southland

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Landcare Research Contract Report: LC0607/061

PREPARED FOR:
Environment Southland

DATE: December 2006

ISO 14001

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Summary

Project and Client

Methods for monitoring the impact of vertebrate pest animal control on the biodiversity of indigenous flora and fauna were investigated by Landcare Research for Environment Southland (ES; Contract No. ESRC205), under funding from the Foundation for Research, Science and Technology's (FRST) Envirolink Medium Advice Grant scheme. The work was undertaken between October and December 2006, and followed a preliminary study by Landcare Research on the same topic funded by FRST under its Envirolink Small Advice Grant scheme earlier in the same year.

Objectives

- To provide ES and community groups involved in vertebrate pest management in Southland with suitable techniques for monitoring the effect of controlling pests on:
    - key native flora and fauna in selected indigenous forest communities
    - pest abundance.
- To use selected community groups involved in local pest control to 'model' best practice pest management for other community groups committed to protecting native flora and fauna.

Main Findings

- Monitoring the effects of vertebrate pest control undertaken by community groups in Southland's remnant native habitats should be based on techniques that are reasonably robust and cost-efficient, and are easy to use.
- The techniques considered for native species include 5-minute counts, fixed-width transect counts, and distance sampling for birds; pitfall trapping, malaise trapping, and artificial refuges for invertebrates; pitfall trapping, capture-mark-recapture, canopy searches, and artificial refuges for lizards; and permanent forest plots, point height intercept, foliar browse indices, and whole-plant inspections for vegetation.
- The techniques considered for pest species include trap-catch, bait interference, bait-take, spotlight counts, and faecal pellet counts for possums; capture-mark-recapture, kill-trapping, tracking tunnels, and bait take for rodents; kill-trapping and tracking tunnels for feral cats, ferrets, stoats, and hedgehogs; and spotlight counting and faecal pellet counts for rabbits and hares.

Recommendations

Strategic

- Mores Reserve and Omaui Reserve should be established as a paired treatment/non-treatment trial for a community group to demonstrate the effect of controlling several common pest species including possums, ship rats, and mice on key native fauna and flora.
- Such a trial lacks replication, and thus inferential power, but the approach is useful as a demonstration of the benefits likely to arise from community involvement in local pest management.

- Strategies, control techniques, and monitoring methods from the above trial should be used to guide community groups involved in pest control in other remnant native habitats in Southland.
- Where paired treatment/non-treatment site comparisons are proposed, the sites selected must be similar in habitat (i.e. aspect, topography, vegetation), species composition, and pest control history.
- **Before** beginning other control operations, the abundance of key fauna and flora present on treatment and non-treatment sites should be assessed to allow stronger inference of treatment effects.

Monitoring the impact of pest control on native flora and fauna

To determine the status and trend of key biodiversity elements at risk from the impact of vertebrate pest species:

- Bird populations in Mores and Omaui reserves should continue to be surveyed using the 5-minute count technique. Bird populations in other areas of indigenous habitat in Southland in which pests are controlled to protect biodiversity values should be assessed in the same way.
- Where cryptic bird species are present and considered to be at risk, species-specific population survey methods should be used to monitor their populations.
- Invertebrate populations should be surveyed using artificial refuges.
- Ground-based and arboreal lizard populations should be surveyed using both ground-based artificial refuges and tree houses, respectively
- The impact of possums on the health of upper forest tiers and on individual iconic plant species should be surveyed using foliar browse index scoring and whole-plant inspection techniques, respectively. Oblique photographs of heavily browsed trees or canopy may provide useful publicity material.
- The impact of livestock on forest understorey should be surveyed using permanent forest plots.

Monitoring pest populations

For vertebrate pest species managed in Southland's remnant native habitats:

- Possum abundance should be monitored using the nationally-approved Trap-Catch Index (TCI) protocol.
- Ship rat and mouse populations should be indexed via lines of standard rodent kill-traps.
- Feral cat, stoat and ferret populations should be indexed using catch data recovered from lines of kill-traps used for their control. No attempt should be made to monitor stoat populations.
- Hedgehogs should be indexed from catch data recovered from trap lines set for possums, ferrets and feral cats, and by using tracking tunnels.
- Monitoring pest abundance in non-treatment sites should involve the use of non-lethal techniques, e.g. TCI techniques using soft-catch traps for possums, and tracking tunnels for rodents, ferrets, and hedgehogs.

1. Introduction

Methods for monitoring the impact of vertebrate pest animal control on the biodiversity of indigenous flora and fauna were investigated by Landcare Research for Environment Southland (ES; Contract No. ESRC205), under funding from the Foundation for Research, Science and Technology's (FRST) Envirolink Medium Advice Grant scheme. The work was undertaken between October and December, 2006, and followed a preliminary study by Landcare Research on the same topic funded by FRST under its Envirolink Small Advice Grant scheme earlier in the same year.

2. Background

In the past, ES's strategic focus on the management of pest animals has been on the animals themselves rather than on their impacts. This approach has been taken because of the relative ease with which animal populations can be measured compared with their impacts. Such damage includes reduced pasture production by rabbits (*Oryctolagus cuniculus*) that graze it, and reduced livestock production by possums (*Trichosurus vulpecula*) and ferrets (*Mustela furo*), which act as feral vectors of bovine tuberculosis (Tb). Amongst bird pests, the potential damage to crops has led to rooks (*Corvus frugilegus*) being targeted, while magpies (*Gymnorhina tibicen*) have been controlled because of their purported impact on native bird species.

Pest control programmes have been assessed via performance monitoring programmes focused on indexing pest abundance after the completion of programmes for their control. Examples of this approach used in Southland are the Modified McLean Scale for rabbits (Bell 1992), nest counts for rooks (recently upgraded in NPCA 2006), and the Trap Catch Index (TCI) for possums (NPCA 2004), although the impact of possum control is also directly assessed by the changes in the number of cattle and deer herds infected with Tb. However, performance measures based on pest abundance are problematic because they are unlikely to be correlated in a linear fashion with pest impact (Hone 1994). This means that it does not necessarily follow that a given reduction in pest abundance translates into a commensurate or similar reduction in pest impact. The effectiveness of such pest control is therefore often largely unknown. In particular, where a damage threshold exists, reductions in pest abundance to levels above the threshold can potentially achieve few if any benefits, while exposing operators to ethical issues arising from killing pest animals for no significant benefit (Coleman et al. 2006).

Environment Southland's pest management objectives have now broadened in recognition of evidence of the serious local decline due to predation and browsing of key native species and in key habitats. These objectives include mitigating the impacts of pests on important biodiversity values, i.e. indigenous species that are important ecosystem drivers, or are iconic, or are easy to measure. A pest-led approach in this case has limitations because of the reasons spelt out above, and because it is often very difficult to ascertain which pest species is having what impact on which native animal or plant species. Measuring pest impacts on biodiversity is not, however, straightforward. It requires good planning, good science input, and robust methodologies. Moreover, the cost of implementing impact monitoring on a regional basis (e.g. monitoring the conservation benefits of possum control) is likely to be prohibitive.

Environment Southland requested advice from Landcare Research on monitoring the impacts of pest animal control on the indigenous biodiversity in Southland, particularly those on privately owned lands, to enable improvements to be made to its Regional Pest Management Strategy (currently under review; Anon. 2006). The advice sought included that on techniques suitable for use by community action groups committed to improving the biodiversity of local native flora and fauna. Such community groups are likely to play a key role in assisting ES to conserve native biodiversity in Southland in the foreseeable future. An initial request was made through FRST's Envirolink Small Advice Grant scheme, and on the completion of that work (Norbury 2006), a follow-up request was made under FRST's Envirolink Medium Advice Grant scheme for an expansion of the original advice given.

A site-based approach for measuring and mitigating the impacts of pest control on biodiversity values was proposed by Norbury (2006) in his recent preliminary study on this topic for ES. He proposed choosing a small number of sites representative of the range of key ecosystems in Southland and being 'managed' by community groups long-term, together with sites proposed for future management, which through intensive pest and impact monitoring could provide showcases (exemplars) of local ecosystem management.

This study sought to identify, for two similar indigenous forest sites, best practice tools and techniques (including sampling intensity and statistical reliability) for monitoring what effect controlling key vertebrate pests has on their impact on selected native flora and fauna at those sites, and the direct effects of control on pest abundance. Such information is likely to be transferable to, and provide suitable tools for monitoring, a range of key native species located in other examples of a range of native ecosystems at sites as yet unidentified elsewhere in Southland, i.e. in lowland forest, montane forest, coastal wetland, and tussock grassland.

3. Objectives

- To provide ES and community groups involved in vertebrate pest management in Southland with suitable techniques for monitoring the effect of controlling pests on:
    - key native flora and fauna in selected indigenous forest communities
    - pest abundance.
- To use selected community groups involved in local pest control to 'model' best-practice pest management for other community groups committed to protecting native flora and fauna.

4. Methods

In September 2006 the authors met with Richard Bowman (Biosecurity Manager, ES) and David Burgess (Biosecuity Supervisor, ES) to scope the expanded project, visit proposed study sites, and assess them for their suitability for this work. Information on the techniques (for monitoring pest numbers and the impact on native species of their control) most suited for this work were subsequently obtained in discussion with scientific colleagues, via a literature review, and from the authors' own databases.

To determine the effect on native flora and fauna of best-practice pest control by local community groups, two areas of similar forest habitat were selected for study, one under ongoing pest control (the 'treatment' area) and the other under investigation for similar action in the future (the 'non-treatment' area).

Field inspections identified Mores Reserve, immediately south of Riverton, as the treatment area, because it provided the best opportunity to measure the impact of ongoing control of possums and rats (*Rattus rattus*), and of the bycatch of mice (*Mus musculus*), ferrets, and feral cats (*Felis catus*). This area was chosen despite the lack of data on pest population abundance and habitat condition from before the start of pest control for use in demonstrating the impact of initial control. Mores Reserve comprises c. 200 ha of coastal cutover podocarp/hardwood forest. The area contains a diverse forest community, including iconic invertebrates such as Helms' stag beetle (*Geodorcus helmsi*), the Onychophoran *Peripatus* sp., little ground weta (*Hemiandrus* spp.), and *Powelliphanta* land snails in inland areas.

Pest control in Mores Reserve is being undertaken by the Aparima Pest Busters, a community action group that has established a grid of c. 137 bait stations (for rats) loaded with bromadiolone baits alternating at 50-m intervals over most of the reserve with c. 139 bait stations (for possums) loaded with Pestoff® brodifacoum baits. Beginning in September 2005, each bait station is nominally re-baited each month.

Environment Southland has overseen the control programme run by Aparima Pest Busters, and has monitored the impact of the control using trained and approved contractors. Bird populations have been monitored at 3-monthly intervals beginning in March 2006 (see Section 5.2), rat populations have been assessed using tracking tunnels (see Section 5.1), and rat and possum 'bait-take' records have been obtained for each control operation (see Section 5.1). Earlier control of possums was undertaken by ES as part of its Tb possum control programme, and TCI data are available from this work. Future monitoring of both pests and native species is likely to remain under the control of ES (S. Smith, ES, pers. comm.).

A second site at Omaui Reserve, near Invercargill, and considered by ES to be broadly similar to Mores Reserve in both plant and animal species composition if not species abundance, was selected as a non-treatment site. Omaui Reserve comprises c. 200 ha of coastal cutover broadleaf/podocarp forest, with no recent history of vertebrate pest control and, as yet, no established community action group. However, in line with rat and bird population abundance surveys in Mores Reserve, similar and concurrent surveys have been undertaken in Omaui Reserve (see Sections 5.1 and 5.2).

The ability of both the Aparima Pest Busters group associated with Mores Reserve and any future community group associated with Omaui Reserve to work within the research brief is a precondition of the proposed treatment/non-treatment comparison. In October 2006, this support was limited to an 'expression of interest' by some members of the Aparima Pest Busters (S. Smith, ES, pers. comm.).

5. Main Findings – Alternative Tools and Techniques

5.1 Monitoring the impact of pest control on native flora and fauna

General

Methods of monitoring populations of native flora and fauna are outlined below, with an emphasis on techniques that provide robust population estimates at modest cost. In the case of paired treatment and non-treatment sites such as Mores and Omaui reserves, identical techniques must be used at both sites to allow for site comparisons. The techniques chosen for these sites should be extended to other forest remnants monitored to allow for broader between-site comparisons. *It is critical that such comparisons are based on sites that are as similar as possible in both plant and animal species composition and abundance, and in their pest control history, and areas with distinct differences should not be compared. While recognising the difficulty of identifying twin sites that are 'similar', the selection of two areas with minor differences in their flora and fauna and in their control histories (i.e. Mores and Omaui reserves) makes the interpretation of sampling data of pest populations and of their impacts difficult, and may lead to false assumptions on the value to native species of pest control.*

Birds

The objectives and techniques available for monitoring terrestrial bird populations in New Zealand were reviewed by Spurr & Ralph (2006) following a workshop held at Blenheim in December 2005. Their key recommendations relevant to this study were:

- Monitoring of terrestrial bird populations should ideally provide reliable, robust, and spatially explicit information on long-term population trends.
- All species (both indigenous and introduced) should be recorded, as all are an integral part of the modern New Zealand environment, and it cannot be predicted which species will be an issue in the future.
- Sampling should be undertaken at fixed permanent sites.
- The sampling design should be consistent.

Spurr & Ralph (2006) identified three main techniques used in New Zealand to monitor terrestrial bird populations: 5-minute counts (= point counts; detailed in Spurr & Powlesland (2000)), fixed-width line transect counts, and distance sampling (from points or along transects). Only the first two methods are commonly used, with distance sampling not considered feasible for general surveys (Spurr & Ralph 2006). Additional methods include mist netting, banding and re-sighting, and radio-telemetry, but these are generally considered too expensive and/or time consuming for multi-site monitoring, and are used primarily as research tools (e.g. Armstrong & Ewen 2000). These additional techniques are therefore unlikely to be the techniques of choice when measuring pest impacts on bird populations in remnant patches of forest in Southland. Unfortunately, the attendees at the bird monitoring workshop were unable to reach agreement on which technique of the first two listed was most suitable for monitoring populations of common forest birds, confirming that there is no national protocol for monitoring changes in New Zealand land bird populations. While some workshop participants favoured 5-minute counts for use in forest habitats because they are safer for observers when travelling between stations in difficult terrain and are used commonly by greater numbers of field staff, others favoured line-transect counts because all bird detections are recorded (versus ignoring birds between points) and the technique is thus more likely to record semi-cryptic birds.

In light of this lack of consensus, and of the ongoing 5-minute count surveys in both Mores and Omaui reserves, it seems sensible that 5-minute counts should continue to be used. Monitoring teams should follow the technique as outlined by Spurr & Powlesland (2000), and:

- Ensure consistency in monitoring format with regard to topography, weather, time of day, and ability of observers to allow both spatial (between sites) and temporal comparisons.
- Record the distance of each sighted and identified bird from each observation point (using either unlimited distance or in distance bands; optional — no professional agreement exists so no preference is given).
- Use similar sampling intensities between blocks.
- Count at the same time each day. Because some species are clearly more active at certain times (e.g. kererū (*Hemiphaga novaeseelandiae*) near sunset (Gillies et al. 2003) or morepork (*Ninox novaeseelandiae*) at night), their presence on sites selected for bird monitoring may determine the best time to undertake point counts, and may require unique surveys for them alone.
- Undertake surveys only in spring or summer (i.e. once per year when counts are greatest and most cost-effective, and not four times per year as occurs in Mores and Omaui reserves; see below), and do not attempt cross-season comparisons as they are likely to be misleading.
- Avoid comparison of counts of different species, as detectabilities are likely to differ (Spurr & Powlesland 2000).
- Avoid days or periods of rain and wind.
- Use only adequately trained monitoring staff.
- Switch observers between lines during successive counts to reduce observer biases.

The 5-minute count programme established at Mores and Omaui reserves broadly follows the above practice (on recommendation from DOC, S. Smith pers. comm.) and is based on 20 listening stations at Mores Reserve and 14 stations at Omaui Reserve (to be expanded to 20; S. Smith, pers. comm.). Whether 20 stations at these sites are sufficient for statistical and economic reasons warrants further consideration. If 20 is too few, population changes will be difficult to detect; if 20 is too many, money and human resources will be wasted. A power analysis of the numbers of bellbirds (*Anthornis melanura*) heard (the most robust data recorded so far, cf. numbers seen) at Omaui Reserve indicated that the present data provide about an 80% chance (the standard convention used by statisticians) of detecting a 53% change in bellbird numbers (Appendix 1). Similar analyses for Mores Reserve (Appendix 2; where the sample size and sample variance was higher), and for both areas pooled (Appendix 3) indicated an 80% chance of detecting 40% and 43% changes in bellbird numbers, respectively, and the data were, by comparison, less sensitive. A rough doubling of the present number of counting stations in both areas (to 40) would provide increases in the ability to detect real changes in bellbird numbers of <30% in both areas, but is probably neither necessary nor cost-effective. Power analyses of other bird species counted were not attempted for either area as their average numbers seen or heard per counting station were considerably smaller than that of bellbirds, i.e. generally <1% per station compared with >4%, ensuring detection differences based on these data would be considerably higher. An increase in the number of counting stations necessary to detect similar changes in population counts for all other bird species recorded would need to be very substantial (at least 100–200), and again seems unwarranted.

The use of power analyses to detect differences in bellbird numbers between Omaui and Mores reserves (non-treatment and treatment areas) is not valid due to the difficulty of separating the effect of site from that of the treatment (i.e. there is no replication). While recognising this problem, a ‘rough’ analysis (data not presented) based on the numbers of bellbirds heard in March 2006 and the listening stations used indicates that such an experiment would have an 80% likelihood of detecting a 60% difference in bellbird numbers.

Until a consensus is reached on which bird population monitoring is favoured, we believe 5-minute counts should be the method of choice for the ongoing monitoring of bird populations in both Mores and Omaui reserves, and in other areas of indigenous habitat in Southland in which pests are controlled to protect biodiversity values. Provided the existing counting is undertaken following the guidelines set out in Spurr & Powlesland (2000), any alternative method of monitoring favoured in the future will be able to be phased in over time. Unique methods for cryptic bird species such as early morning/late evening display flight counts for kererū (Innes et al. 2004) or call-counting for nocturnal species such as morepork should be used where these or other cryptic species are present.

Recommendations: Bird populations in Mores and Omaui reserves should continue to be surveyed using 5-minute counts. Bird populations in other areas of indigenous habitat in Southland in which vertebrate pests are controlled to protect biodiversity values should be assessed in the same way.

Where cryptic bird species are present and considered to be at risk, species-specific population survey methods should be used to monitor their populations.

Invertebrates

There are a number of iconic species amongst the wide range of native invertebrates occurring in forest remnants in Southland. For example, Mores Reserve contains populations of New Zealand’s largest stag beetle, Helms’ stag beetle, *Peripatus* sp., and little ground weta, while the large hepialid moth *Aoraia dinodes* occurs from Invercargill to Fiordland (T. Jewell, pers. comm.).These and some other native species appear likely to be of sufficient interest to warrant monitoring their populations for possible impact by predators, and confirmation of their presence in local forest remnants should be sought from local invertebrate biologists.

A wide range of methods exist for monitoring invertebrate populations, including those providing absolute estimates (number of individuals per unit area), relative estimates (catch per unit effort or trapping) and indices determined from ‘sign’ (Southwood 1978). Of these, two methods have been published in New Zealand for use in determining the impact of predation on native invertebrates and the benefits of predator control – namely pitfall trapping and Malaise trapping (Spurr & Powlesland 2000). Additional methods used in New Zealand to monitor baseline insect populations and their trends include litter sampling

(Moeed & Meads 1986) and the use of artificial refuges as monitoring sites (Trewick & Morgan-Richards 2000; Spurr & Berben 2004).

Pitfall traps (containers sunk into the soil to ground level to capture cursorial animals) provide a relatively low cost, rapid survey system that has been widely used in the past to survey insect populations. The use of such traps requires consideration of the following:

- For most species, a good knowledge of the life history of targeted invertebrates is required to develop best-practice sampling regimes.
- Catch rates are generally highest in autumn, with different life stages of different species present at different times (Spurr & Powlesland 2000).
- Catches of invertebrates are usually positively correlated with temperature and are likely to be highest on warm days (Moeed & Meads 1986).
- Traps should be installed at least 1 month before trapping.
- Traps should be placed at 10-m intervals on at least five randomly located lines containing a minimum of four traps per line located on each habitat or stratum being surveyed (Spurr & Powlesland 2000).
- Prior to use, traps should be partly filled with an invertebrate preservative, and covered to exclude rain and litter (Note, such traps may pose a danger to lizards).
- Traps should be checked and emptied daily for at least 4 days.
- Data analysis should follow Spurr & Powlesland (2000).

Because the power of pitfall traps to detect changes in population indices is normally low (given the samples sizes traditionally used; Spurr & Powlesland 2000), we recommend its use in the present study only where artificial refuges (see below) are not suitable.

In contrast to pitfall traps, Malaise traps comprise an open-fronted netting trap (or tent) with a slanting roof that guides incoming flying insects towards a collecting container at the rear of the trap. Malaise traps can be used to collect invertebrates at ground level or up through the various forest tiers. The technique has the same environmental limitations as pitfall trapping (i.e. site, season, and temperature), and in addition, is limited by the large size and cost of each trap, and the time to set up the trap, making the technique more suitable for qualitative than quantitative sampling. The power of Malaise trap systems to detect changes in invertebrate populations has not been determined (Spurr & Powlesland 2000), and because of the limitations listed above, we do not recommend it for monitoring invertebrates in Southland's remnant forests.

Artificial refuges (weta houses) and capture-mark-recapture studies have been used to provide measures of population change of both tree (*Hemideina* spp.) and cave weta (e.g. *Gymnoplectron* spp.) and of other invertebrates using the refuges (Trewick & Morgan-Richards 2000; Spurr & Berben 2004). Similarly, a range of artificial covers (wooden discs or 'Onduline' tiles placed on the ground; see 'Lizards' below) are being used as monitor sites to provide time-series data on invertebrate populations in several restoration projects in New Zealand, e.g. Quail Island in Lyttelton Harbour and in Orokanui in Otago (E. Edwards, DOC, Southland, pers. comm.), and to monitor katipo spider (*Latrodectus katipo*) populations on Kaitorete Spit (Lettink & Patrick 2006). Users of artificial refuges to index invertebrate populations should consider the following:

- Weta houses should be established 1–3 years in advance of their use as monitors (Trewick & Morgan-Richards 2000) as their occupation (and presumably that of other artificial covers) by some species may take several years. The technique may therefore be of limited use in short-term studies, although when used simultaneously in both treatment and non-treatment sites, the slow rate of occupancy will have no effect on any attempted site comparison. Alternatively, pitfall trapping could be used for short-term studies but the technique is generally ineffective at catching large weta and is therefore not favoured.

- Individual refuges (roosts and covers) monitor very limited areas (only a few metres in the immediate vicinity) and may be occupied by key invertebrates only seasonally (Trewick & Morgan-Richards 2000).
- Onduline covers are cheap (c. $1), easy to distribute and quick to check, and observer bias is generally minimal (Lettink & Patrick 2006).
- The numbers and spacing of artificial refuges to best index invertebrate populations is unavailable. In lieu of such information, we suggest following that proposed for ground-based 'Lizards' below, while refuges placed in trees should be whatever is feasible.
- The use of artificial refuges for long-term monitoring may be inappropriate (as with other indices) as their occupancy may not reflect true local abundance (Lettink & Patrick 2006).
- The statistical power of artificial refuges to determine changes in invertebrate populations is unresolved but is under investigation (M. Lettink, University of Otago, pers. comm.).

In contrast to these concerns, E. Edwards (DOC, pers comm.) argues that artificial refuges provide the only cost-effective technique available for widespread use in monitoring invertebrate populations by non-professional or semi-professional survey teams. We support this contention, and recognise that due to their general low cost (although some weta houses may be relatively expensive) and ease of use, artificial refuges, in their many forms, are becoming the method of choice for monitoring invertebrate populations by many entomologists in New Zealand.

Recommendation: Artificial refuges (weta houses for weta and tiles for ground invertebrates) should be the method of choice for monitoring invertebrate populations in Southland.

Lizards

Several species of geckos and skinks live in or are potential residents in Southland's remnant forest patches, including the Southland form of the Otago/Southland large gecko (*Hoplodactylus* sp.), green gecko (*Naultinus gemmeus*), cryptic skink (*Oligosoma inconspicuum)*, McCann's skink (*O. maccanni*) and common skink (*O. nigriplantare polychroma*). Their numbers are thought to be reduced in part through the impact of introduced predators. However, such impact has apparently never been assessed in Southland, largely because of the difficulty of monitoring lizard populations in heavily vegetated habitats. Spurr and Powlesland (2000) summarised lizard population monitoring techniques listed in Towns (1975, 1991, 1994), Whitaker (1994), and Towns & Elliott (1996) (articles not seen by the present authors), and recognised that appropriate methods for widespread monitoring of New Zealand's reptile populations have not been published. The methods favoured by Spurr & Powlesland (2000) include pitfall trapping and minimum number alive (capture-mark-recapture). Additional techniques include visual canopy searches favoured by Neilsen et al. (2004) to survey arboreal striped skinks (*O. striatum*) in the North Island. The same method could be used for green geckos.

In contrast to the more traditional methods of sampling, C. O'Donnell (DOC, pers. comm.) is evaluating artificial refuges in the form of single bitumen-based heat-retaining 'Onduline' tiles to monitor the abundance of ground-dwelling skinks and tree 'houses' to monitor the abundance of arboreal geckos in the Eglinton Valley, Fiordland. While the calibration of the technique is incomplete, results look promising. Similar artificial refuges in the form of two tiles placed one on top of the other are being used to detect and index common skinks and common geckos on Kaitorete Spit and Quail Island in Canterbury (M. Lettink, pers. comm.). Initial results indicate that bitumen tiles are favoured by geckos, while skinks show no preference for bitumen, concrete or iron roofing tiles. Both refuges appear very successful at detecting both species, and as they 'catch' more lizards than pitfall traps, they are our method of choice for use in monitoring lizard populations in Southland.

All of the methods listed above have limitations for use in Southland's remnant forests. For ground-dwelling species, pitfall trapping appears to provide a cost-effective technique for long-term multi-site monitoring of lizard populations, although the catch may be low and the power of the technique to detect changes in population indices in forests is unknown, although being investigated (M. Lettink pers. comm.). The minimum-number-alive technique provides an extension of pitfall trapping, in that animals are marked before release and recovered at a later date to detect changes in population size. The standard method for marking lizards is toe-clipping but it is labour intensive. An alternative method is a non-permanent mark on the surface of the lizard using a xylene-free marker pen. The mark will remain on the lizard for the duration of a capture session (e.g. 5 days), requires less skill than toe-clipping, and is more humane. This way, the number of unique individuals caught can be derived.

For ground-based lizards, users of pitfall trapping should follow that outlined in Spurr & Powlesland (2000), unless otherwise specified, and:

- Use pitfall traps as described above for the collection of invertebrates.
- Set traps at 3-m spacings on grids of at least 20 traps (G. Norbury, unpubl. data). The latter approach can presumably be applied within 'strata' favoured by skinks such as amongst the rocky tors present in Mores Reserve or on sunny bush edges, thus reducing the trapping effort spent in habitat less favoured or actively avoided by lizards.
- Check traps daily for at least 4 days.
- Survey non-treatment areas (if used) in a similar manner, and over the same time period.
- Express the results as the number of uniquely marked lizards captured per 100 trap nights (i.e. 50 traps set for 4 nights = 200 trap nights).
- Follow Spurr & Powlesland (2000), particularly with regard to sampling intensity, the density, setting and baiting of traps, and analysis of data.

By comparison with pitfall trapping, users of artificial ground-based refuges (tiles) should:

- Set up refuges 1 month before each survey to allow lizards time to colonise them, and then remove refuges after each survey so that the artificial habitat does not have an effect on population size (M. Lettink pers. comm.).
- Set out 20 tiles at 3-m spacings.
- Check the tiles daily for 4 days.
- Undertake counts on cool days when lizards are less mobile and thus easier to identify and count.
- Be aware that:
    - Low numbers of ground-based reptiles occur in many forests (as also identified by pitfall traps) and the likelihood of collecting robust data is fairly limited.
    - Lizard species differ in their preferences for different types of refuges.
    - Lizard numbers vary seasonally, with lowest numbers being 'trappable' in winter. As such, annual surveys conducted in spring or summer seem likely to provide adequate data for the present study.

- Because of the strong selection for the tiles, the numbers of reptiles seen under them may not reflect the population at large.

For indexing arboreal lizards, monitoring poses particular problems that can only readily be resolved by direct counting and by the use of tree houses. Direct counting has been used for monitoring ground-based Otago skinks (Patterson 1992) and arboreal striped skinks (Neilsen et al. 2004), and appears likely to be a cost-effective, though expensive, technique for monitoring nocturnal reptile species occurring in shrubs on the shrub/forest margin and thus within sight of human observers. The technique is easy to implement, but is affected by time of day, weather, season, skill of the observer, and the density of the vegetation. As it generally provides data of limited value, it is not recommended. Conversely, tree houses appear likely to provide a less expensive monitoring technique that, unless proven otherwise by current research, appears a more suitable option.

Recommendation: Despite the shortcomings of the ground-based techniques listed above, particularly the lack of any power analyses for any of the techniques used to determine population changes, based on cost and ease of data collection, generally higher catch rates, and increasing investigation and use to sample lizard populations (Lettink, pers. comm.), we recommend artificial refuges including both ground-based tiles and tree houses to measure ground and arboreal reptiles, respectively, in forest remnants in Southland.

Vegetation

A range of techniques have been developed and used in New Zealand to measure the impact of browsing mammals on native forest ecosystems. The techniques providing quantitative data and those most favoured for measuring responses to browsing animals of forest understorey are permanent forest plots and point-height intercept surveys, while those favoured for measuring similar impacts to forest canopy and subcanopy tiers are permanent forest plots, foliar browse indices, and whole-plant inspections (see below). Less favoured techniques not considered further here are descriptive accounts of the understorey and canopy (non-quantitative data), hemispherical (fish-eye) photography (not species-specific), and remote sensing (still being developed). Whatever the technique used, their use and/or interpretation should be accompanied by robust data on browsing animal abundance. Ground-based photographic records of individual plants and forest tiers targeted by possums, while difficult to quantify, may have value in publicity material supporting long-term changes in pest impacts arising from control programmes.

Permanent forest plots (typically 20×20-m quadrats) have traditionally been used, and continue to be used to measure changes in the condition of the understorey arising, amongst other factors, from the browsing of ungulates, and of overstorey species from the browsing of possums. The technique is too extensive for précis here, but is detailed in Allen (1993). Such plots provide robust measures of forest change and of individual sapling and tree mortality not readily obtainable using other methods. As a relevant example of its use, Gillies et al. (2003) uses this method to deduce the trigger levels that possums must be held below to ensure the long-term recovery in forest condition in Trounson Kauri Park.

Where the causes of forest change are unclear, the comparison of permanent plot data with that from nearby fenced exclosures has been used to clarify the local impact of ungulates (Stewart & Burrows 1989), while the use of existing/recent fences (e.g. as at Mores Reserve) as ready-made exclosures may provide opportunities to assess the impact of the grazing and browsing of livestock on forest margins (e.g. in South Westland; Timmins 2002). Woody species browsed by cattle in the latter study and occurring in Southland forest remnants include patē (*Schefflera digitata*), broadleaf (*Griselinia littoralis*), pigeonwood (*Hedycarya arborea*), supplejack (*Ripogonum scandens*), māhoe (*Melicytus ramiflorus*), milk tree (*Streblus heterophyllus*), lancewood (*Pseudopanax crassifolium*), and hen and chickens fern (*Asplenium bulbiferum*).

The establishment and monitoring of permanent forest plots should be based around the following:

- random location of plots, where possible, as anything less will affect the statistical rigour, overall representativeness, and inferential value of the data (Allen 1993)
- stratification in the location of plots to allow for more efficient sampling (Allen 1993)
- subjectively placing plots in rare, ecologically important, or heavily damaged sites
- the permanent marking of all plots and on-site plants
- the periodic (5-yearly if possible) measurement of all seedlings, saplings and larger trees
- the guidelines provided by Allen (1993) for plot layout, plot measurement, frequency of remeasurement, and analysis of data. We are unaware of any existing power analysis of sampling intensity, however.

Point-height intercept (PHI) methodology was promulgated by Park (1973) as a ground-based method for quantifying low-to-medium forest (i.e. readily visible) vegetation. It consists of projecting a number of vertical sight-lines (normally a sampling rod in low vegetation and a telescope for subcanopy and canopy vegetation) up through the vegetation and scoring any intercepts with vegetation. However, PHI will only provide information on the impacts of browsing where both browsed and unbrowsed foliage is intercepted, it is difficult to use in multilayered forests, and it is time consuming and thus expensive to undertake (Payton et al. 1999). For these reasons, it is not favoured for the present study and is not discussed further.

Foliar browse index scoring was developed by Payton et al. (1999) as a ground-based method specifically to assess damage of the overstorey by possums by scoring browse in the subcanopy, canopy, and sometimes in emergent forest trees containing a representative selection of species known to be targeted locally by possums. The technique uses assessment and reassessment of permanently marked individual trees to determine trends in foliage cover on a 10-point scale and in possum browse damage on a 5-point scale, and has been used recently to assess the impact of possums in several New Zealand forests, e.g. in mixed beech/hardwood forests in South Westland (Sweetapple et al. 2004), and on kohekohe (*Dysoxylum spectabile*) stands in forests in Northland (Nugent et al. 2002).

The methodology behind the foliar browse index is again too extensive to précis here, but its use should include consideration of the following:

- the careful selection of readily visible, locally abundant plant species preferred by possums and above deer-browse height. For Southland, these will include such species as māhoe, fuchsia, kāmahi (*Weinmannia racemosa*), wineberry (*Aristotelia serrata*), bush lawyer (*Rubus* spp.), patē, southern rata (*Metrosideros umbellata*) and lancewood, with species selected likely to vary in occurrence between local patches of forest remnants
- differentiating the impact of possums from other agents suspected of impacting on the health of local forests (e.g. salt damage or insect attack), by including some trees not browsed by possums in each survey
- recording dieback and the proportion of possum-browsed leaves, as well as foliage cover
- excluding cross-season comparisons, because possum browse is most evident in winter and spring, and foliage cover is highest in summer

- being aware of the likelihood of observer bias, and attempting to reduce this by using 2-person teams that generally agree in their scoring, by rotating the observers on plots, and by attempting to ensure at least one member of the survey team is present during successive remeasurements
- being aware that plots located on the forest edge are more likely to be heavily browsed than those located in the interior of forests (Bach & Kelly 2004)
- following the guidelines provided by Payton et al. (1999) on plot layout, sampling intensity, plot measurement, the frequency of remeasurement, and the analysis of the data
- recognising that a sample of 50 individuals is required to reliably detect whether a 10% change in foliar cover score is statistically significant.

Whole-plant inspections are a variant of the Foliar Browse Index technique, and have been used to demonstrate the benefits of reducing possum numbers on the condition of selected and rare individuals of species highly favoured by possums (e.g. Sessions & Kelly 2001; Sessions et al. 2001). Sweetapple et al. (2002) used this technique to determine the level of management of a possum population in the central North Island necessary to ensure the survival of the loranthaceous mistletoe *Tupeia antarctica.* In his study, Sweetapple's protocol consisted of:

- setting up a long-term monitoring programme of the condition of individual at-risk specimens of the chosen plant parasite
- locating and permanently marking as many specimens of the at-risk species visible from ground level as possible
- annually recording the size (width and height of live stems) and quantity of possum browse (on a 5-point scale)
- annually recording the percent foliage cover (on a 10-point scale)
- calculating plant volumes from the size data recorded.

Depending on the plant species selected, this technique can be modified to achieve similar estimates of condition to that determined using Foliar Browse Index surveys.

Permanent forest plots, the Foliar Browse Index, and whole-plant inspections provide robust but labour-intensive and costly measures of mammal browse and are all suitable for use in Southland's remnant forests.

Recommendations: Where possum populations are suspected of being unacceptably high and adversely affecting the health of local forests, a combination of the Foliar Browse Index to demonstrate overall browse patterns and whole-plant inspections to show possum impact on the health of individual iconic plant species should be considered. Oblique photographs of heavily browsed trees or canopy may provide useful publicity material.

Where livestock or wild ungulates are invading forests, permanent forest plots should be used to provide incontrovertible evidence of their impacts.

5.2 Monitoring pest populations

General

Possums, ship rats, and stoats (*Mustela erminea*) are likely to be the most common vertebrate pest species that community groups will seek to control in order to protect native biodiversity in key remnant patches of indigenous habitat in Southland. In addition, feral cats, ferrets, stoats, and mice may be targeted either directly or taken as by-catch in programmes targeting possums or rats. Managing such species effectively requires reliable estimates of pest abundance that are robust, precise, and cost-efficient. Methods suitable for monitoring the species listed above are outlined below. The monitoring techniques currently employed to monitor pest populations in Mores Reserve, and to a lesser degree at Omaui Reserve, are also detailed.

Possums

Six methods have been used frequently in New Zealand to estimate or index possum populations. They include a range of trap-catch methods, bait interference (using wax tags), bait take from bait stations, spotlight counts, faecal pellet counts, and the use of mortality-sensing radio collars (Warburton 2000). Of these, the trap-catch method, now formalised in a National Protocol, is the method of choice used by all regional councils and by the Department of Conservation for most if not all operational (control-based) monitoring (NPCA 2004). The 'Protocol' is based on sampling possum populations by means of a standardised leg-hold trapping survey using Victor No. 1 hard-jawed traps, with the capture data used to calculate a trap-catch index (TCI; pre-control), a residual (survivor) trap-catch index (RTCI; post-control), and, if desired, an operational percent kill. The 'Protocol' is too detailed for précis in this report. It is, however, recommended reading for all intending users of the technique, and in summary sets out:

- how to design a TCI survey, including the stratification of control areas
- the sampling intensity required for areas of different size (e.g. for areas of <500 ha, 10 lines of 10 traps spaced at 20-m intervals should be used)
- the random selection of trap lines
- line spacing – at least 200 m apart
- how to set traps for ground and raised sets
- trap checking and clearance – daily for 3 days
- weather constraints – undertake in fine weather only, and what to do if trapping is broken by wet weather
- habitat constraints
- recording and analysing the data, and presenting it as an index of abundance expressed as the number of possums caught per 100 trap nights.

The sampling intensity of the TCI method is designed to provide a relatively high degree of precision around each population index and allow for robust comparisons between the abundances of separately controlled populations. For an area of 200 ha (the size of Mores Reserve), 10 lines of 10 traps should be used, while still following the protocol, and this sampling intensity should provide precision estimates on population indices of 5% TCI of ±5%. At lower possum densities (i.e. TCIs of 2%), now accepted as the level needed for the protection of some locally scarce species such as mistletoe (e.g. *Tupeia* spp.) and tree fuchsia (*Fuchsia excorticata*), TCIs are relatively poor indicators of possum abundance and must be interpreted conservatively.

The indexing of possum populations in non-treatment areas should be undertaken in a similar manner but using soft-catch (soft-jawed) traps to allow for the release of any captured animals.

While there are obvious shortcomings in the ability of this trap-catch technique to identify modest population changes, and while population indices generated within 1–2 months of control are normally biased low (Coleman & Coleman 2001), no other method is now commonly used by pest managers in New Zealand to index possum populations, and we suggest that for the current study no other method should be contemplated. This position is based on the accepted high costs of methods that estimate population size and density (e.g. capture-mark-recapture) and, compared with trap-catch, the generally lower accuracy and precision of all other population index measures available (i.e. wax tags, faecal pellet counts, and bait-take). Wax tags and faecal pellet counts are not recommended: the rigour of the technique of wax tags is still being debated, while faecal pellet counts have long been discarded because of problems of observer bias (some recorders find very few pellets) and pellet decay. Similarly, bait-take is not recommended, despite such data being collected from stations nominally filled for possums each month in Mores Reserve by the Aparima Pest Busters, from September 2005 to July 2006. Such data have little statistical rigour, as the number of stations checked and filled each month has varied from between <20 and c. 180, and 'bait-take' at Mores Reserve and elsewhere by possums is typically further confused by bait removed by other species, e.g. rats (Warburton 2000).

Recommendations: Possum populations under control should be monitored using the TCI method. Non-treatment populations should be monitored using the TCI technique but with soft-catch traps to allow for animal release.

Ship rats and mice

Methods of estimating or indexing rodent population size that are commonly used in New Zealand include kill-trapping, tracking tunnels, and capture-mark-recapture in its various forms.

Capture-mark-recapture methods are considered to provide the best estimates of mouse numbers (Ruscoe et al. 2001; Wilson et al. 2006). Of such techniques, the minimum number alive (MNA), based on either one or three nights' catch, was found to be most strongly correlated with estimated densities of mice in Fiordland National Park (Ruscoe et al. 2001). Typically, MNA involves grids of a minimum of 7×7 Elliott mouse traps set at a minimum of 10-m spacings and baited with peanut butter and rolled oats for 3–5 nights.

Trap-catch (using kill-traps such as snap traps) and tracking rates (in tunnels) appear to be useful techniques for indexing the abundance of rats and mice at high to medium densities, but may not be correlated with real numbers when densities are low (Blackwell et al. 2002). Trap-catch does appear, however, to be the best option for indexing abundance by pest managers and community groups (W. Ruscoe, Landcare Research, pers. comm.) and, following Weihong et al. (1999), Gillies et al. (2003), and Wilson et al. (2006), should broadly involve:

- 4–5 marked trap lines of about 25 sites either with pairs of rat and mouse 'Ezeset' traps or alternating rat and mouse traps set at 20–30-m intervals
- traps baited with a mixture of peanut butter and rolled oats
- traps set and cleared daily for at least 3 days during periods of fine weather
- the catch data corrected for sprung traps and converted into an index of abundance expressed as the number of rats or mice caught per 100 corrected trap nights.

Despite there being some evidence that conventional long trap lines appear less efficient at detecting rat presence than the same traps used in trapping grids (Weihong et al. 1999), the use of long trap lines recognises the limits that may be imposed by trapping grids in small areas of dense or broken habitat, the likely cost differential, and the abilities of non-professional community groups undertaking the control. Kill-trapping, however, is unsuitable for monitoring rodent populations in non-treatment areas because of short-term population losses.

Tracking tunnels are the most commonly used method for indexing rodent abundance at conservation sites within New Zealand (Gillies & Williams, DOC unpublished note). Tracking tunnels are useful for indicating very large differences in rodent activity but greatly overestimate real population size (Jones & Toft 2006), and appear to be unrelated to mouse density (Ruscoe et al. 2001). They may however be used to compare relative abundance of mice within the same or similar habitats, but should be complemented with a second density index (Blackwell et al. 2002). Data from tracking tunnels must, therefore, be interpreted conservatively, and the method is not recommended for the present study except in non-treatment areas where kill-trapping is unsuitable (see above).

Tracking tunnels presently being used to monitor rat and mouse abundance vary greatly in their design and size (Gillies & Williams, DOC unpublished note). Where large enough, they incidentally record ferret and hedgehog (*Erinaceus europaeus*) activity (as occurs at our identified study areas). In both Mores and Omaui reserves, four lines of 10 Cor-flute tunnel stations have been set up, with 3 or 4 lines run each sampling session (March, June, September and December), following a protocol provided by C. Gillies (DOC, Hamilton). All tunnels were deployed several weeks before the initial survey (March 2006) and have been left on site permanently to overcome tunnel shyness. Tunnels are presently run for one night only before being checked for identifiable footprints. In addition, some early tracking data exist from Mores Reserve for November 2004. Unfortunately, the extreme variability of the data gathered from both areas (from 0 to 14 mice, 0 to 5 rats, and 0 to 1 stoat) over the two seasons of data received by Landcare Research, the high number of zero records, and the small numbers of sampling stations (normally 30 per site) do not enable us to generate with any rigour any estimate of the size of a tracking tunnel programme required to provide robust estimates of population change within or between sites.

Bait-take from toxic bait stations loaded with bromadiolone baits in PVC pipes to control rodents in Mores Reserve is recorded each month from September 2005 by the Aparima Pest Busters when the stations are refilled, and provide an additional if unconventional index of rodent abundance. However, because the stations checked each month have varied between <20 and c. 180 (see 'Possums' above), and because the standard of the data is thought to be modest (S. Smith, ES, pers. comm.), bait-take is not recommended as an index for either the rat or mouse populations in Mores Reserve. Further, because the 'take' is not specific to any of the rodent species present (although much is thought to be taken by mice; S. Smith, ES, pers. comm.), the technique is also not recommended for use elsewhere in Southland.

Recommendations: Ship rat and mouse populations under control should be monitored using conventional trapping lines. Non-treatment populations should be monitored using tracking tunnels, preceded by an off-site calibration of the two techniques.

Feral cats and mustelids

Because of the large sample error generally associated with all estimators of population size of feral cats and ferrets, and thus the high cost of undertaking statistically robust surveys, both species are usually roughly indexed from catch data recovered from trap lines used for their control (Keedwell & Brown 2001; Moller et al. 2002; Gillies et al. 2003). Such indices are usually generated despite the lack of any randomness of line locations, stratification of trapping areas, or correction for 'sprung' traps. Robust estimates of population size of cats or ferrets (normally by capture-mark-recapture) are generally confined to research studies (e.g. Caley & Morriss 2001) or for specific management purposes (Norbury & Efford 2004). Control (and hence catch-derived population indices) is normally based on:

- trap lines of Victor 1½ hard-jaw traps (for cats and ferrets) or Mark IV Fenns (for ferrets only)
- traps baited with rabbit, hare (*Lepus europaeus*), or possum flesh (if rabbit carcases are hard to come by)
- a minimum of 100 traps set at 100–150-m intervals
- trap lines placed along scrub/forest ecotones
- trap lines monitored for 10+ days (Anon. 2002).
-

Importantly, the traps widely used (Victor 1½) for cat and ferret control recently failed animal welfare requirements, and are now being replaced by the DOC250 and DOC150 kill-traps (B. Warburton, Landcare Research, pers. comm.).

Trapping for ferrets, as distinct from trapping for cats, poses special problems, and should only be employed in late summer – early autumn when greatest catches are recorded. Catches should therefore not be compared across seasons, and where trap-catch is undertaken over a minimum of 5 days and produces <3 ferrets/100 trap nights, the data do not permit any inference on animal density (Anon. 2002). As with trap-catch data from other species, particularly where low catches are expected, trap biases are likely due to predator hunger, trap-shyness, season, sex (towards female ferrets), the predator guild present, and the trapping techniques used, and from the immigration of targeted animals into the area (Keedwell & Brown 2001). These concerns limit the usefulness of the technique to ‘broad brush’ indexing of populations only from single sites trapped under identical conditions and do not permit comparisons of indices taken under more variable conditions (Keedwell & Brown 2001; Anon. 2002).

Trapping for cats and ferrets is likely to also catch hedgehogs, and any index of abundance of cats or ferrets derived from trapping data must allow for non-target catches.

Tracking tunnels are not a preferred option (Moller et al. 2002), but where cat and ferret populations are to be indexed in uncontrolled (non-treatment) areas, tracking tunnels appear to offer limited advantages over all other commonly used methods, if only because of the apparently lower levels of shyness involved, e.g. using soft-catch traps to allow for the release of any captured animals.

Stoat populations, which are likely to occur at particularly low densities compared with other pest species, have been indexed both using kill-traps set on long lines (King & White 2004) and from tracking tunnels (Wilson et al. 2006). However, Choquenot et al. (2001) argue the need for very large samples of detection devices to demonstrate variation in stoat populations, i.e. >150 tunnels to detect a population of <6 stoats living in 10 000 ha. Such approaches will rarely lend themselves to management-driven studies and are not considered further.

Recommendation: Kill-trapping for cats and ferrets seems the best control option for community groups, and will provide a rough population index of both species. Data on hedgehog populations will also be forthcoming. Populations in non-treatment areas should be monitored using tracking tunnels. No attempt should be made to measure stoat populations.

Hedgehogs

Hedgehogs are regular by-catch in trap lines set for possums, cats and ferrets, and their populations can be roughly indexed by this method (for details, see ‘Feral cats and mustelids’ above), although the inevitable low catch will result in high sample error (Keedwell & Brown 2001; Jones & Toft 2006). However, between-site or between-year comparisons rely on consistent patterns and use of traps. Once again, estimates of density are likely to be a cost disincentive for use by land managers for this species.

The use of the tracking tunnels (see ‘Ship rats and mice’ above) currently set in both Mores and Omaui reserves to index rodent abundance will also provide a rough approximation of hedgehog abundance. Provided the data are interpreted conservatively, this approach is the only non-lethal technique suitable for use in the present study

Recommendation: Hedgehog populations should be indexed from data recovered from trap lines set for possums, feral cats, ferrets, or stoats (where this occurs). Populations in both treatment and non-treatment areas should be monitored using tracking tunnels.

Rabbits and hares

Spotlight counts and pellet counts on cleared plots are the only two regularly used techniques for indexing rabbit and hare populations, and only pellet counts are suitable for use in scrub and forest habitats. Once again, such techniques provide estimates of relative abundance only (Wilson et al. 2006).

Recommendation: Unless rabbit and hare populations are believed to be seriously impacting on forest-edge understorey, no attempt should be made to index their abundance.

6. Recommendations

Strategic

- Mores Reserve and Omaui Reserve should be established as a paired treatment/non-treatment trial for a community group to demonstrate the effect of controlling several common pest species including possums, ship rats, and mice on key native fauna and flora.
- Such a trial lacks replication, and thus inferential power, but the approach is useful as a demonstration of the benefits likely to arise from community involvement in local pest management.
- Strategies, control techniques, and monitoring methods from the above trial should be used to guide community groups involved in pest control in other remnant native habitats in Southland.
- Where paired treatment/non-treatment site comparisons are proposed, the sites selected must be similar in habitat (i.e. aspect, topography, vegetation), species composition, and pest control history.
- **Before** beginning other control operations, the abundance of key fauna and flora present on treatment and non-treatment sites should be assessed to allow stronger inference of treatment effects.

Monitoring the impact of pest control on native flora and fauna

To determine the status and trend of key biodiversity elements at risk from the impact of vertebrate pest species:

- Bird populations in Mores and Omaui reserves should continue to be surveyed using the 5-minute count technique. Bird populations in other areas of indigenous habitat in Southland in which pests are controlled to protect biodiversity values should be assessed in the same way.
- Where cryptic bird species are present and considered to be at risk, species-specific population survey methods should be used to monitor their populations.
- Invertebrate populations should be surveyed using artificial refuges.
- Ground-based and arboreal lizard populations should be surveyed using both ground-based artificial refuges and tree houses, respectively.
- The impact of possums on the health of upper forest tiers and on individual iconic plant species should be surveyed using foliar browse index scoring and whole-plant inspection techniques, respectively. Oblique photographs of heavily browsed trees or canopy may provide useful publicity material.
- The impact of livestock and wild ungulates on forest understorey should be surveyed using permanent forest plots.

Monitoring pest populations

For vertebrate pest species managed in Southland's remnant native habitats:

- Possum abundance should be monitored using the nationally approved Trap-Catch Index (TCI) protocol.
- Ship rat and mouse populations should be indexed via lines of standard rodent kill-traps.
- Feral cat, stoat and ferret populations should be indexed using catch data recovered from lines of kill-traps used for their control. Do not attempt to monitor stoat populations.
- Hedgehogs should be indexed from catch data recovered from trap lines set for possums, ferrets, and feral cats, and using tracking tunnels.
- Monitoring pest abundance in no-treatment sites should involve the use of non-lethal techniques, e.g. TCI techniques using soft-catch traps for possums, and tracking tunnels for rodents, ferrets, and hedgehogs.

7. Acknowledgements

We thank Richard Bowman, David Burgess, and Sherman Smith of ES for assisting in scoping this project and in the selection of study sites, the Foundation for Research, Science and Technology for funding the work under its Envirolink Medium Advice Grants scheme, Warwick McCallum of the Aparima Pest Busters, Riverton. Andrea Byrom, Christine Bezar, and Eric Spurr provided editorial comment, and Guy Forrester undertook the Power analyses.

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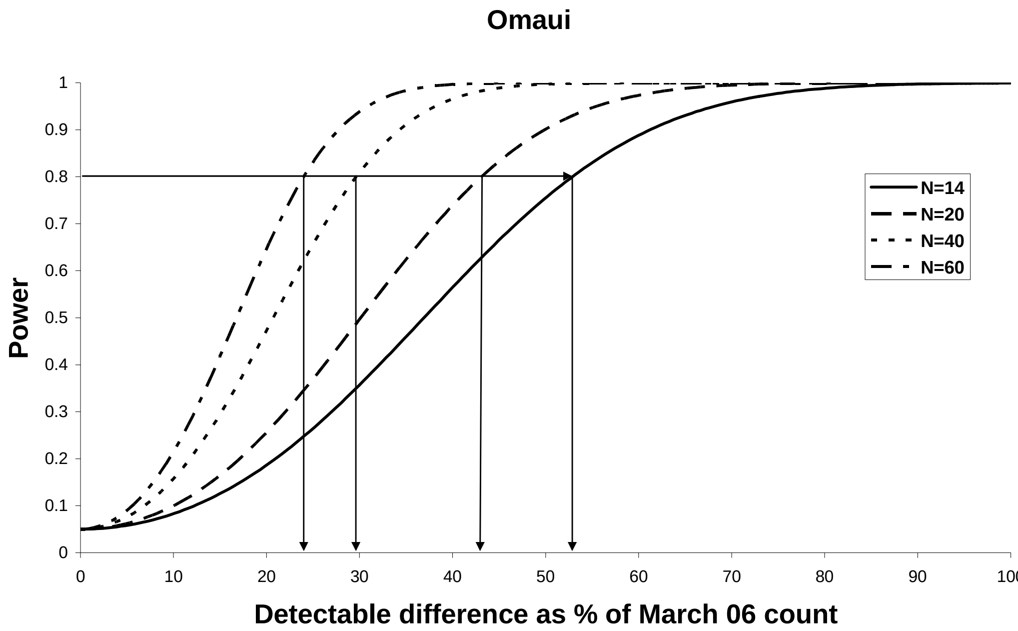
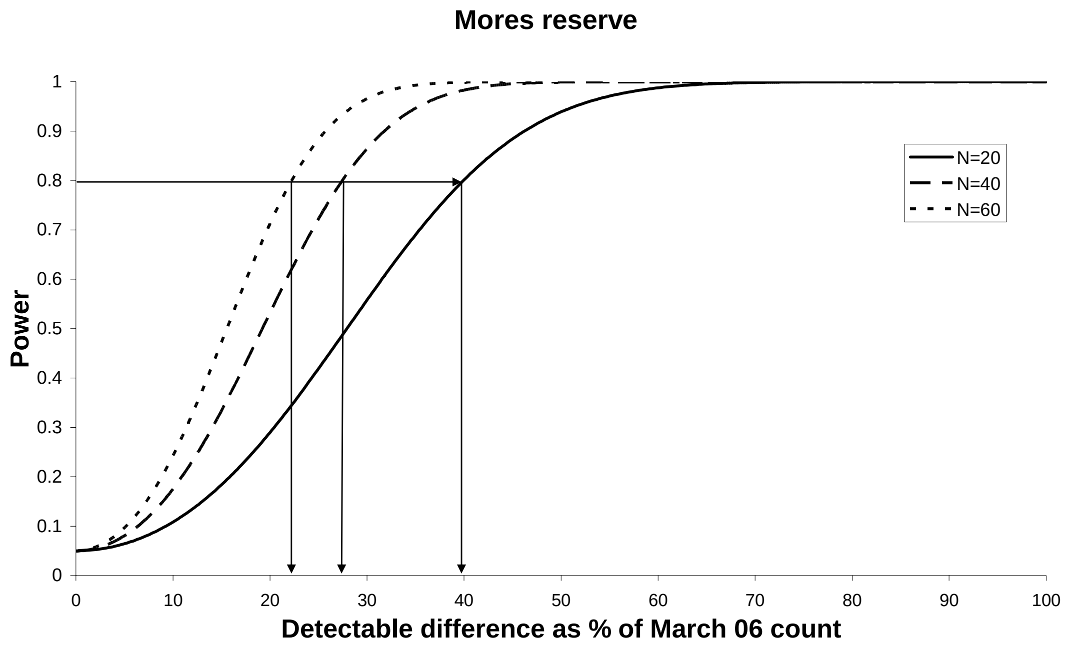
Appendix 1

Power curves for bellbirds heard in Omaui Reserve for samples of 14 (the current number of counting stations), 20, 40, and 60, showing the 80% chance of detecting differences as a percentage of March counts.



Appendix 2

Power curves for bellbirds heard in Mores Reserve for samples of 20 (the current number of counting stations), 40, and 60, showing the 80% chance of detecting differences as a percentage of March counts.



Appendix 3

Power curves for bellbirds heard in Mores Reserve and Omaui Reserve pooled for samples of 20, 40, and 60, showing the 80% chance of detecting differences as a percentage of March counts.