Best practice operational and outcome monitoring for pest management – a review of existing council approaches and activity

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Summary

Project and Client

Horizons Regional Council, acting on behalf of a consortium of 15 Regional and Unitary Authorities (RUAs), asked Landcare Research (through Envirolink funding HZLC56) to design and analyse a survey of RUA animal pest management activity and its associated operational and outcome monitoring. The Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) subsequently funded expansion of the survey to include weeds, and the survey was conducted by Landcare Research with joint funding from the RUAs and MAFBNZ.

Objectives

- To design, conduct, analyse, and report on a survey of animal pest and weed control and associated monitoring undertaken by 15 territorial authorities during the period 1 July 2005 – 30 June 2008
- To identify issues with current practice, and provide advice on improvements
- To present findings to council biosecurity managers group and MAFBNZ pest management group

Methods

- A list of survey questions was compiled for use at interviews with council staff. Horizons Regional Council acted as a test case for the interview process. Based on that interview the questionnaire was further refined before the remaining participating RUAs were interviewed.
- Surveys were conducted in August 2008, mostly by face-to-face interviews to ensure accuracy of data and a good level of survey participation. Meetings with Biosecurity managers, or one of their staff, also allowed for discussion of the local and regional issues associated with each RUA.
- For each control operation or programme, details were collected about what pests were targeted, what control work was done, by whom, why, where, when, and how; we also collected information on what associated operational and/or outcome monitoring was done and how it was done; and estimates of effort and/or costs of monitoring.
- Operations were defined as either ‘species-led’ programmes, where the aim of control is targeted at individual species, or ‘site-led’ programmes which aim to control a suite of species in a particular area for a broader overall goal. Most site-led programmes and some species-led programmes (e.g., possum control) had many operations with similar targets and monitoring. In such situations, data from individual operations were combined.
- A Microsoft Access database was constructed to hold the data and facilitate its analysis. Some data were converted to categories to simplify analysis.

Results

- Animal and plant pest focussed control operations (i.e. species-led) were much more prevalent than site-led operations.
- The primary objective (= goal) for control, as described by the interviewees, was mostly for biodiversity or production protection. Other goals were protection of amenity, environmental, human health or cultural values. Often, more than one justification was provided for control operations.

- Control operations were carried out mostly by RUA staff themselves or by external contractors. RUAs funded approximately half of the operations required under the Regional Pest Management Strategies (RPMSs). Most landowner-funded pest control was compliance related, and undertaken to meet criteria notified in the RPMSs. Of the 102 operations identified in the survey 84 were initiated through a RPMS versus other means.
- RPMSs specify a large number of pests, namely 61 animal species and 196 plant species. Only 32 animal (52%) and 132 plant pests (69%) were recorded as being targeted by RUA control operations in 2005-08.
- Of these, possums were the most frequent, followed by mustelids, rats, rabbits, goats and rooks. For plants, Contorta pine, old man's beard, African feather grass, gorse, Nasella tussock, nodding thistle, woolly nightshade, and broom were targeted most frequently.
- Average annual expenditure on pest control over the three years covered by the survey was about $20 million, with roughly the same spent on direct RUA staff costs and external costs (direct operating expenditure and/or contractor fees).
- A wide range of results monitoring techniques was used to measure the progress of pest control. A smaller set of these was used for outcome monitoring.
- About 20% of RUA funding dedicated to pest control was used for monitoring. Monitoring for compliance purposes accounted for 62% of all monitoring by value, even although it was only done by only six out of the 15 RUAs surveyed.
- Outcome monitoring accounted for about 7% of the total monitoring expenditure, and about 1.5% of the total spent on council-funded pest control. More than half the RUAs we surveyed did no outcome monitoring and one programme from Environment Canterbury, 'biodiversity sites', accounted for almost half the total expenditure ($130,000).
- Most (91%) control operations had some form of results target or 'goal'. For those operations with specified targets, the most common measures were a specified % reduction in pest numbers (26%), a target threshold (e.g. numbers, area) below which pests were to be reduced (25%), and zero density (24%). None of the operations that had associated outcome monitoring had specified outcome targets.
- Overall, about 82% of operations had some form of results monitoring, compared with only 16% with some form of outcome monitoring. Nine operations (11%) had no monitoring at all.
- The most common design (71%) was for a single treatment area, no non-treatment area, and results monitoring only, the second least robust of designs. Only three (4%) of the 83 operations where monitoring was carried out had both treatment and non-treatment areas and both results and outcome monitoring.
- All but one example of outcome monitoring that was identified in the survey had biodiversity protection as its primary goal – there was no reported monitoring for economic outcomes of RUA pest management for forestry or agricultural production.

Conclusions

- RUA pest management is largely focussed on species-led programmes but with a developing move towards site-led operations, with better integrated animal and plant pest control aimed at producing a wider range of benefits at key sites. Many of these benefits (e.g., more birdlife, better forest integrity) were, however, implicit expectations rather than explicit goals (e.g., greater nesting success of bird species).
- Compared with Australia, many more pest control operations conducted by RUAs in New Zealand had some form of monitoring of either pest or resource. But the design used most frequently for monitoring of pest control operations in both countries, namely a single treatment area, no non-treatment area, and results monitoring only, has very low reliability of inference and generates only 'anecdotes' about the ecological outcomes of pest control.
- In an ideal world, control using input monitoring would be sufficient to produce the desired outcome. The implicit assumption in the successful operation of such a process is that the relationship between pest impact and pest density is well known, as is the relationship between

input monitoring and pest reduction. Unfortunately, these relationships are reasonably well known for only a very limited number of pest/impact systems in New Zealand, and the use of input monitoring as a surrogate for outcome monitoring is therefore not recommended until more robust information is available.

- Additionally, variation between sites in the response of biodiversity or resources of economic value to pest management is poorly understood. When added to all the other sources of variation, this might preclude the development of cross-region outcome monitoring programmes because of the high costs of establishing sufficiently robust monitoring systems, or limit them to identification of trends.
- Lack of outcome monitoring was due to concerns about the effectiveness of available tools and the design of monitoring programmes; a lack of resources, both staff and money, to conduct effective monitoring programmes and/or analyse the information; institutional/political issues about support for long-term programmes, and a view that killing pests was the priority; and other issues such as the short term cycle of planning, lack of forward planning precluding baseline data collection, lack of clarity between strategic and operational goals and objectives, and failure to set specific (SMART) long term objectives for pest management.
- Encouraging community groups to undertake monitoring themselves is likely to become more frequent in the future. Such groups will need help to design adequate monitoring programmes and training in implementation to avoid poor quality data, and confusion over goals and reasons for monitoring.
- RUAs need to increase the pace of their moves towards best practice methodologies for control and monitoring, and to common systems for recording and analysing data from results and outcome monitoring and to an agreed and consistent methodology for costing. This applies to pest management for both production and non-production benefits, and will both prepare RUAs for likely future national reporting requirements and enable them to better defend expenditure on pest management and the particular methodologies used.

Recommendations

- RUAs need to ensure that outcomes of pest management are clearly defined, with meaningful, measurable indicators of progress that can provide the basis for assessment of achievement against these outcomes. A logic framework and SMART objectives should be used to ensure appropriate and quantitative measures are specified. RUAs should review their current processes, goals and objectives against such a template.
- The reliability of inference and the rules of thumb discussed in the report should be used to guide the design of future monitoring associated with RUA pest control activities.
- RUAs should aim to standardise result (output) and outcome monitoring methods, particularly protocols for FBI and 5-minute bird counts, and management of all data associated with pest control operations. RUAs should investigate the utility of the frameworks being developed at present by some councils and by DOC to help them achieve this.
- Councillors need to be convinced of the need for and benefits of outcome monitoring to ensure the required long-term commitment for such reporting. MAFBNZ should support RUAs in this advocacy to council governance and pest managers to assist with its current projects on performance frameworks for pest management, which will require robust monitoring programmes.
- Council pest managers need to decide on the appropriate balance between statistical robustness of both results and outcome monitoring design and practicality in terms of resources (staff and money).
- Monitoring of large, common pest control programmes (e.g., possums, rabbits, rooks, Contorta pine, Nasella tussock) should be coordinated nationally to provide consistency and improved reporting. Such national programmes will require cross-RUA support and resourcing, an issue also identified by the MAFBNZ PMF project.

- The minimum defensible design for outcome monitoring of a species or site based control operation for biodiversity benefit should consist of either two matched replicated treatment and non-treatment areas monitored for an appropriate period after control, or two treatment and non-treatment areas monitored for an appropriate period before control and after control (BACI method). Further evaluation is needed of the design of potential trend indicators and their contribution to outcome measurement.
- Standard protocols should be used for results monitoring and for FBI and/or 5-minute bird counts for outcome monitoring of possum and predator control for biodiversity protection. RUAs should review options for outcome monitoring of reptiles and invertebrates in advance of future needs.
- Methods that measure changes in pasture production (e.g., dry matter production) should be used for outcome monitoring of rabbit, possum, and rook control for pasture protection.
- For control of weeds, outcome measures should involve assessment of replacement of weeds with native species, pasture, crop species or yield.
- Councils should consider a review of social outcomes monitoring as a basis for national coordination and reporting. Such a review should deal with current RUA approaches to social outcomes and future options for national best practice, and is recommended because community values and expectations and non-market valuation will be increasingly important inputs to RPMSs. Such a review could be funded through Envirolink.
- RUAs should take a lead role in assisting communities involved in pest control to set up and undertake robust results and outcome monitoring.
- RUAs should undertake development of an outcomes monitoring plan for each region that delivers regional insight into regional programmes and is coordinated closely with the proposed national PMF. This should be tailored to and deliver insights into regional programmes and benefits for ratepayers. This could be done for one RUA as an Envirolink project, and the project outcome then used as a template for other RUAs.
- Biosecurity Managers Group should identify those recommendations it wishes to adopt and then develop and resource an implementation plan.

1. Introduction

Under the Biosecurity Act (1993), Local and Unitary Authorities (hereafter referred to as RUAs) in New Zealand are tasked with controlling pests within their respective regions. Sixteen RUAs throughout New Zealand have adopted Regional Pest Management Strategies (RPMSs) that provide a strategic and statutory framework for management of pest plants and animals in their region. Currently, there are a total of 196 plant species and 61 animal species listed as pests under RPMSs (MAF BNZ website). RUAs have limited resources to spend on operational and outcome monitoring in relation to their pest management activities, and so they need to apply those resources using the most cost-effective and robust management and monitoring methods to ensure the benefit to the environment is maximised. Increasingly, RUAs are likely to be called upon to justify their pest management activities from an animal welfare viewpoint, and reliable estimates of the benefits of pest management will help them do that.

Horizons Regional Council, acting on behalf of a consortium of 15 RUAs (see Appendix 1), therefore asked Landcare Research (through Envirolink funding HZLC56) to design and analyse a survey of RUA animal pest management activity and its associated operational and outcome monitoring, identify issues with current practice, and provide advice on improvements. The Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) subsequently funded expansion of the survey to include weeds, and the survey was conducted by Landcare Research with joint funding from the RUAs and MAFBNZ.

2. Background

Project background

RUAs are currently reviewing how they can address their needs for evidence based reporting on biodiversity benefits of pest management activities to (i) meet obligations under the Resource Management Act and the Biosecurity Act; and (ii) justify and prioritise expenditure on pest management. This requires a change from mainly operational monitoring to both operational and outcome focussed monitoring.

Operational (or result) monitoring aims to provide an estimate of the proportional changes in the pest population as a consequence of the control action, whereas outcome monitoring provides an estimate of the effectiveness of pest management for protecting a defined resource (e.g., native biodiversity or crop yield). Operational monitoring of pest management activities is currently undertaken by councils using various methodologies, frequencies and intensities. Outcome monitoring is currently rarely conducted by RUAs but is increasingly needed to assess the effectiveness of pest control on resource protection. This is particularly true of biodiversity-focussed pest control, where aims are often complex (e.g., protecting ecosystem integrity and enhancing native species biodiversity) compared with production- focussed pest control (e.g., increasing grass or crop production).

Ongoing revision of RPMSs is providing RUAs with an opportunity to re-examine the balance of operational and outcome monitoring and the information needed for good decision-making. This project aimed to work within that process. Because the scope of the project was beyond the capacity of any individual RUA, 15 RUAs committed jointly to this project. RUAs are also interested in advice that will ultimately lead to nationally consistent, best practice systems. Ideally, these would be based on quality science advice with operational and outcome monitoring robustly designed to address specific/local and general/national information requirements for better environmental management.

MAFBNZ is concurrently developing a national performance measurement framework (PMF) for pest management (Jones 2008a,b). Inconsistent monitoring methodologies, frequencies and levels of resolution across the range of organizations involved in pest management, varying use of terminology, and differences in processes for defining outcomes are considered as impediments to gauging the performance of agencies towards achieving outcomes in any common metric or at a national scale. The development of a common, national performance monitoring framework based on a transparent, logical structure is seen by MAFBNZ as essential for the strategic management of post-border biosecurity in New Zealand (Jones 2008a).

The MAFBNZ project (i) covers MAF, DOC, AHB, and RUA's efforts in terrestrial, fresh water, and marine environments, whereas the current project was focused solely on RUA operational work on weeds and animal pests in terrestrial and freshwater environments; and (ii) focuses principally on how performance against stated "higher level" national outcomes (e.g., policy statements) is both measured and reported, whereas the current project is regionally focused and reviews the detailed operational performance against goals of the RPMSs, with a view to developing best practice. The main synergy between the two projects will be in identifying issues that need to be addressed jointly for the efficient operation of both systems, thus enabling each to make effective linkages between the more operational level and the higher level reporting, and a clearer understanding of how operational detail can best be used to contribute to a national reporting framework.

Best practice monitoring – an overview

Jones (2008 a,b) recently conducted a comprehensive review of performance management in the context of development of a national system for reporting on progress with pest management. Excerpts from these reports are reproduced here because they are highly relevant to discussions about best practice, particularly in relation to biodiversity outcomes where change in response to intervention may be slow and there is a need to establish clear intermediate and end outcomes.

"The Performance Measurement (PM) process is, ideally, simple and logical with a hierarchical structure of inputs and activities (or 'interventions') leading to measurable outputs, which in turn influence intermediate and longer-term changes in the state of a system (or 'outcomes'). This structure is commonly envisaged in the form of an intervention logic model that consists of a graphical representation of the links between various levels of the hierarchy and can be accompanied by written details of links to agency goals, methods to be used, and any risks and assumptions associated with the programme.

In spite of this logical simplicity, a number of challenges must be addressed in designing a set of performance measures for a programme. Two of the most significant are time lag and attribution. High level, ultimate outcomes for the public sector tend to be achieved gradually, sometimes over many years. On the other hand, performance reporting is usually needed comparatively regularly (e.g. quarterly, annually). So, the challenge is how to show meaningful progress towards high level outcomes over relatively short time frames. Changes in high level indicators may not be evident on a yearly basis. In addition, short-term patterns in data may fluctuate due to background 'noise' such as seasonal changes and other extraneous factors. A good approach to address this is to break the end outcome down into different levels (e.g. intermediate outcomes) to reach a temporal scale amenable to demonstration of shorter-term progress. Thus shorter-term measures provide information on the efficiency of a programme in delivering outputs and longer-term indicators inform on the effectiveness of outputs in contributing to outcomes (Fig. 1).

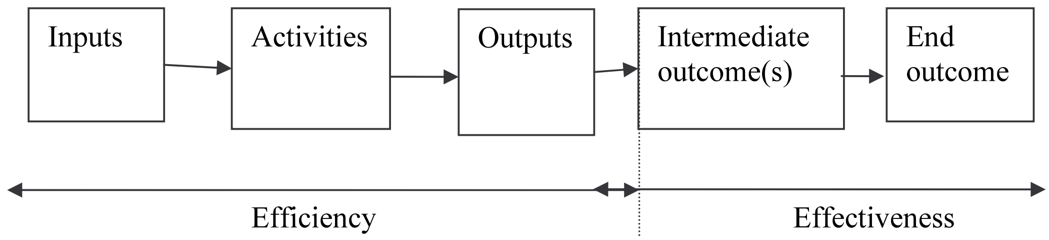

Fig. 1 Simple logic model structure showing the links between a programme's inputs (funding, equipment) and the intended outcomes.

An organisation, programme and/or policy cannot be held accountable for outcomes over which it has little or no control. There is a significant difference between affecting and controlling an outcome; the uncertainty can be expressed on two levels: we can rarely be certain that today's inputs and outputs will lead to the desired outcomes, and even if the desired outcomes occur we can rarely be certain that the agency's intervention was the primary cause. One of the problems with attributing intended outcomes to the introduction of performance measures in public service is the lack of experimentation in government policy. Performance measures are not generally introduced in a controlled trial manner, but as a result of a policy change. Often they are accompanied by other changes in incentives, so it can be difficult to isolate the impact of introduction of PM from other policy changes that are implemented at the same time (Burgess et al. 2002). To address this 'challenge of causal attribution', a clear performance story needs to be told, which:

- *Argues convincingly that activities are likely to contribute to ultimate outcomes)*
- *Demonstrates that activities are achieving results at some meaningful level (intermediate outcomes)*
- *Communicates the performance story effectively to clearly elucidate the logical steps in linking inputs to outcomes.*

The case studies included in this review use different forms of PM to drive either programme service improvements, cost savings or a combination of both. Although not all programmes use an intervention logic approach explicitly, a key point is that there are clear parallels with this technique in all of the cases, for example:

- *Programme outcomes are defined in advance in line with agency policies and aims*
- *Clear links are made between interventions and expected outputs and outcomes*
- *Indicators and measures of performance are used to gauge programme progress*
- *Performance measures are used to provide feedback which, in turn, guides programme improvements.*

As with other types of programme, PM is an important tool in assessing the progress of natural resource management programmes. In contrast to many other management fields, there are further complexities to natural systems that can potentially make both attribution and effective measurement towards end outcomes more difficult. Natural systems generally have multiple scales of interaction and response; high frequency of non-linearity (i.e. relationships are complex), uncertainty, and time lags; multiple stakeholders with contrasting objectives; and highly specific desired outcomes (Campbell et al. 2001). This issue was summarised by the Australian National Audit Office (2001) as:

> *… determining suitable performance information can be technically difficult when measuring change in environmental conditions. This is because there are substantial time lags between an action (such as revegetation in a catchment) and the result expected (for example, increased biodiversity and/or reductions in the level of the water table to control salinity).*

Thus, time lags present both long- and short-term challenges to effective PM: in the short term, reporting by outputs provides little information about progress towards desired outcomes for a system. End outcomes may not be apparent within the lifespan of a programme and will almost certainly not be measurable at the scale at which programme assessment and reporting is carried out. It is therefore useful to focus on intermediate *outcomes in reporting on natural resource management programmes. Typical types of intermediate outcome may be:*

- *Changes in the attitudes and practices of resource managers (e.g. resource managers are doing something differently as a result of participation in projects)*
- *Overall changes in how a region or locality is managed (e.g. as a result of resource manager change, a number of hectares or a percentage of a region is managed in a different way leading to reduced pest damage, more hectares of land protected)*
- *Changes in the focus of investment towards a certain group, catchment or industry component (Carr & Woodhams 2008)*
- *Measurable biological changes such as increases in the numbers of a valuable species or measurable habitat changes that may reasonably be assumed to indicate a species or ecosystem recovery in the long term."*

The simple logic model structure described in Fig. 1 has potential application in related areas of RUA activity, particularly to the stronger outcomes focus and measurement that RUAs are being required to demonstrate in their Long Term Council Community Plans (LTCCPs).

The issue of reliability of inference (i.e., attribution) was also addressed by Reddiex and Forsyth (2006) in their review of the design of pest control actions and associated monitoring in Australia. The critical design factors they examined were inclusion of non-treatment areas as controls, the monitoring of pests and resources, the assignment of areas as treatment or control, and replication of treatment and control areas. On the basis of this analysis they ordered the various designs for pest control actions in relation to statistical reliability of the inferences that could be drawn from the data collected (see Table 1). Their rational was as follows:

- A pest control action that aims to reduce the abundance of a pest to achieve some stated objective is a test of a hypothesis – that is, pest control can be considered as an 'experimental' treatment, with the stated objective as the 'response' variable.
- The weakest inference comes when pest control is conducted in a single area with no monitoring of pest or resource (Rank 1).
- More reliable information will be generated if an appropriate 'response' variable is measured. However, attribution of any change in 'resource' to the pest control action requires that the results of pest control also be measured (Rank 4).
- But even if monitoring reveals a decline in pests and an increase in resource, such changes may have resulted from other factors (e.g., changes in food availability), and the only way to determine whether the change in resource was really the result of pest control is to compare the treatment area with a non-treatment area (Rank 7).
- Because it is not possible to perfectly match treatment and non-treatment areas, the reliability of inferences will be further increased by randomly assigning areas to treatment or non-treatment, and by having more than one set of such paired areas (i.e., replication) (Rank 9).
- The strongest possible inference thus comes from an operation that has multiple treatment and control areas, random assignment of those to treatment and non-treatment, and monitoring of both pest and resource (Rank 10).

Table 1 Relationship between reliability of inferences and the design of pest control actions (from Reddiex & Forsyth 2006). Random means treatment and non-treatments assigned at random. Note: statistical inferences cannot be made from designs that do not include replication and random allocation of areas.

Reliability of inferences	Rank	Treatment areas	Non-treatment areas	Pest monitoring	Resource Monitoring
Least reliable	1	1	0	No	No
↓	2	1	0	Yes	No
	3	1	0	No	Yes
	4	1	0	Yes	Yes
	5	1	1	Yes	No
	6	1	1	No	Yes
	7	1	1	Yes	Yes
	8	1, random	1, random	Yes	Yes
	9	≥2	≥2	Yes	Yes
Most reliable	10	≥2, random	≥2, random	Yes	Yes

Monitoring approaches

DOC has recently begun to develop a comprehensive inventory and monitoring toolbox (McNutt et al 2007) that will establish national standards and specifications for inventory and monitoring methods. In addition, the toolbox has decision support frameworks to help users select appropriate methods. The toolbox currently includes methods for counting populations of birds, bats, animal pests, threatened plants, and for assessing impacts of animal pests on vegetation. DOC's intention is to extend the toolbox with methods applicable to reptiles, amphibians, invertebrates and freshwater species. DOC intends to make the toolbox available to external agencies, including RUAs.

Result monitoring – animal pests

There have been a number of reviews of methods for monitoring the results of control operations against animal pests. Fraser (1998) reviewed monitoring methods for medium to large-sized wild mammals. Norbury et al. (2001) reviewed monitoring methods for small to large-sized mammal pests and provided recommendations on frequency and design of monitoring. Many of the recommended methods are usually applied on medium to large areas and so may need adaptation for small reserves (see Cowan 2008).

The simplest method of operational monitoring is change in 'catch' per unit effort. While this often refers to trapping (e.g., catch/100 trap nights) or hunting (e.g., kills/person-day) it can equally be applied to other indices such as non-toxic bait interference, or the proportion of tracking tunnels, wax tags or chew cards marked by the pest. The NPCA web site (www.npca.org.nz) provides protocols for use of traps and wax tags for possum monitoring. Forsyth (2005) details a protocol for estimating changes in the relative abundance of deer using a faecal pellet index. Goats and pigs may be monitored by a similar faecal pellet index, although frequency of pig sign (e.g., rooting) is used more often as a monitoring method (Hone 1995). Rabbits and hare numbers are usually monitored using spotlight counts or an index based on sign and faecal pellets (modified McLean scale). Trapping is the standard method for monitoring most small mammals (rodents, mustelids), usually with lines of 10–20 traps at fixed spacing, with distance dependant on species (see Norbury et al. 2001 for suggested spacings). Methods for and design of ant monitoring are described by Ward (2007a,b). Spurr (1995, 1996) provides details about the attractiveness of different baits for wasps.

Results monitoring – plant pests

A comprehensive overview of weed monitoring rationale and methodology was conducted by Partridge et al. (2002) who developed an annotated flow chart to guide choice of monitoring methods and a set of monitoring modules that can be applied in the field. They adopted this approach, rather than a prescribed set of preferred approaches, because agencies making decisions about weed monitoring need to take into account a wide range of factors ranging from site-, local- and regional-specific issues to trade offs between statistically ideal approaches and resource availability. Techniques for monitoring the impacts of weed biocontrol agents are discussed at www.landcareresearch.co.nz/research/biocons/weeds/book/ (accessed 10 February 2009).

In some respects the nature of operational monitoring of weed management will be dictated by the classification of species under the RPMSs. For boundary control pests and containment pests the main goal is usually the prevention of spread, so monitoring of local and regional distribution will be important. For progressive control pests, prevention of spread is also important, but so too are reductions in density and distribution. For total control pests the goal is eradication and so in addition to reductions in overall density and distribution, elimination from individual sites will be vital. The differing monitoring requirements for each of these approaches are addressed by Partridge et al. (2002).

Outcome monitoring – animal pests

Animal pests have a wide range of impacts on native and non-native ecosystems and their constituent plant and animal species or communities. The greatest impacts of animal pests on biodiversity values are likely to be through predation of native animals and browsing damage to native vegetation. Impacts on non-native ecosystems (in most cases production landscapes) are likely to be greatest on agricultural crops and/or pasture production.

Where predation of native animals is the key threat at a site, the native animal species most commonly used for monitoring the outcomes of pest management are native birds and native insects, particularly weta and beetles. Ure (2003) briefly reviews the main methods for monitoring native birds, namely 5-minute counts and distance sampling. The main issue in relation to the use of these methods in small reserves is the limited number of independent counting stations that can be fitted into such reserves, which results in low power to detect significant change and a longer time until change can be detected. This might be addressed by using slow walk transects (Ure 2003) if these were designed to provide maximal coverage of the reserve and so provide an approximate total count of birds in the reserve. Species lists might also be useful, on the assumption that in the absence of introduced predators of birds a wider range of native birds might use a reserve. Numbers of weta and other invertebrates can be indexed using artificial refuges (weta 'houses', Spurr & Berben 2004). Watts (2004, 2007) describes methods for assessing benefits of rodent eradication for ground dwelling beetles. Some taxonomic expertise is required for beetle identification, but simple keys could be developed for RUA use
(e.g., www.landcareresearch.co.nz/services/biosystematics/bioassist/index.asp accessed 10 February 2009).

Damage to native vegetation is likely to be mostly from foliage and seedling browsing, and consumption of fruits or seeds of native plants. Ure (2003) reviews the most commonly used methods for vegetation condition assessment at both reserve (e.g., satellite or aerial photos) and more detailed scales (photopoints, permanent plots, exclosures, foliar browse index). Choice of monitoring method should be dictated by a combination of the animal pests causing damage (e.g., possums impact on canopy, ungulates on lower vegetation tiers and seedlings, rodents on seedlings, seeds and invertebrates), the type of damage (e.g., leaf or seedling browsing) and the size of the reserve (e.g., several small plots may provide more representative information than a single large 20 × 20 m or RECCE plot (Hurst & Allen 2007a,b) in a small or highly heterogeneous reserve. The impacts of wasps and invasive ants are mainly on native invertebrates so changes in numbers of key invertebrates could provide an appropriate method for outcome monitoring. For wasp impacts, stick insects or orb web spiders could be monitored, while for invasive ant impacts, particularly Argentine ants, changes in the occurrence and numbers of native ants might provide a suitable monitoring method.

The measurement of outcomes related to the impacts of animal pests on the productive sector is likely to be focussed principally on changes on the economic costs of those impacts relative to the costs of control; for example, a reduction in losses from bird damage to grapes from $x/ha to $y/ha. Methods for damage estimation are reasonably well established. A recent book by Hone (2007) and an earlier account by Walker (1983) provide good overviews of methodologies.

Outcome monitoring – plant pests

The various types of threat posed by weeds to conservation values provide the context for outcome monitoring. Owen (1998) listed these as threats to (i) native plants from smothering, shading or other forms of competition and exclusion, (ii) native animals from habitat degradation affecting food supply, breeding sites, etc, and (iii) native communities from displacement of species, altered successional processes and changes to energy and nutrient flows. Outcomes of weed management are therefore likely to be reflected in changes in numbers and or distribution of threatened native plants and animals, and in measures of species occupancy, environmental representation and native dominance (Lee et al. 2005) of native communities.

Ure (2003) and Myer (2007) both recommended photo points to monitor broad changes in vegetation cover. Changes in native animal numbers and/or distribution could be monitored using techniques described above, but the appropriate technique would depend to some extent on the particular species to be monitored. Changes in native plant numbers, condition and/or distribution could be monitored using the same techniques described for weeds by Partridge et al. (2002) and above for browsing animal pests (i.e., permanent plots).

The measurement of outcomes related to the impacts of plant pests on the productive sector is, as for animal pests, likely to be focussed principally on changes on the economic costs of those impacts relative to the costs of control. Suitable methods are described in the references noted above.

3. Objectives

- To design, conduct, analyse, and report on a survey of animal pest and weed control and associated monitoring undertaken by 15 territorial authorities during the period 1 July 2005 – 30 June 2008
- To identify issues with current practice, and provide advice on improvements
- To present findings to council biosecurity managers group and MAFBNZ pest management group

4. Methods

A survey was designed to gather information about what animal and plant pest control and associated monitoring the participating RUAs had undertaken during the period 1 July 2005 – 30 June 2008, excluding AHB operations (see Appendix 1 for participating RUAs). Operations conducted by the Animal Health Board (AHB) were excluded from the survey because they are performance-based contracts designed to achieve a specific residual trap catch index, and they have an associated independent monitoring programme that is carried out according to NPCA best practice guidelines. The current project was mainly focussed on control conducted as part of RPMSs, but also collected information on any other substantial pest control involving council resources (either staff time or operating expenditure), for example community programmes with council support. For each control operation or programme, details were collected about what pests were targeted, what control work was done, by whom, why, where, when, and how; information was also collected on what associated operational and/or outcome monitoring was done and how it was done; and estimates of effort and/or costs of monitoring.

A draft list of questions was compiled for use at interviews with council staff. This was based in part on a similar project conducted in Australia (Reddiex et al. 2006). Several animal pest and weed researchers at Landcare Research commented on the draft questions and, after modification, these were discussed with B. Reddiex and M. Harre, MAFBNZ, on 16 June 2008, and further changes incorporated. Horizons Regional Council agreed to act as a test case for the interview process, and after meeting with them on 29 July 2008, the questionnaire was further refined before the remaining participating RUAs were interviewed. The final set of questions used in the survey is given in Appendix 2.

Key contacts were identified from 12 regional councils and three territorial, or unitary, authorities (i.e. district councils) who have the same level of responsibility for administering the RPMS in their regions (Appendix 1). Surveys were conducted in August 2008, mostly by face-to-face interviews to ensure accuracy of data and a good level of survey participation (recommended by B Reddiex, MAFBNZ). Meetings with Biosecurity managers, or one of their staff, also allowed for discussion of the local and regional issues associated with each RUA. The only survey not conducted in person but by phone, was with the West Coast Regional Council (C. Ingle, pers. comm.), who have almost no involvement in non-AHB pest control activities. Data from the West Coast are therefore not considered any further. Similarly, the Chatham Islands Council has a RPMS but scant resources devoted to its implementation when compared with mainland councils, so it was not interviewed. Nelson City Council is a RUA but contributes to the RPMS framework through a joint management strategy administered by the Tasman district council. During data entry and analysis, occasional contact was made with interviewees to check and clarify some information.

We defined a pest control programme as any type of pest control that an RUA either funded directly via rates, or required landowners to do and spent time co-ordinating this (i.e., ensuring compliance). Both scenarios generally happened through the RPMS legislation. Interviewees were asked a variety of questions relating to the aims, justification, types of control and administration of operations. They were also asked about all monitoring conducted in association with each operation. We defined *result* monitoring as techniques used to measure the success or failure of the actual control work and *outcome* monitoring as techniques used to measure the response of the values that a pest control operation was attempting to protect. The *funder* of the operation was considered either to be the council, the landowner, or both. In situations where the landowner (or land manager, e.g., DOC) funded control, no further financial details were sought. Tenure of land was considered to be either private, public, mixed or council owned. Summary statistics on the RUAs are noted in Appendix 4.

Labour costs were defined as paid hours for council staff, as opposed to actual operational costs, which could include contractor time and the cost of chemicals or devices. In situations where staff gave costs in hours, we have used a common conversion of $50,000 per staff member per year, $350 per day or $50 per hour of staff time. For monitoring costs, we obtained one figure only, incorporating both labour and operating.

Nearly all programmes (>80%) on which we collected information were considered as ongoing and had been in operation before the 2005 financial year. Because of this and for simplification of data collection and analyses, we averaged the costs of the 3 years 2005–08 to give a single annual estimate reflective of the whole period.

To simplify the categories set out in RPMSs, we used two broad groupings, based on the general overall goals for management of a pest and the recommendations of the Biosecurity Generic Guidelines Group (BGGG 1998) – "eradication", where the aim is to remove every individual from an area (sometimes referred to as total control or zero density); and "containment", where the aim is to reduce the density of a pest in an area (incorporates boundary control, reduction, sustained control and suppression). The BGGG also suggested using surveillance as a category, but we did not do this because only pest control programmes were the subject of this review.

Operations were defined as either 'species-led' programmes, where the aim of control is targeted at individual species, or 'site-led' programmes which aim to control a suite of species in a particular area for a broader overall goal. The data from most site-led programmes and some species-led programmes (e.g. possum control) have been grouped under their budgets because of the large numbers of these operations in some regions. The usual scenario was that one budget was used to finance many different programmes (e.g., in the Bay of Plenty more than 170 sites are managed with a goal of protecting biodiversity and in the Horizons-Manawatu region there are 40 possum control operations each with a target of 10% RTC). We took this pragmatic approach because detailed information was not needed on each operation when overall goals, approach and administration were the same and, more importantly for this project, if there were very few differences between operations in their associated monitoring.

Every attempt has been made to ensure accurate data, but in some cases there were inconsistencies between the answers that interviewees gave and the stated goals of a RPMS. Where this was the case, we have used the verbal version. We also had some difficulty reconciling financial information and ensuring consistency between different regional councils, often because of different internal reporting structures (both financial and operating). The figures reported to us are assumed to reflect the actual dollars spent on control. Responsibilities and funding for programmes are often shared between RUAs and/or with other government, or non-government, organizations, however, and so the contributions of individual RUAs may have been underestimated because of the way information was gathered.

A Microsoft Access database was constructed to hold the data and facilitate its analysis. Some data were converted to categories to simplify analysis. Details of the database and categories used are provided in Appendix 3, and further details can be obtained from Richard Clayton (claytonr@landcareresearch.co.nz). Sample sizes vary between some analyses because some interviewees did not provide answers to all questions.

5. Results

Summary of control operations

Animal and plant pest focussed control operations (i.e. species-led) were much commoner than site-led operations (Table 2). This is partly a reflection of the way in which we treated some of the information. Plant pest-led operations were often collections of species (rather than individual species-led operations) managed as a suite with a particular focus (e.g. containment, boundary control, total control, etc). There was usually a single budget for such suites of plant pests, and it would have been difficult or misleading to break it down into smaller groups. Some of the site-led programmes were individual sites but most, as above, represent a collection of areas managed with the same overall goals and budget.

Table 2 Number of control operations during 2005-08 focussed on animal or plant pest or site-focussed. Data from large groups of site-led programmes within regions were pooled to create one entry. Two species-led programmes had significant components of site-led operations, and so were counted in both categories.

RUA	Animal pests	Plant pests	Site-led
Northland	3	1	1
Auckland	5	3	1
Bay of Plenty	4	2	5
Waikato	3	2	1
Gisborne	5	2	0
Taranaki	4	4	1
Hawkes Bay	4	2	1
Horizons	3	2	1
Greater Wellington	4	2	2
Tasman	2	1	1
Marlborough	2	2	1
West Coast	0	0	0
Canterbury	3	4	1
Otago	2	3	1
Southland	5	5	3
TOTAL	49	35	20

The primary objective (= goal) for control, as described by the interviewees, was mostly for biodiversity or production protection (88%), with 10% for amenity and environmental protection (Table 3). Often, more than one justification was provided for control operations (Table 4). Biodiversity and production protection were by far the most common highest priority justifications. Many operations (57%) had a secondary justification, with biodiversity protection being the most common.

Table 3 Number of control operations within each RUA categorized by primary objective. Environmental protection included operations to prevent or reduce soil erosion or maintain water quality.

Region	Amenity	Biodiversity	Environmental protection	Health	Production	Research
Auckland	1	8			1	
Bay of Plenty		5	2		4	
Canterbury		4			4	
Gisborne		2			5	
Hawkes Bay		2			4	1
Horizons		3			3	
Marlborough		1			4	
Northland		3			2	
Otago	1	1			4	
Southland	2	8			3	
Taranaki	1	2			4	
Tasman	1	2			2	
Waikato		1	1		2	
Wellington	1	3		1	3	
Total	7	45	3	1	45	1

Table 4 Number of control operations categorized by priority assigned to the justification.

	Priority				
Justification	**1**	**2**	**3**	**4**	**Total**
Production	45	14	3	2	64
Biodiversity	45	34	5	2	86
Amenity	7	4	5	1	17
Environmental Protection	3	4	3	0	10
Human Health	1	1	3	1	6
Cultural Values	0	0	2	0	2
Research	1	0	0	0	1

For biodiversity and production protection justifications, interviewees indicated a wide range of desired outcomes from pest control operations (Table 5). For biodiversity protection, most interviewees indicated that general protection of forest, shrubland or grassland, and increasing bird numbers and native dominance were key goals. For production sector pest control the most desired outcomes were pasture protection and crop protection/increased crop yield.

Table 5 Number of control operations for all RUAs with justifications tabulated against desired outcomes. This table includes all justifications for each project, regardless of their priority order.

	Justification						
Desired Outcome	**Amenity**	**Biodiv**	**Cultural Values**	**Envir protn**	**Human Health**	**Prodn**	**Research**
Ecosystem protection		4		3		1	
Forest integrity		37					
Grassland integrity		2					
Increase native dominance		13					
Increased crop yield						7	
Lake integrity				3			
More birds		15					
More fish						2	
More pasture						29	
Prevent allergies					1		
Prevent TB						6	
Protect bats		1					
Protect crop production						8	
Protect native inverts		5					
Protect plantings				4		3	
Shrubland integrity		1					
Soil Conservation						1	
Reduce impacts on lifestyle	5				1		
Wetland integrity		1					
Unspecified	12	7	2		4	7	1
Total	17	86	2	10	6	64	1

Control operations were undertaken at a range of scales. Roughly equal numbers of operations were applied to the whole region (54) as to part of the region (48), although some detail was lost here as operations often appeared to be described as region-wide for convenience – for example, the stated aim of rook programmes was always to eradicate rooks from a region although the actual control happened over a part of the region.

Control operations were carried out mostly by RUA staff themselves or by external contractors, and less frequently by both, or by landowners themselves (Table 6). When control was conducted by a landowner (usually as a requirement of compliance with RPMS rules) further data were not usually collected.

Table 6 Number of pest control operations conducted by RUA staff, by contractors, by both, or by landowners.

	Operation Controller			
Region	**Both**	**Contractor**	**RUA**	**Landowners**
Auckland	3	2	4	1
Bay of Plenty	2	5	4	
Canterbury	1	1	1	5
Hawkes Bay	2	3	2	
Gisborne		2	3	2
Horizons	1	1	4	
Marlborough	1	1	1	2
Northland	2	2	1	
Otago	2	1	2	1
Southland		7	1	5
Taranaki	1	3		3
Tasman	1		2	2
Waikato		2	1	1
Wellington	3	2	3	
Total	19	32	29	22

Councils funded approximately half of the operations required under the RPMS (Table 7). Most landowner-funded pest control was compliance related, and undertaken to meet criteria notified in the RPMSs.

Table 7 Number of operations funded by RUAs, private (landholder), or shared

Region	**RUA**	**Landowner**	**Shared**
Auckland	6		4
Bay of Plenty	3	1	7
Canterbury	1	5	2
Gisborne	5	2	
Hawkes Bay	7		
Horizons	4		2
Marlborough	2	2	1
Northland	2		3
Otago	2	2	2
Southland	4	5	4
Taranaki	3	2	2
Tasman	2	2	1
Waikato	2	1	1
Wellington	6		2
Total	49	22	31

More than half of operations were conducted on land of mixed tenure, i.e. in both private and public ownership (Table 8). Secondarily, control was undertaken on private land, with only a few examples of operations solely on council land, and these were in regions where councils could afford it (i.e., Auckland and Wellington, with large networks of regional parks) or for objectives such as flood protection (e.g., Hawkes Bay). Of the 102 operations 84 were initiated through a

RPMS versus other means e.g. self-help groups. So-called 'self-help' projects could also be considered as RPMS-initiated, as they are allowed for in the relevant legislation.

Table 8 Number of operations conducted on council, private, public or mixed tenure land.

	Programme controller			
Region	**Council**	**Mixed**	**Private**	**Public**
Auckland	3	6		1
Bay of Plenty		8	3	
Canterbury		7	1	
Gisborne		1	6	
Hawkes Bay		2	5	
Horizons		2	3	1
Marlborough		3	2	
Northland		3	2	
Otago		4	2	
Southland	2	7	3	1
Taranaki		3	4	
Tasman		5		
Waikato		2	2	
Wellington	1	4	3	
Total	6	57	36	3

RPMSs specify a large number of pests, namely 61 animal species and 196 plant species. Not all of these were identified by interviewees as being targeted for control in the 2005-08 period. Only 32 animals (52%) were recorded as being targeted by RUA control operations in 2005-08 (Table 9). Possums were the most frequent of these, followed by mustelids, rats, rabbits, goats and rooks.

Table 9 Pest animals listed with the number of operations in which they were specifically targeted (in brackets).

Species and total number of operations targeting that species
Possum (29), Mustelids (19), Rat (16), Rabbit (11), Goat (11), Rook (10), Feral cat (9), Argentine ant (6)
Deer, Magpies (4)
Dama wallaby, Darwins ant (3)
Catfish, Hare, Koi carp, Pig (2)
Bennett's Wallaby, Black House Ant, Brushtailed rock wallaby, Fallow deer, Gambusia, Hedgehog, House mouse, Parma wallaby, Perch, Red deer, Rudd, Sika deer, Swamp wallaby, Tench, Wapiti, Wasps, White-footed Ant (1)

One hundred and thirty two plant pests were recorded as being targeted in 2005-08 (Table 10), more than four times the number of animal pests and also a higher percentage (69%) of those listed in the RPMSs than for animal pests (52%). For plants, Contorta pine, old man's beard, African feather grass, gorse, Nasella tussock, nodding thistle, woolly nightshade, and broom were targeted most frequently.

Table 10 Pest plants listed with the number of operations in which they were specifically targeted (in brackets)

Species and total number of operations targeting that species
Contorta pine (11), Old man's beard (11), African feather grass (10), Gorse (10), Nasella tussock (9), Nodding thistle (9), Woolly nightshade (9), Broom (8), Climbing spindleberry (8), Ragwort (8), Boneseed (7), Moth plant (7), Spartina (7), Senegal tea (6), Variegated thistle (6), Weeds (6), Wild ginger (6), Banana passionfruit (5), Darwin's barberry (5)
Australian Sedge, Bathurst bur, Cathedral bells, Chilean needle grass, Evergreen buckthorn, Lagarosiphon, Lantana, Manchurian wild rice, Mignonette vine, Saffron thistle, Smilax, White-edged nightshade (4)
Boxthorn, Chinese pennisetum, Climbing asparagus, Cotoneaster, Egeria, Hornwort, Madeira vine, Pampas, Privet, Purple loosestrife, Reed sweet grass, Water poppy (3)
Alligator weed, Asiatic knotweed, Blackberry, Bur daisy, Chilean flame creeper, Eel grass, Elderberry, Giant needlegrass, Gunnera, Hawkweed, Hawthorn, Himalayan honeysuckle, Holly, Japanese honeysuckle, Kudzu vine, Marshwort, Mist flower, Phragmites, Plumeless thistle, Rhamnus, Royal fern, Spiny emex, Sweet pea shrub, Sycamore (2)
Acmena, African club moss, Agapanthus, Apple of sodom, Asparagus, Balloon vine, Barberry, Bomeria, Bittersweet, Blue passion flower, Blue-leaved wattle, Broomsedge, Brush wattle, Burdock, Bushy asparagus, Californian thistle, Chinese privet, Common ivy, Cotton thistle, Crack willow, Devil's fig, Devil's tail, Elaeagnus, Elodea, Entire marshwort, German ivy, Giant buttercup, Giant gunnera, giant reed, Goats rue, Great reedmace, Green cestrum, Grey willow, Heather, Hemlock, Horse nettle, Houttuynia, Japanese spindleberry, Jasmine, Kangaroo grass, Knotweeds, Mexican feather grass, Montbretia, Mountain pine, Noogoora bur, Parrots feather, Purple nutsedge, Purple pampas, Red cestrum, Reed canary grass, Sagittaria, Scotch thistle, Scrambling lily, Siberian lyme grass, Spanish heath, Stonecrop, Sweet briar, Tutsan, Undaria, White bryony, Wild kiwifruit, Wild turnip, Yellow water lily (1)

Pest plant control operations were conducted using herbicides or other chemicals, mechanical means, or biological control, usually in combination. For animal pests, the tools employed included toxins (1080 aerial and ground baiting, pindone, brodifacoum, diphacinone, feratox/cyanide and cholecalciferol for mammals; DRC1339 for rooks; X-tinguish bait for ants), shooting, trapping, electric fishing, draining (aquatic fish pests), and de-sexing (cats only). A number of RUAs also used releases of Rabbit Haemorrhagic Disease virus to control rabbits.

Average annual expenditure on animal and plant pest control was about $20 million, with roughly the same spent on RUA direct staff costs and external costs (direct operating expenditure and/or contractor fees) (Table 11).

Table 11 Estimated costs of anim and plant pest control operations. The figures are the average annual cost for 2005-08 derived from supplied data on staff times, operating costs and contractor fees, with staff time valued using standard rates.

Region	Labour costs	Operating costs
Auckland	1 037 000	1 740 000
Bay of Plenty	1 067 500	179 000
Canterbury	10 000	1 075 000
Gisborne	278 000	30 000
Hawkes Bay	894 000	295 000
Horizons	1 700 000	1 470 000
Marlborough	41 000	55 000
Northland	492 500	550 000
Otago	425 000	120 000
Southland	12 000	229 000
Taranaki	390 000	330 000
Tasman	95 000	0
Waikato	1 300 000	3 900 000
Wellington	1 950 000	255 000
Total	9 692 000	10 228 000

Results and outcome monitoring

A wide range of monitoring techniques was used to measure the progress of pest control. For animals these included (with frequency of use in brackets) five-minute bird counts (5), transect bird counts (1), bait take (1), foliar browse index (6), hunter returns (including use of Judas goats) (7), modified MacLean rabbit index (4), spotlight counts (9), pitfall traps (1), wax tags (1), residual trap catch pre-control (4), RTC post-control (5), RTC pre- and post-control (11), faecal pellet counts (1), tracking tunnels (7), baited vials (for ants) (5).

For plants, methods used were aerial photographs (2), annual site inspections only (15), site inspection with follow up after treatment (15), site inspection with GIS (15), permanent vegetation plots (20 x 20 m) (5), photopoints (7), belt transects (3), plots on transects (1), RECCE plots (1), species list with abundance (3).

A smaller set of 11 of these was used for outcome monitoring (Table 12).

Table 12 List of outcome monitoring techniques used by RUAs

Region	5 Min Bird Counts	Aerial photos	Belt transects	FBI	Permanent plots	Photo points	Pitfall traps	RECCE plots	Site inspection with GIS	Species list with counts	Transect bird counts
Auckland	1	1		1		1					
Bay of Plenty					1	1			1		
Canterbury		1			1				1		1
Hawkes Bay			1	1	1	1					
Marlborough						1				1	
Southland	3			1		1		1			
Wellington	1			2	2	1	1				
Grand Total	5	2	1	5	5	6	1	1	2	1	1

Expenditure on monitoring (calculated in the same way as for expenditure on pest control operations) is summarized in Table 13.

Table 13 Total funding for monitoring by region.

Region	Outcome monitoring	Result monitoring (excluding compliance)	Compliance - related result monitoring	Total
Auckland	30 000	275 000	0	305 000
Bay of Plenty	15 000	2 500	0	17 500
Canterbury	160 000	108 000	1 535 000	1 803 000
Gisborne	0	187 500	0	187 500
Hawkes Bay	10 000	141 000	0	151 000
Horizons	0	160 000	0	160 000
Marlborough	0	20 000	193 500	213 500
Northland	0	45 000	0	45 000
Otago	0	25 000	495 000	520 000
Southland	2 500	28 000	22 500	53 000
Taranaki	0	57 000	300 000	357 000
Tasman	0	30 000	120 000	150 000
Waikato	0	195 000	0	195 000
Wellington	55 000	178 000	0	193 000
Total	282 500	1 312 000	2 666 000	4 260 500

About 18% of RUA funding dedicated to pest control was used for monitoring. Monitoring for compliance purposes accounted for 62% of all monitoring expenditure, even though it was only done by six of the RUAs. The very large expenditure on compliance monitoring by Environment Canterbury is a deliberate policy to ensure that pest management is undertaken. It is focussed principally on rabbits ($360,000), Nasella tussock ($440,000), old man's beard ($275,000), and containment plants ($400,000).

Outcome monitoring accounted for about 7% of the total monitoring expenditure, and about 1.5% of the total spent on council-funded pest control. More than half of the local authorities we surveyed did no outcome monitoring and one programme from Environment Canterbury, 'biodiversity sites', accounted for almost half of the total expenditure ($130,000). The only other substantial commitment to outcome monitoring came from Greater Wellington Regional Council whose 'regional parks' had an outcome monitoring budget of about $50,000.

Most (91%) control operations had some form of results target or 'goal'. For those operations with specified targets, the most common measures were a specified % reduction in pest numbers (26%), a target threshold (e.g. numbers, area) below which pests were to be reduced (25%), and zero density (24%). None of the operations that had associated outcome monitoring had specified outcome targets.

Table 14 summarises the design of animal and plant pest control and associated monitoring assessed using the reliability of inference framework developed by Reddiex and Forsyth (2006). Nineteen control operations that were conducted solely for compliance purposes were excluded from the analysis. Overall, about 82% of operations had some form of results monitoring, compared with only 16% with some form of outcome monitoring. Nine operations (11%) had no monitoring at all. We did not examine the detailed design of monitoring, and so cannot comment on the adequacy of monitoring where it was undertaken.

Table 14 Summary of design of animal and plant pest control and associated monitoring (cf. Table 1).

Treatment areas	Non-treatment areas	Result monitoring	Outcome monitoring	Rank	Number	%
1	0	No	No	1	9	10.7
1	0	Yes	No	2	59	71.4
1	0	No	Yes	3	5	6.0
1	0	Yes	Yes	4	6	6.0
1	1	Yes	No	5	1	1.2
1	1	No	Yes	6	0	0.0
1	1	Yes	Yes	7	3	3.6

The most common design (71%) was for a single treatment area, no non-treatment area, and results monitoring only, the second least robust of designs in the framework above. Only three operations (4%) of the 83 that had monitoring had both treatment and non-treatment areas and both results and outcome monitoring, and no operations were conducted to the highest standard in Table 1.

Operations with both treatment and non-treatment areas and both results and outcome monitoring were

- a small biodiversity-focussed operation that targeted possum, rats, mustelids, elderberry and hawthorn. Result monitoring was done by belt transect for weeds, pre-control RTC for possums, and tracking tunnels for mustelids and rats. Outcome monitoring was done by RECCE plots and 5-minute bird counts.
- a small biodiversity-focussed operation that targeted possums, rats, mustelids, magpies, holly, cotoneaster and Darwin’s barberry. Result monitoring was done by pre- and –post control RTC for possums, and tracking tunnels for mustelids and rats. Outcome monitoring was done by photopoints for weeds, and 5-minute bird counts and foliar browse index for animal pests.
- a large production-focussed possum control operation for Tb and pasture protection (with biodiversity protection as a second priority). Outcome monitoring was by foliar browse index, but no measures of changes in impact on pasture production were made.

Five other operations (3 site-led, 2 species-led, all biodiversity-focussed) had results and outcome monitoring on the treatment area but lacked a non-treatment area. Outcome monitoring was by photopoints (2), 5-minute bird counts (3), foliar browse index (3), permanent vegetation plots (2), and pitfall traps (1).

All outcome monitoring that was identified in the survey except one operation had biodiversity protection as its primary goal – there appeared to be no monitoring for economic outcomes of pest management for forestry or agricultural production.

6. Discussion and Conclusions

Project findings

The primary objective of this project was the collection and synthesis of baseline information to help identify areas of improvement, particularly with respect to outcome monitoring, and so that the benefits of future changes to RUA pest management can be measured against this baseline.

RUAs differed in the extent to which their involvement with pest management was mainly regulatory (or 'compliance-based'), or undertaken by RUAs themselves. Most RUAs combine these two approaches, but some lean strongly towards one or the other. For example, most staff time in Canterbury, Taranaki and Otago (particularly for weeds), is spent on site-inspections, issuing notices and checking that landholders have undertaken the required work. In the case of rabbit management in Otago, one third of the estimated cost of control of $4.5M annually is spent by the council and then billed to the relevant landholders. This contrasts with Auckland, Gisborne and Wellington with large teams of field staff undertaking the work themselves.

RUA pest management is still largely focussed on species-led programmes. However, most RUA managers commented on the trend towards site-led operations, with better integrated animal and plant pest control aimed to produce a wider range of benefits at key sites (although many of the benefits were implicit expectations rather than explicit goals).

The primary goal for RUA pest control was split equally between biodiversity and productive sector protection. Productive sector focussed operations used biodiversity protection as a key supporting justification much more often than vice versa, which is perhaps a reflection of the increasing emphasis on justifying multiple benefits of pest control. However, the economic emphasis was not reflected in actual measurement – there was no outcome monitoring of the economic benefits of pest management for productive sector protection. This may be because RUAs consider the particular industries involved should be responsible, it may be partly because of implicit assumptions of a direct link between pest reduction and reduced losses based on prior knowledge, or it may reflect an unstated application of the precautionary principle (in the absence of prior knowledge, reduce pest to as low numbers as possible). It may also be because the collection of robust data on production outcomes would require funding of a level and duration well beyond the ability of any individual RUA to fund (C. Leckie, pers. com.)

Within biodiversity-focussed operations, there was a wide range of desired outcomes, but the three most frequent (75%) were improved or sustained forest integrity, increased numbers of native birds, and increased dominance of native species. Most production sector-focussed operations had the desired outcome of increased pasture production (45%) or reducing crop losses (23%). Some RUAs also directed resources to pest control for the prevention of bovine Tb (9%), presumably an adjunct to existing AHB operations as a risk management strategy in areas where AHB control has now ceased, or to sustain other perceived benefits of control of wildlife for bovine Tb. In general, all these goals were only loosely defined.

In most RUAs landowners either conducted some control themselves or shared costs with RUAs. Landowners conducted about 22% of control operations themselves (mainly for compliance reasons), but a significantly higher proportion of control operations (51%) was either wholly or partly funded by landowners. This result largely reflects the difference in emphasis between councils on regulatory as opposed to internally proactive approaches.

RUA pest control targeted a very large number of species, including 32 animal and 132 plant pests. However, these represent only 52% of animal and 69% of plant pests listed in the RPMSs, suggesting no control is being undertaken of some designated pests. A wide range of control methods was also used. Conversations with some interviewees suggested regional differences in methodology that could complicate reporting on pest management at national levels. DOC is currently developing best practice control methodologies under its SOP framework, for example for rat control, mustelid control, feral cat control, goat control, as well as possums (K. Broome pers. com.). The development and consistent use of best practice control methodologies by RUAs would lead to more effective pest management both within and between RUAs and also facilitate the development and use of best practice monitoring methodologies.

A wide range of methods and methodologies was used for results monitoring. Apart from RTC and wax tag monitoring of possum control, there are no best practice protocols used across RUAs, although as indicated earlier these are being developed by DOC as part of their inventory and monitoring framework and toolbox (e.g., tracking tunnels).

Outcome monitoring was rarely carried out by RUAs. Only 14 out of 83 operations had outcome monitoring and of these, only 3 had both treatment and non-treatment areas.

About 20% of total funding for pest control was spent on monitoring, but 62% of that was spent on monitoring for compliance purposes in response to targets or thresholds set in the RPMSs (e.g., monitoring of rabbits to enforce a requirement in the RPMS for landowner control if the McLean index of rabbit numbers exceeded a specified level). Excluding compliance monitoring, about 8% of total funding for pest control was spent on result and outcome monitoring. This is significantly less than the 15–20% recommended by Choquenot and Warburton (1998).

Compared with Australia (Reddiex & Forsyth 2006), many more pest control operations conducted by RUAs in New Zealand had some form of monitoring of either pest or resource. But considering only operations where some form of monitoring was undertaken, the design used most frequently for monitoring of pest control operations, namely a single treatment area, no non-treatment area, and results monitoring only, was the same in New Zealand (72%) and Australia (63%). As Reddiex and Forsyth (2006) point out, such a design has very low reliability of inference and generates only ‘anecdotes’ about the ecological effects of pest control (McArdle 1996).

Supposed inadequacies in experimental design of outcome assessment of possum control, conducted both by management agencies and researchers, were a significant component of some submissions to ERMA in relation to the supposed benefits of possum control with 1080 (www.ermanz.govt.nz/news-events/focus/1080/index.html consulted 3 February 2009). Such challenges to evidence in support of benefits from use of non-specific toxins for pest management are only likely to increase, and RUAs are likely to need increasingly robust data to support future pest management using such methods.

Reddiex and Forsyth (2006) in translating the reliability of inference framework in Table 1 to practical application suggested five rules of thumb for designing pest control operations and associated monitoring:

- If there is no prior ‘reliable knowledge’ about the pest or resource outcomes of the intended pest control, then the design should aim to gain the most reliable knowledge (i.e., design rank ≥7,Table 1).
- If there is reliable knowledge that pest control produces the desired change in the resource, then less stringent designs may be acceptable (e.g., rank 3, 6), although if the resource does not respond as predicted then a design for subsequent pest control should be used that generates more reliable system knowledge.
- If a choice is necessary (e.g., financial constraints), it is better to monitor the resource than the pest.

- Replication is more important than randomisation.
- The monitoring design must have institutional support for the period of activity agreed at the outset of the operation.

Encouragement of community groups to undertake monitoring themselves was reasonably common and likely to become more frequent in the future as focus shifts towards these community-focussed efforts. However, communities need help to design adequate monitoring programmes and training in implementation to avoid poor quality data, and confusion over goals and reasons for monitoring. Issues with lack of long-term commitment, resources and adherence to best-practice are likely to be exacerbated if such responsibility is handed over to communities without ongoing partnership with RUAs. We suggest RUA staff should provide guidance on monitoring design at the earliest stages of such projects.

Harris (1999) in a case study review of regional implementation of the Biosecurity Act made a number of recommendations some of which remain pertinent in the context of this project. These include:

- Collection and collation of information on the costs and benefits of pest control at the farm or property level, particularly of the more extensive and common weed and animal pests included in RPMSs.
- Development of a decision making framework for pests of limited scale distribution, and for which limited information is available on its likely effect on the region.
- Development of appropriate monitoring techniques in order for councils to be better prepared for the next round of strategies.
- Inclusion of greater data gathering within the monitoring programmes, including information on the actual costs of pest control, and the effectiveness of regional intervention.

In the context of these recommendations, RUAs need to move to best practice methodologies for control and monitoring, to common systems for recording and analysing data from results and outcome monitoring, and to an agreed and consistent methodology for costing. This applies to pest management for both production and non-production benefits. This will both prepare RUAs for likely future national reporting requirements and enable them to better defend expenditure on pest management and the particular methodologies used. The MAFBNZ PMF project proposes to do this as one of its medium term aims (C Jones pers. com.)

Why is outcome monitoring uncommon?

Although it was not part of the original survey, at the suggestion of one RUA manager we followed up the survey with a simple question – what were the key issues or barriers in your region to the use of outcome monitoring? There were four general categories of responses. Concerns were expressed about:

- methods for outcome monitoring – the effectiveness of available tools and the design of monitoring programmes.
- resources, both staff and money, were often lacking to conduct effective monitoring programmes and or analyse the information.
- institutional/political issues about support for long-term programmes, and a view from councillors that killing pests was the priority.
- other issues such as the short term cycle of planning (usually 3-yearly), lack of forward planning precluding baseline data collection, lack of clarity between strategic and operational goals and objectives, and failure to set specific (SMART: specific, measurable, achievable, realistic, timebound) long term objectives for pest management.

Many of these concerns can be addressed, but lack of commitment at various levels in councils to long-term monitoring and better specification of goals and measurable outcomes needs to be addressed.

Cross RUA outcome monitoring

The real benefit of outcome monitoring comes from demonstration of a direct link between the pest management activity and change in the resource affected by the pest. The first step must always, therefore, be definition of clear and measurable outcomes. Robust demonstration of progress towards or achievement of these outcomes also requires well defined objectives (intermediate outcomes) and long-term commitment to rigorous monitoring programmes. A thorough assessment of existing monitoring programmes should be undertaken against the reliability of inference criteria and rules of thumb of Reddiex and Forsyth (2006) as part of general improvements in outcome and objective definition. Decisions about acceptable level of uncertainty around result and outcome monitoring rest, however, ultimately with RUA managers.

Sites where pest control is undertaken are likely to vary in ways that potentially influence the outcomes of pest control. For example, there are site differences in the susceptibility of fuchsia and kamahi to possum browsing and whatever is responsible for these site differences (e.g., soil fertility) may influence the pattern and rate of recovery of foliage after possum control. Such variation between sites is usually poorly understood, but it may be sufficient, when added to all the other sources of variation, to preclude the development of cross-region outcome monitoring programmes because of the costs in establishing robust monitoring systems, or limit monitoring to identification of trends.

Outcome monitoring for biodiversity benefits

This project examined where potential monitoring synergies exist between RUAs tackling similar animal or plant pests to assess possibilities for increasing the robustness of individual regional outcome monitoring results. Theoretically, operations where the same pest species is controlled using the same control methods, and the same outcome monitoring method is used, could be considered as replicates, which would strengthen inference. Inference would be further strengthened if each individual operation had matched treatment and non-treatment areas, and strengthened again if areas were matched across regions. Matching operations and operational sites, however, is difficult even within regions, and is usually addressed statistically by increasing replication. Matching control method is important – for example, aerial poisoning with 1080 kills rats as well as possums and so would be expected to result in a different outcome measured by 5-minute bird counts than ground control of possums. Both FBI (Payton et al 1999) and 5-minute bird counts (Dawson & Bull 1975) also require efforts to be made to minimise variability of data (e.g., trained observers, fixed time of year). Ideally a power analysis should be carried out on all experimental designs to deduce what effect size a given design is able to detect. This will necessarily involve the use of pilot studies to obtain an estimate of variation in the system being studied.

Only three examples of outcome monitoring with both treatment and non-treatment areas were reported in the survey, and only two of those shared a common outcome monitoring method (Foliar Browse Index). The current survey did not examine the details of design of outcome monitoring, and so cannot comment on the adequacy of monitoring to detect change. This highlights another aspect of monitoring, namely the need to decide the minimum amount of change it is desired to detect and with what level of reliability, normally estimated using a power analysis. There may also be practical issues – in small reserves the limited number of independent counting stations or vegetation plots that can be fitted in provides low power to detect significant change and results in a longer time until change can be detected.

Possums and key predators of native animals (mustelids and rodents) were the most common mammals controlled. The most commonly used techniques for measuring outcomes of mammal control were FBI and 5-minute bird counts. Bird counts can be used to measure responses to control of a range of predators whereas FBI is used primarily to assess responses to possum control. FBI and 5-minute bird counts are reasonably well researched in terms of design and factors that need to be taken into account to reduce variability in data collection. These pest species and monitoring methods would thus seem to provide the strongest basis for an integrated RUA outcome monitoring programme. With time a wider suite of outcome measures may be needed by RUAs, including measures for groups such as reptiles and invertebrates. Regardless of method, outcome monitoring in such a programme needs to be done using standard protocols/best practice methodology to minimise variability.

In an ideal world, RUAs would conduct control using input monitoring on the understanding that the level of pest reduction achieved would be sufficient to produce the desired outcome in terms of FBI or 5-minute bird counts. The implicit assumption in the successful operation of such a process is that the relationship between pest impact and pest density is well known, as is the relationship between input monitoring and pest reduction. Unfortunately, these relationships are reasonably well known for very few pest-resource systems. For example, the RTCI required for protection from possum browsing has been shown to vary from as low as 3% for mistletoe at Hauhungaroa (Sweetapple et al. 2002), <7–9% for Northern rata forest canopy at Waipoua (Payton et al. 1997), <10% for kohekohe at Motatau, to <25% for common broadleaf species at Matamateaonga (Nugent et al. 2001). The use of input monitoring as a surrogate for outcome monitoring is therefore not recommended until more robust information is available.

To overcome this shortage of information RUAs could make more use of adaptive management approaches. The following example from one RUA is informative :

"Foliar browse monitoring was started to show there was possum damage to trees and to justify control (but not to justify control target). The 5% RTC target was picked because it followed the AHB way of doing things and the possum control operators were familiar with the intensity of control needed. We saw that when we keep possum RTCs below 5%, it is hard to detect possum damage in the trees. At the same time (anecdotally) was the increase in bird numbers. The outcome-based decision was maintain possums to sub-5% because it improves the canopy and brings back the birds. There is no longer any value in looking at the canopy anymore, just looking at RTCs. Though a bit of FBI might still be done to "keep and eye on things" it was not needed because RTC was a more efficient measure and FBI didn't tell us what the "biodiversity" was doing. It was too late to bother monitoring bird abundance because we had no pre-treatment data. We did it anyway on the off chance a new species turned up or to provide some back-up data if the politicians decide to pull out of the programme (i.e. show a subsequent decline in birds post-cessation of possum control). Possum control continued. As an aside, the bird data contributes to the Ornithological Soc bird atlas. The change in bird distributions between the two Atlas' in some grid squares of interest hints that integrated pest control of rats and possums is the key to keeping the birds. We carry on using brodifacoum in bait stations because it kills the rats too. Fortunately we were doing rat monitoring too, so evidence is more than anecdotal."

Such an approach has an intuitive attraction, but to provide robust evidence of outcomes it requires the same rigour in design and monitoring as in the replicated matched-sites approach described above.

A third approach, which is dependent on forward planning, is the BACI design, before-after-control-intervention. This involves at least one pair of (preferably) matched treatment and non-treatment sites, where the measure of interest (e.g., FBI, 5-minute bird counts) is taken at both sites for some period before pest control is applied at the treatment site, and then for some period afterwards. Time (before-after) provides a means of controlling temporal variability.

A fourth approach involves outcome monitoring on a large number of treatment sites receiving similar pest management, and the collection of data on site or other factors that may also influence the outcome (e.g., habitat type). For example, FBI would be undertaken on all sites where possum control was undertaken. Statistical analysis (e.g., regression) could then be used to examine the relationship between FBI outcome and those factors recorded, including pest management.

Many of these issues are discussed by Reddiex and Parkes (2003) in relation to the experimental design of a project to measure the conservation benefits of AHB possum control on public conservation lands. Their conclusions generally match those discussed above in noting constraints on design from non-random allocation of treatment and non-treatment areas, treatment variability, and trade offs between replication and the number and quality of response variables. They recommended the use RTC for assessment possum numbers, RECCE plots for matching sites, and two outcome monitoring methods, FBI and 5-minute bird counts, for assessing biodiversity change.

Outcome monitoring for production benefits

Table 5 suggests that mitigation of damage to pasture and crops is the main focus of pest management for the productive sector. It is not, however, sufficient just to focus on the perceived benefits of damage reduction. Unless pest management produces a net (usually economic) benefit then it is not cost-effective. This means that monetary costs of pest management must also be measured and related to the monetary benefits of increased production, taking into account any indirect benefits (e.g., possum control for pasture protection may also contribute to management of bovine Tb). Measuring the costs of pest control is a simple matter of record keeping. Measuring the benefits is somewhat more complex. Nevertheless, it is important that all aspects of both are taken into account in evaluating cost effectiveness.

For pasture, there are two potential approaches to measuring outcome benefits as a result of pest management: firstly, measuring changes in pasture production (e.g., wet or dry matter production) and secondly, measuring changes in grazing livestock production (e.g. body weight, milk production, etc). The assumption in the first method is that more pasture translates into increased animal production (which may not always be the case). Possums and rabbits are the key animal species that compete with livestock for pasture, while rooks are considered to damage pasture while searching for invertebrates (as well as causing damage to a wide variety of crops). The economic costs of possum, rabbit and rook damage to pasture are not well quantified (Norbury & Reddiex 2005; NPCA 2006; Cowan 2007).

Much the same consideration needs to be given to design principles of outcome monitoring for productive sector as for biodiversity. Changes in pasture production can be assessed by mowing or clipping pasture using a standard protocol from fixed or random plots of known area from which livestock (but not possums or rabbits) are excluded, and then drying material to obtain an estimate of dry matter production per unit area. Alternatively, production in plots that exclude livestock and pests can be compared with those that exclude only livestock. Replication is important to control for variation between paddocks and sites, as plots are usually small. It is possible to build exclosures that exclude rabbits but not possums and these could be used where both pests were present at a site and only one was controlled. Norbury and Norbury (1996) provide an example of measuring change in production of pasture following rabbit control.

For rooks, a similar approach could be adopted but plots would need to be sited in areas of pasture already damaged by rooks before control was undertaken. For rooks, the issue is also the area of damaged pasture. Methods used to assess pig rooting (e.g., Hone 1995) before and after pig control could be adapted to measure broad scale changes in the extent of rook damage, which could then be combined with information from plots about changes in pasture production to estimate overall changes in pasture production from rook control.

For weed impacts on pasture, it is necessary to measure the area of infestation before and after control (which might be done as part of results monitoring) and the extent to which weeds have been replaced by pasture, as well as any local effect on pasture production.

Alternatively, production data, such as livestock body weights or milk production, could be obtained from farmers and examined for trends over a number of years, assuming that there was adequate data from several years before control. With a large enough number of farms and several years of pre- and post-control data, trends should be detected. A more powerful comparison, to control for natural annual variation in production and other factors, would be between similar farms with and without pest management. The use of production data has the advantage of addressing the ultimate outcome from pest management, and the potential to do so at a regional scale.

Assessing changes in damage to crops from animal pests is less complex, assuming that damage from different pests can be discriminated. Table 9 indicated that only rooks and magpies are targeted, and the latter probably for biodiversity rather than production reasons, so possum and rabbits are probably the species of most concern. As indicated above, there are standard methods for measuring the extent and economic costs of damage to crops, usually on a before and after control basis. Crop damage often varies greatly from farm to farm and is mostly related to local pest populations (e.g., farms adjoining bush or forest are more vulnerable). As for pasture, there are few reliable estimates of mammal pest damage to crops in New Zealand (King 2005).

Social outcomes monitoring

Review of monitoring of social outcomes was not part of this project, although it is undertaken by all councils, often in the form of customer satisfaction surveys or systems that assess performance against specified standards for responses to enquiries. These data, if collated across RUAs, could be used to identify ratepayer understanding of pest issues and concerns.

Future issues

Methods and approaches for measuring biodiversity benefits of pest management are not well developed, and the most commonly used ones such as FBI and 5-minute bird counts have both practical and theoretical limitations. Three initiatives may change this situation in the next few years. Firstly, DOC's Natural Heritage Management System (NHMS) will come into use. NHMS is being developed to create a nationally consistent, scientifically sound system of natural heritage management, enabling prioritisation, planning and monitoring of achievement (DOC Statement of Intent 2008–2011). To support this system, the Department is working to improve the accuracy and efficiency of its data collection (including field data), and to develop a greater ability to integrate data both internally and with other agencies (such as regional and local authorities). There is ongoing development of nationally consistent inventories, classification systems, prioritisation processes, and monitoring and reporting methods. The longer term aim is to develop the natural heritage management system into a system that is shared with others to contribute towards national planning and reporting on the state of New Zealand's biodiversity.

Secondly, the dearth of suitable methods for biodiversity assessment and monitoring is recognized as a high priority research gap, some research is underway (e.g., DOC CDRP project), and additional proposals to address this issue are being put up for funding.

Thirdly, MAFBNZ is developing a PMF for New Zealand pest management (Jones 2008a,b) that encompasses national reporting. Such a system will require agreement with RUAs on outcomes and measures for regional and national reporting, both of results of pest management and a variety of outcomes (e.g. biodiversity, production). Development of outcomes by RUAs needs to take place in collaboration with the development of the PMF.

Finally, RUAs are undertaking proactive steps such as streamlining their reporting systems, sharing GIS-enabled database systems and proposing the creation of a biodiversity managers group. Developing and supporting systems such as these will undoubtedly help with the overall better management of pests in the local government sector. Overall, the complexity of the tasks associated with better quality monitoring will require dedication from RUAs and a long term commitment from all staff associated with pest control. One final suggestion is that consideration should be given by each RUA to assigning specific responsibility to the co-ordination and improvement of all result and outcome monitoring.

7. Recommendations

- RUAs need to ensure that outcomes of pest management are clearly defined, with meaningful, measurable indicators of progress that can provide the basis for assessment of achievement against these outcomes. The logic framework in Fig. 1 and SMART indicators of progress should be used to ensure appropriate and quantitative measures are specified. RUAs should review their current processes, goals and objectives against such a template.
- The reliability of inference and the rules of thumb discussed above should be used to guide the design of future monitoring associated with RUA pest control activities.
- RUAs should standardise result (output) and outcome monitoring methods, particularly protocols for FBI and 5-minute bird counts, and management of all data associated with pest control operations. RUAs should investigate the utility of the frameworks being developed at present by some councils and by DOC to help them achieve this.
- Councillors need to be convinced of the need for and benefits of outcome monitoring to ensure the required long-term commitment. MAFBNZ should support RUAs in this advocacy to council governance and pest managers to assist with its current projects on performance frameworks for pest management, which will require robust monitoring programmes.
- Council pest managers need to decide on the appropriate balance between statistical robustness of outcome monitoring design and practicality in terms of resources (staff and money).
- Outcome monitoring of large, common pest control programmes (e.g., possums, rabbits and rooks) should be coordinated nationally to provide consistency and improved reporting. Such national programmes will require cross-RUA support and resourcing, an issue also identified by the MAFBNZ PMF project.
- The minimum defensible design for outcome monitoring of a single operation or site for biodiversity benefit should consist of either two matched replicated treatment and non treatment areas monitored for an appropriate period after control, or two treatment and non treatment areas monitored for an appropriate period before control and after control (BACI method). Further evaluation is needed of the design of potential of trend indicators and their contribution to outcome measurement.
- Standard protocols for FBI and/or 5-minute bird counts should be used for outcome monitoring of possum and predator control for biodiversity protection. RUAs should review options for outcome monitoring of reptiles and invertebrates in advance of future needs.

- Methods that measure changes in pasture production should be used for outcome monitoring of rabbit, possum, and rook control for pasture protection. For weed control, outcome measures must involve assessment of replacement of weeds with native species or pasture.
- Councils should consider a review of social outcomes monitoring as basis for national coordination and reporting. Such a review should deal with current RUA approaches to social outcomes and future options for national best practice, and is recommended because community values and expectations and non-market valuation will be increasingly important inputs to RPMSs. Such a review could be funded through Envirolink.
- RUAs should undertake development of an outcomes monitoring plan for each region that delivers regional insight into regional programmes and is coordinated closely with the proposed national PMF. This should be tailored to and deliver insights into regional programmes and benefits for ratepayers. This could be done for one RUA as an Envirolink project, and the project outcome then used as a template for other RUAs.
- Biosecurity Managers Group should identify those recommendations it wishes to adopt and then develop and resource an implementation plan.

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9. References

Biosecurity Generic Guidelines Group (BGGG) 1998. An overview paper: Monitoring regional pest management strategies for performance and review. Report for Biosecurity Technical Advisory Group, New Zealand. 19 pp.

Choquenot D, Warburton B 1998. How much pest monitoring is enough? Allocation of monitoring resources in pest management programmes. Landcare Research Contract Report LC9899/05 for Department of Conservation.

Cowan P 2007. How many possums make a cow? New Zealand Journal of Ecology 31: 261-262.

Cowan PE 2008. Nelson City Esplanade and Foreshore Reserves – maximising the effectiveness of biosecurity management. Envirolink Project 448-NLCC11. Landcare Research Contract Report LC0708/140.

Dawson DG, Bull PC 1975. Counting birds in New Zealand forests. Notornis 22; 101-109

Forsyth DM 2005. Protocol for estimating changes in the relative abundance of deer in New Zealand forests using the Faecal Pellet Index (FPI). Lincoln, New Zealand, Manaaki Whenua Press.

Fraser KW 1998. Assessment of introduced wild mammal populations: a manual for monitoring and estimating relative and absolute densities and selected impacts of medium to large-sized introduced wild mammals. Landcare Research Contract Report LC9798/079.

Harris S 1995. Regional implementation of the Biosecurity Act 1993. MAF Policy Technical Paper 99/4. MAF, Wellington.

Hone J. 1995. Spatial and temporal aspects of vertebrate pest damage with emphasis on feral pigs. Journal of Applied Ecology 32: 311-319

Hone J 2007. Wildlife Damage Control: Principles for Managing Vertebrate Pests. Melbourne, CSIRO Publishing.

Hurst JM, Allen RB 2007a. A permanent plot method for monitoring indigenous forests - field protocols. Lincoln, Canterbury, New Zealand, Manaaki Whenua Landcare Research. 66p.

Hurst JM, Allen RB 2007b. The Reece method for describing New Zealand vegetation - field protocols. Lincoln, Canterbury, New Zealand, Manaaki Whenua Landcare Research. 39 p.

Jones C 2008a. Performance Measurement in New Zealand Pest Management. A review of national and international processes and requirements for a national performance measurement framework. Landcare Research Contract Report: LC0809/015 for MAF Biosecurity New Zealand.

Jones C 2008b. Demonstrating the Value of Performance Measurement: a Series of Case Studies. Landcare Research Contract Report: LC0809/060 for MAF Biosecurity New Zealand.

King CM 2005. Handbook of New Zealand Mammals. Oxford University Press, Auckland.

Lee WG, McGlone M, Wright E 2005. Biodiversity Inventory and Monitoring: a review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation. Landcare Research Contract Report LC0405/122.

McArdle BH 1996. Levels of evidence in studies of competition, predation and disease. New Zealand Journal of Ecology 20: 7-15.

McNutt K, Wright E, Greene T, O'Donnell C 2007. DOC's inventory and monitoring toolbox – why are we standardising monitoring methods? DOC Science Poster 96. DOC Science and Technical Publishing, Department of Conservation, Wellington.

Myer B 2007. Nelson City Council Waterworks Reserves Pest Plant Management Strategy. Report to Nelson City Council by Te Ngahere. 74p.

Norbury, D, Norbury, G. 1996. Short-term effects of rabbit grazing on a degraded short-tussock grassland in Central Otago. New Zealand Journal of Ecology 20*:* 285-288.

Norbury G, Reddiex B 2005. European rabbit. In, Handbook of New Zealand Mammals. King CM (ed). pp 131-150. Oxford University Press, Auckland.

Norbury D, Warburton B, Webster R 2001. Long term monitoring of mammalian pest abundance in Canterbury. Landcare Research Contract Report LC0001/144 for Department of Conservation.

NPCA 2006. Pest Rooks. Monitoring and control. NPCA, Wellington.

Nugent G, Whitford J, Innes J, Prime K 2002. Rapid recovery of kohekohe (*Dysoxylum spectabile*) following possum control. New Zealand Journal of Ecology 26: 73-79.

Owen S 1998. Department of Conservation Strategic Plan for Managing Invasive Weeds. Wellington, Department of Conservation.

Partridge TR, Whaley KJ, Hunter GG 2002. Pest plant control monitoring techniques for regional and district councils. Part 1 Monitoring Framework. Landcare Research Contract Report LC0001/076 for Regional Council Biosecurity Managers Group.

Payton IJ, Forrester L, Frampton CJ, Thomas MD 1997. Response of selected tree species to culling of introduced Australian brushtail possums *Trichosurus vulpecula* at Waipoua Forest, Northland, New Zealand. Biological Conservation 81: 247-255.

Payton IJ, Pekelharing CJ, Frampton CM 1999. Foliar Browse Index : A method for monitoring possum (*Trichosurus vulpecula*) damage to plant species and forest communities. Manaaki Whenua Landcare Research, Lincoln, New Zealand. 62 p.

Reddiex B, Parkes J 2003. Conservation benefits of Animal Health Board possum control on public conservation lands. I. Experimental design. Landcare Research Contract Report LC0203/062 for department of Conservation.

Reddiex B, Forsyth DM, McDonald-Madden E, Einoder LD, Griffioen PA, Chick RR, Robley AJ 2006a. Control of pest mammals for biodiversity protection in Australia. I. Patterns of control and monitoring. Wildlife Research 33: 691–709.

Reddiex B, Forsyth DM. 2006b. Control of pest mammals for biodiversity protection in Australia. II. Reliability of knowledge. Wildlife Research 33: 711–717.

Spurr EB 1995. Protein bait preferences of wasps (*Vespula vulgaris* and *V. germanica*) at Mt Thomas, Canterbury, New Zealand. New Zealand Journal of Zoology 22: 281–289.

Spurr EB 1996. Carbohydrate bait preferences of wasps (*Vespula vulgaris* and *V. germanica*) (Hymenoptera: Vespidae) in New Zealand. New Zealand Journal of Zoology 23: 315–324.

Spurr, EB, Berben, PH 2004. Assessment of non-target impact of 1080-poisoning for vertebrate pest control on weta (Orthoptera : Anostostomatidae and Rhaphidophoridae) and other invertebrates in artificial refuges. New Zealand Journal of Ecology 28: 63–72.

Sweetapple PJ, Nugent G, Whitford J, Knightbridge PI 2002. Mistletoe (*Tupeia antarctica*) recovery and decline following possum control in a New Zealand forest. New Zealand Journal of Ecology 26: 61-71.

Ure G 2003. Nelson City Council Waterworks Reserve: Natural values and condition assessment. Report for Nelson City Council. 84pp.

Walker PT 1983. Crop losses: the need to quantify the effects of pests, diseases and weeds on agricultural production. Agriculture, Ecosystems, and Environment 9: 119-158.

Ward DF 2007a. Measuring the reduction in pest ants. Envirolink Project NRLC52. Lincoln, New Zealand, Landcare Research.

Ward DF 2007b. Prioritised surveillance for invasive ant species in Southland. Envirolink Project ESRC117. Lincoln, New Zealand, Landcare Research.

Watts CH 2004. Ground-dwelling beetles in Karori Wildlife Sanctuary before and after mammal pest eradication. Landcare Research contract report LC0304/126.

Watts CH 2007. Beetle community responses to mammal eradication in the southern exclosure of Maungatautari. Landcare Research Contract Report LC0607/170 for Maungatautari Ecological Island Trust .

10 Appendices

Appendix 1 List of participating regional authorities

Regional authority	Biosecurity Manager	E-link project contact
Northland Regional Council	Don McKenzie	donm@nrc.govt.nz (09) 438 4639
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Environment Bay of Plenty	John Mather	john.mather@envbop.govt.nz 0800 368 267
Gisborne District Council	Trevor Freeman	trevor@gdc.govt.nz 06 867 2049
Hawkes Bay Regional Council	Campbell Leckie	Allan Beer 06 833 8053 allan@hbrc.govt.nz
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Horizons Regional Council	Bill Martyn/James Lambie	Bill.Martyn@horizons.govt.nz James.Lambie@horizons.govt.nz 06 9522 800
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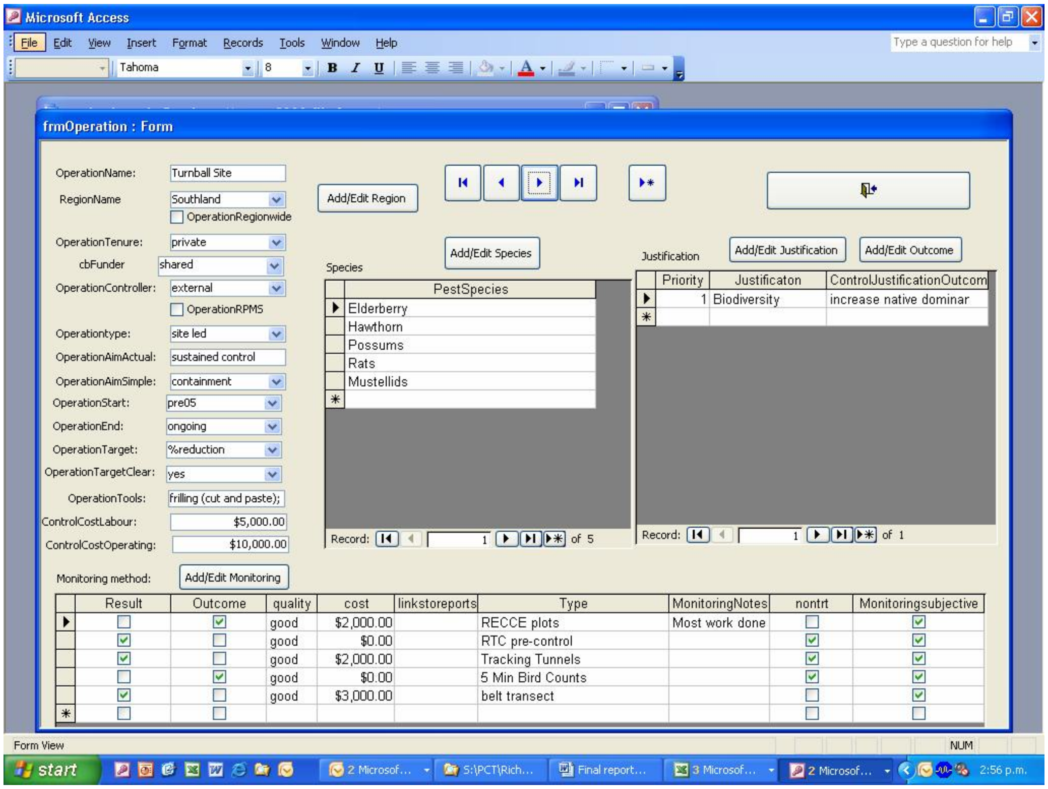
Marlborough District Council	Alan Johnson	ajo@marlborough.govt.nz 03 520 7400
Tasman District Council	Lindsay Vaughan	lindsay.vaughan@tdc.govt.nz (03) 543 8432
Environment Canterbury	Graham Sullivan	Graham.Sullivan@ecan.govt.nz (03) 353-9007
West Coast Regional Council	Chris Ingle	chris.ingle@wcrc.govt.nz 03 768 0466
Otago Regional Council	Jeff Donaldson	jeff.donaldson@orc.govt.nz 03 474 0827
Environment Southland	Richard Bowman	richard.bowman@es.govt.nz (03) 211 5115

Appendix 2 Survey questionnaire

Organization
Interviewer
Interviewee (s)
Operation name
Control area size
Location of area controlled
Land tenure
Agency(s) funding control
Agency(s) conducting control
Nature of control
Pest species targeted
Species-led or site-led control?
Aim(s) of control
Justification for control
If biodiversity protection, what outcome?
If productive sector protection, what outcome?
Was operational target specified?
if yes, specify
Was Outcome measure specified?
If yes, specify
Control start date
Control end date
Type(s) of control
Intensity and frequency of control
Effort spent on control
Operational costs
Pre-control operational monitoring
Monitoring design
Monitoring methods
Monitoring intensity and frequency
Monitoring cost
Post-control operational monitoring
Monitoring design
Monitoring methods
Monitoring intensity and frequency
Was the area stratified and if so how?
Monitoring cost
Non-treatment area monitored
Non treatment monitoring design and methods same as treatment area
If NO, describe non-treatment monitoring design, sampling procedure, and methods
Monitoring cost
Outcome monitoring
Monitoring design
Monitoring methods

Monitoring intensity and frequency
Cost
Non-treatment area monitored
Non treatment monitoring design and methods same as treatment area
If NO, describe on-treatment monitoring design, sampling procedure
Monitoring cost - $ staff time or operating
Monitoring results - operational raw data available
Monitoring results - operational report available
Monitoring results - outcome raw data available
Monitoring results - outcome report available

Appendix 3 Database information categories and codes – sample page



Appendix 4. Summary statistics for RUAs (population, total staff numbers and total operating budgets taken from local government website www.localcouncils.govt.nz/lgip.nsf accessed 24 December 2008).

Authority	Population	Total council staff	Pest plant staff	Pest animal staff	Pest policy staff	Total annual pest budget ($000)	Pest budget as % of total budget	Pest staff as % of total staff
Northland	148 470	120	4	4.5	1.5	1 000	6.9	8.3
Auckland	1 303 068	519	12	3	5	5 000	2.8	3.9
Bay of Plenty	257 379	213	7	6	1	5 000	10.6	6.6
Waikato	382 713	271	3.5	4.5	3	6 500	9.2	4.1
Gisborne	44 600	234	3	5	1	800	1.3	3.8
Taranaki	104 124	89	4	11	3	1 900	17.6	20.2
Hawke's Bay	147 783	125	5	3	1	2 300	8.9	7.2
Horizons	222 423	215	13	3	4	4 800	14.1	9.3
Wellington	448 956	410	15	8	4	2 000	1.5	6.6
Tasman	44 625	195	2	1	1	400	0.7	2.1
Marlborough	42 546	180	2	2	2	1 000	1.8	3.3
Canterbury	521 832	362	12	8	2	3 700	4.3	6.1
Otago	193 800	141	4	3	1	800	4.0	5.7
Southland	90 873	82	2.5	1	0.5	1 150	6.6	4.9