Background to the Department of Conservation's plan for implementing an Inventory and Monitoring programme

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This report was produced by Landcare Research New Zealand Ltd for the Department of Conservation. ***This report was originally published in June 2010 and reissued December 2013.****The Department started progressively implementing a national biodiversity monitoring and reporting system in 2011/12. Please note that the implemented system differs in some aspects from that described in the report, including associated costs.*

Contents

Abstract 1

1 Introduction 3

1.1 Summary of current practice 3

1.2 Summary of proposed inventory and monitoring programme and scope of this report ... 4

2 Objectives 6

3 National and regional reporting of status and trend in ecological integrity 7

3.1 Advantages and disadvantages of sampling on a grid 7

3.2 Potential for better outcomes from the same financial investment 9

3.3 Examples of how the data might be presented for reporting 9

4 Informing prioritisation for resource allocation on Conservation lands 11

4.1 Advantages and disadvantages of sampling on a grid 11

4.2 Potential for better outcomes from the same financial investment 13

4.3 Examples of how the data might be presented for prioritisation 14

5 Evaluating the effectiveness of conservation management and policy 16

5.1 Advantages and disadvantages of sampling on a grid 16

5.2 Potential for better outcomes from the same financial investment 17

5.3 Examples of how the data might be presented for evaluating managment effectiveness19

6 Providing an early-warning system 20

6.1 Advantages and disadvantages of sampling on a grid 20

6.2 Potential for better outcomes from the same financial investment 21

6.3 Examples of how the data might be presented for early warning 21

7 Conclusions 24

8 Recommendations 25

9 Acknowledgements 26

10 References 26

Background to the Department of Conservation's plan for implementing an Inventory and Monitoring programme

Anna Marburg and Rob Allen

Abstract

Recently it has been recommended that a more systematic approach to monitoring Conservation lands would help the department meet four key aims: (1) National and regional reporting of status and trend in ecological integrity. (2) Informing prioritisation for resource allocation on Conservation lands. (3) Evaluating the effectiveness of conservation management and policy. (4) Providing an early-warning system. An integrated inventory and monitoring programme based on a regular grid of permanent sample points was subsequently developed, tested and costed. The proposed inventory and monitoring programme presents an opportunity for DOC to meet multiple needs with a single dataset. It has several key advantages over current practice: (1) Comparable data for a range of indicators will enable an integrated assessment of threats to and measures of ecological integrity; supporting regular reporting as well as ad hoc requests from policymakers. (2) Consistent data intensity and design across management units will allow resources to be allocated objectively. (3) Appropriate, unbiased data will support evaluation of effectiveness. (4) Regular measurements of permanent sites will provide an early-warning system with more comprehensive coverage than that used at present.

1 Introduction

The need for quantitative data to guide implementation of New Zealand's conservation policies has been apparent for some time (e.g. Masters et al. 1957). However, implementation of monitoring programmes by the Department of Conservation (DOC) and its predecessors has been fragmented and often disconnected from current policy needs (Lee et al. 2005). Although New Zealand has benefited from wide-spread adoption of some standard methods, as compared with international experience, there has been limited coordination among individual projects with regard to key response variable(s), criteria for selecting study sites, remeasurement intervals, or the balance between permanent and one-off sampling (Lee et al. 2005). The importance of objective location of plots has been stressed (e.g. Allen 1992) but less emphasis has been placed on ensuring that study area locations are unbiased nationally, although LUCAS was designed as a systematic sample of virtually all indigenous forests and shrublands (Table 1).

1.1 Summary of current practice

- **Ad hoc.** Currently to report on its progress in meeting policy goals, DOC assembles information from about 1800 different monitoring projects across the department (Gautam et al. 2008 unpubl.). These projects are designed and implemented independently by each Conservancy and Area Office, using a variety of methods. The ad hoc nature of current monitoring makes it difficult for the Department to connect management decisions to monitoring results or to make robust statements about its progress in meeting its biodiversity conservation objectives (Lee et al. 2005). Conservancies vary widely in the number of projects they undertake and in the taxa that they focus on (Gautam et al. 2008, unpubl.). In addition, projects vary in quality. A review of a stratified sample of 448 monitoring projects indicated that while most (92 ± 1%) projects met a set of criteria for sound monitoring design only 70% (± 1) of projects met the criteria for sound sampling design (Gautam et al. 2008, unpubl.).
- **Biased.** Although current methods in the DOC toolbox specify objective location of plots within any given monitoring area, the uncoordinated nature of monitoring area selection means that at a regional or national scale the data are not representative – areas where ecological integrity is under threat are likely over-represented, as are late-successional communities. While this is a long-recognised problem for the 'biased survey' approach (Table 1), it is also a problem for treatment and control studies – treatments are often applied in areas where deleterious impacts have been observed, but conclusions about the severity of pest impacts and the efficacy of control programmes is generalised to all Conservation lands.

Table 1. Data types in current use for assessing ecological integrity, prioritising management efforts, evaluating management effectiveness and detecting future threats
(For each data type, current examples are given. Biased/unbiased refers to national estimates based on the data, while subjective/objective refers to the arrangement of samples within a selected study area. In recent decades, the importance of objective location of samples has been stressed, but less emphasis has been placed on ensuring that study area locations are unbiased.)

Data type	NZ example
Unbiased regular grid	LUCAS as designed
Biased surveys using standard methods – subjective plot location	Some data in NVS
Biased surveys using standard methods – objective plot location	Some data in NVS
Biased regular grid, i.e. sampling intensity set by local interest/accessibility	Ornithological atlas
Treatment/Control – biased study area selection, objective plot location	Adaptive Management of Forests and Deer Project
Treatment with no control	Offshore sanctuaries
Long-term research sites	Orongorongo, Murchison Mountains
Invasion fronts	Possums in Westland National Park
Expert opinion	Pest range maps
Nothing	Large parts of total Conservation land

- **Changing locations.** Monitoring areas are often not maintained long term, but are added and dropped according to current regional concerns, greatly complicating efforts to track long-term trends in ecological integrity and evaluate emerging threats. The majority of monitoring initiatives summarised by Lee et al. (2005) had been in place for less than 3 years.
- **Cheap.** An advantage of the current system is that it requires no explicit funding for a national initiative, relying entirely on work that Conservancies and Area Offices are already conducting. However, this must be offset against the staff time required to try and make national assessments with disparate, and often inadequate, local-scale data sources.

1.2 Summary of proposed inventory and monitoring programme and scope of this report

Recently it has been recommended that a more systematic approach to monitoring Conservation lands is warranted (Lee et al. 2005). An integrated inventory and monitoring programme based on a regular grid of permanent sample points was subsequently developed, tested and costed (Allen at al. 2009a, b).

The proposed inventory and monitoring programme selected two indicators (having five measures) of ecological integrity from the 18 indicators of ecological integrity laid out by Lee et al. (2005). The selected indicators — exotic weed and pest dominance, and composition — focus on components of ecological integrity that contribute to achieving the outcome 'indigenous dominance and species occupancy'. The five measures of these two indicators are: size-class structure of canopy dominants, representation of plant functional types, demography of widespread birds, distribution and abundance of three mammal pests considered a threat, and abundance of weeds considered a threat. The integrated sampling of both ecological integrity and its threats is one of the programme's key advances over current practice (Fig. 1).

The goal of this report is to provide input to a Departmental business case for implementation of the proposed inventory and monitoring programme. We have focused, therefore, on a concise outline of how the proposed programme will help the Department achieve four key goals (discussed below). Readers looking for a more comprehensive discussion of the design, testing and costing of the proposed inventory and monitoring programme are referred to the lengthier reports of Allen et al. (2013a, b).

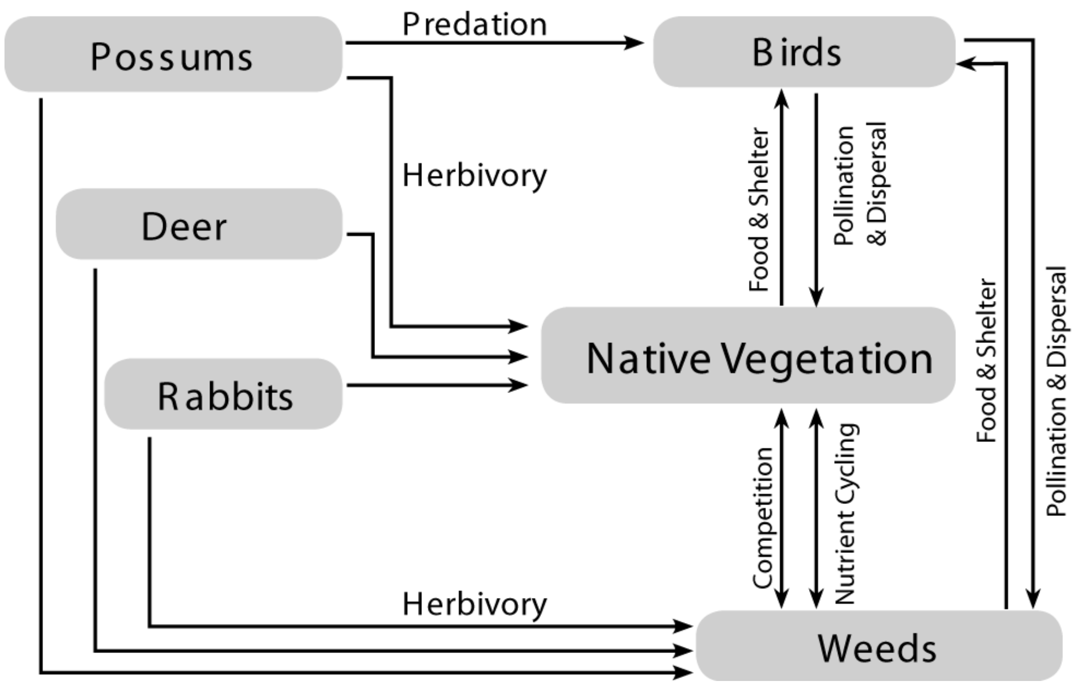

Figure 1. Measures included in the proposed Inventory and Monitoring Programme and their major interactions.

We discuss in turn four key goals of a successful inventory and monitoring programme:

1. National and regional reporting of status and trend in ecological integrity
2. Informing prioritisation for resource allocation on Conservation lands
3. Evaluating the effectiveness of conservation management and policy
4. Providing an early-warning system

For each goal we address three key points. (1) The advantages and disadvantages of sampling on a regular grid, as opposed to other sampling designs such as stratification or random point location. (2) Suggestions for how the information produced by the proposed programme could lead to improved outcomes from a broad range of DOC activities, for the same overall investment. The proposed programme would require a significant proportion of the resources traditionally allocated to monitoring. As the information provided by the inventory and monitoring programme will allow DOC to more effectively manage for ecological integrity, the costs and benefits of the programme must be assessed in a whole-Department framework. Finally (3), we give examples of how the information collected by the proposed programme could be presented, either graphically or as text, as a basis for evidence-based decisions. Wherever possible we address these points using concrete examples comparing the proposed programme with current practice in New Zealand and overseas.

2 Objectives

- To provide explicit examples of how a national inventory and monitoring programme would improve the Department of Conservation's ability to conserve the natural heritage of New Zealand.
- To demonstrate how the proposed inventory and monitoring programme will achieve four goals:

1. National and regional reporting of status and trend in ecological integrity
2. Informing prioritisation for resource allocation on Conservation lands
3. Evaluating the effectiveness of conservation management and policy
4. Providing an early-warning system

Specifically, we discuss how the proposed programme will address three aspects of each goal:

1. Advantages and disadvantages of sampling on a grid
2. Potential for better outcomes from the same financial investment
3. Examples of how the data might be presented as a basis for evidence-based decisions.

3 National and regional reporting of status and trend in ecological integrity

The Department of Conservation (and New Zealand) has multiple reporting obligations – internal, national and international – to assess whether New Zealand is meeting its goals for conserving its natural heritage (Lee et al 2005). The proposed programme will allow the Department to meet these diverse obligations using one consistent dataset collected from a national grid of sampling locations. The initial cost of collecting the data needs to be offset against the savings over current practice in staff time spent on data assembly and analysis of data with considerable limitations.

3.1 Advantages and disadvantages of sampling on a grid

3.1.1 Advantages of sampling on a grid

- **Provide unbiased estimates of ecological integrity**. To report on the ecological integrity of Conservation lands, DOC needs to sample across all Conservation lands. Data collected on a grid are unaffected by intense interest in areas that appear to be in trouble or are close to major urban centres. In contrast, aggregating local monitoring schemes for national reporting would require many more sampling points, as spatial autocorrelation needs to be accounted for. This would mean a loss of statistical power when compared with plots not put in blocks.
    - Basing national reporting on assembling catchment-scale studies risks misjudging the state of the overall population if the selected catchments are not representative of all Conservation land. For example, the s e-structure of canopy trees varies from catchment to catchment (Fig. 2). At any given time, some catchments will have net recruitment and some will have recruitment deficits, even if the overall population is stable.

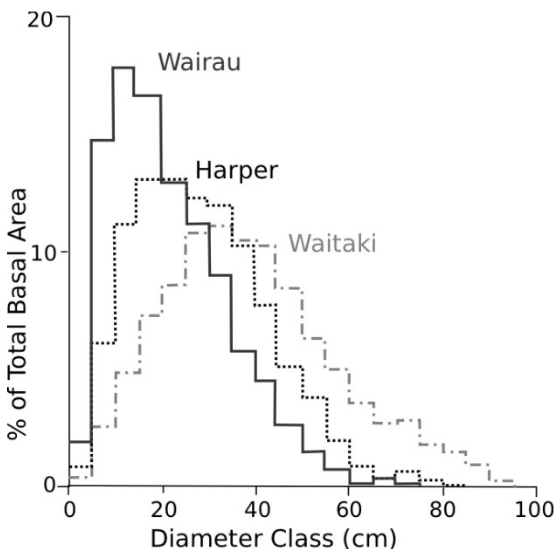

Figure 2. Variation in size-class distribution of mountain beech in three catchments: Wairau (249 plots) Harper (214 plots) and Waitaki (158 plots) catchments (Wardle & Allen 1983).

- **Allow flexible internal comparisons**. Strata can be imposed post-hoc on the regular sampling design for interpretive purposes. Unlike stratified designs, where the strata are chosen before sampling begins, post-hoc strata can be varied depending on the question. Each of the Department's reporting obligations have a slightly different focus, and the proposed grid provides the needed flexibility. With an 8-km grid, significant changes can be detected in strata as small as 38 000 ha (6 plots), as long as the changes on all plots are in the same direction. Detection of more subtle changes will require denser sampling in the area of interest, as in current practice.
    - Fuchsia (kotukutuku – *Fuchsia excorticata*) is endemic to New Zealand and a signature component of two widespread forest classes: Kamahi–hardwood forest (612 000 ha) and Marbleleaf–pepperwood–wineberry forest (189 000 ha; Wiser & Hurst 2008). Fuchsia is favoured by both deer and possums, but its susceptibility to browsing varies; in some catchments it is quickly eliminated, while in others populations remain healthy (Nugent et al. 2001). 32 plots in the LUCAS data contain Fuchsia >2.5 cm dbh; 16 of those plots are Kamahi–hardwood forest and 6 are Marbleleaf–pepperwood–wineberry forest (Wiser & Hurst 2008). The proposed monitoring programme will enable assessments of fuchsia regeneration not only for New Zealand as a whole, but also by region and for the vegetation communities of which it is a signature component, although assessments of fuchsia regeneration in Marbleleaf–pepperwood–wineberry forest will be able to detect only changes that affect all plots in the same direction.
- **Is simple**. Grid designs are readily understood by policymakers and other end-users. They are also easy to design and implement.
    - The National Vegetation Survey Databank (NVS) contains records from approximately 77 000 vegetation survey plots. However, due to the unsystematic nature of plot locations, using NVS to estimate 1990 carbon was challenging (Hall et al. 2001). In contrast, estimating carbon for the year 2000 from LUCAS was a much simpler exercise.
- **Is an international standard**. The grid approach has been adopted for forest monitoring elsewhere, for example Scandinavia, Austria and the United States. In the United States, the design has been slightly modified so that plots are randomly located within a grid cell, rather than at each grid intersection.

3.1.2 Disadvantages of sampling on a grid

- **Is statistically inefficient.** For any given statistical question, greater statistical power can be achieved with fewer plots if they are stratified according to the variable of interest. However, stratification makes it harder to use the same dataset to answer multiple questions. Additionally, deciding on the strata to use can be contentious: administrative boundaries, management levels and environmental types all have their uses and their advocates. Not only is the appropriate type of stratification to use debatable, classification schemes themselves change through time, as the Department is reorganised or ecological understanding is refined.
- **Cannot report on rare taxa or ecosystems.** With low-intensity sampling, or lack of a specific stratification, there will always be sub-regions (e.g. Waitutu) or rare ecosystems (e.g. dunes) with insufficient data to analyse separately. Consequently,

population trends for taxa with limited ranges or specialised habitats will be difficult to detect with the proposed system. The system will, however, measure rare taxa that become common or common taxa that become rare.

3.2 Potential for better outcomes from the same financial investment

- **Meet multiple reporting requirements with one programme.** The Department not only has specific obligations for reporting on its activities but also supports other agencies (e.g. the Ministry for the Environment (MfE) and the Ministry of Agriculture and Forestry (MAF)) in their reporting efforts.
    - The vegetation indicator measures provide a systematic basis for Convention on Biological Diversity, State of the Environment, Montreal Process and Departmental annual reporting.
- **Meet whole-of-government aspirations**. The proposed programme overlaps with aspirations of MfE's Environmental Performance Indicators (EPI) programme as well as reporting by MAF, Statistics New Zealand, Biosecurity New Zealand and Regional Councils. The adoption of a robust and flexible monitoring programme by DOC could provide leadership to other agencies to do likewise; enabling measures of ecological integrity to be tracked beyond Conservation land, for a better understanding of how landscape context affects conservation reserves.
- **Achieve cost-effectiveness from complementary systems.** MfE's Land Use Carbon Accounting System (LUCAS) initiative collects data for some of the measures at most sampling locations on Conservation land. The proposed monitoring programme is designed to be consistent with LUCAS efforts, achieving considerable cost savings (Allen et al. 2013b).

3.3 Examples of how the data might be presented for reporting

- **Show user-friendly graphs**. The five measures of ecological integrity should be presented graphically in ways that are easily understood by managers with diverse backgrounds and training.
    - For example, box plots are a good way to show both central-tendency (median) and variation in the data. In the hypothetical example shown in Fig. 3, Vegetation Community 3 has high ecological integrity (as measured by abundance of common birds), which is maintained through time. In contrast, Vegetation Community 1 has low ecological integrity in the first measurement, but it is also more variable than Community 3. In the second measurement the median bird abundance in Vegetation Community 1 has improved, but the variability has declined, so that not only have the plots with very few birds improved, there are fewer plots with exceptionally high bird abundances. This hypothetical example underscores the importance of reporting both central tendency and variation in the indicators.

- **Show relevant comparisons**. The grid design enables internal comparisons at multiple scales. DOC's reporting requirements all have a slightly different focus and the internal comparisons presented should reflect that. As long as each subdivision has sufficient plots, there are no constraints on how the country can be subdivided – e.g. by Conservancy, by vegetation community or by management type. For example, the abundance of common birds could be compared across vegetation communities, or by Conservancies (Fig. 3).
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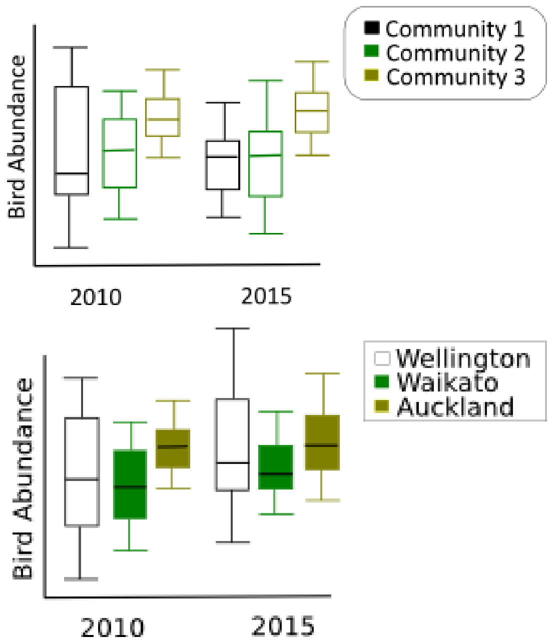

Figure 3. Hypothetical example of two different ways of reporting on bird abundance from the same data – by vegetation community (top) and by Conservancy (bottom) – highlighting the flexibility of the grid approach. The box shows the middle 50% of the data values, and the 'whiskers' more extreme values. The median (middle) values are shown as a solid bar within each box.

4 Informing prioritisation for resource allocation on Conservation lands

Resources for biodiversity conservation have always fallen short of requirements for active management of all conservation lands and will likely continue to do so in the future. The Department must, therefore, apportion resources among conservation outcomes and geographic regions according to some sort of prioritisation. The proposed inventory and monitoring programme will provide objective data with which to do that, leading to improved conservation outcomes and providing a means for more constructive engagement with stakeholders.

4.1 Advantages and disadvantages of sampling on a grid

4.1.1 Advantages of sampling on a grid

- **Transparent and defensible decisions**. By using an objective sample across all ecosystems and administrative units, DOC will be able to make evidence-based decisions about the relative impact of different threats in a transparent and defensible manner.
    - Much of what we know about deer impacts on tree regeneration comes from forests where impacts are high – but data from LUCAS demonstrates that these forests appear to be atypical. In the example shown in Fig. 4, the s e structure of a palatable tree species, mahoe (*Melicytus ramiflorus*), inside and outside a set of long-standing deer exclosures is compared to the s e distribution of all mahoe found in the LUCAS data (Peltzer & Mason 2009). While there is a marked lack of small trees in plots immediately outside exclosures, suggesting a regeneration deficit, nationally, mahoe s e structure shows no such deficit (Fig. 4).
- **Common data for all ecosystems and regions.** A regular grid enables prioritisation of threats to ecological integrity to be done over DOC-administered lands as a whole. The proposed programme provides for the same data intensity and design across management units; rendering transparent disparities among Conservancies and ecosystems in the range and severity of threats they face. The existence of a common design for all Conservation lands has several important flow-on effects:
- **Data available from previously undersampled parts of the landscape**. Currently few vegetation data are available from Taranaki and Northland.

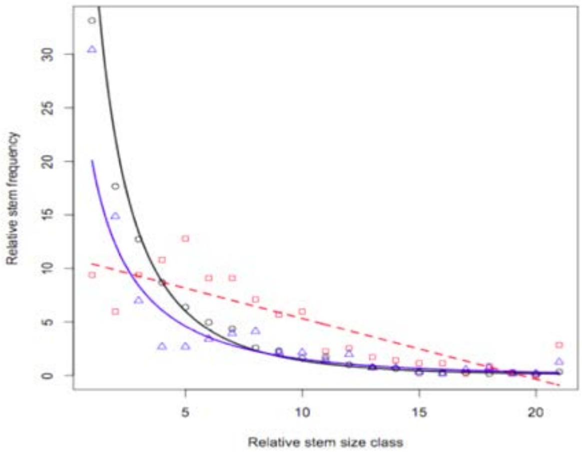

Figure 4. S e structure of the common tree mahoe, which is highly palatable to deer. The *black line* and data points are derived from unbiased plots in forests nationally. The *blue line* and data points are from inside fenced deer exclosures nationally and the *red line* and data points are from areas of forest immediately outside exclosures. (reprinted from Peltzer & Mason 2009).

- **Objective context for where DOC does or does not undertake management.** The pilot inventory and monitoring programme showed that ungulates are widely variable in abundance (Fig. 5). Setting a target population s e would clearly identify areas where control is not currently considered necessary.

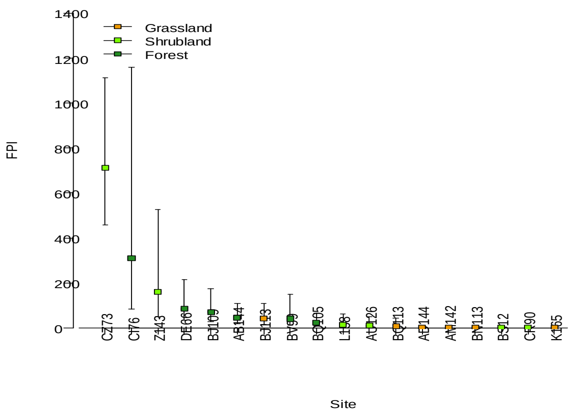

Figure 5. Indices of deer and feral goat abundance from an unbiased national assessment of forests, shrublands, and grasslands (18 points from an 8 × 8 km grid: 2008–09). Redrawn from Allen et al. (2013b).

- **Consistent data throughout vegetation succession.** Vegetation is always changing. Over time, some of the permanent plots in the proposed inventory and monitoring programme will succeed from grasslands to shrubland to forests, while disturbances will turn some areas that are currently forested into shrublands, grasslands or bare ground. By having a common design for all vegetation communities, ecological integrity can be seamlessly assessed through these transitions.
  - EBEX21^{TM} is a service that enables New Zealand landowners to sell carbon credits from regenerating native forest to third parties. When designing the

EBEX21^{TM} mensuration methodology, stratification was considered but ultimately an objective sampling strategy (random points within the entire 'eligible' forest area) was selected. This decision has been vindicated by the rapid rate of change in some sites — some sites have changed vegetative state entirely within 8 years. If grassland plots had been excluded in the initial measurement of these plots the landowner would not have had a baseline against which to measure shrubland gain (Fiona Carswell, pers. comm.).

4.1.2 Disadvantages of sampling on a grid

- **Localised threats and rare ecosystems will be under-weighted in national assessments**. If prioritisation is only done at a large scale, then threats that are restricted in extent (e.g. the subtropics, high latitudes, high elevation) will be under-resourced. Regions with more typical climates and habitats will get a disproportionate share of resources. This risk can be mitigated by considering multiple scales in the prioritisation exercise and including information from DOC's Tier 2 and Tier 3 monitoring. Again, the grid supports the multi-scale internal comparisons that would be required for multi-scale prioritisation.

4.2 Potential for better outcomes from the same financial investment

- Foster greater commitment to priority projects through objective resource allocations.
    - Management of introduced species is often contentious. Although real differences exist between advocacy groups, objective guidelines for control could open the way for more constructive relationships at both the national and local level.
- **Improve land acquisition and land-use decisions for biodiversity outcomes**. When evaluating land for purchase, or disposal, DOC could put in a mini-grid (e.g. 1 km or 500 m) and compare the ecological integrity of contested land to the total area of Conservation land. This would provide an objective way to make decisions in a highly contentious arena, although care would need to be taken in interpretation to account for spatial-autocorrelation and the increased probability of detecting rare taxa and ecosystems.
    - A protected natural areas (PNA) survey was undertaken over areas of crown land on the Buller coal plateaux (Stockton and Denniston) which have the potential for future coal mining. However, it was unclear how the target area compared with areas of Conservation land outside the Buller coal plateaux.
- **Improve use of monitoring data within a defined framework.** Little systematic use is made of much of the current data collected (Gautam et al. 2008 unpubl.; Lee et al. 2005). Greater systematic use of data should lead to better prioritisation decisions. Greater national and regional level scrutiny of biodiversity monitoring activities should lead to measuring the right things, in the right place, at the right time.

4.3 Examples of how the data might be presented for prioritisation

- **Show evidence used and decisions reached**. Both the outcome of the prioritisation exercise and the data used to support it need to be presented so that they can be understood by a wide range of stakeholders and policymakers.
    - For proposed land acquisitions DOC could compare the value for each indicator of the target parcel (derived from a mini-grid, described above) compared with the distribution of indicators regionally and nationally. As described above, interpretation of these data will need to take account of different sampling intensities.
- **Make liberal use of maps**. The location of areas selected for management will be of interest to many stakeholders. Maps can also be used to show how multiple considerations intersect.
    - Some areas have higher densities of pests than others (Fig. 5), but the areas with the highest pest density are not always the most vulnerable to herbivory. Maps of pest density could be created with the data collected by the proposed programme, either by applying mean densities per vegetation class (e.g. Wiser & Hurst 2008) to a map of those vegetation classes, or by building a predictive model of pest abundance. Mapping the distribution of palatable plants, along with the distribution and abundance of introduced herbivores, would allow key areas for control to be identified. When identifying areas for pest control, it is important to consider the spatial context. It may be necessary to do control on some lower-priority areas near high-priority areas to avoid leaving a refuge; which will lead to prompt reinvasion after control. (Fig. 6).

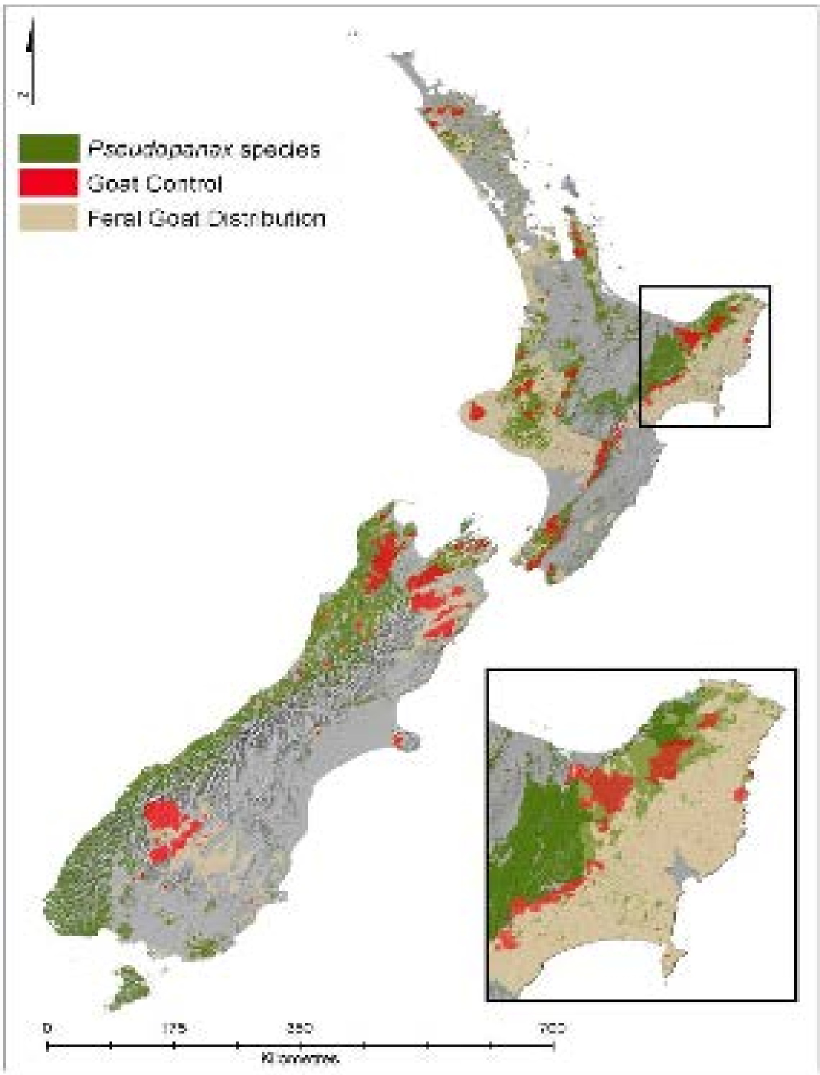

Figure 6. Example of the projected distribution of goat-palatable *Pseudopanax* spp. trees nationally, based on occurrence in LUCAS plots, the distribution of feral goats, and the areas in which goat control is being conducted. Reprinted from Allen et al. (2013b).

5 Evaluating the effectiveness of conservation management and policy

The Department of Conservation is under increasing pressure to demonstrate the effectiveness of its management. This pressure comes in the form of official requirements from government and pressure from stakeholders, e.g. local opposition to aerial 1080 drops. The proposed inventory and monitoring programme will allow DOC to answer three key questions: Did the targeted animal respond? Were non-target animals harmed? And, did native biota respond as expected?

5.1 Advantages and disadvantages of sampling on a grid

5.1.1 Advantages of sampling on a grid

- **Measure real-world impacts of management**. A treatment–control approach only allows inferences about the effectiveness of the specific treatments that were applied. Cost forces experimenters to consider only a handful of treatments, which are often more extreme than those than can be attained operationally. The proposed programme allows evaluation of management interventions under real-world conditions.
    - The last ERMA review highlighted that data about the impacts (positive and negative) of 1080 applications on many species of native birds are limited or geographically biased (Anon. 2007). With the proposed programme, DOC could compare densities of common native birds in areas where 1080 has been applied and areas where it has not.
    - Intensive management areas (e.g. Mainland islands) are argued to have a spillover or 'halo' effect on surrounding areas that partly justifies their cost. This benefit could be tested with as few as 5–6 sites nationally each at least 20 ha in s e if changes were unidirectional.
    - A national grid together with data on hunting effort and extent would allow DOC to assess the effectiveness of commercial and recreational hunting in controlling deer populations, both nationally and regionally.
    - The proposed monitoring programme would allow the effectiveness of internal quarantines – intended to control the spread of weeds and pests within New Zealand – to be assessed.
- **Robust to shifts in conservation priorities**. An unbiased grid is inefficient for any one purpose but is robust to shifts in management concerns. Stratification is statistically efficient but inflexible. If the variable of interest changes or management units are redefined, then the whole study needs to be redesigned and it may be impossible to calculate long-term trends.
    - The National Forest Survey (Masters et al. 1957) varied the intensity of sampling depending on the timber production potential of the forest. This stratification according to areas with high production potential means that some areas with low production potential but high local plant endemism, e.g. northwest Nelson, were poorly sampled and as a result we have little information from the 1940s–50s to assess trends for these areas.

  - When LUCAS was designed, stratification was considered – the suggestion was to split forest and shrublands into those types that would change in carbon and those that would not. However, in the 10 years since LUCAS was designed, information about the spatial distribution of vegetation types and their sequestration rates has improved tremendously. Opting for a regular grid meant that the estimates of 2000 carbon could take advantage of that refined ecological understanding. Additionally, it is unlikely that the LUCAS data would have enjoyed the broad uptake that they have if the design had been narrowly focused on carbon sequestration rates.

- **Collect consistent data across ecosystems**. A unified design, such as the one proposed, facilitates comparisons across ecosystems. Using different methods in different ecosystems, as in current practice, complicates and limits the ability to compare ecological integrity across ecosystems.
  - The proposed design of vegetation data has measurements at the 0.75-m^2 scale, the 25-m^2 scale, and the 400-m^2 scale. Although the overall plot s e is much larger than usually used in non-forested systems, calculating the frequency in 0.75-m^2 subplots gives a measure of abundance of herbaceous species in height classes that is not dissimilar to methods more commonly associated with herbaceous communities in New Zealand, like the Scott Height Frequency or the Wraight method (Wiser & Rose 1997).

- **Provide context for control–treatment experiments**. Experimental assessments of management effectiveness have historically struggled to find suitable control and treatment areas. Areas that were initially believed to be comparable have turned out to have fundamental differences in soils, animal abundance, etc. An appropriate solution may well be to select control plots from the widespread grid network of plots to compare with any particular treatment area.

5.1.2 Disadvantages to sampling on a grid

- **Provide little insight about small-scale management interventions**. Smaller-scaled studies will always be needed to test new management interventions and understand their effectiveness. As mentioned before, the coarse grain of the sampling grid means it cannot draw inferences about highly localised phenomena.
  - Possum-proof collars around trees hosting mistletoe are very effective, but will not impact national estimates of occupancy and abundance of palatable species.
  - Stoat trapping along rivers to boost whio (blue duck) numbers is too localised to assess with the proposed grid.

5.2 Potential for better outcomes from the same financial investment

- **Facilitate adaptive management.** The information collected by the proposed programme, when matched with locally intensive data, would allow adaptive management to be implemented. Only by monitoring ecological integrity both where active control is being undertaken and where it is not can the Department assess which interventions are effective.

- **Integrated animal and vegetation sampling enables system-specific analyses.** Evaluating the success of a management intervention requires knowing the capacity of the ecosystem to respond. Different ecosystems are differentially sensitive to threats.
    - Regeneration of canopy trees depends on many factors besides herbivory, such as stand age, canopy cover, seed availability and disperser densities. In the example shown in Fig. 7, seedling densities are much more closely correlated with basal area than with deer abundance, suggesting that in this area, regeneration is limited by light and aggressive deer control would have little impact (Fig. 7).
    - Kamahi (*Weinmannia racemosa*) is browsed by both deer and possums. Comparing s e-class distributions with both deer and possum abundances would allow assessment of which animal poses more of a threat to continued indigenous dominance in forests where kamahi is common. It may be that control is only effective if both pests can be controlled at once.

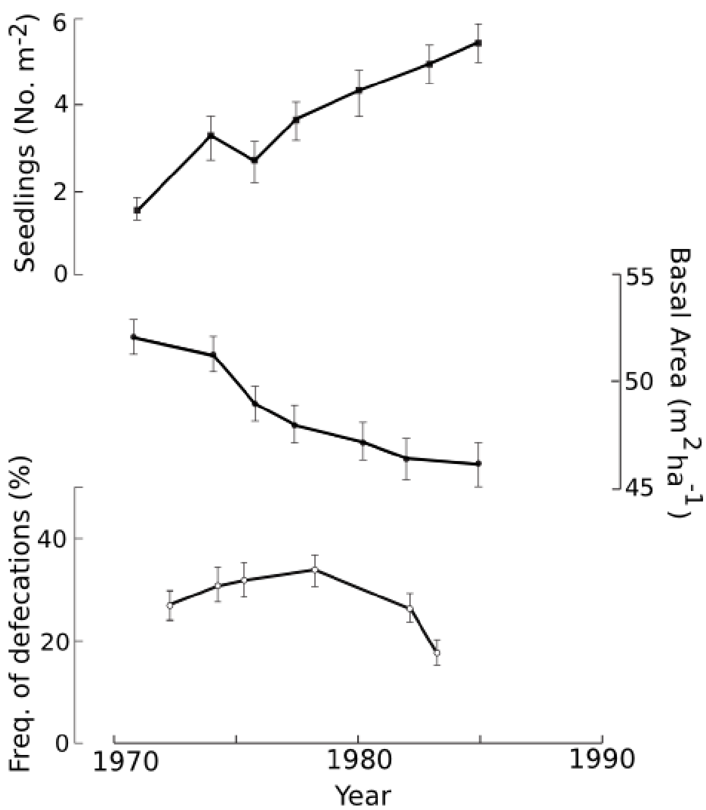

Figure 7. Seedling density is more closely correlated with tree basal area than deer density (as measured by frequency of defecations) between 1970 and 1985 in the Harper-Avoca catchment, Canterbury (redrawn from Allen et al. 2002).

5.3 Examples of how the data might be presented for evaluating managment effectiveness

- **Include as much historical information as possible**. Evaluations of effectiveness depend critically on expectations for ecological integrity. In the same way that weather records help us judge the severity of current droughts or heat waves, historical biodiversity data can give a sense of how current data compare with the range of natural variability.
- **Connect management actions directly to improvement in ecological integrity**. It is increasingly less acceptable for DOC to assert that successful control operations must have improved ecological integrity: they need to demonstrate it.
    - Instead of assessing effectiveness of possum control efforts by measuring outputs (did possum numbers fall?), the Department will be able to answer questions about outcomes: Did bird populations decline? And, did palatable native trees respond as expected? (Fig. 8)

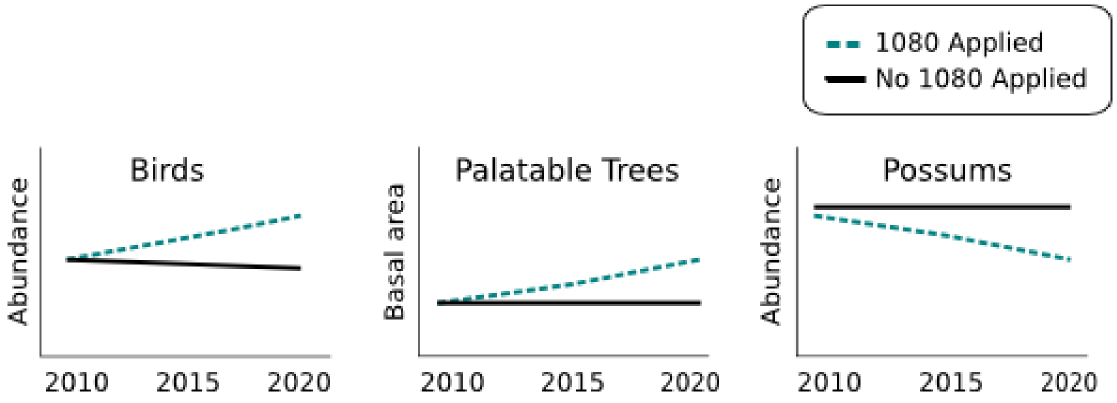

Figure 8. Hypothetical example of evaluating the impact of aerial 1080 drops on ecological integrity by looking at three measures included in the proposed programme: abundance of common birds, dominance level of palatable trees, and possum abundance. The integrated sampling of birds, plants and pests will allow the Department of Conservation to answer three crucial questions about management effectiveness: did the targeted animal respond? Were non-target animals harmed? And, did native biota respond as expected?

6 Providing an early-warning system

There are many examples locally and internationally of sudden deleterious changes to ecosystems. Perhaps the most famous is the chestnut blight that wiped out a canopy dominant across the eastern Unites States in less than 40 years. Even if they cannot be controlled, advance warning of major changes, such as range shifts due to climate change, would allow the Department to adjust its priority areas for land acquisition, pest control and restoration to reflect incipient changes.

6.1 Advantages and disadvantages of sampling on a grid

6.1.1 Advantages sampling on a grid

- **Detect any widespread, unanticipated event.** Grid sampling gives an even coverage of sample points when compared with random or stratified sampling. An important consequence is that it is well positioned to measure impacts large-scale natural disturbances (e.g. cyclones, volcanoes). In contrast, with random or stratified sampling, even a large disturbance, such as a cyclone, could, just by chance, strike an area with too low a density of points for internal comparisons.
- **Monitor condition of high-value regions**. By monitoring ecological integrity across all Conservation lands, the proposed programme will give early warning of threats to areas with high conservation values. In contrast, an initiative that focused on ports and other invasion hotspots would be monitoring land of mostly low conservation value that may not contain the most at-risk species.
  - A pathogen that attacked mature podocarps would not be detected in a ‘Maginot Line’ placed around ports, but would be detected with a grid spread across all Conservation land.
- **Detect slow declines** Many currently endangered taxa were once abundant. The proposed grid will pick up a 5% change in any indicator, which would not be detected by casual observation.
  - If the proposed monitoring programme had been implemented in the 1950s, kaka might have been included in a list of ‘common’ birds and their decline detected much sooner.
- **Distinguish between new and newly-detected problems**. In setting management priorities for controlling biological invasions, it is important to distinguish between new and newly-detected invaders and to determine the rate of range expansion. Monitoring only areas where problems are suspected would miss these two important pieces of data.

6.1.2 Disadvantages of sampling on a grid

- **Some disturbance configurations affect their detectability**. The impact of spatially compact disturbances (e.g. storm damage) will be easier to distinguish than linear ones (e.g. lahars). This will be true for any sampling configuration except a stratified sample for that particular disturbance (which in many cases cannot be implemented in advance).

- **Worse performance for rapid invaders**. An 8-km grid with a rolling 5-year remeasurement is unlikely to sample new invaders when they are highly localised and easy to control. For plants and vertebrate invaders, focusing early detection efforts around ports, urban boundaries and other hotspots would be more effective. However, this approach would miss plant pathogens that attack mature forest.

6.2 Potential for better outcomes from the same financial investment

- **Separate signal from noise**. When new concerns arise, long-term trends within the affected regions can be back-calculated, allowing the Department to distinguish between new problems, newly-detected problems, and non-problems.
  - Long-term phenological records around the world have provided evidence of climate change.
  - Bare landslips in the South Island High Country were presumed to be caused by high deer densities, before further research indicated that many had existed prior to European colonisation (Bellingham & Lee 2006).
  - Canopy dieback in forests has been a concern since the 1950s. Possums are frequently suspected; however, in many cases the evidence is weak. In some cases the rot-resistance of standing dead spars has created a false impression of sudden dieback, whereas evidence from plots collected over >20 years show that some tree species in these forests that are palatable to possums, e.g. kamahi, have stable populations (Bellingham & Lee 2006).
- **Detect interactions among threats**. Climate change may alter the ranges of both native species and pest species and may change the severity of disease outbreaks. Early warning of these changes is essential for efficient allocation of pest-control resources
  - The illegal introduction of rabbit haemorrhagic disease to New Zealand was associated with increases in both possum and exotic weed populations and decreases in predator populations (Ruscoe et al. 2006).
- **Share costs.** Currently few resources are devoted to early warning of threats to ecological integrity. With the proposed inventory and monitoring programme, costs for an early-warning system would be shared across multiple agency goals (governmental reporting requirements, prioritisation of resource allocation, evaluation of management outcomes).

6.3 Examples of how the data might be presented for early warning

- **Use spatial and temporal comparisons to gain early-warning insights**. Questions to consider are: Is the phenomenon happening everywhere (Fig. 9)? If not, has the phenomenon happened elsewhere in the past? What was the trajectory of the affected regions before the phenomenon was observed (Fig. 10)? These questions will provide insight into whether the affected area is a leading indicator of a new problem, or an example of a natural fluctuation.
  - For indigenous dominance to be maintained, mortality and recruitment must be in balance. Therefore, recruitment deficits are concerning and may be an early

warning of future declines in ecological integrity. However, mortality and recruitment rates naturally vary. At any given time, some areas will be experiencing net recruitment and others a recruitment deficit. In the example shown in Fig. 9, recruitment rates of geographically separate populations silver beech, black and mountain beech and kamahi generally exceed or match their mortality rate, while Halls' totara is more concerning, with half the observed populations experiencing a recruitment deficit (S. Richardson, unpubl. data).

- Monitoring trends through time is also a key component of an early-warning system. For example, heavy snowfall in the Harper-Avoca catchments two years after a network of permanent plots were established provided an opportunity to study dieback in beech forests. Increased mortality from this natural disturbance and matching increases in recruitment were still evident nearly a decade later (Fig. 10). Plots with little snow damage did not show a sustained increase in mortality (Wardle & Allen 1983). Although it concerns natural successional dynamics, this example underscores the importance of both temporal and spatial comparisons when drawing conclusions about demographic processes.

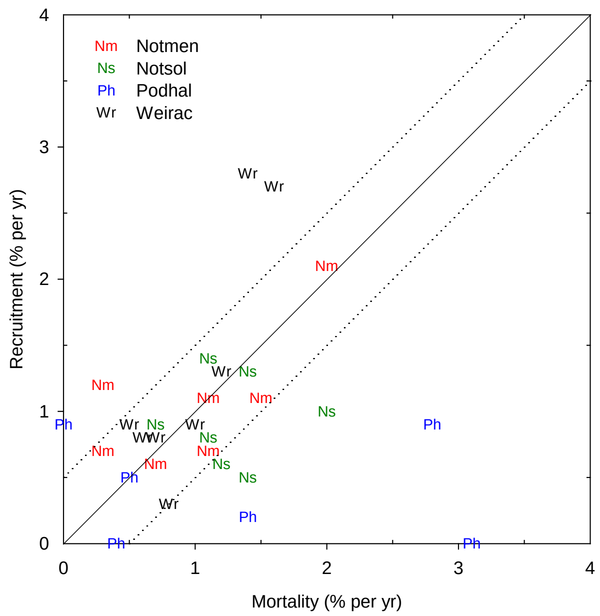

Figure 9. An example of how rates of mortality and recruitment vary among populations across the landscape. The solid line indicates a 1:1 relationship between mortality and recruitment, and the dashed lines contain the area ± 0.5% per year of this 1:1 line. Each data point represents a species at a site (data from Bellingham et al. 1999a, analysis by S. Richardson, unpubl. data).

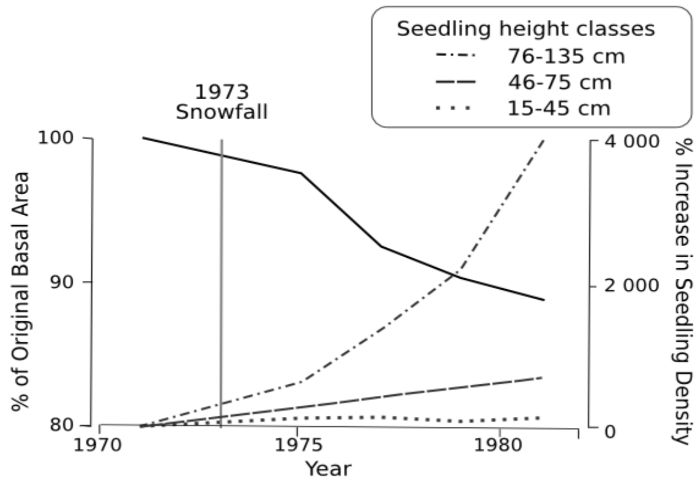

Figure 10. Increases in seedling density in response to canopy mortality associated with heavy snow storms in mountain beech forest (redrawn from Wardle & Allen (1983)).

7 Conclusions

The proposed inventory and monitoring programme presents an opportunity for DOC to meet multiple needs with a single dataset (Fig. 11). As such it has several key advantages over current practice:

- Comparable data for a range of indicators will enable an integrated assessment of threats to and measures of ecological integrity; supporting regular reporting as well as ad hoc requests from policymakers.
- Consistent data intensity and design across management units will allow resources to be allocated objectively.
- Appropriate, unbiased data will support evaluation of effectiveness.

Regular measurements of permanent sites will provide an early-warning system with more comprehensive coverage than that used at present. Distributing the cost of monitoring over several objectives means that the marginal cost of an early-warning system is low.

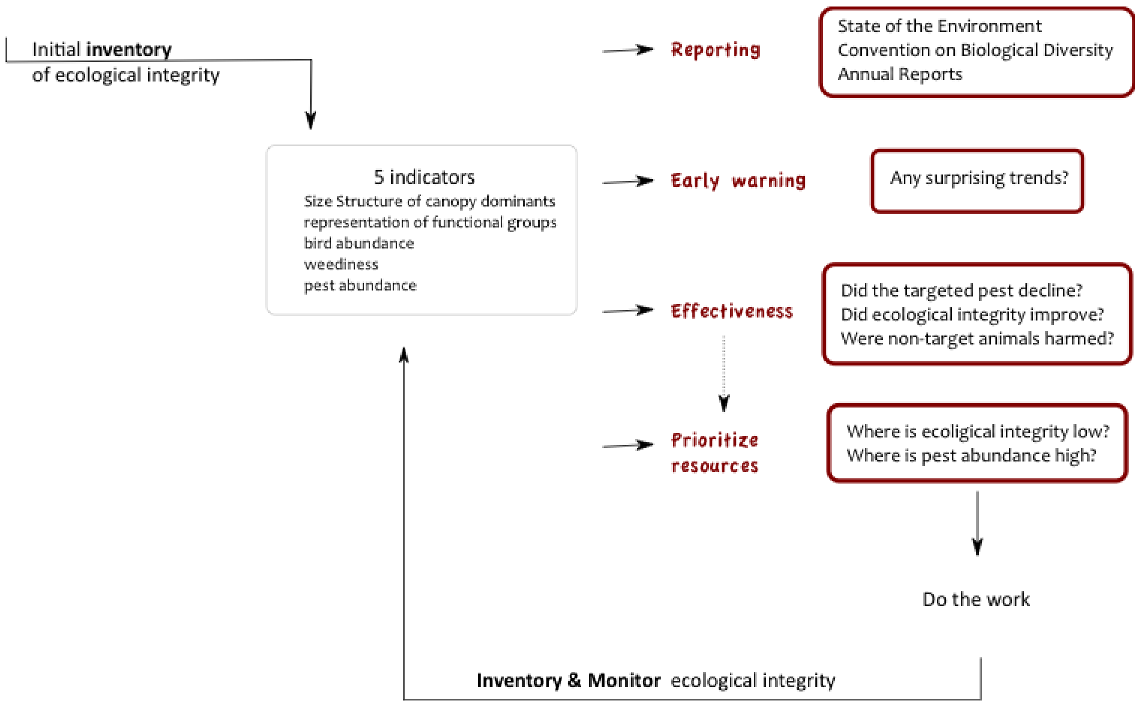

Figure 11. The five measures collected by the proposed inventory and monitoring scheme will help the Department of Conservation achieve four key aims: meeting reporting obligations, early warning of new threats, evaluation of the effectiveness of management and prioritisation of resource allocation. Note that evaluations of the effectiveness of management will feed into the prioritisation of resources in subsequent years.

8 Recommendations

There are five steps the Department can take to ensure successful implementation of the proposed inventory and monitoring system:

Demonstrate usefulness. Buy-in by agency staff will be crucial for the long-term success of the programme. Without the data from the first measurement it is difficult quantify the case for implementation. Therefore, DOC should build buy-in by agency staff by quickly developing projects to demonstrate how the data can be used to set management goals, prioritise interventions, and evaluate the results. Evaluating the impact of 1080 application on possum abundance, the ecological integrity of forests and native birds (as in Fig. 8) could be done with the first round of data and would address a current policy need.

Invest in data entry and informatics. The savings in staff time envisaged by this report will only be realised if the data are readily available shortly after collection in an easily analysed format.

Implement rigorous quality control. The proposed programme is expensive. We believe that this cost is justified, given the multiple needs that the programme fulfils. However, for those gains to be realised, the data must be trusted. Therefore, a rigorous auditing and quality control system is essential.

Integrate historical data into trend assessments. Assessments of trends in ecological integrity are critically dependent on the length of the record being assessed. The proposed inventory and monitoring programme has been designed to allow use of historical data (Allen et al 2013a). However, for a few indicators, maintaining a unified national design has required a deviation from prior approaches. Field trials in grasslands directly comparing the Wraight and Scott height-frequency methods (Wiser & Rose 1997) with the 20 × 20 m permanent plot method would allow better integration of historical data into trend assessments of the vegetation indicators.

Develop guidelines for assessing outcomes. All four goals – reporting, prioritising, evaluating and early warning – require comparisons of current state and trends in indicators to desired outcomes. As part of the implementation of the inventory and monitoring programme, DOC, supported by the scientific community, will need to develop guidelines for what is considered ‘good’ or ‘poor’ ecological integrity for each indicator. These guidelines should explicitly consider temporal trends and ecosystem context rather than attempting to set binary ‘thresholds’.

9 Acknowledgements

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