Department of Conservation biodiversity indicators:

2012 assessment

Landcare Research
Manaaki Whenua

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EXECUTIVE SUMMARY

This technical report underpins the intermediate outcome 'the diversity of our natural heritage is maintained and restored' in the Department of Conservation's (DOC) Annual Report for the year ended 30 June 2012.

INFORMATION SOURCES AND APPROACH TO REPORTING

It reports on the status of biodiversity in New Zealand's public conservation lands, focusing mainly on native forests. DOC has developed a Biodiversity Monitoring and Reporting System to assess whether ecological integrity on public conservation lands is being maintained. Data and information, used to inform indicators and measures, were drawn from three primary sources: (1) an unbiased sample of locations (328 and 75 locations for vegetation and animal surveys respectively) within indigenous forests on public conservation land; (2) expert-driven threat listings of ecosystems; and (3) land tenure and management information. Detailed analyses and results are presented, to show how the indicators and measures contribute to the four goals of the Biodiversity Monitoring and Reporting System. These are: (1) National and regional reporting of status and trend in ecological integrity; (2) Evaluating the effectiveness of conservation management and policy; (3) Providing an early-warning system; and (4) Informing prioritisation for resource allocation on Conservation lands. The Biodiversity Monitoring and Reporting System has recently been adopted by the Department of Conservation is therefore currently in an early phase of implementation. For some indicators, the data and information currently available are initial and limited, thus constraining interpretation. As the temporal and spatial coverage increases in the future, DOC will have greater confidence about status and trends.

GOAL 1 – STATUS AND TREND

Indigenous dominance – are the ecological processes natural? In native forests on New Zealand's public conservation land, native plant species continue to greatly outnumber weed species. Although exotic weeds are widespread (occupying 33% of sampling locations), their current distribution and frequency remain largely unchanged compared with 10 years ago. Possums and ungulates are also widespread in these areas (occupying 75–80% of sampling locations), but less abundant on the South Island and in forests where beech (*Nothofagus* spp.) is a major component. Although mammal pests are widespread in native forests in national parks, these areas have fewer weed species and lower abundance of possums (but not ungulates) relative to other conservation lands.

Species occupancy – are the species present the ones you would expect naturally? At a national scale, kāmahi, the highly palatable species that possums, deer and goats most prefer to eat, were regenerating 10 years ago across native forests on public conservation land and are continuing to regenerate now. Native forests are at least twice as rich in native bird species as they are in introduced bird species, regardless of whether beech (*Nothofagus* spp) is a substantial component of the forest or not. Of the 12 most widespread bird species, 10 are native and are found throughout more than 40% of native forests. Three species – grey warbler, tomtit, and bellbird – are found in more than 75% of native forests.

Ecosystem representation – are the full range of rare ecosystems protected in New Zealand? Naturally uncommon ecosystems have been included in national conservation policy and the recent application of the International Union For Conservation Of Nature's Ecosystem Red-List criteria to these ecosystems provides a rational basis for identifying which ecosystems are the most threatened, and so inform conservation priority setting. Eighteen critically endangered, 17 endangered and 10 vulnerable naturally uncommon ecosystem types were identified; 27 others are not endangered. A number of uncommon endangered ecosystems have less than 20% of their total area under formal protection.

GOAL 2 – MANAGEMENT EFFECTIVENESS

What is the status of introduced and native species where possums are being managed?

Control was defined as having occurred when at least one possum control operation was administered by either DOC or the Animal Health Board (AHB) within 500 m of a sampling location during a 4-year period (2008–2011), irrespective of the area, frequency, or type (ground vs aerial) of control implemented. This broad definition was used due to the small number of locations that met the criterion of "control".

In non-beech forest on public conservation lands, possum control appears effective in reducing possum abundance. In beech forest, possums and ungulates were less widespread where control occurred. There is no evidence that possum control had any effect on whether weeds invaded forests.

Bird communities in native forests (measured as the number, distribution or abundance of species) were similar irrespective of whether forests had been subject to possum control or not. However, the data indicate that there may be inconsistent trends among native bird species, suggesting that this nationwide sample is not yet adequate to detect whether their abundances differ according to whether or not possum control has been conducted.

The widespread common tree kāmahi is often a major component of possum diets, and is a useful indicator of browsing impacts in forests. There was no change in the average diameter of kāmahi trees on plots first measured in 2002 and most recently in 2012. This means the population of adult trees has generally persisted and those kāmahi trees that died have been replaced by younger stems that have grown in diameter.

GOAL 3 – EARLY-WARNING SYSTEM

Monitoring weeds – Although weeds were present on 33% of all forest plots, they were primarily abundant only on plots close to grasslands and settlements. Most widespread weeds are non-woody and shade intolerant, and therefore unlikely to complete with forest canopy species except at the seedling stage.

Mammal pest abundance – Abundances of deer were lower in the South Island, likely reflecting the history of sustained intensive commercial harvesting of red deer there since the 1970s. Possum control may have led to increased abundances of ungulates (deer and/or goats) in non-beech forests, possibly because commercial and recreational hunters avoid forests where toxins (e.g. 1080) have been applied. Relative to possums and ungulates, rabbits and hares are extremely uncommon in New Zealand forests and hence unlikely to have important impacts on biodiversity. However, these pests may still be important at forest margins and in upland forest patches.

Native birds – Most of New Zealand's bird research and monitoring effort to date has focused on rare and endangered species, particularly those in forest habitats. However, monitoring changes in widespread and common bird communities is also important, as these species may help maintain key ecosystem services and functions. The nationwide survey of native forests on public conservation land, estimated that there were at least five native bird species per location, with each location supporting, on average, three times as many native birds (9 species) as introduced ones (3 species).

Although introduced bird species are widespread in native forests, native birds are thus still dominant in this habitat.

GOAL 4 – PRIORITISATION FOR MANAGEMENT

Weeds – Current management priorities, of focusing attention on management of weeds close to forest margins (especially those close to grasslands) and on forests close to settlements, are soundly based. The national assessment of forests on public conservation land shows that some widespread, locally abundant weeds merit re-evaluation of their status as possible weeds of concern.

Palatable tree species and introduced mammals – Evidence of widespread regeneration and maintenance in the canopy of kāmahi, a tree that is palatable to possums and ungulates, contrasts with low levels of its regeneration in fenced exclosures throughout New Zealand. A priority for management will be to focus on where and why local forest areas, including those with exclosures, depart from the national trend. This investigation will be strengthened with more data nationally, and will be enhanced by evaluations of past management and disturbances to the forest canopy, and soil nutrient status, all of which are likely to influence both forest composition and the abundances of introduced mammals.

Managing multiple invasive species – There is no relationship between the faecal pellet indices for introduced ungulates (goats and deer) and trap catch indices for possums. There is also no relationship between the extent of mammal (possum and ungulate) invasions and invasions either by weeds or introduced birds. Therefore there is no reason to assume that optimising management to control one invader, or group of invaders, will necessarily lead to gains in all native components of ecosystems.

Threatened naturally uncommon ecosystems – Critically endangered and endangered ecosystems that are in 'stewardship' land might merit higher prioritisation for management. Management for critically endangered and endangered ecosystems on public conservation land could include mapping and biological inventories of these ecosystems (including collation of existing information), and determination of suitable methods for determining the status, trend, and threats within and among them.

INTRODUCTION

This technical report underpins the intermediate outcome 'the diversity of our natural heritage is maintained and restored' in the Department of Conservation's Annual Report for the year ended 30 June 2012. It reports on the status of biodiversity in New Zealand's public conservation lands, focusing mainly on native forests because an unbiased sample of data was only available for this land-cover class. A subset of ***indicators*** and ***measures*** from the ***Biodiversity Monitoring and Reporting System*** are used to report on the following three components of ecological integrity[1]:

- ***Indigenous dominance*** – are the ecological processes natural?
- ***Species occupancy*** – are the species present the ones you would expect naturally?
- ***Ecosystem representation*** – are the full range of rare ecosystems protected in New Zealand?

This report consists of four sections:

INDICATORS AND MEASURES – This outlines the ***indicators*** and their associated ***measures*** from the ***Biodiversity Monitoring and Reporting System***[1] used to assess the ecological integrity of New Zealand's public conservation lands.

INFORMATION SOURCES – Data and information were drawn from three primary sources: (1) an unbiased sample of locations within indigenous forests on public conservation land; (2) land tenure and management information; and (3) expert-driven threat listings of ecosystems. This section also provides detail on the methods used, citing the primary literature for existing sampling protocols.

APPROACH TO REPORTING – An overview of the approach undertaken for reporting is provided, justifying the reasons for any stratification of the data and analyses. As the ***Biodiversity Monitoring and Reporting System*** is in an early phase of implementation, the data and information currently available are limited, thus constraining interpretation of results. For example, this report focuses primarily on evaluating the ecological integrity of native forests on public conservation lands, as there was an unbiased sample of data for this land-cover class. In the future, DOC will be in a position to expand on the detail presented, when information collected from the 1311 possible sampling locations (Fig. 1) will allow further stratification and interpretation.

ANALYSES AND RESULTS – Detailed analyses and results are presented, to show how the ***indicators*** and ***measures*** contribute to the four goals of the ***Biodiversity Monitoring and Reporting System***. Results are presented within these goals: (1) National and regional reporting of status and trend in ecological integrity; (2) Evaluating the effectiveness of conservation management and policy; (3) Providing an early-warning system; and (4) Informing prioritisation for resource allocation on Conservation lands.

[1] Lee W, McGlone M, Wright E comps 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. 216 p.

INDICATORS AND MEASURES

DOC has developed a ***Biodiversity Monitoring and Reporting System*** to assess whether ***ecological integrity*** on public conservation lands is being maintained.[2] This system defines ***ecological integrity*** as the full potential of indigenous biotic and abiotic features, and natural processes, functioning in sustainable communities, habitats and landscapes.[2] ***Ecological integrity*** encompasses all levels and components of biodiversity, and can be assessed at multiple scales, up to and including the whole of New Zealand. More specifically, the ***Biodiversity Monitoring and Reporting System*** was designed to assess whether the following three components of ***ecological integrity*** are being maintained on public conservation lands:

- ***Indigenous dominance*** – the level of indigenous influence on the composition, structure, biomass, trophic and competitive interactions, mutualisms and nutrient cycling in a community.
- ***Species occupancy*** – the extent to which any species capable of living in a particular ecosystem is actually present at a relevant spatial scale.
- ***Ecosystem representation*** – the abiotic aspects of ecosystems. This measures the distribution of indigenous biota across environmental gradients derived from data layers based on climate, soils, and geology.

Each component of ***ecological integrity*** is assessed using a specified ***indicator*** and its associated ***measures*** (Table 1).

[2] Lee W, McGlone M, Wright E comps 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. 216 p.

Table 1: Summary of indicators and measures used to assess the three components of ecological integrity.

Ecological integrity			Information source
Component	Indicator	Measure	
Indigenous dominance	Indicator 2.2 Exotic weed and pest dominance	Measure 2.2.1 Distribution and abundance of exotic weeds and animal pests considered a threat – Weeds	An unbiased sample of *locations* (n = 328) within native forests on public conservation land
		Measure 2.2.1 Distribution and abundance of exotic weeds and animal pests considered a threat – Pests	An unbiased sample of locations ($n_{possums}$ = 69; $n_{ungulates}$ = 68; $n_{lagomorphs}$ = 68) within native forests on public conservation land[3]
Species occupancy	Indicator 5.1 Composition	Measure 5.1.1 Size-class structure of canopy dominants	An unbiased sample of locations (n = 327) within native forests on public conservation land
		Measure 5.1.2 Demography of widespread animal species – Birds	An unbiased sample of locations (n = 70) within native forests on public conservation land
		Measure 5.1.3 Representation of plant functional types	An unbiased sample of locations (n = 327) within indigenous forests on public conservation land
Ecosystem representation	Indicator 6.1 Environmental representation and protected status[4]	Measure 6.1.3 National change in extent and integrity of threatened naturally uncommon and significantly reduced habitats	Expert-driven assessment of threat listing considered for naturally uncommon ecosystem types (n = 72) across New Zealand
		Measure 6.1.4: Proportion of threatened naturally uncommon and significantly reduced habitats under protection	Threatened naturally uncommon ecosystems (n = 45) across New Zealand reviewed in the context of land tenure and management information

[3] Note that while surveys for lagomorph (rabbit *Oryctolagus cuniculus* and hare *Lepus europaeus*) pellets were carried out, these were not detected. Subsequently no data are presented for lagomorphs in this report.

[4] Note that additional information on the percentage of environmental unit under indigenous cover and protected (Measures 6.1.1 and 6.1.2) are provided in an accompanying report entitled by the Department of Conservation biodiversity indicators: 2012 assessment – supplementary material.

INFORMATION SOURCES

To assess whether the three components of ***ecological integrity*** are being maintained on public conservation lands, data and information were drawn from the three primary sources: (1) an unbiased sample of locations within native forests on public conservation land; (2) expert-driven threat listings of ecosystems; and (3) land tenure and management information. This section also provides detail on the methods used, citing the primary literature for existing sampling protocols.

Indigenous dominance and species occupancy

An unbiased sample of locations

Field surveys for the five ***measures*** used to assess the ***indigenous dominance*** and ***species occupancy*** components of ***ecological integrity*** are undertaken using a regular, unbiased sampling framework across New Zealand's public conservation land. This framework builds upon a national infrastructure established to measure carbon, vegetation structure and composition – the Land Use Carbon Accounting System[5] (LUCAS) network of vegetation plots in forests and shrublands (Fig. 1). The LUCAS network measures these attributes at regular sampling points on an 8 × 8 km grid superimposed upon areas designated as indigenous forests or shrublands in the Landcover Database (LCDB2). DOC's sampling framework extends the LUCAS grid to all public conservation land. There are 1311 possible sampling locations on public conservation land (covering the North, South and Stewart islands), with a common sampling framework used for all five ***measures*** (Fig. 2). Each sampling location is permanently marked and allows for repeated sampling at that location. Vegetation measurements are all made within a fixed 20 × 20 m plot. Data on mammal pests and common birds are collected within a much larger area (220 × 220 m), using a design that radiates out from the edges of the central vegetation plot (Fig. 2). Standardised field sampling protocols were used for both the vegetation[6,7] and animal[7,8] surveys.

In this report, vegetation changes were assessed using information collected from 328 sampling locations within native forests on conservation lands (Fig. 3; Table 1); these sampling locations were a unbiased sample of the permanent LUCAS vegetation plots overlapping native forests on conservation lands. The vegetation plots at each of the 328 sampling locations were first measured[9] in 2002–2003 and remeasured in 2009–2012. In 2012, a subset (n = 82) of these vegetation sampling locations was randomly selected for concurrent animal surveys. Difficult terrain or weather conditions prevented the field teams from completing a full set of animal-related measurements at some sampling locations, resulting in uneven sample sizes among the different ***measures*** (Table 1; Fig. 3). However, at least one bird or mammal-pest survey was undertaken at >82% of these locations. Note that while surveys for lagomorph (rabbit *Oryctolagus cuniculus* and hare *Lepus europaeus*) pellets were carried out, these were not detected. Subsequently no data are presented for lagomorphs in this report.

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[5] MfE 2005. Measuring carbon emissions from land-use change and forestry. The New Zealand Land-Use and Carbon Analysis System. http://www.mfe.govt.nz/publications/climate/carbon-emissions-land-use/measuring-carbon-emissions.pdf

[6] Payton IA, Newell CL, Beets P 2004. New Zealand carbon monitoring system indigenous forest and shrubland data collection manual. Prepared for the New Zealand Climate Change Office, Ministry for the Environment, Wellington, New Zealand. 68 p.

[7] Allen RB, Wright EF, MacLeod CJ, Bellingham PJ, Forsyth DM, Mason NWH, Gormley AM, Marburg AE, MacKenzie DI, McKay M 2009. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Landcare Research Contract Report LC0809/153.

[8] DOCDM-828397 Tier 1 monitoring (201112) MASTER protocol booklet.pdf

[9] All surveys were carried out over the austral summer where, for example, 2002 refers to the austral summer 2001/02.

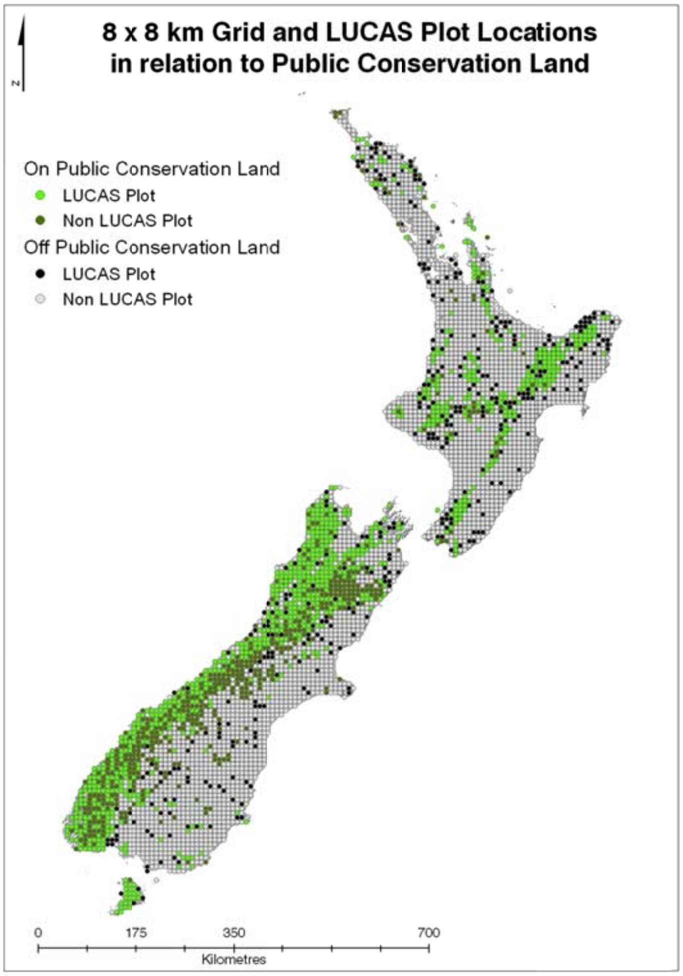

Fig. 1: The regular, unbiased sampling framework extends the 8 × 8 km LUCAS grid of vegetation plots in forests and shrublands to encompass all New Zealand's public conservation land.

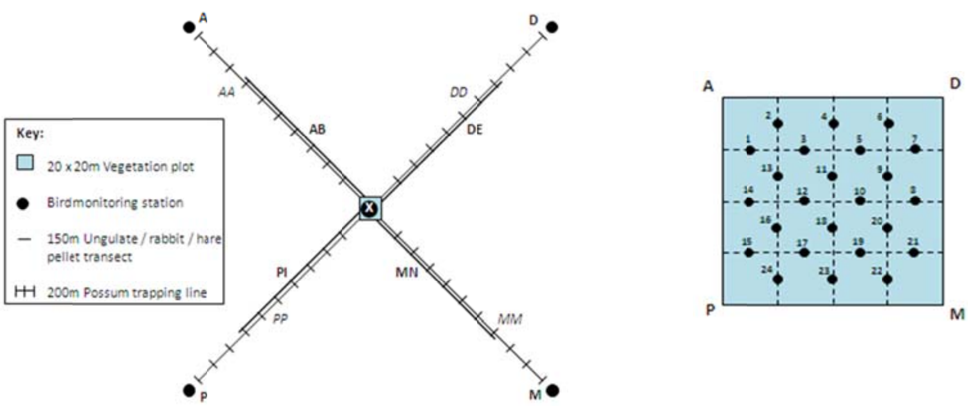

Fig. 2: Layout of the animal-survey sampling units in relation to the vegetation plot at each sampling location, along with an outline of the 20 × 20 m vegetation plot and each of the 24 (0.75 m^2) seedling subplots within it.

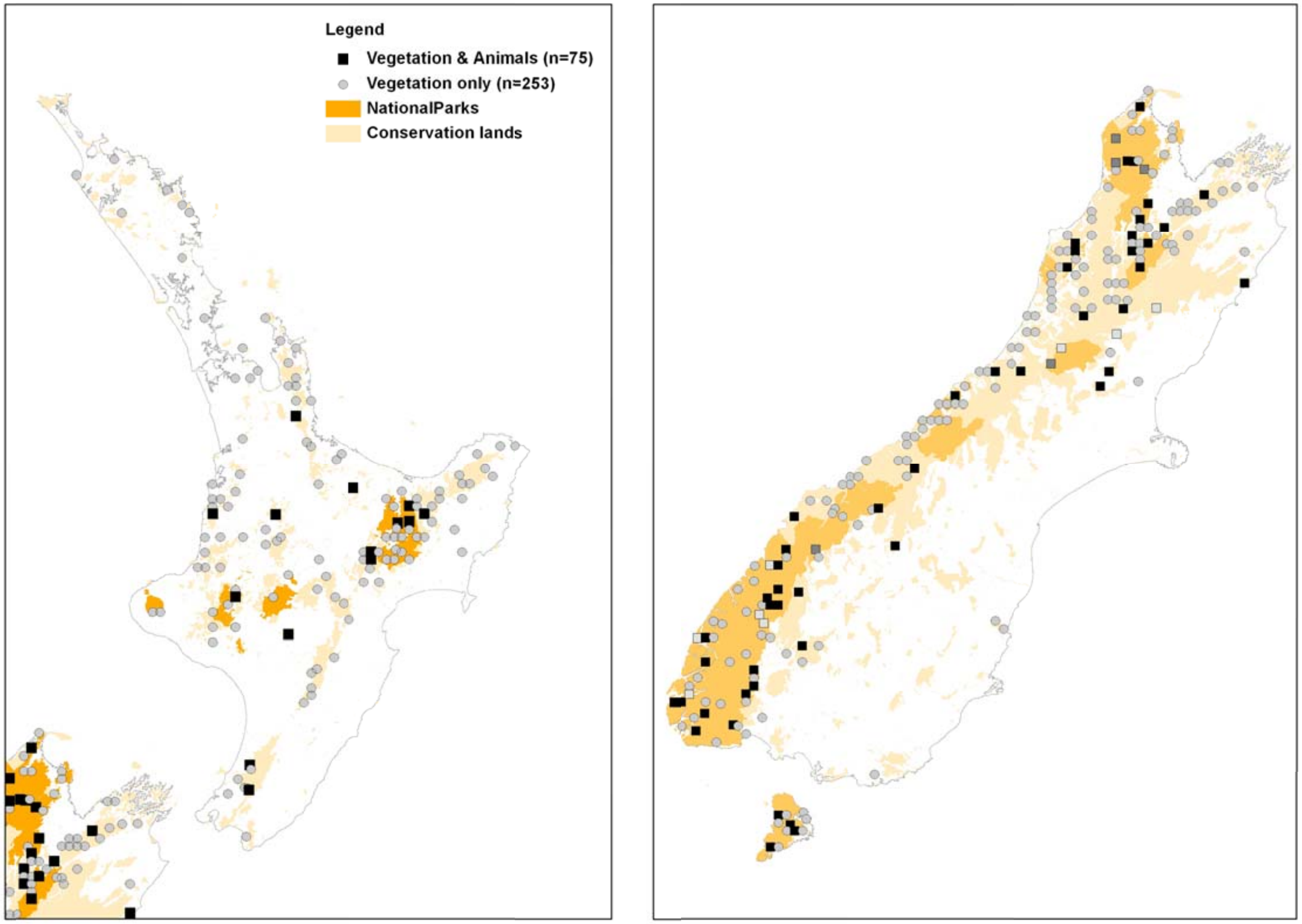

Fig. 3: Distribution of native-forest sampling locations (n = 328) on public conservation land in New Zealand in relation to the location of national parks.

Ecosystem representation

Expert-driven threat listing

Data are limited on the current distributions of New Zealand's naturally uncommon ecosystems[10] and their current rates of change in area and function. Therefore, this classification was based on declines over the past 500 and the last 50 years that are inferred or suspected by experts.[11] Where these were available, published sources were used to assess each threat criterion. In most cases, however, declines were identified through unpublished estimates of area, extent, and rates of decline. In these cases, group discussions among experts were used to estimate levels of decline.

To facilitate this process, a panel of seven experts[12] was convened for a one-day workshop and this was followed up by email queries to panel members and other recommended experts. Area of occupancy was determined either by summing the area of mapped polygons of each ecosystem type or by estimating total area occupied on a logarithmic scale (e.g., 100–1000 ha, 1000–10 000 ha) for those ecosystems that had not yet been mapped and then using the upper limit of this estimate to evaluate the relevant criterion.[11] The panel of experts used the set of specified indicators and thresholds (Table 1) and arrived at a general consensus on the relevance of each threat-assessment criterion.

A precautionary but realistic attitude toward uncertainty was taken.[13] The ecosystem was listed as threatened on the basis of what were considered realistic upper limits of inferred or suspected declines. Thus, a lack of quantitative data did not prevent assessment of the status of ecosystems for which sufficient qualitative knowledge existed to estimate current area and rates of decline.[14] Only one ecosystem (subterranean basalt fields) was considered truly 'data deficient' and excluded from subsequent analyses.

Land tenure and management

Concurrently, DOC and Landcare Research have been collaborating to map the current extent of each of the 72 naturally uncommon ecosystems: 15 maps are at a final draft stage; 12 of these represent threatened (i.e. critically endangered, endangered or vulnerable) ecosystems. Data on land tenure and management were obtained for those ecosystems for which GIS layers of current extent were available (N = 15 ecosystems) by overlaying existing layers of land tenure[15] to calculate the area of each ecosystem that occurred on public conservation land (stewardship land or other Conservation land) and privately owned land (Nga Whenua Rahui, QEII and other land use types).

[10] Williams PA, Wiser SK, Clarkson B, Stanley M 2007. New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. New Zealand Journal of Ecology 31: 119–128.

[11] Holdaway RJ, Wiser SK, Williams PA 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26: 619–629.

[12] Peter Williams, Susan Wiser, Sarah Richardson, Geoff Rogers, Bev Clarkson, Mark Smale and Robert Holdaway.

[13] IUCN (International Union for Conservation of Nature) 2010.Guidelines for using the IUCN Red List categories and criteria. Version 8.1. Gland, Switzerland, IUCN. Available from http://intranet.iucn.org/webfiles/doc/SSC/RedList/RedListGuidelines.pdf (accessed June 2011).

[14] Grantham HS, Wilson KA, Moilanen A, Rebelo T, Possingham HP 2009. Delaying conservation actions for improved knowledge: How long should we wait? Ecology Letters 12: 293–301.

[15] Data source was the National GeoDatabase hosted by Department of Conservation.

Table 2: Summary of criteria used to assess ecosystem status.[16] These were based on the International Union For Conservation Of Nature's Ecosystem Red-List criteria.[17]

	Class		
Criterion	Critically endangered	Endangered	Vulnerable
A1: Short-term[18] decline in distribution	≥ 80%	≥ 50%	≥ 30%
A2: Short-term[18] decline in ecological function[19]	Very severe decline throughout ≥ 80% of extant distribution	(a) Very severe decline throughout ≥ 50% of extant distribution, or (b) Severe decline throughout ≥ 80% of extant distribution	(a) Very severe decline throughout ≥ 30% of extant distribution, or (b) Severe decline throughout ≥ 50% of extant distribution, or (c) Moderately severe decline throughout ≥ 80% of extant distribution
B1: Historical[20] decline in area	≥ 90%	≥ 70%	≥ 50%
B2: Historical[20] decline in ecological function[19]	Very severe decline throughout ≥ 90% of extant distribution	Very severe decline throughout ≥ 70% of extant distribution	Very severe decline throughout ≥ 50% of extant distribution
C1: Small current distribution (extent of occurrence) and decline, or very few locations	Extent of occurrence ≤ 100 km^2 and at least one of the following: (a) continuing decline in distribution (b) continuing reduction in ecological function[21] (c) exists at only one location	Extent of occurrence ≤ 5000 km^2 and at least one of the following: (a) continuing decline in distribution (b) continuing reduction in ecological function[21] (c) exists at 5 or fewer locations	Extent of occurrence ≤ 20 000 km^2 and at least one of the following: (a) continuing decline in distribution (b) continuing reduction in ecological function[21] (c) exists at 10 or fewer locations
C2: Small current distribution (area of occupancy) and decline, or very few locations	Area of occupancy ≤ 10 km^2 and at least one of the following: (a) continuing decline in distribution (b) continuing reduction in ecological function (c) exists at only one location	Area of occupancy ≤ 500 km^2 and at least one of: (a) continuing decline in distribution (b) continuing reduction in ecological function (c) exists at 5 or fewer locations	Area of occupancy ≤ 2000 km^2 and at least one of the following: (a) continuing decline in distribution (b) continuing reduction in ecological function (c) exists at 10 or fewer locations
D: Very small current distribution (area of occupancy) and serious threats	Area of occupancy ≤ 5 km^2 and serious plausible threats[22]	Area of occupancy ≤ 50 km^2 and serious plausible threats[22]	Area of occupancy ≤ 100 km^2 and serious plausible threats[22]

[16] Holdaway RJ, Wiser SK, Williams PA 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26: 619–629.

[17] Rodriguez JP, Rodriguez-Clark KM, Baillie JEM, Ash N, Benson J, Boucher T, Brown C, Burgess ND, Collen B, Jennings M, Keith DA, Nicholson E, Revenga C, Reyers B, Rouget M, Smith T, Spalding M, Taber A, Walpole M, Zager I, Zamin T 2011. Establishing IUCN Red List Criteria for Threatened Ecosystems. Conservation Biology 25: 21–29.

[18] Short-term decline is over any 50-year period including the present.

[19] Declines in ecological function estimated with ecological integrity indicators.[16]

[20] Historical decline is estimated over previous 500 years.

[21] Continuing reduction in ecological function is defined as a moderately severe decline in one or more ecological integrity indicators over >30% of its extant distribution and ongoing increase in severity or extent of decline over the next 50 years.

[22] Serious plausible threats are those that, if current trends continued, have the potential to result in a decline in ecological function or distribution that would be sufficient to meet the vulnerable threshold of criterion A1 or A2 within the next 50 years.

APPROACH TO REPORTING

In this report, the ***ecosystem representation*** component of ***ecological integrity*** is assessed at the national scale, while the ***indigenous dominance*** and ***species occupancy*** components are evaluated for native forests on public conservation lands. As the ***Biodiversity Monitoring and Reporting System*** is currently in an early phase of implementation, the data and information currently available are limited, thus determining what results can be reported and the level of confidence for interpretation. For example, this report focuses primarily on evaluating the ecological integrity of native forests on public conservation lands, as there was an unbiased sample of data for this land-cover class. In the future, DOC will be in a position to expand on the detail presented, when information collected from the 1311 possible sampling locations (Fig. 1) will allow further stratification and interpretation.

Indigenous dominance and species occupancy

Why report nationally?

In this report, the ***indigenous dominance*** and ***species occupancy*** components of ***ecological integrity*** are evaluated nationally for native forests on New Zealand's public conservation lands. These measures are based on information collected from the North, South and Stewart Islands of New Zealand (Fig. 3).

DOC (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.[23] DOC also needs to know where heritage outcomes are being achieved and how management interventions can be used to improve outcomes. However, until recently, monitoring programmes implemented by DOC and its predecessors were inadequate for policy needs. Typically monitoring areas are selected in an uncoordinated way so data at a regional or national scale are not representative – areas where ***ecological integrity*** is under threat are likely over-represented, as are late-successional communities. The ad hoc nature of most past monitoring made it difficult for DOC to connect management decisions to monitoring results or to make robust statements about its progress in meeting its biodiversity conservation objectives.[23]

[23] Lee W, McGlone M, Wright E comps 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. 216 p.

Why focus on forests?

This report focuses primarily on assessing the ecological integrity of native forests on public conservation lands, because an unbiased sample of data was only available for this land-cover class. Evaluations of ***ecological integrity measures*** among ***forest classes***[24] were limited to comparisons between beech and non-beech forests, as there were only sufficient data to classify sampling locations according to these major vegetation elements.[25]

Native forests, however, are a logical focus for monitoring, as they cover 23% of the New Zealand landscape[26] (Fig. 4) and have been an important environment for the evolution of New Zealand biodiversity. Native forests are also the dominant ecosystem type (>60%) on public conservation lands[27] and were the natural vegetation for >85% of New Zealand[28] at human settlement. Beech forests – those with a large proportion of one or more *Nothofagus* species – are the most abundant type of native forest (68% of remaining native forests[26]). They are much more common in the South Island (84% of forests) than in the North Island[26] (40%) because beech is predominant, although not exclusively so, in areas where climates are both cool and moist. Beech forests are structurally and functionally different from non-beech forests or those in which beech is a minor component[29]. They are often structurally simpler and often have fewer species of vascular plants[26]. Co-occurring tree species, which often dominate where beech is rare or absent, are often reduced to a minor role where beech dominates (e.g. kāmahi, rātā). Beeches are small-leaved so that more light reaches the forest floor than in many non-beech forests. In contrast with many non-beech species, beeches acquire nutrients through ectomycorrhizal fungi. As a result, soil processes in beech forests, including soil structure, nutrient cycling, decomposition and microbial communities,[30] also differ and may drive substantial differences in our indicators between beech and non-beech forest types – hence we distinguish these two ***forest classes*** in our report.

[24] ***Forest class*** is a derived variable and is defined on page 24.

[25] Wiser SK, Hurst JM, Wright EF, Allen RB 2011. New Zealand's forest and shrubland communities: a quantitative classification based on a nationally representative plot network. Applied Vegetation Science 14: 506–523.

[26] Wardle 1984.The New Zealand beeches. Christchurch, New Zealand Forest Service.

[27] Data source: LCDB3 (data provided by the Department of Conservation)

[28] McGlone MS 1989. The Polynesian settlement of New Zealand in relation to environmental and biotic changes. New Zealand Journal of Ecology 12: 115–129.

[29] McGlone MS, Mildenhall DC, Pole MS 1996. History and palaeoecology of New Zealand *Nothofagus* forests. In: Veblen TT, Hill RS, Read J eds The ecology and biogeography of *Nothofagus* forests. Yale University Press. Pp. 83–130.

[30] Orwin KH, Kirschbaum MUF, St John MG, Dickie IA 2011. Organic nutrient uptake by mycorrhizal fungi enhances ecosystem carbon storage: a model-based assessment. Ecology Letters 14: 493–502.

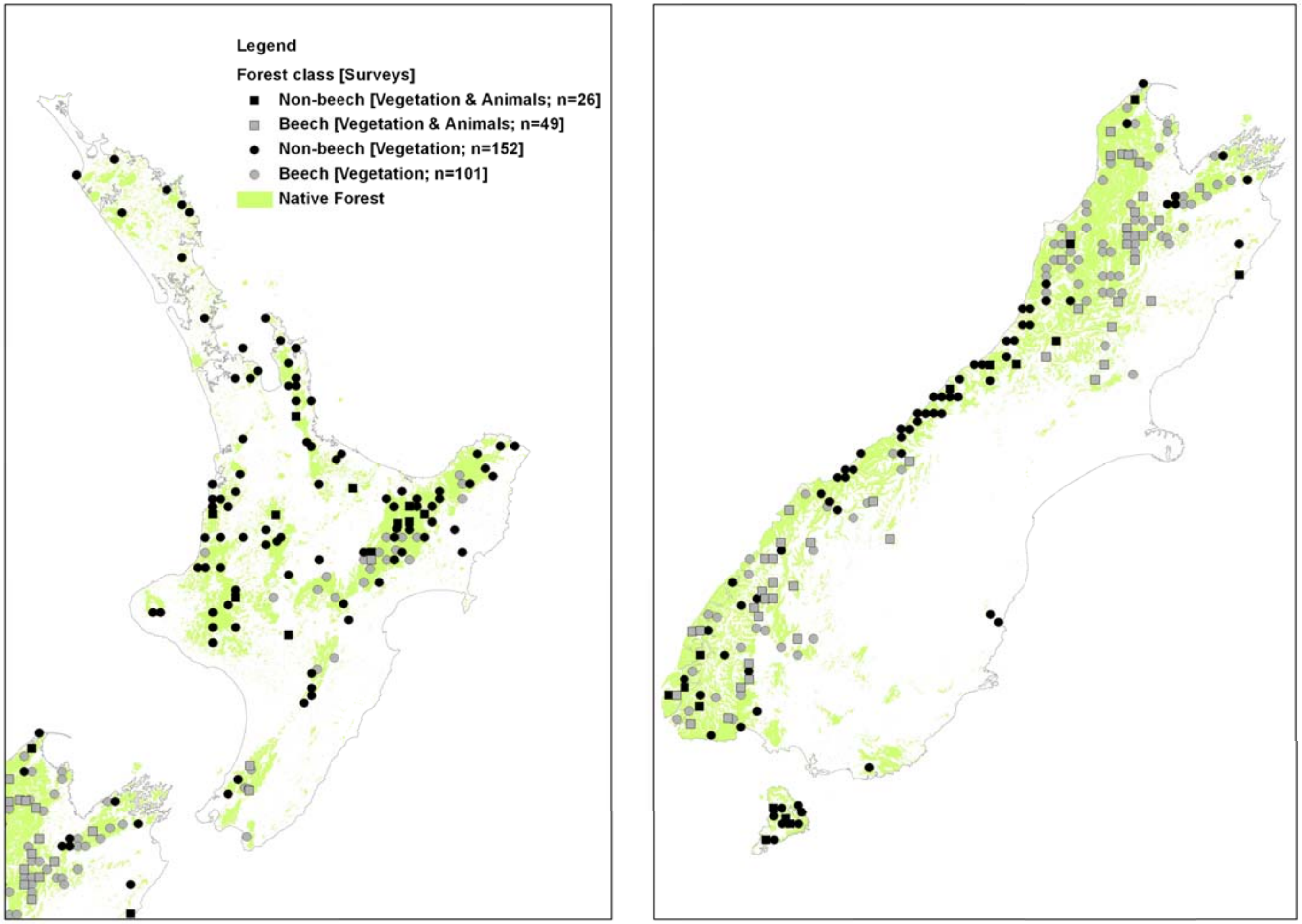

Fig. 4: Distribution of sampling locations (n = 328) on New Zealand's public conservation lands in relation to *forest class*[31] (beech vs non beech) and surveys implemented. The native forest distribution shown in this map is based on the 'Indigenous Forest' land cover class in the Landcover Database (LCDB2).

[31] ***Forest class*** is a derived variable and is defined on page 24.

Why focus on national parks?

An assessment of the impacts of national park management on ***indigenous dominance*** and ***species occupancy measures*** was feasible because the extent of native forests on public conservation lands occurring within and outside national parks is similar (i.e. a comparable number of locations were sampled within these two types of protected areas). While the comparisons do not explicitly link ***ecological integrity*** differences to specific management actions, they do indicate whether national parks benefit biodiversity.

National parks worldwide provide for the long-term protection of large natural or near-natural areas, their biodiversity, underlying ecological structure and supporting ecological processes and ecosystem services, and thereby create opportunities for education and recreation[32]. As a signatory to the Convention on Biological Diversity, New Zealand is required to meet and report on the standards applied by the IUCN for the planning, establishment and management of protected areas, such as national parks. The National Parks Act 1980 provides the basis for managing national parks in New Zealand and the highest level of legal protection of the environment compared with much of the other public conservation land. Currently, DOC administers one-third of New Zealand's land area, including 14 national parks that cover a total land area of 3.116 million hectares (Fig. 3). Of the 5 million hectares of native forest on public conservation land, c. 40% is contained within national parks and 60% in other conservation land. The national parks provide extensive areas of forest, unique habitats and ecosystems and are places where emphasis is given to the preservation of New Zealand's unique flora and fauna.

Why focus on possum control?

This report investigates whether ***ecological integrity measures*** vary between sampling locations with and without possum control. Possum control was selected because this management action is widely implemented in native forests on public conservation lands. It is also predicted to impact both the ***indigenous dominance*** and ***species occupancy measures*** considered in this report.

Possum control is used throughout New Zealand (e.g. Fig. 5) for reasons that include relieving predation pressure on native birds, reducing herbivory on native flora, and suppressing possum populations to low densities in order to eliminate bovine TB. Possum control consists of a variety of methods from trapping in open and/or developed habitats to aerial 1080 poisoning in dense forested habitats. However, there is also an ongoing debate about the effect of possum control on bird communities in forests on public conservation land.[33,34]

Possum control using aerially dropped 1080 has repeatedly been demonstrated to be effective at reducing possum populations to low levels, as well as those of ship rats (*Rattus rattus*) and stoats (*Mustela erminea*) – potentially resulting in numerous conservation benefits.[35] Recently, it has been demonstrated that sustained control can reduce mortality of possum-preferred tree species.[36] There can, however, be negative effects of control on birds,[37] whether by direct poisoning via consumption

[32] Dudley N, ed 2008. Guidelines for Applying Protected Area Management Categories. Gland, Switzerland: IUCN. x + 86pp.
[33] Green W 2004 The use of 1080 for pest control: a discussion document. Animal Health Board and Department of Conservation.
[34] Parliamentary Commissioner for the Environment 2011. Evaluating the use of 1080: Predators, poisons and silent forests. Parliamentary Commissioner for the Environment, Wellington.
[35] Nugent G, Warburton B, Thompson CC, Sweetapple PJ, Ruscoe WA 2011. Effect of prefeeding, sowing rate and sowing pattern on efficacy of aerial 1080 poisoning of small-mammal pests in New Zealand. Wildlife Research 38: 249–259.
[36] Gormley AM, Holland EP, Pech RP, Thomson C, Reddiex B In press. Conservation benefits from extensive control of an invasive herbivore. Journal of Applied Ecology
[37] Veltman C, Westbrooke I 2011. Forest bird mortality and baiting practices in New Zealand aerial 1080 operations from 1986 to 2009. New Zealand Journal Ecology 35: 21–29.

of 1080 baits or suggested secondary poisoning via consumption of arthropods.[38] It is therefore important to compare differences in the status of indicators (possums, ungulates, birds, palatable plants and exotic weeds) at sampling locations with and without possum control to assess the overall effectiveness and benefits of possum management.

Ecosystem representation

Why report nationally?

In this report, the IUCN's Ecosystem Red-List criteria[39] were used to provide a nationwide ecosystem threat assessment of New Zealand's naturally uncommon ecosystems. Naturally uncommon ecosystems, such as basaltic outcrops and coastal turfs, frequently occur outside existing public conservation areas[40] and represent a distinct set of environmental conditions often associated with rare and threatened endemic species.[42] Although naturally uncommon ecosystems have been included in national conservation policy,[41] agencies need to know which are the ecosystems most threatened with elimination in order to inform conservation priority setting.

New Zealand's naturally uncommon ecosystems are defined[42] as those that before human colonisation (approximately AD 1280)[43] had an estimated maximum total area of <0.5% of New Zealand's land area (268 680 km^2) (i.e. <134 000 ha) and have been classified as such by experts on the basis of their physical and physiognomic characteristics.[42] Although one-third of New Zealand's land area is legally protected, there is a strong bioclimatic bias in the distribution of reserves toward montane and alpine regions, whereas many lowland ecosystems are facing ongoing and increasing threats from agricultural intensification, conversion to plantation forestry, mining, urban development, and invasive non-native species.[44]

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[38] Lloyd B, McQueen S 2000. An assessment of the probability of secondary poisoning of forest insectivores following an aerial 1080 possum control operation. New Zealand Journal of Ecology 24: 47–56.

[39] Rodriguez et al. 2011. Establishing IUCN Red List criteria for threatened ecosystems. Conservation Biology 25: 21–29.

[40] Wiser SK, Buxton RP 2008. Context matters: matrix vegetation influences native and exotic species composition on habitat islands. Ecology 89: 380–391.
Rogers G M, Wiser SK 2010. Environment, composition and conservation of coastal turfs of mainland New Zealand. New Zealand Journal of Botany 48: 1–14.

[41] MfE & DOC 2007b. Protecting our places: information about the statement of national priorities for protecting rare and threatened biodiversity on private land. Wellington, Ministry for the Environment and Department of Conservation.

[42] Williams PA, Wiser SK, Clarkson B, Stanley M 2007. New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. New Zealand Journal of Ecology 31: 119–128.

[43] Wilmshurst JM, Anderson AJ, Higham TFG, Worthy TH 2008. Dating the late prehistoric dispersal of Polynesians to New Zealand using the commensal Pacific rat. Proceedings of the National Academy of Sciences (USA) 105: 7676–7680.

[44] Allen RB, Lee WG, eds 2006. Biological invasions in New Zealand. Berlin, Springer.
Walker S, Price R, Rutledge D, Stephens RTT, Lee WG 2006. Recent loss of indigenous cover in New Zealand. New Zealand Journal of Ecology 30: 169–177.

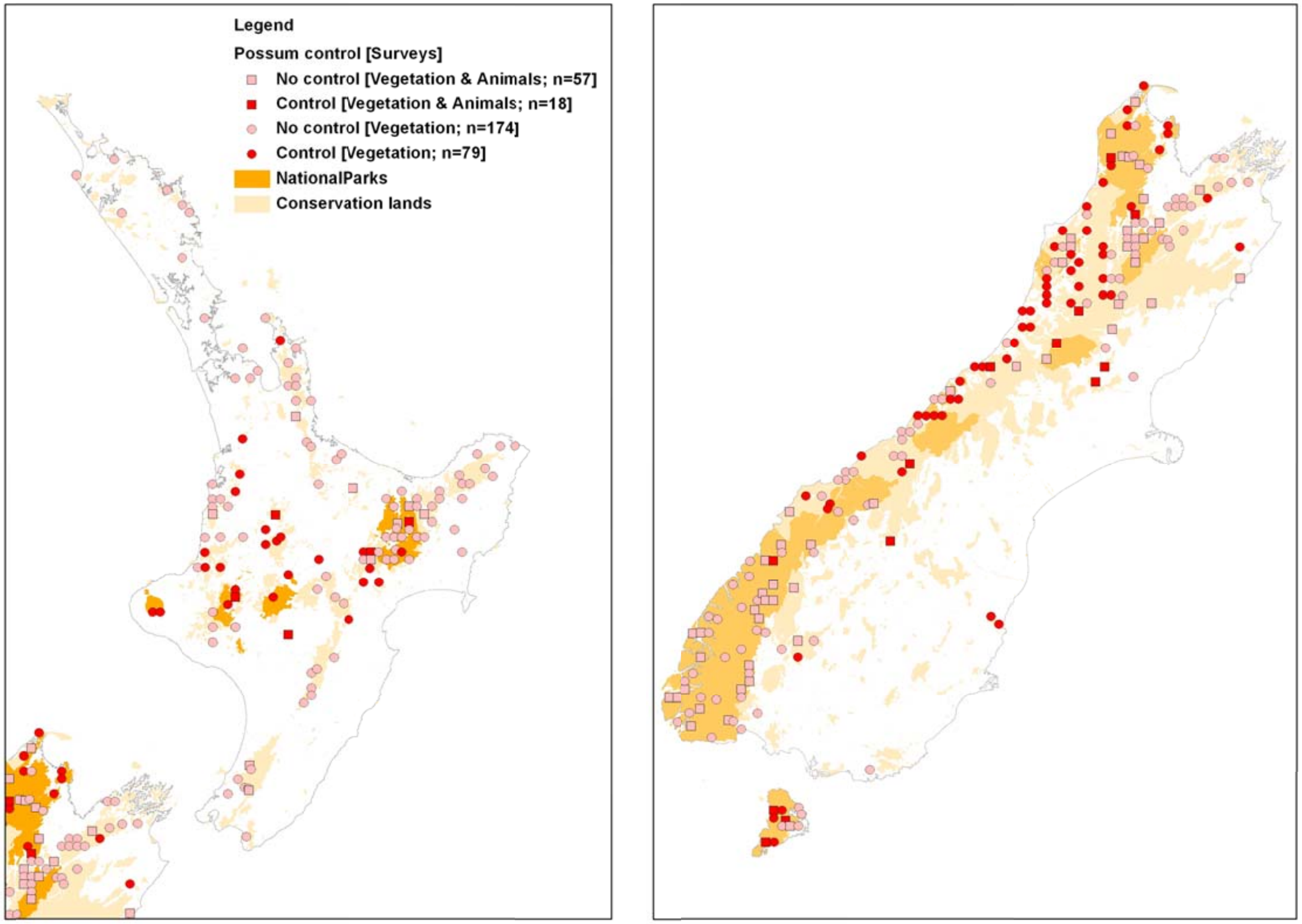

Fig. 5: Distribution of sampling locations (n = 328) on conservation lands in relation to *possum control*[45] and surveys implemented.

[45] ***Possum control*** is a derived variable and is defined on page 43.

ANALYSES AND RESULTS

The ***Biodiversity Monitoring and Reporting System*** was designed to address DOC's following four management goals: (1) National and regional reporting of status and trend in ecological integrity; (2) Evaluating the effectiveness of conservation management and policy; (3) Providing an early-warning system; and (4) Informing prioritisation for resource allocation on Conservation lands. This section draws on information from each of the ***Biodiversity Monitoring and Reporting System's measures*** to help inform these four management goals (Table 1).

The underpinning material for each ***measure*** is presented briefly for general readership. Referencing is provided to source material. Two or three ***measures*** are reported for each component of ***ecological integrity*** (Table 1).

For the first two management goals, the material for each measure is presented using the following structure:

- **MEASURE:** Specifies which ***Biodiversity Monitoring and Reporting System measure*** was used to assess ***ecological integrity***.
- **DEFINITION:** Specifies what metrics are used to quantify the ***measure***.
- **METHODS:** Outlines how, when, and where the data were collected. It then describes the data processing and analysis approaches used. Derived variables used to inform the analysis are highlighted (bold italics) and defined (footnotes provide links to the definitions).
- **RESULTS:** Explains the key results presented in accompanying figure(s) or table(s).
- **INTERPRETATION AND IMPLICATIONS**: Discusses the significance of the results in a wider ecological and management context.

Goal 1: Status and trend

Introduction

This section reports on the following three components of ***ecological integrity*** (Table 1):

- ***Indigenous dominance*** – are the ecological processes natural?
- ***Species occupancy*** – are the species present the ones you would expect naturally?
- ***Ecosystem representation*** – are the full range of rare ecosystems protected in New Zealand?

As the ***Biodiversity Monitoring and Reporting System*** is currently in an early phase of implementation, the data and information currently available are limited, thus determining what results can be reported. For example, it is not currently feasible to report on trends for the ***measures*** considered in this report (as only one or two surveys have been undertaken), but it is possible to report on their current status and, where remeasurements have occurred, whether there has been any change in status since the initial survey. This report, therefore, provides important baseline information for measuring future change when a longer time-series of data is available.

To inform the analyses presented in this section, the following variables were derived:

Weeds**:** Plant species were classified as exotic in accordance with the National Vegetation Survey Databank version May 2012. While it is recognised that not all exotic species are necessarily environmental weeds, all exotic species are categorised as weeds in this report.

Weeds of concern**:** From DOC's list of environmental weeds,[46] 47 species that are 'of concern' to DOC have been selected using expert opinion. These species were chosen, because they represent a range of life forms, likely climatic envelopes, stages of invasion and habitat specialists and generalists[47] that are found on conservation land.

Distance to nearest grassland, settlement and road**:**[48] These variables were calculated from each forest sampling location using GIS spatial information from the Landcover Database (LCDB2) and the Topographic TOPO50 series. A settlement was defined using information derived from the Topographic TOPO50 series feature Geoname (where description code field was limited[49] to 'TOWN', 'METR', 'USAT', or 'POPL'). These variables were used as surrogate measures of anthropogenic pressures as they relate to changing disturbance regimes, land management practices, land use history and propagule pressure, all of which are known to impact to varying degrees on weed species distributions and community composition.

Forest classes**:** Each sampling location was classified as 'beech' or 'non-beech' forest, using LUCAS data collected in 2012. In beech forest plots, the cumulative cover of *Nothofagus* spp. was at least 25% of the vegetation plot area.[50]

National Parks**:**[48] Each sampling location was classified according to whether it was in a national park or other public conservation land.

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[46] Howell C 2008. Consolidated list of environmental weeds in New Zealand. DOC Research & Development Series 292. Department of Conservation, Wellington

[47] Allen RB, Wright EF, MacLeod CJ, Bellingham PJ, Forsyth DM, Mason NWH, Gormley AM, Marburg AE, MacKenzie DI, McKay M 2009. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Landcare Research Contract Report LC0809/153.

[48] Data provided by the Department of Conservation.

[49] Description code fields ('TOWN', 'METR', 'USAT', or 'POPL') are all defined on this website:http://apps.linz.govt.nz/topo-data-dictionary/index.aspx?page=class-geographic_name

[50] Wiser SK, Hurst JM, Wright EF, Allen RB 2011. New Zealand's forest and shrubland communities: a quantitative classification based on a nationally representative plot network. Applied Vegetation Science 14: 506–523.

Indigenous dominance – are the ecological processes natural?

MEASURE 2.2.1: Distribution and abundance of exotic weeds and pests considered a threat – Weeds

DEFINITION: This ***measure*** assesses the status of exotic vascular plant species on New Zealand's public conservation land at the national scale. It quantifies the percentage of vascular plant species in forests that are exotic, as a measure of exotic invasion. It also measures the number of exotic vascular plant taxa, their frequency of occurrence, and abundance nationally to determine whether distance to nearest grassland, settlement and road influence their distribution. Previous studies of weed invasions of New Zealand forests have shown that the extent of invasion can be positively correlated with these factors.[51,52,53,54] In particular, it considers changes in the distributions of 47 selected species classified as ***weeds of concern***[55] by DOC.[56]

METHODS: Changes in the distribution and abundance of weeds over the past decade were investigated for 328 native forest plots located on a national 8-km grid (Fig. 3). Plots were initially measured[57] in 2002–2003 and remeasured in 2009–2012. Relevé (Recce) measurements were used to describe the composition and structure of vegetation, including all plant species present and their percentage cover estimate within given height tiers. Paired *t*-tests were used to evaluate changes in the number and frequency of occurrence of weed species and their percentage relative to native species. Weed abundance was measured as the number of seedling subplots per plot in which a given species was recorded (Fig. 2). Seedling subplots allow for a more detailed quantitative assessment of changes in weed abundance than could not be achieved on the plot scale. A general linear model was fitted (with Poisson error distribution) to test for changes in abundance between measurements. To compare the status of weed communities within ***National Parks***[55] relative to those on other public conservation land (Fig. 3), the mean percentage and number of weeds within plots were calculated. To determine whether ***distances to nearest grassland, settlement and road***[55] were significant predictors of weed community composition, a multiple regression model was fitted.

RESULTS: Native plant species greatly outnumber the number of weed species present in native forests on public conservation land (on average about 26 native species to every weed). Although weeds are widespread throughout the forests – a third of plots measured had weeds present – they primarily occur at low frequency, on average 3% per plot (Fig. 6). The number (t_{328} = 1.58, P = 0.11) and abundance (t_{327} = 1.79, P = 0.075) of weed species did not change between measurements (Table 3). Of the 47 species considered ***weeds of concern***, 20 were recorded in the plots, but only 15 in the seedling subplots where their abundance remained largely unchanged between measurements (Fig. 7). Interestingly, several species were more abundant than species considered ***weeds of concern***. Overall weed abundance differed significantly among weed species (d.f. = 128, P < 0.001), between measurements (d.f. = 1, P < 0.01) and for both factors combined (d.f. = 128, P < 0.001). Native forests in ***National Parks*** have on average fewer weed species present (c. 1 species) than forests on other types of public conservation land (4 species) (Fig. 8). Plots closer to a grassland or settlement had a higher percentage and number of weeds than plots further away (Fig. 9). ***Distance to grassland and settlement*** explained 12% of the difference in the percentage of weed

[51] Wiser SK, Allen RB, Clinton PW, Platt KH 1998. Community structure and forest invasion by an exotic herb over 23 years. Ecology 79: 2071–2081.
[52] Sullivan JJ, Timmins SM, Williams PA 2005. Movement of exotic plants into coastal native forests from gardens in northern New Zealand. New Zealand Journal of Ecology 29: 1–10.
[53] Wiser SK, Buxton RP 2008. Context matters: matrix vegetation influences native and exotic species composition on habitat islands. Ecology 89: 380–391.
[54] Sullivan JJ, Williams PA, Timmins SM, Smale MC 2009. Distribution and spread of environmental weeds along New Zealand roadsides. New Zealand Journal of Ecology 33: 190–204.
[55] Variables in bold italics are defined on page 24.
[56] Allen RB, Wright EF, MacLeod CJ, Bellingham PJ, Forsyth DM, Mason NWH, Gormley AM, Marburg AE, MacKenzie DI, McKay M 2009. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Landcare Research Contract Report LC0809/153.
[57] All surveys were undertaken in the austral summer, for example 2002 encompasses the austral summer 2001/02.

species in forest plots and 13% of the difference in the number of weed species. Both values are significant ($P < 0.01$).

INTERPRETATION AND IMPLICATIONS: Native species dominate the forests across the DOC estate. Weeds occur in low abundance and are not pervasive in New Zealand forests. Serious long-term changes in weed abundance and distribution are difficult to detect and predict. Nevertheless, well-known and persistent weed species, such as *Ulex europaeus, Pseudotsuga menziesii* and *Hedychium gardnerianum,* should be treated with caution and carefully watched, because they can transform ecosystems and displace uncommon plants or specialised plant communities.[58,59] ***Weeds of concern*** to DOC and those that may become a problem should be carefully monitored, especially in public conservation areas that are more vulnerable to weed invasion, such as outside ***National Parks***, around forest edges, and in close proximity to settlements.

Table 3: Summary of number and frequency of weed species in 328 forest plots. Mean values are given with 95% confidence intervals. There was no significant difference in either the number of weed species or native species between measurements.

	2002–2003 measurement	2009–2012 measurement
No. of native species	704	731
No. of weed species	122	127
Percentage of plots with weeds (%)	40.5	32.6
Mean no. of weed species per plot	1.7 (± 0.5)	1.5 (± 0.4)
Mean percentage of weeds per plot	3.4 (± 0.9)	3.1 (± 0.9)

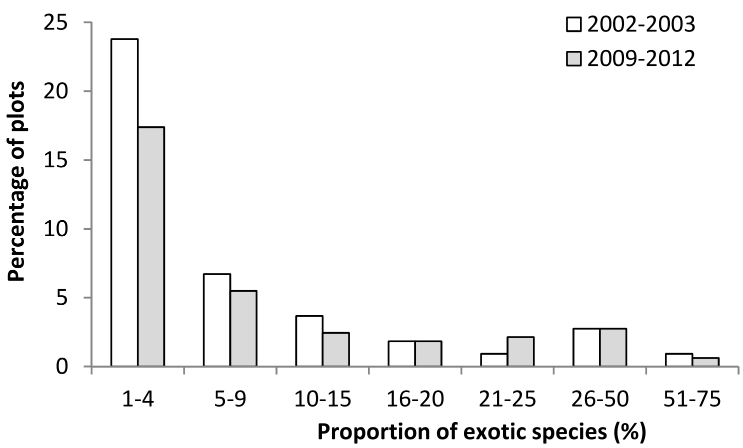

Fig. 6: Changes in frequency of exotic species in 328 forest plots.

[58] Williams PA, Winks C, Rijkse W 2003. Forest processes in the presence of wild ginger (*Hedychium gardnerianum*). New Zealand Journal of Ecology 27: 45–54.

[59] Sullivan JJ, Williams PA, Timmins SM 2007. Secondary forest succession differs through naturalised gorse and native kanuka near Wellington and Nelson. New Zealand Journal of Ecology 31: 22–38.

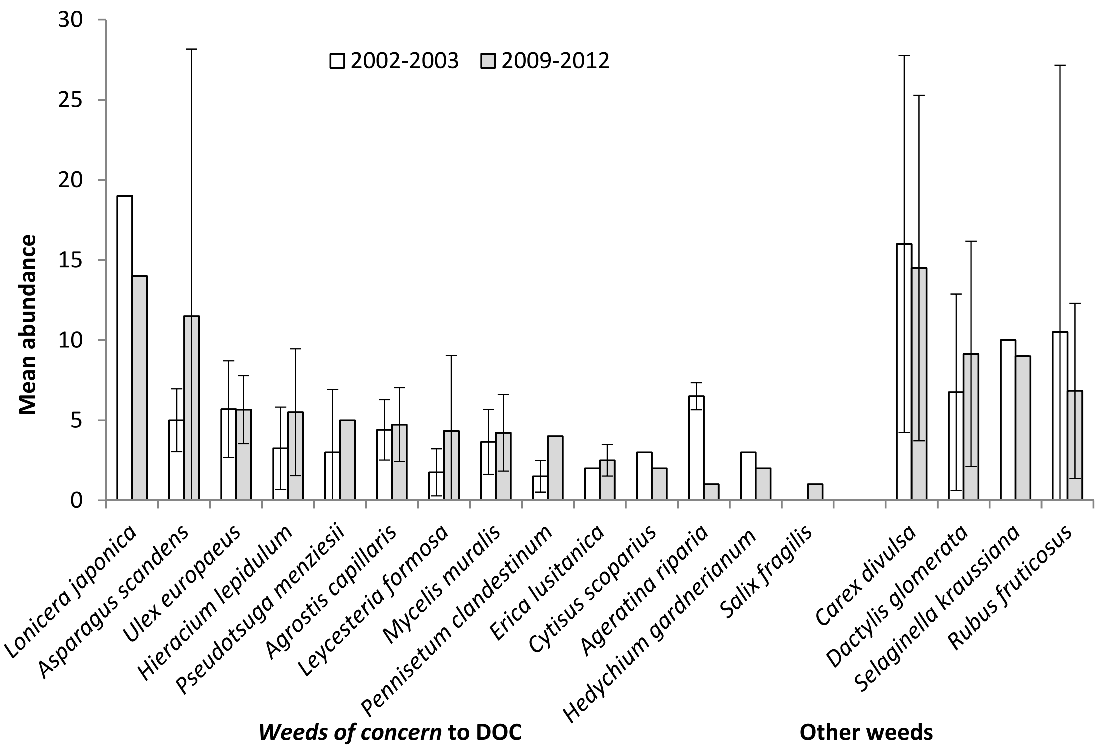

Fig. 7: Changes in mean abundance of selected weed species with 95% confidence intervals. Absent confidence intervals indicate species that were only found in one plot.

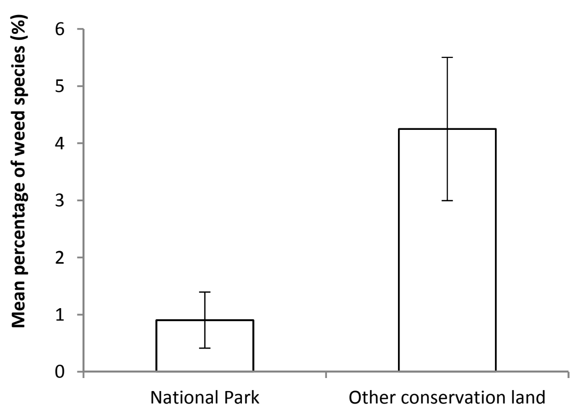

Fig. 8: Average percentage of weeds (with 95% confidence intervals) in forest plots located in *National Parks* (n = 108) versus other public conservation land (n = 220).

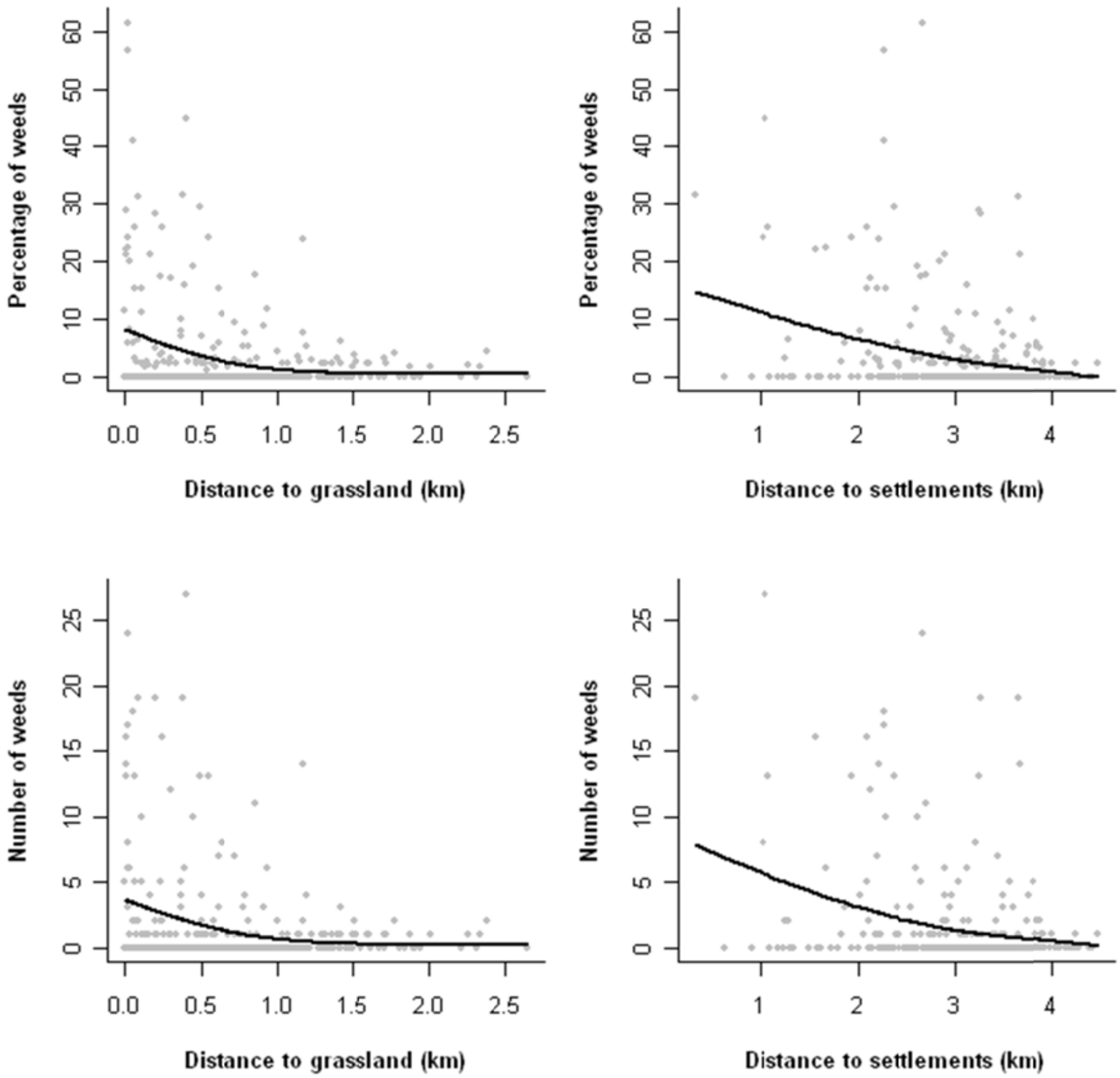

Fig. 9: Differences in weed percentage and abundance in relation to *distance of nearest grassland and settlement* (n = 328). Distances were log transformed.

MEASURE 2.2.1: Distribution and abundance of exotic weeds and pests considered a threat – Ungulate pests

DEFINITION: This ***measure*** assesses the distribution and abundance of wild ungulates (feral goats *Capra hircus*; and seven deer taxa Family Cervidae) on New Zealand's public conservation land at a national scale. It measures occupancy (proportion of sampling locations occupied) and relative abundances[60] of ungulates.

METHODS: Ungulate occupancy and relative abundances were evaluated at 68 forest sampling locations on a national 8-km grid overlapping public conservation lands. Field surveys were carried out in 2012.[61] Four 150-m transects were set up in a cruciform shape at each sampling location (Fig. 2) and the number of intact faecal pellets in circular plots of 1-m radius spaced at 5-m intervals (i.e. 30 plots per transect) were counted.[62,63] The total number of pellets along each transect (termed the Faecal Pellet Index; FPI) has been shown to be linearly and positively related to known abundance of deer.[64] The ungulate species thought to be present at each sampling location, conditional on pellets being detected, were determined through the expert opinions of local DOC staff. The data were analysed to account for imperfect detection (joint occupancy–abundance model[65]).

RESULTS: Wild ungulates (deer and goats) occurred in three-quarters of New Zealand forest sampling locations, with a mean occupancy of 0.75 (95CI[66] = 0.63–0.84), and a relative abundance (FPI) of 53.9 (95CI = 39.6–72.3). Occupancy and relative abundances were higher on Stewart Island (occupancy = 1.0; FPI = 106.0) and the North Island (occupancy = 0.93, FPI = 99.2) than the South Island (occupancy = 0.66; FPI = 34.8). Occupancy was similar in beech and non-beech forests (c. 0.75)[67], but relative abundances in non-beech (FPI = 78)[68] were almost double that in beech (FPI = 42) (Fig. 10). There was no difference in occupancy and relative abundances of ungulates in forests within ***National Parks*** and in other public conservation land (Fig. 11), and there was no linear relationship in relative abundances with elevation or latitude. The mean FPI at sampling locations where feral goats and deer are believed present (FPI = 18.6) is much lower than where only deer are believed present (FPI = 68.3). Sampling locations with only red deer (*Cervus elaphus scoticus*) present had moderate relative abundances (FPI = 61.0).Sampling locations with white-tailed deer (*Odocoileus virginianus borealis*) present had the highest relative abundances (FPI = 89.7; although there were only four sampling locations – all on Stewart Island).

INTERPRETATION AND IMPLICATIONS: These measures confirm that although ungulates are commonly present in New Zealand forests, they are mostly present at low abundances relative to the high abundances observed in the 1950s–1970s.[69,70] It should be noted that previous estimates are derived from a range of different methods and do not necessarily provide unbiased or comparable estimates. The mostly low abundance of ungulates at forest sampling locations is likely due to the sustained effects of commercial and recreation hunters, and DOC control operations. The highest

[60] A relative abundance estimate is expressed in a unit that is known or assumed to be positively related to the (unknown) true abundance (cf. absolute abundance or density).

[61] 2012 encompasses the austral summer 2011/12.

[62] Forsyth DM 2005. Protocol for estimating changes in the relative abundance of deer in New Zealand forests using the Faecal Pellet Index (FPI). Landcare Research Contract Report LC0506/027.

[63] Allen RB, Wright EF, MacLeod CJ, Bellingham PJ, Forsyth DM, Mason NWH, Gormley AM, Marburg AE, MacKenzie DI, McKay M 2009. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Landcare Research Contract Report LC0809/153.

[64] Forsyth DM, Barker RJ, Morriss G, Scroggie MP 2007. Modeling the relationship between fecal pellet indices and deer density. Journal of Wildlife Management 71: 964–970.

[65] Wenger SJ, Freeman MC 2008. Estimating species occurrence, abundance, and detection probability using zero-inflated distributions. Ecology 89: 2953–2959.

[66] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

[67] Probability of higher occupancy in non-beech = 0.59.

[68] Probability of higher abundance in non-beech > 0.99

[69] King CM ed. 2005. Handbook of New Zealand mammals. 2nd edn. Oxford University Press.

[70] Forsyth DM, Thomson C, Hartley LJ, MacKenzie DI, Price R, Wright EF, Mortimer JAJ, Nugent G, Wilson L, Livingstone P 2011. Long-term changes in the relative abundances of introduced deer in New Zealand estimated from faecal pellet frequencies. New Zealand Journal of Zoology 38: 237–249.

deer abundances were observed in forests on the North and Stewart islands, and are 'something to watch' at this stage. The unbiased estimates of ungulate occupancy and relative abundance provide important baseline information for comparing against future assessments and different management interventions. In particular, sustained changes to the commercial, recreational and DOC harvests would be expected to alter the occupancy and abundance of ungulates in forest and impacts on biodiversity.

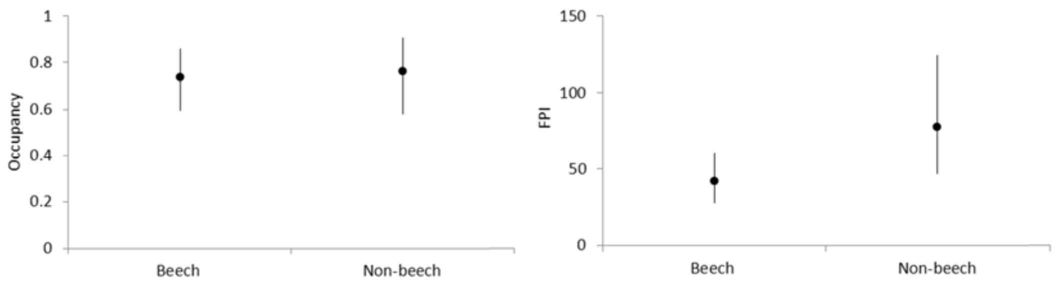

Fig. 10: Mean (±95CIs[71]) occupancy (left) and relative abundance (right) of ungulates by *forest class* (number of sampling locations: beech = 43; non-beech = 25).

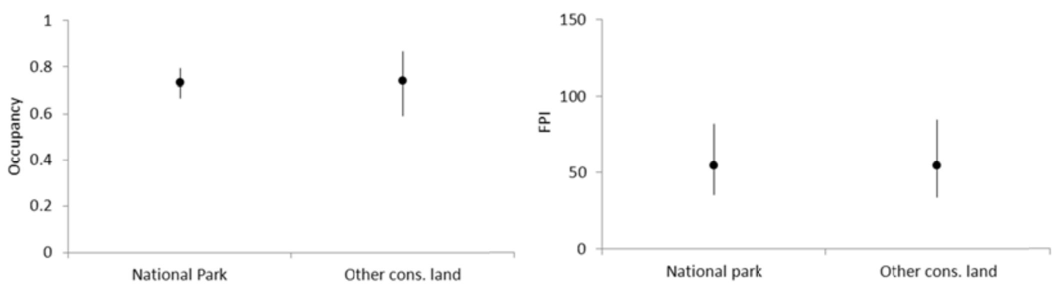

Fig. 11: Mean (±95CIs[71]) occupancy (left) and relative abundance (right) of ungulates by *National Parks* status (number of sampling locations: *National Parks* = 38; other public conservation land = 30).

[71] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

MEASURE 2.2.1: Distribution and abundance of exotic weeds and pests considered a threat – Possum pests

DEFINITION: This ***measure*** assesses the status of brushtail possums (*Trichosurus vulpecula*) on New Zealand's public conservation land at a national scale. It measures occupancy (proportion of sampling locations occupied by possums) and relative abundance.[72]

METHODS: Possum occupancy and abundances were evaluated at 69 forest sampling locations on a national 8-km grid overlapping public conservation lands. Field surveys were carried out in 2012.[73] At each sampling location the presence/absence of possum faecal pellets was recorded in each plot along the four ungulate FPI transects described above (Fig. 2). Four additional 200-m transects, each containing 10 leg-hold traps set at 20-m intervals for two fine nights as per the national possum monitoring protocol,[74] were also used (Fig. 2). Traps were checked daily. The number of possums caught per 100 trap nights was estimated for each of the four transects (termed the Trap Catch Index; TCI), and this has been shown to be positively related to true abundance.[75,76] The data were analysed using a model to account for imperfect detection (joint occupancy–abundance model[77]).

RESULTS: Nationally, possums occurred in 80% of forest sampling locations on public conservation land (mean occupancy = 0.8, 95CI[78] = 0.69–0.88) with a relative abundance (TCI) of 4.3% (95CI = 3.7–4.8%). Occupancy was similar in beech-dominated and non-beech forests (c. 0.79), but relative abundances were lower in beech (TCI = 3.5%) compared with non-beech (TCI = 5.8%)[79] (Fig. 12). The occupancy of possums was similar in ***National Parks*** (0.79) and other public conservation land (0.80), but the relative abundance of possums was lower in ***National Parks*** (TCI = 2.6%) than in other conservation land (TCI = 6.3%)[80] (Fig. 13). The relative abundance of possums decreased with increasing latitude (Fig. 14): highest relative abundances occurred in northern sampling locations. There was a quadratic relationship between relative possum abundance and elevation (Fig. 14), with highest relative abundances occurring at c. 600 m a.s.l.

INTERPRETATION AND IMPLICATIONS: These measures confirm that possums are commonly present in New Zealand forests. However, possum abundances were considerably lower than expected nationally and in low-elevation forests.[81] The lower-than-expected abundances of possums may be due to a number of reasons, such as previous studies estimating possum abundances at locations known to contain possums rather than at an unbiased sample of locations, or methods that differed from the current protocol. The unbiased estimates of possum occupancy and relative abundance provide important baseline information for comparing against future assessments. For example, the eradication of possums from defined areas (e.g. the North, South or Stewart Island as part of a Pest-free New Zealand campaign) would be validated by occupancy and relative abundances at sampling locations in those areas being 0%.

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[72] An estimate of relative abundance is expressed in a unit that is known or assumed to be positively related to the (unknown) true abundance (cf. absolute abundance or density).

[73] 2012 encompasses the austral summer 2011/12.

[74] National Pest Control Agencies 2011. Possum population monitoring using the trap-catch method. Wellington, National Pest Control Agencies.

[75] Forsyth DM, Link WA, Webster R, Nugent G, Warburton B 2005. Nonlinearity and seasonal bias in an index of brushtail possum abundance. Journal of Wildlife Management 69: 976–984.

[76] Ramsey D, Efford M, Ball S 2005. The evaluation of indices of animal abundance using spatial simulation of animal trapping. Wildlife Research 32: 229–237.

[77] Wenger SJ, Freeman MC 2008. Estimating species occurrence, abundance, and detection probability using zero-inflated distributions. Ecology 89: 2953–2959.

[78] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

[79] Probability of 0.997

[80] Probability > 0.999

[81] Efford M 2000. In: Montague T ed. The brushtail possum: biology, impacts and management of an introduced marsupial. Lincoln, Manaaki Whenua Press. Pp. 47–61.

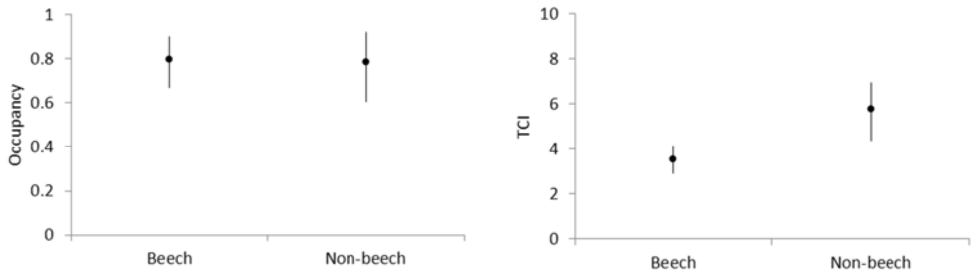

Fig. 12: Mean (±95CIs[82]) occupancy (left) and relative abundance (right) of possums by *forest class* (number of sampling locations: beech = 45; non-beech = 24).

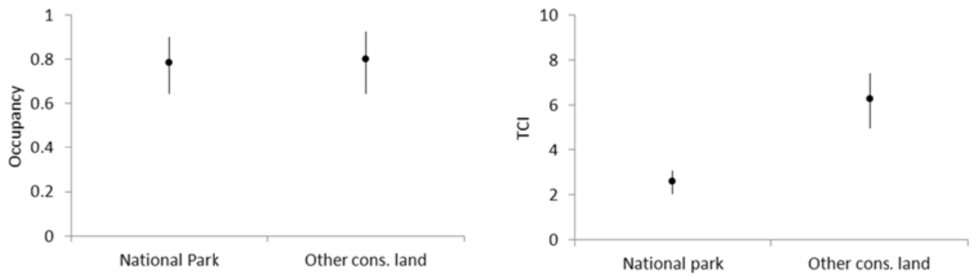

Fig. 13: Mean (±95CIs[82]) occupancy (left) and relative abundance (right) of possums by *National Park* status (number of sampling locations: *National Parks* = 38; other public conservation land = 31).

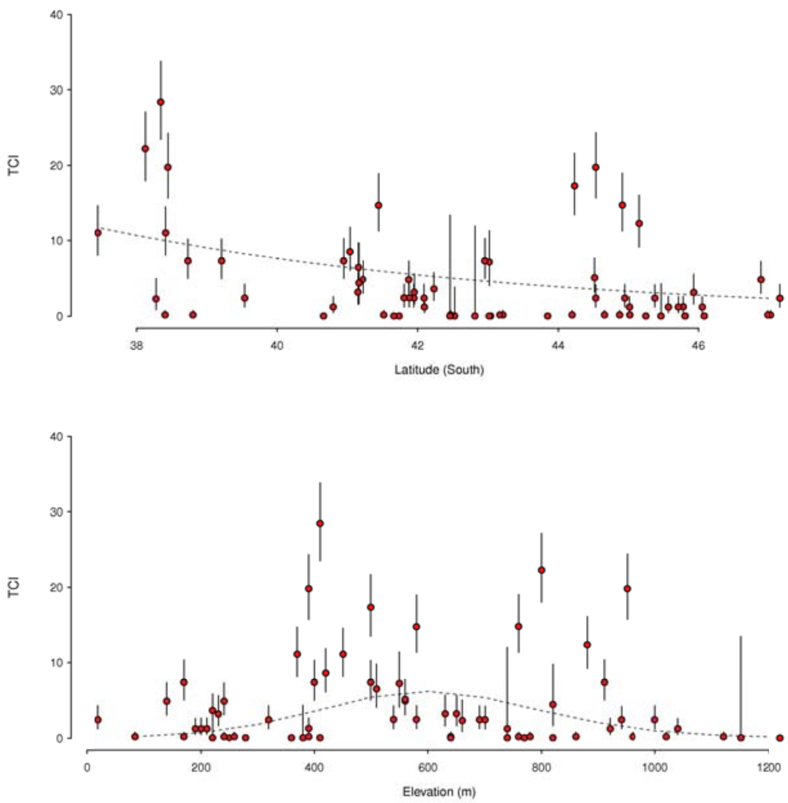

Fig. 14: Relationship between possum TCI (Trap Catch Index) and latitude and elevation (dashed lines indicate predicted TCI by latitude and elevation).

[82] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

Species occupancy – are the species present the ones you would expect naturally?

MEASURE 5.1.1: Size-class structure of canopy dominants – Kāmahi

MEASURE 5.1.3: Representation of plant functional types – Palatable tree species

DEFINITION: This measure assesses the status and trend of a highly palatable canopy tree species – kāmahi (*Weinmannia racemosa*) – in native forests on New Zealand's public conservation land at a national scale. Kāmahi was selected because it is our most abundant tree species forming forest canopies throughout New Zealand and is highly palatable to ungulates and possums. Death of adult trees at local scales has been attributed to possum browsing.[83] We report the abundance and size-class structure using three metrics: the total number of stems in 20 size classes, the mean stem diameter in each plot, and the mean number of stems per plot. These metrics are compared between 2002 and 2012 to assess whether the population is stable at a national scale, and whether the balance between recruitment of small individuals and mortality of large individuals is being maintained

METHODS: Kāmahi population structure was assessed from 327 forest plots on an 8-km grid nationally. The diameter of each stem was measured[84] initially in 2002–2007 and again in 2009–2012 following the permanent plot method.[85] For the first analysis, we removed the few stems greater than the 99.9th percentile diameter for kāmahi nationally (77.3 cm) as they had a disproportionate effect on the size class structure[86]. Stems were then allocated to one of 20 equal-width diameter size classes. We plotted the number of stems in each size class for the 2002–2007 data and the 2009–2012 data and fitted a general linear model (GLM) to each with a log-link function. We visually examined whether the standard errors of the fitted models overlapped between the two measurements. We used all stems and paired *t*-tests with unequal variance to determine whether the mean diameter per plot and the number of stems per plot had changed between measurements. We only used plots where kāmahi was present (172 of the 327 plots). Lastly, all analyses were made across all forests and then contrasted between ***forest classes***[87] (beech vs non-beech forests).

RESULTS: At a national scale, the size class structure of kāmahi has not changed between 2002–2007 and 2009–2012 (Fig. 15). Both size-class distributions followed a 'reverse J' shape pointing to a greater abundance of small stems relative to larger ones, indicative of a self-replacing population. This national-scale pattern was consistent between beech and non-beech forests (Fig. 16). The mean diameter per plot remained statistically similar between the two measurements at a national scale (mean diameter = 13.0 cm for both measurements; $t_{171} = -0.149$, $P = 0.88$) and within beech forests (mean diameter in 2002 = 12.4 cm; in 2012 = 12.8 cm; $t_{69} = 0.98$, $P = 0.33$) and non-beech forests (mean diameter in 2002 = 13.4 cm; in 2012 = 13.2 cm; $t_{101} = -0.25$, $P = 0.80$). Nationally, the mean number of kāmahi stems per plot declined significantly by 0.9 stems per plot from 36.7 to 35.8 ($t_{171} = 2.04$, $P = 0.04$). The number of kāmahi stems remained statistically similar between the two measurements in beech forests (mean in 2002 = 34.1, in 2012 = 32.8; $t_{69} = -1.88$, $P = 0.064$) and non-beech forests (mean in 2002 = 38.4, in 2012 = 37.9; $t_{101} = -1.07$, $P = 0.29$) when considered separately, but the effect size was stronger in beech forests and was marginally significant.

INTERPRETATION AND IMPLICATIONS: These measures suggest that at a national scale, the size class, structure and abundance of kāmahi are being maintained. Qualitatively similar results were found for 14 other palatable species (Appendix I). The decline in the number of stems per plot is intriguing, particularly as the signal seems to be strongest in forests where kāmahi co-occurs with

[83] Rogers GM, Leathwick JR 1997. Factors predisposing forests to canopy collapse in the southern Ruahine Range, New Zealand. Biological Conservation 80: 325–338.
[84] Years refer to the financial year that sampling occurred (i.e. 2012 encompasses the austral summer 2011/12).
[85] Payton IA, Newell CL, Beets P 2004. New Zealand carbon monitoring system indigenous forest and shrubland data collection manual. Prepared for the New Zealand Climate Change Office, Ministry for the Environment, Wellington, New Zealand. 68 p.
[86] Peltzer DA, Mason NWH 2011. CDRP Project 3 Milestone 6: Understand consequences of change in indicator. Investigation number 3497. Landcare Research Contract Report LC0017. 53 pgs.
[87] ***Forest class*** is a derived variable and is defined on page 24.

beech, and we consider it of ecological rather than conservation interest at this stage. New Zealand's forests are dynamic ecosystems and changes can arise for many interacting reasons. Because the mean diameter remained unchanged between measurements, we know this decline in stem number was not size-specific in either *forest class*, and did not reflect a widespread loss of **either** small stems (which we would expect if it was driven by deer eating small stems) **or** large stems (which we would expect if it was driven by possums eating large stems). However, our results would be consistent with a loss of both small **and** large stems from the population.

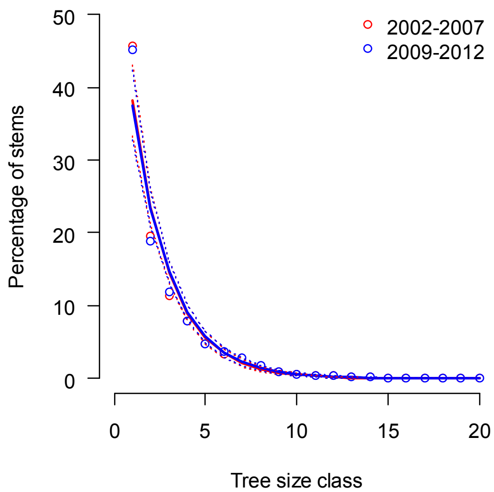

Fig. 15: Size-class distribution of kāmahi nationally for two periods. Fitted solid lines are general linear models of stem counts within 20 equal-sized diameter size classes (models were fitted with a log-link function). Fitted dashed lines are standard errors around the fitted lines.

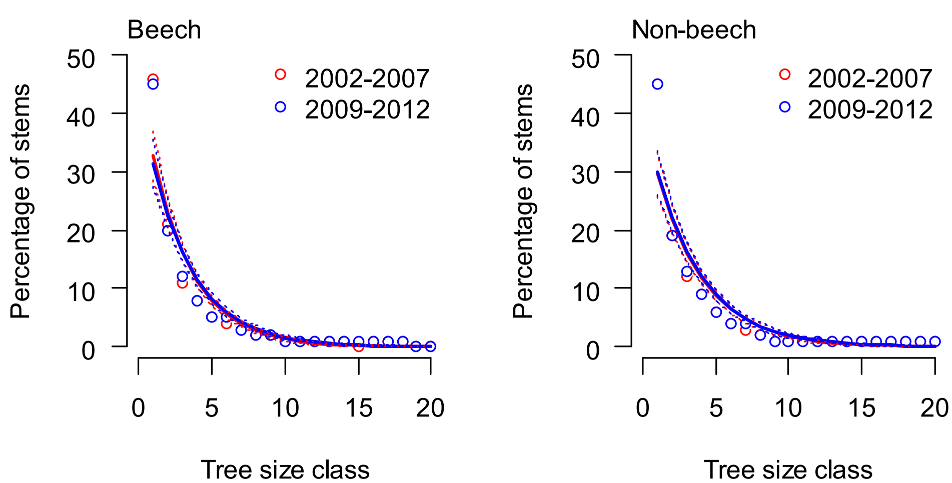

Fig. 16: Size-class distribution of kāmahi nationally for two periods in beech forests and non-beech forests. Fitted solid lines are general linear models of stem counts within 20 equal-sized diameter size classes (models were fit with a log-link function). Fitted dashed lines are standard errors around the fitted lines.

MEASURE 5.1.2: Demography of widespread animal species – Birds

DEFINITION: This measure assesses the status of communities of widespread and common bird species on New Zealand's public conservation land at a national scale. It measures bird species richness (the number of species present), occupancy (the proportion of forest occupied by a given species) and density (the number of individuals of a given species within a hectare of forest). It also considers two subsets of bird species, grouped according to their origin: native or introduced.

METHODS: The composition of bird communities in New Zealand's native forest was evaluated, using 70 sampling locations in forests nationally on an 8-km grid overlapping the public conservation lands. In 2012,[88] a cluster of up to five count stations (200 m apart) was set up at each location (Fig. 2), with bounded bird-point counts carried out on two consecutive days at each station.[89] Variation in species detection probabilities was accounted for when calculating species richness and occupancy estimates (using a hierarchical modelling approach[90]) and species' densities (using distance sampling[91] for 12 species with ≥ 70 detections). Estimates were compared in relation to the ***forest classes***[92] and ***National Park*** status of sampling locations.

RESULTS: New Zealand's forests support at least twice as many native bird species as introduced ones (total species richness, with 95% credible intervals.[93] native = 26, 23–36; introduced = 10, 9–16; mean species richness: native = 9.49, 7.99–12.39; introduced = 2.95, 2.09–5.00). This pattern is consistent irrespective of the ***forest class***[92] (beech vs non-beech) or ***National Park*** status and regardless of which species richness metric is considered (Fig. 17). Overall, occupancy of native bird species is higher than that of introduced birds (0.39, 0.29–0.65 vs 0.30, 0.19–0.57 respectively); a weak relationship that is maintained in beech but not non-beech forests (Fig. 17). Of the 12 most widespread and abundant bird species observed within forests on public conservation land, 10 are native and occupy >40% of forests within the conservation land (Fig. 18). Of the seven most abundant bird species (Fig. 19), three – grey warbler, tomtit, and bellbird – are found in more than 75% of native forests. Overall, native bird densities were similar across ***forest classes*** (Wald = 2.55; P = 0.42; Fig. 20) but varied in relation to ***National Park*** status (Wald = 13.16, P = 0.01; Fig. 20). Beech forest locations supported higher densities of riflemen (Wald = 1.77, P = 0.1); the most abundant bird species in native forests overall. Tomtit densities were higher within ***National Parks*** than on other conservation land (Wald = 2.56, P = 0.002).

INTERPRETATION AND IMPLICATIONS: These measures represent New Zealand's first assessment of forest bird community composition at the national scale, thus providing important baseline information for monitoring future changes. While native species remain dominant in forest bird communities on New Zealand's public conservation land (only two introduced species were among the 12 most abundant and widespread species), a key question is whether the functional integrity of these forests is also being maintained. Encouragingly, the 12 most abundant and widespread species in native forests include three of New Zealand's main bird pollinators and potential fruit dispersers[94] (bellbird, tūī and silvereye) as well as three cavity-nesting birds (tomtit, rifleman and kākāriki spp.) potentially prone to mammal predation.[95] Potential concerns, however, are the relatively low occupancy estimates for kererū (c. 35%), New Zealand's primary large-seed disperser, and yellowhead (c. 5%), a cavity-nesting species particularly prone to mammal predation.

[88] 2012 encompasses the austral summer 2011/12.

[89] MacLeod CJ, Greene T, MacKenzie D, Allen R 2012. Monitoring widespread and common bird species on New Zealand's conservation lands: a pilot study. New Zealand Journal of Ecology 36: 300–311.

[90] Royle JA, Kéry M 2007. A Bayesian state–space formulation of dynamic occupancy models. Ecology 88: 1813–1823.

[91] Thomas L, Buckland ST, Rexstand EA, Laake JL, Strindberg S, Hedley SL, Bishop JRB, Marques TA, Burnham KP 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5–14.

[92] ***Forest class*** is a derived variable and is defined on page 24.

[93] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

[94] Kelly D, Robertson AW, Ladley JJ, Anderson SH, MacKenzie RJ 2006. The relative (un)importance of introduced animals as pollinators and dispersers of native plants. Chapter 15.in Allen RB, Lee WG eds Biological Invasions in New Zealand. Berlin: Springer.

[95] Innes J, Kelly D, Overton JMcC, Gillies C 2010. Predation and other factors currently limiting New Zealand's forest birds. New Zealand Journal of Ecology 34: 86–114.

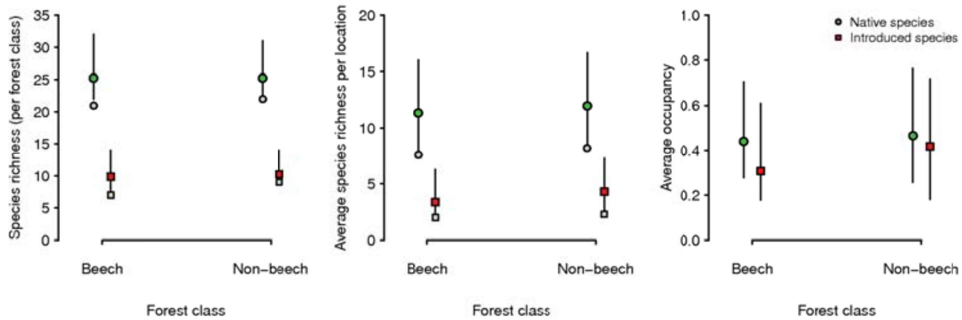

Fig. 17: Estimates (±95CI[96]) of total species richness, mean species richness and mean species occupancy for native (green circles) and introduced (red squares) species (the observed numbers of species are shown by a grey circle or squares) in two *forest classes* (44 beech and 26 non-beech locations).

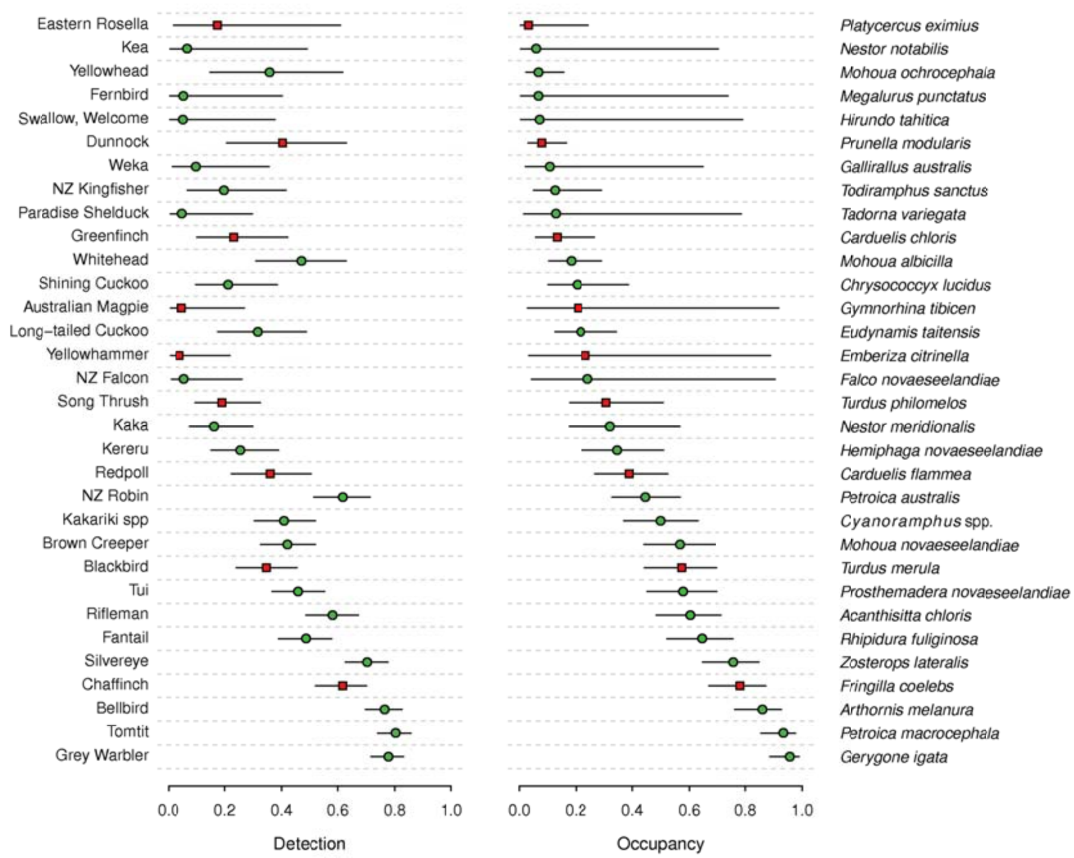

Fig. 18: Estimates of mean (±95CI[96]) of detection and occupancy probabilities for native (green circles) and introduced (red squares) species. Cavity-nesting species (kea, kākā, kākāriki spp., New Zealand kingfisher, rifleman, tomtit and yellowhead) are regarded as a high-conservation-risk group because they are susceptible to mammal predation.[97] Another important functional group is New Zealand's main bird pollinators and/or potential fruit dispersers[98] (bellbird, tūī, silvereye and kererū).

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[96] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

[97] Innes J, Kelly D, Overton JMcC, Gillies C 2010. Predation and other factors currently limiting New Zealand's forest birds. New Zealand Journal of Ecology 34: 86–114.

[98] Kelly D, Robertson AW, Ladley JJ, Anderson SH, MacKenzie RJ 2006. The relative (un)importance of introduced animals as pollinators and dispersers of native plants. Chapter 15 in Allen RB, Lee WG eds Biological Invasions in New Zealand. Berlin, Springer.

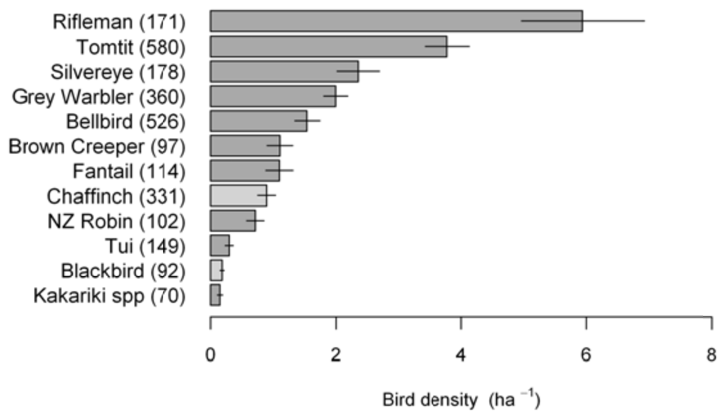

Fig. 19: Mean (± standard errors) densities per hectare of the 12 most widespread and common bird species in native forests on public conservation land (native species dark grey and introduced species light grey). (The number of detections used to fit the detection functions to estimate density for each species is specified in brackets.)

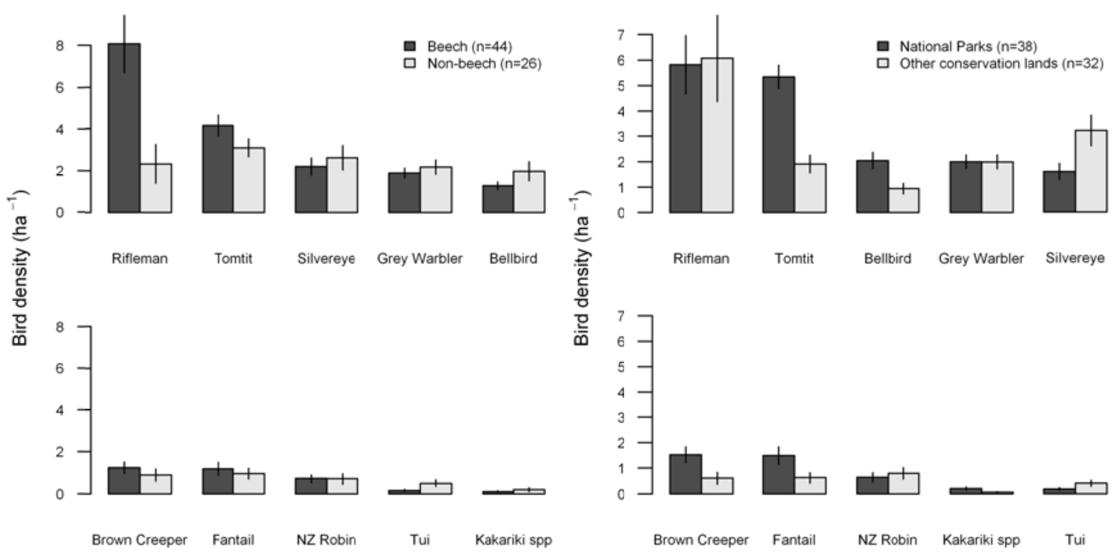

Fig. 20: Mean (± standard errors) densities per hectare of native bird species in relation to *forest class* and *National Park* status.

Ecosystem representation – are the full range of rare ecosystems protected in New Zealand?

MEASURE 6.1.3: National change in extent and integrity of threatened naturally uncommon and significantly reduced habitats

DEFINITION: Naturally uncommon ecosystems, such as basaltic outcrops, coastal turfs, and geothermal ecosystems, frequently occur outside existing public conservation areas and represent a distinct set of environmental conditions often associated with rare and threatened endemic species. Seventy-two different types of naturally uncommon ecosystems have been identified in New Zealand.[99] This ***measure*** assesses the national change in extent and integrity of these ecosystems.

METHODS: The IUCN's Ecosystem Red-List criteria are based on assessments of changes in extent of ecosystems and reductions in ecosystem processes.[100] This analysis uses expert opinion to judge these changes in New Zealand's 72 naturally uncommon ecosystem types[99] over the past 500 and the last 50 years. Ecological integrity indicators (e.g. declines in native vegetation cover and increases in abundance of exotic weeds and pests) were used as a framework to evaluate reduction in ecosystem processes.

RESULTS: Eighteen critically endangered, 17 endangered and 10 vulnerable naturally uncommon ecosystem types were identified; 27 are not endangered (Table 4). Significantly, naturally uncommon ecosystems contain 145 (85%) of mainland New Zealand's taxonomically distinct nationally critical, nationally endangered, and nationally vulnerable plant species, 66 (46%) of which are thought to be endemic to naturally uncommon ecosystems.

INTERPRETATION AND IMPLICATIONS: Naturally uncommon ecosystems have been included in national-level conservation policy and the recent application of the IUCN's Ecosystem Red-List criteria to these ecosystems now provides a rational basis to identify which ecosystems are the most threatened and so inform conservation priority setting.[101]

[99] Williams PA, Wiser SK, Clarkson B, Stanley M 2007. New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. New Zealand Journal of Ecology 31: 119–128.

[100] Rodriguez JP, Rodriguez-Clark KM, Baillie JEM, Ash N, Benson J, Boucher T, Brown C, Burgess ND, Collen B, Jennings M, Keith DA, Nicholson E, Revenga C, Reyers B, Rouget M, Smith T, Spalding M, Taber A, Walpole M, Zager I, Zamin T 2011. Establishing IUCN Red List Criteria for Threatened Ecosystems. Conservation Biology 25: 21–29.

[101] Holdaway RJ, Wiser SK, Williams PA 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26: 619–629.

Table 4: Status of the 45 threatened naturally uncommon ecosystems in New Zealand.[102,103]

Critically endangered	Endangered	Vulnerable
Shell barrier beach (chenier plain)	Active sand dune	Coastal cliffs on mafic rock
Coastal turf	Dune deflation hollow	Screes of calcareous rock
Old tephra plains (frost flats)	Stony beach ridge	Young tephra plains and hill slopes
Inland sand dunes	Shingle beach	Boulder fields of calcareous rock
Outwash gravels	Stable sand dune	Cliffs, scarps & tors of mafic rocks
Inland saline	Coastal cliffs on calcareous rock	Cliffs, scarps & tors of calcareous rocks
Leached terraces	Ultramafic sea cliffs	Moraine
Fumeroles	Volcanic dunes:	Lake margins
Geothermal stream sides	Sandstone erosion pavements	Blanket mire
Geothermal heated ground	Frost hollows	Estuary
Geothermal hydrothermally altered ground	Volcanic boulder fields	
Seabird guano deposits	Sinkholes	
Seabird burrowed soil	Dune slacks	
Marine mammal influenced sites	Domed bog (*Sporadanthus*)	
Cave entrances	Lagoons	
Ephemeral wetlands	Braided riverbeds	
Gumlands	Seepages and flushes	
Damp sand plains		

[102] Williams PA, Wiser SK, Clarkson B, Stanley M 2007. New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. New Zealand Journal of Ecology 31: 119–128.
[103] Holdaway RJ, Wiser SK, Williams PA 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26: 619–629.

MEASURE 6.1.4: Proportion of threatened naturally uncommon and significantly reduced habitats under protection

DEFINITION: Naturally uncommon ecosystems, such as basaltic outcrops, coastal turfs, and geothermal ecosystems, frequently occur outside existing public conservation areas and represent a distinct set of environmental conditions often associated with rare and threatened endemic species. Seventy-two different types of naturally uncommon ecosystems have been identified in New Zealand,[104] 45 of which are threatened.[105] This ***measure*** assesses the proportion under formal protection for those 45 ecosystems considered threatened.

METHODS: Concurrently, DOC and Landcare Research have been collaborating to produce maps of the current extent of each of the 72 naturally uncommon ecosystems. Fifteen maps are at a final draft stage; 12 of these represent threatened (i.e. critically endangered, endangered or vulnerable) ecosystems. When ecosystems are mapped, the land tenure and protection status can be examined using GIS analysis.

RESULTS: Four of the 12 mapped threatened ecosystems (volcanic dunes, hydrothermally altered ground, shingle beaches and coastal turfs) have less than 20% of their total area under formal protection; as such they are high priority for future protection efforts (Fig. 21). Seven of the 12 ecosystems have more than 20% of their total extent on public conservation land. Of these, four ecosystems (leached terraces, seabird guano deposits, active sand dunes and seabird burrowed ecosystems) have more than 20% of this classed as 'Stewardship Land', which includes land that has undetermined conservation status (Fig. 22).

INTERPRETATION AND IMPLICATIONS: Naturally uncommon ecosystems have been included in national conservation policy[106] and the recent application of the IUCN's Ecosystem Red-List criteria to these ecosystems now provides a rational basis to identify which ecosystems are the most threatened and so inform conservation priority setting.[105] Of the 45 threatened ecosystems, the four ecosystems that have so far been identified as having less than 20% of their total area under formal protection are of high priority for future protection efforts. The four threatened ecosystems having more than 20% of their total extent classed as 'Stewardship Land' indicate that improved conservation status is merited.

[104] Williams PA, Wiser SK, Clarkson B, Stanley M 2007. New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. New Zealand Journal of Ecology 31: 119–128.
[105] Holdaway RJ, Wiser SK, Williams PA 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26: 619–629.
[106] MfE 2007. Protecting our Places: Information about the Statement of National Priorities for Protecting Rare and Threatened Biodiversity on Private Land. Ministry for the Environment and Department of Conservation, Wellington.

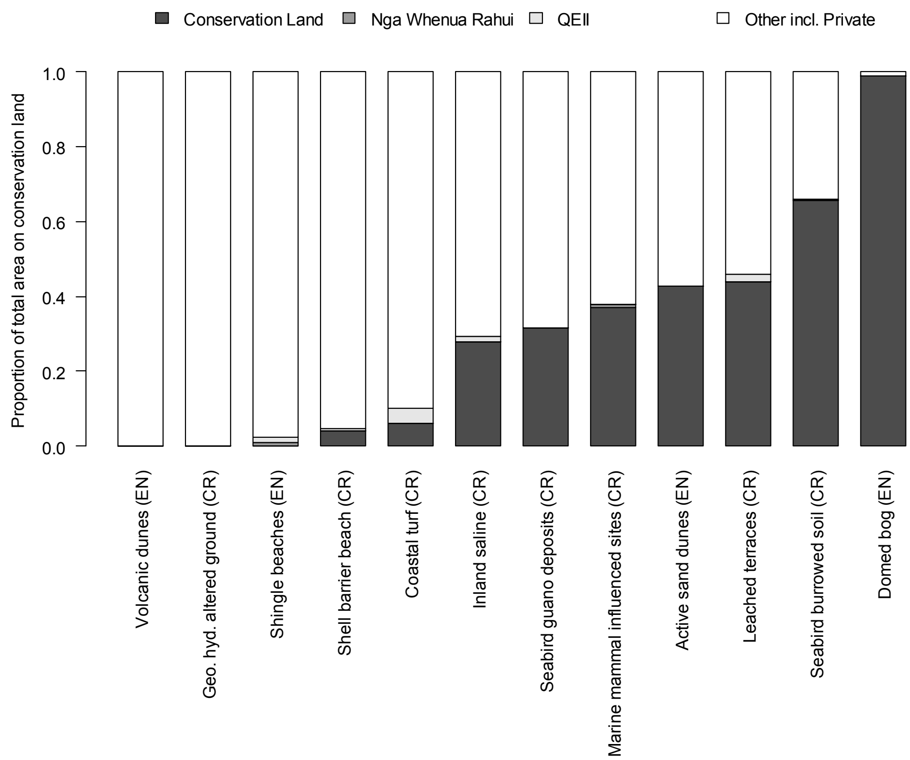

Fig. 21: Proportion of the total extent of each of 12 threatened (CR = critically endangered, EN = endangered) naturally uncommon ecosystems under different land tenures.

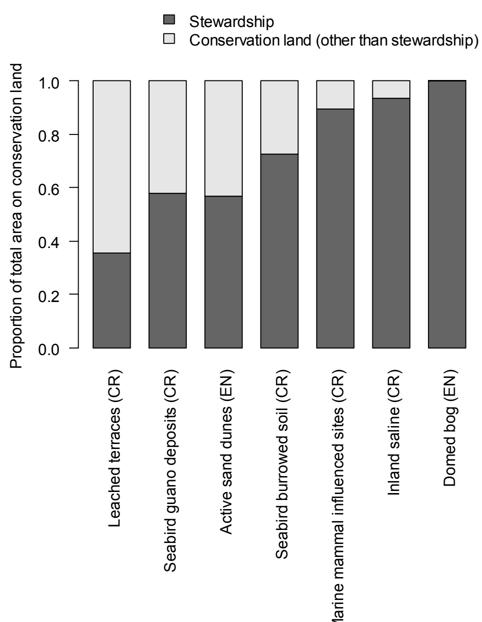

Fig. 22: The proportion of the total extent on public conservation land of each of seven threatened (CR = critically endangered, EN = endangered) naturally uncommon ecosystems on land classed as 'Stewardship' versus other conservation classifications.

Synopsis

INDIGENOUS DOMINANCE – ARE THE ECOLOGICAL PROCESSES NATURAL?

Native plant species continue to greatly outnumber weed species in native forests on New Zealand's public conservation land. Although exotic weeds are widespread, their current distribution and frequency remain largely unchanged compared with 10 years ago. Possums and ungulates, which are also widespread in native forests on public conservation land (occupying 75–80% of sampling locations), tend to be less abundant on the South Island and in forests where beech (*Nothofagus* spp.) is a major component. Although mammal pests are widespread in native forests in national parks, these areas have fewer weed species and possums, but not ungulates, relative to other conservation lands.

SPECIES OCCUPANCY – ARE THE SPECIES PRESENT THE ONES YOU WOULD EXPECT NATURALLY?

At a national scale, the tree species that possums, deer and goats most prefer to eat were regenerating 10 years ago across native forests on public conservation land and are continuing to regenerate now. The abundance of the highly palatable species, kāmahi, has been maintained across forests nationally.

Native forests on public conservation land are at least twice as rich in native bird species as they are in introduced bird species, regardless of whether beech (*Nothofagus*) is a substantial component of the forest or not. Of the 12 most widespread bird species, 10 are native species and are found throughout more than 40% of the native forests on public conservation land. Three species – grey warbler, tomtit, and bellbird – are found in more than 75% of our native forests.

ECOSYSTEM REPRESENTATION – ARE THE FULL RANGE OF RARE ECOSYSTEMS PROTECTED IN NEW ZEALAND?

Naturally uncommon ecosystems have been included in national conservation policy and the recent application of the IUCN's Ecosystem Red-List criteria to these ecosystems now provides a rational basis to identify which ecosystems are the most threatened and so inform conservation priority setting.[107] Eighteen critically endangered, 17 endangered and 10 vulnerable naturally uncommon ecosystem types were identified; 27 others are not endangered. Significantly, naturally uncommon ecosystems contain 145 (85%) of mainland New Zealand's taxonomically distinct nationally critical, nationally endangered, and nationally vulnerable plant species, 66 (46%) of which are thought to be endemic to naturally uncommon ecosystems.

Of the 45 threatened ecosystems, the four ecosystems that have so far been identified as having less than 20% of their total area under formal protection are of high priority for future protection efforts. The four threatened ecosystems having more than 20% of their total extent classed as 'Stewardship Land' point to such lands as being of high priority for having their conservation status evaluated.

[107] Holdaway RJ, Wiser SK, Williams PA 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26: 619–629.

Goal 2: Management effectiveness

Introduction

This section reports on the status of species where possums are being managed. It combines information about where possum control operations are undertaken with the ***indigenous dominance*** and ***species occupancy measures*** (Table 1) to increase DOC's understanding of management effectiveness.

For the purposes of these analyses, ***possum control*** was measured as a binary variable (control vs no control). Control was assumed to occur when at least one possum control operation was administered by either DOC or the Animal Health Board (AHB) within 500 m of a sampling location during a 4-year period (2008–2011),[108] irrespective of the area, frequency, or type (ground vs aerial) of control implemented. (The resolution of the derived ***possum control*** data considered in this analysis was, in part, determined by the information available, e.g. for 23 of the locations subject to control, the operation type was not recorded.)

Of the 328 forest sampling locations used to assess changes in vegetation composition (see ***indicators*** and ***measures*** in Table 1), 97 were subject to some form of possum control and most of those locations (n = 60) were only subject to control in one of the four years considered. Control occurred at 24% of 75 sampling locations used to quantify animal-related ***measures*** and the environmental characteristics of those locations were broadly similar to those without control (Fig. 23).

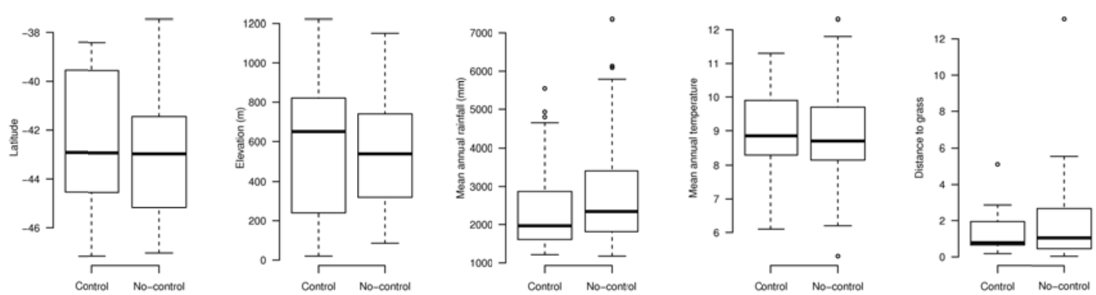

Fig. 23: Environmental characteristics of sampling locations (where the animal-related surveys occurred) subject to *possum control* (n = 18) relative to those without control (n = 57).

[108] 2008 and 2011 refer to the financial years (1 July – 30 June) 2007/08 and 2010/11 respectively.

What is the status of introduced and native species where possums are being managed?

MEASURE 2.2.1: Distribution and abundance of exotic weeds and pests considered a threat – Possum pests

DEFINITION: This ***measure*** assesses the status of brushtail possums (*Trichosurus vulpecula*) on New Zealand's public conservation land at a national scale. It measures occupancy (proportion of sampling locations occupied by possums) and relative abundance.[109] Possum control is used to reduce the impacts of possums on native forests and animals, as well as eradicating bovine TB from possum populations (possums are the main source of TB infection to livestock). This analysis considers the effectiveness of ***possum control*** on the occupancy and relative abundance of possums.

METHODS: Possum occupancy and abundances were evaluated at 69 forest sampling locations on a national 8-km grid overlapping public conservation lands. Field surveys were carried out in 2012.[110] At each sampling location the presence/absence of possum pellets was recorded in each plot along the four ungulate FPI transects described above (Fig. 2). Four additional 200-m transects (Fig. 2) each contained 10 leg-hold traps set at 20-m intervals for two fine nights as per the national possum monitoring protocol.[111] Traps were checked daily. The number of possums caught per 100 trap nights was estimated for each of the four transects (termed the Trap Catch Index; TCI), and this has been shown to be positively related to true abundance.[112,113] The pellet and TCI data were analysed using a joint occupancy–abundance model[114] that accounts for imperfect detection at the transect level. ***Possum control***[115] was scored as a binary variable for each location (no control or control) and did not qualify the duration of control or the control methods used.

RESULTS: Nationally, possum occupancy and relative abundances are lower at sampling locations subject to possum control (occupancy = 0.64; TCI = 2.8%) compared with those not subject to control (occupancy = 0.84; TCI = 4.8%; Fig. 24)[116]. When forest type is also considered, occupancy is lowest in beech forest sampling locations subject to control but similarly higher in the other three classes (Fig. 25). The relative abundance of possums was similarly low in beech forest sampling locations with and without control and in non-beech sampling locations subject to control (TCI < 4 %), but was much higher in non-beech-forest sampling locations not subject to control (TCI = 8%; Fig. 25).

INTERPRETATION AND IMPLICATIONS: At a national scale, possums were present in more than 75% of the sampling locations evaluated in non-beech forests on public conservation land, irrespective of recent ***possum control***. However, despite similar estimates of occupancy, possum control substantially reduced the relative abundances of possums in non-beech forests. In contrast, within beech forests, occupancy of possums was higher at sampling locations with no ***possum control***, yet relative abundances of possums were similar with and without control. These results suggest ***possum control*** is more effective in reducing possum abundance in non-beech forests relative to beech forests. It should be noted that possum control ranged from aerial poisoning to trapping, and the distribution of these methods may differ between forest types. A larger number of sampling locations (N = 1311) in future years will enable the presence and magnitude of these

[109] An estimate of relative abundance is expressed in a unit that is known or assumed to be positively related to the (unknown) true abundance (cf. absolute abundance or density).
[110] 2012 encompasses the austral summer 2011/12.
[111] National Pest Control Agencies 2011. Possum population monitoring using the trap-catch method. Wellington, National Pest Control Agencies.
[112] Forsyth DM, Link WA, Webster R, Nugent G, Warburton B 2005. Nonlinearity and seasonal bias in an index of brushtail possum abundance. Journal of Wildlife Management 69: 976–984.
[113] Ramsey D, Efford M, Ball S 2005. The evaluation of indices of animal abundance using spatial simulation of animal trapping. Wildlife Research 32: 229–237.
[114] Wenger SJ, Freeman MC 2008. Estimating species occurrence, abundance, and detection probability using zero-inflated distributions. Ecology 89:2953–2959.
[115] ***Possum control*** is a derived variable and is defined on page 43.
[116] Probabilities of 0.96 and 0.99 for occupancy and abundance respectively.

relationships to be determined with a greater degree of confidence. Furthermore, it will be possible to allow for the potentially confounding effects of ***forest class*** and control method.

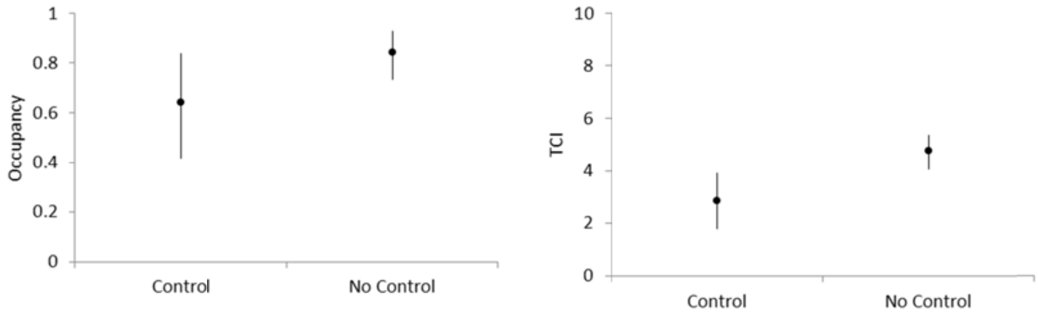

Fig. 24: Mean (±95CI[117]) occupancy (left) and relative abundance (TCI; right) of possums in relation to *possum control* (number of sampling locations: control = 17; no control = 52).

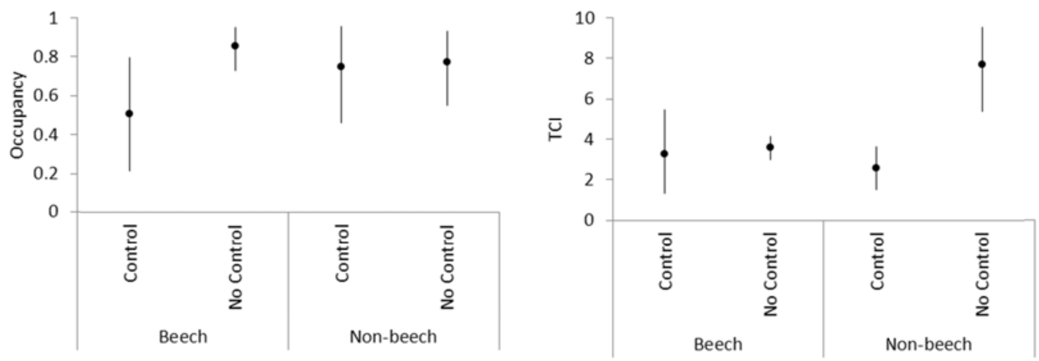

Fig. 25: Mean (±95CI[117]) occupancy (left) and abundance (TCI; right) of possums in relation to *possum control* and *forest class* (number of sampling locations: non-beech control = 9; non-beech no control = 15; beech control = 8; beech no control: 37).

[117] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

MEASURE 2.2.1: Distribution and abundance of exotic weeds and pests considered a threat – Ungulate pests

DEFINITION: This ***measure*** assesses the distribution and abundance of wild ungulates (feral goats *Capra hircus*; and seven deer taxa, Family Cervidae) on New Zealand's public conservation land at a national scale. It measures occupancy (proportion of sampling locations occupied) and relative abundances[118] of ungulates. As some types of possum control, namely aerial application of 1080 poison, can adversely affect ungulates,[119,120] this analysis assessed the effectiveness of ***possum control***[121] on the distribution and abundance of ungulates.

METHODS: Ungulate occupancy and abundances were evaluated at 68 forest sampling locations on a national 8-km grid overlapping forest on public conservation lands. Field surveys were carried out in 2012.[122] Four 150-m transects were set up in a cruciform shape at each sampling location and the number of intact pellets in circular plots of 1-m radius spaced at 5-m intervals (i.e. 30 plots per transect) were counted.[123,124] The total number of faecal pellets along each transect (termed the Faecal Pellet Index; FPI) have been shown to be linearly and positively related to known abundances of deer.[125] The ungulate species thought to be present at each sampling location, conditional on pellets being detected, were determined through the expert opinions of local DOC staff. The data were analysed using a joint occupancy–abundance model[126] that accounts for imperfect detection at the transect level. ***Possum control*** was scored as a binary variable for each location (no control or some control) and did not qualify the duration of control or the control methods used. Analysis was for all sampling locations together and then locations grouped by ***forest class***.

RESULTS: There is weak evidence that ungulate occupancy was lower at sampling locations subject to possum control (occupancy = 64%) compared with those not subject to possum control (78%; Fig. 26)[127]. Conversely, there is moderate evidence that sampling locations subject to possum control had greater relative ungulate abundances (FPI = 83.1) compared with sampling locations without control (TCI = 45.3; Fig. 26)[128]. When forest type was considered, relative ungulate abundances were highest in non-beech-forest sampling locations not subject to possum control (TCI = 167.7; Fig. 27).

INTERPRETATION AND IMPLICATIONS: Overall, ***possum control*** appears to affect ungulate (deer and/or feral goats) abundances, with highest estimates of relative abundance in forests subject to recent possum control. However, these effects differ between forest classes. In non-beech forest, relative abundances were greater in sampling locations subject to possum control. In contrast, in beech forests, the occurrence and abundance of ungulates was lower in sampling locations subject to possum control than those without control. This suggests that possum control can potentially affect the abundances of pest animals in unexpected directions. The mechanism(s) underpinning these relationships are unclear: for example are they due to an interaction with possum density and ungulate density, or are they an artefact of the non-random application of possum control, i.e. control being carried out in non-beech forests that previously supported a higher abundance of ungulates. A

[118] An estimate of relative abundance is expressed in a unit that is known or assumed to be positively related to the (unknown) true abundance (cf. absolute abundance or density).
[119] Green W 2004. The use of 1080 for pest control: a discussion document. Animal Health Board and Department of Conservation.
[120] Parliamentary Commissioner for the Environment 2011. Evaluating the use of 1080: Predators, poisons and silent forests. Wellington, Parliamentary Commissioner for the Environment.
[121] ***Possum control*** is a derived variable and is defined on page 43.
[122] 2012 encompasses the austral summer 2011/12.
[123] Forsyth DM 2005. Protocol for estimating changes in the relative abundance of deer in New Zealand forests using the Faecal Pellet Index (FPI). Landcare Research Contract Report LC0506/027.
[124] Allen RB, Wright EF, MacLeod CJ, Bellingham PJ, Forsyth DM, Mason NWH, Gormley AM, Marburg AE, MacKenzie DI, McKay M 2009. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Landcare Research Contract Report LC0809/153.
[125] Forsyth DM, Barker RJ, Morriss G, Scroggie MP 2007. Modeling the relationship between fecal pellet indices and deer density. Journal of Wildlife Management 71: 964–970.
[126] Wenger SJ, Freeman MC 2008. Estimating species occurrence, abundance, and detection probability using zero-inflated distributions. Ecology 89: 2953–2959.
[127] Probability of occupancy lower at locations with control = 0.85.
[128] Probability of abundance lower at locations with control = 0.076.

larger number of sampling locations (N = 1311) in future years will enable the presence and magnitude of these relationships to be determined with a greater degree of confidence. Furthermore, a larger number of sampling locations will enable separation of locations by method of ***possum control*** (i.e. 1080 poisoning or otherwise), as well as whether the 1080 used contained deer repellent or not.

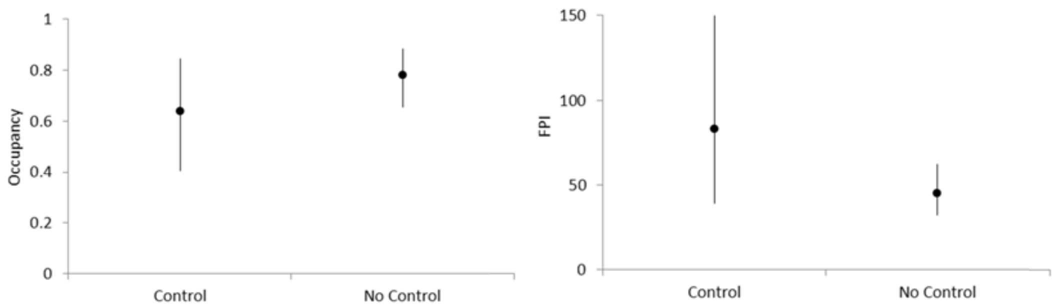

Fig. 26: Mean (±95CI[129]) occupancy (left) and relative abundances (FPI; right) of ungulates at sampling locations with and without possum control (number of sampling locations: control = 16; no control = 52).

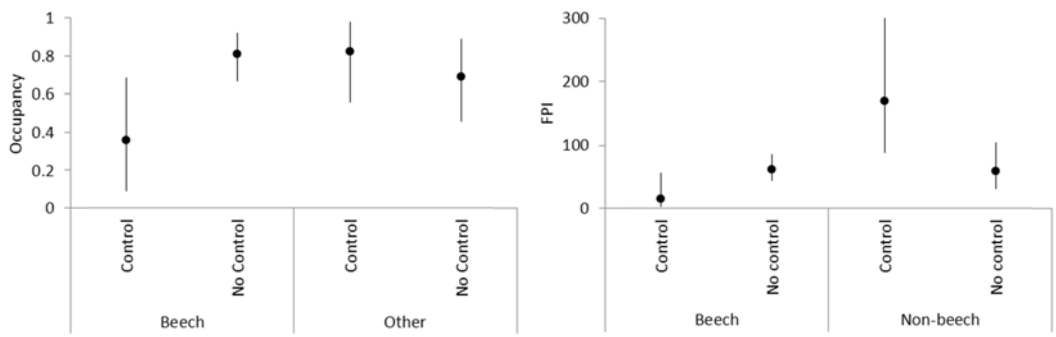

Fig. 27: Mean (±95CI[129]) occupancy (left) and relative abundances (TCI; right) of ungulates at sampling locations in two forest types with and without possum control (number of sampling locations: non-beech control = 9; non-neech no control = 16; beech control = 7; beech no control: 36).

[129] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

MEASURE 5.1.2: Assemblages of widespread animal species – Birds

DEFINITION: This ***measure*** assesses the status of assemblages of widespread and common bird species on New Zealand's public conservation land at a national scale. It measures bird species richness (the number of species present), occupancy (the proportion of forest occupied by a given species) and density (the number of individuals of a given species within a hectare of forest). Species were also grouped according to their origin: native or introduced. Here, bird community composition was evaluated with respect to **possum control**, since there are conflicting views about whether ***possum control*** is beneficial or detrimental to bird populations.[130,131]

METHODS: The composition of bird communities in New Zealand's native forest was evaluated, using 70 sampling locations in forests nationally on an 8-km grid overlapping public conservation lands. In 2012,[132] a cluster of up to five count stations (200 m apart) were set up at each location, with bounded bird-point-counts carried out on two consecutive days at each station.[133] Variation in species detection probabilities was accounted for when calculating species richness and occupancy estimates (using a hierarchical modelling approach[134]) and species densities (using distance sampling[135] and a multivariate model-based approach,[136] densities were only estimated for native species (n = 10) with ≥ 70 detections). These analyses tested for evidence of effects of ***possum control***[137] and ***forest class***.[137] ***Possum control*** was scored as a binary variable for each sampling location (no control or some control) and did not qualify the duration of control or the control methods used.

RESULTS: The total number of bird species was similar whether areas had been subject to ***possum control*** or not (23 native and 9 introduced species; Fig. 28). The number of both native (11) and introduced (3) bird species per location was also comparable (Fig. 28), as were average occupancy estimates for both native and introduced species (Fig. 29). However, at the species level, dunnock, whitehead and kererū occupancy estimates tended to be higher where ***possum control*** had occurred (Fig. 29). For native birds, there was no evidence of possum control impacts on densities at either the community or species level in both ***forest classes*** (Fig. 30).

INTERPRETATION AND IMPLICATIONS: There is debate about the effect of ***possum control*** on bird communities in forests on public conservation land.[130] The nationwide sample is not yet adequate to detect whether the abundance of individual native bird species differs according to whether or not ***possum control*** has been conducted. The data so far indicate that there may be inconsistent trends among individual native bird species. Likewise the current number of sample points is inadequate to detect whether there are differences in the abundances of bird species between beech and non-beech forests (with and without ***possum control*** in both). The larger number of samples that will result from planned future monitoring years is very likely to resolve whether there are differences in the abundances of birds according to areas of possum control and across different kinds of forests.

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[130] Green W 2004. The use of 1080 for pest control: a discussion document. Animal Health Board and Department of Conservation.
[131] Parliamentary Commissioner for the Environment 2011. Evaluating the use of 1080: Predators, poisons and silent forests. Wellington, Parliamentary Commissioner for the Environment.
[132] 2012 encompasses the austral summer 2011/12.
[133] MacLeod CJ, Greene T, MacKenzie D, Allen R 2012. Monitoring widespread and common bird species on New Zealand's conservation lands: a pilot study. New Zealand Journal of Ecology 36: 300–311.
[134] Royle JA, Kéry M 2007. A Bayesian state–space formulation of dynamic occupancy models. *Ecology* 88: 1813–1823.
[135] Thomas L, Buckland ST, Rexstand EA, Laake JL, Strindberg S, Hedley SL, Bishop JRB, Marques TA, Burnham KP 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5–14.
[136] Wang L, Naumann U, Wright ST, Warton DI 2012. mvabund – an R package for model-based analysis of multivariate abundance data. Methods in Ecology and Evolution 3: 471–474.
[137] ***Possum control*** and ***forest classes*** are derived variables and are defined on pages 43 and 24 respectively.

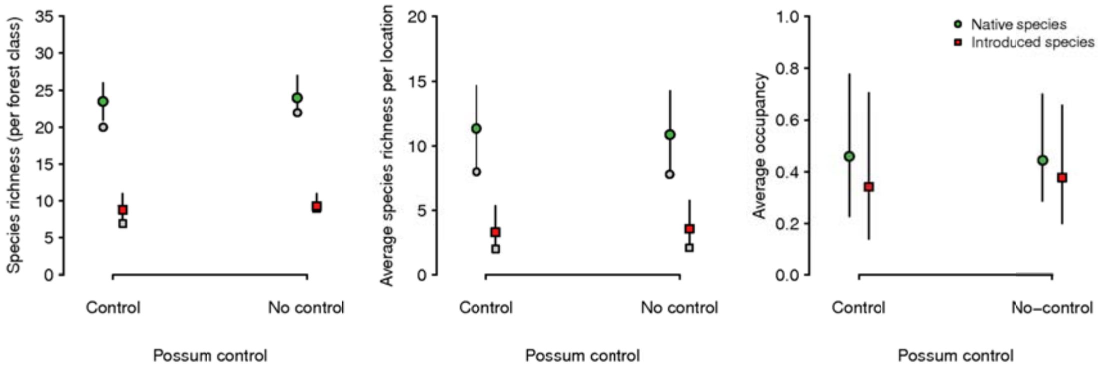

Fig. 28: Estimates (±95CI[138]) of total species richness, mean species richness and mean species occupancy for native (green circles) and introduced (red squares) species (the observed number of species is shown by a grey circle or squares) in relation to *possum control* (17 control and 53 no-control locations).

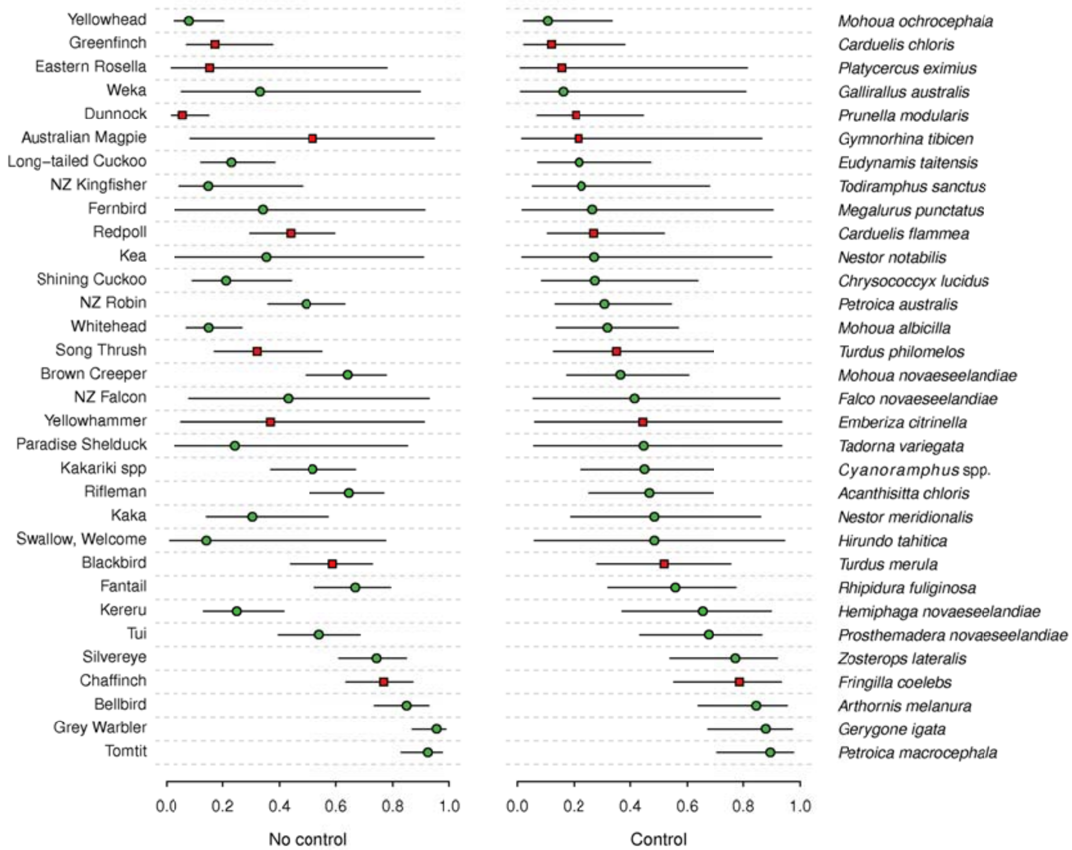

Fig. 29: Estimates of mean (±95CI[138]) of occupancy native (green circles) and introduced (red squares) species for sampling locations with and without possum control (17 control and 53 no control locations). The level of risk of 1080 impacts for bird species[139] is classified as: high (kākā, kea, fernbird, yellowhead), medium (tomtit, grey warbler, bellbird, tūī and fantail) or low (kererū, rifleman, kākāriki spp., NZ falcon, brown creeper, whitehead, NZ robin, weka).

[138] 95CI is the 95% Credible Interval (or Bayesian confidence interval). These are analogous to confidence intervals in frequentist statistics.

[139] Anon. 2007. Evaluation and Review Report: Reassessment of 1080 (HRE05002). Prepared for the Environment Risk Authority.

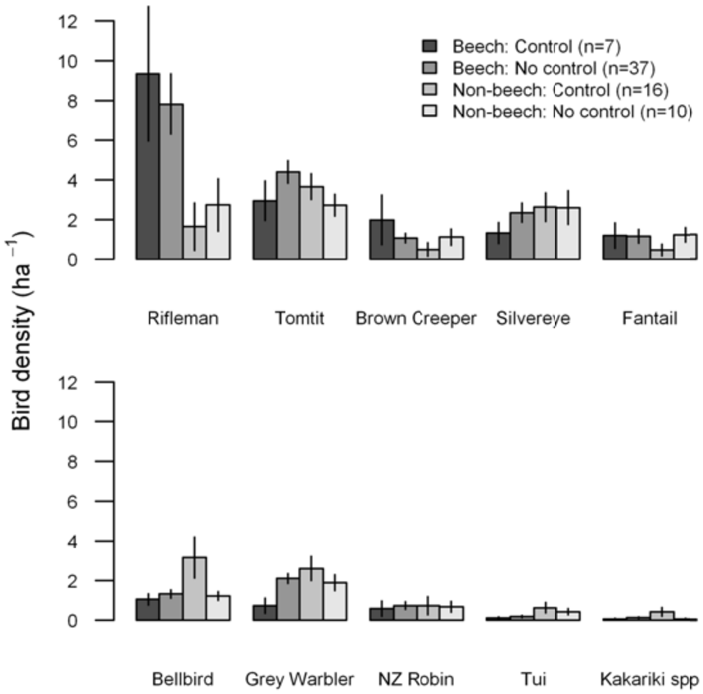

Fig. 30: Mean (± standard error) density estimates per hectare for native birds at sampling locations in relation to *forest classes* and *possum control*.

MEASURE 5.1.1: Size-class structure of canopy dominants – Kāmahi

MEASURE 5.1.3 Representation of plant functional type – Palatable tree species

DEFINITION: This ***measure*** assesses the status and trend of a highly palatable canopy tree species – kāmahi (*Weinmannia racemosa*) – in native forests managed for possum control on New Zealand's public conservation land at the national scale. Kāmahi was selected as a study species because it is our most abundant canopy-forming tree species, occurring throughout New Zealand and is highly palatable to deer, goats and possums. Death of adult kāmahi trees at local scales has been attributed to browsing by possums.[140] The indicator measures the abundance and size-class structure using three metrics: the total number of stems in 20 size classes nationally, the mean stem diameter in each plot, and the mean number of stems per plot. These metrics are compared between 2002 and 2012 in forests that received possum control and those that did not, to assess whether possum control influences population size and the balance between recruitment of small individuals and mortality of large individuals.

METHODS: The effect of possum control on the population structure of kāmahi was assessed from 327 forest sampling locations located on an 8-km grid nationally. The diameter of each stem was measured[141] initially in 2002–2007 and again in 2009–2012 following the permanent plot method.[142] ***Possum control***[143] was scored as a binary variable for each sampling location (no control or some control) and did not qualify the duration of control or the control methods used. For the first analysis, we calculated the 99.9th percentile diameter for kāmahi nationally (77.3 cm) and removed stems greater than this as these eight stems had a disproportionate effect on the national size-class structure. Stems were then allocated to one of 20 equal-width size classes. We plotted the number of stems in each size class for the 2002–2007 data and the 2009–2012 data for forests that received possum control and those that did not, and fitted a general linear model (GLM) with a log-link function to each. We visually examined whether the standard errors of the fitted models overlapped between the two measurements and between forests that had received possum control and those that had not. For subsequent analyses, we used all stems. Paired *t*-tests with unequal variance were used to determine whether the mean diameter per plot and the number of stems per plot had changed between measurements and with possum control. We only used plots where kāmahi was present (172 of the 327 plots).

RESULTS: At a national scale, the size-class structure of kāmahi has not changed between 2002–2007 and 2009–2012 and the structures overlapped between forests that received possum control and those that did not. There was no effect of possum control on the change in mean diameter per plot between the two measurements at a national scale (mean change without possum control = −0.23 cm, mean change with possum control = −0.56 cm; $t_{125} = -1.22$, $P = 0.22$) or the change in the number of stems per plot (mean change without possum control = −0.7 stems per plot, mean change with possum control = −1.0 stems per plot; $t_{141} = 0.35$, $P = 0.73$; Fig. 31).

INTERPRETATION AND IMPLICATIONS: We know from the Species Occupancy indicator[144] that kāmahi size class structure was stable between 2002–2007 and 2009–2012 but that plots lost an average of 0.9 kāmahi stems each over that period. This indicator suggests that the loss of kāmahi stems nationally was not related to possum control. However, possum control was modelled as a binary predictor and did not accommodate information about the duration of control (which ranged from <1 year to 4 years), or the method of control used. Future analyses of the full network of

[140] Rogers GM, Leathwick JR 1997. Factors predisposing forests to canopy collapse in the southern Ruahine Range, New Zealand. Biological Conservation 80: 325–338.
[141] All surveys were undertaken in the austral summer, e.g. 2012 encompasses the austral summer 2011/12.
[142] Payton IA, Newell CL, Beets P 2004. New Zealand carbon monitoring system indigenous forest and shrubland data collection manual. Prepared for the New Zealand Climate Change Office, Ministry for the Environment, Wellington, New Zealand. 68 p.
[143] ***Possum control*** is a derived variable and is defined on page 43.
[144] See page 33.

DOC/LUCAS sampling locations (>900 forest plots) will have sufficient statistical power to include details of possum control.

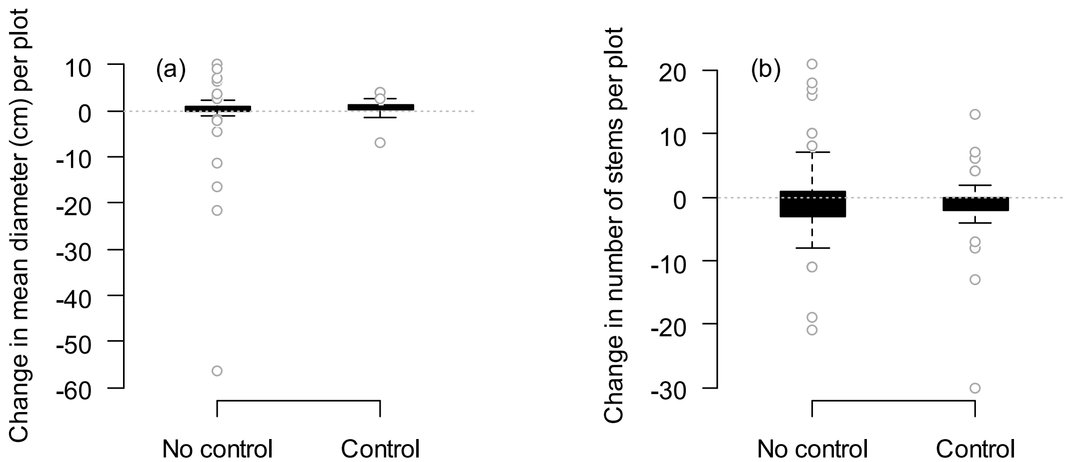

Fig. 31: Change in the mean diameter per plot (a) and number of stems per plot (b) for kāmahi across 327 permanent forest plots between 2002–2007 and 2009–2012. Plots are separated into those that received possum control and those that did not.

MEASURE 2.2.1: Distribution and abundance of exotic weeds and pests considered a threat – Weeds

DEFINITION: This ***measure*** assesses the status of exotic vascular plant species on New Zealand's public conservation land at the national scale. It quantifies the percentage of vascular plant species in forests that are exotic, as a measure of exotic invasion. It also measures the number of exotic vascular plant taxa and their frequency of occurrence and abundance. In particular, it considers changes in the distributions of 47 selected species classified as '***weeds of concern***' by DOC[145] to determine whether ***possum control***[146] resulted in differences in the balance between the richness of native plants and weeds.

METHODS: The effect of possum control on the distribution of weeds was investigated for 328 forest sampling locations located on a national 8-km grid for two measurement periods,[147] 2002–2003 and 2009–2012. Relevé (Recce) measurements were used to assess changes in the composition of all weed species present on a permanent vegetation plot[145]. ***Possum control*** was scored as a binary variable for each sampling location (no control or some control) and did not qualify the duration of control or the control methods used. Interactions among ***possum control***, *forest class* and changes in both number and frequency of occurrence of weed species were assessed with a two-way ANOVA.

RESULTS: There was no evidence that ***possum control*** had a significant effect on either the number of weed species or their frequency (Fig. 32). On average, about two weed species occurred per plot regardless of possum control; this is c. 3% of the total number of vascular plant species. Similarly, there was no significant interaction between possum control and forest class for weed occurrence (F_{325} = 0.095, P = 0.909).

INTERPRETATION AND IMPLICATIONS: There is no evidence that ***possum control*** affects the current distribution and number of weeds in New Zealand forests. This result is likely because weeds are patchily distributed and occur at relatively low abundance in our forests. The unevenness of possum control operations across the country makes detection of possum impacts or interactions with weeds difficult to separate from the numerous other factors driving weed dynamics.

[145] Allen RB, Wright EF, MacLeod CJ, Bellingham PJ, Forsyth DM, Mason NWH, Gormley AM, Marburg AE, MacKenzie DI, McKay M 2009. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Landcare Research Contract Report LC0809/153.

[146] ***Possum control*** is a derived variable and is defined on page 43.

[147] All surveys were undertaken in the austral summer, e.g. 2012 encompasses the austral summer 2011/12.

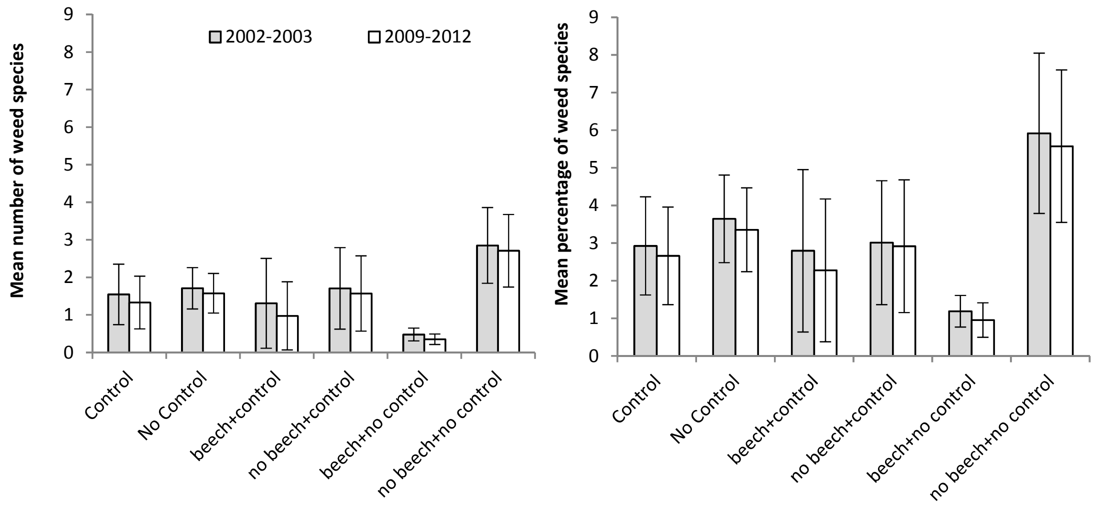

Fig. 32: Mean changes (with 95% confidence intervals) in the number and percentage of weed species per plot in response to *forest class* and *possum control*.

Synopsis

WHAT IS THE STATUS OF SPECIES WHERE POSSUMS ARE BEING MANAGED?

On public conservation land nationally, possums occupied about 70% of non-beech forests, irrespective of whether possum control occurred or not, but their abundance was lower in these forests where control occurred. In non-beech forests, therefore, possum control appears effective in reducing possum abundance. In beech forests, both possums and ungulates were less widespread where control occurred. In future years, when a larger number of sampling locations have been monitored, DOC will be able to verify these relationships between mammal pests and forest class and possum control.

The total number of bird species was similar whether native forests had been subject to possum control or not. The numbers of both native and introduced bird species per location were also comparable, as were average occupancy estimates for both native and introduced species. However, dunnock, whitehead and kererū occupancy estimates tended to be higher where possum control had occurred. For native birds, there was no evidence of possum control impacts on densities at either the community or species level in both forest classes. However, the data so far indicate that there may be inconsistent trends among individual native bird species, suggesting that this nationwide sample is not yet adequate to detect whether their abundances differ according to whether or not possum control has been conducted. The larger number of samples in future years is very likely to resolve whether there are differences in the abundances of birds according to areas of possum control and across different kinds of forests.

The widespread, common tree, kāmahi, is often a major component of possum diets, and is a useful indicator of browsing impacts in forests. There was no change in the average diameter of kāmahi trees on plots first measured in 2002 and most recently in 2012. This means the population of adult trees has generally persisted and those kāmahi trees that died have been replaced by younger stems that have grown in diameter. On the other hand, all forest plots that had kāmahi present in 2002 had lost one kāmahi stem by 2012. New Zealand's forests are dynamic ecosystems and these sorts of changes can arise for many interacting reasons. However, we are confident that the reason for change is unrelated to possum control because the number of kāmahi stems lost per plot was no different between forests that had been subject to possum control and those that had received none. Likewise the average size of kāmahi stems in forests that had been subject to possum control was not different from that in forests where no control had been undertaken. The number of stems lost and the change in diameter were also unrelated to whether or not they were in forests where beech was a major component (with or without possum control).

There is no evidence that possum control had any effect on whether weeds invaded forests. Between 2002 and 2012, the average number of weeds per plot (2 species) did not change and was the same in areas with and without possum control. Similarly, the percentage of weeds of the total number of species in plots remained the same (c. 3%) over time – a pattern that was consistent across forests with and without possum control.

Goal 3: Providing an early-warning system for biodiversity

Introduction

This section provides early-warning signals to potential management responses or research needs in the future. It draws primarily on information and analyses already presented (under the first two management goals; Table 1).

Monitoring weeds

Weeds were relatively widespread throughout forests: they were present on 33% of all forest plots (Measure 2.2.1). However, weeds were abundant (≥ 25% of the seedling subplots on a plot) on only 10% of all plots. These plots are those close to grasslands and closest to settlements, confirming work conducted at local scales in the past.[148,149] Most widespread weeds were non-woody, and most are therefore unlikely to compete with forest canopy species except at the seedling stage. Some long-lived herbaceous weeds, e.g. *Tradescantia fluminensis* have been demonstrated to reduce canopy seedling abundance[150]. Some species were recorded in the first measurement of nationwide plots but not the second, and *vice versa*. Many of the species that invade forests, both woody (e.g. gorse, *Ulex europeaus* and Scotch broom, *Cytisus scoparius*) and non-woody (e.g. the grasses browntop, *Agrostis capillaris* and cocksfoot, *Dactylis glomerata*, Fig. 7) are intolerant of shade, and if forest canopies closed this could be an explanation for lack of persistence of these species on plots between the first and second measurements. Another issue is that species could have been missed or misidentified by different teams and among years.

The nature of weed invasions is that most forest weeds have a long lag phase while they are establishing and usually are not detected until they enter a phase of exponential growth and dispersal mechanisms determine the presence of a species, but the conditions may be unsuitable for long-term persistence. For this reason, the nationwide plots will detect few new weeds because they are at a relatively coarse grain in the landscape. Early warnings of new weeds, or of expanding distributions, will be achieved by combining national plots (Tier 1) with local scale networks of plots (Tier 2 plots) with histories of measurements. The latter will help reveal whether some weed species have populations that remain in areas and which may be dependent on local processes (such as tree falls) for their colonization and growth.

Possum abundance

Although possums were present in a high proportion of forest on the North, South and Stewart islands, the abundances of possums nationally and at low-elevation sampling locations were substantially lower than expected[151] (Measure 2.2.1). The method for estimating possum abundances from trap catch (TCI) has undergone many changes that can affect the estimated TCI independent of any changes in true possum abundance. Hence, estimates from previous studies partly depend on

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[148] Wiser SK, Allen RB, Clinton PW, Platt KH 1998. Community structure and forest invasion by an exotic herb over 23 years. Ecology 79: 2071–2081.

[149] Sullivan JJ, Timmins SM, Williams PA 2005. Movement of exotic plants into coastal native forests from gardens in northern New Zealand. New Zealand Journal of Ecology *29*: 1–10.

[150] Standish RJ, Williams PA, Roberston AW 2001. The impact of an invasive weed *Tradescantia fluminensis* on native forest regeneration. Journal of Applied Ecology 38, 1253–1263.

[151] Efford M 2000. In: Montague T ed. The brushtail possum: biology, impacts and management of an introduced marsupial. Lincoln, Manaaki Whenua Press. Pp. 47–61.

the protocol used in that survey. The comparability of TCI estimates from the sampling protocol and those collected elsewhere therefore depend on the sampling protocol used elsewhere[152].

Further insight as to the effectiveness of possum control can be gained by comparing estimates of possum abundance for each sampling location against estimates of carrying capacity (K) of possums (Fig. 33)[153]. (Note that estimates of K are based on relationships between possum density and habitat type (derived from LCDB2) and therefore may not reflect the actual density of possums at that location). There was moderate evidence for a positive correlation between TCI and K at sampling locations with no recent possum control ($r = 0.274$, $P = 0.048$), with no evidence for a correlation at sampling locations with recent possum control ($r = 0.007$, $P = 0.978$). Although estimates of TCI are not directly comparable with estimates of carrying capacity, the difference in correlation is further evidence for an effect of possum control on reducing possum abundance.

The ultimate value of the monitoring approach is that data from a larger number of sampling locations planned for future years will enable a more precise model of abundance to be determined. The relationship between abundance and a range of biophysical variables can be determined which can then be projected across all public conservation land to derive maps of possum abundance based on empirical data. These models need to take into account depletion caused by possum management, and past habitat degradation by possums which may have removed palatable species (as has happened with the elimination of kōtukutuku, *Fuchsia excorticata*, in some regions of New Zealand[154]).

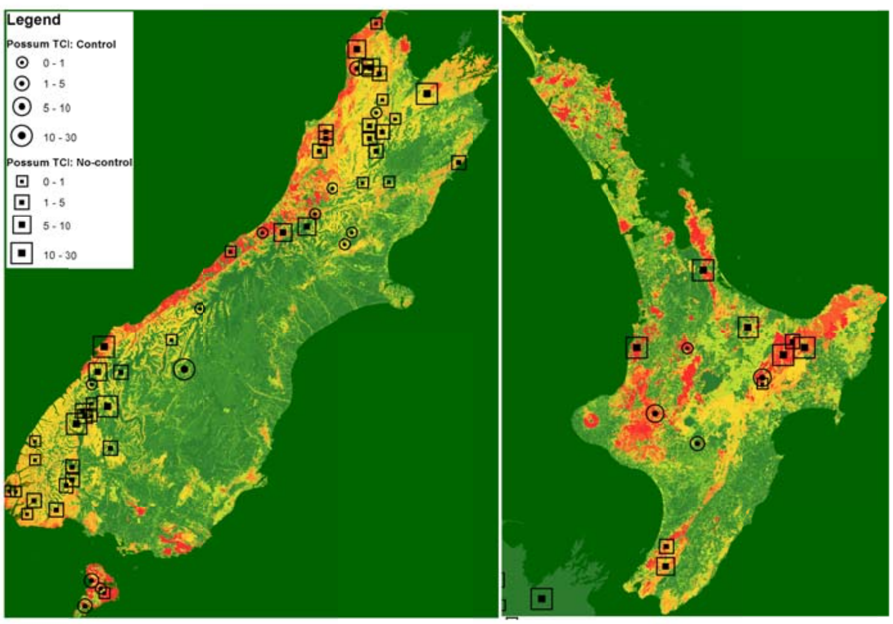

Fig. 33: Possum trap catch indices to compare estimates of possum abundance (TCI) for each sampling location against estimates of carrying capacity (K) of possums[153]. Estimates of K are based on relationships between possum density and habitat type (derived from LCDB2) and therefore may not reflect the actual density of possums at that location (red and green shading indicate high and low K estimates, respectively).

[152] Forsyth DM, Ramsey DSL 2012. Comparability of possum Trap Catch Index (TCI) estimates from the Tier 1 and NPCA monitoring protocols. Unpublished report to New Zealand Department of Conservation. 4 pp.

[153] Warburton B, Cowan P, Shepherd J 2009. How many possums are now in New Zealand following control and how many would there be without it? Landcare Research Contract Report LC0910/60

[154] Pekelharing CJ, Parkes JP, Barker RJ 1998. Possum (*Trichosurus vulpecula*) densities and impacts on fuchsia (*Fuchsia excorticata*) in South Westland, New Zealand. New Zealand Journal of Ecology 22: 197–203

Deer abundance

Little is known about changes in the abundances of deer and feral goats on public conservation land since the 1980s.[155] Our results (Measure 2.2.1) indicate that currently the highest abundances of deer in forests are on the North Island (multiple taxa) and Stewart Island (primarily white-tailed deer *Odocoileus virginianus borealis*). Abundances of deer were lower in the South Island, likely reflecting the history of sustained intensive commercial harvesting of red deer (*Cervus elaphus scoticus*) there since the 1970s.[156] There was also evidence that possum control may have led to increased abundances of ungulates (deer and/or goats) in non-beech forests. One possible mechanism is that commercial and recreational hunters avoid forest in which toxins such as 1080 have been applied, over-compensating any by-kill of ungulates in the poisoning operation.[157]

Rabbits and hares

The absence of rabbits and hares at forest locations was unexpected (Measure 2.2.1). Both species are known to sometimes occur in forests and can impact plant communities through grazing and browsing.[156] Our results indicate that, relative to possums and ungulates, rabbits and hares are extremely uncommon in New Zealand forests and hence unlikely to have important impacts on biodiversity. However, these pests may still be important at forest margins and in upland forest patches.

Native birds

Most of New Zealand's avian research and monitoring effort to date has focused on rare and endangered species, particularly those in forest habitats.[158] However, monitoring changes in widespread and common bird communities is also important, as these species may help maintain key ecosystem services and functions.[159] A 'diminishing dawn chorus' across mainland New Zealand is often cited as evidence that New Zealand's native birds are declining; this has fuelled public debate about whether current management actions are sufficient to sustain the country's native bird communities.[160] To determine if these concerns are valid or not, DOC requires an unbiased assessment of the status of native bird communities at a national scale. A nationwide survey of native forests on public conservation land (Measure 5.1.2), estimated that there were at least five native bird species per location (Fig. 34), with each location supporting, on average, three times as many native birds (9 species) as introduced ones (3 species). So although introduced bird species are widespread in native forests (Fig. 34), native birds are still dominant in this habitat. This indicates that native forests on public conservation lands may not be as silent as perceived. In the future, when the *Biodiversity Monitoring and Reporting System* is implemented across a wider range of locations, DOC will be able to draw stronger inferences about how native bird community composition varies in relation to forest composition and different regions across public conservation lands.

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[155] Forsyth DM, Thomson C, Hartley LJ, MacKenzie DI, Price R, Wright EF, Mortimer JAJ, Nugent G, Wilson L, Livingstone P 2011. Long-term changes in the relative abundances of introduced deer in New Zealand estimated from faecal pellet frequencies. New Zealand Journal of Zoology 38: 237–249.
[156] King CM ed. 2005. Handbook of New Zealand mammals, 2nd edn. Oxford University Press.
[157] Nugent G, Yockney I 2004. Fallow deer deaths during aerial poisoning of possums in the Blue Mountains, Otago. New Zealand Journal of Zoology 31: 185–192.
[158] Innes J, Kelly D, Overton JMcC, Gillies C 2010. Predation and other factors currently limiting New Zealand's forest birds. New Zealand Journal of Ecology 34: 86–114.
[159] Gaston K 2010. Valuing common species. Science 327: 154–155.
[160] Parliamentary Commissioner for the Environment 2011. Evaluating the use of 1080: Predators, poisons and silent forests. Wellington, Parliamentary Commissioner for the Environment.

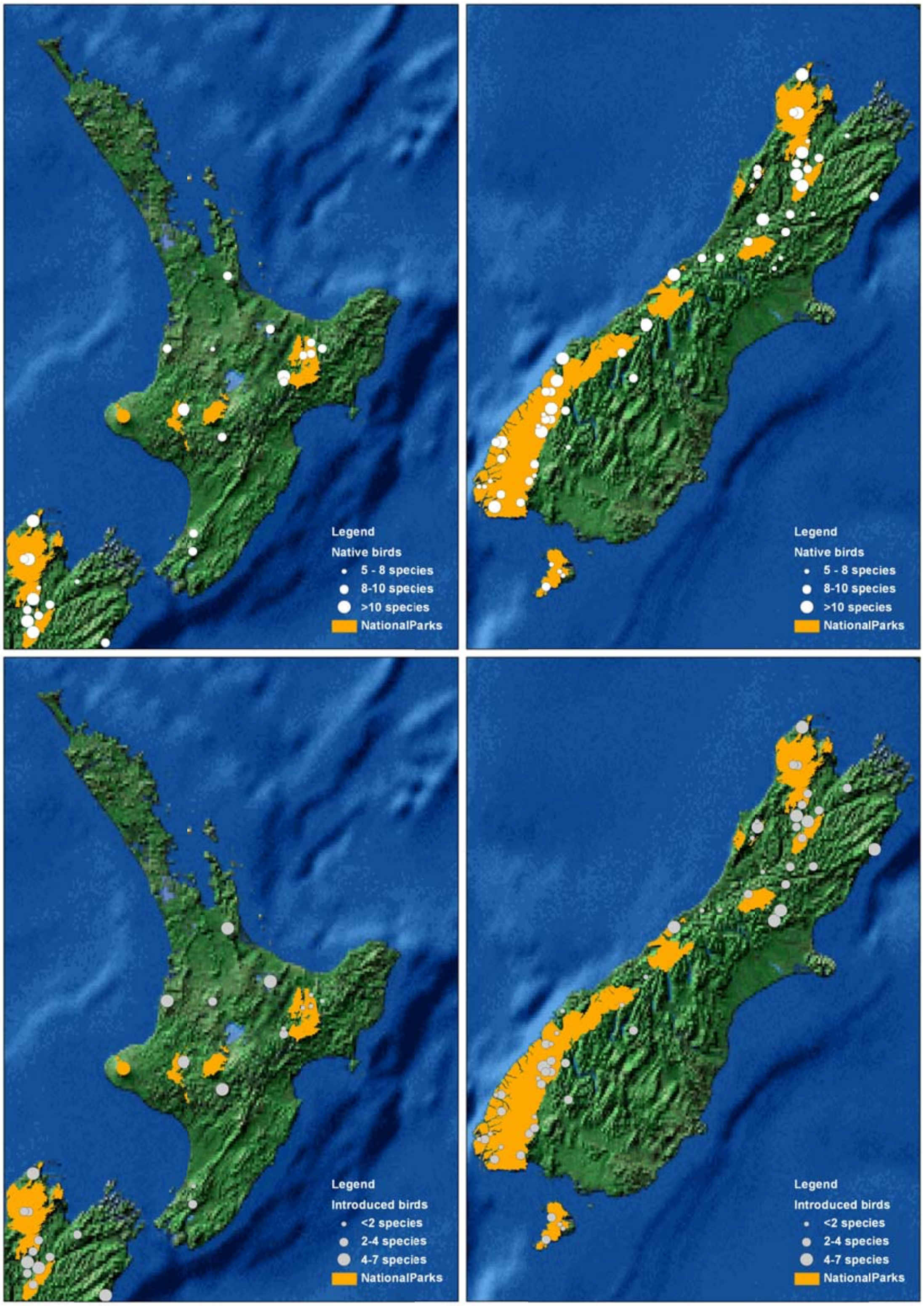

Fig. 34: Species richness estimates for native and introduced birds (Measure 5.1.2) for sampling locations in native forests on public conservation lands in relation to *National Parks*.

Goal 4: Prioritisation for management

Introduction

This section reviews the results presented in this report to provide guidance on the prioritisation of management to maintain ***ecological integrity***, largely on native forests on public conservation land. It draws primarily on information and analyses already presented (under the first three management goals), but also integrates the data available for the different ***ecological integrity measures*** (Table 1).

Weeds

An emergent finding from unbiased nationwide evaluation of weed distribution and abundance is to confirm that current management priorities of focusing attention on management of weeds close to forest margins, especially those close to grasslands, and on forests close to settlements are soundly based. Regular remeasurements of Tier 1 plots will also allow DOC to update its schedule of ***weeds of concern***. An interesting feature of measurements so far is that species considered ***weeds of concern*** were not necessarily the most abundant. Some widespread, locally abundant weeds that are not currently considered ***weeds of concern*** are of low biomass as adult plants; examples include the grass cocksfoot (*Dactylis glomerata*) and the creeping ground cover African clubmoss (*Selaginella kraussiana*). Plants of low biomass are often assumed to be of little consequence for ecological function and maintenance of forest regeneration. While this can be the case[161], it isn't always so[162]. Therefore, in light of current national assessments, some targeted research could focus on the effects of widespread, locally abundant weeds currently not considered as ***weeds of concern*** to determine whether they might merit a change in status, and that in any case these species are "something to watch" in future measurements of Tier 1 and Tier 2 plots.

Palatable tree species and introduced mammals

One of New Zealand's most widespread canopy trees, kāmahi, is palatable to both ungulates and possums. At a national scale, there is no evidence over the last decade that its regeneration is impeded or that kāmahi canopies are not being maintained. The widespread regeneration of kāmahi contrasts with long-term records from fenced exclosures throughout New Zealand, in which it is apparent that ungulates can suppress regeneration of palatable species, including kāmahi, over several decades, especially in forests that are recovering from past natural disturbances, such as storms that destroyed the previous canopy[163,164]. An implication of this discrepancy is that fenced exclosures give a useful, but unrepresentative, view of forest regeneration. It is important, for prioritisation of management, to determine why some forests depart from the general nationwide trend and have lower levels of regeneration.

A priority for management will be to focus on where and why local forest areas depart from the national trend, i.e., have poor regeneration of palatable tree species. Reasons could include that there has been little control of mammals or that environmental conditions result in circumstances that support high mammal densities, or that palatable species have been removed by dense populations

[161] Grime JP 1998. Benefits of plant diversity to ecosystems: immediate, filter and founder effects Journal of Ecology 86: 902–910.
[162] Peltzer DA, Bellingham PJ, Kurokawa H, Walker LR, Wardle DA, Yeates GW 2009. Punching above their weight: low-biomass non-native plant species alter soil properties during primary succession Oikos 118: 1001–1014.
[163] Mason NWH, Peltzer DA, Richardson SJ, Bellingham PJ, Allen RB 2010. Stand development moderates effects of ungulate exclusion on foliar traits in the forests of New Zealand. Journal of Ecology 98: 1422–1433
[164] Husheer SW 2007. Introduced red deer reduce tree regeneration in Pureora Forest, central North Island, New Zealand. New Zealand Journal of Ecology 31: 79–87

of mammals in the past, and that palatable plants have not dispersed to these areas since, or are outcompeted by the induced unpalatable community[5,165]. The capacity to make direct links between mammalian herbivore density and the maintenance of palatable tree species will be improved in future years when we have a larger number of sample points with indices of mammal densities.

Palatable plant species are often most abundant on soils with high levels of soil nutrients, and these more fertile areas may, in turn, support high densities of introduced mammalian herbivores. To find out if this is the case, we have collected data on soil nutrient concentrations from 70 of the nationwide network of plots. There is little data to make strong inferences, but there are some indicative trends and future years' data will reveal whether these relationships are sufficiently strong to allow us to better target control of introduced mammals. For example, there was a weak positive relationship between the index of densities of wild ungulates (deer and goats) and the concentration of phosphorus (P) in soils (Spearman rank correlation r = 0.28, P = 0.033; Fig. 35). Unexpectedly, however, the dominance of palatable plant species (as defined in earlier studies of ungulate exclosures[163]) was not significantly related to soil P concentrations (Spearman rank correlation r = –0.21, P = 0.11; Fig. 35). With increasing numbers of remeasured plots, we anticipate that we will be better able to identify the characteristics of where introduced mammals and palatable plants most frequently coincide nowadays and where management might be expected to have maximum effect.

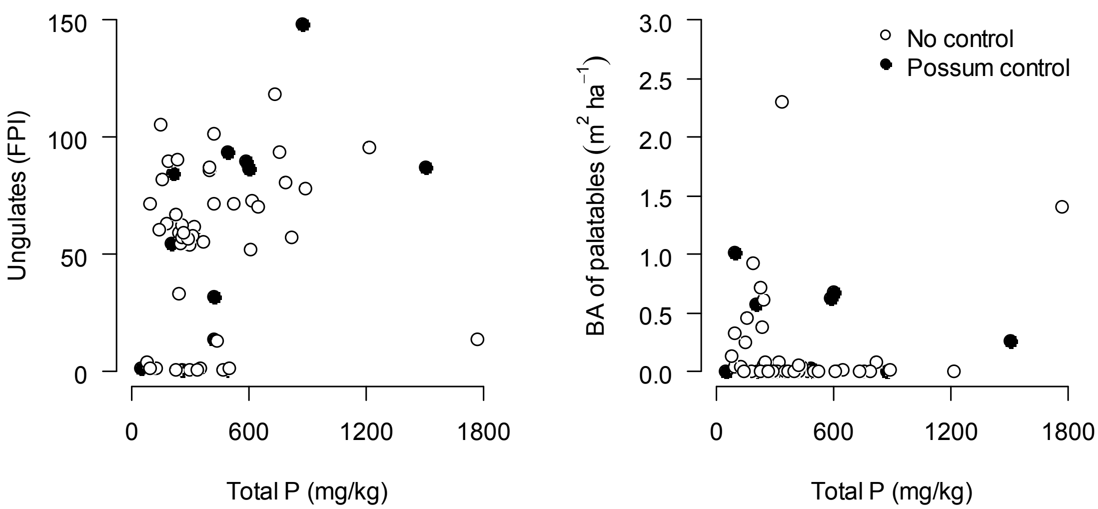

Fig. 35: Correlations between soil total phosphorus[166,167] (Total P) and the abundance of ungulates (left) and basal area of palatable plant species (right) at locations with (filled symbols) or without (open symbols) possum control. N = 58 locations for both panels.

Managing multiple invasive species

The national evaluation of introduced mammals and weeds across New Zealand's forests gives us the first opportunity to evaluate on patterns of co-occurrence. Other invasions that hitherto seldom receive much priority (invasions by introduced birds) might also be considered in an evaluation of how much the goal of optimising ecological integrity is being achieved.

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[165] Coomes DA, Allen RB, Forsyth DM, Lee WG 2003. Factors preventing the recovery of New Zealand forests following control of invasive deer. Conservation Biology 17: 450–459.

[166] Blakemore LC, Searle PL, Daly BK 1987. Methods for chemical analysis of soils. NZ Soil Bureau Scientific Report 80.

[167] Richardson SJ, Peltzer DA, Allen RB, McGlone MS, Parfitt RL 2004. Rapid development of phosphorus limitation in temperate rainforest along the Franz Josef soil chronosequence. Oecologia 139: 267−276.

If multiple pests (mammals and weeds) co-occur at particular locations, management can be focused on a subset of the landscape. Indications from the sample points so far are that individual groups of introduced organisms do not invade the same regions of forests. For example there is no relationship between the faecal pellet indices for introduced ungulates (goats and deer) and trap catch indices for possums in forests nationally (both in areas subject to possum control and those without; Fig. 366). There is no relationship between the extent of mammal (possum and ungulate) invasions and invasions either by weeds or introduced birds (All Spearman rank correlation tests *P* >0.1), and there is no relationship between the extent of invasion and the number of native species present (either of native palatable plant stems, native birds, or both; Fig. 36).

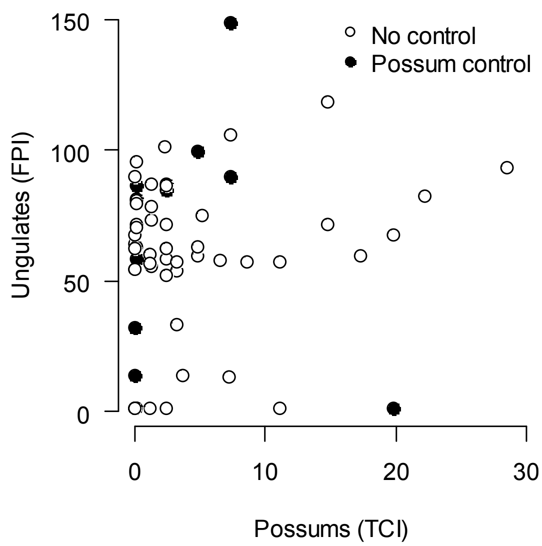

Fig. 36: Relationship between the abundance of ungulates and possums at locations with and without possum control (64 locations).

The implication is that priorities for management action will require better understanding of the drivers of individual invasions, and whether the impacts of invasions are additive. More samples from the widespread plot network (Tier 1), supplemented by local plot networks (Tier 2) will assist in these interpretations, and repeated measurements will reveal the extent to which there is change with time (for example, during forest succession after disturbance). Another implication is that benefits for ecological integrity will require optimisation in space[168] and time[169], and that there is no reason to assume that optimising management to control one invader, or group of invaders, will necessarily lead to gain in all native components of ecosystems[168].

The power to detect impacts of possum control will improve with more sample points. The range of response variables (native plants and birds) evaluated will allow a more integrated view of ecosystem response to control. This will allow improved reporting by DOC that is required by regulations relating to use of toxins (e.g. as required by the Environmental Protection Agency).

[168] Mason NWH, Ausseil AE, Dymond JR, Overton JM, Price R, Carswell FE 2012. Will use of non-biodiversity objectives to select areas for ecological restoration always compromise biodiversity gains? Biological Conservation 155: 157–168.
[169] Dickie IA, Yeates GW, St. John MG, Stevenson BA, Scott JT, Rillig MC, Peltzer DA, Orwin KH, Kirschbaum MUF, Hunt JE, Burrows LE, Barbour MM, Aislabie J 2011. Ecosystem service and biodiversity trade-offs in two woody successions. Journal of Applied Ecology 48: 926–934.

Threatened naturally uncommon ecosystems

An implication of the process of evaluation of threats to naturally uncommon ecosystems[170] is that DOC might evaluate whether the current levels of protection of critically endangered and endangered ecosystems is adequate on public conservation land. In particular, critically endangered and endangered ecosystems that are in 'stewardship' land might merit higher prioritisation for management.

The designation of some naturally uncommon ecosystems as critically endangered and endangered on public conservation land might also inform some priorities for management action. These actions could include mapping and biological inventories of these ecosystems (including collation of existing information), and determination of suitable methods for determining the status, trend, and threats within and among them.

[170] Holdaway RJ, Wiser SK, Williams PA 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26: 619–629.

APPENDIX I

Changes in the mean number of stems per plot and the mean diameter per plot for 14 palatable species between the first (2002–2007) and second (2009–2012) measurement of the permanent plot network. Diet indicates the animal species to which each plant species is palatable (D = deer; P = possum; G = goat)[171]. No. plots are the number of plots where the species was present at the first measurement. T-test statistics and *P* values are given for each species, testing for a significant difference in the value of mean change from zero. Degrees of freedom for each species are number of plots – 1. The following palatable species were not analysed as they were present on ≤ 10 plots at the first measurement: *Coprosma rotundifolia*, *Coprosma tenuifolia*, *Fuchsia excorticata*, *Raukaua edgerlyii*, *Hoheria lyallii*. Note that all analyses were conducted on non-quality assured data.

Species	Diet	No. plots	Mean no. stems 2002	Mean no. stems 2009	Mean change	*t*	*P*	Mean diameter 2002	Mean diameter 2009	Mean change	*t*	*P*
Aristotelia serrata	DP	18	13.0	11.4	–1.6	0.727	0.477	5.8	6.0	0.17	0.200	0.844
Brachyglottis repanda	P	22	24.0	24.7	0.7	0.200	0.844	3.3	3.5	0.20	0.639	0.530
Coprosma foetidissima	DGP	77	14.9	14.8	–0.1	0.261	0.795	3.6	3.8	0.26	2.006	0.048
Coprosma grandifolia	DGP	40	8.9	8.9	0.0	0.000	1.000	6.6	6.4	–0.21	0.349	0.729
Coprosma lucida	DG	30	3.1	3.8	0.7	1.650	0.110	4.9	4.1	–0.79	1.728	0.095
Geniostoma ligustrifolIum	G	36	10.0	12.4	2.4	0.997	0.325	4.0	4.4	0.37	1.126	0.268
Griselinia littoralis	DG	102	9.1	8.9	–0.2	0.568	0.571	13.1	14.0	0.87	2.018	0.046
Melicytus ramiflorus	DGP	86	11.9	12.9	1.0	1.401	0.165	9.4	9.6	0.18	1.021	0.310
Myrsine salicina	P	31	19.4	22.6	3.2	1.358	0.185	9.1	8.9	–0.20	0.682	0.501
Podocarpus hallii	P	86	7.8	8.1	0.3	1.947	0.055	11.1	11.2	0.09	0.604	0.548
Pseudopanax arboreus	DGP	11	30.5	44.1	13.6	1.280	0.229	5.8	6.5	0.75	1.316	0.217
Pseudopanax crassifolius	DGP	106	4.4	4.8	0.4	2.513	0.014	6.3	6.5	0.26	0.900	0.370
Raukaua simplex	DGP	60	6.6	6.5	–0.1	0.467	0.642	6.5	6.7	0.18	0.633	0.529
Schefflera digitata	DGP	27	6.4	7.3	0.9	0.618	0.542	4.9	5.2	0.30	0.578	0.568

[171] Allen RB, Wright EF, MacLeod CJ, Bellingham PJ, Forsyth DM, Mason NWH, Gormley AM, Marburg AE, MacKenzie DI, McKay M 2009. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Landcare Research Contract Report LC0809/153.