Recovery after sustained ungulate control: the structure and condition of kamahi forests at Mount Bruce, Wairarapa

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ABSTRACT

Deer and goats are ubiquitous in New Zealand forests. These introduced mammals have caused widespread damage and modification to forest structures and altered the mix of plant species. There are few areas on mainland New Zealand where deer and goats are excluded or controlled to a low density. Here, we examine the structure and condition of forest of the c. 1000-ha Mount Bruce Reserve in Wairarapa after sustained deer and goat control since the late 1990s. There were encouraging signs of a recovery in the diversity of plant species in the forest understorey, indicating the resilience of the forest. Regeneration of kamahi (*Weinmannia racemosa*) trees was also widespread. Kamahi are an important structural component of forests in the Tararua Range. Monitoring at Mount Bruce offers an opportunity to compare forest processes with similar forest types in the Tararua Range. This should enable a better understanding of the long-term ecological effects of deer and goats in the Wellington region.

INTRODUCTION

The population dynamics of dominant canopy tree species are of much interest to conservation managers. As Allen *et al.* (2002) pointed out: "*Relatively high mortality over large areas, and little or no recruitment, would give…cause for concern*".

In the case of kamahi (*Weinmannia racemosa*) for example, several studies have shown that there are inadequate levels of regeneration in some North Island forests (e.g., Payton *et al.* 1984; Rogers and Leathwick 1997). These authors linked the regeneration failure to the presence of deer and goats eating young kamahi plants.

A lack of young kamahi plants over several decades may lead to a decline in the population, as older stems succumb to mortality. Husheer (2005) identified an imbalance of kamahi mortality over recruitment in the Tararua

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Range between 1975 and 1985, with few seedlings being recruited into taller height classes. In contrast, Bellingham *et al.* (1999) found that in eight out of nine forests throughout the country, kamahi mortality was less than, or more or less equal to, recruitment over a 14–23 year period. Nevertheless, given Husheer's recent analysis, an important management question for the Department of Conservation is the extent to which ungulate control is required to protect kamahi forest regeneration.

The Department of Conservation has produced a plan to monitor deer and goat impacts in forests it administers in Wellington Conservancy (Urlich 2005). Monitoring is focused on whether there is adequate regeneration of structurally dominant tree species, as well as palatable (ungulate preferred) understorey and subcanopy species. This means monitoring in places where deer and goats are excluded or controlled such as at Pukaha Mount Bruce, and where the Department controls goats only as in the nearby Tararua Range.

In April and May 2005, the Department established permanent vegetation plots and seedling ratio transects at Mount Bruce. Data will eventually be compared to data gathered from the Tararua Forest Park (Urlich 2005). In the interim, the purpose of this report is to address the following questions:

1. What is the structure and composition of Mount Bruce hill forests dominated by kamahi?
2. What is the population structure of kamahi?
3. What is the regeneration status of plant species preferred by deer and goats; how do they compare with moderately preferred and not-preferred species?

METHODS

Data collection – permanent plots

Sampling was stratified by the presence of intact kamahi forest. Permanent plots of 20 m × 20 m dimension were established along transects; plots were spaced 100 m apart[3]. A map of plot locations is in an appendix. Vegetation within plots was measured according to the methods described in Allen (1993) and Payton *et al.* (2004).

Seedling plot methods were modified within the permanent plots. Nine 1.14 m radius subplots were positioned at the intersection of internal quadrat boundary lines. All plants rooted within the three dimensional radius were recorded. This enabled the recording of kamahi seedlings that were established on raised substrates or epiphytic on tree ferns. All woody species were counted in standard understorey height tiers 15–45, 46–75, 76–105 and 106–135 centimetres.

3 For expanded methodology and raw data and analysis contact the author.

Kamahi seedlings (>5 cm high but <2.5 cm diameter at breast height, dbh) that were rooted within the 1.14 m radius understorey plot were tagged with aluminium tree tags tied to the seedling base by plastic or wire ties. Plants heights were recorded for 51 tall seedlings. Note that "extended" plant height measurement was used (to highest apical bud) instead of "natural, standing height" as this was considered a more accurate and consistent method for recording changes in individual plant height.

Analysis – permanent plots

Basal area and stem density were calculated for individual plant species. These were analysed with respect to the ungulate diet preference classification (Preferred, Not-Selected, Avoided) from Forsyth *et al.* (2002). These are defined as follows:

"Preferred – plant species eaten more than expected from their availability;
Not selected – plant species eaten in proportion to their availability;
Avoided – plant species eaten less than expected based on their availability."

Data collection and analysis – seedling ratio transects

Twenty transects of twenty plots were established to study the ratio of plants with different diet preference classifications. Transects were established at 200 m intervals. Plot measurement was based on Sweetapple and Nugent (2004). All woody species, lianes, and selected fern species with a natural height (i.e., not extended) <30 cm that were rooted within a 49-cm radius of the subplot centre were recorded for presence. All species (described above) between 30 cm and 200 cm natural height were recorded for presence if rooted within a 114-cm radius of the subplot centre.

RESULTS

Permanent plots species composition

Mean plot basal area was 90.5 m^2/ha (Table 1). Stem and saplings numbers were similarly high, with all plot means >3250 per ha. This probably reflects recovery of the understorey and sub-canopy following the removal of ungulate browsing pressure.

Table 1. Mean n0. of stems and saplings per hectare from the 12 plots (+ 1 standard error) for all species combined. Also shown is the mean basal area from each plot (m^2/ha).

Mean no. stems + 1 SEM	Range	Mean no. saplings + 1 SEM	Range	Mean plot basal area + 1 SEM	Range
3277 + 272	2275–5550	3325 + 470	1400–6100	90.5 + 4.5	65.6–119.0

To examine this in more detail, individual plant species density and basal area were analysed (Table 2). The first point to note is that kamahi dominated the stand structure in each plot. Mean basal area was 55.0 m^2/ha and stem density was over double that of the next most abundant species, which was

the ungulate-avoided kātote (*Cyathea smithii*) (Table 2). Kātote typically occupied the lower tiers of the forest, and their ubiquity may partly be an artefact of past animal abundance.

Table 2. Mean number of stems and saplings (per hectare + 1 standard error) of the most common species in each diet preference class at Mount Bruce, and mean basal area from each plot (m^2/ha). Ungulate diet preferences taken from Forsyth *et al.* (2002).

Species	Mean no. stems + 1 SEM	Range	Mean no. saplings + 1 SEM	Range	Mean plot basal area + 1 SEM	Range
'Preferred'						
Kamahi	1260 + 317	350–4250	152 + 48	0–450	55.0 + 4.6	27.8–77.5
Kanono	15 + 12	0–150	46 + 11	0–125	0.01 + 0.01	0–0.1
Broadleaf	65 + 43	0–525	98 + 32	0–375	0.4 + 0.2	0–2.7
Māhoe	50 + 19	0–225	344 + 113	0–1200	0.7 + 0.4	0–3.8
'Not selected'						
Hīnau	102 + 47	0–600	252 + 89	0–925	1.9 + 0.9	0–10.2
Pigeonwood	240 + 80	0–1025	694 + 165	175–2275	1.2 + 0.5	0–5.7
Toro	352 + 157	0–1875	85 + 44	0–425	3.5 + 1.3	0–14.5
Putaputaweta	2 + 1	0–275	2 + 1	0–125	0.9 + 0.6	0–5.8
'Avoided'						
Rimu	8 + 4	0–25	13 + 13	0–150	6.9 + 3.9	0–37.9
Maire	46 + 14	0–125	404 + 112	25–1100	1.5 + 0.7	0–6.4
Rewarewa	77 + 44	0–525	85 + 33	0–375	2.3 + 1.5	0–18.2
Mountain horopito	160 + 54	0–525	127 + 42	0–375	0.4 + 0.2	0–2.2
Lowland horopito	92 + 30	0–325	50 + 16	0–175	0.3 + 0.1	0–1.8
Kātote (Tree fern)	446 + 105	25–1200	150 + 34	0–350	10.5 + 2.7	0.3–30.2

Hīnau, pigeonwood, toro, rewarewa, and black maire were the most common hardwood tree species associated with kamahi in the canopy tier, with occasional emergent rimu present in four of the twelve plots. There were good numbers of 'preferred' and 'not-selected' species throughout the plots, although their distribution was patchy. A list of plant species identified in this study is in Table 3. In contrast to other studies from the Tararua range, the 'avoided' pepperwood did not dominate the plot understorey.

Permanent plots stand structure

To examine the overall kamahi population structure, size-class data from all plots was combined (Fig. 1). The population was dominated by stems in the smallest two classes (2.5 cm up to 22.4 cm dbh). Saplings numbers were less than one-third of the number of stems in the smallest size class, and almost half the saplings (44%) were epicormic shoots from existing trees. Kamahi

seedling density (>5 cm high) was around 1150 per hectare, indicating ongoing regeneration.

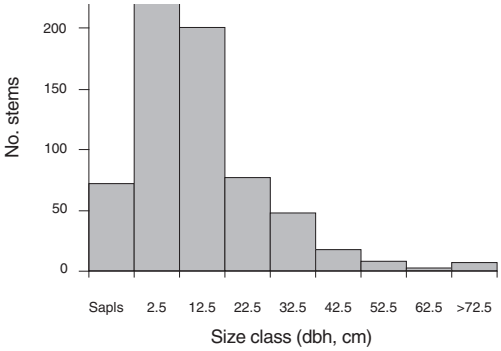

Figure 1. Size-class frequency distribution of kamahi stems at Mount Bruce (n = 678).

To further test whether the forest was recovering from sustained ungulate browse, size-class frequency distributions for 'preferred' and 'avoided' species were examined (Fig. 2). All 'preferred' species (kanono, broadleaf and Māhoe) had structures characteristic of young and/or rapidly cycling populations (Figs. 2a–c). All had a majority of stems in the sapling class, with the rest in the two smallest size classes. In contrast, the 'avoided' horopito (Fig. 3d) had less numbers of saplings than small stems; although the population was likely to be of similar age to the 'preferred' species.

Seedling ratio transect patterns

There were no obvious differences in the ratio of plants with different ungulate diet preferences (Fig. 3). There were abundant 'preferred' seedlings and saplings, indicating that the patterns in the permanent plots were widespread across the reserve. This provides further support for recovery of plant communities from the reduction of ungulate browsing.

DISCUSSION

The kamahi stands appear to be healthy and relatively free of deer and goat predation. 'Preferred' plant species are a significant part of the understorey in the intact forest. 'Avoided' woody species do not dominate this tier, as they do in the nearby Tararua range (e.g., Holloway *et al.* 1963; Husheer 2005). However, 'avoided' tree ferns are common, possibly reflecting these species have benefited from the influence of past sustained ungulate browsing.

The kamahi population appears to be in good shape, with plenty of small stems and some establishment of new plants evident. Much of Mount Bruce was burnt or cleared, and browsing animals impacts were also severe in the past (Tony Silbery, Department of Conservation, Wairarapa Area Office, pers comm.). Kamahi regeneration throughout Mount Bruce, particularly in

seral (regenerating) stands, appears to be widespread. Tall kamahi seedlings (between 30 and 200 cm) were found in 75% of the Seedling Ratio Index (SRI) transects.

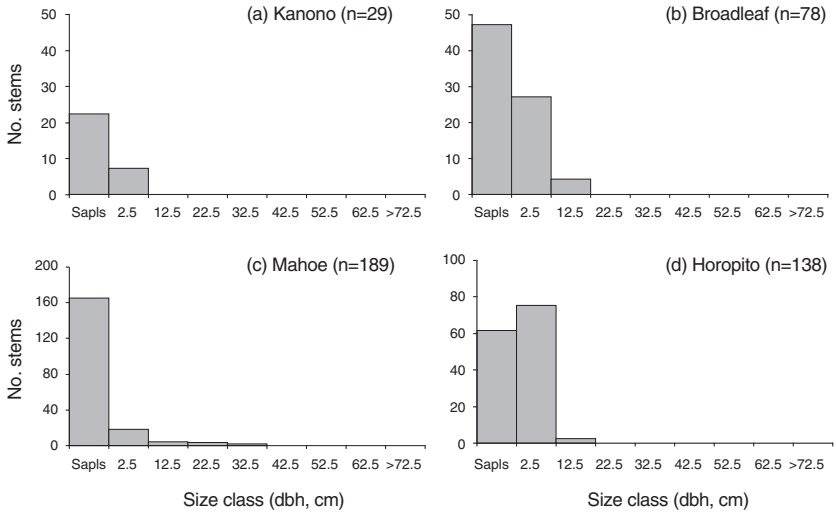

Figure 2. Size-class frequency distribution of (a) kanono, (b) broadleaf, (c) Māhoe, and (d) mountain horopito stems at Mount Bruce.

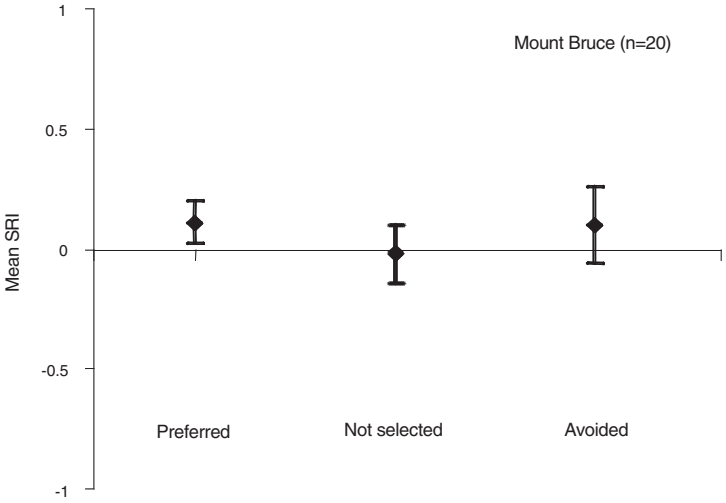

Figure 3. Mean SRI score (Seedling Ratio Index *sensu* Sweetapple and Nugent 2004) +/- 95% confidence intervals by ungulate diet preference classes at Mount Bruce, Wairarapa forests.

Ungulates (deer and goats) have been intensively controlled over the last 10 years, and eradication has been attempted from 2001 (Tony Silbery, pers comm.). 'Judas' goats were inserted in 2004, and monitoring suggests that goats are now in extremely low numbers and eradication appears imminent. Deer are either absent or in such low numbers that sign is difficult to detect. The response of 'preferred' plants in the plots reflects the release from predation, and the high plot basal areas suggest the plots are now in recovery.

Increased numbers of plant species preferred by deer and goats should also benefit native birds such as kererū (*Hemiphaga novaeseelandiae*) and kokako (*Callaeas cinerea*). This is because these plants provide berries for native birds. Increasing the abundance and diversity of native birds is a central goal of the Pukaha Mount Bruce restoration project.

ACKNOWLEDGMENTS

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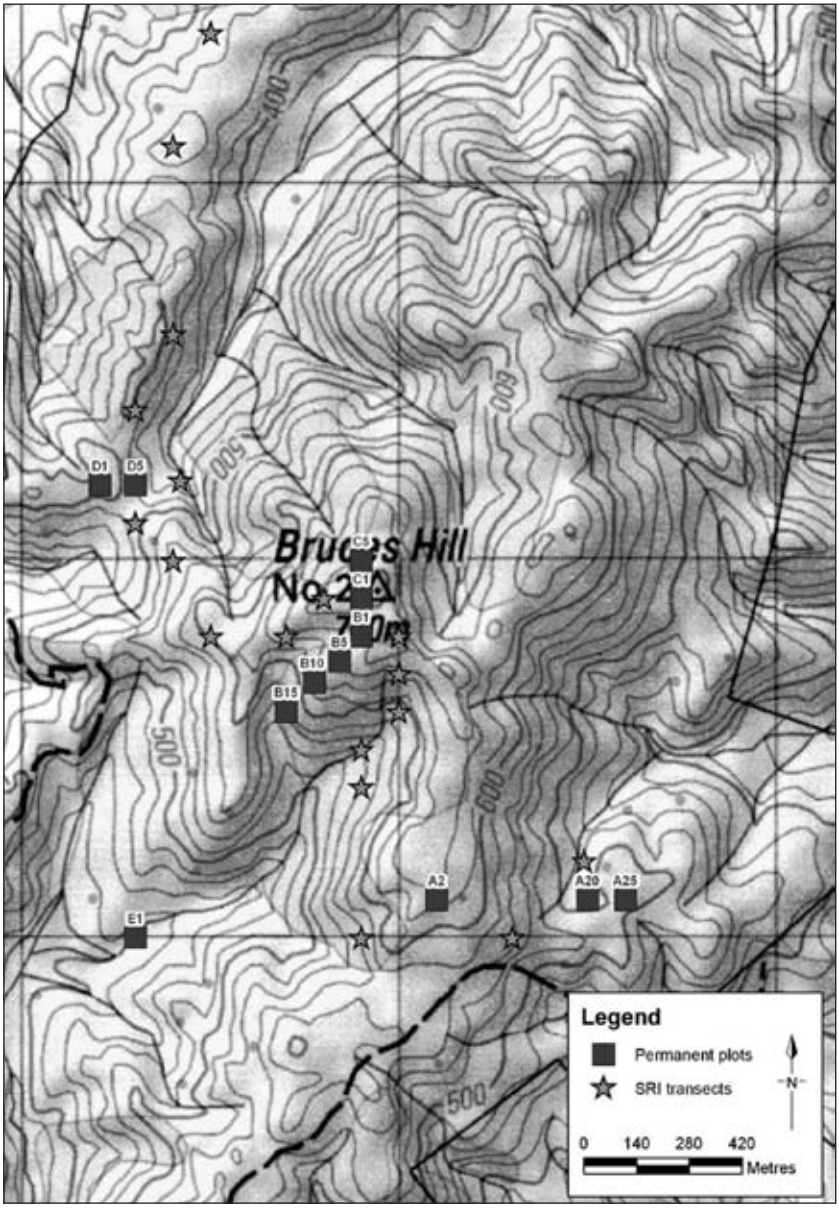
APPENDIX 1

Map showing permanent plot locations and approximate location of seedling ratio index transects at Pukaha Mount Bruce.



APPENDIX 2

List of plant species by ungulate diet preference class found in the 12 permanent plots and 20 SRI transects (after Forsyth *et al.* 2002); and Sweetapple and Nugent (2004) for species not included in Forsyth *et al.* Where there is inconsistency with browse preference between these authors, the classification of Forsyth *et al.* has been used.

Woody species		Ferns and lianes	
'Preferred'			
Kamahi	*Weinmannia racemosa*	Hen and chickens fern	*Asplenium bulbiferum*
Broadleaf	*Griselinia littoralis*	Hound's tongue	*Microsorum pustulatum* subsp. *pustulatum*
Māhoe	*Melicytus ramiflorus*	Supplejack	*Ripogonum scandens*
Narrow-leaved māhoe	*Melicytus lanceolatus*		
Kanono	*Coprosma grandifolia*		
Karamu	*Coprosma lucida*		
Wineberry	*Aristotelia serrata*		
Pate	*Schefflera digitata*		
Five-finger	*Pseudopanax arboreus*		
Lancewood	*Pseudopanax crassifolius*		
Raukawa	*Raukaua edgerleyi*		
Hangehange	*Geniostoma ligustrifolium* var. *ligustrifolium*		
Matipo	*Myrsine australis*		
Fuchsia	*Fuchsia excorticata*		
Hoheria	*Hoheria sexstylosa*		
Hoheria	*Hoheria* aff. *sexstylosa* (AK 234306; Tararua Ranges)		
'Not selected'			
Rangiora	*Brachyglottis repanda*	Kiokio	*Blechnum novaezelandiae*
Putaputaweta	*Carpodetus serratus*	Prickly shield fern	*Polystichum vestitum*
Pigeonwood	*Hedycarya arborea*	Wheki	*Dicksonia squarrosa*
Toro	*Myrsine salicina*	Bushlawyer	*Rubus cissoides*
Mapou	*Myrsine divaricata*	Clematis	*Clematis* spp.
Hīnau	*Elaeocarpus dentatus*		
Pokaka	*Elaeocarpus hookerianus*		
Kaikomako	*Pennantia corymbosa*		
Tarata	*Pittosporum eugenioides*		
Hupiro	*Coprosma foetidissima*		
Common coprosma	*Coprosma rhamnoides*		

Woody species		**Ferns and lianes**	
Haumakaroa	*Raukaua simplex*		
Heketara	*Olearia rani*		
'Avoided'			
Rimu	*Dacrydium cupressinum*	Kātote	*Cyathea smithii*
Miro	*Prumnopitys ferruginea*	Silver fern	*Cyathea dealbata*
Mountain totara	*Podocarpus cunninghamii*	Crown fern	*Blechnum discolor*
Tawa	*Beilschmiedia tawa*	Heruheru	*Leptopteris hymenophylloides*
Rewarewa	*Knightia excelsa*	Water fern	*Histiopteris incisa*
Black maire	*Nestegis cunninghamii*	Native jasmine	*Parsonsia spp.*
White maire	*Nestegis lanceolata*		
Red beech	*Nothofagus fusca*		
Mountain horopito	*Pseudowintera colorata*		
Lowland horopito	*Pseudowintera axillaris*		
Rohutu	*Neomyrtus pendunculata*		
Upland coprosma	*Coprosma colensoi*		
Ongaonga	*Urtica ferox*		
Ongaonga	*Urtica incisa*		
Alseuosmia	*Alseuosmia pusilla*		
Mingimingi	*Leucopogon fasciculatus*		