Floristic changes over 30 years in a Canterbury Plains kānuka forest remnant, and comparison with adjacent vegetation types

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Abstract: The Canterbury Plains have lost most of their pre-Polynesian indigenous vegetation, primarily forest and shrubland. One of the few remaining areas is the 2.3 ha Eyrewell Scientific Reserve which consists mostly of low kānuka (*Kunzea ericoides*) forest and a small area of grassland. We assessed the Reserve vegetation using a combination of plots and transect surveys at different times of the year between 2001–2003. For comparison with the Reserve vegetation we also assessed plots in an adjacent grazed kānuka remnant, adjacent cultivated pasture and Eyrewell Forest, a pine plantation. Our study of the Eyrewell Reserve in 2001–2003 found that since an assessment of the Reserve in 1972, 28 indigenous species were no longer present but 14 indigenous species and 48 adventive species were newly recorded. The dramatic invasion of the Reserve is illustrated by the fact that 60% of the 118 species recorded in 2003 were adventives compared to 34% in 1972. Despite this invasion and the loss of indigenous species, Reserve plots still have more than twice as many species as plots in the adjacent pine plantation. The Reserve also included several species of high conservation value such as the "Chronically Threatened" *Leptinella serrulata*, and the "At Risk" *Aciphylla subflabellata*, *Coprosma intertexta* and *Pterostylis tristis*. Plots in the Reserve grassland and adjacent pasture had the lowest percentage of indigenous species of all habitat types, with the pasture plots having no indigenous vascular plant species. In contrast the understorey of the old pine stands had the highest percentage of indigenous species of any of the habitats and in places was dominated by kānuka up to 4 m tall, indicating that these plantations also have conservation value. Eyrewell Reserve and the few other remaining kānuka remnants in the Canterbury Plains represent an important pool of indigenous species for conservation. Options for the future management of the Reserve are discussed.

Keywords: Eyrewell Reserve; biodiversity; vascular plants; succession; plantation forests; *Pinus radiata*; indigenous; adventive.

Introduction

The Canterbury Plains are among the regions of New Zealand that experienced the most severe loss of the original, pre-Polynesian vegetation (McEwen, 1987; Leathwick *et al.,* 2003). Today the Plains are mostly farmland and urban areas with some exotic plantation forest. Little remains of the natural vegetation, and in the Lower Plains Ecological District this accounts for less than 0.5% of the total area (E. Brockerhoff, unpublished data; Thompson *et al.,* 2003). The pre-Polynesian vegetation of the dry Canterbury Plains (average annual rainfall is about 800 mm) is thought to have consisted of lowland podocarp-broadleaf forest on deeper soils, kānuka (*Kunzea ericoides*) shrubland on stony, free-draining soils, and some grassland primarily on disturbed sites (Molloy and Ives, 1972; McGlone, 1989; Wardle, 1991). Low forest or tall shrubland of kānuka was probably a dominant feature of the Eyrewell area (Burrows, 1969; Molloy, 1969). Recent modelling of the potential natural vegetation suggests that much of the Canterbury Plains sustained tall podocarp forest as climax, but on the poorest stony soils, as in the Eyrewell area, kānuka forest, perhaps with some totara (*Podocarpus totara*), may well have been the climax (Matt McGlone, Landcare Research, Lincoln, pers. comm.) or at least a long seral stage following natural disturbance.

Only a few small remnants that are representative of the original kānuka shrubland remain on the Canterbury Plains and in the adjacent Culverden Basin (Molloy, 1971b; Meurk *et al.*, 1995), totalling less than 200 ha out of about 720 000 ha in these two ecological districts. The largest of these remnants, the Medbury Scientific Reserve in the Culverden Basin, extended over 55 ha but in February 2003 a fire destroyed about 70% of vegetation in the reserve (Head *et al.,* 2005). On the Plains all remnant patches

of kānuka are <20 ha, and the two Department of Conservation (DoC) managed reserves, Bankside Scientific Reserve[1] and Eyrewell Scientific Reserve, cover only 2.6 ha and 2.3 ha, respectively (Molloy, 1971a; Meurk *et al.*, 1995). As representatives of the formerly common Lowland Plains kānuka shrubland, these vegetation remnants are considered to be among the most important in Canterbury (Molloy and Ives, 1972), and they are one of the rarest remaining indigenous ecosystems in New Zealand. Because of their small size and high degree of fragmentation they are susceptible to abiotic and biotic disturbance. The consequences of fragmentation and edge effects include increased susceptibility to invasions by exotic plants and animals (Timmins and Williams, 1991; Hobbs and Huenneke, 1992; Murcia, 1995; Ross *et al*., 2002). The small fragments in this dry region are also threatened by fire, which is exemplified by the recent devastating fire in the Medbury Reserve.

A detailed account of the vegetation, climate, geology, soils, history, and fauna of Eyrewell Scientific Reserve is given by Molloy and Ives (1972). Another description of Eyrewell Reserve was given by Kelly (1972). A more recent account of the vegetation of Eyrewell Reserve and several other kānuka remnants of the Canterbury Plains was given by Meurk *et al.* (1995). These studies suggest that the plant communities characteristic of this kānuka shrubland appear structurally simple, but they are in fact relatively species rich, and each site has a unique suite of species. Molloy and Ives (1972) recorded 84 vascular plant species in Eyrewell Reserve whereas Meurk *et al.* (1995) found 49 species. The latter survey was based on only one brief autumn visit, but notes an invasion of exotics and loss of indigenous species.

Recently, we carried out a comprehensive survey of the vegetation of Eyrewell Reserve to identify the changes in indigenous and exotic plant species composition that occurred since the original survey by Molloy and Ives (1972). We also assessed a small, grazed kānuka remnant adjacent to the Reserve for comparison with the protected and ungrazed DoC managed reserve. In addition, we assessed representatives of the other major vegetation types in the area, namely pasture and plantations of pine, *Pinus radiata*. This enabled us to examine to what extent elements of the kānuka remnants occur in the land occupied by a non-native grassland and in a managed forest with a non-native canopy tree species to assess their potential conservation value as surrogate habitats, and also whether the grassland or plantation forest act as sources of invasive species that were found in the Reserve. The pine stands surveyed are all part of Eyrewell Forest and were planted about 4–5, 16, and 26 years prior to our survey, representing young, mid-rotation, and mature stands, respectively.

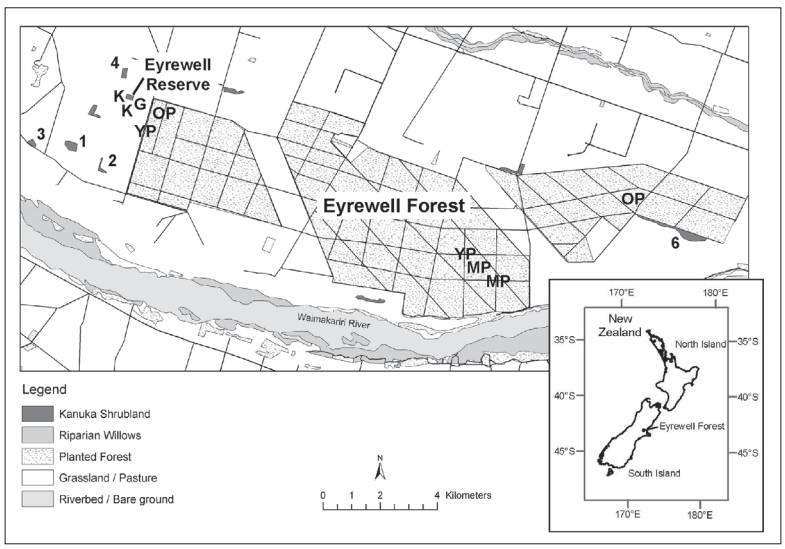

Figure 1. The kānuka fragment archipelago in the sea of exotic vegetation around Eyrewell Reserve, and the location of study plots in kānuka shrubland (K), grassland/pasture (G), and young, mid-rotation and mature stands in the Eyrewell Forest pine plantation (YP, MP, OP, respectively). Numbers adjacent to kānuka shrubland refer to descriptions in Meurk *et al.* (1995) where site 6 is indicated as 'farm' site on Hetherton Rd.

[1] The Reserves Act 1977 (Section 21) defines the principal purpose of 'Scientific Reserves' as "…the protection and preservation in perpetuity of areas for scientific study, research, education and the benefit of the country."

Table 1. Description of study plots in Eyrewell Scientific Reserve, adjacent pasture and in Eyrewell Forest, a pine plantation (plot area 314 m^2).

Vegetation	Location	Latitude (South)	Longitude (East)
Kānuka shrubland and low forest	Eyrewell Reserve	43°23'	172°12
Kānuka shrubland	Adjacent Eyrewell Reserve	43°23'	172°12'
Grassland, some kānuka	Eyrewell Reserve	43°23'	172°12'
Pasture	Adjacent Eyrewell Reserve	43°23'	172°12'
Pine, 4 yr (stand 1)	Adjacent Eyrewell Reserve	43°23'	172°12'
Pine, 5 yr (stand 2)	Central Eyrewell Forest	43°26'	172°20'
Pine, 16 yr (stand 3)	Central Eyrewell Forest	43°26'	172°21'
Pine, 16 yr (stand 4)	Central Eyrewell Forest	43°26'	172°21'
Pine, 26 yr (stand 5)	Adjacent Eyrewell Reserve	43°23'	172°12'
Pine, 26 yr (stand 6)	Eastern Eyrewell Forest	43°25'	172°24'

Methods

Study areas and assessment methods

Eyrewell Reserve is located on the Canterbury Plains about 6 km north of the Waimakariri River and 4 km east of Burnt Hill at an altitude of 215 m (Fig. 1). Most of the adjacent land is pasture but there is a home garden and a farmyard directly to the west. Other kānuka remnants on private land near the Reserve are located to the south, and the Eyrewell Forest plantation is about 200 m southeast of the Reserve. Eyrewell Forest was originally planted with *Pinus radiata* between 1928 and 1932, and before this, the area was partly covered in open kānuka shrubland up to 10 m tall (Wendelken, 1966). A total of 25 vegetation reconnaissance plots were assessed for this study with three to six replicates per habitat type, covering shrubland and grassland in Eyrewell Reserve, adjacent, grazed kānuka shrubland, and pasture, as well as three chronosequence stages of the pine plantation (Table 1). Most reconnaissance plots were assessed in January and February 2001, and some pine plots were examined in November 1997 and January 1998. Vegetation reconnaissance plots were circular with a radius of 10 m (area ca. 0.031 ha). Plots were assessed with a relevé method (Hall, 1992; Allen *et al.,* 1995) similar to that of Mueller-Dombois and Ellenberg (1974). This entailed recording the vegetation in each of five vertical tiers: <0.3 m, 0.3–2 m, 2–5 m, 5–12 m, and >12 m. In each tier, cover classes were assigned for each recorded vascular plant species according to the following classification: <1% cover, 1; 1–5% cover, 2; 5–25%, 3; 25–50%, 4; 50–75%, 5; 75–100%, 6. In addition, data on height and diameter were obtained for several kānuka and pine trees in January 2001. Diameter was measured at breast height (dbh), and tree height was estimated with a Vertex digital hypsometer.

The recent species list for Eyrewell Reserve was compiled from plot data and additional intensive searching of the reserve on 6–7 February 2001, 3 December 2001, 2 December 2002 and 7 March 2003 covering different times from early summer to early autumn. During those visits the reserve was comprehensively searched using a series of north to south transects. Plant identifications were made either in the field or from specimens collected for later identification. Voucher specimens were lodged in the National Forestry Herbarium, Rotorua (NZFRI). The Allan Herbarium (CHR) was searched for voucher specimens lodged by Molloy and these were re-assessed if they were affected by taxonomic revisions or where there was possible disparity with our identifications. Species nomenclature follows Allan Herbarium (2000).

Data analysis

Raw data consisting of cover and tier values for each species were combined to give one importance value for each species for use in ordination and other analyses according to Allen *et al*. (1995). To group vegetation plots along similarity gradients, we performed detrended correspondence analysis (DECORANA, DCA) (Hill, 1979). Rescaling and detrending was performed using 26 segments per axis. SAS V. 8 or SYSTAT V. 9 were used to perform ANOVAs and LSD tests for post-hoc comparison of means. PC-ORD for Windows, V. 4.01 (McCune and Mefford, 1999), was used for DCA.

Results

Flora of Eyrewell Reserve

Dramatic changes in the vegetation of Eyrewell Reserve have occurred since 1972. Kānuka and exotic grasses

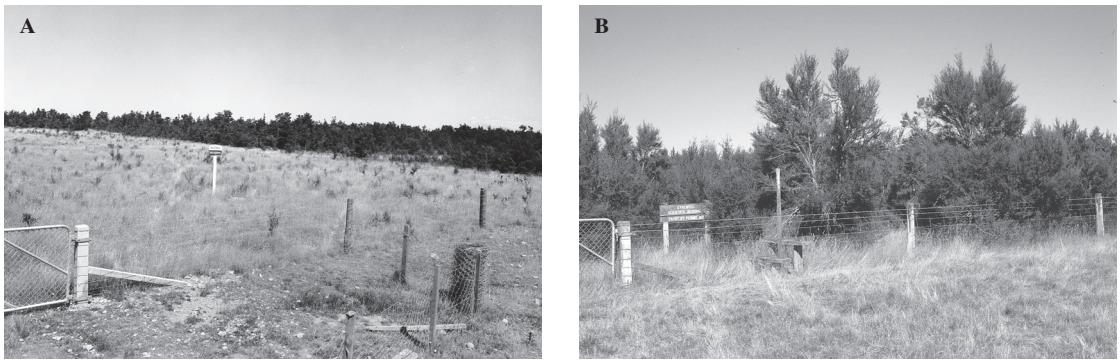

Figure 2. The open indigenous grassland and herbfield area at the eastern end of Eyrewell Reserve. (a) In 1972 (Molloy and Ives, 1972). (b) 2003.

have invaded most of the former indigenous grassland, which has been reduced to a few scattered tussocks, and a dry open herbfield has virtually disappeared (Fig. 2). A total of 153 vascular plant species, including 75 indigenous and 78 adventive species, have been recorded during the two previous surveys and our survey of the small reserve (Tables 2 & 3). In the present study 118 species were found; in comparison Molloy found 88 species (84 species were included in the report (Molloy and Ives, 1972) but four additional species collected by Molloy were vouchered in the Allan Herbarium). Twenty-eight indigenous species found by Molloy or Meurk *et al*. (1995) could not be found despite repeated searches. These species were all previously found either in the short tussock grassland, an open herbfield or along the edges of the kānuka shrubland. Indigenous species not found in the present study include 16 dicotyledonous herbs, two grasses, three orchids, one sedge, one fern, and five shrubs. In addition, seven adventive dicotyledonous herbs were not found.

On the other hand, 14 indigenous species were found in the reserve that had not been previously recorded. Single plants were found of two of these species, *Coprosma intertexta* and *Melicytus alpinus*, which had previously been recorded near, but not in, the reserve (Molloy and Ives, 1972). Indigenous species new to the reserve included the ferns *Asplenium flabellifolium*, *Hypolepis ambigua* and *Microsorum pustulatum*, as well as several herbs and shrubs that are common in disturbed habitats such as *Epilobium cinereum*, *Senecio glomeratus, Senecio minimus*, and *Solanum laciniatum*.

The greatest change to the flora of the reserve, however, is the large number of adventive vascular plant species, 48 in all, which have established since 1972 (Fig. 3, Table 3). Adventive species now constitute 60% of the flora in this reserve compared with about 34% recorded by Molloy. Adventives that have become major components of the vegetation, in approximate order of importance, are *Anthoxanthum odoratum* (mean summed cover value 7.5), *Agrostis capillaris* (3.5), *Crepis capillaris* (3.0), and *Hypochoeris radicata* (2.3). The two exotic grasses have replaced much of the indigenous grassland and some of the indigenous understorey vegetation. In addition, broom, *Cytisus scoparius*, has become very prominent in patches, although it did not score a high cover value in the plots. New adventives that are particularly noteworthy because of their weed potential include *Ribes sanguineum* (1.3), *Sambucus nigra* (0.8), *Buddleja davidii* (0.5), *Cotoneaster simonsii* (0.5), and *Rubus fruticosus* (0.3). Furthermore, a large *Pinus radiata* (17.2 m tall, 0.54 m dbh), with some scattered seedlings occurred near the northwestern boundary of the Reserve. This pine was more than double the height of the surrounding kānuka trees despite their greater age. Some of the largest kānuka in the Reserve were measured at 5.8 – 7.4 m tall and 85–148 mm dbh.

Comparison with surrounding vegetation

Eyrewell Reserve is more species rich (plot means of 18.5 indigenous and 21.8 adventive species) than an adjacent, grazed kānuka remnant on private farmland (10.0 indigenous, 16.0 adventive). These kānuka plots, taken together, are considerably richer in both indigenous and adventive species than the plots in adjacent grassland/pasture and the pine plantation (Fig. 4). Pasture plots were entirely exotic (means of 0.0 indigenous species, 12.5 adventives) and even the grassland plot inside Eyrewell Reserve was dominated by adventives (9 indigenous, 16 adventive). In the pine plantation, there was no great difference in mean richness among young, mid-rotation and old stands but the percentage of indigenous species increased significantly from young to old stands.

Table 2. Indigenous species recorded in Eyrewell Reserve by Molloy *et al.* (1972), Meurk *et al*. (1995) or in the present study, and species recorded in vegetation plots in nearby unfenced shrubland, pasture or pine plantation.

Species	1972	1995	2001-2003	Shrubland	Pasture	Pine forest	Species	1972	1995	2001-2003	Shrubland	Pasture	Pine forest
Acaena novae-zealandiae	†	x					*Leptinella pusilla* [3]	x	x	x	x		x
Aciphylla subflabellata [1, 2]	x						*Leptinella serrulata* [2, 3]	x					
Asplenium flabellifolium			x				*Leptospermum scoparium*	x	x				
Brachyglottis bellidioides [3]	x	x	x				*Leucopogon fraseri* [3]	x	x	x			x
Caladenia lyallii	x						*Luzula rufa* var. *rufa*	x		x			
Carex breviculmis	x	x	x			x	*Melicytus alpinus* [3]	†		x			
Carex colensoi	x						*Mentha cunninghamii*	x					
Carex goyenii			x			x	*Microlaena stipoides*	x	x	x	x		x
Carmichaelia australis [3]	x	x	x	x		x	*Microsorum pustulatum*			x			
Celmisia gracilenta	x	x	x			x	*Microtis unifolia*	x		x			x
Clematis quadribracteolata			x			x	*Muehlenbeckia axillaris*	x	x				x
Coprosma crassifolia			x				*Nertera setulosa*	x	x	x			
Coprosma intertexta [2]	†		x				*Ophioglossum coriaceum*	x					
Coprosma propinqua	x	x	x				*Oxalis exilis* [3]	x	x	x	x		
Coprosma rhamnoides	x	x					*Ozothamnus leptophyllus* [3]	†	x				
Cyathodes juniperina	x	x	x			x	*Pimelea* sp. (seedling)	x					
Deyeuxia avenoides	x	x	x			x	*Poa cita* [3]	x	x	x			
Dichelachne crinita	x	x	x	x		x	*Poa pusilla*			x			
Dichondra brevifolia	x					x	*Pomaderris* aff. *phylicifolia* [3, 6]	x		x			x
Dichondra repens	x	x	x	x		x	*Prasophyllum colensoi*	x					
Discaria toumatou	†	x	x				*Pteridium esculentum*						x
Epilobium alsinoides ssp. *atriplicifolium*			x				*Pterostylis tristis* [2, 3]	x					
Epilobium cinereum			x				*Pyrrhanthera exigua*	x					
Euchiton audax [3]	x	x	x	x		x	*Ranunculus multiscapus* [3]	x					
Euchiton collinus [3]						x	*Raoulia monroi*	x					
Euchiton sphaericus [1]	x						*Rytidosperma clavatum* [3]	x			x		x
Festuca novae-zelandiae	x		x				*Rytidosperma gracile* [3]	x		x			x
Galium perpusillum	x						*Rytidosperma unarede* [3]	x	x	x	x		x
Galium propinquum	x	x	x				*Scleranthus uniflorus* [1]	x					
Geranium microphyllum	x		x	x			*Senecio glomeratus*			x	x		x
Geranium sessiliflorum	x						*Senecio minimus*			x			
Gonocarpus incanus [4]	x						*Senecio quadridentatus*						x
Gonocarpus micranthus [3]	x						*Solanum laciniatum*			x			
Helichrysum filicaule	x						*Stackhousia minima*	x	x	x			
Hydrocotyle moschata [5]	x	x	x				*Thelymitra longifolia*	x		x			x
Hypericum gramineum	x	x	x			x	*Thelymitra pauciflora*	x	x[7]	x			
Hypolepis ambigua			x				*Viola cunninghamii*	x					
Kunzea ericoides [3]	x	x	x	x		x	*Wahlenbergia albomarginata*	x	x				
Lagenifera strangulata [3]	x	x	x				*Wahlenbergia violacea* [3]	x	x	x	x		x

† Species growing in the area but not recorded from the reserve.

[1] Although not reported by Molloy *et al.* 1972 as growing in the reserve the locality given on the voucher in the Allan Herbarium (CHR) is "Eyrewell Reserve".

[2] Threatened species, see de Lange *et al.* (2004).

[3] Species recorded under another name by Molloy and Ives (1972) or Meurk *et al*. (1995)

[4] This species is on the voucher sheet (CHR 386268) collected by B.P.J. Molloy together with *Gonocarpus micranthus*.

[5] Meurk *et al*. (1995) record *Hydrocotyle novae-zeelandiae* in Eyrewell Reserve but we found *H. moschata* and suggest that these two species have been confused.

[6] *Pomaderris* aff. *phylicifolia* is the very common species which reaches its southern limit at Eyrewell (Brandon *et al*. 2004, Peter de Lange pers. comm.) and is not the species recorded as threatened by de Lange *et al.* (2004).

[7] Identification uncertain.

Table 3. Adventive species recorded in Eyrewell Reserve by Molloy *et al.* (1972), Meurk *et al*. (1995) or in the present study, and species recorded in vegetation plots in nearby unfenced shrubland, pasture or pine plantation.

Species	1972	1995	2001-2003	Shrubland	Pasture	Pine forest	Species	1972	1995	2001-2003	Shrubland	Pasture	Pine forest
Acaena agnipila						x	*Linum catharticum*	x					
Acer pseudoplatanus (1 seedling)			x				*Lolium perenne*			x	x	x	
Achillea millefolium			x	x	x	x	*Luzula flaccida*[2]			x			
Agrostis capillaris[1]	x	x	x	x	x	x	*Mycelis muralis*			x			
Agrostis stolonifera					x	x	*Pelargonium inodorum*	x		x	x		
Aira caryophyllea	x	x	x	x		x	*Pinus radiata*			x			x
Anthoxanthum odoratum	x	x	x	x	x	x	*Plantago lanceolata*			x	x	x	x
Anthriscus caucalis			x				*Poa pratensis*			x		x	
Aphanes inexspectata			x				*Prunus cerasus*[2]			x			
Bromus stamineus			x				*Prunus* sp. (seedlings)			x			
Buddleja davidii			x				*Ribes sanguineum*			x			
Cardamine hirsuta			x				*Rosa rubiginosa*	x		x			x
Cerastium fontanum ssp. *vulgare*[1]	x	x	x	x		x	*Rubus fruticosus* agg.			x			
Cerastium glomeratum			x			x	*Rubus idaeus*			x			
Chenopodium album			x				*Rubus laciniatus*						x
Cirsium arvense			x			x	*Rubus* sp.			x			
Cirsium vulgare	x	x	x	x		x	*Rumex acetosella*	x	x	x	x	x	x
Conyza sumatrensis[1]			x				*Sagina apetala*	x					
Cotoneaster simonsii			x				*Sambucus nigra*			x			
Crepis capillaris	x	x	x	x	x	x	*Senecio jacobaea*			x			
Crepis vesicaria ssp. *taraxifolia*			x				*Sisyrinchium striatum*			x			
Cynosurus echinatus			x				*Solanum dulcamara*			x			
Cytisus scoparius	x	x	x			x	*Sonchus asper*			x	x		
Dactylis glomerata			x	x			*Sonchus oleraceus*			x			
Digitalis purpurea			x				*Spergularia rubra*	x					
Dryopteris filix-mas			x				*Stellaria media*			x			
Duchesnea indica			x				*Tanacetum parthenium*			x			
Echium vulgare					x		*Taraxacum officinale*			x	x		x
Elymus rectisetus[1]	x	x	x	x	x	x	*Trifolium arvense*	x					
Epilobium ciliatum			x	x			*Trifolium dubium*	x	x	x			
Fallopia convolvulus			x				*Trifolium glomeratum*	x					
Festuca rubra			x				*Trifolium repens*	x	x	x	x	x	x
Fragaria vesca			x				*Trifolium striatum*	x					
Galium aparine			x				*Trifolium subterraneum*	x	x			x	x
Hieracium aurantiacum						x	*Ulex europaeus*	x	x	x	x		x
Hieracium lepidulum[1]	x		x			x	*Urtica urens*			x			
Hieracium pilosella	x	x	x	x		x	*Verbascum thapsus*	x	x	x	x		
Hieracium praealtum	x	x	x			x	*Veronica arvensis*			x			
Holcus lanatus	x		x	x	x		*Vicia sativa*[1]	x		x			x
Hypochoeris radicata	x	x	x	x	x	x	*Vicia tetrasperma*			x			
Leucanthemum vulgare						x	*Viola odorata*			x			
Leontodon taraxacoides	x		x				*Vulpia bromoides*	x		x	x		

[1] Species recorded under another name by Molloy and Ives (1972) or Meurk *et al*. (1995).
[2] Identification uncertain.

The different species composition of these vegetation types is reflected in the consistent plot grouping in the ordination analysis (Fig. 5). The kānuka plots inside Eyrewell Reserve are clearly separated from all other plots. By contrast, the grassland plot in the Reserve is placed near the pasture plots and the young pine plots adjacent to the reserve, all of which are dominated by adventive species. Between these plots and the Eyrewell Reserve kānuka plots are the two grazed kānuka plots on farmland which included a number of grassland species. The other pine plots are separated along the first ordination axis from the remainder of the plots. This grouping is not due to the presence of many unique elements in the pine area

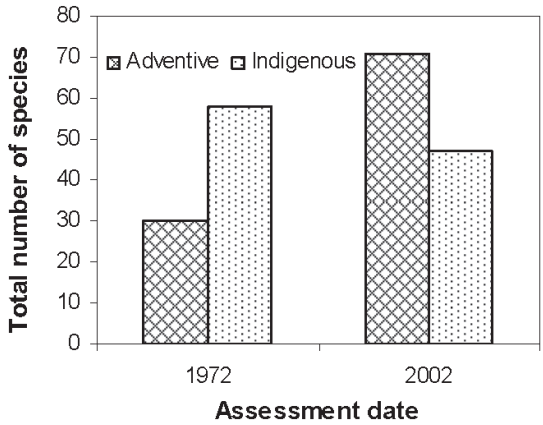

Figure 3. Changes to indigenous and adventive vascular plant species richness in Eyrewell Reserve from 1972 (Molloy and Ives, 1972) to 2003. Note: Two species Molloy & Ives (1972) recorded as native, *Elymus rectisetus* (= *Agropyron scabrum*) and *Pelargonium inodorum*, are now considered adventive and were included in the analysis as such.

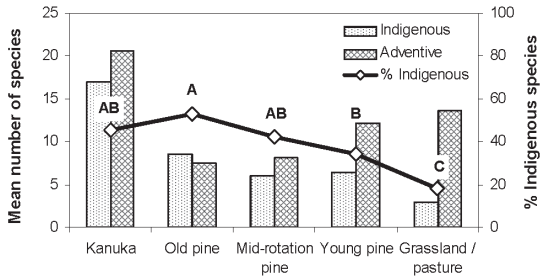

Figure 4. Mean species richness and percentage of indigenous species in plots in kānuka shrubland/low forest, three successional stages in an adjacent pine plantation and in grassland/pasture (plot area 314 m^2). Note: Kānuka includes plots in the Eyrewell Reserve and in adjacent kānuka on private farmland, and grassland/pasture includes grassland in the Reserve and pasture on the adjacent farmland. Significant differences (P <0.05) in the percentage of indigenous species are indicated by habitat types not sharing a letter.

(only seven species are exclusive to these pine plots, the indigenous *Euchiton collinus*, *Pteridium esculentum*, *Senecio quadridentatus*, and the adventives *Acaena agnipila*, *Hieracium aurantiacum*, *Leucanthemum vulgare*, and *Rubus laciniatus*, all of which are sparse), but rather to the absence of numerous indigenous grassland herbs and a number of adventives. Only two species, *Agrostis stolonifera* and *Echium vulgare,* were in the pasture plots and not also found in the Reserve. Most species of conservation interest were exclusively recorded in the Reserve except for *Pomaderris* aff. *phylicifolia* which occurred in both the Reserve and in some of the plots in the pine plantation.

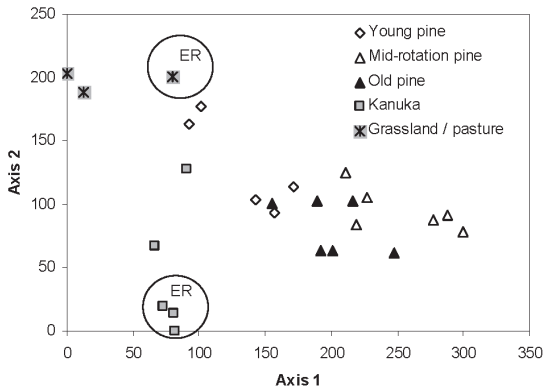

Figure 5. DCA ordination of vegetation reconnaissance plot data for kānuka remnants, a pine plantation chronosequence, and grassland/pasture. Eyrewell Reserve plots are encircled and marked 'ER'. Note: Grassland/pasture plot (co-ordinates 80/201) is in the Eyrewell Reserve, the other plots are grazed pasture.

Discussion

Eyrewell Reserve vegetation

This study confirms the special significance of the Eyrewell Scientific Reserve as a relic of the once widespread kānuka woodland vegetation of the Canterbury Plains. Despite its small area, it has a remarkably large number of indigenous vascular plant species, compared to other sites on the Canterbury Plains. Apart from its value as a locally threatened plant community, the Reserve records also include several species of high conservation value (de Lange *et al.*, 2004): *Leptinella serrulata*, listed as 'Chronically Threatened' and under 'Gradual Decline'; *Aciphylla subflabellata*, *Coprosma intertexta*, and *Pterostylis tristis*, listed as 'At Risk' and nationally 'Sparse'; and *Pomaderris* aff. *phylicifolia*, which is at its southern limit and has its only natural occurrence in the South Island in this area. However, a significant decline of several indigenous elements of the Reserve vegetation, including some threatened species, has occurred since the assessment more than 30 years ago by Molloy (Molloy and Ives, 1972), and the dramatic increase of adventive species is another cause for concern.

A major change in the reserve is that the indigenous species of open grassland and dryland herbfields have largely disappeared as kānuka and exotic grasses have invaded the open areas. Compared with the original assessment (Molloy and Ives, 1972), only a few scattered plants remain of the "small area dominated by fescue tussock (*Festuca novae-zelandiae*)" (Molloy and Ives, 1972). Even though a few species could have been easily missed, such as the ephemeral orchids *Pterostylis tristis* and *Caladenia lyallii*, the diminutive fern *Ophioglossum coriaceum*, as well as *Dichondra brevifolia*, *Leptinella serrulata* and *Rytidosperma clavatum*, this does not account for the absence of 28 indigenous species. Among the species lost is the nationally 'Sparse' *Aciphylla subflabellata*. An intriguing apparent loss is that of mānuka (*Leptospermum scoparium*) which used to be the second-most important species "numerically" according to Molloy and Ives (1972). This is probably mainly due to mānuka blight which has devastated this species in the Canterbury lowlands (Zondag, 1977) and it is well known that mānuka declines over time while kānuka becomes dominant (e.g. Allen *et al*., 1992; Bergin *et al*., 1995). Although we were unable to find any mānuka within the Reserve, there is one by a nearby water race. Furthermore, there are only a few remaining matagouri plants and we found only a single *Melicytus alpinus*, which suggests that these species are barely persisting in the reserve. Molloy and Ives (1972) may have correctly predicted that these species, as well as *Ozothamnus leptophyllus* and *Coprosma intertexta*, would eventually be eliminated as they become out-competed and overtopped by the faster growing kānuka. An additional species that appears to have been lost already from the area is *Olearia lineata* which is listed as nationally 'Sparse'. A herbarium specimen collected in 1946 (NZFRI 3595) and labelled as from "mixed scrub" at "Eyrewell" confirms that *O. lineata* was present at least in the wider area and it may still be on Burnt Hill (Colin Meurk, Landcare Research, Lincoln, N.Z., pers. comm.).

While Molloy & Ives (1972) commented on the "relatively low number (30) of adventive species", we recorded more than twice as many (71), even though a few species from the original list of adventives seem to have gone. This invasion by adventives, especially grasses, has certainly contributed to the decline of indigenous species in the Reserve. Many adventive plants are considered environmental weeds because they compete with or even replace indigenous plant species or communities (Atkinson and Cameron, 1993; Williams and West, 2000; Mack *et al*., 2000). A substantial number of serious environmental weeds now occur in Eyrewell Reserve. Exotic tall grasses are invading and apparently replacing the indigenous grassland and understorey communities. A decline of indigenous tussock grassland species and replacement by adventive species, similar to our observations, has also been noted in the South Island High Country (e.g. Connor, 1992; Rose *et al*., 1995). Similar impacts could occur on kānuka and other woody elements of the Reserve if the establishment of taller species such as sycamore and pine was allowed to proceed.

Probable sources of most of the adventives are directly adjacent to the Reserve, such as the pasture for tall grasses and other pasture plants and a garden to the west of the Reserve for garden escapes such as raspberry, black currant, buddleia, and sycamore. Apart from the proximity of seed sources of such weeds, the small area of the Reserve would contribute to its invasibility (e.g. Timmins and Williams, 1991; Hobbs and Huennecke, 1992). Furthermore, the occurrence of this kānuka forest in a landscape dominated by short pasture could make it an effective seed trap for both wind and bird-dispersed species, and with its relatively open canopy it may also provide favourable light conditions for their establishment.

As the Reserve is surrounded by primarily exotic vegetation, it is far more likely to be colonised by adventive than indigenous species. However, most of the new indigenous species are either wind-dispersed or bird-dispersed and could have come from a considerable distance. Some species, especially the newly arrived ferns, may also indicate a response to a change to wetter, shadier and more sheltered understorey conditions, a consequence of the development of the denser kānuka canopy. With the kānuka increasing, open grassland habitats are giving way to more shaded, sheltered sites, favouring a different suite of species.

Other kānuka remnants

Molloy and Ives (1972) considered the Eyrewell Reserve to be "one of the most important reference sites for plants and soils in Canterbury." and the Reserve to represent "the largest primitive community known for the Canterbury Plains". However, there are several other, equally small, kānuka forest remnants in the area (Fig. 1) that are also important (Meurk *et al*., 1995). Some of these contain additional species of conservation interest such as *Senecio dunedinensis* (NZFRI 24516) which is classed as 'Sparse' (de Lange *et al.*, 2004) and noted in Head and Given (2001) as "of uncertain presence in Canterbury". However, most of these remnants are currently not adequately protected. The unfenced kānuka area on private land next to the Reserve, which is being grazed, is not as rich and distinctive as the Eyrewell Reserve. Furthermore, the small area of these kānuka remnants and the frequent high fire risk, exemplified by the recent fire that destroyed a large part of the Medbury Reserve in the

Culverden Basin, indicates that all kānuka remnants on the Plains are extremely endangered.

In the Eyrewell area relatively small kānuka trees may be quite old. A kānuka of less than 100 mm dbh in a stand near the Eyrewell Reserve was about 48 years old (Meurk *et al.,* 1995) indicating that in this environment kānuka is very slow growing and that stands with larger trees will not be replaced quickly if burnt.

Comparison with other, adjacent vegetation

The vegetation of the adjacent areas is strongly modified and less rich in species than the reserve, but some interesting species and communities were detected. The pasture plots stood out because of the total absence of indigenous vascular plant species. Identical observations on the entirely exotic composition of pasture have been made in other studies (Harris and Burns, 2000).

In contrast, some of the plantation forest stands we surveyed featured many of the indigenous species that were recorded in the Reserve. Of all habitats, including the Eyrewell Reserve, the old pine stands had the smallest number of adventive species both in absolute numbers and relative to the number of indigenous species. The pattern of increasing indigenousness of understorey plants with increasing age of pine plantations was noted in other studies in New Zealand (Allen *et al*., 1995; Brockerhoff *et al*., 2003). This is thought to be related to the shady forest environment that is suitable for indigenous understorey species but not to adventive herbaceous and woody species which are predominantly shade intolerant colonisers and species of open habitat. The most obvious similarity between Eyrewell Forest and Eyrewell Reserve is that the understorey of some pine stands is dominated by kānuka growing up to about 4 m tall which indicates that there are good prospects for indigenous forest restoration if this was ever contemplated. From our recent work in Eyrewell Forest it is apparent that the largest stands of kānuka remaining on the Canterbury Plains are probably those which have developed recently as an understorey to the radiata pine.

Plantation forests can provide habitat for indigenous plants (Norton, 1989; Allen *et al*., 1995; Ogden *et al*., 1997; Norton, 1998; Brockerhoff *et al*., 2001; Brockerhoff *et al*., 2003), and for other taxa, for example, birds (Clout and Gaze, 1984) and insects (Hutcheson and Jones, 1999). Occurrence of several threatened species in plantations is well documented, including orchids (Gibbs, 1988), kiwi (Kleinpaste, 1990), and bats (Daniel, 1981). In the case of the ground beetle *Holcaspis brevicula* Butcher, a plantation (Eyrewell Forest) appears to be the only remaining habitat of this critically endangered species (Brockerhoff *et al.,* 2005). Also of conservation interest in Eyrewell Forest is the abundant occurrence of *Pomaderris* aff. *phylicifolia*.

Methods for improving plantation forest management practises to enhance conservation benefits have been reviewed by Hartley (2002). In regions where natural forest habitat is abundant there may not be a need to consider plantation forests for their contribution to conservation. However, in areas like the Canterbury Plains, where natural forests have all but disappeared, a plantation forest can provide important habitat and may become a critical refugium for indigenous biodiversity. In this context, the relatively impoverished Eyrewell Forest appears to be more important for conservation than plantation forests in other regions even with their comparatively rich understorey (Brockerhoff *et al*., 2003) because they are located in regions where natural forests are still more or less abundant.

Management implications for Eyrewell Reserve and adjacent vegetation

The trends in Eyrewell Reserve indicate that more active and continued management is required to maintain the unique indigenous vegetation in this and the few other kānuka remnants in the Canterbury Plains. Urgent attention is needed to reduce the exotic vegetation in these remnants. Although weed management had not been undertaken in the Eyrewell Reserve for many years, the large pine tree, its seedlings, and most of the broom that had become widespread throughout the Reserve were destroyed by the Department of Conservation after our assessment.

The removal of grazing may have resulted in the short-term dominance of the grassland vegetation by adventive grasses (Meurk *et al.,* 1989). Apart from the obvious mechanical and chemical weed control methods, grazing has been suggested as a means of preserving or restoring the indigenous grassland area in the Eyrewell Reserve (Meurk *et al*., 1995). However, this should be considered with care as the plots in the grazed kānuka adjacent to the Reserve were found to be invaded even more by adventives. Likewise, grazing was not found to be beneficial to the recovery of tussock species (Grove *et al*., 2002), and Walker and Lee (2002) noticed a decrease in indigenous species with grazing. Meurk *et al.* (1989) acknowledge that browsing of the kānuka shrubland association would be harmful to the palatable native species, but at the time of their study there were some low-growing native species that were more prevalent in grazed shrubland-grassland. Clearly, there is an urgent need for more research to determine which management regime, including non-grazing or light grazing (Meurk & Greenep, 2003) by sheep or one of the large ratites

such as ostriches as surrogate moa, is most appropriate to protect the greatest range of indigenous species.

The spread of kānuka into the grassland area would also need to be halted if the open habitat was to be preserved and more losses of indigenous open habitat species prevented. Special attention should be given to *Aciphylla subflabellata*, *Coprosma intertexta*, *Leptinella serrulata*, *Pomaderris* aff. *phylicifolia* and *Pterostylis tristis* and others that may still be present although not found by us. The spread of kānuka into the open area and the eventual loss of many of the indigenous grassland species could be tolerated if their protection was possible in other tussock grassland remnants in the region. However, management strategies for the reserve need to be carefully tailored to meet specific objectives. The occurrence of *Pomaderris* aff. *phylicifolia* in the adjacent plantation also highlights that conservation efforts should not stop at the Reserve gate.

Other issues that could be considered are the potential impact of the irrigation channel next to the Eyrewell Reserve and the proposed extension of irrigation channels in this area. Meurk *et al*. (1995) speculated that a higher water table might make it more prone to invasion by woody weeds such as gorse and broom and other adventives. The intensification of agriculture in the area, including the increase in intensive dairying, is likely to pose additional threats to the Reserve and other kānuka remnants in the area.

Addressing all these concerns may still not ensure the sustainability of Eyrewell Reserve and the other Canterbury Plains kānuka remnants because all are probably below the critical size that is required to reduce edge effects and invasion by adventives. Therefore, any and all opportunities to add kānuka remnants and other indigenous vegetation in private ownership to the conservation estate should be considered. Protecting all the remnants is an immediate priority, as most small remnants tend to have a unique assemblage of species, so that full representation is found only in the cumulative flora of all the remnants.

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