Succession in tussock grasslands:

implications for conservation management

SCIENCE FOR CONSERVATION: 61

C.A. Jensen, R.J. Webster, D. Carter, M. Treskonova

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

Science for Conservation presents the results of investigations by DoC staff, and by contracted science providers outside the Department of Conservation. Publications in this series are internally and externally peer reviewed

ISSN 1173-2946
ISBN 0-478-01948-3

This publication originated from work done under Department of Conservation contract 2079 carried out by C.A. Jensen, R.J. Webster and D. Carter, Knight Frank (NZ) Ltd., Land Resources Division, 76 Cashel Street, Christchurch; and M. Treskonova, 104a Wakefield Ave, Sumner, Christchurch. It was approved for publication by the Director, Science and Research Division, Department of Conservation, Wellington.

Cataloguing-in-Publication data

Succession in tussock grassland: implications for conservation management / C.A. Jensen ... {et al.} Wellington, N.Z. : Dept. of Conservation, 1997.
1 v. ; 30 cm (Science for conservation, 1173-2946; 61.)
Includes bibliographical references.
ISBN 0478019483
1. Grasslands--New Zealand--South Island. 2. Grassland ecology--New Zealand--South Island. 3. Vegetation monitoring--New Zealand- - SouthIsland. I. Jensen, C. A. (Carolyn Ann), 1948- II. Series: Science for conservation (Wellington, N.Z.) ; 61.
574.5264309937 20
zbn97-112295

CONTENTS

Abstract

Vegetation changes were investigated on 42 transects on land retired from stock grazing since the late 1970s. The study sites were located in Otago, Canterbury and Marlborough in the South Island high country and were generally in tall tussock grassland (*Chionochloa* spp.). Permanent transects were established between 1982-1985 and were remeasured between 1990 and 1996. Results show a general slight increase in vegetation cover, and in the frequency of *Chionochloa* spp. The frequency of short tussocks (*Festuca novae-zelandiae* and *Poa colensoi*) has declined and there has been a tendency for shrubs to increase in frequency in some areas. *Hieracium* species (in particular *H. pilosella*) have increased despite reduced grazing. The combined frequency of both native and exotic herbs (excluding *Hieracium* spp.) has declined. Increased ground cover does not appear to be related to an increase in any one species. Reduced pastoral impact is likely to have influenced the observed trends, although the specific effect of retirement is uncertain. Evaluation of management options depend on conservation objectives, and would also benefit from further research into retirement effects.

1. Introduction

The objective of this contract was to investigate the successional processes in a range of tussock grassland environments in the conservation estate, to assist in the development of management strategies.

The investigation involved remeasurement of a range of permanent transects in retirement areas. The report describes the vegetation and changes observed, and relates such trends to management, environment, and ecological factors. Based on this information, management strategies for the maintenance of conservation values are considered.

By the early 1980s a number of high country areas, many of them previously pastoral leases, had been retired from grazing and were classified as Crown Land Management Areas. Many of these areas had Crown Land Management Plans (see References). Other areas were retired and developed as skifields. All these areas are now administered by the Department of Conservation and are called Conservation Areas. The management objectives at the time of establishment mostly related to the maintenance of soil and water conservation values through increased vegetation cover. In some areas, an increase in native species was indicated as an objective. In the mid 1980s the Department of Lands and Survey established vegetation monitoring transects on some of these retired areas to measure the extent to which these objectives were being met. Both vegetation cover and species composition data were recorded, and consequently recent remeasurement of some of these transects has allowed an assessment of changes that have occurred over time.

2. Study areas

2.1 GENERAL DESCRIPTION

The sites studied in this report are from eight conservation areas. Much of this retired land is rugged and broken country, especially the higher peaks and ridges. The lower country is often scrub or bush covered and the middle slopes tussock covered. Most of the original transects, including the 42 remeasured transects, were sited on the mid altitude tussock grassland slopes. While the results provide limited representation of each study area as a whole, the exercise does allow an overview of vegetation trends in such areas.

Transects in this study were all established between 1982 and 1985. Those at Kirkliston, Mt Studholme, Pahau, Porter and Treble Cone locations were remeasured in the 1995-96 season. Recent data from Shingleburn (remeasured in 1990), Ohau, and Remarkables (remeasured in 1993) have also been included. Most of the study areas are in Canterbury, with one at Shingleburn in Marlborough and others at Treble Cone and the Remarkables in Otago (Fig. 1). Table 1 summarises details for each of the study areas.

TABLE 1. DETAILS OF INDIVIDUAL STUDY AREAS.

STUDY AREAS	BEDROCK	SOIL TYPES	RAINFALL (mm)	ALTITUDE RANGE OF TRANSECTS (m)	DATE OF INITIAL MONITORING	DATE OF LAST MONITORING	TRANSECTS ESTABLISHED	TRANSECTS REMEASURED
Shingleburn	Greywacke	HCYB	860	805-1105	Feb. 1985	Jan. 1990	4	4
Pahau	Greywacke	HCYB	1030	990-1270	March 1984	March 1996	5	2
ohau	Greywacke	UYB	1046	655-850	Feb. 1983	Jan. 1993	40	4
Porter	Greywacke	HCYB / UYB	900	880-1410	March 1984	March 1996	14	10
Mt Studholme	Greywacke	HCYB	638	910-1000	Dec. 1983	Nov. 1995	12	6
Kirkliston	Greywacke	HCYB / YB	550	1060-1560	Nov. 1982	Nov. 1995	27	6
Treble Cone	Schist	YB	1412	1380-1730	Jan. 1982	Jan. 1996	19	5
Remarkables	Schist	YB / ALP	832	1660-1870	March 1984	March 1993	12	5

Rainfall estimated from nearest rainfall station;
Soil types are high country yellow brown earth (HCYB), upland yellow brown earth (UYB), yellow brown (YB), and alpine (ALP), Land Resource Inventory (NR'ASCO, 1975-79).

2.2 STUDY AREA DETAILS

Shingleburn

The Shingleburn Valley is part of the Ferny Gair Conservation Area in Marlborough. The conservation area ranges in altitude from 450 to 1669 m, with steep sided valleys, many bluffs, and steep rubbly slopes. The transects were located between 805 and 1105 m, on the better vegetated spurs and easier slopes dominated by short tussock grassland.

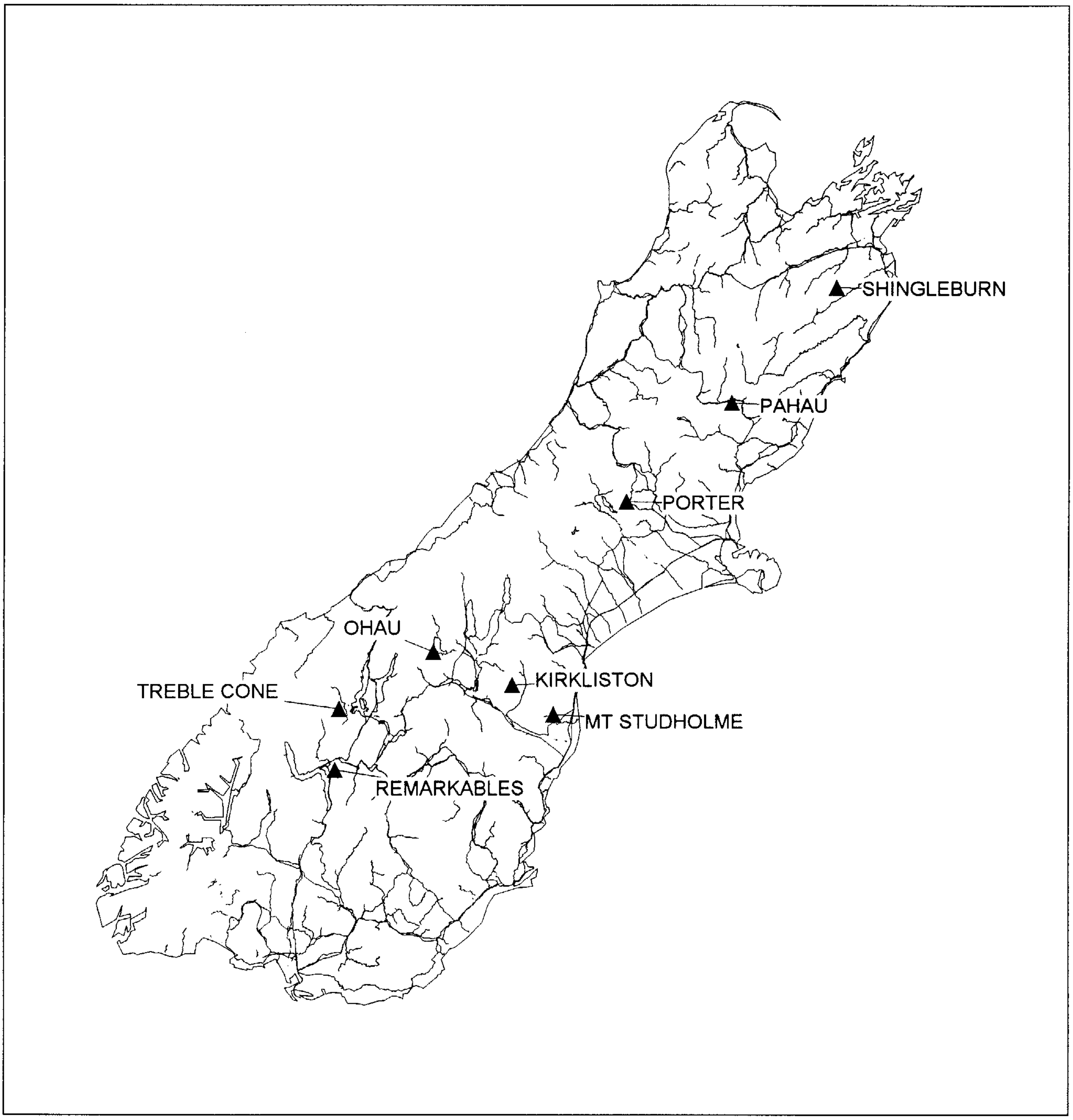


FIGURE 1. STUDY AREAS.

Pahau

The Pahau transects lie within the Lochiel Run near Hanmer in North Canterbury. The retired area has steep actively eroding slopes. Altitudes range from 500 to 1356 m. The transects were located between 990 and 1270 m, in a sparsely vegetated zone of snow tussock *(Chionochloa* spp.*),* short tussock *(Festuca novae-zelandiae, Poa cita,* and *Poa colensoi),* and small shrubs. Below about 950 m short tussock grasslands dominate, with some shrub patches.

Ohau

The Ohau Conservation Area, near Lake Ohau in South Canterbury, covers the entire Ohau Range, from 520 to 2300 m. Forty transects were established in 1982 covering a wide range of altitudes and community variation. The four lowest transects were remeasured in 1993 in response to an application to graze the area. These transects were in short tussock grassland between 655 and 850 m with one transect including some scattered tall tussock. Most other transects were at higher altitudes and had a greater component of snow tussock.

Porters

The Porter Conservation Area lies west of Lake Lyndon near Porters Pass. Altitudes range from 840 to 2015 m. Remeasurement was carried out on 10 transects in the mid altitude zone of snow tussock and *Dracophyllum* spp., between 880 and 1410 m. Vegetation is more sparse, with extensive screes, at higher altitudes.

Mt Studholme

The Studholme Conservation Area occupies the steep southwestern slopes below Mt Studholme, on the Hunters Hills in South Canterbury. Altitudes range from 450 to 1669 m. The area sampled was between 910 and 1000 m, and generally covered with tall tussock grassland with some *Dracophyllum* spp. and shrub cover. In gullies there is some bush and taller shrub species. The vegetation is more sparse at higher altitudes.

Kirkliston

The Kirkliston Range Conservation Area, west of the Hakataramea Valley in South Canterbury, ranges in altitude from 900 to 1864 m. The highest altitudes are bare and rocky. The remeasured transects were between 1060 and 1560 m on steep rubbly slopes with tall tussock.

Treble Cone

Treble Cone Skifleld Conservation Area occupies a high altitude basin above Lake Wanaka between 1240 and 2058 m. The establishment of the original monitoring programme was related to the effect of ski field activities. Earth moving and ski trail oversowing have obliterated or drastically altered many of the original transects. The five transects remeasured are in steep hummocky country between 1380 and 1730 m with tall tussock / *Celmisia lyallii* grasslands that have not been modified by ski field developments.

Remarkables Skifield

The Remarkables Skifield lies within the Remarkables Conservation Area near Lake Wakatipu. The altitudinal range is from 1220 to 2324 m. The monitoring was established to measure the effect of skifield activities. Many of the original transects have been obliterated by slope modifications. Results from the 1993 remeasurement of 5 unmodified transects between 1660 and 1870 m have been used for this report.

2.3 EARLY GRAZING MANAGEMENT

Very little historical grazing and burning information is available for the specific study areas. Originally all the study areas were part of large pastoral runs. These were mostly occupied by the 1860s, and typical high country management is likely to have applied. Sheep numbers in the high country probably peaked in the late 1880s, declined considerably by the 1920s, and continued to gradually reduce with subsequent grazing restrictions or ultimate retirement in the 1970s (Whitehouse, 1984; O'Connor and Harris, 1992). Regular tussock burning was used as a common management tool throughout the high country up until the 1960s (Whitehouse, 1984).

2.4 EFFECTIVENESS OF RETIREMENT

All the areas in this study have technically been retired from grazing, and in most cases retirement fences were constructed prior to initial monitoring. There is no such retirement fence on the Kirkliston Range, however retirement has been reasonably effective in that area through regular oversowing and top dressing of the country below the conservation area.

Despite technical retirement, most of these areas still appear to receive some grazing. Sheep were observed in several of the conservation areas during fieldwork (Porter, Pahau, and on oversown ski slopes at Treble Cone). On Shingleburn there was some evidence of sheep and goat browsing and pig rooting. Sheep camps, tracks, and evidence of tussock browsing were observed on Pahau and Porters. Browsing that may be related to wallabies or hares was noticed on the Kirklistons and Mt Studholme.

Unauthorised stock grazing has probably resulted from lack of fence maintenance or lack of stock control in adjacent pastoral country. Although sheep grazing can be controlled, some long term grazing is probably to be expected from hares and grasshoppers, and animal pests including goats, pigs and, in some places, wallabies. While it is obvious that complete retirement has not been achieved, the study areas have probably received much less grazing and burning over the monitoring period than in their earlier days of pastoral occupation.

3. Methods and analysis

3.1 FIELD METHODS

The description of the character and trends in vegetation has been based on data obtained from 100 m transects marked with permanent fibreglass poles. Ground cover and species information was based on recordings within a 50 cm by 50 cm quadrat, placed at two metre intervals along each transect.

Within each quadrat, ground cover was estimated to the nearest 5 % for vegetation, litter, bare ground, and rock and rubble. The presence of every species was also recorded in each quadrat. For the sites remeasured in 1995-96 (Kirkliston, Mt Studholme, Pahau, Porter and Treble Cone), the cover for all species present in each quadrat was also recorded. Species cover was estimated using 6 cover classes (<1;1-5; 6-25; 26-50; 51-75; 76-100%).

Photographs were taken up and down each transect, and some photo points were retaken from vantage points within each area (Appendix, plates 1,2,6).

All transect locations were defined by grid reference on the New Zealand Map Grid. At each site altitude above sea level, aspect, slope, and slope type, were recorded. Rainfall was estimated from the nearest available rainfall stations. Soil and bedrock descriptions were taken from the New Zealand Land Inventory data set (NWASCO, 1975-79).

3.2 ANALYSIS

Within each transect, quadrat ground cover scores were averaged to provide the mean ground covers of vegetation, litter, bare ground, and rock and rubble. The proportion of quadrats in which each species was present was calculated as a percent frequency. For the more recent species cover class results, transect mean covers were calculated for every species by averaging the midpoint of the cover classes. The determination of trends over time has been based on mean ground cover and species percent frequency data, with species cover data providing further information where available.

Ordination was used to describe the vegetation of the study transects. The initial monitoring data for each of the 42 transects was used for this analysis. Percent frequency scores for all species that occurred on more than two transects was ordinated using Detrended Correspondence Analysis (DCA) (Hill and Gauch, 1980), using the program Canoco (ter Braak, 1988).

Analysis of temporal trends between initial monitoring and the latest data was based on changes in ground cover of vegetation and litter, and changes in percent frequency for each species. Due to variations between surveys in the time interval between monitoring, all differences were standardised to a 10 year rate of change. To test the significance of temporal trends across all 42 transects, the non parametric Wilcoxon signed-rank test (Sokal and Rohlf, 1981) was applied to each species, and also the cover of vegetation and litter.

Spearman rank correlations (r_s) were calculated between selected species and measured environmental variables far further description and explanation of the observed trends, using the initial species frequency, and rate of change.

Temporal trends within individual study areas were also considered. For each study area species were ranked according to changes in frequency, averaged over all transects. For those areas where six or more transects were remeasured, the significance of frequency changes was analysed by the Wilcoxon signed rank test (Porter, Studholme, and Kirkliston). However, the scale of this project precluded a major consideration of trends within individual study areas.

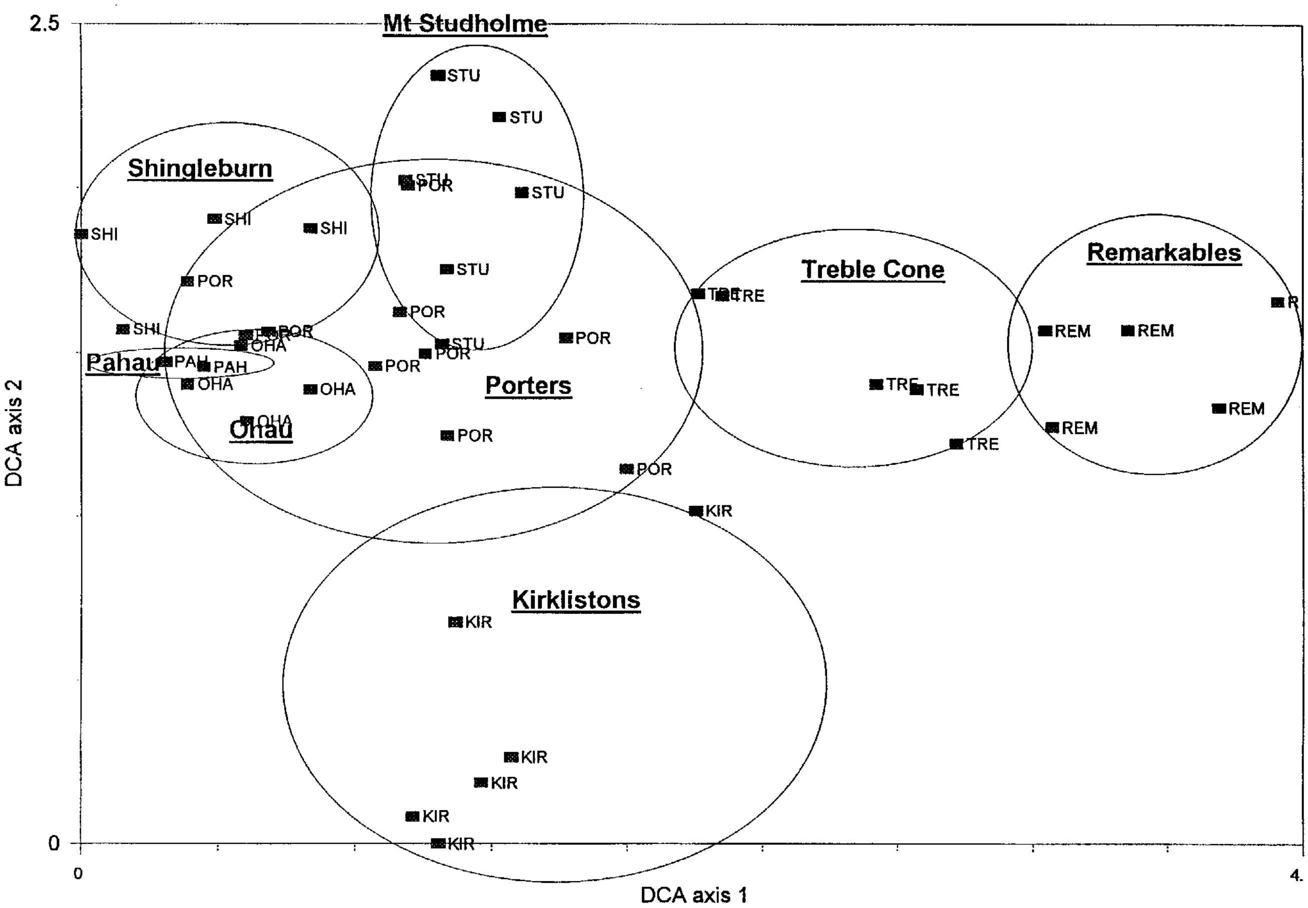


FIGURE 2. DISTRIBUTION OF SITES ON THE FIRST AND SECOND AXES OF ORDINATION USING DETRENDED CORRESPONDENCE ANALYSIS APPLIED TO THE PERCENT FREQUENCY DATA FROM THE INTIAL MONITORING. ELLIPSES INDICATE APPROXIMATE ORDINATION SPACE BOUNDARIES FOR EACH STUDY AREA.

Four tall tussock species occurred on the transects. These were *Chionochloa rigida, C. macra, C. pallens,* and C *flavescens. In* some areas a degree of hybridisation appears to be occurring, making specific identification difficult and uncertain. For this reason *Chionochloa* spp. data have been combined for most purposes, although individual species have been mentioned in the discussion relating to some survey areas.

4. Description and explanation of vegetation change

4.1 VEGETATION DESCRIPTION

DCA ordination of the initial percent frequency data for the 42 transects showed that the study areas differed significantly in species composition (Fig. 2. and Table 2). The first DCA axis, or primary vegetation gradient, reflected compositional changes from disturbed communities (low proportion of native

TABLE 2. RELATIONSHIPS BETWEEN THE FIRST AND SECOND DCA AXES, SITE SCORES AND EXPLANATORY AND DESCRIPTIVE VARIABLES.

	DCA axis 1	DCA axis 2
Eigenvalue	0.603	0.287
Length of gradient	4.4	2.3
Explanatory variables:		
Altitude (m)	0.75*	-0.33*
Rainfall (mm)	-0.16	0.5
Aspect(')	0.17	0.33*
Continentality	0.21	-0.48*
Study area	***	***
Descriptive variables:		
Native proportion (%)	0.9***	-0.2
Perennial proportion (%)	0.75***	0.09
Chionochloa spp. frequency (%)	0.49**	-0.16
Shrub sum of frequency	0.02	-0.44*

*Spearman rank correlation coefficients (and for Study area one way ANOVA) : *=P<0.05; ** _ P<0.01; ***=P<0.001.*
Explanatory variables include:
Rainfall, *estimated from mean annual rainfall at the nearest rainfall stations;*
Aspect, *in degrees from magnetic north (due north being 0, east and west both 90, and south 180);*
Continentality, *the shortest distance from each transect to the coast, or the main divide;*
Study area, *a nominal variable grouping transects by study areas.*
Descriptive variables include:
Native proportion, *the number of native species recorded on the transect relative to the total number of species;*
Perennial proportion, *the number of perennial species relative to the total number of species;*
Chionochloa spp. ***frequency (%),*** *the percent frequency for* Chionochloa;
Shrub sum of frequency, *the sum of all percent frequency scores for shrub species on the transect,*

and perennial species, and low *Chionochloa* frequencies) with low positions on the first axis, to native communities at high positions, with greater *Chionochloa* frequencies. This arrangement of sites was positively correlated with altitude. The significance of these correlations is presented in Table 2.

Figure 3a illustrates the main vegetation forms for each study area, expressed as a proportion of total species frequencies, for the initial measurement. Figure 3b illustrates these groups expressed as cover proportions, where species covers were available from most recent measurement. Study areas are ordered according to mean first axis DCA scores, which also produces an arrangement from lower altitude transects (left), to higher altitudes (right). The frequency graph (Fig. 3a) accentuates the proportion of herbs, which generally includes many species occurring at high frequency but low cover. Tall tussock was the single most important percentage cover component (Fig. 3b), and this increased in relative importance from the lower altitude study areas such as Shingleburn, Pahau, and

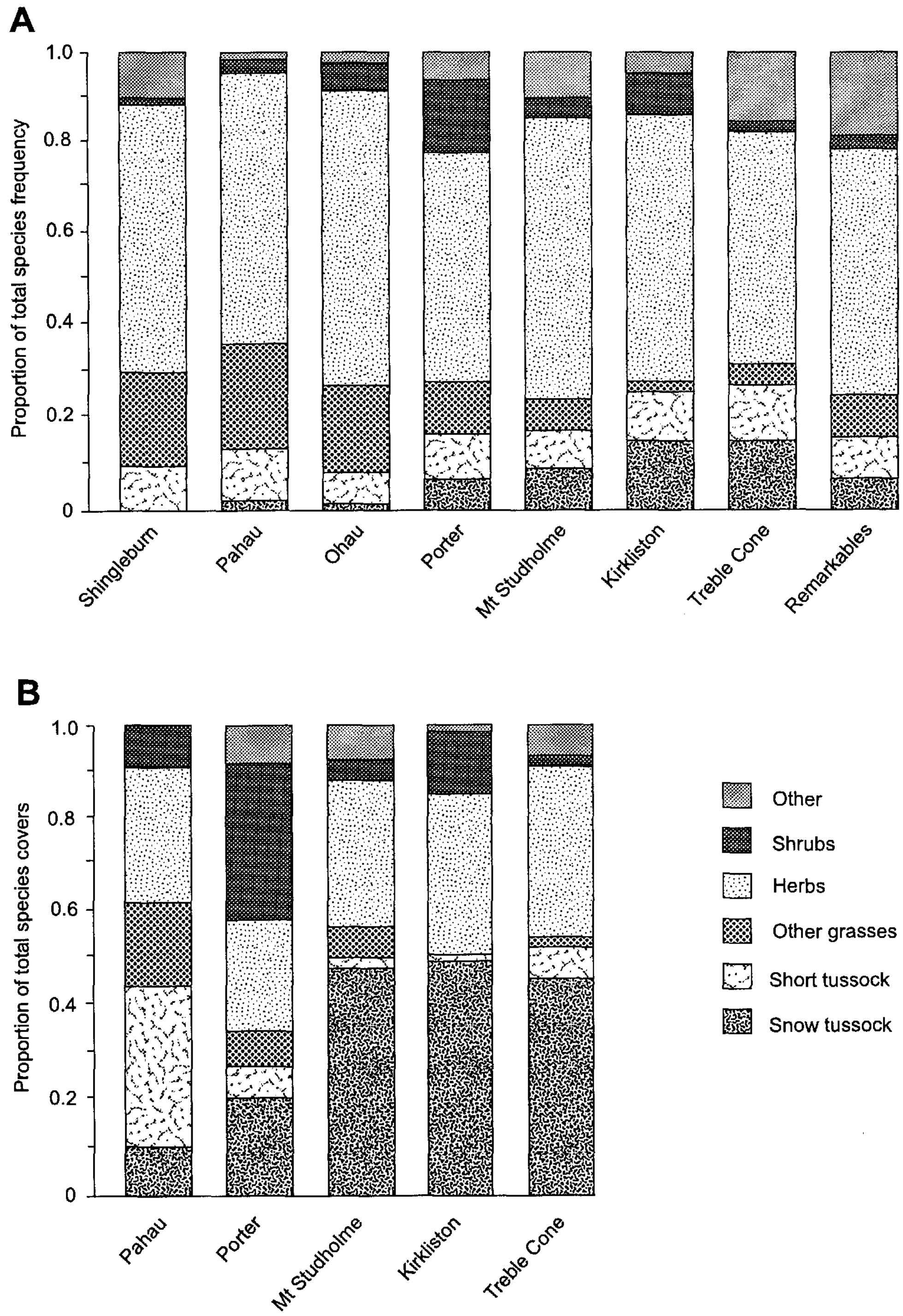


FIGURE 3. MAIN VEGETATION FORMS OF EACH STUDY AREA, EXPRESSED AS A PROPORTION OF:
(A) THE TOTAL SUM OF FREQUENCIES;
(B) THE TOTAL SUM OF COVERS. (SPECIES FREQUENCIES TAKEN FROM INITIAL MEASUREMENT DATA. SPECIES COVERS WERE OBTAINED AT LATEST MEASUREMENT ONLY, FOR PAHAU, PORTER, STUDHOLME, KIRKLISTON, AND TREBLE CONE). STUDY AREAS ARRANGED ACCORDING TO MEAN TRANSECT FIRST AXIS DCA SCORES.

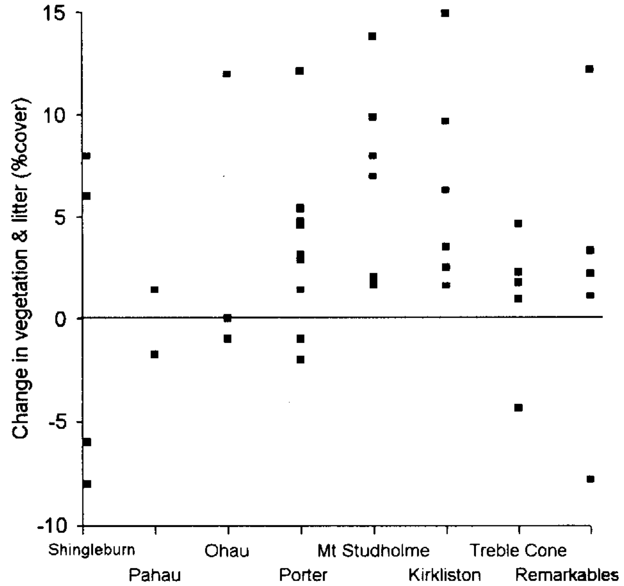


FIGURE 4. CHANGE IN COVER OF VEGETATION AND LITTER FOR EACH TRANSECT, AS A RATE OVER 10 YEARS.

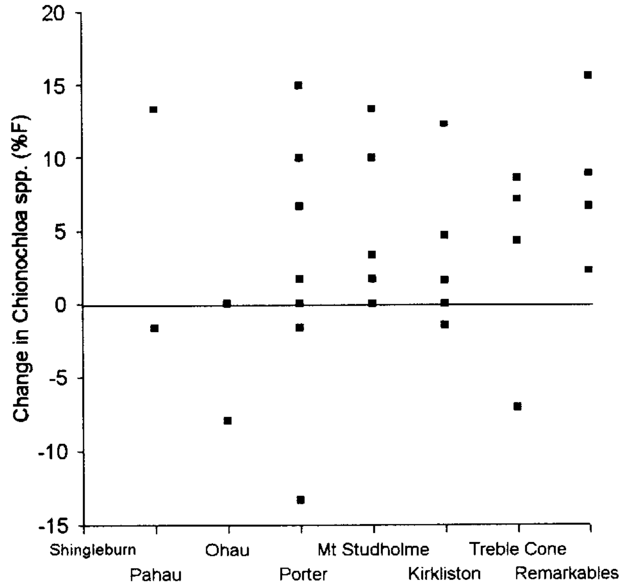
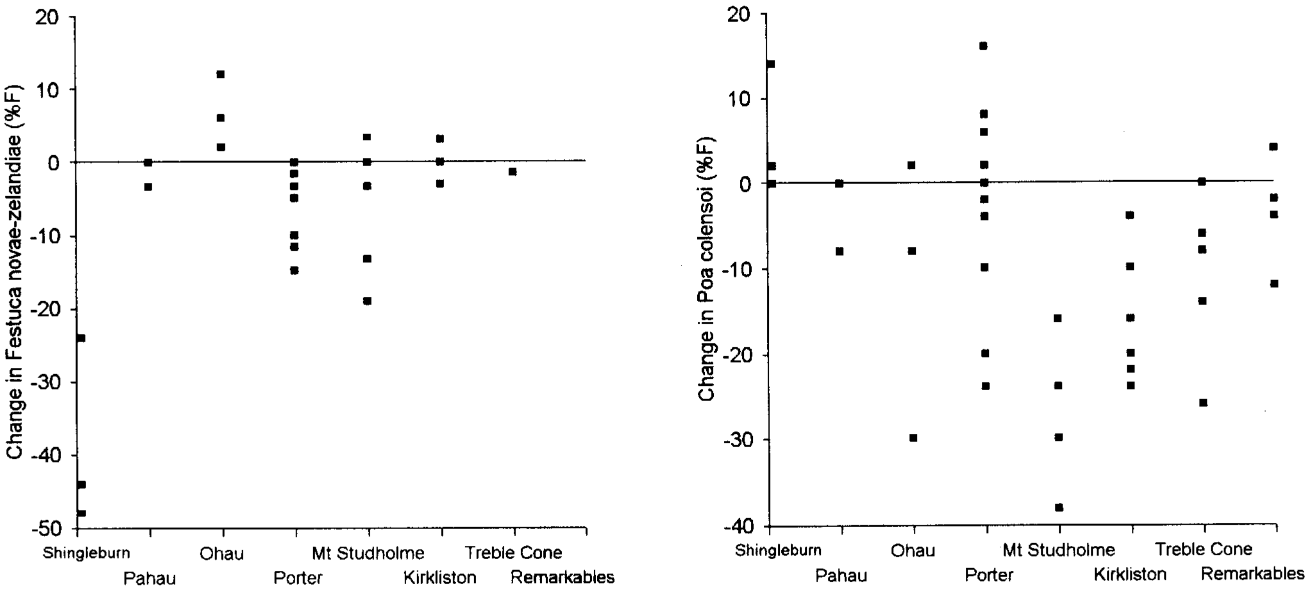


FIGURE 5. CHANGE IN *CHIONOCHLOA SPP.* PERCENT FREQUENCY FOR EACH TRANSECT AS A RATE OVER 10 YEARS.



(A)

(B)

FIGURE 6. CHANGE IN PERCENT FREQUENCY OF SHORT TUSSOCK SPECIES FOR EACH SURVEY AREA, AS A RATE OVER 10 YEARS.
(A) = *FESTUCA NOVAE-ZELANDIAE, (B) = POA COLENSOI.*

Ohau, across to the higher altitude and less modified study areas of Kirkliston and Treble Cone. The higher alpine sites measured on the Remarkables had less tall tussock and a higher proportion of herbs (Fig. 3a). Short tussock species were a common component of all study areas, while other grasses (mainly introduced pasture species), were more prevalent on the lower study areas. Shrub species were a common component throughout, but were especially notable at Porters. Herbs, both flat and upright, were common throughout.

4.2 MAIN VEGETATION TRENDS

The results of the analysis of time trends over the 42 transects, standardised for time periods between measurement, are summarised in Table 3. This includes all species with significant temporal trends in frequency (P<0.05, Wilcoxon rank signed test), and also vegetation cover.

Table 4 provides a summary of the species with the most notable temporal trends for each study area.

Vegetation cover

Vegetation (including litter) increased on 32 of the 42 transects (Table 3). This increase was highly significant (P<0.001, Wilcoxon). Mean vegetation cover increased in all study areas except Shingleburn and Pahau (Table 4). Changes in vegetation cover were generally at a rate of less than 10% cover over 10 years (Fig. 4).

No significant correlations were found between change in vegetation cover and any measured site variable.

Tall tussock

The occurrence of *Chionochloa* species showed a highly significant increase in frequencies (P<0.001, Wilcoxon). The mean percent frequency of *Chionochloa* spp increased in all study areas where found, except Ohau (Table 4). *Chionochloa* spp. increased on 17 transects and decreased on 3 transects (Table 3). However, increases were fairly slight on most transects. No transect had an increase in percent frequency of more than 15%, averaged over 10 years (Fig-5). The photographic evidence shows little apparent change (Appendix, plates 1,3,4,5). Where measured, *Chionochloa* spp. cover was generally low. No site achieved 50% cover, and only 8 sites exceeded 35% cover.

As discussed earlier, *Chionochloa* spp. frequency and altitude were both highly correlated with the primary vegetation gradient of the data set. Initial frequency of tall tussock was associated with greater altitude (r_s=0.47, P<0.01) and greater cover of litter (r_s=0.61, P<0.01). No statistically significant correlations were found between the actual change in *Chionochloa* spp. frequency and any measured environmental variable. While an increase in *Chionochloa* spp. was common, it was not confined to any particular environment.

Short tussock

Four short tussock species were identified on the study transects. *Poa cita* (silver tussock) and *Rytidosperma setifolium* each occurred on less than ten transects, and showed no clear trends over time. *Festuca novae-zelandiae* and *Poa colensoi* each occurred on the majority of sites, and both demonstrated significant decreases (Figs. 6, 7, and Table 3).

Festuca novae-zelandiae was found on 31 transects, decreased on 12 transects, and increased on 4 transects. (Table 3, P<0.01, Wilcoxon). The mean percent frequency, averaged over all transects, declined in all study areas where *F. novae-zelandiae* was found, except for Ohau and Treble Cone (Table 4).

TABLE 3. SUMMARY OF CHANGES IN MEAN PERCENT FREQUENCY BETWEEN INITIAL AND LATEST MEASUREMENT FOR SELECTED SPECIES.

	ANN/PER 8i ORIGIN	FREQUENCY (%) MEAN	RATE OF CHANGE	NO. OF TRANSECTS SHOWING: DECREASE	NO CHANGE	INCREASE	TREND
(A) INCREASING SPECIES							
Tall Tussock							
Chionochloa species	PN	61	+ 4	3	16	17	***
***Hieracium* spp.**							
Hieracium lepidulum	PI	9	+ 6		10	8	***
Hieracium pilosella	PI	28	+ 21		4	21	*'*
Hieracium praealtum	PI	36	+ 7	4	9	10	ns
Other herbs							
Aciphylla aurea	PN	16	+ 2	4	11	9	
Thelymitra longifolia	PN	3	+ 4	0	5	3	
Shrubs							
Dracophyllum acerosum	PN	39	+ 3		5	3	
Dracophyllum uniflorum	PN	8	+ 5	2	8	7	
Gaultheria crassa	PN	12	+ 2	0	7	1	
(B) DECREASING SPECIES							
Short tussocks							
Festuca novae-zelandiae	PN	31	- 7	12	16	3	**
Poa colensoi	PN	38	- 7	23	12	5	***
Grasses							
Anthoxanthum odoratum	PI	47	- 2	12	9	5	ns
Elymus solandri	AN	17	- 9	11	5	2	
Holcus lanatus	PI	17	- 3	8	7	1	
Herbs							
Acaena caesiiglauca	PN	13	- 10	7	11		
Cerastium fontanum	PI	6	- 4	10	7	1	**
Crepis capillaris	AI	17	- 16	8	7	2	
Geranium microphyllum	PN	19	- 12	7	1		
Geranium sessiliflorum	PN	14	- 7	9	10	2	
Helichrysum bellidiodes	PN	29	- 16	9	6		**
Hypocboeris radicata	PI	40	- 13	23	8	1	***
Luzula rufa	PN	20	· 6	19	9	4	***
Oxalis exilis	PN	13	- 15	5			
Rumex acetosella	PI	21	- 13	23	9	2	***
Viola cunninghamii	PN	20	- 11	17	15	2	***
Wahlenbergia albomarginata	PN	20	- 10	23	9	4	***
(C) VEGETATION AND LITTER		73% cov	+ 4% cov	8	2 T	32	***

Columns are described as follows.

Ann/Per & Origin, indicates whether species are annual (A) or perennial (P), native (N), or introduced (1);
Mean frequency (%) indicates the average frequency over all transects, including initial and latest data;
Rate of change indicates the increase (+) or decrease (-) in percent frequency expressed as a rate over 10 years, averaged over all transects;
Number of transects indicates the number of transects on which the species decreased at a rate of more than 4% frequency over 10 years (decrease), increased by more than 4% frequency over 10 years (increase), or changed at a rate less than 4% frequency over 10 years (no change);
*Trend lists the significance of each species trend over time, expressed as a rate per 10 years, by the Wilcoxon signed-rank test, where * = P<0.05; ** = P<0.01; *** = P<0.001. Vegetation and litter covers were combined, and statistics result from the same analysis as for species frequencies, with the number of transects with any decrease or increase in cover tabulated.*

Poa colensoi was found on 40 sites, and demonstrated notable decline on 23 sites, and an increase on only 4 sites. This decrease was highly significant across the data set (Table 3, P<0.001, Wilcoxon). The mean frequency of *Poa colensoi* declined in all study areas except Shingleburn (Table 4).

Tested independently against measured site environment factors, changes in neither *Festuca novae-zelandiae* nor *Poa colensoi* demonstrated any obvious site preference.

Herbs

Herbs accounted for a major proportion of the total frequency in most areas (Fig. 3a), although tussock and grass species were generally more significant in total cover (Fig. 3b). Overall, there was a marked decline in the total frequency of both flat and erect herbs. Excluding *Hieracium* spp. (discussed separately), a decline in frequency of herbs was common to all study areas (Fig. 7a). A decline in the total quadrat occurrence of herbs was common for both native and introduced herbs, both annual and perennial, over all study areas (Fig. 7b). Of the 72 herbs that occurred at more than three transects, 51 showed a mean frequency decrease over the transects in which they occurred, and 12 of these species displayed a significant decrease (Table 3). Of these 12 decreasers, all were perennials except *Crepis capillaris.*

The flatweed *Hypochoeris radicata* (catsear) declined significantly. The species showed a notable reduction in frequency on 23 transects and increased significantly on only 1 transect (Table 3, P<.001, Wilcoxon). This species showed a mean decrease in all study areas, and was amongst the most noticeable changes on Pahau, Ohau, and Kirkliston (Table 4).

Rumex acetosella, Viola cunninghamii, and *Wahlenbergia albomarginata* all declined significantly (Table 3, P<0.001, Wilcoxon). A decline in mean frequency of each of these species was observed in every study area, except for *Viola cunninghamii* at the Remarkables, where the mean frequency increased slightly (Table 4).

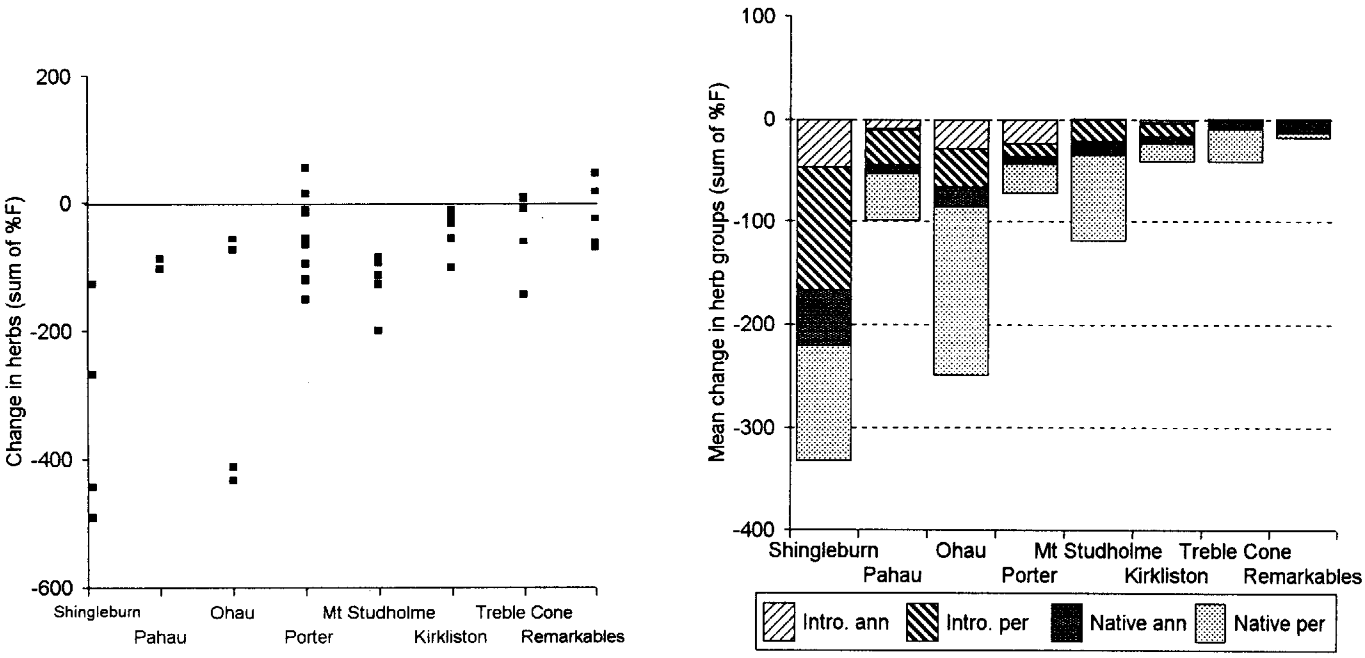
The sum of initial herb frequencies showed a strong relationship with altitude, with a greater herb frequency at lower altitudes (r_s=-0.47, P<0.01). Sites at lower altitudes, with greater initial herb frequency, also experienced a greater decline in herbs. This relationship, between change in herb frequency and altitude, was also significant (r_s=0.6, P<0.01).

TABLE 4. MEAN PERCENT FREQUENCY, AND COVER OF VEGETATION AND LITTER, FOR INITIAL AND LATEST MEASUREMENT, EACH STUDY AREA.

STUDY AREA	SHINGLEBURN			PAHAU			OHAU		
TRANSECTS MEASURED	4TRANSECTS			2TRANSECTS			4TRANSECTS		
DATES		1885	1990		1984	1996		1983	1993
Vegetation and litter % cover		82	82		42	42		84	87
Tall tussock									
Chionochloa species		-	-		12	19		6	4
Short tussock									
Festuca novae-zelandiae		51	37		40	38		76	84
Poa colensoi		5	9		11	7		15	6
Grasses									
Anthoxanthum odoratum		56	70	#	56	41		97	87
***Hieracium* spp.**									
Hieracium lepidulum		1	2		-	-		-	-
Hieracium pilosella	#	1	19		10	19	#	37	75
Hieracium praealtum		14	22		-	-		67	85
Other herbs									
Acaena caesiiglauca	#	40	20		12	14		-	.
Hypochoerisradicata		74	63	#	27	11	#	79	41
Rumex acetosella	#	78	52	#	31	17		29	22
Viola cunninghamii		39	29		11	3	#	50	16
Wahlenbergia albomarginata		30	26	#	30	<1		50	32
a	#	59	78	#	14	2	#	35	60
	#	67	40				#	30	7
c									
d									
	a *Agrostis capillaris*			a *Cerastium fontanum*			a *Deyeuxia avenoides*		
	b *Crepis capillaris*						b *Hydrocotyle novaezelandiae*		

For each study area, table lists five species with greatest change in mean frequency (#) and where six or more transects remeasured significant species (") (P<0.05, Wilcoxon rank sign test applied within study area). Means calculated over total number of transects in each study area. Lower section lists species which achieved such levels in single study areas.

PORTER			STUDHOLME			KIRKLISTON			TREBLE CONE			REMARKABLES		
10 TRANSECTS			6 TRANSECTS			6 TRANSECTS			5TRANSECTS			5TRANSECTS		
	1984	1996		1983	1995		1882	1995		1982	1996		1984	1993
	72	77		60	68		55	63		90	91		69	71
	53	56	*	73	79		70	74		88	93	#	48	58
#*	32	21		15	8		7	6		4	4		-	-
	42	39	#*	50	27	#*	37	21	#	68	58		65	62
#	34	21		33	33		-	-		4	5		-	-
#*	3	12		<1	<1		<1	1		13	18		·	-
#*	10	24	*	28	49		62	69		·	-		-	
				7	6		-	-						-
	5	4	*	9	5		-	-		<1	1		-	-
	37	29		58	51	*	13	6		1	<1		-	-
	19	16		21	5	#*	14	4		3	<1		-	-
	4	2	#*	28	8		3	<1	#	29	19		28	29
#	31	21		15	5		8	2		12	6		4	2
*	30	33	*	9	15	#	10	2	#	14	6	#	19	26
*	6	2	#*	30	12	#*	3	12	#	16	5	#	28	14
*	3	1	#*	43	20	#*	22	13	#	2	9	#	32	40
*	1	<1										#	2	9
a *Dracophyllum acerosum*			a *Aciphylla aurea*			a *Carex breviculmis*			a *Galium perpusillum*			a *Agrostis muelleriana*		
b *Elymus solandri*			b *Geranium microphyllum*			b *Dracophyllum uniflorum*			b *Geum leiospermum*			b *Epilobium tasmanicum*		
c *Lagenifera cuneata*			c *Helichrysum bellidioides*			c *Luzula rufa*			c *Schoenus pauciflorus*			c *Rytidosperma pumilum*		
d *Schleranthus uniflorus*												d *Uncinia fuscovaginata*		



(A) (B)

FIGURE 7. CHANGE IN HERBS.
(A) CHANGE IN SUM OF PERCENT FREQUENCY OF ALL HERB SPECIES, EXCLUDING *HIERACIUM* SPP., FOR EACH STUDY AREA, AS A RATE OVER 10 YEARS.
(B) CHANGE IN SUM OF PERCENT FREQUENCY FOR INTRODUCED ANNUALS (INTRO. ANN), INTRODUCED PERENNIALS (INTRO. PER) EXCLUDING *HIERACIUM* SPP., NATIVE ANNUALS (NATIVE ANN), AND NATIVE PERENNIALS (NATIVE PER), AVERAGED OVER ALL TRANSECTS IN EACH STUDY AREA, AS A RATE OVER 10 YEARS.

Hieracium species

An increase in the overall frequency of *Hieracium* spp. was common to almost every transect (Fig. 8). *Hieracium pilosella* (mouse-ear hawkweed), *H. lepidulum* (tussock hawkweed), *H. praealtum* (king devil) and *H. aurantiacum* (orange hawkweed) were all found on the study transects. *Hieracium pilosella* and *H. lepidulum* both showed significant increases (Table 3, P<0.001, Wilcoxon) and they increased in all study areas where found (Table 4). *Hieracium* species were the only introduced species to show any significant increase in frequency.

The initial frequency of *Hieracium pilosella* was significantly correlated with altitude, with higher sites having little or no *H.* pilosella (r,= 0.72, P<0.001). *Hieracium praealtum* had a similar strong relationship with altitude, again being more common on the lower altitude sites (r,=-0.75, P<0.001). *Hieracium lepidulum* showed some relationship with rainfall, being found on the sites in higher rainfall areas (r_s=0.43, P<0.01). However, considering the trends over time in each of these species, increases were not significantly correlated with any measured site variables.

Shrubs

Shrubs represented a minor proportion of the vegetation in the study areas, in both frequency and cover (Fig. 3a and b). Shrub frequency increased at most

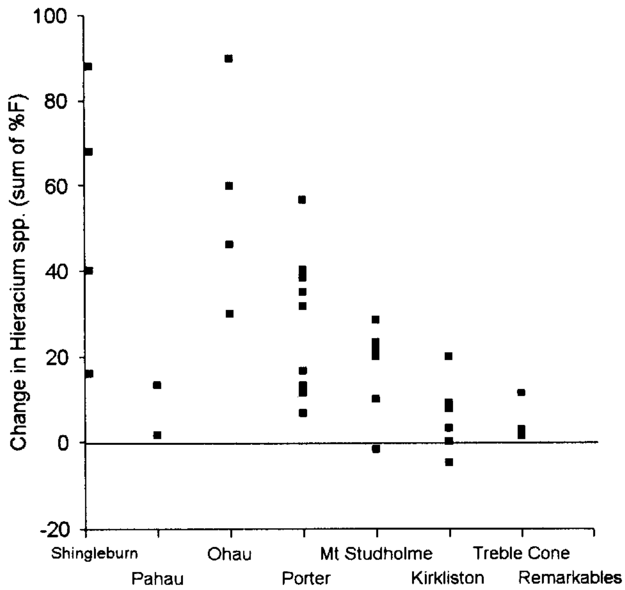


FIGURE 8. CHANGE IN SUM OF PERCENT FREQUENCY FOR ALL *HIERACEUM* SPECIES, AS A RATE OVER 10 YEARS.

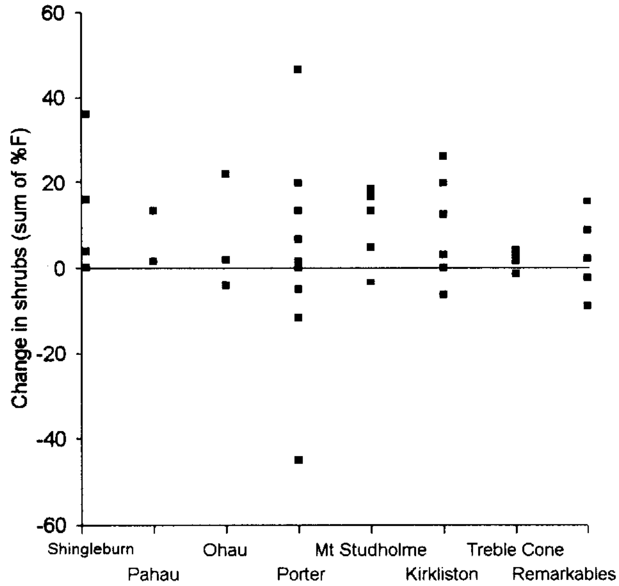


FIGURE 9. SUM OF CHANGE IN PERCENT FREQUENCY FOR ALL SHRUB SPECIES AS A RATE OVER 10 YEARS.

sites (Fig. 9). Twenty seven shrub species were found on the study transects, and 17 of these species demonstrated an overall increase in mean frequency. Nine species decreased in mean frequency, but none of these decreases were of any statistical significance.

Dracophyllum uniflorum, D. acerosum, and *Gaultheria crassa* increased in frequency significantly. *Dracophyllum acerosum* occurred only in the Porters study area. Here it increased notably on 3 out of the 8 sites found (Table 3, $P<0.05$, Wilcoxon).

Correlations were not significant between overall shrub frequency or shrub increase, and any measured environmental variable. Individual shrub species did not occur on a sufficient number of transects to allow generalisations on species patterns.

4.3 INDIVIDUAL STUDY AREA TRENDS

The scale of this project required a synoptic approach to vegetation trends, rather than detailed analysis of patterns within individual study areas. However, some analysis was undertaken within each study area. Table 4 lists the most notable changes within each study area.

Most trends within individual study areas reflect the general trends discussed in 4.2, with a common increase in snow tussock and *Hieracium,* a minor increase in shrubs, and a decrease in short tussock and herb frequencies. Most additional species with major changes over time within particular study areas were examples of a declining presence of herbs. However, a few grasses were ranked amongst the main increases in specific areas. This included *Agrostis capillaris* at Shingleburn, *Deyeuxia avenoides* at Ohau, and Agrostis *muelleriana* and *Rytidosperma pumilum* at the Remarkables.

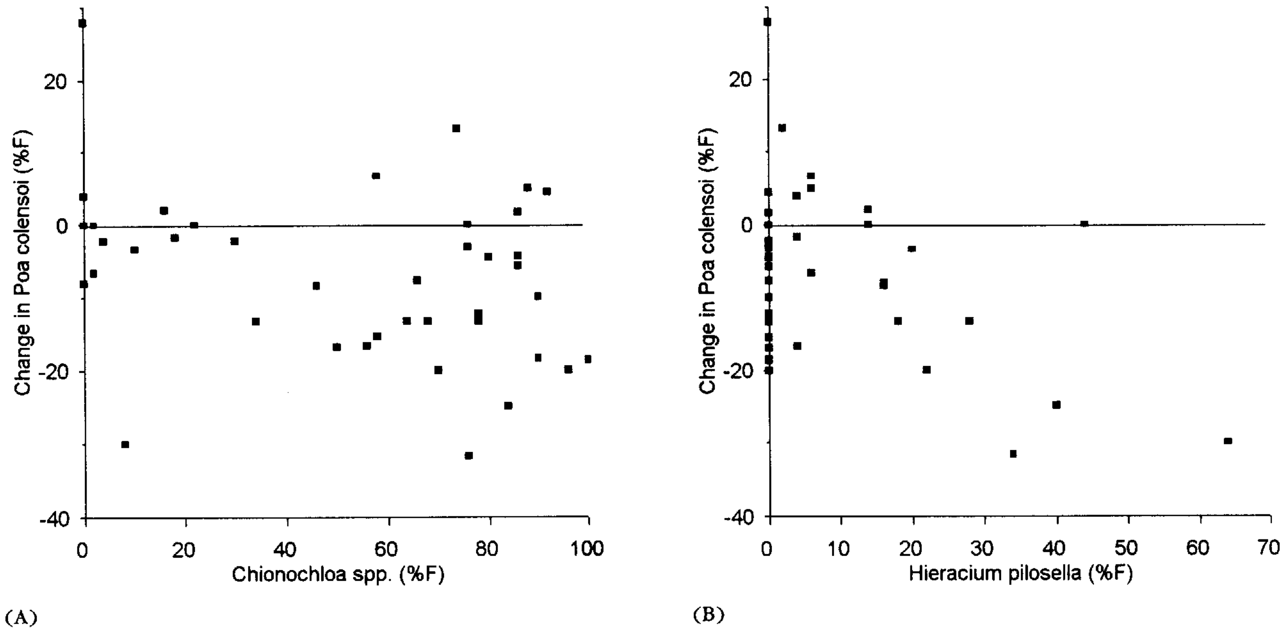


FIGURE 10. CHANGE IN PERCENT FREQUENCY OF *POA COLENSOI* AS A RATE OVER 10 YEARS PLOTTED AGAINST:
(A) PERCENT FREQUENCY OF *CHIONOCHLOA* SPP AT INITIAL MEASUREMENT.
(B) PERCENT FREQUENCY OF *HIERACIUM PILOSELLA* AT INITIAL MEASUREMENT.

4.4 EXPLANATION OF VEGETATION CHANGES

Overall, despite the geographic and altitude variation within the data set, some notable trends have emerged. Along with a reduction in bare ground, there has been an increase in tall tussock, shrubs, and *Hieracium* species, and a general decline in herbs and short tussock species.

This section considers interrelationships between these trends, and compares these results with other published studies.

Vegetation cover increase

An increase in vegetation has occurred on most transects. Comparing the increase in cover with trends in the major increasing species, rank correlations were not significant (P>0.05) between change in cover of bare ground and change in frequency of *Chionochloa* species, any *Hieracium* species, or the sum of shrub frequencies. Ground cover changes are likely to have resulted from cover changes in a variety of species, depending on circumstances. There appears to be no single explanation for the improvement in cover.

Tall tussock increase

As mentioned above, an increase in *Chionochloa* spp. was common to most transects, rather than a feature of specific environments.

It is probable that the increase in *Chionochloa* spp. has been promoted by lower grazing levels and an absence of tussock burning since retirement. An increase in *Chionochloa* spp. associated with reduced grazing has been observed elsewhere

(Scott, Dick and Hunter, 1988; Rose and Platt, 1992; Lee, Fenner and Duncan, 1993; Hunter, 1994). It has been noted that an increase in *Chionochloa* spp. may be caused by the growth of existing plants or recruitment (Scott *et al.,* 1988), and that recruitment is required for the continuation of the community (Rose and Platt, 1992). We made no specific investigations to assess the relative importance of growth and recruitment in causing the observed tussock increase, although seedling tussocks were observed at a number of transects.

Short tussock decrease

Festuca novae zelandiae and *Poa colensoi* both commonly declined in frequency, without obvious preference for any particular measured environmental situation.

Competition from increasing tall tussock or *Hieracium* spp. does not appear to have had any primary influence in causing this decline in short tussock. Change in neither *Festuca novae-zelandiae* nor *Poa colensoi* showed any significant correlation with any increase in tall tussock or *Hieracium* species. However, decline in *Poa colensoi* was slightly more common on sites with greater initial frequency of *Chionochloa* spp. (Fig. 10a), although this relationship was not significant ($P>0.05$). Further, decline in *Poa colensoi* was often greater on sites with higher initial *Hieracium pilosella* frequency, although this relationship was also not significant. It is notable that many sites without any *Hieracium pilosella* showed equal decline (Fig. 10b).

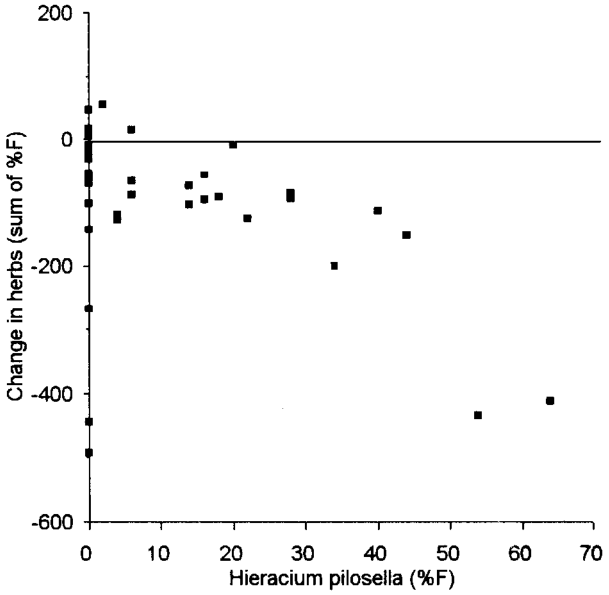
The decrease in *Festuca novae-zelandiae* may have occurred quite independently of the reduced grazing levels. A decrease in *Festuca novae-zelandiae* has been observed elsewhere in situations where grazing has continued (Rose, 1983; Rose, Platt and Frampton, 1995; Scott *et al.,* 1988). With retirement, the fate of *Festuca novae-zelandiae* has varied. While Scott *et al.* (1988) observed a decline, Rose (1983) and Rose *et al.* (1995) observed a slight increase in some retirement situations.

Scott *et al* (1988) suggested that there may be a threshold in species cover above which *Festuca novae zelandiae* will tend to increase, but below which it will decrease. A threshold cover of about 10% was suggested. Except for one site at Pahau, which had a cover of 16%, all sites with recent cover data in this study had a cover of *Festuca novae-zelandiae* of less than 6%. Possibly related to earlier heavier grazing, it may be that sites in this study have insufficient short tussock cover to avoid a decline.

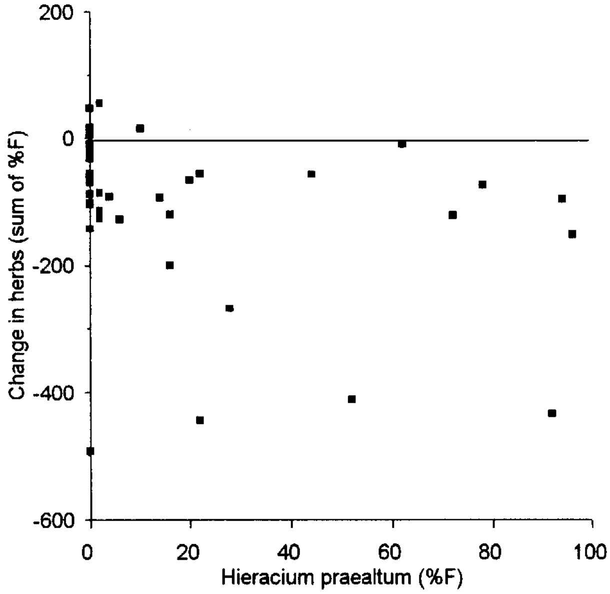
Scott *et al* (1988), and Connor (1992) observed decreases in *Poa colensoi* in both snow tussock and short tussock grassland. However, under retirement conditions an increase in *Poa colensoi* was measured in the Harper-Avoca area (Rose, 1983; Rose *et al.,* 1995).

Herb decrease

It has already been noted that a decline in herb frequencies was common, with lower altitude sites often experiencing the greatest decline. This decline is unlikely to be related to seasonal climatic factors, since most of the major declining herb species were perennial, and many native.



(A)



(B)

FIGURE 11. CHANGE IN SUM FREQUENCY OF HERBS AS A RATE OVER 10 YEARS PLOTTED AGAINST:

(A) FREQUENCY OF *HIERACIUM PILOSELLA* AT INITIAL MEASUREMENT.

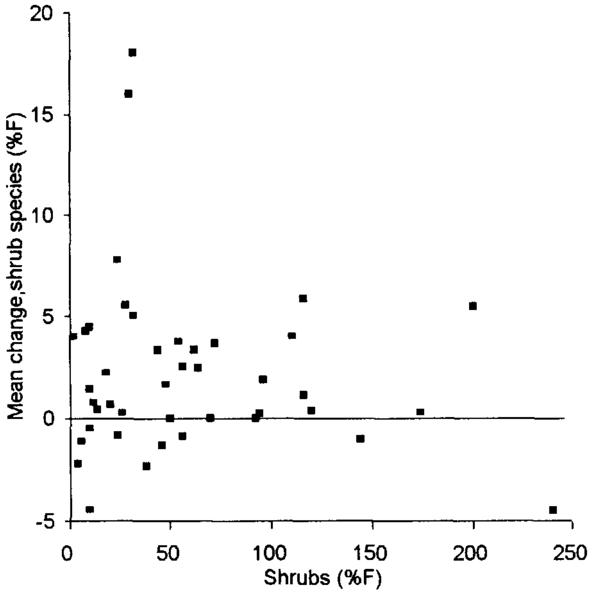
(B) FREQUENCY OF *HIERACIUM PRAEALTUM* AT INITIAL MEASUREMENT.

Herb frequency (excluding *Hieracium)* declined more on sites where *Hieracium pilosella* and *Hieracium praealtum* had high initial frequencies (Figs. lla and llb). However, there was no statistically significant correlation between herb decline and the actual increase in any *Hieracium* species. Out of 36 sites with a decline in the sum of herb frequencies, 8 sites had neither *Hieracium pilosella* nor *H. praealtum*.

Competition from increasing tall tussock is another possible cause of herb decline. It has been observed elsewhere that the abundance of herbs is generally low where there is a very high cover of tussock and litter (Connor and MacRae, 1969; Mark, 1969), and one might therefore expect that increased tall tussock cover might result in a reduction in herbs. There was some correlation between the change in sum of herb frequency and initial *Chionochloa* spp. frequency (r_S=0.47, P<0.01), but this may be more likely to be due to their dual relationship with altitude, both tending to be characteristic of lower altitude locations. The relationship between change in sum of herb frequency and change in *Chionochloa* spp. frequency was not significant. Overall, the actual cover of tussock and litter at the study sites is still quite low, and actual cover increases are likely to have been of a very minor magnitude. While inconclusive, it would appear that herb decline may not necessarily be related to the increase in tall tussock.

Most of the herb species identified in the current study that had major decreases (Table 3) were also observed to have declined in the Harper-Avoca (Rose *et al.,* 1995), under both grazing and retirement, and in communities without tall tussock. This includes such herbs as *Acaena* species, *Cerastium fontanum, Crepis capillaris, Hypochoeris radicata, Luzula* species, *Rumex acetosella,* and *Viola cunningbamii.*

FIGURE 12. MEAN CHANGE IN PERCENT FREQUENCY OF SHRUB SPECIES, AS A RATE OVER 10 YEARS, AND INITIAL SUM OF PERCENT FREQUENCY.



Hieracium species increase

It has been noted that there has been a general increase in *Hieracium* spp. frequencies, particularly *H. pilosella, H. praealtum,* and *H. lepidulum*.

Scott (1993) suggested that in the Waimakariri an exponential increase in cover of *Hieracium* species could be expected up to the stage where its cover reached a level of 15%, a less rapid increase once that level is reached, with stabilization in *Hieracium spp.* cover at around 34%.

In the current study, while cover data were obtained from 27 sites with *Hieracium* spp., on only 4 of those sites was the combined cover of all *Hieracium* species greater than 15%. The greatest combined *Hieracium* spp. covers were found at Porters, where on transect 5 the combined cover was 33% (19% *H. pilosella,* 12% *H. praealtum),* and on transect 6 the combined cover was 26% (15% *H. praealtum,* 10% *H. pilosella).* It may be that a considerable expansion *of Hieracium* spp. has yet to occur on most transects.

The relationship of *Hieracium* species to grazing remains unclear, although its increase has been noted in many high country environments (Rose, 1983; Hunter, 1991; Scott, 1993; Rose *et al.,* 1995; Duncan, Colhoun and Foran, 1996). The `invasive weed' hypothesis claims that the species is an aggressive invader *of* the high country, irrespective of management (e.g., Scott, 1985). An alternative explanation is that *Hieracium* spp. are a symptom of depletion, related to overgrazing and burning (Treskonova, 1991). Rose *et al.* (1995) found no evidence that sheep grazing enhanced the spread *of Hieracium pilosella,* or that retirement prevented its invasion.

Since this study did not compare retired and grazed conditions, the exact effect *of* retirement on *Hieracium* spp. cannot be established. The significant increase in *Hieracium* spp. observed in this study, despite reduced grazing for nearly 20 years, would suggest that reduced grazing may be unlikely to halt the spread in these environments, which are already modified by previous heavier grazing, burning, and tussock canopy reduction.

Shrub increase

While slightly increased shrub frequencies were common to most sites in each study area, shrubs are still a minor component of the studied communities, with most shrub species occurring on relatively few of the 42 transects.

It has been noted elsewhere that shrubs will increase in a community where a seed source exists (Calder *et al.,* 1992; Rose and Platt, 1992; Rogers and Leathwick, 1994) and where there is a suitable microclimate for regeneration. However, in this study there was no clear relationship between initial frequency and the level of shrub increase (Fig. 12). The relative influence of growth and recruitment is not known.

Little is known about whether the observed increase in shrub frequency is due to reduced grazing, lack of burning, or other factors. However, many of the native shrub species are probably more flammable than palatable, and hence their current increase is perhaps more likely to be related to the lack of fire in recent history. In the North Island, Rodgers and Leathwick (1994) noted the advance of *Dracophyllum* species, *Leptospermum scoparium* and *Kunzea ericoides* in country still grazed, but not burnt since the 1950s. Certainly fire, rather than grazing, has been suggested as a means of controlling shrub advancement (Calder *et al.,* 1992).

5. Implications and management options

Remeasurement of 42 transects in the eight selected conservation areas has revealed an increase in vegetation cover and an increase in frequency of tall tussock, shrubs, and *Hieracium*. Some short tussock species have declined in frequency, as have many herbs. In general, these changes were slight but widespread.

However, the specific influence of retirement in causing these trends remains uncertain. Some of the observed trends may relate to other factors, or be characteristic of more widespread adjustments in the high country, following more intensive pastoral practices in the early European era.

5.1 MANAGEMENT OBJECTIVES AND OPTIONS

A common initial objective in the retirement of these areas was to increase vegetation cover, towards enhanced soil and water conservation. The increase in vegetation cover demonstrates at least partial success in achieving this aim under retirement management. However, with the transfer of these areas to the Department of Conservation, management objectives may have broadened.

If the Department of Conservation wishes to allow natural succession processes to operate, then a continuation of the current retirement management may be contemplated. If the observed trends do relate to retirement, with a continuation of this management over a longer period of time vegetation cover may improve further, with an improved tussock canopy, and less short tussock and herbs. *Hieracium* spp. could be expected to increase but may stabilize at some point (Scott, 1993). Shrubs could be expected to increase, and in the long term may become a major component in some environments.

It may be possible to achieve a greater level of retirement than has been the case since this monitoring was established. Sheep grazing could probably be further reduced, with attention to fencing and unauthorized grazing by runholders. However, the current work does not permit an evaluation of the exact benefits of a greater commitment to retirement.

Alternatively, the Department could seek the recovery of these areas to their original state. Although changes under retirement management possibly show some trends towards the original vegetation, it is unlikely that future vegetation communities will ever completely replicate the original because of the presence of exotic species, especially *Hieracium* spp. with their unknown future impact on the tussock grassland ecology.

If retention of a tall tussock grassland community is desired then intervention may be necessary in the future, in areas below the natural timberline. Over this monitoring interval there has only been a slight increase in shrub frequencies, however in the future woody vegetation may become more dominant in some environments. Burning has been shown to have an effect in reducing the shrub component (Calder *et al.,* 1992; Rogers and Leathwick, 1994). However, there are risks involved in burning. The demographic structure and vigour of the tussock community is likely to be compromised, and with the opening up of the canopy the invasion of *Hieracium* species J ensen, Mason and Treskonova, 1994) and other exotic species is likely, so reducing conservation values. Given that a short term increase in bare ground and a longer term decrease in litter are likely consequences of burning, the risks of soil loss or degradation need to be evaluated.

In some instances the Department of Conservation may entertain multi purpose objectives, and consider allowing limited grazing in these conservation areas. The likely effect of such action would depend on the level of grazing allowed. It may be possible to achieve similar vegetation trends, and improved cover, under limited grazing. Further work could be helpful in this regard. With significantly more grazing the likely outcome would be a decline in tall tussock in terms of stature and seedling recruitment (Lee *et al.,* 1993; Rose and Platt, 1992), and shrub increase would probably remain static or decline. However, *Hieracium* spp. may continue to increase and short tussock and herbs may well continue to decrease (Rose, 1983,1995).

Individual study areas have their own specific management issues. At Treble Cone major intervention has occurred, with the oversowing of exotic grass species on ski trails. This has significantly altered these once native areas, and has also encouraged stock migration to higher altitudes than might otherwise occur, particularly with the application of fertilizer. While slope protection may have been the initial concern, the Department of Conservation may have objectives for this area related to native vegetation. It may be more appropriate to revegetate areas disturbed due to ski field development with native grasses, such as *Poa colensoi.*

The Porter Conservation Area has a higher proportion of shrubs than other study areas. *Dracophyllum* spp. have a particularly notable presence, particularly on some of the more shady aspects. If the *Dracophyllum* spp. were burnt, it is likely that they would be replaced by a complex of exotic grass and herb species, including browntop and *Hieracium* spp., rather than by tall tussock grassland. While the original vegetation is likely to have been beech forest, the Department of Conservation may view the shrubby *Dracophyllum* spp. slopes as a landscape feature, and aim to protect these shrub communities, and remaining forest remnants, from fire or wilding pine spread.

5.2 FURTHER RESEARCH

Aspects worthy of further research would include the relative importance of growth and recruitment as a cause of tall tussock increase, the expansion or contraction of tall tussock in areas with alpine cushion vegetation, and further research into the effects of burning in tussock grasslands. The nature of change in more barren environments and shingle slides could also be investigated.

However, this synoptic view of changes over the last decade has uncovered some noteworthy vegetation trends. The most worthwhile extension of this work would be to determine whether such trends have occurred in other areas, and to attempt to isolate the influence of retirement. Transects were established in many other Conservation Areas, and in some cases equivalent monitoring was established on nearby pastoral lease land, under block stock limitations. An extension of this programme including equivalent sites under pastoral conditions would help determine both the extent of such trends, and whether retirement is necessary to achieve the Department's objectives. This should be particularly relevant in the review of tenure on marginal pastoral lands, and the evaluation of limited grazing as an alternative to retirement in the conservation estate.

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