VITTADINIA TRILOBA AND *RUMEX ACETOSELLA* COMMUNITIES IN THE SEMI-ARID REGIONS OF THE SOUTH ISLAND

P. A. WILLIAMS

Botany Division, DSIR, Private Bag, Christchurch

SUMMARY: Floristics of *Vittadinia triloba* communities in Central Otago and the upper Waitaki valley and *Rumex acetosella* communities in the upper Waitaki, are compared with each other and with similar communities elsewhere in the South Island. Many species are common to all semi-arid areas, but each area has as its own special features, either the presence of a particular species or the greater abundance of a widespread species. The recent increase in *Vittadinia triloba* is thought to be due to a combination of reduced rabbit grazing pressure, changing land and stock management and recent droughts.

INTRODUCTION

In the South Island there are several inter-montane regions that have the driest climate in New Zealand (Fig. 1). Native grasslands once dominated here (Petrie, 1912; Connor, 1964), but have been replaced by the so-called scab-weeds *(Raoulia* spp.) and many naturalised species because of repeated fires, over-grazing by sheep *(Ovis aries)* and rabbits *(Oryctolagus cuniculus)* and the aridity. Parts of Central Otago for example, have become notable for their covering of the highly scented wild thyme *(Thymus vulgaris)*. Scattered amongst the thyme and often forming extensive patches on adjacent sites is another naturalised sub-shrub, vittadinia *(Vittadinia triloba)*. This too has increased in recent times, the pale grey-green of its foliage being a conspicuous feature of the landscape.

Further north in the upper Waitaki valley, almost pure stands of vittadinia grow adjacent to the State Highway between Kurow and Otematata (Figs 2 and 3). Further inland from the western-most stands of vittadinia the Waitaki valley opens onto the outwash plain of the Ahuriri River. Sorrel *(Rumex acetosella)* dominates extensive areas in this southeast corner of the Mackenzie basin that are clearly visible on both sides of the State Highway from Omarama southward to the entrance to the Lindis Pass. Connor (1964) described several sorrel-dominated "weed communities" further north on the banks of the Pukaki River. The more extensive sorrel communities on the flats near Omarama have not been described.

Central Otago and southeastern Mackenzie basin, being semi-arid regions, receive only *c*. 400 mm of precipitation, with very warm dry summers and cold winters. Towards the Lindis Pass where the sorrel communities grade into short-tussock grassland, the precipitation increases to *c*. 800 mm and snow may lie for several weeks in winter (O'Connor, 1976).

Moore (1954) described sorrel communities in Marlborough and these probably experience a similar climate, though slightly wetter, being at

FIGURE 1. *The three driest regions of the South Island (dotted), modified from McLintock (1959).*

FIGURE 2. *Sparse vegetation of the middle Waitaki valley* - Sophora prostrata *shrubs with* Echium vulgare, Trifolium arvense *and* Vittadinia triloba.

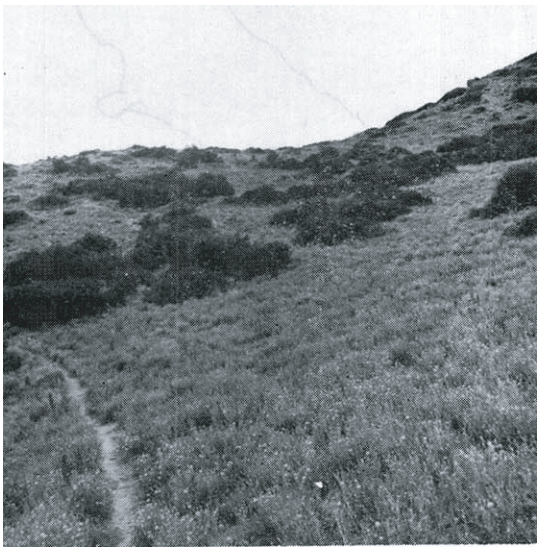

FIGURE 3. *A dense stand of* Vittadinia triloba *with* Sophora prostrata, *near Lake Aviemore.*

higher altitudes (c. 900 m) than the Omarama sorrel communities ($\bar{x}$ 424 m, range 366-488 m).

Vittadinia colonises predominantly brown-grey earths of moderate fertility but with marked summer deficit in Central Otago and the upper Waitaki valley. The sorrel stands are on yellow-brown earths and associated soils that are less fertile but as dry in summer.

Writing of the introduction of alien plants into the degraded tussock grasslands Moore (1954) noted, "(a) that not all the common northern hemisphere weeds of similar latitudes have arrived; (b) that the weed florulas of widely separated districts of similar climate are still, for historical reasons, not quite alike; (c) that the relative importance of individual species varies widely from place to place; and (d) that in any district the species listed for the depleted ground arrange themselves into rather distinct communities". Only rarely, e.g. Healy (1969), have the floristic details of these generalisations been recorded in the following 25 years.

Here I describe the distribution and compare the floristics of the vittadinia communities in the upper Waitaki and Central Otago, and secondly, I compare the floristics of the sorrel communities in the south eastern Mackenzie basin with those in Marlborough.

Field Investigations In Otago And Mackenzie Basin

Stands were sampled during spring (November 1977 and 1978) to cover the full range of sites where vittadinia and sorrel were physiognomically important, 35 in the Mackenzie basin and 15 in Central Otago. Plots 2 X 10 m were laid out along the slope and the physical characters of the sites noted. Grid references are given in the appendix. Each species within the plot was scored on a three point scale: 3, throughout the plot with more than 10% cover; 2, throughout the plot but with less than 10% cover; 1, scattered individuals. Species within a 2 m strip around the plot (an aggregate of 84 m^2) were noted. Three lines were placed along the plot and 100 points were taken to record only the first hits. Graduations on the stick were used to measure the height of vittadinia bushes to the nearest 2.5 cm.

Results And Discussion

Vittadinia communities

Vittadinia triloba is native to southeast Australia where it grows commonly in grassland, woodland, and dry forest habitats (Burbridge and Gray, 1970). In the drier parts of eastern South Island, Nelson and southern North Island it forms compact, twiggy bushes up to 40 cm tall, with small, grey-green hispid leaves that are seldom browsed by sheep. The

numerous small flowers have purplish ray florets, but the fruiting stage is most conspicuous, when bushes become densely studded with buff-coloured pappus hairs. The native New Zealand vittadinia *(Vittadinia australis)* rarely grows as tall as *V. triloba,* has white ray florets, never forms such extensive colonies, and is more widespread throughout New Zealand, in open habitats from sea level to the montane zone.

In Central Otago the vittadinia stands are most abundant in; the Cromwell Gorge, especially on the terraces, fans and hillslopes of the true right bank, up to about 430 m; the lower Manuherikia valley, particularly on sunny aspects of the Clare Hills and Merton Hills; the rolling country between Olrig trig and the lower Manorburn dam and much of the hill country southeast of Alexandra to about Roxburgh.

In the upper Waitaki, vittadinia has a more restricted distribution, being virtually confined to the south side of the valley between Lake Waitaki and the Ahuriri Pass west of Otematata. The densest s'ands grow adjacent to the State Highway between Lake Aviemore and Otematata.

Vittadinia grows on terraces and fans, through rolling hill country, to steep hillsides with slopes of 30∞, up to 500 m. All sites in the upper Waitaki and most of those in Central Otago were on a north west to north east aspect (Fig. 4), often in markd contrast to the herbaceous vegetation of the south faces. Dense patches grow around sheep-yards and recently ploughed lucerne *(Medicago sativa)* paddocks such as those on the banks of Lake A vie more (Fig. 5). Sheep camps high up on sunny faces or in the lee of prevailing northwest winds often have well developed stands of vittadinia and from here it appears to have spread to adjacent country.

Most sites occupied by vittadinia have a high proportion of bare ground (Table 1), about thirty per cent on the average being stones. The very low amount of bare ground at some of the upper Waitaki sites results from a dense sward of annual

grasses. Seldom, however, are either grasses or herbs the dominant ground cover, so that if the sites were to be named following Atkinson (1962), most would be "stonefields" or "sandfields".

Vittadinia shrubs are about 20 cm tall on average (Otematata 18 ±4 cm; Central Otago 21 ±6 cm). The tallest stands are found at the sites of old sheep camps in sheltered situations, on foot slopes, or local outwash material. Bush height was markedly reduced near the altitudinal limit of vittadinia as an important species.

In eastern Canterbury vittadinia never dominates:

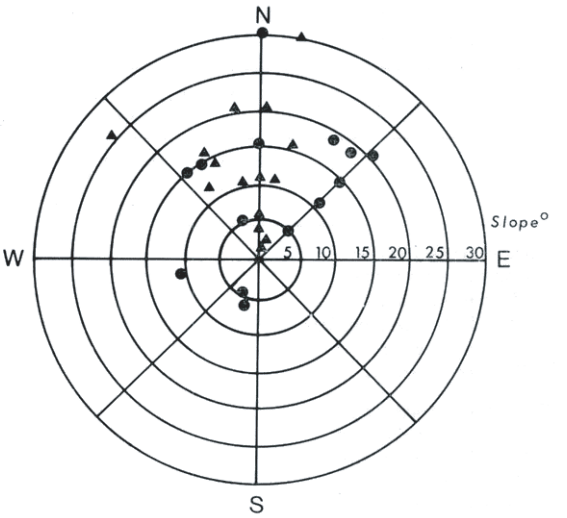

FIGURE 4. *The aspect and slope of* Vittadinia triloba *sites in the Waitaki valley (triangles) and Central Otago (circles).*

FIGURE 5. Vittadinia triloba *forming a dense cover (right) in an area previously sprayed for barley grass* (Hordeum *spp.).*

it grows as scattered plants in low-tussock grassland, waste places and unattended lands (Healy, 1969), especially on Banks Peninsula. Similar sites, and

TABLE 1. *Frequency, dominance, or cover % for all species recorded from sorrel* (Rumex acetosella) *and vittadinia* (Vittadinia triloba) *communities*.

	Sorrel communities Omarama			Vittadinia communities Otematata			Vittadinia communities Central Otago		
	Frequency[1] %	Dominance[2], or Cover Mean	%(bold)[3] Range	Frequency %	Dominance, or Cover Mean	%(bold) Range	Frequency %	Dominance, or Cover Mean	%(bold) Range
NANOPHANEROPHYTES									
Carmichaelia ramosa				1	1				
Hymenanthera alpina				2	1				
Muehlenbeckia complexa				1	4	**1-8**			
* *Rosa rubiginosa*	2	1		2			2	1	
Sophora prostrata				1	1				
WOODY CHAMAEPHYTES									
* *Artemisia absinthium*				1	1				
Carmichaelia monroi				1	8	**5-11**			
Pimelea pulvinaris				2					
* *Thymus vulgaris*							3	4	**1-13**
Vittadinia australis				3	1		3		
* *V. triloba*				5	1		5	**18**	**2-39**
HERBACEOUS CHAMAEPHYTES									
Acaena buchananii	1	1		1	1		J	I	
A. caesiiglauca							I	1	
A. novae-zelandiae							1	1	
* *A. agnipila*				1	1				
Colobanthus brevisepalus	1	1		1	1				
Convolvulus verecundus	3	1		2	1		1	J	
Cotula pectinata	1	2	**1-5**	**1**	**15**	**1-30**			
C. *serrulata*	1	1		1	1				
Cyathodes fraseri							1	1	
Dichondra repens				2	1				
* *Echium vulgare*	3	1	**1-2**	5	1	**1-4**	3	1	
* *Eschscholtzia californica*				1	1				
* *Marrubium vulgare*				2	1		2	2	**1-4**
* *Medicago sativa*	1	1							
Muehlenbeckia axillaris	1	4	**1-6**	1	1				
Oxalis exilis	1	1		4	1		2	1	
Raoulia australis	3	2	**1-6**	3	2	**1-4**	3	1	
R. hookeri	1	1		1	1		2	1	
R. subsericea	5	2	**1-9**				1	1	
Senecio quadridentatus				1	1				
Scleranthus uniflorus	1	1		2	1				
Stellaria gracilenta	1	1		1	1		2	1	
HEMICRYPTOPHYTES									
Dicotyledons									
* *Cirsium arvense*							1	1	
* *C. vulgare*				1	1		1	1	
* *Crepis capillaris*	3	1	**1-4**	1	3	**1-5**	4	2	**1-11**
Epilobium alsinoides	3	1							
E. billardierianum ssp. *cinereum*							1	1	
E. rostratum	3	1							
Geranium sessiliflorum	3	1		2	1		3	2	**1-5**
Gnaphalium audax	1	1							
G. *luteo-album*	1	1					1	1	
* *Hieracium pilosella*	3	1	**1-2**						

TABLE 1 continued. *Frequency, dominance, or cover % for all species recorded from sorrel* (Rumex acetosella) *and vittadinia* (Vittadinia triloba) *communities.*

	Sorrel communities			Vittadinia communities					
	Omarama			Otematata			Central Otago		
	Frequency[1] %	Dominance[2], or Cover Mean	%(bold)[3] Range	Frequency %	Dominance, or Cover Mean	%(bold) Range	Frequency %	Dominance, or Cover Mean	%(bold) Range
* *H. praealtum*	3	1							
* *Hypericum perforatum*	1	1	**1-2**				2	1	
* *Hypochoeris glahra*	2	1		4	1	**1-3**			
* *H. radicata*	4	1		3	2		2	1	
Ischnocarpus novae-zelandiae				1	1				
Kirkianella novae-zelandiae	1	1							
Lepidium sisymbrioides	1	1		1	1				
Oreomyrrhis rigid a				1	1				
* *Reseda luteola*				3	1		2	1	
* *Salvia verbenaca*	1	1		2	1				
* *Sonchus asper*				1	1				
* *Taraxacum officinale*	1	1		2	1				
* *Verbascum thapsus*	1	1		3	1		3	4	**1-10**
* *V. virgatum*							2	1	
Wahlenbergia albomarginata	1	1		2	1				
Monocotyledons									
Agropyron scabrum	2	1		1	1				
Agrostis muscosa	1	1							
* *A. tenuis*	3	4	**1-12**						
* *Anthoxanthum odoratum*	2	2	**1-4**						
Carex albula	1	1		1	1				
C. *breviculmis*	3	4	**1-28**	2	1	**1-3**	2	1	
* *Dactylis glomerata*							1	1	
Dichelachne crinita				1	1				
* *Festuca rubra*	1	1							
F. novae-zelandiae	2	1							
* *Lalium perrene*				1	1		1	1	
Notodanthonia clavata							4	3	**1-9**
N. maculata	4	2	**1-8**	2	9	**1-13**	2	2	**1-7**
N. racemosa	1	1		1	1				
N. thompsonii	2	1							
Poa caespitosa	1	1		1	1		2	1	**1-4**
P. colensoi	2	1							
P. lindsayi	1	1					1	1	
P. maniototo	4	2	**1-11**	2	1		3	1	**1-2**
* *P. pratense*	1		2		1		2	1	
GEOPHYTES									
Dicotyledons									
* *Rumex acetosella*	5	**13**	**1-36**	4	2	**1-6**	2	2	**1-4**
R. flexuosus				1	1				
FILICOPSIDA									
Cheilanthes sieberi				1	1		3	1	
THEROPHYTES									
Dicotyledons									
* *Anagallis arvensis*							1	1	
* *Aphanes arvensis*	1	1		1	1		2	1	
* *Arenaria serpyllifolia*				3	2	**1-10**	1	1	
* *Capsella bursa-pastoris*				2	1				

TABLE 1 continued. *Frequency, dominance, or cover % for all species recorded from sorrel* (Rumex acetosella) *and vittadinia* (Vittadinia triloba) *communities.*

	Sorrel communities			Vittadinia communities					
	Omarama			Otematata			Central Otago		
	Frequency[1] %	Dominance[2],. or Cover Mean	%(bold)[3] Range	Frequency %	Dominance, or Cover Mean	%(bold) Range	Frequency %	Dominance, or Cover % (bold) Mean	Range
* *Cerastium fontanum*	2	1		1	1		1	1	
* *Dianthus armeria*				2	**3**	**2-5**			
* *Erodium cicutarium*	3	**3**	**1-4**	4	**4**	**1-12**	5	**2**	**1-14**
* *Erophila verna*	3	**1**	**1-5**	1	1		1	1	
* *Euphorbia peplus*				1	1		2	1	
* *Filago minima*	3	1		1	1				
* *Gypsophila australis*	1	1		3	**1**	**1-2**	2	1	
* *Linum catharticum*				1	**4**	**1-8**	2	1	
* *Myosotis discolor*	5	**4**	**1-32**	2	**3**	**1-11**	2	1	
* *Navarettia squarrosa*				2	1		1	1	
* *Potentilla argentea*				1	1				
* *Sedum acre*				1	1		2	1	
* *Silene gallica*	1	1		2	1				
* *Spergula arvensis*				2	1				
Tillaea sieberiana				2	1		1	1	
* *Trifolium arvense*	3	**2**	**1-6**	5	2		5	**4**	**1-18**
* *T. dubium*	1	1		2	1				
* *T. micranthum*							1	1	
* *Veronica verna*	4	**3**	**1-13**	1	**4**	**1-7**	4	**1**	**1-5**
Monocotyledons									
* *Aira caryophyllea*	2	1		2	**1**	**1-2**	3	1	
* *Bromus mollis*	1	1		4	**4**	**1-8**	2	1	
* *B. sterilis*				3	**2**	**1-8**			
* *B. tectorum*	5	**5**	**1-20**	5	**3**	**1-13**	5	**3**	**1-17**
* *Hordeum murinum*				2	1		1	1	
* *Vulpia* spp.	5	**4**	**1-19**	5	**11**	**1-36**	4	**5**	**1-14**
MOSSES	4	7	**1-22**	1	1		2	**4**	1-7
LICHENS	5	5	**1-14**	1	**6**	**5-8**	3	**5**	**1-11**
LITTER	2	**13**	**1-25**	1	**2**	**1-3**	4	**12**	**1-47**
BARE GROUND	5	**54**	**32-80**	5	**47**	**3-66**	5	**47**	**19-81**
Total number of species	61			80			56		

* Naturalised species.

[1]. Frequency %: n = 25 for Omarama sorrel communities and n = 15 for vittadinia communities. 1, 1-19%; 2, 20-39%; 3,40--59%; 4, 60-79%; 5, 80-100%.

[2]. Dominance: Scored on a 3 point scale: 3, species throughout the plot with > 10% cover; 2, throughout the plot but with < 10% cover; 1, present as scattered individuals. Values are shown only in the absence of cover % data.

[3]. Cover (%): Means are calculated assigning a cover of 1 % to those plots where a species was present but not hit.

particularly road cuttings and verges, are occupied In the drier parts of Marlborough, occasionally as far inland as the middle Clarence valley.

Floristics of vittadinia communities

Of the 94 species recorded, 41 are common to both the Otematata and Central Otago stands. The most frequent and important of these are the herbs *Erodium cicutarium, Rumex acetosella* and *Trifolium arvense;* the annual grasses *Bromus tectorum* and *Vuipia* spp. (both *V. bromoides* and *V. myuros* are present) and the perennial tussock *Notodanthonia maculata**. Several species common to both areas have higher frequencies or cover/dominance in one or other area, e.g. *Arenaria serpyllifolia, Bromus mollis, Echium vulgare* and *Oxalis exilis* at Otematata, and *Crepis capillaris* and *Veronica verna* in Central Otago.

Of the 26 species found in the Otematata stands but not in the Central Otago stands, only *Filago minima* and *Spergula arvensis* were not seen elsewhere in Central Otago during the study. The native species, *Cotula* spp., *Lepidium sisymbrioides* and *Rumex flexuosus* and the adventive *Hypochoeris glabra* may be locally abundant in low-tussock grassland not occupied by vittadinia, while *Capsella bursa-pastoris* frequently grows in lucerne fields. All the herbaceous species found in the Central Otago stands but not in the Otematata stands were seen elsewhere in the Mackenzie basin, two for example, *Gnaphalium luteo-album* and *Hypericum perforatum,* were found in the son-el stands.

The *Sophora prostrata/Vittadinia triloba* shrublands in the upper Waitaki and the *Vittadinia triloba / Thymus vulgaris* shrublands in Central Otago are conspicuous kinds of vegetation unique to their respective areas. Thyme has a similar distribution to vittadinia in Central Otago, but grows more extensively on a wider range of sites, including those with a southerly aspect-the north side of the Cromwell Gorge for example-and severe north facing sites such as old gold tailings.

Petrie (1912), in describing the vegetation and flora of the "grass-denuded lands of Central Otago" as they were 65 years ago, provides an interesting comparison with the present data. Many of his observations on the condition of the landscape and behaviour of individual species still apply to areas occupied by vittadinia. *Raoulia* spp. have reduced in abundance, but sorrel and the ephemeral *Erodium cicutarium* and *Vulpia bromoides* are still abundant. Petrie noticed *Bromus mollis* too, but this species is now much less important than *B. tecto rum* which Petrie did not record, but which was abundant by the early 1950s (Saxby, 1957). Thyme and the herbs *Crepis capillaris, Echium vulgare, Hypochoeris radicata* and *Verbascum thapsus* have all become important since Petrie's day.

Petrie (1912) mentioned *Notodanthonia buchananii* (then *Danthonia buchananii)* as one of the dominant grasses, but the DSIR, Lincoln herbarium (CHR) records indicate that this would have included the *N. maculata* of Zotov (1963). *Notodanthonia maculata* then, is still the dominant native grass over much of the driest country, although *N. clavata* now contributes significantly to the grass component too (Table 1).

Vittadinia triloba was not recorded by Petrie (1912) although herbarium records suggest he was familiar with it elsewhere in Otago (as *Vittadinia australis* var. *linearis).* The extensive writings of Cockayne (see Douglas, 1970) make reference only to *Vittadinia australis.* In one instance though, he could have been referring to *V. triloba.* Writing of the vegetation near Cromwell, Cockayne (1920, p. 92) records, "*Vittadinia australis,* a daisy-like plant as yet without a proper name". Yet Thomson (1922, pp. 426-27) lists *V. triloba* as *Vittadinia australis* and noted "Cockayne thinks this is the plant which is forming large colonies in parts of Central Otago". This must have been a personal communication. Vittadinia appears to have spread rapidly within the last ten years, possibly in response to periods of drought (A. J. Healy, *pers. comm.).* Table 2 shows

* *Rytidosperma* Steudel 1854 is now accepted as an earlier name for *Notodanthonia* Zotov 1963 (Connor and Edgar, 1979).

TABLE 2. *Total soil moisture deficit (mm) for the months October to March inclusive for Alexandra and Tara Hills.*

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Alexandra	486	419	512	566	316	381	329	392	399	395	403	484	547	471	425	397
Tara Hills	400	386	439	380	201	322	206	271	438	431	454	380	538	388	432	441

Data obtained from the New Zealand Meteorological Service.

that the late 1960s were generally more moist than the early]960s or early 1970s. Sheep numbers rose considerably on "Otago dry" runs too, in the period to 1971-73 compared with]965-67 (Hughes, 1974). These increased stock would have been largely supported by the products of increasing oversowing and topdressing that occurred during the same period (Hughes *et al.,* 1974). However, because these runs graze a very high percentage of their total area (Hughes, 1974), sunny faces may still have been subjected to stock concentrations resulting in bare ground and enhanced nutrient status. Vittadinia is reputed to have become a troublesome weed in the middle Waitaki since the loss of flat land beneath the new Lake Benmore in 1965 led to more intensive use of the lower hill slopes. For example, Figure 5 shows how vittadinia has dominated one comer of an intensively grazed lucerne paddock that was sprayed for barley grass *(Hordeum* spp.). The eruptive phase of vittadinia would have had to await the decline of the rabbit, like so much of the present vegetation of these regions, but the causal factors now are probably a combination of changing land and stock management creating conditions suitable for vittadinia and perhaps assisted by recent droughts.

Sorrel communities

Sorrel is widespread in New Zealand on cultivated land, waste places and low-tussock grassland especially, and has been intensely studied because of its importance to agriculture (e.g. Harris, 1970).

The sorrel and vittadinia communities of the upper Waitaki have many species in common, notably *Echium vulgare, Erodium cicutarium, Hypochoeris radicata, Myosotis discolor, Raoulia* spp., *Trifolium arvense, Veronica verna* and *Vulpia* spp., as well as sorrel itself (Table 1).

Table 1 indicates the greater importance of hemicryptophytes in the sorrel stands compared with the more diverse nanophanerophyte, woody chamaephyte and therophyte flora of the Otematata vittadinia stands. In particular, the presence of *Agrostis tenuis* and *Anthoxanthum odoratum* in the sorrel stands and the absence of *Arenaria serpyllifolia* and relatively greater frequency of *Hieracium* spp. indicate the less severe aridity and lower rabbit numbers on the flat sites compared with the sunny hillslopes dominated by vittadinia. *Epilobium rostratum, Notodanthonia thompsonii* and *Raoulia subsericea* were found only in the sorrel stands on the lower terraces of the Ahuriri River. Mosses and especially lichens are more important in the sorrel stands partly because of the greater stability of the flat ground surface (Table 1).

On the outwash surfaces of the Ahuriri River, anastomising channels and rises, a few metres across and often less than a metre deep, provide a subtle mosaic of micro-sites, varying in soil depth and moisture status. Crests have shallow stony soils dominated by herbs, especially sorrel or *Vulpia* spp., while the deeper soils of the hollows support *Agrostis tenuis, Anthoxanthum odoratum* and *Bromus tectorum.* An intermediate zone often has a predominance of *Myosotis discolor,* the masses of tiny blue flowers contrasting with the red sorrel and the purple-green of grasses in the hollows. The yellow flowered *Hieracium* spp. and *Hypericum perforatum* and the blue flowered *Echium vulgare,* as O'Connor (1976) noted, also contribute to the colour of the semi-desert, although *E. vulgare* is characteristically best developed on younger surfaces than those dominated by sorrel.

The most frequent species recorded from the sorrel dominated stands at Molesworth by Moore (1954) were *Arenaria serpyllifolia, Cirsium lanceolatum, Oxalis corniculata* (= ***O**. exilis)* and *Raoulia lutescens* (= *R. austraUs),* with no species apart from sorrel covering more than 5 % of the ground. If communities where sorrel was the second most important species are considered, the list includes *Agropyron scab rum, Carex breviculmis, Holcus lanatus, Geranium sessiliflorum, Hypochoeris radicata, Poa colensoi, Raoulia hookeri* and *Wahlenbergia albomarginata* (Moore, 1954). Few of these species are significant contributors to the sorrel communities at Omarama. *Notodanthonia maculata,* the most drought and grazing resistant of the native danthonias, is not recorded in the Molesworth area and neither is vittadinia.

Herbarium records (CHR) show that several naturalised species important at Omarama today were present in the Molesworth area at the time of Moore's field work in the late 1940s and early 1950s, mostly in association with human occupation or on cultivated land, e.g. *Echium vulgare, Erophila verna, Erodium cicutarium, Trifolium arvense* and *Veronica verna.* Both *Anthoxanthum odoratum* and *Hypochoeris radicata* were known from other communities on Molesworth at that time but together with browse-susceptible species such as *Hieracium praealtum,* they were excluded from the sorrel communities by grazing pressure. Other naturalised species presently abundant at Omarama had not been recorded from Molesworth at that time, e.g. *Bromus tectorum, Filago minima* and *Vulpia* spp.. The absence of herbarium records suggests they may still be absent there. Moore (1976) grouped species according to their response to reduced grazing pressure into "decreasers", "persisters" or

"increasers". It is interesting that *Arenaria serpyllifolia,* a "decreaser", was important in the early sorrel stands at Molesworth, while in the upper Waitaki it appeared only in the vittadinia stands-further evidence for the extreme aridity and present overgrazing of this part of the Mackenzie basin.

Floristics of the Omarama sorrel stands are similar to the Pukaki weed communities described by Connor (1964) but with the addition of *Echium vulgare, Hieracium* spp., *Filago minima, Salvia verbenaca, Silene gallica* and *Myosotis discolor*. This last was recorded merely as present from only two of Connor's fescue tussock grassland plots, whereas Allan (1940) described it as "remarkably abundant" in modified low-tussock grassland in the Mackenzie basin-perhaps Allan was referring to the Omarama area. *Echium vulgare* has been present in the Mackenzie basin for many years, but has become abundant more recently in the vicinity of the upper reaches of Lake Benmore and eastward of the Ahuriri River. *Filago minima* is a recent arrival (Macmillan, 1979) that is now a conspicuous component of the local Omarama flora. Most of the above 6 species were introduced into New Zealand as seed impurities (Healy, 1969) and their presence probably indicates the early attempts at pasture establishment in the vicinity of Omarama, on better soils than Connor's "weed communities".

CONCLUSIONS

Portions of the several semi-arid and related denuded landscapes of central and eastern South Island have a core of common species made up of an indigenous element and a larger naturalised element, the latter especially of annuals. Each area has its own special features, either the presence of a particular species or the greater abundance of a species common to two or more of the areas. These differences partly reflect differences in climate or site factors and partly a differing history of human occupation and land management or mismanagement, ranging from rabbit control to the side effects of hydro dam construction, as well as the all-important differences in the available biota. The floristics of these landscapes especially are ever-changing, lacking as they do a dominant native element capable of tolerating grazing by sheep and rabbits and the aridity. This account has provided the floristic detail that re-affirms Moore's (1954) generalisations and a base with which future changes can be compared.

ACKNOWLEDGEMENTS

Dr B. P. J, Molloy (DSIR) brought the vittadinia communities to my notice and the New Zealand Meteorological Service provided the soil moisture deficit data.

REFERENCES

ALLAN, H. H. 1940. A handbook of the naturalised flora of New Zealand. *New Zealand Department of Scientific and Industrial Research Bulletin* 83. 344 pp.

ATKINSON, I. A. E. 1962. Semi-quantitative measurements of canopy composition as a basis for mapping vegetation. *Proceedings of the New Zealand Ecological Society* 9: 1-8.

BURBRIDGE, NANCY T.; GRAY, MAX. 1970. *Flora of the Australian Capital Territory*. Australian National University Press, Canberra. 446 pp.

COCKAYNE, L. 1920. An economic investigation of the montane tussock-grasslands of New Zealand. V. Regeneration of grassland after depletion. *New Zealand Journal of Agriculture* 19: 82-94.

CONNOR, H. E. 1964. Tussock grassland communities in the Mackenzie country, South Canterbury, New Zealand. *New Zealand Journal of Botany* 2: 325-51.

CONNOR, H. E.; EDGAR, E. 1979. *Rhytidosperma* Steudel *(Notodanthonia* Zotov) in New Zealand. *New Zealand Journal of Botany* 17: 311-38.

DOUGLAS, J. A. 1970. The Cockayne plots of Central Otago. *Proceedings of the New Zealand Ecological Society* 17: 18-24.

HARRIS, W. 1970. Yield and habit of New Zealand populations of *Rumex acetosella* at three altitudes in Canterbury. *New Zealand Journal of Botany* 8: 114-31.

HEALY, A. J. 1969. The naturalised flora in Canterbury. *In:* Knox, G. A. (Editor). *The Natural History of Canterbury*. pp. 261-333. A. H. and A. W. Reed, Wellington.

HUGHES, J. G.; GAUGH, JANET; WARDELL, P. J. 1974. High country production survey 1972/73. *Tussock Grasslands and Mountain Lands Institute Review* 28: 31-69.

HUGHES, J. G. 1974. Changes in high country pastoral production in recent years. *Tussock Grasslands and Mountain Lands Institute Review* 29: 64-86.

MACMILLAN, B. H. 1979. Shoreline flora and vegetation of Lake Pukaki, South Canterbury, New Zealand. *New Zealand Journal of Botany* 17: 23-42.

McLINTOCK, A. H. 1959. *A Descriptive Atlas of New Zealand*. R. E. Owen, Government Printer, Wellington. 109 pp.

MOORE, L. B. 1954. Some *Rumex acetosella* communities in New Zealand. *Vegetatio* 5-6: 268-78.

MOORE, L. B. 1976. The changing vegetation of Molesworth Station, New Zealand, 1944 to 1971. *New Zealand Department of Scientific and Industrial Research Bulletin* 217. 118 pp.

O'CONNOR, K. F. 1976. *An Introduction to the Waitaki. New Zealand Man and the Biosphere Report No. I.* Tussock Grasslands and Mountain Lands Institute, Lincoln College. 85 pp.

PETRIE, D. 1912. Report of the grass-denuded lands of Central Otago. *New Zealand Department of Agriculture. Industries and Commerce. Bulletin* No. 23 *(New Series):* 1-16.

SAXBY, S. H. 1957. Ecology and grassland. *Proceedings of the New Zealand Ecological Society* 5: 1-3.

THOMSON, G. M. 1922. *The Naturalisation of Animals and Plants* in *New Zealand*. Cambridge University Press, London. 607 pp.

ZOTOV, V. D. 1963. Synopsis of the grass subfamily Anmdinoideae. *New Zealand Journal of Botany* 1: 69-78.

APPENDIX 1

GRID REFERENCES FOR SAMPLE SITES

Otematata:	NZMS 1 S117; 885 242, 885 243, 888 244, 889 244, 891 243, 891 244, 898 241, 901 233, 914 238, 915 237, 923 226, 946 218, 254 216, 955 205, 956 212.
Omarama :	NZMS 1 S109; 684 418, 685 425, 685 425. S116; 556 358, 556 358, 580 370, 588 384, 595 365, 595 385, 600 380, 625 385. S117; 694 395, 694 395, 694 395, 721 386, 722 387, 722 387, 735 389, 735 395, 743 392.
Central Otago:	NZMS 1 S133; 063 654, 065 654, 073 634, 076 647, 078 645, 092 636, 992 654. S143; 153 392, 156 388. S144; 209 459, 218 465, 218 467, 236 475, 266 523, 280 530.