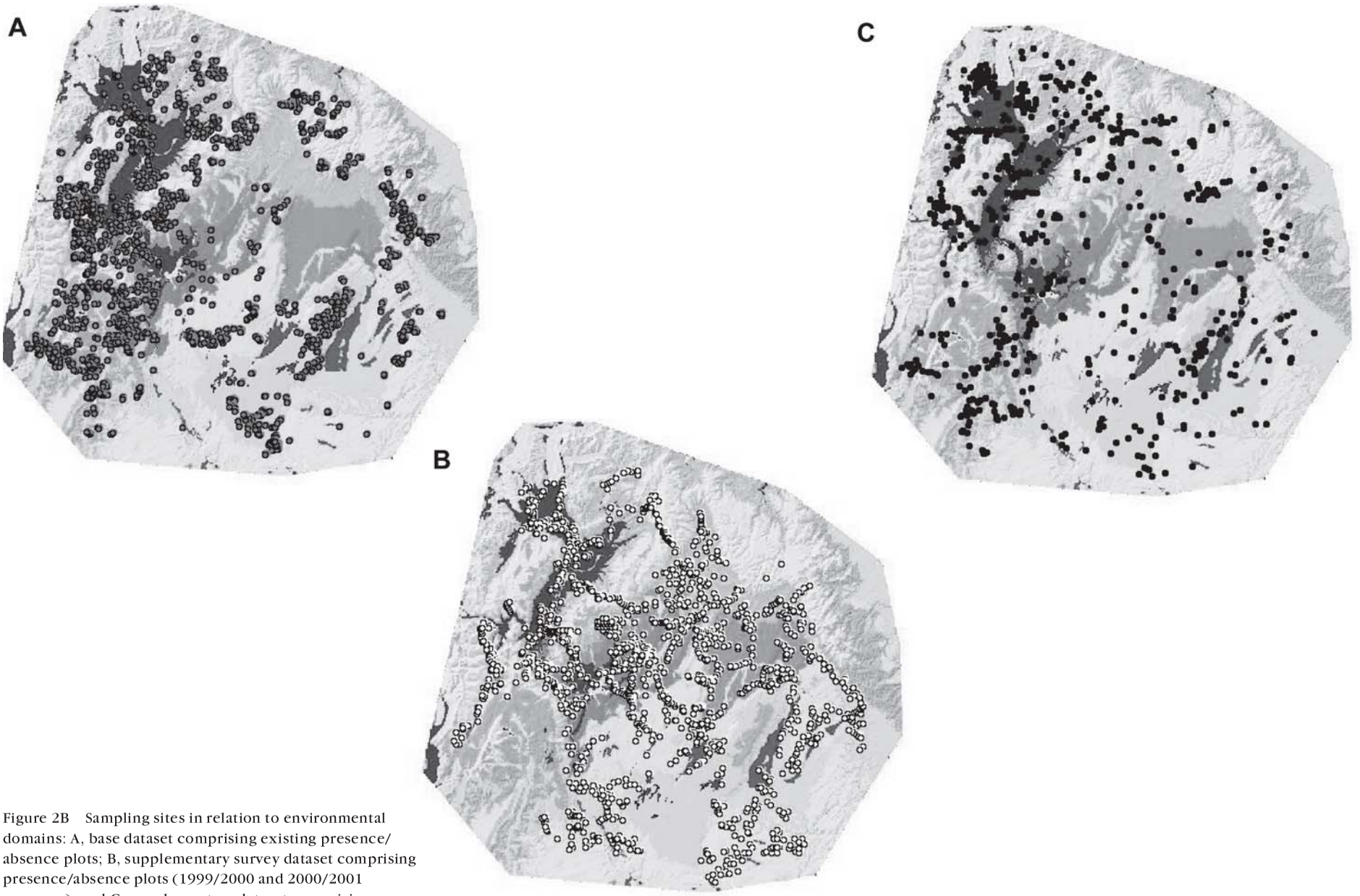

Figure 2B Sampling sites in relation to environmental domains: A, base dataset comprising existing presence/absence plots; B, supplementary survey dataset comprising presence/absence plots (1999/2000 and 2000/2001 summers); and C, supplementary dataset comprising presence-only data.

TABLE 1 CENTRAL OTAGO ENVIRONMENTAL DOMAINS (NUMBERS 1 TO 18): ATTRIBUTES AND AVERAGE ENVIRONMENTAL CHARACTERISTICS (see Appendix 1 for details).

NUMBER	ENVIRONMENTAL DOMAIN (MEAN ELEVATION)	AREA OF DOMAIN (km^2) WITHIN 15 500 km^2 STUDY AREA	% OF STUDY AREA	SLOPE (°)	MEAN ANNUAL TEMPERATURE (°C)	TEMPERATURE SEASONALITY (°C)	OCTOBER VAPOUR PRESSURE DEFICIT (kPa)	ANNUAL MOISTURE DEFICIT (mm)	RAINFALL TO POTENTIAL EVAPOTRANSPIRATION RATIO	MEAN ANNUAL SOLAR RADIATION ($MJ\ m^{-2}\ DAY^{-1}$)	SOLAR RADIATION SEASONALITY ($MJ\ m^{-2}\ DAY^{-1}$)	AGE (1= OLD, 3 = YOUNG)	PHOSPHATE (1= LOW, 5 = HIGH)	CALCIUM (1= LOW, 5 = HIGH)	PARTICLE SIZE (1= SMALL, 5 = LARGE)	SALINITY (1= LOW, 5 = HIGH)	DRAINAGE (1= POOR, 5 = GOOD)
1	Clutha Basin (330 m)	951	6	5	10.0	-2.9	0.54	234	1.3	13.9	-0.74	2.7	3.0	2.0	3.1	1.3	4.5
2	Alexandra Basin rim (450 m)	810	5	6	8.7	-3.1	0.54	218	1.1	13.5	-0.50	2.1	3.0	2.0	3.8	1.6	4.8
3	Maniototo Basin (430 m)	1032	7	2	8.9	-2.9	0.51	224	1.0	13.5	-0.40	2.4	3.3	2.2	2.4	2.3	4.0
4	Recent semiarid soils (380 m)	235	2	1	9.1	-3.4	0.54	248	1.0	13.6	-0.52	1.2	3.0	2.0	2.1	2.2	3.2
5	Northern valley terraces (530 m)	66	< 1	5	9.0	-2.4	0.50	148	1.7	14.0	-0.74	1.2	3.0	2.0	2.2	1.2	3.7
6	Upper Maniototo (630 m)	676	4	4	8.1	-2.4	0.50	123	1.5	13.5	-0.34	2.5	3.4	1.7	2.6	1.3	4.2
7	Northern basin rims (730 m)	1565	10	13	7.8	-2.3	0.51	103	1.8	13.7	-0.52	2.0	3.0	1.7	4.0	1.0	4.3
8	Lakes ranges (770 m)	313	2	19	8.0	-1.2	0.48	33	2.8	13.9	-0.54	2.0	3.0	2.0	3.9	1.0	4.1
9	Upper Nevis Valley (840 m)	15	< 1	3	7.0	-1.2	0.38	15	2.8	13.5	-0.47	1.8	3.0	2.1	2.4	1.0	4.6
10	Northern ranges (1240 m)	2454	16	16	5.2	-0.1	0.43	8	3.2	13.5	-0.26	2.0	3.0	1.6	4.0	1.0	4.6
11	Rolling ridge crests (1300 m)	999	7	8	4.5	0.4	0.36	0	3.7	13.2	-0.18	2.0	3.0	2.0	4.0	1.0	3.7
12	Manorburn uplands (670 m)	2016	13	6	7.5	-1.5	0.45	81	1.7	13.1	-0.13	2.3	3.0	2.0	3.2	1.1	4.1
13	Lammerlaw (910 m)	1318	9	8	6.2	-0.4	0.39	5	2.8	12.9	0.02	2.0	3.0	1.9	3.9	1.0	3.9
14	Lammerlaw wetlands (860 m)	42	< 1	2	6.4	-0.8	0.35	13	2.5	12.9	-0.01	1.2	1.4	1.2	1.5	1.0	1.5
15	Recent Taieri soils (380 m)	263	2	2	8.8	-1.4	0.46	102	1.5	12.9	-0.03	1.1	3.0	2.0	2.0	1.1	3.6
16	South-eastern ranges (580 m)	537	4	13	8.2	-0.8	0.45	38	2.1	12.9	0.07	2.0	3.0	1.1	3.9	1.0	4.9
17	South-eastern valleys (300 m)	959	6	5	9.3	-1.0	0.48	136	1.4	12.9	0.08	2.5	3.0	2.0	2.5	1.0	4.2
18	Coastal hill country (440 m)	1065	7	6	8.5	0.0	0.44	39	2.1	12.6	0.12	2.3	3.0	2.0	3.1	1.0	4.0

TABLE 2 CENTRAL OTAGO ENVIRONMENTAL DOMAINS (NUMBERS 1 TO 18): PERCENTAGE OF LAND (%) MAPPED IN INDIGENOUS FOREST AND SCRUB CATEGORIES IN THE LCDB1, AND PERCENTAGE OF PLOTS WITHIN EACH ENVIRONMENTAL DOMAIN THAT WERE CLASSIFIED WITHIN THE 14 PRESENT-DAY WOODY PLANT ASSOCIATIONS (A TO N).

		LCDB1 (% OF AREA)		WOODY PLANT ASSOCIATION (% OF PLOTS)													
NUMBER	ENVIRONMENTAL DOMAIN	INDIGENOUS FOREST	SCRUB (INCLUDING EXOTIC)	A BEECH FOREST REMNANTS	B WIDESPREAD FOREST RELICTS	C BROOM-GORSE SHRUBLAND	D BRIAR SHRUBLAND	E DRY MATAGOURI-MINGIMINGI SHRUBLANDS	F DRY *MELICYTUS* SHRUBLAND	G MATAGOURI-NATIVE BROOM SHRUBLAND	H HIGHLY MODIFIED SUBALPINE SHRUBLAND	I *OZOTHAMNUS* LOW ALPINE SHRUBLAND	J *DRACOPHYLLUM* LOW ALPINE SHRUBLAND	K *HEBE ODORA* -MOUNTAIN TOATOA SUBALPINE SHRUBLAND	L *BRACHYGLOTTIS REVOLUTUS* LOW ALPINE SHRUBLANDS	M *DRACOPHYLLUM MUSCOIDES* HIGH ALPINE SHRUBLAND	N WIDESPREAD LOW ALPINE SHRUBLAND
1	Clutha Basin	0.2	6.2			21	26	39	7	4	2						4
2	Alexandra Basin rim	0.1	2.6		3	13	19	54	4	2	4	2					
3	Maniototo Basin	0.0	0.6			52	4	39	2	4							
4	Recent semiarid soils	0.0	0.9		11	56	11	22									
5	Northern valley terraces	1.5	4.1		4	27	12	46	4	4				1			
6	Upper Maniototo	0.1	2.8		1	31	1	50	2	13							1
7	Northern basin rims	0.4	9.0	1	6	4	4	57	12	10	2	1					
8	Lakes ranges	10.9	11.9		11	6		50		22	6	6					
9	Upper Nevis Valley	0.0	2.1									33	50	17			
10	Northern ranges	0.2	0.9		12	1		10	4	6	16	16	12	3	4	11	5
11	Rolling ridge crests	0.3	2.1		3		1			1	13	17	3	18	4	25	13
12	Manorburn uplands	0.7	1.8	6	10	10	2	20		16	7	7	1	13			8
13	Lammerlaw	1.3	1.3	1	12	3	1	1			3	13	3	53	2		6
14	Lammerlaw wetlands	0.0	0.0						5			5		15	5	10	60
15	Recent Taieri soils	0.7	0.5		4	35		26		13	9			4			9
16	South-eastern ranges	12.2	3.9	35	17	14		15		10	1		6	2			
17	South-eastern valleys	0.1	5.0		2	34	6	48		7				3			
18	Coastal hill country	1.3	3.0	3	13	24	4	23	1	12		1	1	18			
	Average	1.1	3.2														

Environmental Domain 3 (Maniototo Basin, mean elevation 430 m) includes the older alluvial surfaces of the Maniototo Plain, and the Ida and Manuherikia valleys.

Environmental Domain 4 (Recent semiarid soils, mean elevation 380 m) comprises the recent lowland alluvial surfaces on the semiarid floors of the Manuherikia, Ida, and Maniototo basins and the lower Nevis Valley.

Environmental Domain 5 (Northern valley terraces, mean elevation 530 m) is limited in extent to recent alluvial surfaces in the Kawarau Gorge and Lindis Valley.

Environmental Domain 6 (Upper Maniototo, mean elevation 630 m) extends south-westward from the toeslopes of the Hawkdun, St Bathans, and Ida ranges and the Kakanui Mountains to meet the Maniototo Basin floors domain at c. 500 m a.s.l.

Environmental Domain 7 (Northern basin rims, mean elevation 730 m) comprises steep incised range slopes in the altitudinal zone immediately above the Clutha Basin, Maniototo Basin, and Upper Maniototo valley floor domains. It is most extensive in the vicinity of the Lindis Valley and on the flanks of the Dunstan Mountains and the Pisa Range, but also occurs in a narrow zone along the north-eastern face of the Old Man Range, on the western faces of the St Bathans and Hawkdun ranges, and on the slopes of Blackstone Hill and North Rough Ridge.

Environmental Domain 8 (Lakes ranges, mean elevation 770 m) is confined to the extreme north-west of the region, where it comprises the steep slopes of the ranges about Lakes Wanaka and Hawea.

Environmental Domain 9 (Upper Nevis Valley, mean elevation 840 m) is restricted to recent alluvial surfaces in the upper Nevis Valley.

Environmental Domain 10 (Northern ranges, mean elevation 1240 m) is the most extensive domain in the Central Otago region. It covers 16% of the study area, principally the steep upper montane, subalpine and alpine zones in the north of the region. It includes much of the Dunstan and Kakanui mountain summits and the Ida, Hawkdun, St Bathans, and Pisa range tops, and a small area on the crest of Rough Ridge. Further south, it occupies the subalpine flanks of the Old Man Range and the Garvie and Umbrella mountains, beneath the rolling ridge crests domain.

Environmental Domain 11 (Rolling ridge crests, mean elevation 1300 m) covers broad alpine summits of block mountain ranges above the Northern ranges domain, with the transition at c. 1000 m. It is most extensive in the Old Man Ecological District, but covers similar topography over smaller areas on the tops of the Dunstan Mountains and the Pisa and Rock and Pillar ranges.

Environmental Domain 12 (Manorburn uplands, mean elevation 670 m) comprises extensive areas of gently rolling uplifted peneplain surfaces in the Manorburn and Macraes districts, including the summit and flanks of Rough Ridge. Narrow altitudinal bands of this domain occur on the slopes of the Rock and Pillar Range and the southern Umbrella and Garvie mountains.

Environmental Domain 13 (Lammerlaw, mean elevation 910 m) extends across the higher-altitude south-eastern part of the Manorburn uplands, and includes the subalpine slopes of the Rock and Pillar Range. An altitudinal zone of steeper terrain, around the southern perimeter of the Umbrella and Garvie mountains, is also classified within this domain.

Environmental Domain 14 (Lammerlaw and Old Man Range wetlands, mean elevation 860 m) includes poorly drained depressions around Lake Onslow and Loganburn (Great Moss Swamp) reservoirs, and small areas of higher-altitude wetlands (c. 1500m) on the Old Man Range.

Environmental Domain 15 (Recent Taieri soils, mean elevation 380 m) encompasses areas of recent alluvium in the south-east of the region. It includes river meanders in parts of the upper Taieri catchment, large tracts of the Strath Taieri plain, and ribbons of alluvial soils along watercourses in the Waipori Ecological District and the Clutha Valley south of Beaumont.

Environmental Domain 16 (South-eastern ranges, mean elevation 580 m) includes two disjunct areas. These are the steep slopes covering much of Dansey Ecological District in the east, and an altitudinal zone between the coastal hill country and the Lammerlaw domains on the slopes of the Umbrella Mountains in the south.

Environmental Domain 17 (South-eastern valley, mean elevation 300 m) encompasses catchments and valley floors in the south and east of Central Otago, including the Clutha Valley south of Roxburgh, the Taieri and Deep Stream catchments south of Hyde, and the lower Shag River Valley in the east of the Macraes Ecological District.

Environmental Domain 18 (Coastal hill country, mean elevation 440 m) covers areas of undulating and dissected terrain on the southern margins of the region, including the Waikaia Valley, the southern Umbrella Ecological District, the Waipori Ecological District south of Deep Stream, and the southern Macraes Ecological District.

6.2 PRESENT-DAY VEGETATION

The principal present-day vegetation gradients identified by the ordination were interpreted in terms of their correlations with environmental and vegetation composition factors. The vectors of significant correlations were plotted on the ordination axes, together with the positions of individual species, and the positions of groups of ecologically similar species and woody plant associations identified by the classification (Figs 3A–B, 4A, Bi–iv). The occurrence of species within the woody plant associations identified by the classification was tabulated and used to describe their floristic composition (Table 3). Average climate, soil and vegetation composition factors were also compared between woody plant associations (Table 4), and the occurrence of plots of different woody plant associations within the environmental domains was used to indicate their spatial distribution within Central Otago (Table 5).

6.2.1 Vegetation gradients

Results of the ordination show two principal vegetation gradients (Axes 1 and 2, Eigenvalues 0.79 and 0.53 respectively) that account for a high proportion of the variation in woody vegetation.

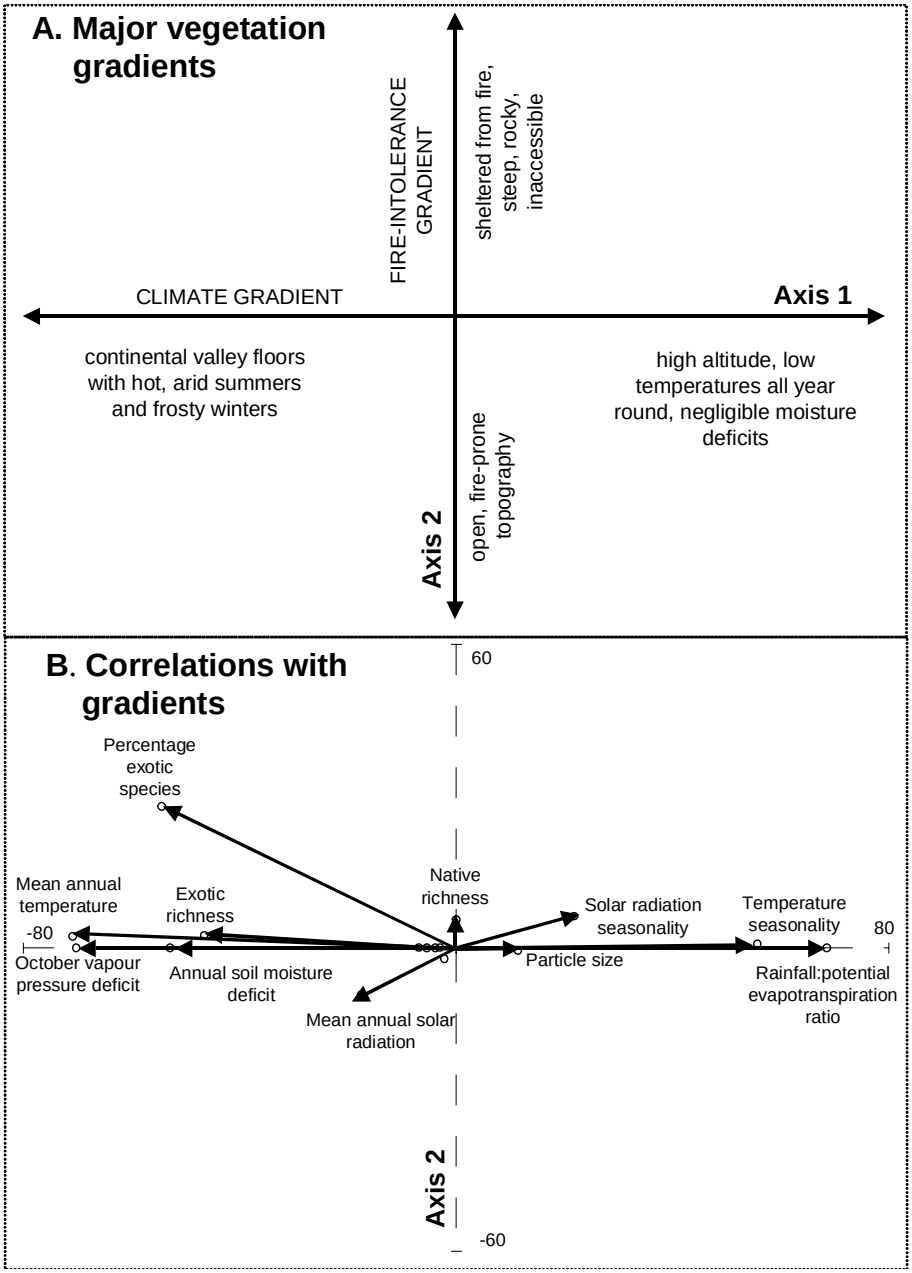

Figure 3 Results of the ordination of present woody vegetation: the main vegetation gradients. A, interpretation of the two principal (climate and fire) gradients in woody vegetation; B, significant correlations of environmental factors and vegetation characteristics with the gradients (showing the direction of the correlation, and the strength of the relationship in terms of the percentage of variation explained). Axis units are percentage variation explained.

Climate gradient

The principal gradient in woody vegetation (represented by ordination Axis 1) is related to climatic characteristics along an altitudinal sequence (Fig. 3A, B). It reflects the vegetation trend from weedy, low-altitude communities in the arid continental lowlands at the left of Axis 1, to prostrate alpine communities at high-altitude sites at the right of this Axis. Simple correlations indicate that rainfall:potential evapotranspiration ratios, and temperature seasonality increase, while mean annual temperature, annual soil water deficit and October vapour pressure deficit decrease significantly along this gradient. Percentage exotic species and exotic richness decrease significantly along this axis, but native richness shows no significant trend.

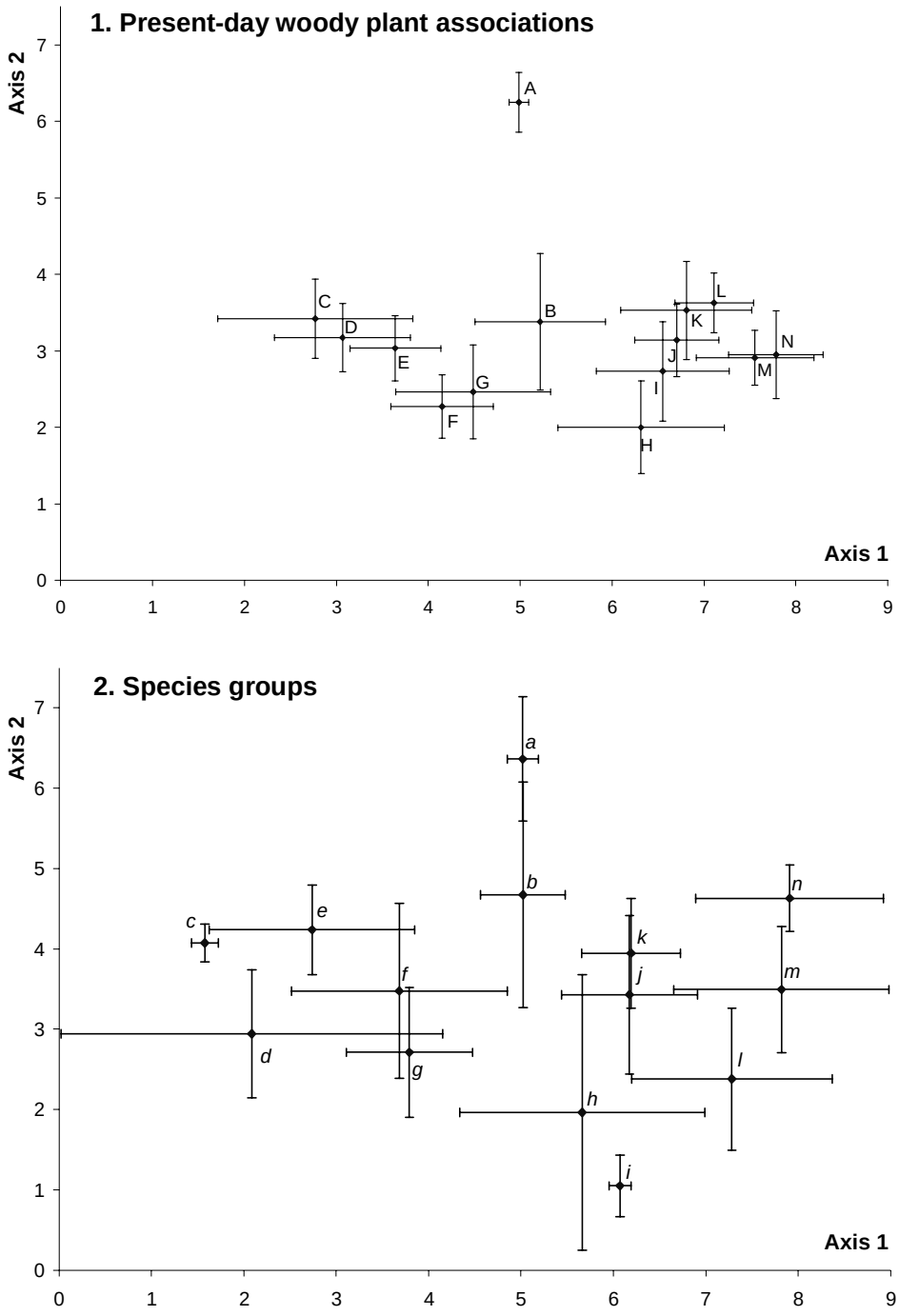

Figure 4A Results of the ordination of present woody vegetation: present-day woody plant associations and woody plant species groups in relation to the principal vegetation gradients. 1, Positions of present-day woody vegetation associations (A to N); and 2, positions of woody plant species groups (*a* to *n*) on the major gradients (Axes) identified by the ordination. Average (centroids) and standard deviations (error bars) of 14 woody plant associations and woody plant species groups are shown. Axis units are standard deviations.

Fire- and grazing-tolerance gradient

The second ordination axis represents a vegetation gradient from woody associations dominated by shade-intolerant shrubs and subshrubs of *Carmichaelia* and *Pimelea* spp., to relatively intact, closed beech forest. Both native and exotic woody species richness, and the percentage of exotic woody species increase significantly along the gradient, which is not strongly correlated with any environmental factors (Fig. 3A, B). At the low end of the gradient the woody plant species are typically fire- and grazing-tolerant, and occur in regularly burned, induced tussock grasslands of open, rolling or flat-topped peneplain surfaces. At the high end of the gradient are fire- and grazing-sensitive woody species, which are restricted to fire-and grazing-sheltered gorges, cliffs, bluffs

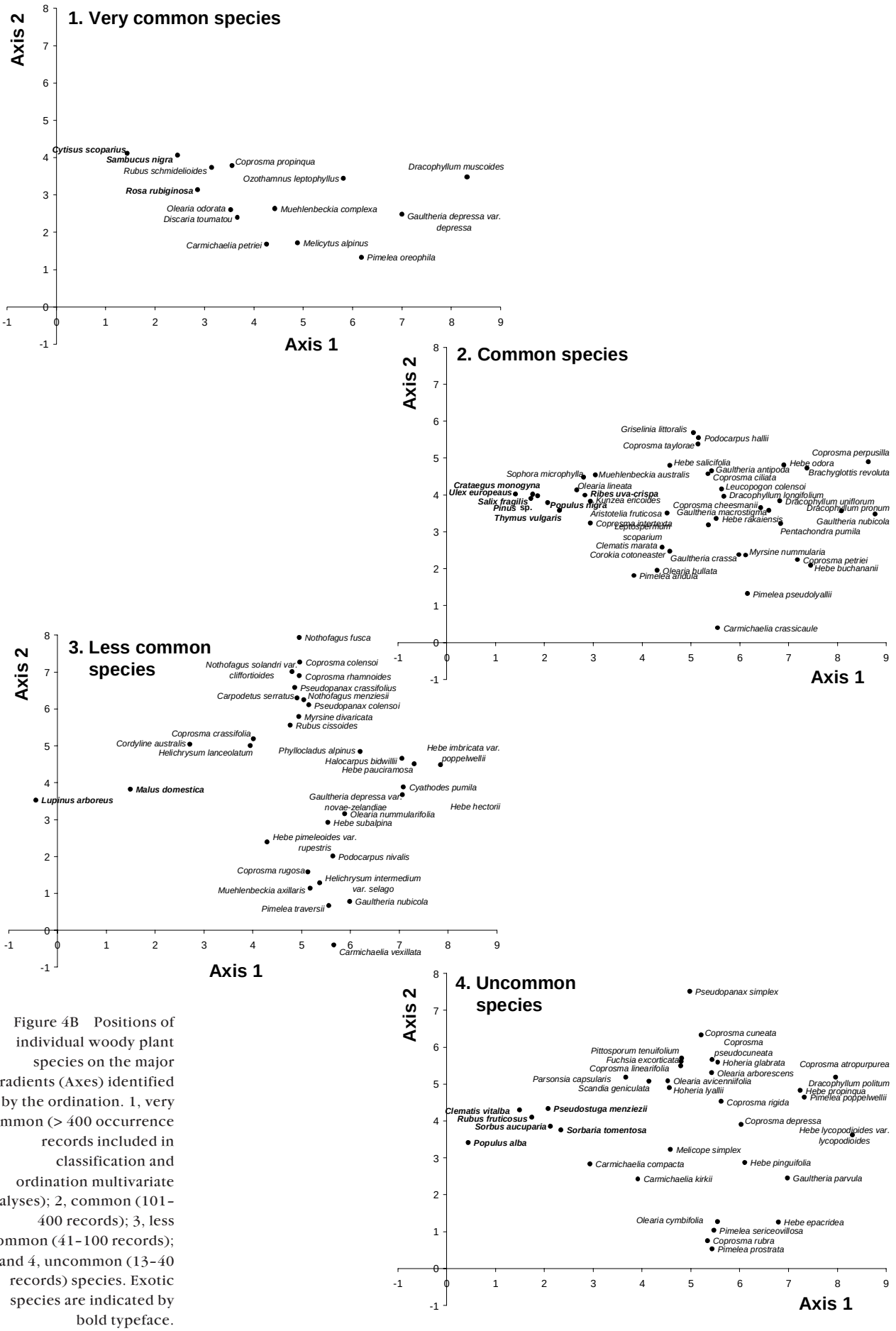

Figure 4B Positions of individual woody plant species on the major gradients (Axes) identified by the ordination. 1, very common (> 400 occurrence records included in classification and ordination multivariate analyses); 2, common (101–400 records); 3, less common (41–100 records); and 4, uncommon (13–40 records) species. Exotic species are indicated by bold typeface.

TABLE 3 TWO-WAY TABLE OF THE CLASSIFICATION OF PRESENT-DAY WOODY VEGETATION IN CENTRAL OTAGO, INDICATING THE PERCENTAGE PRESENCE OF WOODY SPECIES (SPECIES GROUPS *a* TO *n*) WITHIN WOODY PLANT ASSOCIATIONS (A TO N). * INDICATES EXOTIC SPECIES.

GP.	SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N
a	*Pseudopanax simplex*	32	3												
	Hoheria glabrata	5	3								1				
	Coprosma cuneata	11	3												
	Nothofagus solandri var. *cliffortioides*	61	2			1									
	Coprosma 'taylorae'	56	23	1	1	5	2	< 1		1	1	3			
	Podocarpus hallii	47	13			1		1							
	Griselinia littoralis	60	15	1	1	1		1				1	2		
	Pseudopanax colensoi	58	7					< 1			1				
	Nothofagus menziesii	93	11	< 1		< 1		< 1							
	Myrsine divaricata	44	7			1									
	Coprosma rhamnoides	67	2			< 1									
	Coprosma colensoi	72	2			< 1									
	Pseudopanax crassifolius	47	4												
	Rubus cissoides	44	7	1		3		2				< 1			
	Carpodetus serratus	49	6	< 1		< 1									
	Nothofagus fusca	77	2												
b	*Olearia cymbifolia*		6			< 1				1	2	< 1			
	Olearia avicenniifolia		2			1									
	Coprosma linariifolia	4	3			< 1		< 1							
	Hoheria lyallii		4	1		1									
	Coprosma rigida		4	< 1		< 1		< 1		< 1		3			
	Melicope simplex		2			1									
	Olearia arborescens	2	8			< 1		< 1				< 1			
	Coprosma pseudocuneata	11	3									1			
	Pittosporum tenuifolium	5	3			< 1									
	Fuchsia excorticata	7	3			< 1									
c	**Rubus fruticosus*			2		< 1		< 1							
	**Clematis vitalba*			1		1									
	**Malus domestica*			2		1									
d	*Pimelea aridula*		3	2	1	7	41	2	< 1	< 1				< 1	
	**Populus alba*			3	2	< 1		< 1	< 1						
	**Lupinus arboreus*			6	4	1		< 1							
	**Thymus vulgaris*			4	29	6	8	1							
	Hebe pimeleoides var. *rupestris*		1	2	1	3	9		< 1	< 1					
e	**Cytisus scoparius*	2	3	43	4	10	1	4	< 1	1					
	Kunzea ericoides	2	1	6	14	11	2	4	1	1					
	**Pinus* spp.		< 1	25		5	3	1							
	**Salix fragilis*		1	18	2	5	1	4	< 1						
	Cordyline australis		1	2	1	2									
	Leptospermum scoparium		8	3		2	2	3	< 1			7			
	**Ulex europaeus*		< 1	32	3	6	1	5	< 1	< 1					
	Sophora microphylla		3	3	7	6	3	< 1							
	**Sambucus nigra*		3	16	3	21	4	2							
	**Crataegus monogyna*			15	1	7		1							
	Muehlenbeckia australis	2	7	6	1	12	2	2							
	Helichrysum lanceolatum		5			3	1	1							
	Coprosma crassifolia		5			3		< 1							
	Olearia lineata		3	2	3	13	1	1		< 1					
f	**Ribes uva-crispa*		2	5	2	11	2	2							
	Clematis marata		9	1	2	8	1	3		1	1	< 1			
	Hebe subalpina		5			2		3	< 1	1	4	3		< 1	
	Hebe salicifolia	4	15	4		6		3							
	Aristotelia fruticosa		10	1		8		2							
	Olearia bullata		14	9	5	11	3	29		3	1	1			1
	Parsonsia capsularis		2			1									
	Corokia cotoneaster		26	1	1	10	1	4	< 1	< 1		< 1			
	Coprosma rugosa		10	2		2	1	4		< 1		1			
	Coprosma intertexta		2	2		7	1	2				< 1			
	**Sorbus aucuparia*		< 1	1	1	1	1	1							
	**Populus nigra*			2		1		< 1							

GP.	SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N
f	**Pseudostuga menziezii*			< 1		1									
	**Sorbaria tomentosa*					1	1								
	Carmichaelia kirkii		< 1	< 1		< 1		< 1		< 1					
	Scandia geniculata		1			1									
g	*Discaria toumatou*		24	35	13	87	66	68	4	2	1	3			
	**Rosa rubiginosa*		11	32	60	72	50	16	4	1					
	Muehlenbeckia complexa		47	11	2	56	12	27	5	1	2	9			
	Rubus schmidelioides		12	4	4	42	9	6							
	Coprosma propinqua	25	41	10	14	72	13	23	1	3	1	1			
	Melicytus alpinus		52	6	14	48	87	13	26	12	5	1	11	14	2
	Carmichaelia petriei		17	9	2	37	23	44	2	2	1	< 1			
	Olearia odorata		17	6	2	45	19	4	1			< 1			
h	*Muehlenbeckia axillaris*		4	6	2	2	2	3	3	1	2	1			
	Pimelea sericeovillosa		3	2	1	< 1	1	1		1	2			< 1	
	Helichrysum intermedium var. *selago*		7		1	2		1		< 1	7				
	Pimelea prostrata		< 1			< 1	8	< 1	< 1	1		< 1		< 1	1
	Coprosma depressa		1				1			1	2	2			
	Carmichaelia crassicaule		8	1		< 1	2	13	2	3		1			
	Carmichaelia vexillata		3			< 1	3	1	9	5					
	Pimelea traversii		2			2		5	5	3	4	1		< 1	
	Coprosma atropurpurea			< 1	3							2			2
	Gaultheria parvula		< 1	1				1	< 1	4		1			
	Hebe epacridea		1			< 1			1		2			< 1	
	Coprosma rubra		4			< 1				< 1					
	Pimelea poppelwellii		1							2	3				
	Carmichaelia compacta			1	1	1			< 1						
i	*Pimelea pseudolyallii*		3	1		1	1	4	< 1	8	7	8		< 1	
	Gaultheria nubicola		< 1				1	1				7			
j	*Dracophyllum uniflorum*		18	< 1		1		3	3	13	67	10	54		2
	Podocarpus nivalis		20	1		1		2		< 1	2	1			
	Brachyglottis revolutus		6							9	6	1	100		2
	Myrsine nummularia		20			< 1	1	1		6	15	6	9		
	Gaultheria crassa		20			1	1	2		4	42	3	6		1
	Dracophyllum longifolium	4	28	1		< 1		< 1		2	3	5			
	Coprosma ciliata	12	32	1		7		4	< 1	1	4	1			
	Gaultheria depressa var. *novaezelandiae*		3						1	1	51	1		1	1
	Hebe rakaiensis	4	19	1		1		2		2	3	< 1	7		
k	*Ozothamnus leptophyllus*		22	2	1	5		4	< 1	31	16	20	2	1	1
	Coprosma cheesmanii		13	< 1		< 1	1	3		4	11	24	4		
	Gaultheria macrostigma	2	8	1			1	3	< 1	1	3	56		1	
	Hebe odora	2	20					< 1		14	15	38	2		
	Pentachondra pumila		10					2	< 1	18	22	32		2	1
	Leucopogon colensoi	25	19			1	2	7	< 1	7	5	7			
	Phyllocladus alpinus		8	< 1		< 1						15		< 1	
	Gaultheria antipoda	21	23	2		1	1	4				5			
	Olearia nummularifolia		8	1				1	< 1		2	8			
l	*Coprosma petriei*		3			< 1	2	6	5	22	6	5	9	2	50
	Pimelea oreophila		21	1	1	5	16	15	81	35	33	23	9	6	18
	Gaultheria depressa var. *depressa*	2	22			1	8	10	31	82	25	22	41	25	14
	Gaultheria nubicola		2					1	2	4	3	7	9	1	51
m	*Dracophyllum muscoides*		1	1			2		19	10	12	21	26	95	25
	Hebe pauciramosa		2					< 1		2	2	7	2	< 1	
	Hebe buchananii		8			< 1	1	< 1	5	3	3	2	2	19	2
	Hebe hectorii var. *hectorii*		< 1						< 1	1	5	< 1	6	7	4
	Hebe pinguifolia		1			< 1				< 1	2			< 1	
	Dracophyllum pronum		3			1	1	< 1	10	14	26	14	6	15	25
	Hebe lycopodioides var. *lycopodioides*		< 1						< 1	1	3	1		7	
n	*Hebe imbricata* var. *poppelwellii*		1						1	2	2	5	2	2	
	Hebe propinqua		2						1	1	1	6			
	Cyathodes pumila		3						< 1	3	3	9			1
	Halocarpus bidwillii		1			< 1					1	7			
	Coprosma perpusilla			< 1		< 1		1		1	4	25			4
	Dracophyllum politum											5			

TABLE 4 ENVIRONMENTAL ATTRIBUTES (SEE APPENDIX 1 FOR DETAILS) OF THE 14 PRESENT-DAY WOODY PLANT ASSOCIATIONS (A TO N). Four categories are recognised: 1, forests and forest relicts (woody plant associations A and B); 2, lowland and lower montane shrublands (C and D); 3, montane shrublands (E, F and G); and 4, high-elevation shrublands (H to N).

CATEGORY NUMBER		PRESENT-DAY WOODY PLANT ASSOCIATION (MEAN ELEVATION)	SLOPE (°)	MEAN ANNUAL TEMPERATURE (°C)	TEMPERATURE SEASONALITY (°C)	OCTOBER VAPOUR PRESSURE DEFICIT (kPa)	ANNUAL MOISTURE DEFICIT (mm)	RAINFALL TO PET RATIO	MEAN ANNUAL SOLAR RADIATION ($MJ\ m^{-2}\ DAY^{-1}$)	SOLAR RADIATION SEASONALITY ($MJ\ m^{-2}\ DAY^{-1}$)	AGE (1 = OLD, 3 = YOUNG)	PHOSPHATE (1 = LOW, 5 = HIGH)	CALCIUM (1 = LOW, 5 = HIGH)	PARTICLE SIZE (1 = SMALL, 5 = LARGE)	SALINITY (1 = LOW, 4 = HIGH)	DRAINAGE (1 = POOR, 5 = GOOD)
1.	A	Beech forest remnants (500 m)	11	8.60	-1.40	0.40	51	2.19	13.22	-0.27	2.00	3.00	1.12	4.00	1.00	4.77
	B	Widespread forest relicts (860 m)	13	6.76	-0.99	0.34	36	2.46	13.22	-0.20	2.05	3.00	1.77	3.95	1.05	4.30
2.	C	Broom-gorse (460 m)	6	8.85	-1.82	0.42	156	1.49	13.36	-0.31	2.33	3.13	1.92	2.90	1.21	4.28
	D	Briar (420 m)	10	9.29	-2.65	0.46	213	1.35	13.74	-0.64	2.33	3.02	1.98	3.43	1.23	4.55
3.	E	Matagouri-mingimingi (570 m)	12	8.43	-2.17	0.42	137	1.62	13.61	-0.50	2.15	3.04	1.91	3.54	1.13	4.27
	F	Dry *Melicytus* (680 m)	14	8.00	-2.27	0.42	135	1.81	13.84	-0.70	2.03	3.01	1.99	3.83	1.08	4.26
	G	Matagouri-native broom (700 m)	9	7.67	-1.41	0.38	81	1.91	13.35	-0.27	2.22	3.09	1.83	3.45	1.09	4.26
4.	H	Highly modified subalpine (1170 m)	10	5.38	-0.46	0.30	28	2.97	13.43	-0.33	2.02	3.00	1.89	3.94	1.03	4.11
	I	*Ozothamnus* low alpine (1180 m)	10	5.22	-0.15	0.28	13	3.24	13.22	-0.18	2.03	3.00	1.83	3.96	1.01	4.22
	J	*Dracophyllum* low alpine (1120 m)	14	5.61	0.10	0.27	5	3.09	13.04	0.01	2.05	3.00	1.40	3.95	1.00	4.66
	K	*Hebe odora*-mountain toatoa subalpine (1030 m)	6	5.72	0.33	0.28	12	3.01	12.82	0.08	2.05	2.96	1.92	3.74	1.00	3.75
	L	*Brachyglottis revolutus* low alpine (1340 m)	15	4.21	0.72	0.23	0	4.27	13.00	-0.05	1.96	2.93	1.96	3.89	1.00	3.96
	M	*Dracophyllum* high alpine (1520 m)	9	3.53	1.03	0.23	0	4.02	13.19	-0.14	1.99	2.98	1.84	3.97	1.01	3.71
	N	Widespread low alpine (1300 m)	7	4.50	0.31	0.26	11	3.59	13.14	-0.14	1.88	2.81	1.87	3.64	1.03	3.54

TABLE 5 PERCENTAGE OF SITES IN THE 14 PRESENT-DAY WOODY PLANT ASSOCIATIONS (A TO N) THAT FALL WITHIN THE 18 ENVIRONMENTAL DOMAINS (NUMBERS 1 TO 18).

	ENVIRONMENTAL DOMAIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	PRESENT-DAY WOODY PLANT ASSOCIATION	CLUTHA BASIN	ALEXANDRA BASIN RIM	MANIOTOTO BASIN	RECENT SEMIARID SOILS	NORTHERN VALLEY TERRACES	UPPER MANIOTOTO	NORTHERN BASIN RIMS	LAKES RANGES	UPPER NEVIS VALLEY	NORTHERN RANGES	ROLLING RIDGE CRESTS	MANORBURN UPLANDS	LAMMERLAW	LAMMERLAW WETLANDS	RECENT TAIERI SOILS	SOUTH-EASTERN RANGES	SOUTH-EASTERN VALLEYS	
A	Beech forest remnants							5			2	2	28	5			49		9
B	Widespread forest relicts		2					13	1		36	7	12	11			6	1	10
C	Broom-gorse shrubland	20	5	8	1	2	13	6			3	1	9	2		2	3	14	12
D	Briar shrubland	52	14	1	1	2	1	12			1	3	4	1				5	4
E	Matagouri-mingimingi shrublands	15	8	2		1	8	34	1		8		7			1	1	8	5
F	Dry *Melicytus* shrubland	19	4	1		1	2	50			20	2	1		1				1
G	Matagouri-native broom shrubland	6	1	1			8	22	2		19	1	20			1	4	4	9
H	Highly modified subalpine shrubland	3	2					5			49	29	9	3		1			
I	*Ozothamnus* low alpine shrubland		1					2		1	43	34	7	10					1
J	*Dracophyllum* low alpine shrubland							2		3	68	15	2	5			4		2
K	*Hebe odora*-mountain toatoa subalpine shrubland							1			7	31	12	36	1		1	1	10
L	*Brachyglottis revolutus* low alpine shrublands										46	43		9	2				
M	*Dracophyllum* high alpine shrubland										37	61			1				
N	Widespread low alpine shrubland							2			22	46	14	8	8	1			

and crevices (Fig. 4A2, 4B1–4). Therefore, a transition from relatively widespread, highly modified woody plant associations to spatially restricted, less modified forest remnant and relict woody plant associations occurs along this gradient, which we define as representing fire- and grazing-intolerance. Vegetation modification is thought to have been largely due to early anthropogenic fires, although a suite of more recent human activities and pastoral practices have also contributed.

6.2.2 Woody plant associations and species groups

The classification was truncated at the level of 14 groups of plots (present-day woody plant associations A to N; Table 3, Fig. 4A1) and 14 groups of species (species groups *a* to *n*; Table 3, Fig. 4A2).

Species groups and their relationship to principal vegetation gradients

The classification simplifies the flora into groups of ecologically similar species. These tend to be clustered in similar positions on the principal gradients defined by the ordination (Axis 1: climate, and Axis 2: fire- and grazing-intolerance), and may be interpreted accordingly (Fig. 4A2). The positions of individual species are also plotted on the ordination axes (Fig. 4B).

Species of more intact stands and fragments of forest with closed canopies (hereafter referred to as forest remnants) and those of more modified forest fragments (hereafter forest relicts) have high scores on the fire-intolerance gradient and intermediate scores on the climate axis, reflecting the predominant distribution of the remaining, relatively intact forest stands within the montane and subalpine zones. Group *a* comprises species of beech forest stands with closed canopies (e.g. *Nothofagus menziesii*, *N. solandri* var. *cliffortioides*, *N. fusca*, *Podocarpus hallii*, *Griselinia littoralis*, *Carpodetus serratus*, *Hoheria glabrata*, *Pseudopanax colensoi*, *P. crassifolius*, *Raukaua simplex*, *Myrsine divaricata*, *Rubus cissoides*, *Coprosma colensoi*, *C. cuneata*, *C. rhamnoides* and *C.* 'taylorae'), but many of these species were also recorded in more modified forest relicts where the canopy had been opened or lost. Species of group *b* have slightly lower scores on the fire-intolerance axis, but are nevertheless now largely restricted to fire-protected sites, and often occur at low elevations. They are seldom associated with beech forest fragments, and may be derived from a type of lowland forest or woodland that no longer exists in Central Otago, which included species such as *Olearia arborescens*, *O. aviceniifolia*, *O. cymbifolia*, *Coprosma pseudocuneata*, *C. linariifolia*, *C. rigida*, *Fuchsia excorticata*, *Hoheria lyallii*, *Melicope simplex* and *Pittosporum tenuifolium.*

The lowland end of the climate gradient is occupied by woody weed species that occur principally on the arid, frosty basin floors. These include *Clematis vitalba*, *Malus domestica* and *Rubus fruticosus* agg. (species group *c*), *Lupinus arboreus*, *Populus alba*, *Thymus vulgaris* (species group *d*), *Ulex europaeus*, *Cytisus scoparius*, *Salix fragilis*, *Pinus* spp., *Sambucus nigra*, *Crataegus monogyna*, (species group *e*), *Pseudotsuga menziesii*, *Sorbaria tomentosa*, *Sorbus aucuparia*, and *Ribes uva-crispa* (species group *f*).

Two native shrubs (*Hebe pimeleoides* var. *rupestris* and *Pimelea aridula*) are classified within species group *d*, and four native trees occur in species group *e* (*Olearia lineata*, *Cordyline australis*, *Sophora microphylla* and *Kunzea ericoides*). Their positions towards the arid, low-altitude, temperature-inversion-prone end of the climate gradient indicate a high degree of drought-tolerance. Three native shrubs in group *e* (*Muehlenbeckia australis*, *Helichrysum lanceolatum*, *Coprosma crassifolia*) are positioned higher on Axis 2 and may be somewhat less drought- and fire-tolerant. *Leptospermum scoparium* (also species group *e*) is positioned towards the mesic (i.e. more moist and moderate) centre of the climate axis, and its lower position on Axis 2 indicates greater fire-tolerance or some capacity to recover after fire.

Most species in group *f* (e.g. *Olearia bullata*, *Parsonsia capsularis*, *Scandia geniculata*, *Clematis marata*, *Aristotelia fruticosa*, *Corokia cotoneaster*, *Hebe salicifolia*, *Coprosma rugosa* and *Hebe subalpina*) have somewhat higher scores on both the climate and fire- and grazing-intolerance axes, suggesting that they are less tolerant of extremes of drought, frost, fire and grazing than species of group *e*. However, the rare liane *Carmichaelia kirkii* has a relatively low Axis-2 score, and survives in fire- and grazing-prone areas, although it is restricted to steep, rocky, fire refugia within them. Species of group *g* are widespread in fire-prone lowland and montane vegetation (i.e. *Olearia odorata*, *Coprosma propinqua*, *Discaria toumatou*, *Carmichaelia petriei*, *Muehlenbeckia complexa* and *Melicytus alpinus*). Certain shrubs and lianes in both species groups (*f* and *g*) have particularly low Axis-1 scores, suggesting drought-tolerance; these include *Coprosma intertexta*, *Rubus schmidelioides* and the exotic *Rosa rubiginosa*.

Groups *h*, *i* and *l* comprise species of open, gently-rolling topography in the upper montane and subalpine zones. They tend to have moderately high scores on the climate gradient, but low scores on the fire- and grazing-intolerance gradient. Many representatives of the genera *Coprosma* (e.g. *C. atropurpurea*, *C. depressa*, *C. petriei* and *C. rubra*), *Gaultheria* (e.g. *G. nubicola*, *G. parvula* and *G. depressa*), *Pimelea* (e.g. *P. pseudolyallii*, *P. sericeovillosa*, *P. traversii*, *P. poppelwellii*, *P. prostrata* and *P. oreophila*) and *Carmichaelia* (e.g. *C. compacta*, *C. crassicaule*, *C. vexillata*) are classified within these groups, together with *Hebe epacridea*, *H. pimeleoides* var. *rupestris*, *Muehlenbeckia axillaris* and *Helichrysum intermedium* var. *selago.*

Species groups *j* and *k* comprise subalpine species with moderately high scores on the fire- and grazing-intolerance gradient axis, indicating that they may be relatively sensitive to fire, and have been removed from subalpine areas with more intensive histories of burning and grazing. These include *Brachyglottis revolutus*, *Coprosma cheesemanii*, *C. ciliata*, *Dracophyllum longifolium*, *D. uniflorum*, *Gaultheria antipoda*, *G. crassa*, *G. depressa* var. *novae-zelandiae*, *G. macrostigma*, *Hebe odora*, *H. rakaiensis*, *Leucopogon colensoi*, *Myrsine nummularia*, *Olearia nummularifolia*, *Ozothamnus leptophyllus*, *Pentachondra pumila*, *Phyllocladus alpinus* and *Podocarpus nivalis.*

At higher elevations, species of the alpine zone are divided into groups of widespread (species group *m*), with lower Axis-2 scores, and localised (species group *n*) distribution, with somewhat higher Axis-2 scores. The former include *Dracophyllum muscoides*, *D. pronum*, *Hebe buchananii*, *H. hectorii* var.

hectorii, *H. lycopodioides* var. *lycopodioides*, *H. pauciramosa* and *H. pinguifolia*. The latter includes *Halocarpus bidwillii*, *Cyathodes pumila*, *Dracophyllum politum*, *Hebe imbricata* var. *poppelwellii*, *H. propinqua*, and *Coprosma perpusilla.*

Woody plant associations

Fourteen present-day woody plant associations (groups of plots that are similar in species composition) are described here in terms of their spatial distribution and association with environmental domains (Table 5), their environmental characteristics (Table 4), their member species and dominant species groups (Table 3), and their positions on the principal gradients defined by the ordination (Axis 1: climate, and Axis 2: fire-intolerance; Fig. 3A–C).

The present-day woody plant associations fall within four broad categories (Tables 4 and 5): these are forests remnants and forest relicts (woody plant associations A and B), and shrub and subshrub associations of the lowland and lower montane (C and D), montane (E, F and G), and high-elevation (H to N) zones.

A—Beech forest remnants

Beech forest remnants account for about 2% of the sample plots in the present study. Most of the intact beech-forest remnants remain in the Umbrella and Nokomai Ecological Districts (coastal hill country domain and the south-western extension of the Manorburn uplands domain) and in the Waipori Ecological District (coastal hill country domain). These stands comprise either pure *Nothofagus menziesii* (silver beech), or mixed stands of *N. menziesii* (silver), *N. solandri* var. *cliffortioides* (mountain) and *N. fusca* (red) beech. They are relatively intact compared with other Central Otago woody plant associations, and have high average scores on the fire-intolerance gradient.

Species of ecological group *a* are common here (e.g. *Coprosma colensoi*, *C. rhamnoides*, *C.* 'taylorae', *C. cuneata*, *Carpodetus serratus*, *Hoheria glabrata*, *Myrsine divaricata*, *Podocarpus hallii*, *Pseudopanax crassifolius*, *P. colensoi*, and *Raukaua simplex*), while those from species group *b* occur infrequently (e.g. *Coprosma pseudocuneata*, *C. linariifolia*, *Fuchsia excorticata*, *Olearia arborescens* and *Pittosporum tenuifolium*).

B—Widespread forest relicts

This relatively species-rich montane and subalpine woody plant association includes 7% of the sample plots in the present study, extends across a wide range of altitudes and environmental domains, and contains species from several different ecological groups (Plates 1A–F). Most of these were recorded in the northern ranges domain, but the forest relict association is also well represented in the northern basin rims, Manorburn uplands, Lammerlaw, and coastal hill country domains.

Woody weed species are seldom present, and the assemblage invariably contains potential forest canopy species, or shade-tolerant species that may survive following an initial fire through forest or woodland (i.e. species groups *a* and *b*). Original forest cover is most commonly indicated by the presence of species in groups *a*. A moderate degree of modification and invasion is suggested where shrub species in group *f* are present (e.g. *Corokia*

cotoneaster, *Hebe salicifolia*, *Olearia bullata*, *Coprosma rugosa*, *Aristotelia fruticosa*), while group *g* species (e.g. *Melicytus alpinus*, *Muehlenbeckia complexa*, *Coprosma propinqua*, *Discaria toumatou*, *Carmichaelia petriei*, *Olearia odorata* and *Rubus schmidelioides*) occur in the more modified examples. Associations classified as forest relicts also occur at higher elevations, where they harbour relatively fire sensitive species from groups *j* (e.g. *Podocarpus nivalis*, *Brachyglottis revolutus*, *Dracophyllum longifolium*, *Hebe rakaiensis* and *Coprosma ciliata*) and *k* (e.g. *Phyllocladus alpinus* and *Olearia nummularifolia*), which may have been components of more continuous tall-shrubland or low-forest canopies prior to modification by frequent human fire.

C—Broom-gorse shrub association

This weed-dominated shrub association is widespread in the Central Otago lowland and lower montane zones, occurring in about 10% of study plots (Plates 2A–D). It is common in the south-east of the region within the south-eastern valleys and coastal hill country domains, where it occurs on a wide variety of moderately to gently sloping landforms, while in the more droughty Clutha Basin and upper Maniototo domains, it is restricted to disturbed sites such as recent alluvial deposits beside stream channels. It is common along the length of the Clutha Valley, in the eastern Waipori and northern Macraes ecological districts, and in the higher-altitude, north-eastern parts of Maniototo Ecological District in the vicinity of the Kyeburn River.

Cytisus scoparius (broom) and/or *Ulex europaeus* (gorse) are present in most plots, while *Rosa rubiginosa* (briar), *Discaria toumatou* (matagouri), *Pinus* spp. (pines), *Salix fragilis* (willows), *Crataegus monogyna* (hawthorn) and *Sambucus nigra* (elderberry) are relatively common, and *Lupinus arboreus* (tree lupin), *Ribes uva-crispa* (gooseberry) and *Populus alba* (poplar) are present infrequently. Apart from *Discaria toumatou*, native species are rare in this shrub association, with disturbance-tolerant species such as *Coprosma propinqua*, *Olearia bullata*, *Muehlenbeckia axillaris*, *Muehlenbeckia complexa* and *Carmichaelia petriei* being the most frequently recorded.

D—Briar shrub association

The briar shrub association was recorded in about 5% of the study plots (Plate 2C). It is less widespread than the broom-gorse shrub association, and occurrences are concentrated in the lowlands of the north and east of the region. It is characteristic of the floors and lower hillslopes of the Upper Clutha, Lindis and Manuherikia valleys, which experience the most extreme continental climates and high annual solar radiation. Its distribution is centred on the Clutha Basin domain, but extends into the Alexandra basin rim and northern basin rim domains.

The association is typically species-poor, and *Rosa rubiginosa* (sweet briar) is the principal woody species. The subshrub *Thymus vulgaris* (thyme) occurs in about 30% of plots, and *Kunzea ericoides*, *Melicytus alpinus* and *Coprosma propinqua* are common secondary components. *Sophora microphylla* is also occasionally present. Despite its principally northern distribution, variants of the briar association, including *Coprosma propinqua* and occasionally *Olearia*

bullata and *O. lineata*, extend further south into the Macraes, Rock and Pillar, Waipori and Umbrella ecological districts.

E—Matagouri-mingimingi shrub association

The matagouri-mingimingi shrub association is widespread throughout the montane zone in Central Otago, and accounts for about 25% of the vegetation plots in the present study (Plates 3B–E). It is most common in the northern basin rims domain, i.e. on the moderate to steep slopes that fringe the lowland basins. However, it also occurs in the Clutha Basin, Alexandra Basin rim, upper Maniototo, northern ranges, Manorburn uplands, and south-eastern valleys domains. It is recorded less frequently on the Maniototo Basin valley floor, and in environmental domains with lower mean annual solar radiation and higher rainfall:potential evapotranspiration ratios, especially the Lammerlaw, coastal hill country, and south-eastern valleys domains in the Waipori and Umbrella ecological districts.

A high proportion of species recorded in this moderately species-rich association (average 7 species per plot) are classified within species group *g* (*Discaria toumatou*, *Coprosma propinqua*, *Rosa rubiginosa*, *Muehlenbeckia complexa*, *Melicytus alpinus*, *Olearia odorata*, *Rubus schmidelioides*, and *Carmichaelia petriei*). Species of drought- and frost-tolerant groups *d* (*Pimelea aridula*), *e* (trees of *Olearia lineata*, *Kunzea ericoides* and *Sophora microphylla* and the liane *Muehlenbeckia australis*) and *f* (*Olearia bullata*, *Corokia cotoneaster*, *Clematis marata*, *Aristotelia fruticosa*, *Hebe salicifolia*, *Coprosma intertexta*) are also frequent components. Exotic species other than *Rosa rubiginosa* are often present, but rarely dominate; the most common of these are *Sambucus nigra*, *Crataegus monogyna*, *Cytisus scoparius*, *Ribes uva-crispa*, *Thymus vulgaris* and *Ulex europaeus*.

F—Dry *Melicytus* shrub association

This shrub association occurs principally on steep slopes in the montane and subalpine zone in the Kawarau and Cromwell gorges (Plate 3A). About half of the plots lie within the northern basin rims domain, and most of the remainder occur within the northern ranges and Clutha Basin environmental domains. Average elevation and mean annual solar radiation are slightly higher, and mean annual temperature is marginally lower than at sites occupied by the matagouri-mingimingi association (E, above), although annual soil moisture deficits and the October vapour pressure deficits are similar.

Melicytus alpinus is almost invariably present in this sparse shrub association. Two-thirds of plots contain *Discaria toumatou*, while approximately half contain *Pimelea aridula* or *Rosa rubiginosa*. *Carmichaelia petriei*, *Olearia odorata*, *Coprosma propinqua* and *Pimelea oreophila* are common associated species, as are *Thymus vulgaris* and wilding pines (*Pinus* spp.).

G—Matagouri-native broom shrub association

This association occurs within a wide zone of montane and subalpine tussock grasslands on moderate to steep hillslopes in the northern basin rims and northern ranges environmental domains, and on gently sloping peneplain surfaces in the Manorburn uplands domain. Mean annual temperatures and moisture deficits are lower than at plots supporting briar, matagouri-

mingimingi and dry *Melicytus* shrub associations at lower elevations (i.e. woody plant associations D, E and F).

The matagouri-native broom association is woody-species-poor, and typically includes shrubs of *Discaria toumatou* and *Carmichaelia petriei*. *Olearia bullata* (species group *f*), *Carmichaelia crassicaule*, and the subshrubs *Pimelea oreophila* and *Gaultheria depressa* var. *depressa* (species group *h*) are also characteristic. *Coprosma propinqua*, *Muehlenbeckia complexa*, *Melicytus alpinus* and *Rosa rubiginosa* (species group *g*) also occur here, but are less conspicuous than at lower elevations.

H—Highly modified subalpine shrub and subshrub association

This woody-species-poor, highly modified subalpine and low alpine subshrub association occurs principally in the north and west of the region (Plate 4A). It occupies a wide altitudinal range, but occurs mainly within the northern ranges and rolling ridge crests environmental domains, which are characterised by low mean annual temperatures and minimal annual water deficits. It is most common in sunny, northern ecological districts (e.g. Pisa, Dunstan, Old Man, St Bathans, Hawkdun, Dansey) but also occurs locally on the crests of Rough Ridge and the Rock and Pillar Range.

The association typically comprises fire-tolerant subshrubs, of which *Pimelea oreophila* and *Gaultheria depressa* var. *depressa* (species group *l*) are the principal species. *Melicytus alpinus* (species group *g*), *Dracophyllum muscoides*, *D. pronum* (species group *m*), and *Carmichaelia vexillata* (species group *h*) are common, and *Pimelea traversii*, *Hebe buchananii*, *Coprosma petriei*, *Muehlenbeckia complexa* are occasionally present.

I—*Ozothamnus* low alpine shrub and subshrub association

This subalpine and alpine association of shrubs and subshrubs is present immediately above the regional treeline on all of the main Central Otago mountain ranges (Plate 4B). It is most common on gently rolling topography in the northern ranges and rolling ridge crests environmental domains, but is also widespread in the Lammerlaw and Manorburn uplands domains. Mean annual temperatures are low, and annual water deficits are negligible in these environments.

The fire-tolerant subshrubs *Gaultheria depressa* var. *depressa* and *Pimelea oreophila* (species group *l*) are the principal woody species, although this association frequently contains *Melicytus alpinus* (species group *g*) and taller species such as *Ozothamnus leptophyllus* and *Hebe odora* (species group *k*) and *Dracophyllum uniflorum* (species group *j*). *Brachyglottis revolutus* (species group *j*) occurs in the Umbrella, Nokomai and Old Man ecological districts. The numerous dwarf and prostrate shrubs include *Carmichaelia vexillata* (species group *h*), *Pimelea pseudolyallii* (species group *i*), *Myrsine nummularia* (species group *j*), *Pentachondra pumila*, *Leucopogon colensoi* (species group *k*), *Coprosma petriei* (species group *l*), *Dracophyllum pronum* and *D. muscoides* (species group *m*).

J—*Dracophyllum* low alpine shrub and subshrub association

This association occurs on steep slopes at similar elevations to the modified subalpine (woody plant association H) and *Ozothamnus* (woody plant

association I) associations. It is characteristic of the region's southern and eastern mountain ranges, which have lower annual solar radiation inputs and annual water deficits, and less-seasonal temperature regimes, than the ranges further north. It occurs on most Central Otago ranges, with their main centres of occurrence in the Dansey (northern ranges environmental domain), Umbrella and Nokomai ecological districts (northern ranges and rolling ridge crests domains).

Dracophyllum uniflorum, *Gaultheria depressa* var. *novae-zelandiae* and *Gaultheria crassa* (species group *f*) are the principal species. Subshrubs are common, including *Helichrysum intermedium* var. *selago* (species group *h*), *Pimelea pseudolyallii* (species group *i*), *Myrsine nummularia* (species group *j*), *Pentachondra pumila*, *Coprosma cheesemanii* (species group *k*), *Pimelea oreophila*, *Gaultheria depressa* var. *depressa* (species group *l*), *Dracophyllum pronum* and *D. muscoides* (species group *m*). However, several taller shrubs also occur here, including *Brachyglottis revolutus* (species group *f*), *Ozothamnus leptophyllus* and *Hebe odora* (species group *k*).

K—*Hebe odora*-mountain toatoa subalpine shrub association

This association is most common on gently sloping, uplifted peneplain surfaces of the Lammerlaw, rolling ridge crests, Manorburn uplands and coastal hill country domains in the south of the region, particularly on the Rock and Pillar and Lammerlaw Ranges (Plate 4C). A few examples also occur on the Hawkdun, St Bathans and Kakanui ranges in the east, and in the Old Man, Umbrella and Nokomai ecological districts in the south.

Hebe odora (species group *k*) is the characteristic dominant shrub, although the rarer *H. propinqua* (species group *n*) and *H. pauciramosa* (species group *m*) are occasionally present. Occasional remnants of *Phyllocladus alpinus* (species group *k*) and *Halocarpus bidwillii* (species group *n*), and more frequent occurrences of *Ozothamnus leptophyllus*, *Olearia nummularifolia* (species group *k*) and *Leptospermum scoparium* (species group *e*) within this woody plant association suggest that taller, longer-lived shrubs were more widespread in these environments prior to the onset of higher fire frequencies. Numerous subshrubs are present, including *Gaultheria macrostigma*, *G. depressa* var. *depressa*, *G. depressa* × *G. nubicola*, *G. nubicola*, *Pentachondra pumila*, *Coprosma perpusilla*, *C. cheesemanii*, *Pimelea oreophila*, *P. pseudolyallii*, *Myrsine nummularia*, *Cyathodes pumila* and *Leucopogon colensoi*. *Dracophyllum muscoides*, *D. pronum*, *D. uniflorum* and *D. longifolium* are relatively common.

L—*Brachyglottis revolutus* low alpine shrub association

The geographically-restricted erect shrub *Brachyglottis revolutus* is characteristic of this association that occurs on moderately steep slopes in the ranges of the Umbrella, Nokomai and Old Man ecological districts within the northern ranges and rolling ridge crests environmental domains. *Dracophyllum uniflorum* and *Gaultheria depressa* var. *depressa* are the most frequent subsidiary woody species, while *Gaultheria nubicola*, *G. crassa*, *Dracophyllum muscoides*, *D. pronum*, *Hebe rakaiensis*, *H. hectorii* var. *hectorii*, *Melicytus alpinus*, *Myrsine nummularia*, *Coprosma petriei* and *Pimelea oreophila* are relatively common.

M—*Dracophyllum* high alpine subshrub association

Throughout the region, high-alpine range tops support this association of prostrate *Dracophyllum muscoides*, together with *Gaultheria depressa* var. *depressa*, *Dracophyllum pronum*, *Melicytus alpinus*, *Hebe buchananii*, *H. hectorii*, *H. lycopodioides* var. *lycopodioides* and *Pimelea oreophila* (Plate 4D). This association is most extensive within the northern ranges and rolling ridge crests environmental domains on the Garvie Mountains and the Old Man and Pisa ranges, but also occurs locally on the Dunstan Mountains, the Rock and Pillar Range, and on Rough Ridge.

N—Widespread low alpine subshrub association

This association of dwarf and prostrate shrubs (*Gaultheria nubicola*, *Coprosma petriei*, *C. perpusilla*, *Dracophyllum pronum*, *D. muscoides*, *G. depressa* var. *depressa* and *Pimelea oreophila*) occurs in the northern ranges and rolling ridge crests domains in the Old Man, Pisa and Dunstan ecological districts, but is also scattered at lower altitudes within the Manorburn uplands, Lammerlaw and Lammerlaw wetlands environmental domains.

6.3 ZONES OF PRE-SETTLEMENT WOODY VEGETATION

Each of 15 319 grid points (1 × 1 km) was assigned to one of 12 zones of pre-settlement woody vegetation, by classifying the predicted percentage probability of occurrence (P_s) of the 15, presently most common, native, potential canopy species (Fig. 5). This section describes for each pre-settlement woody vegetation zone, the environment, the woody flora predicted to have occurred in each zone by the generalised additive models, and the current composition in terms of present-day woody associations (Section 6.3.1). It describes the available charcoal, subfossil wood and pollen evidence for the former presence of woody species within each zone (Section 6.3.2). Finally, it describes the estimated changes in the extent of woody vegetation in the region (Section 6.3.3).

We assign each pre-settlement woody zone to a vegetation structural class simplified from Atkinson (1985), on the basis of the predicted distributions of the 15 potential canopy species and the fossil record (Figs 5 and 6).

We define three lowland zones as woodland. Because these are the most arid of the Central Otago pre-settlement woody vegetation zones, and the most accessible to humans, any fire-sensitive woody species were probably eliminated at an early stage in human settlement. Therefore, our predictions of the former vegetation hold the greatest uncertainties here, and are undoubtedly biased towards those species that better survive fire (i.e. *Kunzea ericoides*, *Leptospermum scoparium* and *Sophora microphylla*), while fire-intolerant potential canopy species are under-emphasised. Nevertheless, the most drought and frost-prone parts of these three woodland zones presently support several relatively tall (albeit fire-tolerant) woody species, and we suggest they would have previously supported a diverse mosaic of woody and non-woody plant associations.

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