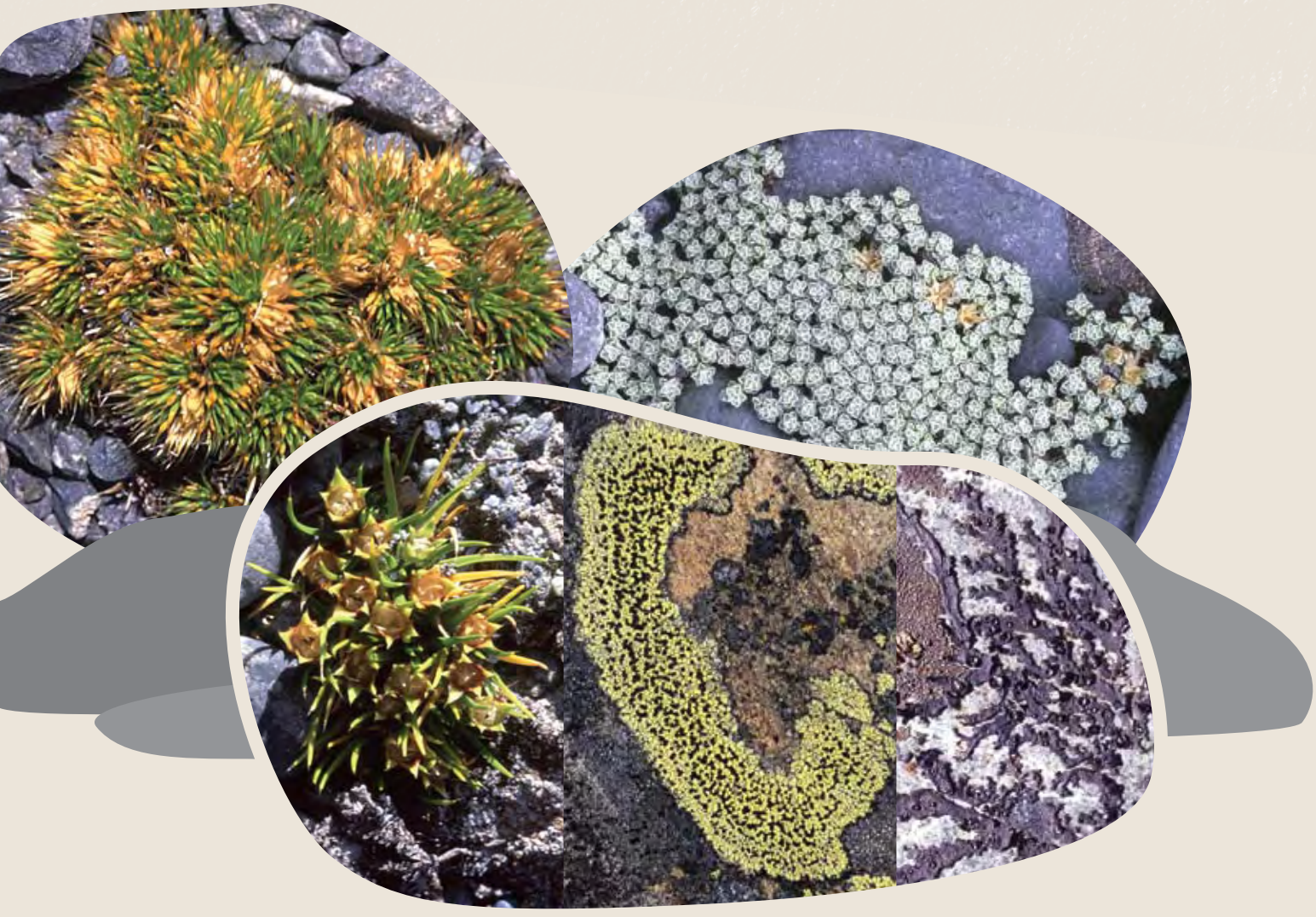
The vegetation of braided rivers in the upper Waitaki basin

South Canterbury, New Zealand

C. B. Woolmore



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Godley River grasslands Photo: C Woolmore

Summary

Braided rivers are generally recognised as supporting a distinctive flora, but there has been little work to date assessing the composition and significance of riverbed plant communities at a regional scale. In particular, the species composition and distribution of riverbed plant communities of the upper Waitaki River is poorly documented. This study describes the plant communities of crown-administered braided-river systems in the upper Waitaki River and some of the factors influencing their distribution.

737 plots were randomly located throughout eleven river systems and vegetation described using the RECCE methodology. Environmental and physical factors recorded at each site include altitude, drainage, landform classification and descriptors, floodplain development stage and depth of surface fines less than 2 mm in diameter. Additional climate data were interpolated from long-run averages of climate station data and include October vapour deficit, water-balance ratio, water deficit, winter minimum temperature, mean-annual temperature, annual-solar radiation and winter-solar radiation. Data were classified into community types based on the presence or absence of species using cluster analysis and vegetation/environment gradients explored using non-metric multidimensional scaling ordinations.

395 vascular plants, 35 lichens, and 22 mosses were recorded from plots. Of the vascular plants 67 percent were native species with *Muehlenbeckia axillaris* being the most commonly recorded in 72% of plots. Eleven plant community types identified during cluster analysis are described in detail. Descriptions include summaries of commonly occurring species, indicator species and community relationships with site and environmental variables. Maps of plot locations are provided for each community.

Climatic factors are found to be important drivers of variation in plant community composition and threatened plant distribution. Key factors include water-balance ratio, water deficit, winter-solar radiation and mean-annual temperature. Other drivers include anthropomorphic influence, and disturbance history. Communities comprised predominantly of native species are situated at higher elevations in river system headwaters with communities dominated by exotics at lower elevations. Native species also show distribution disjunctions, with some occurring most frequently in river headwaters and others found only in lower reaches. Disturbance history and floodplain development stages described by Reinfelds are characterised for upper Waitaki rivers by plant community and river system.

Eighteen plants with threatened species classifications were recorded in the survey; six occurred at more than ten sites, with two of these recorded at more than one hundred sites. The distributions of threatened plants closely follow the climatic gradients described for plant communities.

Plant communities are not distributed evenly throughout river systems with each river containing distinctive combinations of plant communities and threatened plants. The Tasman River contains the largest known populations of the threatened plant *Luzula celata* and extensive examples of early riverbed successions, which are predominantly natural and are not replicated on a similar scale in other catchments.

The Godley River is notable for the range and indigenous character of plant communities and threatened plants it supports, with full uninterrupted vegetation sequences across relatively wide climatic gradients which remain largely natural.
The Murchison River contains a much narrower range of plant communities, but those present are floristically distinct and contain a far lower diversity of exotic species than any other river system. Plant communities of the lower river systems are more dominated by exotic floristic elements but still retain distinctive natural features.

1. Introduction

Combined impacts of loss of habitat through hydroelectric power development, competition from exotic colonising plants and impacts of mammalian predators on the braided-river ecosystems of Canterbury have long been viewed with concern (Balneaves & Hughey, 1990; O'Donnell, 2000; O'Donnell & Moore, 1983). The adverse impacts on specialised birds, dependant on open-gravel riverbeds for feeding and breeding, have been of particular concern. Some bird species are now critically endangered, probably as a result of habitat degradation and predation (Sanders & Maloney, 2002). Less studied than birds, but threatened by similar impacts are the specialised plant communities of braided rivers.

Braided river systems are naturally rare (Williams *et al.*, 2007) and generally recognised as supporting a distinctive flora (Meurk & Williams, 1989; Wardle, 1991). Specialised plants establish on newly deposited or reworked alluvium, and exhibit progressive changes in species composition and community structure with time since disturbance. This process of colonisation has generally been well described. Singleton (Singleton, 1975) describes five age grades associated with plant community development on floodplains of the Waimakariri riverbed. Meurk and Williams (Meurk *et al.*, 1989) identify substrate texture and mechanical stability; rainfall or water-table depth; flooding energy, timing and return period and vegetation/soil system age, as principle factors governing vegetation composition and cover in braided rivers. The regional significance and protection of representative examples of these communities and vegetation assemblages remains undocumented. A protected natural area survey of the Mackenzie ecological region (Espie et al., 1984) recognised the Ahuriri, Tekapo, Pukaki and Ohau rivers as priority natural areas on the basis of specialised bird habitat; however, the flora was not described. Meurk and Williams recommended in 1989 that plant values of braided rivers be assessed regionally. To date there has been little progress towards that goal.

The species composition and distribution of riverbed plant communities within the upper Waitaki basin is poorly documented. Meurk and Williams describe a generalised braided-river flora based on a bibliographic search of species reported from Canterbury braided rivers. Other studies have described communities associated with specific river systems in Canterbury (Burrows, 1977; Williams, 1981a). The only major investigation done in the Waitaki basin is by Wilson (Wilson, 1976) as part of a description of the vegetation of Aoraki/Mt Cook National Park. He describes two main riverbed communities and five plant associations from 70 site descriptions in the upper Tasman, Hooker and Murchison valleys. This study was confined to the Aoraki/Mt Cook National Park and excluded much of the Tasman riverbed. Several other studies provide localised species lists in other parts of the basin (Robertson, O'Donnell & Overmars, 1983; Sinclair, 1995).

This study describes the plant communities of braided-river systems in the upper Waitaki basin and discusses some of the factors influencing their distribution.

2. Study area

The study area covers some 30,000 hectares of high-energy, gravel-based braided rivers in the headwaters of the Waitaki River, central South Island. These rivers have contributed to the formation of a large intermontane basin through widespread deposition of alluvium following a series of glacial advances and retreats. Up to fourteen braided riverbeds have

been identified in the upper Waitaki basin (O'Donnell, 2000; Wilson, 2001), eleven of these are over 500 ha in size.

Lying in the rain shadow of the Southern Alps/Kā Tiritiri o te Moana and flanked to the north and south by the Two Thumb and Ben Ohau ranges the intermontane basin of the upper Waitaki river has a special climatic character. Intermontane basins of the southern South Island have been described as having a 'continental' climate (Maunder, 1965; Ryan, 1987), exhibiting climatic extremes compared with other low-elevation sites. Braided riverbeds in the upper Waitaki basin range in elevation from 400 m asl near Lake Benmore to 1200 m asl in the upper Cass River. A number of climate parameters show range gradients associated with changes in riverbed elevation. Lower elevation sites are characterised by lower mean-annual rainfall, lower levels of water runoff and higher annual water deficits, higher mean-annual temperatures and higher minimum-annual temperatures compared with higher elevation sites (New Zealand Meteorological Service, 1979, 1983, 1984, 1985, 1986).

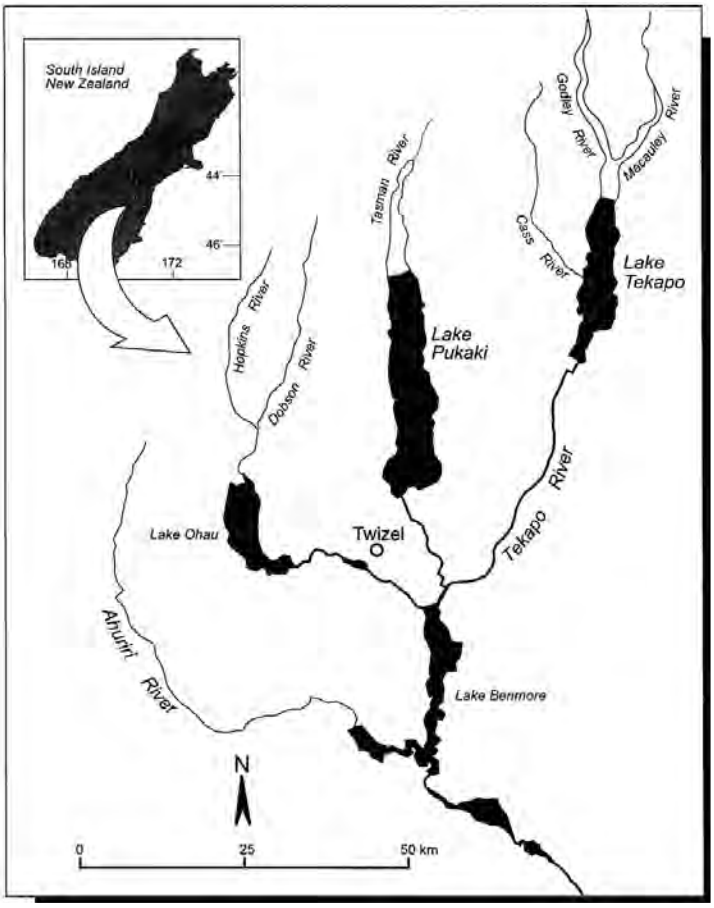

Figure 1. Location diagram

Table 1: Upper Waitaki braided-river areas and number of plots sampled.

BRAIDED RIVER	NUMBER OF PLOTS	ESTIMATE OF RIVERBED SIZE (WILSON 2001) IN HECTARES	ESTIMATE OF RIVERBED SIZE (O'DONNELL 2000) IN HECTARES
Fork Stream	0	151	-
Edwards Stream	0	-	300
Twizel River	0	-	474
Pukaki River	13	512	609
Ohau River	18	433	712
Murchison River	25	1256	956
Cass River	50	-	1583
Macaulay River	32	1534	1783
Dobson River	56	2007	2807
Tekapo River	69	3178	3036
Ahuriri River	76	4354	3324
Hopkins River	88	3549	4779
Tasman River	152	6897	6178
Godley River	158	6833	6730
Totals	737	30704	33271

Table 2: Upper Waitaki River climate data.

	HERMITAGE, MT COOK	LAKE PUKAKI NO.1	LAKE TEKAPO	TWIZEL	TARA HILLS, OMARAMA
Mean-annual rainfall	4098	641	597	467	528
Mean air temperature	8.4	8.9	8.8	9	9.3
Mean-daily-maximum temperature	13.4	14.7	14.4	15.4	15.4
Mean-daily-minimum temperature	3.4	3.1	3.3	2.6	3.1
Mean-ground-frost days	131.7	166.4	175.8	175.8	155.9
Mean-relative humidity	69	74	69	75	72
Mean-sunshine hours	1527	NA	2217	NA	2095
Number of growing degree days with base 5 degrees	1517	NA	1772	NA	1808
Number of growing degree days with base 10 degrees	501	NA	697	NA	733

3. Methods

3.1 Site characteristics

Plots were located within floodplains of the eleven main braided rivers on a restricted random basis. Floodplain boundaries were arbitrarily set as the legal boundaries of crown-administered land within riverine land systems (see maps, Appendix 1). Allocation of plots was proportional to riverbed size and set on a river by river basis at a target sampling intensity of 23 plots per 1000 hectares. Sampling at this intensity is consistent with comparable descriptive studies in forest, shrubland and grassland communities, and is an achievable target. The required number of sample locations (preferred locations) were randomly generated for each river system. A further set of sample locations (50% of the required total for the river system) were randomly generated to be used in the event of a preferred sample site being unusable, e.g. falling in mid-channel of a river. Sample sites were located in the field using handheld GPS; if the preferred location was unusable the next nearest alternative location was sampled.

Plots were boundless, following the RECCE methodology described by Allen (Allen, 1992), with several alterations to accommodate characteristics of riverbed plant communities.

Briefly, each plot occupied an area of varying size and shape but of uniform landform feature, and homogenous vegetation composition. Mean-estimated plot size was 213 square metres. Within plots, species were recorded in each of six height classes: 0–10 cm, 11–30 cm, 31 cm–2 m, and over 5 m. Within each height class, individual species cover was assessed using one of six cover classes: <1%, 1–5%, 6–25%, 26–50%, 51–75%. Total cover and mean height of vegetation for each tier were also estimated.

Both vascular and non-vascular plants were recorded. Vascular plants were identified to species level; lichens and bryophytes were identified to taxonomic levels that could be reliably discriminated in the field. Total percentage groundcover of vascular plants, moss, lichens, litter, soil and mineral substrate were estimated for each plot. The percentage cover of mineral substrate was further divided into each of five size fractions: Fines (<2 mm); gravel and coarse gravel (2–20 mm); pebbles (21–60 mm); cobbles (61–200 mm) and boulders (> 200 mm).

Environmental and physical factors recorded at each plot were altitude, aspect, slope, drainage, landform classification and descriptors (Whitehouse, Basher & Tonkin, 1992), floodplain development stage (Reinfelds & Nanson, 1993) and depth of substrate fines less than 2 mm in diameter. Additional environmental data were drawn from mathematical interpolations of long-run average climate-station data (Leathwick, Wilson & Stephens, 2002) at each plot location. Factors modelled include October vapour deficit (kPa – the capacity of air to take up water vapour in spring, dependent on temperature and humidity), water balance ratio (monthly estimates of rainfall/potential evaporation averaged across all months), water deficit (mm – sum of monthly amounts by which evaporation exceeds rainfall), winter minimum temperature (degrees Celsius – mean-daily-minimum temperature of the coldest month), annual temperature (degrees Celsius – monthly mean-daily temperature, averaged across all months), annual-solar radiation (MJ/m2/day – monthly mean-daily-solar radiation, averaged across all months) and winter solar radiation (MJ/m2/day – mean-daily-solar radiation in June).

Subjective rankings of 'representativeness', 'natural diversity', 'rarity', and 'naturalness' were made at each site (Myers, Park & Overmars, 1987). Buffering was also assessed at each site. Buffering is a subjective assessment of the extent of human activity and human influence surrounding the plot site, extending laterally from the river floodplain to the catchment boundary. It includes consideration of intensity of current grazing, degree of natural vegetation clearance or modification, density of human occupation and infrastructure and intensity of infrastructure use.

3.2 Analysis

Classification, indicator species analysis and ordination of data were undertaken using the programme PC-ORD (McCune & Mefford, 1999). Community species frequency and cover were summarised using the package PC-RECCE (Hall, 1992) and statistical analyses were performed in SPSS. (SPSS., 2006)

Community types

Samples were classified based on the presence or absence of species using cluster analysis ((Clifford & Stephenson, 1975); Euclidian distance measure, Wards linkage method). The classification was terminated at the 11 group level for identification of community types. Each type was then divided into further plant associations based on a subjective assessment of dendrogram structure and community-type species richness.

Community composition and structure were summarised to obtain species frequency and percentage cover data. Indicator species for community types, subtypes and floodplain development stages were identified using Indicator Species Analysis (Dufrene & Legendre, 1997) with a 1000 randomisation Monte Carlo test. Communities were named following Atkinson (Atkinson, 1985).

Site and environmental differences within community types and sub-types were identified using one way ANOVA (quantitative) and Kruskal Wallis (qualitative) tests, comparing values and counts between each division of the classification.

Vegetation gradients

Non-metric multidimensional scaling ordinations (Kruskal, 1964a, 1969b; Mather, 1976) using Sorenson distance measure and default settings were used to summarise variation in species composition, using all sample locations. Because of the high frequency of 0 values in species/plot frequency data, and to improve detection of compositional gradients

(McCune, 1994), data were transformed using Beals Smoothing prior to ordination. A further ordination of key species affecting community classification, as identified during indicator species analysis, was used to further explore species-environment variation. Relationships between environmental variables and ordination scores are shown using joint plots as described in the PC-ORD analysis package.

4. Results

4.1 Overview

A total of 395 vascular plants, 35 lichens, 22 mosses, 5 liverworts, 1 hornwort and 1 alga were recorded from 737 plots. Mean species richness was 25 species per sample (SD 12.17, SE 0.45).

Of the vascular plants recorded, 264 (67%) were native and 131 (33%) exotic. *Muehlenbeckia axillaris* was the most frequently recorded species, occurring in 72% of site descriptions. Only 10 further species occurred in over half of the site descriptions: three native vascular plants (*Epilobium melanocaulon, Raoulia hookeri, Poa lindsayi*); 4 exotic vascular plants (*Trifolium repens*, Agrostis capillaris*, Hieracium pilosell*a**, Holcus lanatus**) and the moss *Racomitrium crispulum*. A high proportion of species was recorded infrequently; 241 species (52%) were recorded from five or fewer samples (see Appendix 2).

Family representation

Vascular plants were recorded from a total of 63 plant families. Twenty families had five or more species and accounted for 81% of all vascular plants recorded (See Appendix 3). Of these, Poaceae and Asteraceae contained the highest number of species (59 and 52 species). Exotic plants had a high level of representation in two families: Salicaceae (8 spp., 100% of total), Papilionaceae (12 spp., 75% of total); and eight families had a high level of native species representation: Asteraceae (29 spp., 75% of total), Cyperaceae (30 spp., 91% of total), Apiaceae (10 spp., 91% of total), Onagraceae (10 spp., 91% of total), Rubiaceae (10 spp., 91% of total), Coriariaceae (6 spp., 100% of total), Haloragaceae (6 spp., 100% of total), and Epacridaceae (6 spp., 100% of total).

4.2 Community descriptions

Eleven broad plant community types were identified from cluster analysis. Frequently occurring species, species dominating cover, indicator species and site and climatic variables associated with each community type are summarised below. Plant structural descriptors follow Atkinson (Atkinson, 1985). Notably, herbaceous plants are defined to include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, cushion plants, mosses or lichens; and cushion plants include all herbaceous, semi-woody and woody plants with dense closely packed branches and closely-spaced leaves that together form dense regularly shaped cushions. Other descriptors are self-explanatory. Community types are also named using the standard methods of Atkinson. Exotic plants are marked with an asterisk (*).

Community 1/ (*Anthoxanthum odoratum**) – (*Agrostis capillaris**) – [*Holcus lanatus**] – [*Festuca rubra**] Grassland

This community is described from 58 plots representing 8 percent of surveyed sites. Site descriptions contain a high diversity of species (32 species per plot) compared with other plots, and exotic species are an important component of these. Of the 252 species recorded in this community, 95 (38%) are exotic and contribute to a high proportion of total plant cover (65%). These grasslands are heterogeneous with only 11 species (4%) occurring in more than 50% of sample descriptions.

This community occurs at sites with poorer drainage, deeper average depths of surface fines and high levels of vascular ground cover compared with other community types. Sample sites are frequently assessed as being at an advanced stage of floodplain development and have a high level of exposure to anthropogenic influence (low buffering).

Figure 2. Location of Community 1 and plant associations

●= association 1a; ■= association 1b; ▲= association 1c

Common species

Six species occur frequently in this community (>70% of samples). All are exotic and five of these consistently contribute high levels of plant cover: The grasses *Agrostis capillaris** and *Anthoxanthum odoratum** consistently occur with high levels of foliar cover in the canopy, usually in association with *Festuca rubra** and *Holcus lanatus**. *Trifolium repens** is commonly present and contributes consistently to foliar cover in the 0–10 cm height tier. The herbaceous plant *Hieracium praealtum** occurs in 74% of descriptions, but contributes to less than 2% of cover in the samples where it is present. Plants that occur less frequently, but dominate cover where they occur, are the sedges *Carex coriacea, C. sinclairii* and *Schoenus pauciflorus*; the tree *Salix fragilis**; and the herbaceous plants *Gunnera dentata,* and *Lotus pedunculatus**. Other indicator species associated with this community are typically found on moist or poorly drained sites.

Table 3: Species commonly occurring (frequency >70% of samples) in Community 1.

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	8	9	10	11
*Agrostis capillaris**	**72**	96	85	25	73	17	91	89	69	11	21
*Anthoxanthum odoratum**	**88**	92	70	18	81	76	72	70	59	13	12
Festuca rubra	**76**	67	34	9	79	72	54	56	25	4	6
*Hieracium praealtum**,	**74**	57	43	4	35	14	65	73	69	52	9
*Holcus lanatus**;	**95**	78	80	13	26	83	89	67	56	6	21
*Trifolium repens***	**91**	86	90	55	24	90	100	94	75	26	12

Indicator species

Plants found more frequently in this community are a variety of sedges, rushes and herbaceous plants which are commonly associated with wet or imperfectly drained sites. Native and exotic species occur in roughly equal proportions as community indicators.

Table 4: Community 1 indicator species (indicator value, P< 0.01).

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	8	9	10	11
Carex coriacea	**32**	5	0	0	0	0	0	0	0	0	0
*Centaurium erythraea**	**17**	0	1	0	0	0	0	1	2	0	0
Epilobium komarovianum	**21**	0	3	0	0	3	0	0	0	0	0
Gunnera dentata.	**17**	1	4	0	0	0	0	0	0	0	0
*Juncus articulatus**,	**29**	1	0	0	0	14	0	0	0	0	0
*Juncus effusus**,	**33**	1	0	0	0	2	0	0	0	0	0
Juncus novae-zelandiae	**17**	1	0	0	0	0	0	0	0	0	0
*Juncus tenuis**;	**23**	2	1	0	0	5	0	0	0	0	0
Isolepis aucklandica	**24**	0	0	0	0	2	0	0	0	0	0
*Prunella vulgaris**,	**18**	4	0	0	0	5	0	0	0	0	0
*Parentucellia viscosa **,	**15**	0	2	0	0	0	0	0	0	0	0

Plant associations

Three further plant associations were recognised in this community:

a) Exotic grassland (26 plots) in which *Carex coriacea* occurs frequently and contributes significantly to total canopy cover. The tussock *Festuca novae-zelandiae* and herbaceous plant *Gonocarpus aggregatus* occur more frequently and with higher levels of cover in this association than other associations in this community type. It occurs most frequently in the upper Ahuriri and lower Hopkins rivers, and occurs on sites with greater mean-substrate depths than other associations.

Table 5: Association 1a indicator species (indicator value, P< 0.01).

	● (A)	■ (B)	▲ (C)
Festuca novae-zelandiae	49	0	1
Gonocarpus aggregatus	49	0	1
Carex coriacea	43	7	4
*Agrostis capillaris**	43	6	26

b) Exotic grassland (14 plots) in which the emergent tree *Salix fragilis**, and shrub *Rosa rubiginosa** occur frequently and contribute significantly to total canopy cover. *Lotus pedunculatus** co-dominates low herbaceous cover with exotic grasses. A number of other exotic herbaceous plants occur more frequently in this association. It is found at lower altitudes in the Ohau, Tekapo, Pukaki and lower Ahuriri rivers and has higher exposure to anthropogenic influence than the rest of this community type.

Table 6: Association 1b indicator species (indicator value, P< 0.01).

	● (A)	■ (B)	▲ (C)
*Salix fragilis**	1	72	0
*Rosa rubiginosa**	6	69	0
*Lotus pedunculatus**	4	61	1
*Plantago lanceolata**	8	56	5
*Ranunculus repens**	0	50	0
*Lupinus polyphyllus**	0	36	0
*Leucanthemum vulgare**	2	34	0
*Verbascum thapsus **	1	33	1
*Ulex europaeus**	0	32	0
*Agrostis stolonifera**	0	29	0
*Mimulus guttatus**	0	27	3
*Arrhenatherum elatius **	0	25	0
*Echium vulgare**	0	21	0

c) Exotic grassland (18 plots) in which *Gunnera dentata* is a significant community component. It is characterised by more common occurrences of many native wetland plants. This association occurs more frequently on earlier floodplain development stages than the rest of this community type, in river valleys above Lakes Ohau, Pukaki and Tekapo.

Table 7: Association 1c indicator species (indicator value, P< 0.01).

	● (A)	■ (B)	▲ (C)
*Aira caryophyllea**	1	0	93
Epilobium komarovianum	3	0	74
Gunnera dentata	1	0	73
Epilobium brunnescens	0	1	60
*Trifolium dubium**,	8	3	59
Carex berggrenii	0	0	56
*Sagina apetala**,	4	9	54
Juncus novae-zelandiae	1	0	54
Leptinella pusilla	0	0	52
Pratia angulata	1	0	49
*Juncus articulatus**	6	29	47
*Linum catharticum**	10	5	46
Raoulia tenuicaulis	2	0	46
*Centaurium erythraea**	1	11	44
Raoulia hookeri	1	0	43
*Juncus bufonius**	2	1	42
*Vulpia bromoides**	0	0	41
Isolepis aucklandica	1	12	40
*Juncus tenuis**	0	33	39
Carex petriei;	0	3	32
Neopaxia australasica	0	0	30
Plantago triandra	0	0	24

Community 2/ [*Discaria toumatou*] / *Agrostis capillaris* * – *Anthoxanthum odoratum** – [*Holcus lanatus**] Grassland

This community is described from 49 plots representing 7 percent of surveyed sites. The community has a number of features that are similar to Community type 1. Site descriptions contain a high diversity of species compared with other plots (32 species per plot) and exotic species are an important component of these. Of the 230 species recorded in this community, 56 (24%) are exotic and contribute to a high proportion of total plant cover (55%). These grasslands are heterogeneous with only 17 species (7%) occurring in more than 50% of sample descriptions.

This community has high average depths of surface fines and high levels of vascular ground cover compared with other community types. Sample sites are frequently assessed as being at an advanced stage of floodplain development and occur at higher altitudes, with better drainage than Community 1.

Figure 3. Location of Community 2 and plant associations

● = association 2a; ■ = association 2b;

The grasses *Agrostis capillaris**, *Anthoxanthum odoratum**, *Holcus lanatus** and *Festuca rubra** (in 67% of plots) commonly dominate a low canopy (<30 cm tall) with *Hieracium pilosella**, *Hieracium praealtum**, *Muehlenbeckia axillaris* and *Trifolium repens**, also having high levels of cover in the 0–10 cm height tier. Plants which occur less frequently but have significant levels of cover where they occur are the sedge *Schoenus pauciflorus*, the shrub *Discaria toumatou*, the cushion plant *Pernettya nana*, the herbaceous plants *Hieracium praealtum**, *Hydrocotyle novae-zelandiae*, *Leucopogon fraseri* and *Festuca novae-zelandiae*.

Table 8: Species commonly occurring (frequency >70% of samples) in Community 2.

	COMMUNITY TYPE										
	1	**2**	3	4	5	6	7	8	9	10	11
*Agrostis capillaris**	72	**96**	85	25	73	17	91	89	69	11	21
*Anthoxanthum odoratum**	88	**92**	70	18	81	76	72	70	59	13	12
*Cerastium fontanum**,	67	**90**	77	21	14	34	63	29	30	1	6
*Hieracium pilosella**,	50	**90**	61	11	91	90	93	75	91	50	6
*Holcus lanatus**;	95	**78**	80	13	26	83	89	67	56	6	21
*Linum catharticum**;	50	**71**	8	1	17	7	35	41	50	4	0
Muehlenbeckia axillaris	34	**82**	83	47	93	97	96	76	84	48	67
*Trifolium repens**	91	**86**	90	55	24	90	100	94	75	26	12

Indicator species

Indicator species include a range of herbaceous plants commonly described from alluvial grasslands (Walker & Lee, 2002) .

Table 9: Community 2 indicator species (indicator value, P< 0.01).

	COMMUNITY TYPE										
	1	**2**	3	4	5	6	7	8	9	10	11
Acaena inermis	4	**17**	1	0	1	1	6	0	1	0	0
*Cerastium fontanum**	10	**19**	14	1	0	3	9	2	2	0	0
Helichrysum filicaule	0	**20**	0	0	0	0	0	0	4	0	0
Hydrocotyle novae-zelandiae	9	**16**	1	0	0	0	2	0	4	0	0
Leptinella pusilla	4	**22**	1	0	0	0	1	0	1	0	0
*Linum catharticum**	9	**18**	0	0	1	0	4	6	9	0	0
Ranunculus multiscapus	3	**15**	0	0	0	0	0	0	0	0	0

Plant associations

Two further plant associations were recognised in this community:

a) Exotic grassland (28 plots) in which *Festuca rubra** contributes consistently to canopy cover and the herbaceous plant *Trifolium arvense** is an important cover component in the ground tier. Other species occurring more frequently in this association are the mosses *Racomitrium crispulum, Polytrichum juniperinum* and the herbaceous plant *Hypericum perforatum**. This association occurs most frequently in the Godley River, and when compared with other associations in this community occurs on sites with a higher level of buffering from anthropogenic influence, significantly (p<.005) lower minimum annual temperatures, lower water-balance ratio and higher water deficits.

Table 10. Association 2a indicator species (indicator value, P< 0.01).

	●(A)	■(B)
*Trifolium arvense**	56	0
Racomitrium crispulum	48	8
Polytrichum juniperinum	46	5
*Hypericum perforatum**	46	0

b) Exotic grassland in which *Festuca novae-zelandiae*, and the herbaceous plants *Acaena inermis, Hieracium praealtum**, and *Hydrocotyle novae-zelandiae* occur frequently and contribute significantly to total canopy cover (21 plots). Other indicator species characteristic of this association are the herbaceous plants *Helichrysum filicaule Hypochoeris radicata*, Leptinella pusilla, Luzula rufa, Pratia angulata, Ranunculus multiscapus, Trifolium pratense*, Wahlenbergia albomarginata*; the cushion plant *Pimelea prostrata*; and the grass *Holcus lanatus**. While many of the indicator species in this association are native, a higher proportion of frequently occurring species are exotic (50% compared with 35%) and exotic plants contribute to a higher proportion of overall vegetation cover (63% compared with 57%) than association a). This association occurs most frequently in the Hopkins and Dobson rivers, has less buffering from anthropogenic influence and significantly (P<.005) warmer minimum annual temperatures, higher water-balance ratios and lower water deficits than association a).

Table11. Association 2b indicator species (indicator value, P< 0.01).

	●(A)	■(B)
Helichrysum filicaule	0	73
Hydrocotyle novae-zelandiae	4	73
*Hieracium praealtum**	8	67
Leptinella pusilla	3	66
*Holcus lanatus**	23	62
*Hypochoeris radicata**	12	59
Wahlenbergia albomarginata	6	57
Luzula rufa	1	51
Ranunculus multiscapus	0	44
*Trifolium pratense**	2	39
Pimelea prostrata	3	37
Pratia angulata	0	29

Community 3/ [*Raoulia tenuicaulis*] – [*Trifolium repens**] Stonefield

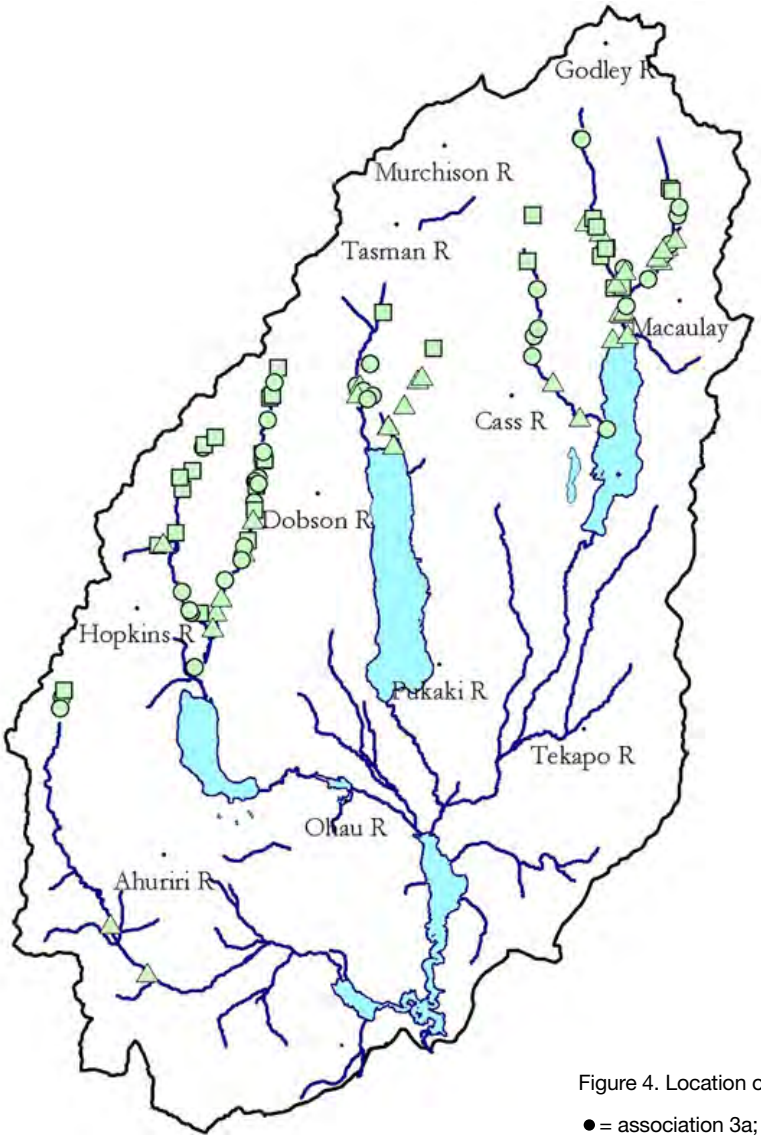

Figure 4. Location of Community 3 and plant associations

● = association 3a; ■ = association 3b; ▲ = association 3c

This community is described from 102 plots representing 14 percent of surveyed sites. Site descriptions contain an average of 24 species. Of the 181 species recorded in this community, 71 (39%) are exotic and these make an important contribution to total plant cover (51%). The species composition of these stonefields is heterogeneous, with only 14 species (8%) occurring in more than 50% of sample descriptions. Vegetative cover is sparse (10% of total ground cover) and predominantly comprised of low growing grasses, cushion plants and herbs, with the majority of plants recorded in the 0–10 cm height class.

This community is recorded more frequently on early floodplain development stages, it has higher levels of surface rock as a proportion of total ground cover (89%) compared with most other vegetation types (1, 2, 5, 6, 7, 8, 9, 10) and, of the three stonefield communities described, has a higher proportion of surface rock as a fines fraction than community 11. It occurs on sites with higher minimum annual temperatures, water-balance ratios, mean-annual-solar radiation and winter solar radiation, and lower water deficits and mean-annual temperatures than communities 1, 5 and 6 (P<.05). The community occurs most frequently in the upper river valleys.

Common species

Twelve species are frequently recorded in this community (>70% of samples): Vegetative cover is higher than other stonefield communities, but sparse compared with all others. *Raoulia tenuicaulis* and *Trifolium repens** are the only plants which consistently contribute a significant level of canopy cover (3.9 and 2.0%); other species are frequently recorded as being present but occur as scattered, small plants (*Agrostis capillaris**, *Holcus lanatus**, *Muehlenbeckia axillaris, Raoulia hookeri*), or have a sparse foliar growth form (*Epilobium melanocaulon*) and contribute less than 1% cover across the community.

Table 12. Species commonly occurring (frequency >70% of samples) in Community 3.

	COMMUNITY TYPE										
	1	2	**3**	4	5	6	7	8	9	10	11
*Agrostis capillaris**	72	96	**85**	25	73	17	91	89	69	11	21
*Anthoxanthum odoratum**	88	92	**70**	18	81	76	72	70	59	13	12
*Cerastium fontanum**	67	90	**77**	21	14	34	63	29	30	1	6
Raoulia hookeri	19	18	**89**	51	4	17	87	75	50	83	85
*Holcus lanatus**	95	78	**80**	13	26	83	89	67	56	6	21
Poa lindsayi	5	1	**87**	30	24	28	96	89	58	85	91
Muehlenbeckia axillaris	34	82	**83**	47	93	97	96	76	84	48	67
Epilobium melanocaulon	14	6	**87**	49	34	45	72	60	45	93	94
Epilobium microphyllum	12	8	**87**	38	20	34	100	67	30	48	61
Raoulia tenuicaulis	22	16	**77**	18	5	38	89	52	19	13	58
*Rumex acetosella**	53	61	**72**	11	84	100	78	79	80	9	15
*Trifolium repens**	91	86	**90**	55	24	90	100	94	75	26	12

Indicator species

There are no indicator species associated with this community.

Plant associations

Three plant associations were recognised in this community:

a) This association is described from 38 plots and has a similar species composition to that described for the community type. There are no indicator species characteristic of this association; all frequently occurring species are present throughout the community type. It has significantly (P<.005) lower levels of vascular cover, higher cover of bare rock contributing to total ground cover and lower numbers (95 species) and diversity of species

(18 species per plot) than other associations. Nine species are recorded in over seventy percent of plots and no individual species contributes to greater than 1% of total vascular cover.

b) This association is described from 31 plots. The cow-pat lichen *Placopsis* spp. may contribute significantly to total plant cover (45% of plots, 5% cover where present), and compared with association a) the main canopy plants have higher levels of cover (*Raoulia tenuicaulis* (5% cover) and *Trifolium repens* (3% cover). The association also has a higher species diversity (26 species per plot). Indicator species characteristic of this association are all native plants and include the mosses *Racomitrium crispulum*, and *R. pruinosum*; and the lichens *Placopsis perrugosa* and cow-pat *Placopsis* spp. It occurs at sites with higher water-balance ratios, lower water deficits, lower October vapour deficits, lower mean-annual temperatures, lower mean-annual-solar radiation and lower winter-solar radiation than associations a) or c).

Table 13. Association 3b indicator species (indicator value, P< 0.01).

	● (A)	■ (B)	▲ (C)
Placopsis spp.	0	31	5
Luzula rufa var. *albicomans*	0	34	4
Placopsis perrugosa	0	42	1
Racomitrium pruinosum	6	47	0
Racomitrium crispulum	14	52	6
Lachnagrostis lyallii	7	52	2
Leptinella pusilla	0	17	0
Trisetum tenellum	0	26	0
Polytrichum juniperinum	2	21	1

c) This association is described from 33 plots. *Raoulia tenuicaulis* and *Trifolium repens* dominate the sparse canopy cover at similar levels to association b). This association has the highest diversity of species with an average of 30 species per plot and a total of 144 species recorded. Fourteen plants occur in over 70% of plots and a higher proportion of these are exotic compared with the rest of this community type. Indicator species are also predominantly exotic.

This association has a lower level of buffering from anthropogenic influence and occurs more frequently on sites with higher October vapour-pressure deficits, and lower water balance ratio than other associations in this community. Compared with association b), it occurs on sites with higher mean-annual temperatures and higher mean-annual-solar radiation.

Table 14. Association 3c indicator species (indicator value, P< 0.01).

	●(A)	■(B)	▲(C)
*Cirsium arvense**	2	0	28
Coriaria sarmentosa	0	0	18
*Crepis capillaris**	2	2	26
Epilobium brunnescens	1	4	45
Epilobium komarovianum	0	0	40
Gunnera dentata	0	0	39
*Hypericum perforatum**	2	9	28
*Juncus articulatus**	1	0	24
*Juncus bufonius**	1	2	25
*Juncus tenuis**	0	0	21
Myosotis laxa var. *caespitosa**	0	0	21
*Rumex crispus**	0	0	30
*Sagina apetala**	6	6	56
Tarweed*	0	0	18
*Trifolium arvense**	2	5	36
*Trifolium dubium**	0	7	35
*Verbascum thapsus**	2	1	22
*Vulpia bromoides**	0	2	54

Community 4/ Stonefield

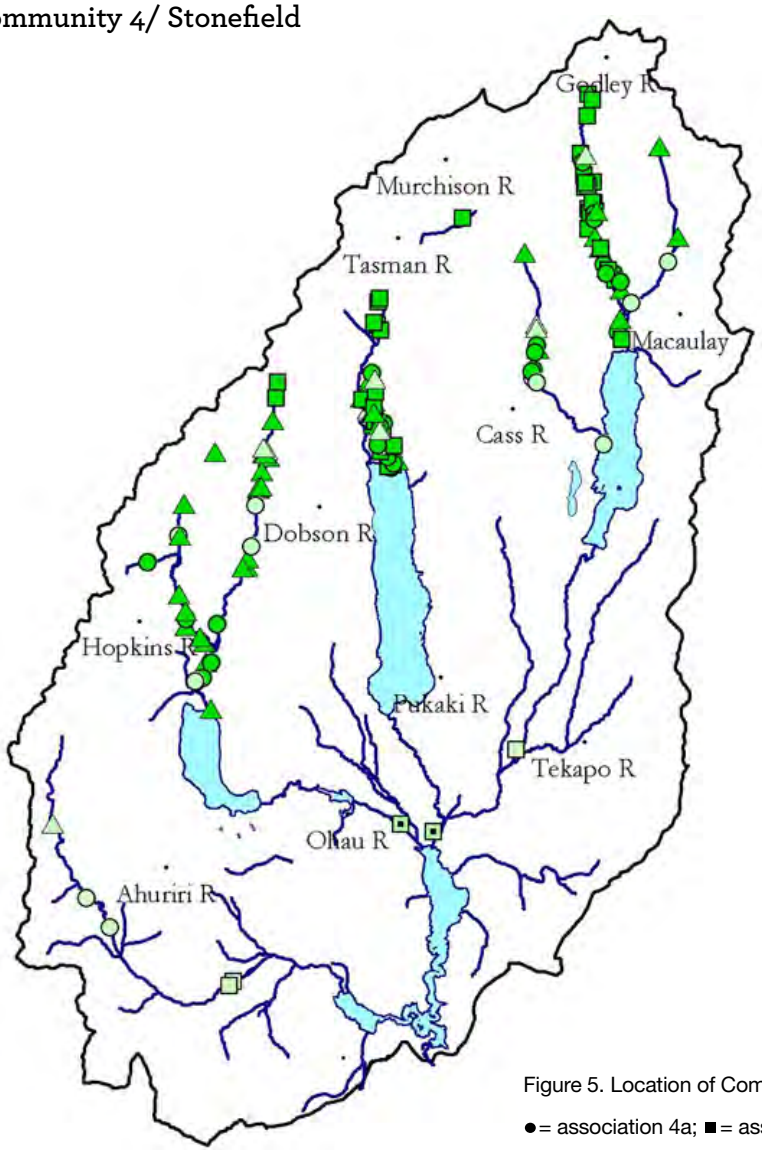

Figure 5. Location of Community 4 and plant associations ●= association 4a; ■= association 4b; ▲= association 4c.

This community is recorded from 141 plots representing 19 percent of surveyed sites. Site descriptions contain an average of 6 species per plot with a total of 104 species recorded. This community has the highest level of species heterogeneity recorded (β diversity = 16.2) and only two plants (*Raoulia hookeri* and *Trifolium repens**) occur in more than 50% of plots. Vegetative cover is extremely sparse, with 13 plot descriptions containing no plants. Ground cover is predominantly bare rock (97%) with vegetation occupying 2%. No plants exceed 1% cover across the community type, although species cover is frequently clumped. Growth forms of plants present in the community are diverse, but few are recorded above the 0–10 cm height class.

This community is recorded more frequently as an early floodplain development stage and has a high level of buffering from anthropogenic activity compared with other communities. It occurs on sites with higher minimum-annual temperatures, water balance ratios, mean-annual-solar radiation, and winter-solar radiation and lower water deficits and mean-annual temperatures than communities 1, 5 and 6 ($P<.05$). Of the three stonefield communities, this community has significantly ($P<.05$) higher levels of fines and gravel-size fractions as a proportion of total surface bare rock, higher mean-annual temperatures and lower levels of winter-solar radiation compared with community 11. The community occurs most frequently in the river valleys above Lakes Ohau, Pukaki and Tekapo.

Indicator species

There are no indicator species associated with this community other than the complete absence of vascular or non-vascular plant cover in 13 plots.

Community 5/ [*Rosa rubiginosa**] / (*Muehlenbeckia axillaris*) Herb – Stonefield

This community is described from 106 plots representing 14 percent of surveyed sites. Site descriptions contain an average of 28 species. Of the 214 species recorded in this community, 109 (51%) are exotic and these make an important contribution to total plant cover (61%). The species composition of this community is heterogeneous, with only 17 species (8%) occurring in more than 50% of sample descriptions. Vegetative cover is moderate; 40% of total ground cover is vegetation comprised of low growing herbs, grasses, and cushion plants with the majority of plants recorded in the 0–10 cm height class. Ground tier vegetation is frequently overtopped by an open shrub layer of *Rosa rubiginosa* in the 30–200 cm height class.

This community has a low level of buffering from anthropogenic activity and occurs at significantly ($P<.05$) lower altitudes than all community types other than community 6. It has significantly higher levels of vegetative ground cover than communities 3–8, 10 and 11, higher levels of litter as a ground cover component than any other community, and lower levels of surface bare rock than communities 3–7, 10 and 11. It occurs on sites with lower minimum-annual temperatures, lower water-balance ratios, lower winter solar radiation and higher water deficits than all communities other than community 6. The community occurs most frequently in the Ohau, Pukaki, Tekapo and Ahuriri rivers.

Common species

Eleven species are recorded frequently (>70% of samples) in this community. The grasses *Agrostis capillaris** and *Festuca rubra**; the cushion plant *Muehlenbeckia axillaris*; the shrub *Rosa rubiginosa**; and the herbaceous plants *Hieracium pilosella**, and *Hypericum perforatum**; co-dominate vegetative cover. Species which occur less frequently (>50% of samples) but co-dominate cover where they occur are the cushion plant *Raoulia australis*, the herbaceous plants *Echium vulgare* * and *Sedum acre**, and the terrestrial lichen

Neofuscelia adpicta on exposed cobbles and boulders. A high proportion of the frequently occurring species in this community (82%), and species dominating cover (60%) are exotic.

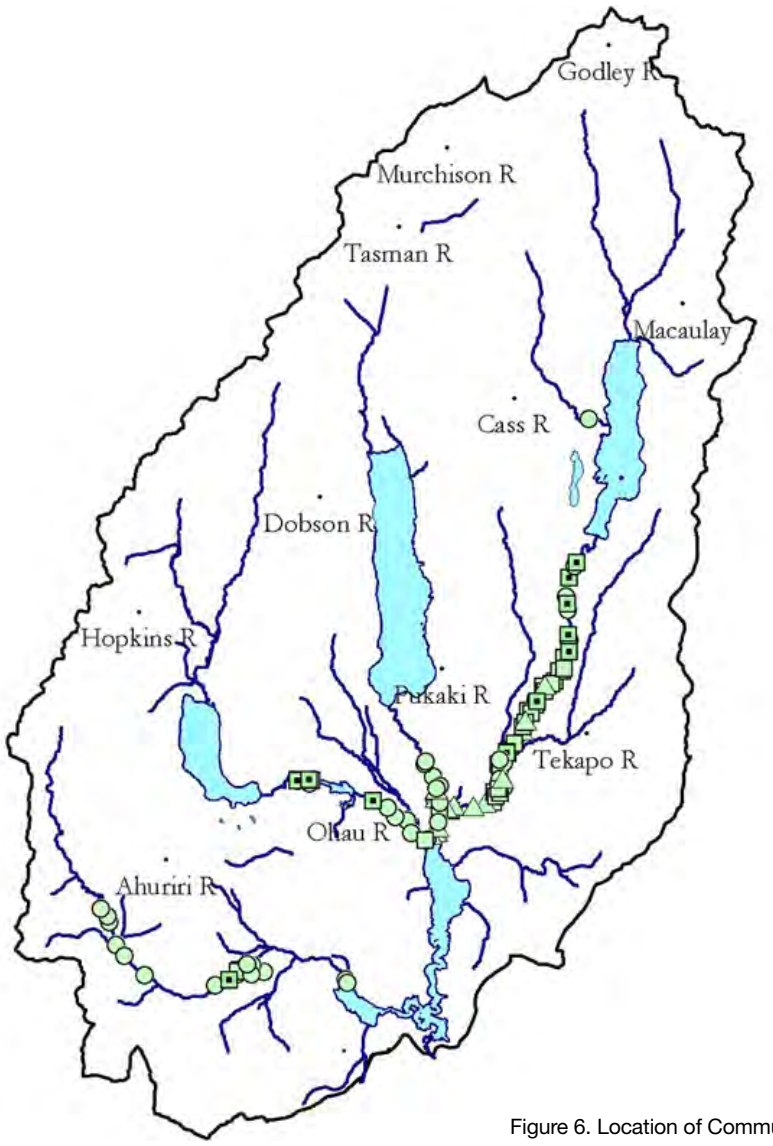

Figure 6. Location of Community 5 and plant associations

● = association 5a; ■ = association 5b;▲ = association 5c; ◘= association 5d

Table 15. Species commonly occurring (frequency >70% of samples) in Community 5.

	COMMUNITY TYPE										
	1	2	3	4	**5**	6	7	8	9	10	11
*Agrostis capillaris**	72	96	85	25	**73**	17	91	89	69	11	21
*Anthoxanthum odoratum**	88	92	70	18	**81**	76	72	70	59	13	12
*Festuca rubra**	76	67	34	9	**79**	72	54	56	25	4	6
*Hieracium pilosella**	50	90	61	11	**91**	90	93	75	91	50	6
*Hypericum perforatum**	33	31	30	4	**71**	21	20	11	55	6	6
Muehlenbeckia axillaris	34	82	83	47	**93**	97	96	76	84	48	67
Racomitrium crispulum	26	51	59	28	**71**	17	100	95	100	93	97
*Rosa rubiginosa**	36	10	1	1	**91**	55	4	3	0	0	0
*Rumex acetosella**	53	61	72	11	**84**	100	78	79	80	9	15
*Trifolium arvense**	19	37	30	3	**71**	83	30	43	25	1	0

Indicator species

Indicator species are almost all exotic, but include the epiphytic lichens *Usnea inermis, Teleoschistes velifer,* and *Ramalina glaucescens,* which are often found on *Rosa rubiginosa* stems. The threatened cushion plant *Muehlenbeckia ephedroides* is also a species indicator in this community.

Table 16. Community 5 indicator species (indicator value, P< 0.01).

	COMMUNITY TYPE										
	1	2	3	4	**5**	6	7	8	9	10	11
*Bromus tectorum**	0	0	0	0	**25**	17	0	0	0	0	0
Chondropsis viridis	0	0	0	0	**20**	0	0	0	0	0	0
*Cytisus scoparius**	0	0	0	0	**15**	0	0	0	0	0	0
*Hypericum perforatum**	4	3	3	0	**17**	1	1	0	10	0	0
*Leucanthemum vulgare**	3	0	0	0	**24**	2	0	0	0	0	0
Muehlenbeckia ephedroides	0	0	0	0	**20**	0	0	0	0	0	0
*Plantago lanceolata**	14	2	0	0	**15**	8	0	0	0	0	0
Ramalina glaucescens	0	0	0	0	**16**	0	0	0	0	0	0
*Rosa rubiginosa**	7	1	0	0	**41**	15	0	0	0	0	0
Teleoschistes velifer	1	2	0	0	**24**	0	0	0	1	0	0
Usnea inermis	0	2	0	0	**15**	0	1	0	0	0	0
Xanthoparmelia glareosa	0	1	0	0	**18**	0	0	0	0	0	0
Xanthoparmelia spp.	0	1	0	0	**22**	0	0	0	0	0	0

Plant associations

Four plant associations were recognised in this community.

a) This association does not differ in composition from the type description.

b) This association is described from 24 plots. 16 species occur frequently (>70% of plots) and 11 of these are exotic (69%). Community composition and structure is similar to that described for the vegetation type, with several differences. Although present in other associations, the grass *Agrostis capillaris** occurs with higher cover scores and frequencies in this association compared with others. The cushion plant *Raoulia australis*, the lichens *Neofuscelia adpicta* and *Cladonia* spp., the herbaceous plant *Sedum acre* and the moss *Racomitrium crispulum* all occur with high frequencies both in this association and association 5d. While *Hieracium pilosella* is frequently present (87% of plots), it is not an important vegetative cover component (0.74% cover) and similarly, *Rosa rubiginosa* remains an important component of vegetative cover, but mostly as a low stature plant (<30 cm). This association and association 5d have higher levels of lichen as a ground-cover component compared with the community type and association b), and it occurs most frequently in the Tekapo River.

Table 17. Association 5b indicator species (indicator value, P< 0.01).

	● (A)	■ (B)	▲ (C)	◘ (D)
*Agrostis capillaris**	13	31	20	14
Coprosma atropurpurea	0	19	0	1
Neofuscelia adpicta	9	39	0	26
*Plantago lanceolata**	1	37	30	5
Rytidosperma setifolia	1	17	0	0
*Sedum acre**	6	32	11	22

c) This association is described from 17 plots. 13 species occur frequently (>70% of plots) and 12 of these are exotic (92%). Compared with other associations in this community, *Agrostis capillaris*, Hieracium pilosella** and *Hypericum perforatum** contribute lower levels of cover, and *Plantago lanceolata** and *Echium vulgare** are more important. This association is more frequently associated with earlier floodplain development stages, and, compared with association 5d, significantly lower minimum-annual temperatures, water-balance ratios and average solar radiation, and higher mean-annual temperatures (P<.05). It occurs most frequently in the lower Tekapo River.

Table 18. Association 5c indicator species (indicator value, P< 0.01).

	● (A)	■ (B)	▲ (C)	◘ (D)
*Carex ovalis**	0	0	24	0
*Cirsium arvense **	2	0	30	0
*Echium vulgare**	24	13	34	3
Epilobium melanocaulon	15	3	27	0
Epilobium microphyllum	5	2	33	0
*Escholzia californica**	0	1	73	0
*Holcus lanatus**	9	4	27	0
*Juncus articulatus**	0	0	21	0
*Leucanthemum vulgare**	2	17	50	2
*Myosotis laxa**	1	0	24	0
*Pinus contorta**	0	0	31	0
*Populus nigra**	0	0	18	0
*Rorippa palustris**	0	0	24	0
*Rumex crispus**	0	0	34	0
*Salix fragilis**	7	2	48	0
*Sanguisorba minor**	0	5	28	0

d) This association is described from 20 plots. The total number of species recorded is similar to other associations (110 species), but the association has a high average species diversity (34 species per plot). 21 species are recorded frequently (>70% occurrence) and compared with other associations, a high proportion of these are native (13 species or 62%). Indicator species include the shrub *Discaria toumatou*; the terrestrial lichens *Candelariella aurella, Cladia aggregata, Cladonia* spp., *Rhizocarpon geographicum, Teleoschistes velifer*, and *Xanthoparmelia glareosa*; the epiphytic lichens *Ramalina glaucescens* and *Usnea inermis*; and the moss *Racomitrium pruinosum*. The lichen *Neofuscelia adpicta*, the moss *Racomitrium pruinosum*, the cushion plant *Muehlenbeckia axillaris* and the herbaceous plant *Hieracium pilosella* all commonly occur with high levels of cover in the ground tier (>10% cover), and *Discaria toumatou* co-dominates an open-shrub canopy with *Rosa rubiginosa* in the 30-cm to 200-cm height tier. This association has higher levels of moss as a proportion of total ground cover. When compared with association 5c, which has a predominance of exotic species, it has higher levels of lichen and lower levels of bare rock as ground cover, occurs at lower altitudes, on sites with lower minimum annual temperatures, lower mean-annual temperatures, higher water-balance ratios and higher mean-annual solar radiation (P<.05).

Table 19. Association 5d indicator species (indicator value, P< 0.01).

	● A	■ B	▲ C	◘ (D)
Candelariella aurella	1	3	0	50
Carex breviculmis	4	3	3	24
Cladia aggregata	2	7	0	47
Cladonia spp.	2	28	0	45
Colobanthus strictus	0	0	0	18
Convolvulus verecundus	0	0	0	18
Discaria toumatou	6	0	0	63
Elymus solandri	2	1	1	24
Festuca novae-zelandiae	1	0	0	20
Geranium sessiliflorum	0	6	0	48
Leucopogon fraseri	0	0	0	33
Luzula rufa var. *albicomans*	0	1	0	20
Melicytus alpinus	1	0	0	27
Poa colensoi	0	1	0	21
Polytrichum juniperinum	4	1	0	29
Racomitrium pruinosum	4	18	0	44
Ramalina glaucescens	4	0	0	42
Raoulia australis	11	27	3	32
Rhizocarpon geographicum	1	4	0	57
Scleranthus uniflorus	0	0	0	39
Stellaria gracilenta	1	1	0	42
Teleoschistes velifer	18	2	0	48
Usnea inermis	8	2	0	46
Wahlenbergia albomarginata	1	0	0	22
Xanthoparmelia glareosa	4	5	0	32

Community 6/ (*Lupinus polyphyllus**) – (*Agrostis stolonifera**) Herb – Stonefield

This community is described from 29 plots representing 4 percent of surveyed sites. Site descriptions contain an average of 30 species and exotic species are a dominant component of these. Of the 108 species recorded in this community, 64 (59%) are exotic and these dominate total plant cover (92%). The species composition of this community is relatively homogenous compared with other community types, with 22 species (20%) occurring in more than 50% of sample descriptions, β diversity (2.6) is low compared with other community types. Vegetative cover is open (26% of total ground cover) and predominantly comprised of herbaceous plants and grasses recorded in the 0-cm to 10-cm, and 10-cm to 30-cm height classes. Bare rock dominates total ground cover (72%).

This community has a lower level of buffering against anthropogenic influence than any other. It has significantly higher levels of vascular cover and lower levels of gravel and pebble-size fractions as a proportion of total bare rock than the stonefield communities (3, 4, 11). It occurs at lower average altitudes, on sites with lower winter-solar radiation and higher water deficits than any other community. Minimum-annual temperatures and water-balance ratios are lower than all communities other than 5 (no significant difference), mean-annual-solar radiation is lower than all communities excepting community 10. The community is recorded only from the lower Ahuriri River.

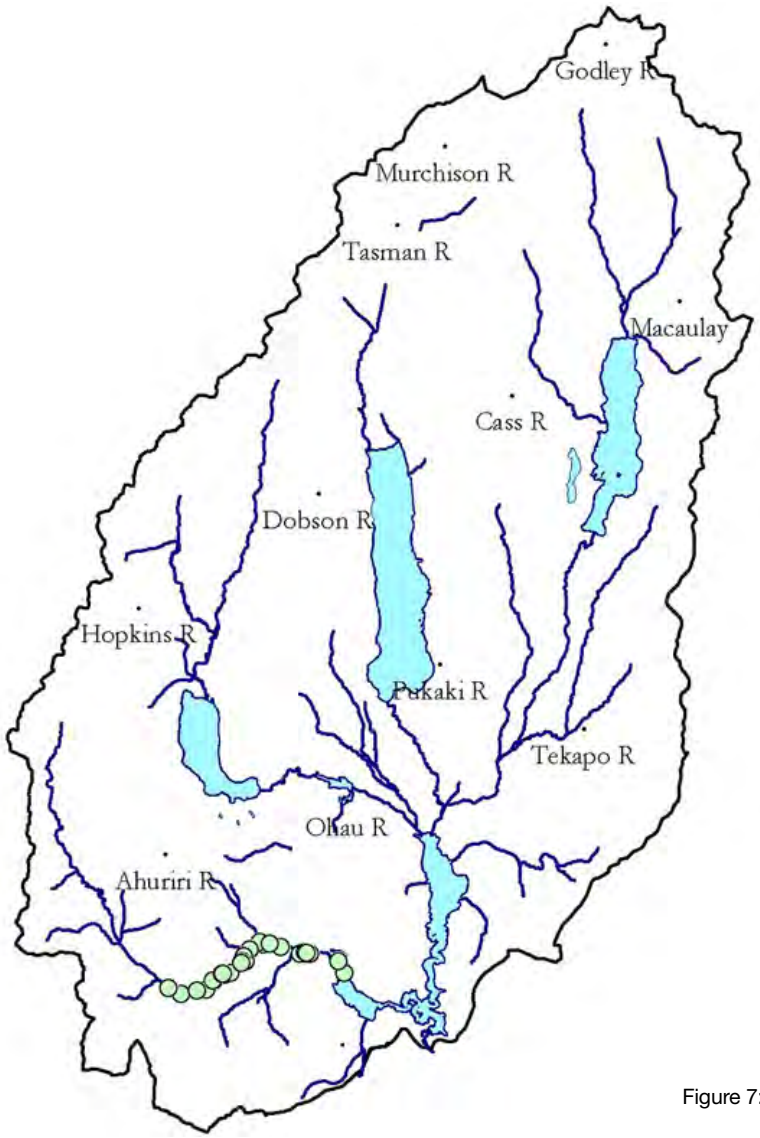

Figure 7: Location of Community 6

Indicator species

Species most closely associated with this community comprise a range of exotic herbaceous plants and grasses: The grass *Agrostis stolonifera** is strongly associated with this community, consistently contributing to total vegetative cover.

Table 20. Community 6 indicator species (indicator value, P< 0.01).

	COMMUNITY TYPE										
	1	2	3	4	5	**6**	7	8	9	10	11
*Achillea millefolium**	8	0	0	0	3	**32**	0	0	0	0	0
*Agrostis stolonifera**	0	0	0	0	1	**80**	0	0	0	0	0
*Bromus diandrus**	0	0	0	0	1	**34**	0	0	0	0	0
*Crepis capillaris**	8	6	2	0	5	**31**	0	0	0	0	0
*Echium vulgare**	0	0	0	0	25	**44**	0	0	0	0	0
*Logfia minima**	0	0	0	0	1	**27**	0	0	0	0	0
*Lupinus polyphyllus**	1	0	0	0	1	**59**	0	1	0	0	0
*Mimulus guttatus**	2	0	0	0	0	**35**	0	0	0	0	0
*Rumex crispus**	13	0	1	0	1	**23**	0	0	0	0	0
*Sagina apetala**	9	2	10	0	0	**19**	3	0	0	0	0
*Spergularia media**	0	0	0	0	0	**49**	0	0	0	0	0
*Trifolium arvense**	1	4	3	0	15	**20**	3	5	2	0	0

Common species

Fourteen species are frequently recorded in this community (>70% of samples) and thirteen of these are exotic (93%). Three species: *Agrostis stolonifera*, Lupinus polyphyllus**, and *Festuca rubra** frequently dominate foliar cover. The community is predominantly low growing (0–30 cm) although highest levels of lupin cover are recorded in the 30-cm to 200-cm height tier

Table 21. Species commonly occurring (frequency >70% of samples) in Community 6.

	COMMUNITY TYPE										
	1	2	3	4	5	**6**	7	8	9	10	11
*Agrostis stolonifera**	7	0	0	2	12	**97**	0	0	0	0	0
*Anthoxanthum odoratum**	88	92	70	18	81	**76**	72	70	59	13	12
*Crepis capillaris**	45	37	20	2	35	**86**	11	0	5	1	0
*Echium vulgare**	5	6	5	0	68	**90**	4	1	1	0	0
*Festuca rubra**	76	67	34	9	79	**72**	54	56	25	4	6
*Hieracium pilosella**	50	90	61	11	91	**90**	93	75	91	50	6
*Holcus lanatus**	95	78	80	13	26	**83**	89	67	56	6	21
Lupinus polyphyllus	9	0	2	4	9	**83**	0	11	0	0	0
Muehlenbeckia axillaris	34	82	83	47	93	**97**	96	76	84	48	67
*Rumex acetosella**	53	61	72	11	84	**100**	78	79	80	9	15
*Sedum acre**	3	1	10	6	60	**86**	4	81	5	0	3
*Trifolium arvense**	19	37	30	3	71	**83**	30	43	25	1	0
*Trifolium repens**	91	86	90	55	24	**90**	100	94	75	26	12
Verbascum thapsus	15	6	17	1	75	**76**	33	1	3	1	6

Plant associations

No additional plant associations are described from this community.

Community 7/ [*Raoulia tenuicaulis*] – [*Placopsis* spp.] – [*Trifolium repens*] Cushionfield – Stonefield

This community is described from 46 plots representing 6 percent of surveyed sites. Site descriptions contain an average of 34 species. Of the 128 species recorded in this community, 86 (67%) are native and these dominate total plant cover (74%). The species composition of this community is relatively homogenous compared with other community types, with 29 species (23%) occurring in more than 50% of sample descriptions, and β diversity (2.8) is low compared with most other community types. Vegetative cover is open (28% of total ground cover) and predominantly comprised of low-growing cushion plants, lichens and herbaceous plants recorded in the 0-cm to 10-cm height class. Bare rock comprises 58% of total ground cover.

Compared with other mixed vascular–stonefield communities (5, 6), this community occurs at significantly higher altitudes, at sites with lower mean-annual temperatures, lower minimum-annual temperatures, lower water deficits, higher water-balance ratios higher mean-annual-solar radiation and higher winter-solar radiation. It has significantly higher levels of vascular plant and lichen cover and lower levels of bare rock as a proportion of total ground cover than the stonefield communities (3, 4, 11). The community is recorded predominantly in the Hopkins, Cass and Godley rivers.

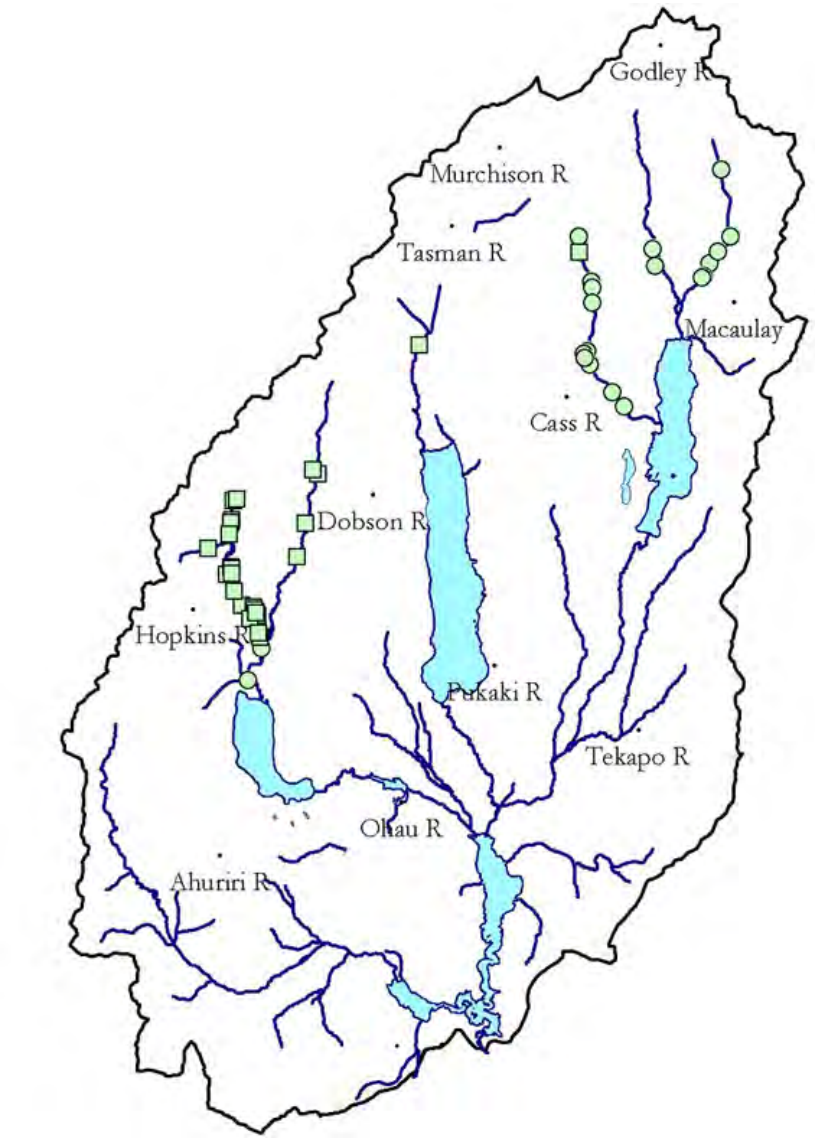

Figure 8: Location of Community 7 and plant associations.

● = association 7a; ■ = association 7b

Indicator species

There are no indicator species most closely associated with this community, although several species co-occur with one other community. The cushion plant *Raoulia tenuicaulis* and herbaceous plant *Epilobium microphyllum* occur with highest frequencies in this community and community 3, and the grasses *Rytidosperma buchananii* and *Lachnagrostis lyallii* occur with highest frequencies in this community and community 10.

Common species

Eighteen species are frequently recorded in this community (>70% of samples) and twelve of these are native (67%). They include a mixture of native and exotic grasses, native cushion plants, mosses and lichens and predominantly exotic herbaceous plants. The cushion plants (*Muehlenbeckia axillaris, Raoulia tenuicaulis, R. hookeri,* and *R. haastii*) frequently dominate foliar cover in association with cow-pat lichens and *Trifolium repens**. *Hypericum perforatum** and *Trifolium arvense** may co-dominate cover where they occur.

Table 22. Species commonly occurring (frequency >70% of samples) in Community 7.

	COMMUNITY TYPE										
	1	2	3	4	5	6	**7**	8	9	10	11
*Agrostis capillaris**	72	96	85	25	73	17	**91**	89	69	11	21
*Anthoxanthum odoratum**	88	92	70	18	81	76	**72**	70	59	13	12
Colobanthus strictus	5	8	15	2	5	0	**72**	89	52	37	6
Epilobium melanocaulon	14	6	87	49	34	45	**72**	60	45	93	94
Epilobium microphyllum	12	8	87	38	20	34	**100**	67	30	48	61
*Hieracium pilosella**	50	90	61	11	91	90	**93**	75	91	50	6
*Holcus lanatus**	95	78	80	13	26	83	**89**	67	56	6	21
Lachnagrostis lyallii	10	0	40	4	4	0	**70**	3	34	65	36
Muehlenbeckia axillaris	34	82	83	47	93	97	**96**	76	84	48	67
Placopsis spp.	0	8	21	3	4	0	**72**	79	67	76	45
Poa lindsayi	5	1	87	30	24	28	**96**	89	58	85	91
Racomitrium crispulum	26	51	59	28	71	17	**100**	95	100	93	97
Raoulia haastii	0	10	41	4	7	10	**80**	95	86	76	88
Raoulia hookeri	19	18	89	51	4	17	**87**	75	50	83	85
Raoulia tenuicaulis	22	16	77	18	5	38	**89**	52	19	13	58
Rumex acetosella	53	61	72	11	84	100	**78**	79	80	9	15
Stellaria gracilenta	7	1	34	3	16	0	**78**	90	55	48	42
*Trifolium repens**	91	86	90	55	24	90	**100**	94	75	26	12

Plant associations

Two additional plant associations are described from this community.

a) This association is described from 20 plots. Nineteen plants occur in over 70% of descriptions. Indicator species include the prostrate shrubs *Helichrysum depressum,* and *Pimelia prostrata*; the herbaceous plants *Arenaria serpyllifolia*; Epilobium rostratum, Hypericum perforatum*, Linum catharticum*, Sagina apetala*, Trifolium arvense**, and *Verbascum thapsus** and the grasses *Poa cita*, and *Poa pratensis**. Cushion plants dominate foliar cover; however, this association has higher levels of *Epilobium melanocaulon, Muehlenbeckia axillaris,* and *Trifolium arvense** co-dominating canopy cover compared with 7b. This association occurs at significantly higher altitudes and has higher levels of bare rock as a proportion of total ground cover than 7b. It occurs on sites with higher mean-annual temperatures and winter-solar radiation, lower minimum-annual temperatures and higher water deficits than 7b, and is recorded most frequently in the Cass and Godley rivers.

Table 23. Association 7a indicator species (indicator value, P< 0.01).

	● (A)	■ (B)
Arenaria serpyllifolia	29	1
Epilobium melanocaulon	55	23
Epilobium rostratum	61	0
Helichrysum depressum	45	0
*Hypericum perforatum**	45	0
*Linum catharticum**	48	3
Pimelia prostrata	32	0
Poa cita	61	14
*Poa pratensis**	36	5
*Sagina apetala**	36	2
*Trifolium arvense**	70	0
*Verbascum thapsus**	66	0

b) This association is described from 26 plots. Seventeen plants occur in over 70% of descriptions. Total number of species recorded, mean number of species per plot and proportion of frequently occurring species which are exotic do not differ significantly from the type description or association 7a. Indicator species include: the prostrate shrub *Coprosma acerosa*; the cushion plants *Raoulia glabra,* and *Colobanthus strictus*; the moss *Racomitrium pruinosum*; the grass *Festuca rubra**; the lichens *Neofuscelia adpicta, Placopsis* spp. and *Placopsis perrugosa*; and the herbaceous plants *Hieracium pratense* Hypochoeris radicata*, Leucopogon fraseri, Luzula celata, Senecio jacobaea**, and *Stellaria gracilenta*. Cushion plants dominate canopy cover however this association frequently has cow-pat lichen (*Placopsis* spp.), *Placopsis perrugosa, Racomitrium crispulum* and *Trifolium repens** present as co-dominants compared to association 7a. This association has a significantly higher level of lichen as a proportion of total ground cover and occurs on sites with higher mean-annual temperatures and higher water-balance ratios. It occurs most frequently in the Hopkins and Dobson rivers.

Table 24. Association 7b indicator species (indicator value, P< 0.01).

	● (A)	■(B)
Colobanthus strictus	22	51
Coprosma acerosa	0	31
*Festuca rubra**	12	46
*Hieracium praeltum**	16	52
Hypochoeris radicata	4	54
Leucopogon fraseri	1	26
Luzula celata	0	54
Neofuscelia adpicta	6	58
Placopsis perrugosa	2	76
Placopsis spp.	12	68
Racomitrium pruinosum	7	44
Raoulia glabra	0	31
*Senecio jacobaea**	0	27
Stellaria gracilenta	24	56

Community 8/ (*Raoulia haastii*) – [*Raoulia australis*] Cushionfield

This community is described from 63 plots representing 8 percent of surveyed sites. Site descriptions contain an average of 32 species and native plants are an important component of these. Of the 113 species recorded in this community, 72 (64%) are native and these dominate total plant cover (90%). Species composition is the most consistent of any community β=2.5), with 34 species (30%) occurring in more than 50% of sample descriptions. Vegetative cover is open, 27% of total ground cover is vegetation and this is comprised of low growing cushion plants, lichens and mosses, with the majority of plants recorded in the 0-cm to 10-cm height class.

This community occurs at significantly (P<.05) lower altitudes than most other community types (2,3,4,7,9,10,11). It has significantly higher levels of vascular plant, moss and lichen cover and lower levels of bare rock as a proportion of total ground cover than stonefield communities (3,4,11). Compared with the other cushion community (7 cushion-stonefield) it occurs on sites with higher October vapour pressure deficits, higher water-balance ratio and higher mean-annual temperatures. The community occurs most frequently in the Tasman River.

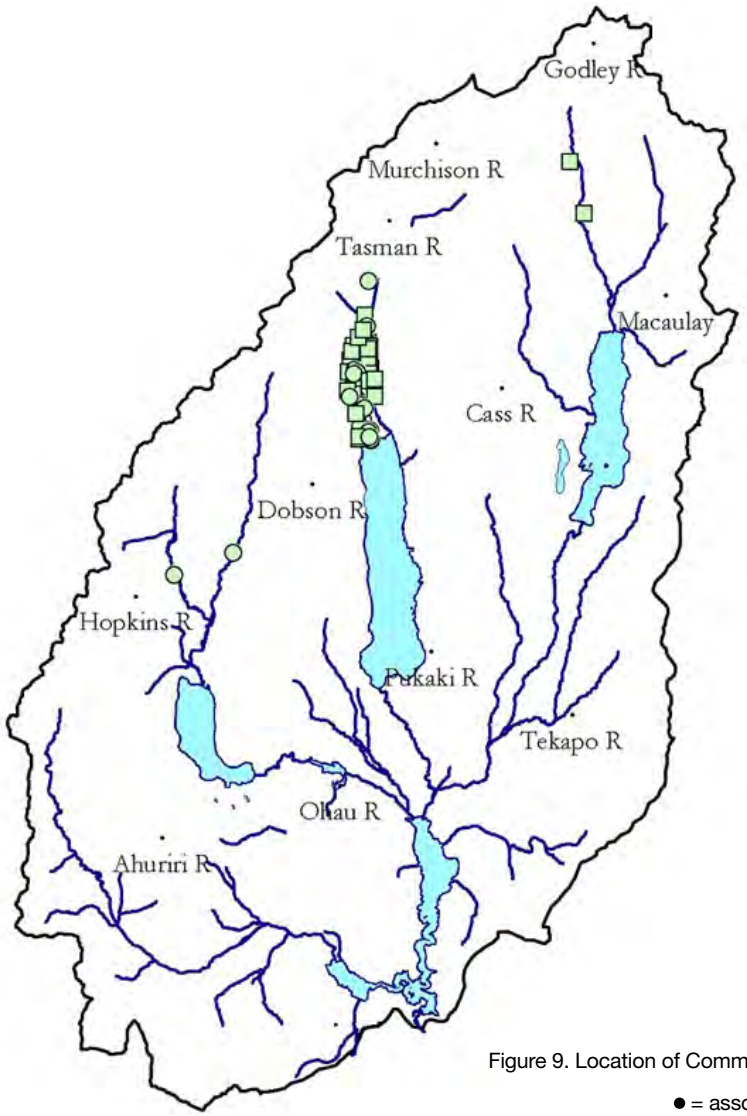

Figure 9. Location of Community 8 and plant associations

● = association 8a; ■ = association 8b

Indicator species

Species most closely associated with this community are: the shrub *Carmichaelia australis*; the cushion plant *Raoulia australis*; the grass *Poa maniatoto*; and the herbaceous plants *Colobanthus strictus* and *Luzula celata*.

Table 25. Community 8 indicator species (indicator value, P< 0.01).

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	**8**	9	10	11
Carmichaelia australis	0	0	0	0	0	0	0	**25**	7	3	3
Colobanthus strictus	0	0	1	0	0	0	18	**27**	9	5	0
Luzula celata	0	0	1	0	0	0	5	**37**	3	0	3
Poa maniatoto	0	0	0	0	0	0	0	**46**	6	0	0
Raoulia australis	0	2	1	0	10	1	10	**23**	9	3	1

Common species

Eighteen species are recorded frequently (>70% of samples) in this community. Cushion plants mosses and lichens dominate canopy cover, especially *Raoulia haastii*, the moss *Racomitrium crispulum*; and cow-pat lichens *Placopsis* spp. Species which occur less frequently (>50% of samples) but can co-dominate cover where they occur are: the shrub *Carmichaelia australis*; the cushion plant *Raoulia tenuicaulis*; and the lichens *Placopsis perrugosa* and *Neofuscelia adpicta*; A high proportion of the frequently occurring species in this community (67%), and species dominating cover (91%) are native.

Table 26. Species commonly occurring (frequency >70% of samples) in Community 8.

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	**8**	9	10	11
*Agrostis capillaris**	72	96	85	25	73	17	91	**89**	69	11	21
*Anthoxanthum odoratum**	88	92	70	18	81	76	72	**70**	59	13	12
Colobanthus strictus	5	8	15	2	5	0	72	**89**	52	37	6
*Hieracium pilosella**	50	90	61	11	91	90	93	**75**	91	50	6
*Hieracium praealtum**	74	57	43	4	35	14	65	**73**	69	52	9
Luzula celata	0	0	11	3	0	0	30	**79**	22	6	21
Luzula rufa var. *albicomans*	0	14	19	2	7	0	65	**81**	72	87	30
Muehlenbeckia axillaris	34	82	83	47	93	97	96	**76**	84	48	67
Neofuscelia adpicta	3	16	7	2	55	3	54	**70**	94	72	15
Placopsis spp.	0	8	21	3	4	0	72	**79**	67	76	45
Poa lindsayi	5	1	87	30	24	28	96	**89**	58	85	91
Poa maniatoto	0	4	5	1	5	0	4	**76**	27	1	3
Racomitrium crispulum	26	51	59	28	71	17	100	**95**	100	93	97
Raoulia australis	5	29	18	5	63	17	65	**97**	61	33	24
Raoulia haastii	0	10	41	4	7	10	80	**95**	86	76	88
Raoulia hookeri	19	18	89	51	4	17	87	**75**	50	83	85
*Rumex acetosella**	53	61	72	11	84	100	78	**79**	80	9	15
*Sedum acre**	3	1	10	6	60	86	4	**81**	5	0	3
Stellaria gracilenta	7	1	34	3	16	0	78	**90**	55	48	42
*Trifolium repens**	91	86	90	55	24	90	100	**94**	75	26	12

Plant associations

Two plant associations were recognised in this community:

a) (8a) This association is described from 31 plots. 16 species occur frequently (>70% of plots) and 4 of these are exotic (25%). A total of 82 species were recorded with an average of 28 species per plot. Species composition and structure is similar to that described for the vegetation type with several differences. This association is more open with significantly higher levels of bare rock as ground cover and better buffering from anthropogenic activity. Cushion plants dominate foliar cover, and although present, lichens and mosses are not important canopy components. Indicator species include: the shrub *Carmichaelia australis*; and the cushion plant *Myosotis uniflora*. This association is more frequently associated with earlier floodplain development stages and occurs on sites with higher mean-annual temperatures, mean-annual-solar radiation and winter-solar radiation than community 8b.

Table 27. Association 8a indicator species (indicator value, P< 0.01).

	● (A)	■ (B)
Carmichaelia australis	55	15
Myosotis uniflora	42	15
Neofuscelia spp.	56	34

b) (8b) This association is described from 32 plots. Compared to association 8a it contains a higher total number of species (100), higher average number of species per plot (36) and a larger number of frequently occurring species (27 species in over 70% of plots). It has significantly higher levels of vascular vegetation, mosses and lichens as a proportion of total ground cover and the moss *Racomitrium crispulum* and lichens *Placopsis perrugosa* and *Neofuscelia adpicta* are important components of total canopy cover. Indicator species are the herbaceous plants *Epilobium rostratum, Hieracium pilosella*, Leucopogon fraseri, Linum catharticum*, Trifolium dubium*, Rumex acetosella**, and *Wahlenbergia albomarginata*; the grasses *Anthoxanthum odoratum** and *Trisetum tenellum*; the prostrate shrub *Pimelia prostrata*, the lichens *Neofuscelia adpicta*, and *Placopsis perrugosa*; and the mosses *Racomitrium pruinosum* and *Polytrichum juniperinum*. This association is more frequently associated with later floodplain development stages and sites with significantly higher mean-annual temperatures and water-balance ratios than association 8a.

Table 28. Association 8b indicator species (indicator value, P< 0.01).

	● (A)	■ (B)
*Anthoxanthum odoratum**	17	59
Epilobium rostratum	5	36
*Hieracium pilosella**	18	63
Leucopogon fraseri	10	50
*Linum catharticum**	1	63
Neofuscelia adpicta	17	59
Pimelia prostrata	9	58
Placopsis perrugosa	12	64
Polytrichum juniperinum	15	45
Racomitrium pruinosum	19	48
*Rumex acetosella**	24	59
*Trifolium arvense**	6	46
*Trifolium dubium**	3	40
Trisetum tenellum	1	57
Wahlenbergia albomarginata	2	36

Community 9/ *Racomitrium pruinosum* – [*Racomitrium crispulum*] – [*Neofuscelia adpicta*] Mossfield

This community is described from 64 plots representing 9 percent of surveyed sites. Site descriptions contain an average of 36 species and native plants are an important component of these. Of the 194 species recorded in this community, 153 (79%) are native and these dominate total plant cover (80%). 30 species occur in more than 50% of sample descriptions and 22 of these are native (73%). Levels of vegetative ground cover are high (73%), dominated by low growing vascular plants (34%) and mosses (27%). Canopy cover occurs predominantly in the 0-cm to10-cm height class.

This community occurs on older floodplain development stages at significantly (P<.05) higher altitudes than other community types and at sites with high levels of buffering from anthropogenic influence. It has significantly higher levels of vascular plant cover than stonefield communities (3, 4, 11), and higher levels of moss (all communities except 10) and lichen (communities 1, 2, 3, 4, 6, 11) as a proportion of total ground cover. Compared to the other moss-stonefield community (10) which has comparable levels of moss cover, this community occurs at sites with significantly higher October vapour pressure deficits and mean-annual-solar radiation, and lower water-balance ratios and mean-annual temperatures (P<.05). The community occurs most frequently in the Tasman, Murchison and Godley rivers.

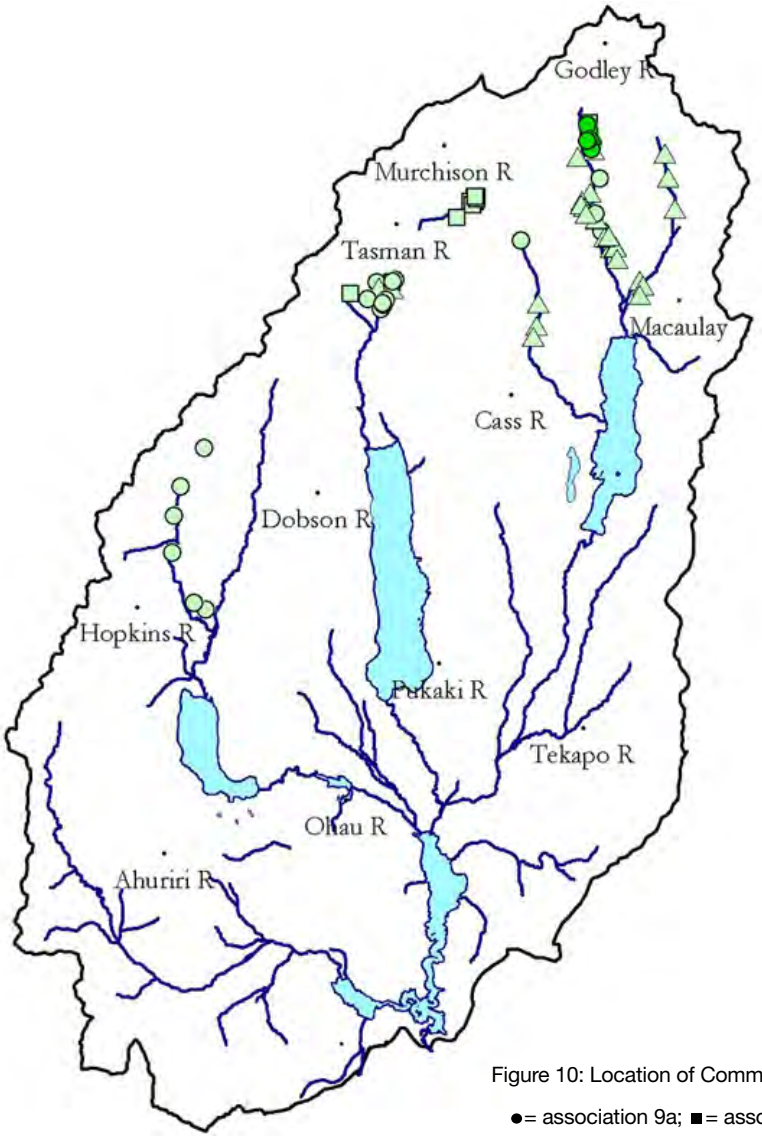

Figure 10: Location of Community 9 and plant associations

●= association 9a; ■= association 9b; ▲= association 9c

Indicator species

Species most closely associated with this community are a variety of native woody and herbaceous plants, grasses and lichens. They are characteristic of open, montane alluvial grasslands with a strong indigenous character.

Table 29. Community 9 indicator species (indicator value, P< 0.01).

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	8	**9**	10	11
Gaultheria crassa	0	0	0	0	0	0	0	0	**14**	1	0
Neofuscelia adpicta	0	1	0	0	8	0	8	12	**22**	13	1
Parahebe decora	0	0	0	0	0	0	0	0	**14**	5	0
Pimelia prostrata	0	3	0	0	0	0	1	13	**26**	15	0
Poa colensoi	0	9	0	0	0	0	0	0	**20**	12	0
Rytidosperma pumila	0	0	0	0	0	0	3	0	**13**	0	0
Wahlenbergia albomarginata	0	8	1	0	0	0	7	3	**22**	6	0

Common species

Thirteen species are recorded frequently (>70% of samples) in this community. Mosses dominate ground cover, especially *Racomitrium pruinosum* in association with the rock lichens *Neofuscelia adpicta*, and *Placopsis perrugosa*. Other cushion plants, herbs and grasses which consistently contribute to canopy cover are *Hieracium pilosella*, Leucopogon fraseri, Muehlenbeckia axillaris, Raoulia haastii* and *Trifolium repens**. Species which occur less frequently (>50% of samples) but co-dominate cover where they occur are: the grasses *Anthoxanthum odoratum*, Poa colensoi*, and *Festuca novae zelandiae*; the cushion plant *Raoulia australis*; the herbaceous plants *Hieracium praeltum*, and *Hypericum perforatum* and cow-pat lichens *Placopsis* spp.

Table 30. Species commonly occurring (frequency >70% of samples) in Community 9.

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	8	**9**	10	11
*Hieracium pilosella**	50	90	61	11	91	90	93	75	**91**	50	6
Leucopogon fraseri	1	61	5	4	7	0	20	52	**70**	24	3
Luzula rufa var. *albicomans*	0	14	19	2	7	0	65	81	**72**	87	30
Muehlenbeckia axillaris	34	82	83	47	93	97	96	76	**84**	48	67
Neofuscelia adpicta	3	16	7	2	55	3	54	70	**94**	72	15
Pimelia prostrata	0	29	6	0	5	0	17	57	**81**	63	0
Placopsis perrugosa	5	14	20	0	22	0	57	65	**86**	80	24
Racomitrium crispulum	26	51	59	28	71	17	100	95	**100**	93	97
Racomitrium pruinosum	0	31	31	14	40	3	46	63	**92**	93	73
Raoulia haastii	0	10	41	4	7	10	80	95	**86**	76	88
*Rumex acetosella**	53	61	72	11	84	100	78	79	**80**	9	15
*Trifolium repens**	91	86	90	55	24	90	100	94	**75**	26	12
Wahlenbergia albomarginata	9	47	14	0	9	0	43	27	**78**	41	3

Plant associations

Three plant associations were recognised in this community:

a) (9a) This association is described from 18 plots. 21 species occur frequently (>70% of plots) and a high frequency of these are exotic compared to associations b and c (9 exotic species, 43%). A total of 132 species were recorded from this community with an average of 38 species per plot. Community composition and structure is similar to that described for the vegetation type with several differences. This association has significantly higher levels of vascular plant cover than association b) and higher levels of moss as a proportion of total ground cover than association c). Mosses dominate canopy cover but compared to the community type, the grass *Anthoxanthum odoratum** and the herb *Trifolium repens** contribute higher levels of canopy cover and the lichen *Neofuscelia adpicta* is less important. Indicator species contain a number of exotic plants and include: the grasses *Anthoxanthum odoratum*, Holcus lanatus**, and *Festuca rubra**; the herbaceous plants *Leptinella pusilla, Linum catharticum**, and *Trifolium dubium**; the lichen *Xanthoparmelia* spp; and the algae *Trentepohlia jolithus*. This association occurs at significantly lower altitudes than the rest of this community type.

Table 31. Association 9a indicator species (indicator value, P< 0.01).

	● (A)	■ (B)	▲ (C)
*Anthoxanthum odoratum**	50	16	4
*Festuca rubra**	29	5	0
*Holcus lanatus**	37	9	14
Leptinella pusilla	33	0	0
*Linum catharticum**	37	10	2
*Trifolium dubium**	30	1	0
Xanthoparmelia spp.	17	0	0

b) (9b) This association is described from 11 plots. 12 species occur frequently (>70% of plots) and 1 of these is exotic (8%). A total of 99 species were recorded from this community with an average of 32 species per plot. This association has fewer herbaceous plants contributing to total canopy cover and higher levels of lichen cover than association a. Canopy cover is low (predominantly <10cm) with a sparse cover of the grass *Poa colensoi* in the 10–30cm height range. Indicator species are a variety of indigenous shrubs, herbaceous plants, grasses, ferns mosses and lichens. Compared to other associations within this community type, this association occurs at sites with significantly lower October vapour deficits, and mean-annual temperatures and higher levels of mean-annual-solar radiation ($P<.05$).

Table 32. Association 9b indicator species (indicator value, $P< 0.01$).

	●(A)	■(B)	▲(C)
Agrostis petriei	0	18	0
Blechnum penna-marina	0	27	0
Brachyscome haastii	0	18	0
Candelariella aurella	3	28	0
Ceratodon purpureus	0	28	3
Coriaria angustifolia	0	35	0
Dracophyllum uniflorum	0	27	0
Gaultheria crassa	1	37	0
Gingidia decipiens	0	56	0
Hebe buchananii	0	36	0
Ozothamnus leptophylla	0	36	0
Parahebe decora	2	50	0
Polystichum vestitum	0	18	0
Raoulia glabra	4	31	0

c) (9c) This association is described from 28 plots. 17 species occur frequently (>70% of plots) and 5 of these are exotic (29%). A total of 108 species were recorded from this association with an average of 35 species per plot. This association has a high contribution to canopy cover from cushion plants compared to others, especially *Raoulia australis* and *R. haastii*. Lichens, cushion plants and mosses dominate a low canopy (<10cm). This association has significantly lower levels of moss and higher levels of bare rock contributing to total ground cover, and occurs at sites with higher mean-annual-solar radiation, higher winter-solar radiation and lower water-balance ratios than other associations of this community ($P<.05$).

Table 33. Association 9c indicator species (indicator value, $P< 0.01$).

	●(A)	■(B)	▲(C)
Epilobium rostratum	1	0	45
Placopsis spp.	5	5	41
Rytidosperma pumilum	0	0	39
*Trifolium arvense**	2	0	41

Community 10/ *Racomitrium pruinosum* – [*Racomitrium crispulum*] – [*Raoulia hookeri*] Moss – Stonefield

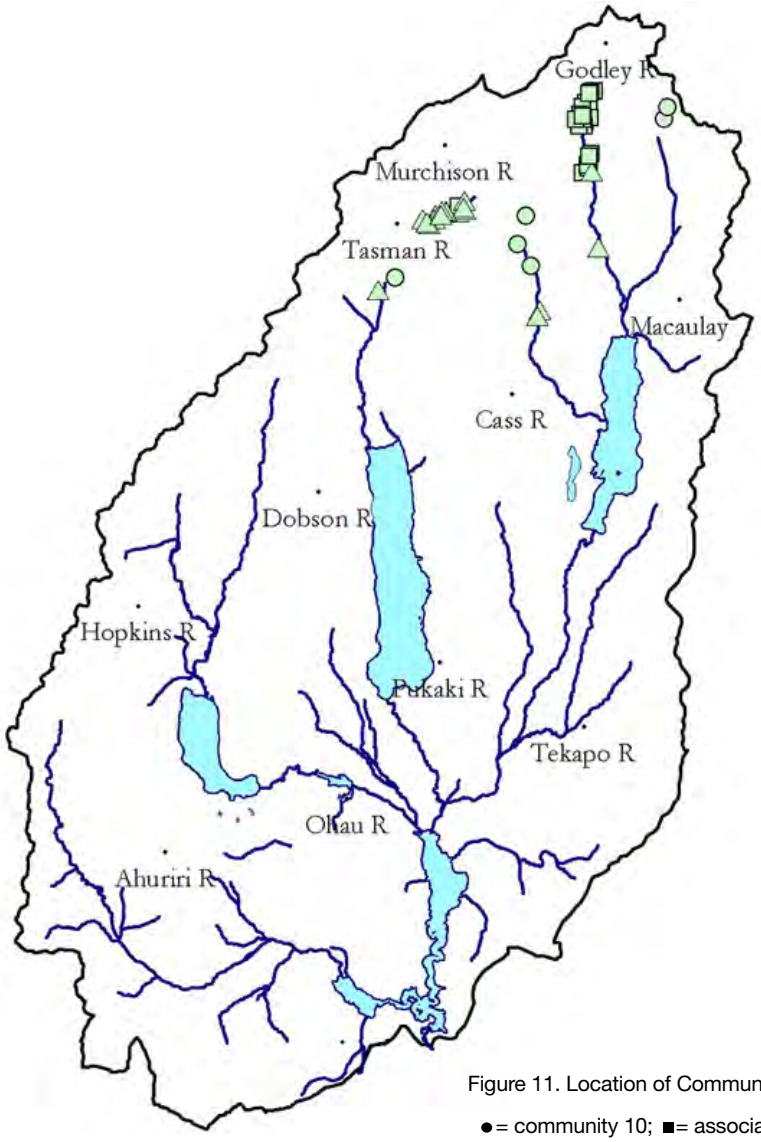

Figure 11. Location of Community 10 and plant associations

●= community 10; ■= association 10a; ▲= association 10b

This community is described from 46 plots representing 6 percent of surveyed sites. Site descriptions contain an average of 26 species and native plants are an important component of these. Of the 128 species recorded in this community, 103 (80%) are native and these dominate total plant cover (93%). 18 species occur in more than 50% of sample descriptions and 17 of these are native (94%). Levels of vegetative ground cover are low (39%), dominated by mosses (21%) and low growing vascular plants (11%). Canopy cover occurs predominantly in the 0-cm to10-cm height class.

This community occurs at significantly ($P<.05$) higher altitudes than other community types, has a higher level of buffering from anthropogenic influence and higher levels of moss (other than community 9) as a proportion of total ground cover. It occurs at sites with significantly higher water balance ratios, lower October vapour pressure deficits and lower mean-annual temperatures than all other communities. Mean-annual-solar radiation is lower than all communities other than 5 and 6. The community occurs most frequently in the Cass, Murchison and Godley rivers.

Indicator species

Species most closely associated with this community include several native grasses, herbaceous plants and the woody sub-shrub *Helichrysum depressum*.

Table 34. Community 10 indicator species (indicator value, P< 0.01).

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	8	9	**10**	11
Blechnum penna-marina	0	1	0	0	0	0	0	0	0	**14**	1
Craspedia incana	0	0	0	0	0	0	0	0	2	**25**	0
Helichrysum depressum	0	0	0	0	0	0	2	0	11	**25**	17
Luzula rufa	0	7	0	0	0	0	0	0	3	**14**	3
Rytidosperma setifolia	0	2	2	0	0	0	6	9	9	**21**	4
Trisetum tenellum	0	0	1	0	0	0	12	5	11	**27**	4

Common species

Fourteen species are recorded frequently (>70% of samples) in this community. Racomitrium mosses dominate canopy cover, especially *R. pruinosum*, in association with the cushion plants *Raoulia haastii* and *R. hookeri*, rock lichens *Neofuscelia adpicta*, and *Placopsis perrugosa*, and the native grass *Rytidosperma setifolia*. The native grass *Poa colensoi* may also contribute significantly to cover where it is present.

Table 35. Species commonly occurring (frequency >70% of samples) in Community 10.

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	8	9	**10**	11
Epilobium melanocaulon	14	6	87	49	34	45	72	60	45	**93**	94
Helichrysum depressum	0	0	9	2	7	0	20	5	52	**76**	64
Luzula rufa var. *albicomans*	0	14	19	2	7	0	65	81	72	**87**	30
Neofuscelia adpicta	3	16	7	2	55	3	54	70	94	**72**	15
Placopsis perrugosa	5	14	20	0	22	0	57	65	86	**80**	24
Placopsis spp.	0	8	21	3	4	0	72	79	67	**76**	45
Poa lindsayi	5	1	87	30	24	28	96	89	58	**85**	91
Polytrichum juniperinum	5	43	16	7	17	0	35	57	69	**74**	15
Racomitrium crispulum	26	51	59	28	71	17	100	95	100	**93**	97
Racomitrium pruinosum	0	31	31	14	40	3	46	63	92	**93**	73
Raoulia haastii	0	10	41	4	7	10	80	95	86	**76**	88
Raoulia hookeri	19	18	89	51	4	17	87	75	50	**83**	85
Rytidosperma setifolia	1	27	25	4	7	0	48	57	58	**87**	39
Trisetum tenellum	0	0	15	3	3	0	61	38	58	**91**	36

Plant associations

Two plant associations were recognised in this community:

a) This association is described from 22 plots. 13 species occur frequently (>70% of plots). A total of 89 species were recorded from this association with an average of 25 species per plot. Community composition and structure is similar to that described for the vegetation type although the moss *Racomitrium pruinosum* clearly dominates canopy cover and the grass *Rytidosperma setifolia* contributes open cover in the 10-cm to 30-cm height tier. Indicator species for this association are the herbaceous plants *Craspedia incana* and *Leucopogon fraseri*. This association occurs at sites with significantly higher water-balance ratios than the rest of this community type. It occurs most frequently in the upper Godley River.

Table 36. Association 10a indicator species (indicator value, P< 0.01).

	●(A)	■(B)
Craspedia incana	68	0
Leucopogon fraseri	50	0

b) This association is described from 18 plots. A total of 70 species were recorded from this community with an average of 28 species per plot. 21 species occur frequently (>70% of plots) and 1 of these is exotic (5%). This association is similar in structure to association 10b with the following differences: moss cover is co-dominated by *Racomitrium crispulum*, the exotic herb *Hieracium praeltum** contributes consistently to canopy cover and the grass *Rytidosperma setifolia* contributes less cover in the 10-cm to 30-cm height tier. Indicator species are the herbaceous plants *Stellaria gracilenta, Epilobium microphyllum, E. rostratum* and *Trifolium repens**; the prostrate shrub *Pimelia prostrata*; and the cushion plants *Myosotis uniflora, Colobanthus strictus*, and *Raoulia australis*. This association occurs at sites with significantly higher October vapour deficits and higher mean-annual-solar radiation than the rest of this community type (P<.05). It occurs most frequently in the Murchison River.

Table 37. Association 10b indicator species (indicator value, P< 0.01)

	●(A)	■(B)
Colobanthus strictus	0	75
Epilobium microphyllum	4	76
Epilobium rostratum	0	78
Myosotis uniflora	9	60
Pimelia prostrata	24	53
Raoulia australis	2	41
Stellaria gracilenta	3	69
*Trifolium repens**	0	48

Community 11/ [*Raoulia haastii*] – [*Epilobium melanocaulon*] Stonefield

This community is described from 33 plots representing 4 percent of surveyed sites. Site descriptions contain an average of 15 species and native plants are an important component of these. Of the 72 species recorded in this community, 58 (80%) are native and these dominate total plant cover (84%). 11 species occur in more than 50% of sample descriptions and all of these are native. Levels of vegetative ground cover are low (8%), dominated by low-growing vascular plants (6%). Canopy cover occurs predominantly in the 0-cm to 10-cm height class.

This community occurs on early floodplain development stages with a high level of buffering from anthropogenic influence. It occurs at significantly (P<.05) higher altitudes than most community types (1, 2, 3, 4, 5, 6, 7, 8), has significantly lower levels of vascular plant cover than most other communities (1, 2, 5, 6, 7, 8, 9, 10), and higher levels of bare rock (communities 1, 2, 5, 7, 8, 9, 10) as a proportion of total ground cover. Compared with the other stonefield communities (3, 4) it has a lower proportion of fines-size fractions contributing to total bare rock. There are no significant differences in climatic variables between this community and the other stonefield communities (3,4). The community occurs most frequently in the Godley and Tasman rivers.

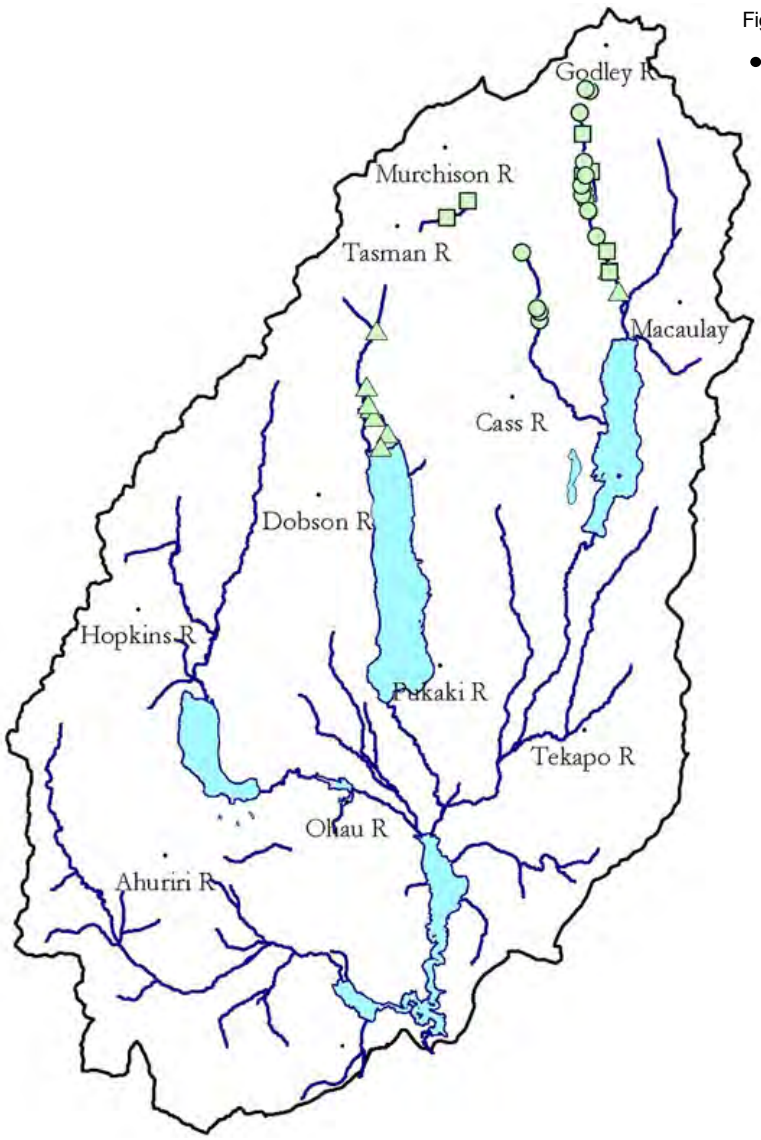

Figure 12. Location of Community 11 and plant associations

●= association 11a; ■= association 11b; ▲= association 11c

Indicator species

There are no indicator species most closely associated with this community, although several species co-occur with few other communities. The cushion plant *Myosotis uniflora* is closely associated with communities 8, 10 and 11 and the herbaceous plant *Epilobium melanocaulon* is associated with communities 3, 10 and 11.

Common species

Six species are recorded frequently (>70% of samples) in this community. Vegetative cover is sparse but dominated by cushion plants, especially *Raoulia haastii*. The herbaceous plant *Epilobium melanocaulon* and grass *Poa lindsayi* are frequently present but contribute low levels of vegetative cover as a result of their sparse growth form.

Table 38. Species commonly occurring (frequency >70% of samples) in Community 11.

	COMMUNITY TYPE										
	1	2	3	4	5	6	7	8	9	10	**11**
Epilobium melanocaulon	14	6	87	49	34	45	72	60	45	93	**94**
Poa lindsayi	5	1	87	30	24	28	96	89	58	85	**91**
Racomitrium crispulum	26	51	59	28	71	17	100	95	100	93	**97**
Racomitrium pruinosum	0	31	31	14	40	3	46	63	92	93	**73**
Raoulia haastii	0	10	41	4	7	10	80	95	86	76	**88**
Raoulia hookeri	19	18	89	51	4	17	87	75	50	83	**85**

Plant associations

No plant associations are described from this community.

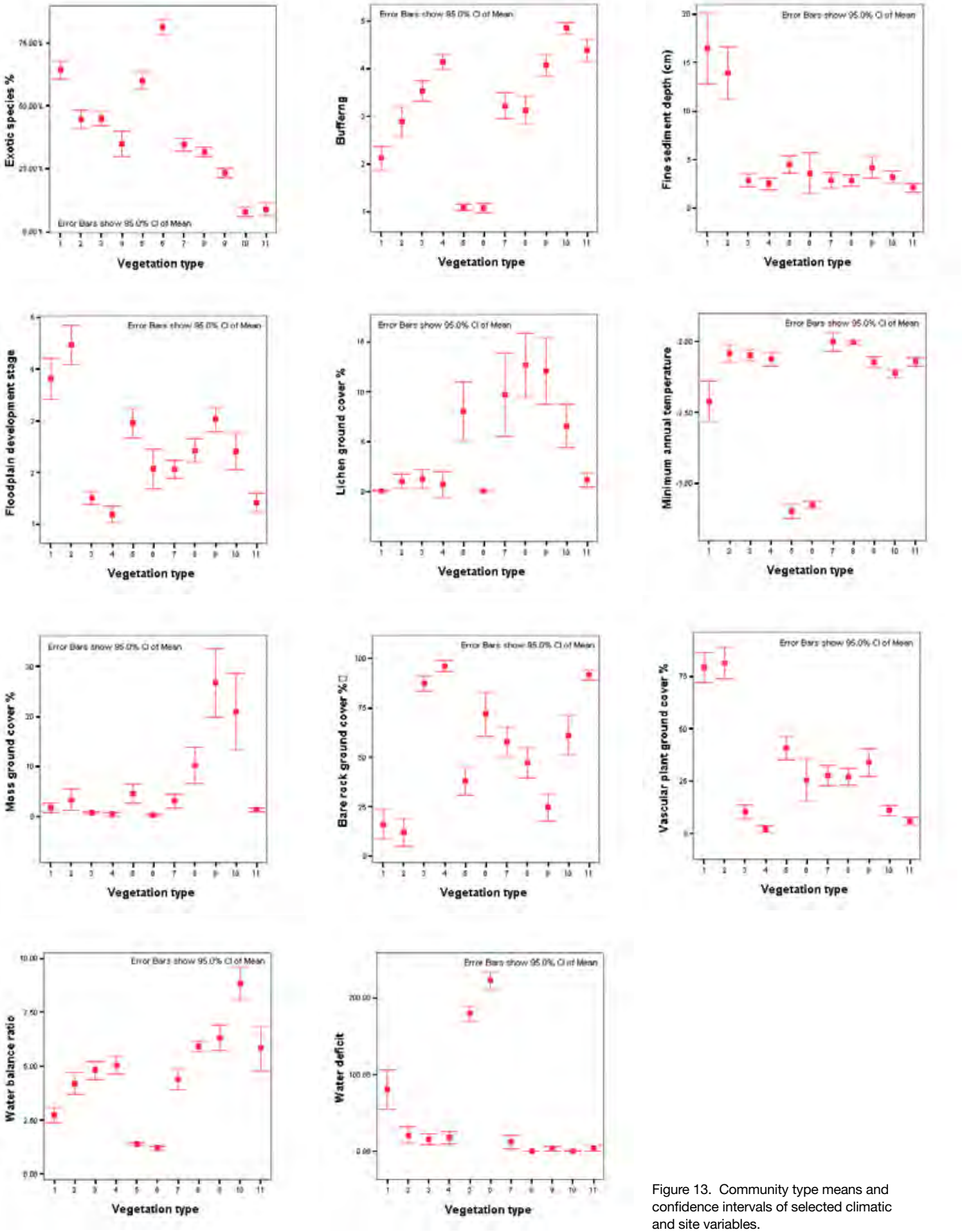

Figure 13. Community type means and confidence intervals of selected climatic and site variables.

4.3 Vegetation Gradients

Three dimensions were identified in the final ordination, cumulatively explaining 99% of the variation in the distance matrix across 724 plots (13 plots containing no species were excluded from the analysis). Environmental variables accounted for 19% of the variation in the primary vegetation gradient (axis 1), correlating with minimum-annual temperature and annual water deficit. In axis two, 74% of variation was accounted for by environmental variables correlating with water-balance ratio, water deficit, winter-solar radiation and mean-annual temperature, while axis three accounted for only 6% of the variation but was correlated with bare surface sediment as a proportion of total ground cover and minimum-annual temperature (See Appendix 4).

Axis 1 and 2: Vegetation types with high water-balance ratios, high winter radiation and lower minimum-annual temperatures located in the upper Murchison and Tasman rivers occupy positions on the right of axis 1. Community indicator species positioned at this end of the axis are most frequently native species found in upper valley sites. They include *Craspedia incana, Gaultheria crassa, Parahebe decora, Helichrysum depressum, Trisetum tenellum, Carmichaelia australis, Luzula celata, Rytidosperma setifolia, Luzula rufa* var. *albicomans, Pimelia prostrata, Lachnagrostis lyallii, Blechnum penna-marina* and *Raoulia haastii*. Although there is a moderate correlation with environmental parameters along these axes, there is also a clear relationship with the occurrence of exotic species (r2 = 0.74, fig. 13). Species situated at the right of axis 1 are predominantly native, while exotics dominate the left side. There is also a corresponding gradient of anthropogenic influence (buffering) from less affected sites with low frequencies of exotics and predominantly native cover on the right, to highly affected sites where exotic species frequency and cover is high on the left. Vegetation type placement along the axis reflects the same gradient of exotic species frequency with types dominated by exotics (1, 5, 6) occupying the left. Vegetation types 1 and 6 at the extreme left have the highest exotic-species frequency and cover of all types described, while types on the right have highest levels of native-species representation (8, 9, 10, 11).

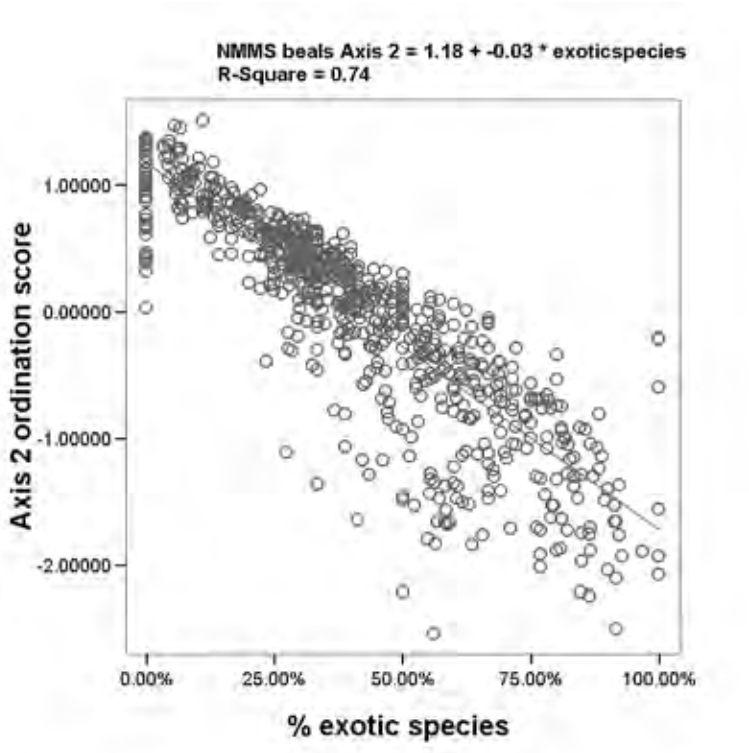

Figure 14. Linear regression of Axis 2 ordination score and percentage exotic species in plots

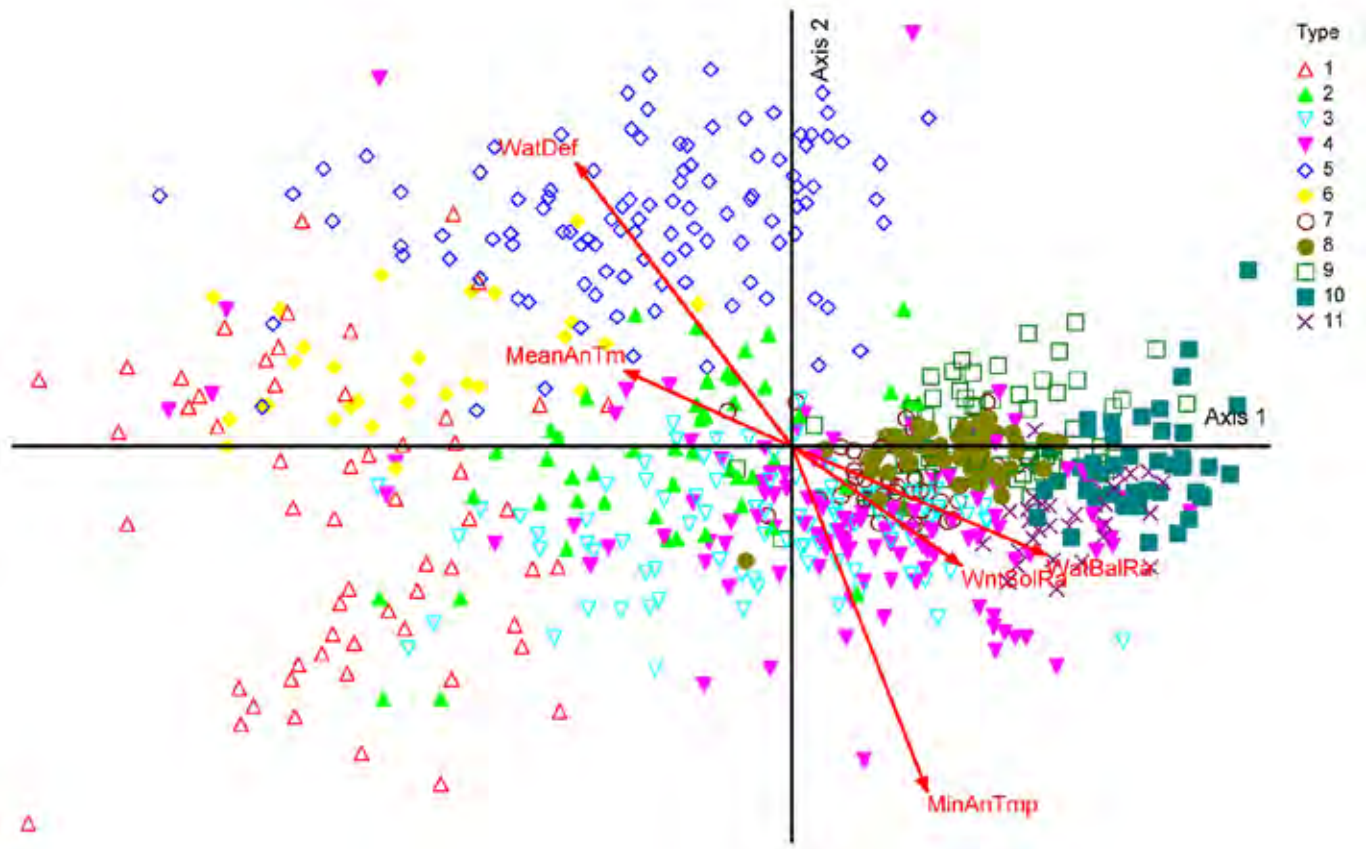

Figure 15. Plot of Axis 1 and Axis 2 ordination scores, site variable bi_plots and community types.

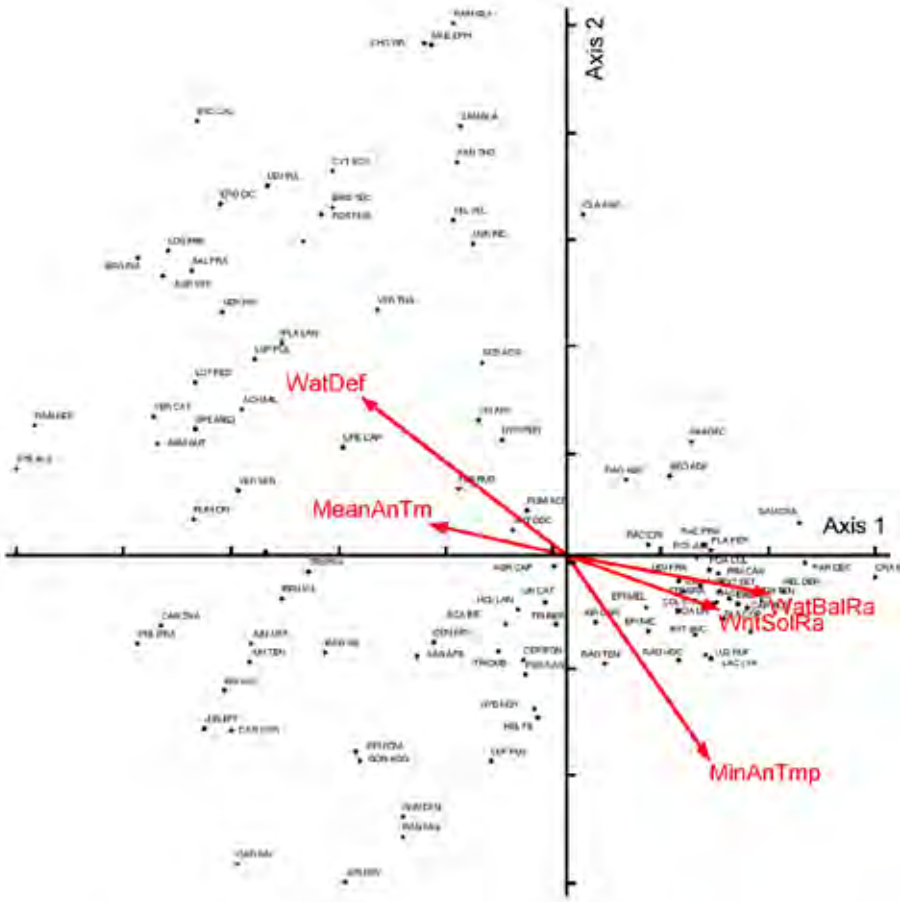

Figure 16. Plot of Axis 1 and Axis 2 ordination scores and site variable bi_plots for species present in more than ten plots.

Sites located in the lower Ahuriri, Ohau and Tekapo rivers associated with high annual-water deficits and warmer mean-annual temperatures (vegetation types (5, 6) are situated in the upper left of the ordination. The lower left side of the ordination is occupied by sites with high frequencies of species associated with wetland communities or moist soils such as *Carex ovalis*, C coriacea, C sinclairii, Isolepis aucklandica*, Juncus effusus*, J tenuis, Juncus articulatus, Epilobium komarovianum, Gunnera dentata, Ranunculus multiscapus, Parentucellia viscosa* (tarweed), *Phleum pratense*. Associations of communities 1 and 3, in which plants typical of wet sites are key indicators, are positioned in the lower left of the ordination.

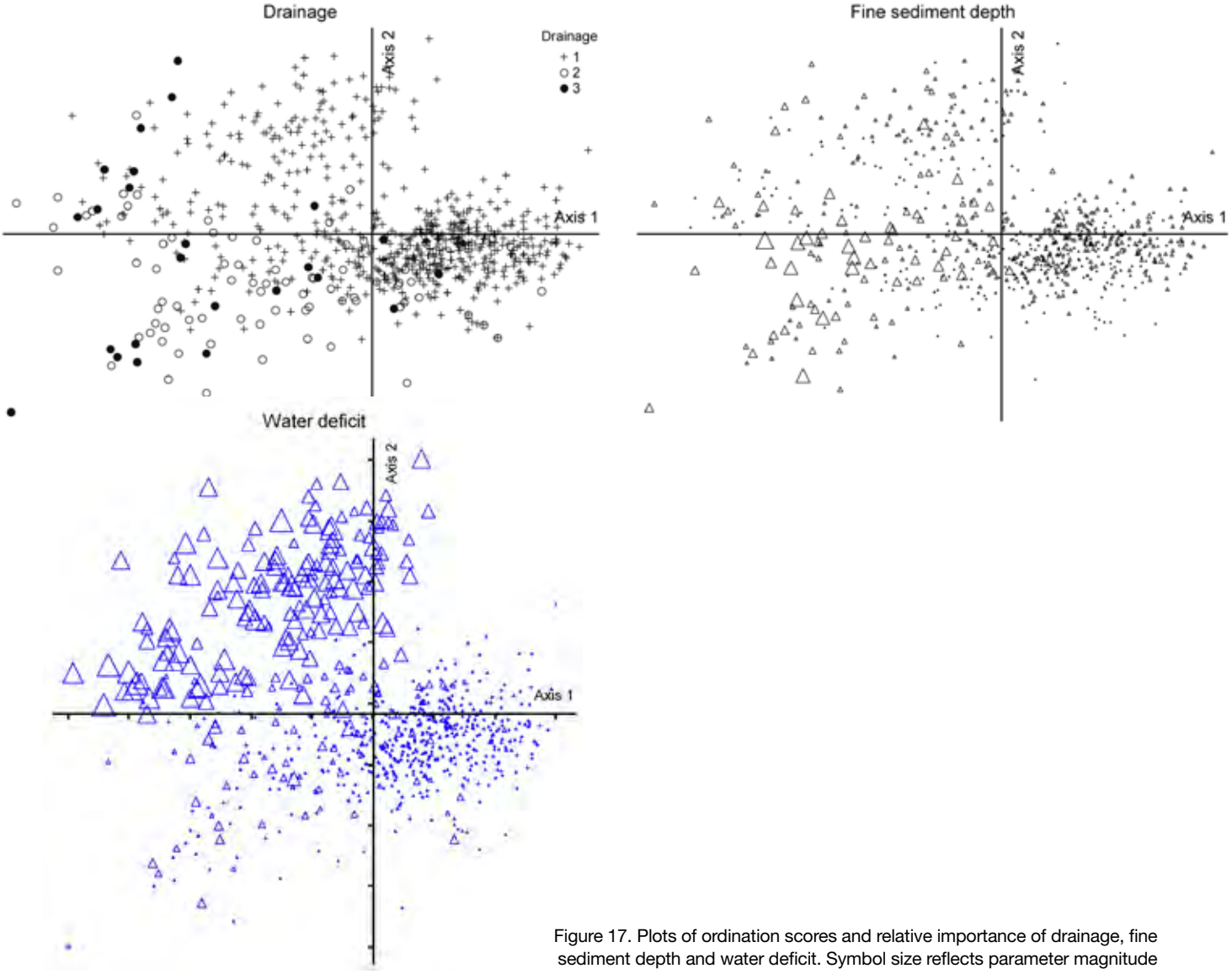

Figure 17. Plots of ordination scores and relative importance of drainage, fine sediment depth and water deficit. Symbol size reflects parameter magnitude

Axis 2 and 3. Recorded site and environmental parameters only account for 6 percent of the variation in axis 3. The principle relationship identified is along a disturbance gradient. Vegetation types (4, 11) occupying the upper right of the ordination are associated with early floodplain development stages, are sparsely vegetated and have high proportions of bare rock as surface cover. Vegetation types (1, 2) situated at the lower end of the axis are associated with advanced floodplain development, greater depths of surface fines and, in the lower right corner of the ordination (9, 10), have high levels of moss and lichen as a proportion of surface cover.

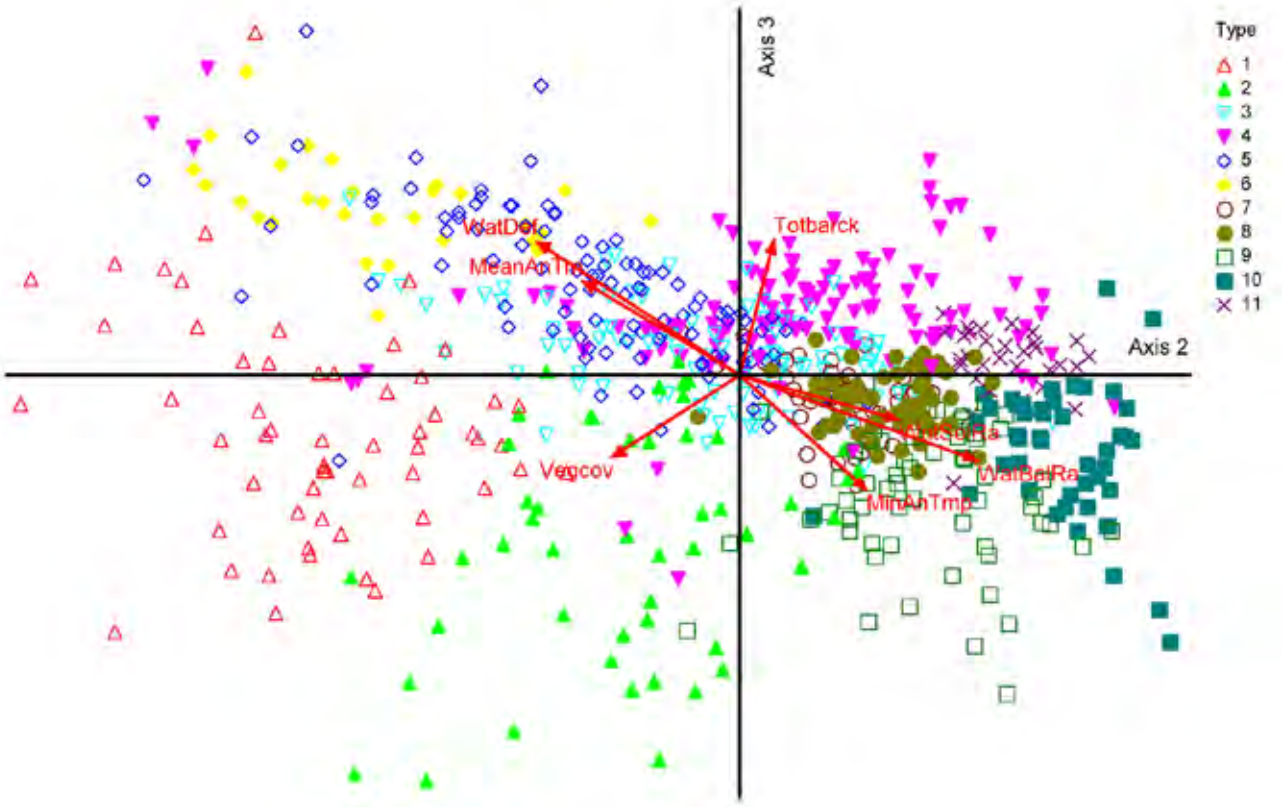

Figure 18. Plot of Axis 2 and Axis 3 ordination scores, site variable bi_plots and community types.

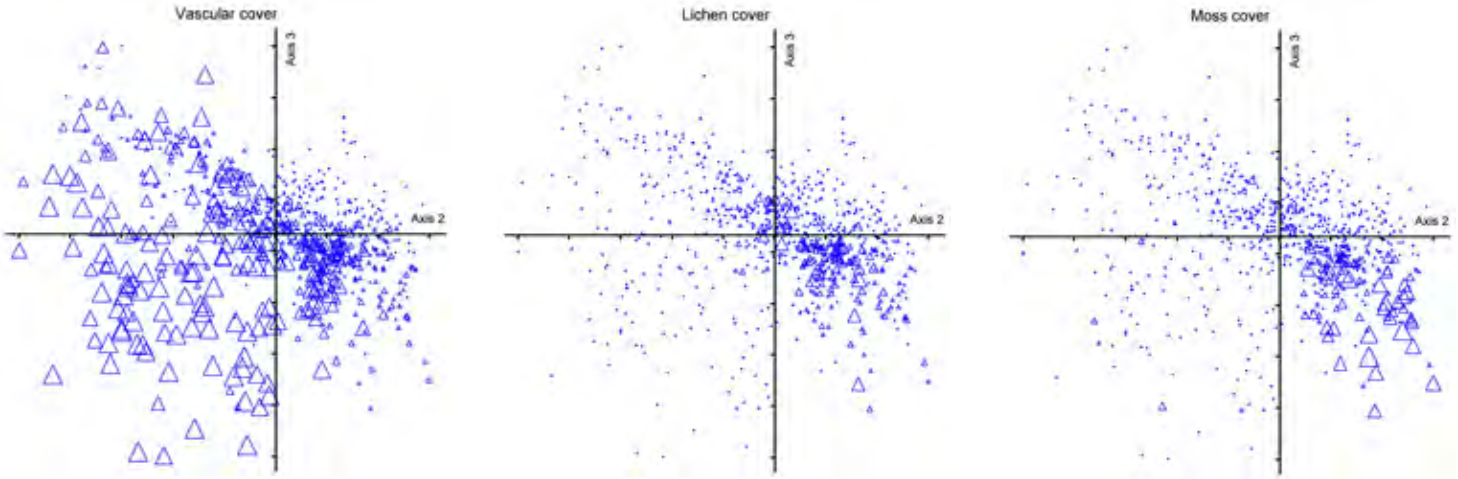

Figure 19. Plots of Axis 2 and Axis 3 ordination scores and relative importance of vascular cover, lichen cover and moss cover. Symbol size reflects parameter magnitude.

4.4 Threatened plants

Under the classification system developed by Molloy (Molloy et al., 2002) and using rankings assigned by Hitchmough (Hitchmough, Bull & Cromarty, 2007), 18 plants with a threat classification were recorded in sample descriptions (see Appendix 5). Of these, six species are classified as 'chronically threatened', nine are classified as 'at risk' and a further three species as 'data deficient'. No 'acutely threatened' species were recorded. Most species were recorded at 5 or fewer sample sites (13 spp.), 4 species (*Carex berggrenii, Carex decurtata, Leptinella serrulata* and *Muehlenbeckia ephedroides*) were recorded at between 10 and 21 sites, and two species (*Luzula celata* and *Myosotis uniflora*) were recorded at over 100 sites.

Muehlenbeckia ephedroides occurs most frequently in the Tekapo and Ohau rivers in community 5. It occupies sites closely associated with Axis 2 in ordination space with high water deficits and high mean-annual temperatures. Both species are recorded in plant communities with high frequencies and percentage cover of exotic plants and are absent from the upper catchment communities of predominantly native composition.

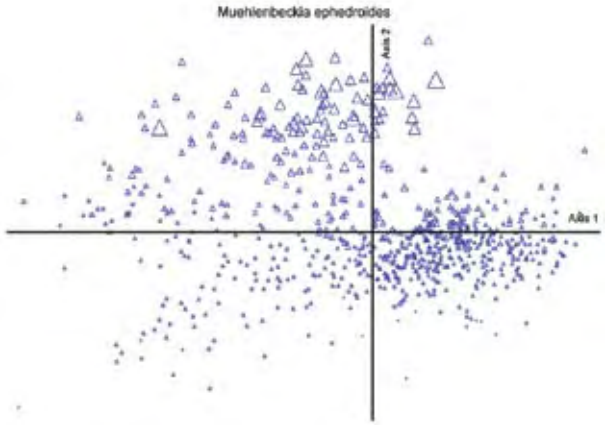

Figure 20. Plots of Axis 2 and Axis 3 ordination scores and relative importance of *Muehlenbeckia ephedroides*.

The distributions of the other threatened plants are, in comparison, quite different. Occurrences of *Carex decurtata, Luzula celata* and *Myosotis uniflora* are strongly associated with Axis 1, occupying sites with high water-balance ratios and low minimum-annual temperatures and occurring in communities with low levels of exotic plant cover and high frequencies of natives. *Carex decurtata* was recorded only from the Godley River catchment, while *Myosotis uniflora* was more widely dispersed through the upper river catchments. The occurrences of *Luzula celata* are by far the most numerous recorded anywhere in New Zealand and, while the plant was recorded in several upper-river catchments, it occurs most frequently in the Tasman River, closely associated with community 8 which is described almost exclusively from this valley.

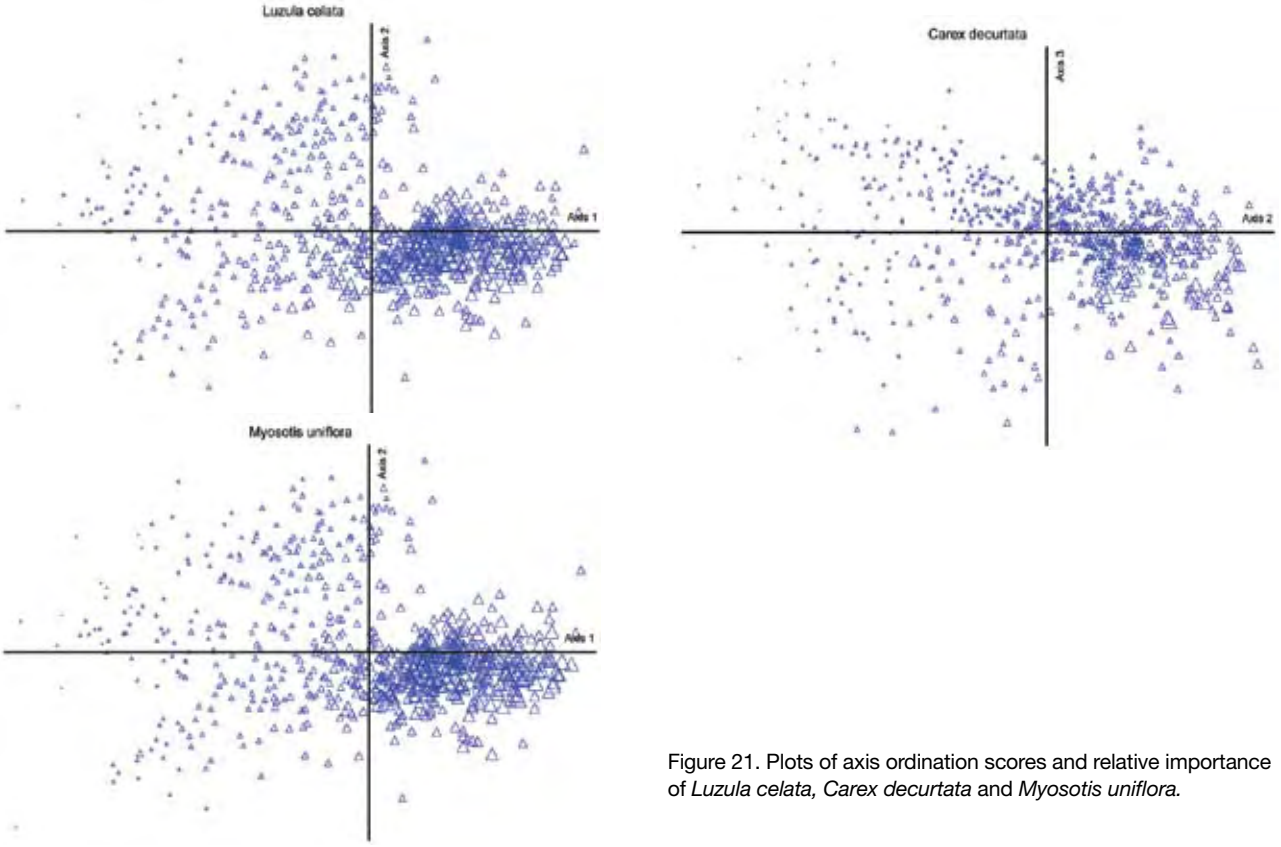

Figure 21. Plots of axis ordination scores and relative importance of *Luzula celata, Carex decurtata* and *Myosotis uniflora.*

Leptinella serrulata and *Carex berggrenii* are recorded most frequently in communities 1 and 2, associated with high levels of vascular-plant cover, high frequencies and cover of exotic species, at sites with advanced floodplain development stages and greater depths of surface fines. Their location in ordination space is negatively correlated with Axis 3 reflecting low levels of site disturbance.

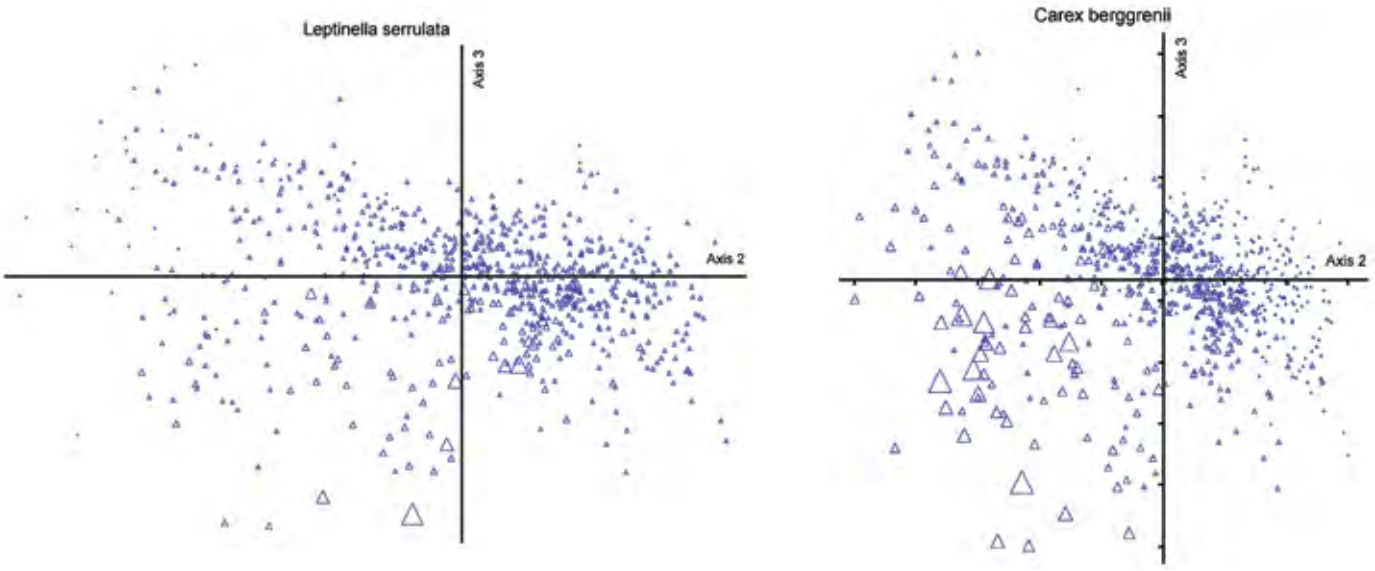

Figure 22. Plots of Axis 2 and Axis 3 ordination scores and relative importance of *Leptinella serrulata* and *Carex berggrenii*.

There are also significant differences in the frequency and diversity of threatened plants recorded in the eleven communities described. Community 1 contains the greatest diversity of threatened plants (14 species), although many of these are recorded from less than five plots. *Carex berggrenii* occurred most frequently in this community, while *Carex lachenalii* subsp. *parkeri, C. muelleri, C. cirrhosa, Deschampsia cespitosa* and *Epilobium chionanthum* were recorded only from this community type. No threatened plants were recorded in community 6. Communities (7, 8, 9, 10, 11) contain highest frequencies of threatened plants. They are characterised by high frequencies of native plants, low frequencies and cover of exotic plants and sites associated with high water-balance ratios, low minimum-annual temperatures, and high winter-solar radiation. Ninety percent of plots in community 8 and over 50 percent of plots in other communities of this group contained one or more threatened plants.

Table 39. Threatened species occurrences in plant communities.

	PLANT COMMUNITY										
	1	2	3	4	5	6	7	8	9	10	11
Total number of plots	58	49	102	141	106	29	46	63	64	46	33
Threatened species diversity	13	6	7	3	7	0	3	5	7	8	3
Frequency of chronically threatened species	7	4	13	3	3	0	16	52	17	4	7
Frequency of at risk species	22	6	3	1	27	0	0	1	15	8	1
Frequency of data deficient species	1	1	10	3	6	0	19	34	23	27	19
Percentage of plots containing one or more threatened species	36	20	21	5	28	0	54	90	59	61	64

Several river systems are notable for their abundance or diversity of threatened plants. Over 80% of plots in the Murchison River contained one or more threatened plants. While only four threatened species were recorded in this river, nearly 75% of all plots contained *Myosotis uniflora*. Similarly, in the Tasman River, 50% of all plots contained threatened plants and a high proportion (42%) of all *Luzula celata* records are from this river system. Other river systems with relatively high records of threatened plants in plots are the Ohau, Godley and Hopkins rivers. The Ahuriri River had the highest number of different threatened plant species present, although they were recorded infrequently in plots.

Table 40. Threatened species occurrences in river systems.

	AHURIRI	OHAU	TEKAPO	PUKAKI	HOPKINS	DOBSON	CASS	TASMAN	GODLEY	MURCHISON
Total number of plots	75	18	69	13	88	54	48	146	156	25
Threatened species diversity	11	5	4	1	7	4	8	6	8	4
Frequency of chronically threatened species	4	3	0	0	19	11	2	62	26	0
Frequency of at risk species	8	6	19	1	6	2	8	1	26	6
Frequency of data deficient species	3	2	2	0	13	5	9	39	51	19
Percentage of plots containing one or more threatened species	15	39	28	8	35	20	29	50	38	84

4.5 Successional development

Visual assessments of the floodplain development stages described by Reinfeld and Nanson correspond closely with other indicators of successional development recorded in this survey. Early floodplain development stages have high levels of bare gravel as a proportion of total ground cover (a surrogate for flood periodicity), sparse vascular cover and shallow depths of surface fines. Increasingly advanced stages of floodplain development are associated with increasing levels of vascular-plant cover, pulses of lichen and moss development, and increasing depths of surface fines. Levels of moss and lichen cover steadily increase across development stages 1 and 2, peaking at stage 3, declining in stages 4 and 5 as vascular-plant cover increases, and becoming more variable in stage 6. Also associated with these changes are increases in species diversity and increases in exotic species frequency and cover as a proportion of total species occurrence (see Figure 23 below and Appendix 6).

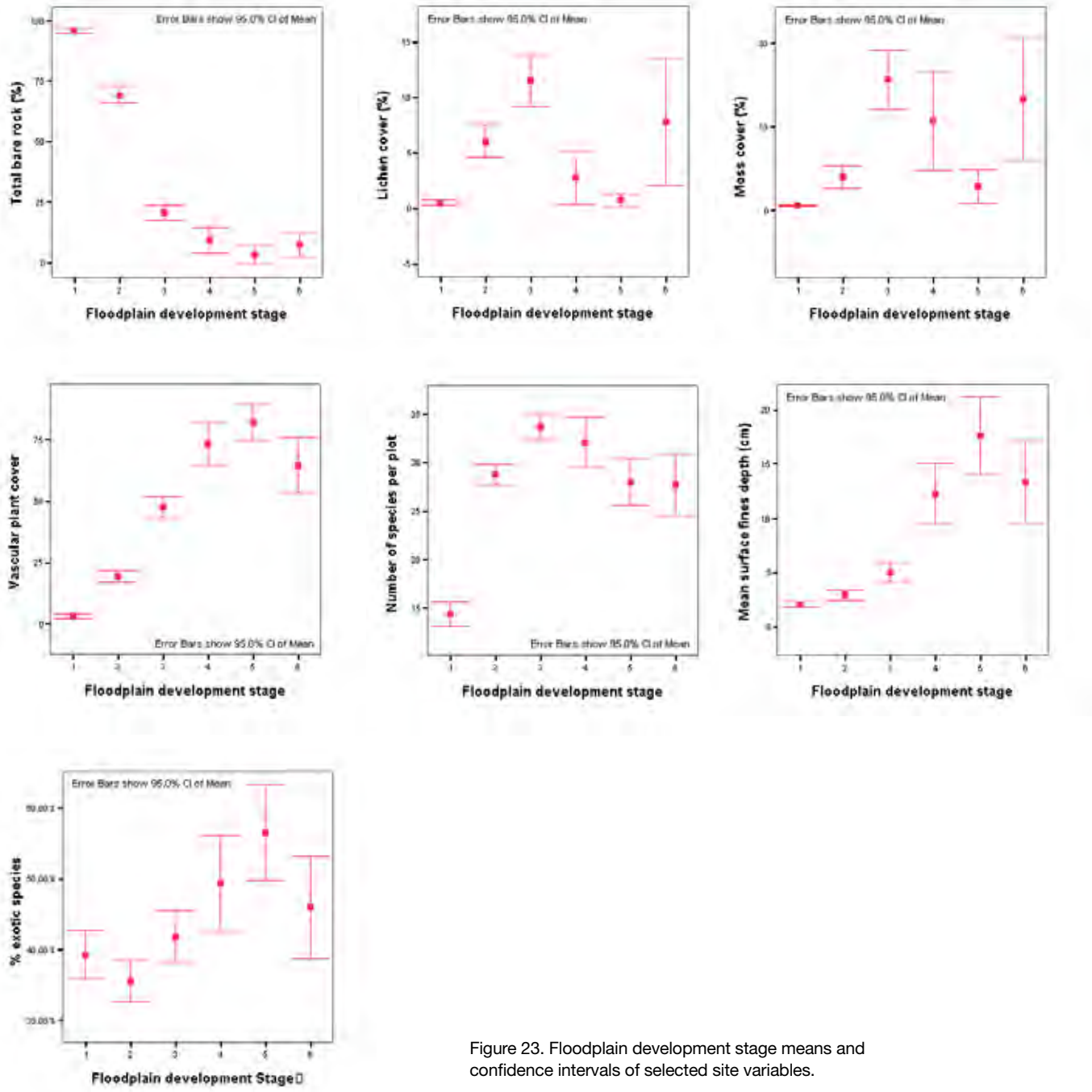

Figure 23. Floodplain development stage means and confidence intervals of selected site variables.

Community type 4 most closely aligns with floodplain development stage 1. Surface cover other than bare rock is almost entirely absent, although very sparse vascular-plant cover is recorded. Community types 3, 7 and 11 are most closely associated with floodplain development stage 2, being sparsely vegetated with high levels of surface bare rock and containing higher frequencies of stage 2 development indicator species including willow herbs *Epilobium melanocaulon*, and *E. microphyllum*, the grasses *Poa lindsayi*, *Lachnagrostis lyallii*; the cushion plants *Raoulia haastii, R. hookeri, R. tenuicaulis, Myosotis uniflora* and the cow-pat lichens *Placopsis* spp. Communities 5, 8, 9 and 10 are most frequently associated with floodplain development stage 3. Indicator species associated with this development stage are the lichens *Neofuscelia adpicta, Placopsis perrugosa,* the mosses *Racomitrium crispulum*, and *R. pruinosum*; the cushion plants *Raoulia australis*, *Muehlenbeckia complexa*, Pimelia prostrata and *Colobanthus strictus* and the herbaceous plants *Hieracium pilosella** and *Sedum acre**. These communities have higher levels of lichen ground cover and communities 8, 9 and 10 have the highest levels of moss cover compared with other community types. Communities 1 and 2 are most frequently associated with development stages 4 or 5. Both have higher levels of vascular cover, greater depths of surface fines and low levels of surface rock, lichen or moss compared with other communities. Community 1 has greater representation of indicator species associated with development stage 5, including the grasses *Anthoxanthum odoratum*, Festuca rubra**, and *Holcus lanatus**; the herbaceous plants *Hypochoeris radicata, Ranunculus multiscapus, Cerastium fontanum*, Hieracium praeltum** and *Trifolium pratense**; the sedge *Carex ovalis** and the rush *Juncus effusus** (See Appendix 7 for table of floodplain development stage indicator species)

4.6 Catchment relationships

The distribution of plants and composition of plant communities are not evenly distributed throughout catchments of the upper Waitaki basin (See Fig 24). The Murchison River has the lowest levels of anthropogenic influence and lowest frequency of exotic species of any other catchment. Other catchments with comparatively low frequencies of exotic species are the Godley and Tasman rivers. All three catchments are strongly associated with climatic variables related to low frequencies of exotic species (water-balance ratio, minimum-annual temperature). In comparison, the Ahuriri, Tekapo and Pukaki have the highest incidence of exotics, high exposure to anthropogenic influence and close association with climatic variables associated with high frequencies of exotics (water deficit, mean-annual temperature).

River systems with highest levels of flood disturbance, indicated by high levels of bare surface gravels, low vascular-plant cover and a high proportion of early floodplain development sites are the Cass and Dobson, followed by the Pukaki, Macaulay, Tasman and Godley rivers. Conversely, the Ahuriri, Tekapo, Ohau and Hopkins rivers are characterised by high levels of vascular-plant cover, the Ahuriri and Hopkins rivers have greater average depths of surface fines, the Ohau River has high levels of surface moss and the Tekapo River has high levels of lichen cover. All of these factors indicate catchments with more stable sites at more advanced stages of floodplain development. The Murchison River lies between these two extremes, being characterised by low levels of surface bare rock, low levels of vascular-plant cover and high levels of moss cover, indicating a relatively early stage of floodplain development but with little recent disturbance in much of the catchment.

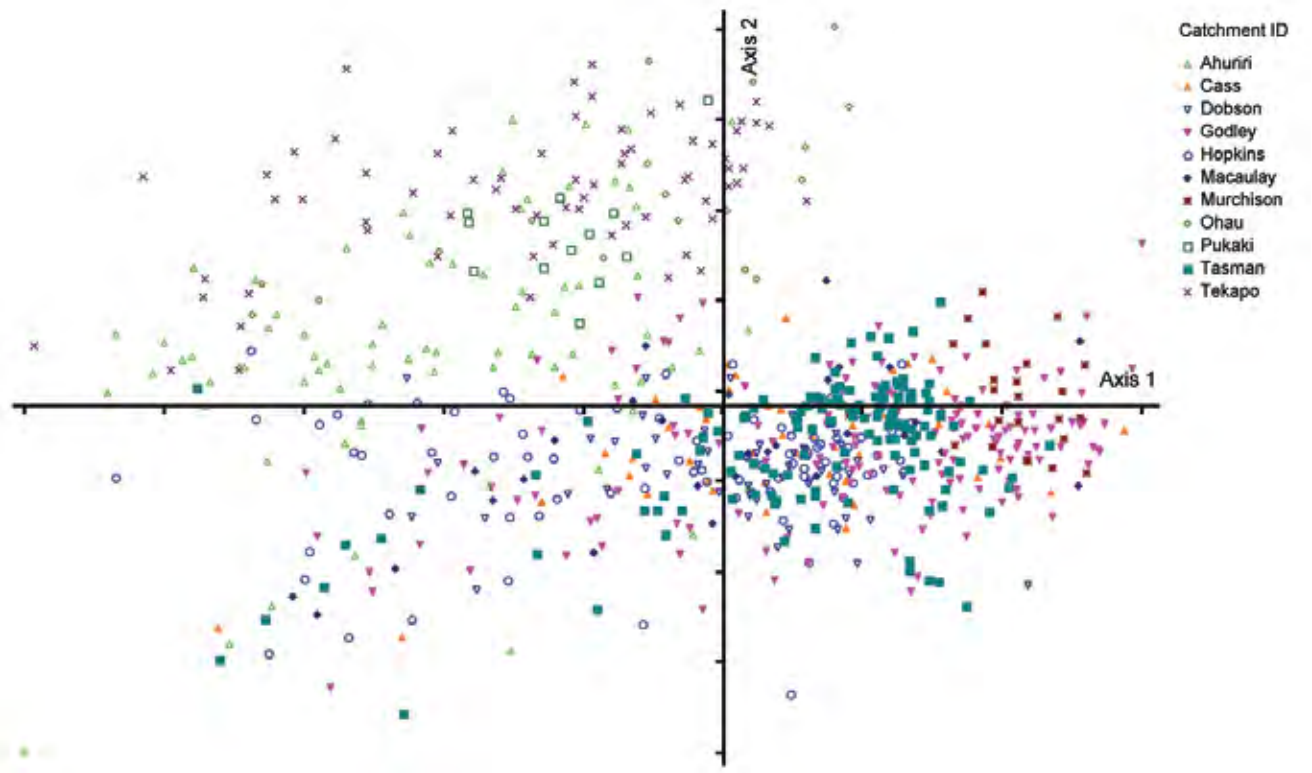

Figure 24. Plot of Axis 1 and Axis 2 ordination scores with catchments identified

5. Discussion

This survey has shown that the braided rivers of the upper Waitaki basin support vegetation with a wide range of compositional variation in both space and time. The observed variation results from varying responses of community floristics to a combination of anthropogenic influence, environment and disturbance history.

The lack of similar surveys of braided-river systems in New Zealand makes inter-river and regional comparisons difficult. Furthermore international literature examining floristic composition along riverine systems is mostly focused on single-channel rivers or fine-sediment floodplains rather then the gravel-based braided rivers characteristic of New Zealand (Decamps, Planty-Tabacchi & Tabacchi, 1995; Planty-Tabacchi, Tabacchi & Bonillo, 2001; Planty-Tabacchi *et al.*, 1995; Tabacchi *et al.*, 1996). In the only large-scale survey of New Zealand braided rivers, Williams and Wiser (Williams & Wiser, 2004) described floristics of four river systems from source to sea across a range of geographic locations – North Island east and west coast (Rangitikei and Ngaruroro rivers) and South Island east and west coast (Waimakariri and Hokitika rivers). Although their survey methodology differed from that used here, some broad comparisons can be made. In both surveys the flora are dominated by Asteraceae and Poaceae in similar proportions, and other important plant families are broadly similar. Their observation of fewer vascular species (289 compared with 395) and a much higher ratio of exotic to native species (60% exotic, 40% native compared with 33% exotic and 67% native) are probably mostly attributable to differences in methodology and geographic-survey range. The exclusion from the survey by Williams and Wiser of floodplain sites with developed soil would exclude many species recorded in this survey, and the predominance of native species in this survey reflects the headwater focus of descriptions in the upper Waitaki River. This is consistent with Williams and Wiser's findings of increased native-species richness in the headwaters of the

two South Island rivers they examined. Those species recorded frequently (greater than 20% occurrence) in the upper Waitaki river, but less frequently or absent (<20% occurrence) from Williams and Wiser's records, are predominantly native (*Raoulia haastii, Stellaria gracilenta, Luzula rufa* var. *albicomans, Colobanthus strictus, Wahlenbergia albomarginata, Pimelia prostrata* and the exotic herb *Hieracium praeltum*). Conversely, species recorded more frequently throughout the Hokitika and Waimakariri rivers are predominantly exotic (*Agrostis stolonifera*, Cytisus scoparius, Prunella vulgaris*, Rumex obtusifolius*, Ulex europaeus*, Anagallis arvensis*, Bromus diandrus*, Conyza bilbaoana*, Leucanthemum vulgare*, Lupinus arboreus*, Rumex crispus**, and the native shrub *Coriaria arborea,* and herbs *Senecio quadridentatus, Epilobium nerteroides* and *Pratia angulata*). Brief descriptions of plant communities recorded in a separate study by Williams in the lower Waitaki River (Williams 1981a) record much higher proportions of exotic species, indicating the strong gradient of exotic encroachment in lower river reaches, through to native dominance in river headwaters. This is also true of the Waitaki River. The same pattern is continued in the rivers of the upper Waitaki where there is a clear gradient of more frequent occurrence and dominance of exotic species in communities of the lower Ahuriri, Tekapo and Ohau rivers, through to predominantly native communities in the upper Godley, Tasman and Murchison rivers.

Factors influencing the distribution and abundance of exotic species in riverine and other ecosystems have been related to a range of mechanisms, including human influence through road and track development; size and proximity of human population; time of human settlement; level of human disturbance; and flow regulation of rivers (Bezuidenhout & Jardine, 2001; Decamps *et al*., 1995; Ferreira & Moreira, 1995; Gelbard & Belnap, 2003; McKinney, 2001; Sullivan *et al*., 2004; Williams *et al*., 2004). The size and proximity of exotic propagule sources through all of the above mechanisms are clearly having the single greatest influence on plant community composition in the upper Waitaki River systems – as reflected in the classification of plant communities and ordination gradients described. The most natural riverbed communities adjoin lands with very little human activity or infrastructure development, and occupy sites at higher elevations where surrounding communities are also predominantly native. This same effect is described in the four rivers examined by Williams and Wiser.

The abundance and distribution of native plants is more closely associated with geographic position and climatic variation. Communities associated with riverbed headwaters in this survey contain native species not recorded in lower sections of the same river system. These plant assemblages in riverbed headwaters are often found to reflect the composition of adjoining montane and subalpine flora (Williams and Wiser 2004). Other native plants and lichens are recorded only from lower riverbed localities (*Convolvulus verecundus, Chondropsis viridis* and *Xanthoparmelia* spp., *Muehlenbeckia ephedroides*) and are shown to be closely associated with soil-moisture deficit, water-balance ratio and temperature gradients. Plant community composition is known to vary with climatic gradients, especially soil-atmospheric-moisture deficits (Leathwick *et al*., 2002) and this effect is demonstrated in upper Waitaki riverbeds.

Other important influences of floristic composition in this study are time since reworking or deposition of gravels, and substrate moisture. Although 'drainage' as assessed in this survey was a poor predictor of community composition, the species ordination suggests that substrate moisture availability had a significant effect on species co-occurrence. Furthermore, several of the plant associations described from communities 1, 2 and 3 are differentiated by frequent occurrence of plants characteristic of wet sites. The assessments of substrate-moisture availability used in this survey relied on visual indicators of surface moisture. These proved to be unreliable in a riverbed environment where thin veneers of free-draining gravel may overlie a shallow water table or fine-textured substrates with

better water-holding capacity. Depth to water table would be a better predictor of floristic composition, although ease of detection would be problematic in a rapid, large-scale assessment such as this.

A number of studies have examined changes in floristics on different aged surfaces in early riverbed successions, generally from relatively small rivers or sections of larger ones (Burrows, 1977; Calder, 1961; Cockayne, 1921; Cockayne & Foweraker, 1916; Foweraker, 1916; Mitchell, 2005; Reinfelds *et al*., 1993; Singleton, 1975; Wilson, 1976). The most recent (Reinfelds *et al*. 1993 and Mitchell 2005) generally correspond well with plant communities and associations described in this study, although species composition is variable between sites. A good example is the floristic diversity observed in community 4, clearly an early successional stage dominated by bare gravels. The species colonising these surfaces are variable, their floristic composition probably reflecting that of immediately adjoining communities and propagule sources, especially the occurrence of exotics. Association 4e occurs more frequently in the lower reaches of the Hopkins, Tasman, and Godley rivers, and the two species most frequently recorded are *Trifolium repens* and *Muehlenbeckia axillaris*. Association 4f, recorded more frequently from the upper Dobson, Tasman and Godley rivers, has most frequent occurrence of *Epilobium melanocaulon* and the moss *Racomitrium crispulum*, reflecting the higher incidence of native species and relative dominance of mosses in communities of upper sections of these rivers. Similar effects are apparent throughout the range of communities described. The influence of exotics on successional trajectories is poorly understood, although it is clear that some such as *Salix fragilis,* broom, gorse, tree lupin and *Lupinus polyphyllus* are capable of competitively excluding native vegetation at very early stages of succession (Balneaves *et al*., 1990; Meurk *et al*., 1989; Williams, 1981a). Others exotics may have significant impacts through changes to a variety of parameters, such as nutrient cycling, nutrient availability, litter production and litter decomposition (Bellingham, Peltzer & Walker, 2005; Ehrenfeld, 2003). It is probably no coincidence that the greatest frequencies of rare plants are found in the catchments and communities where exotic species are least abundant.

5.1 Catchment relationships

The river systems of the upper Waitaki clearly differ in their floras, with each catchment having unique assemblages of plant communities, community associations and species distributions. The Tasman, Godley and Murchison braided rivers are botanical gems, each with distinguishing characteristics.

The Tasman River contains the largest known populations of the threatened plant *Luzula celata* and extensive examples of early riverbed successions which are predominantly natural. The older *Raoulia* cushionfield communities remain intact and are not replicated on this scale in other upper Waitaki catchments; indeed the alluvial *Carmichaelia* shrublands associated with this community are also uncommon nationally. Although the Hopkins and Dobson rivers occupy a similar altitudinal range to the Tasman, these river systems lack the extensive representation of older cushionfield communities and those that are present are more invaded by exotic plants.

The Godley River is notable for the range and indigenous character of plant communities and threatened plants it supports. A diverse range of threatened plants are recorded from this catchment, and some species are not recorded in other river systems. Almost the entire range of upper Waitaki riverbed communities are present within the catchment extending from damp, silty grasslands at the Lake Tekapo delta through to higher altitude successions in which elements of the subalpine flora descend into the riverbed. Although many elements are replicated in other systems this is the only catchment with full,

uninterrupted sequences across relatively wide climatic gradients which remain largely natural.

The Murchison River contains a much narrower range of communities, predominantly communities 9 and 10. Although replicated in other catchments, at the plant association level, the communities in the Murchison are floristically distinct and contain a far lower diversity of exotic species than any other river system. The relative geographical isolation of this catchment provides the best opportunity of all the upper Waitaki rivers to observe high-altitude riverbed successions with minimal influence from exotic invasion.

Although more modified, communities of the lower-river systems also contain native floristic elements which are distinct. Many lichens, mosses and vascular plants present in plant communities of these rivers are absent from the more natural upper rivers. The upper reaches of the Ahuriri River, and the Hopkins River at its confluence with the Dobson River and Lake Ohau delta, contain the most extensive poorly drained grasslands and sedgelands of all the upper Waitaki rivers. These communities are distinctive for the high diversity of threatened plants and variety of more common plants they contain.

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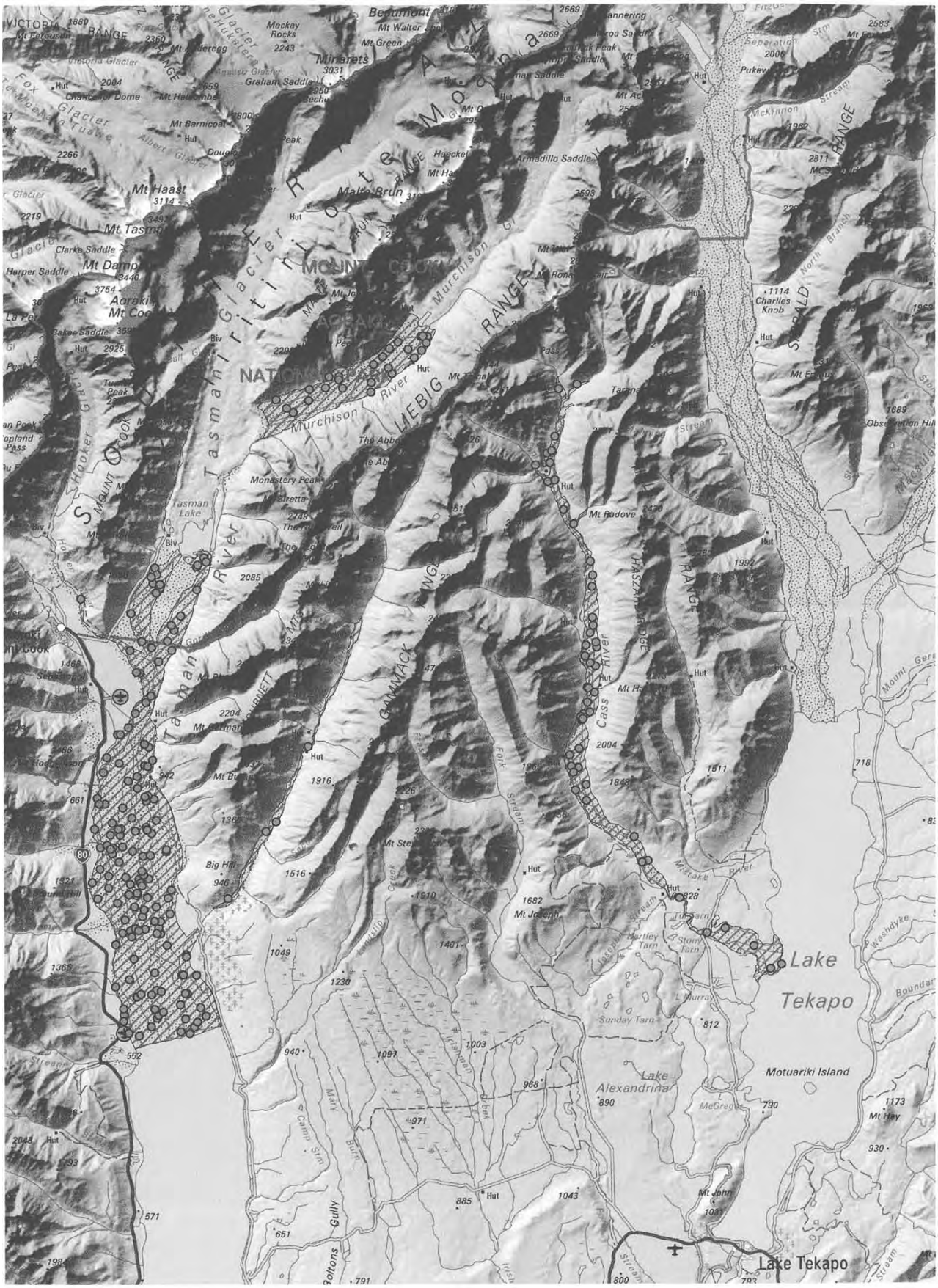
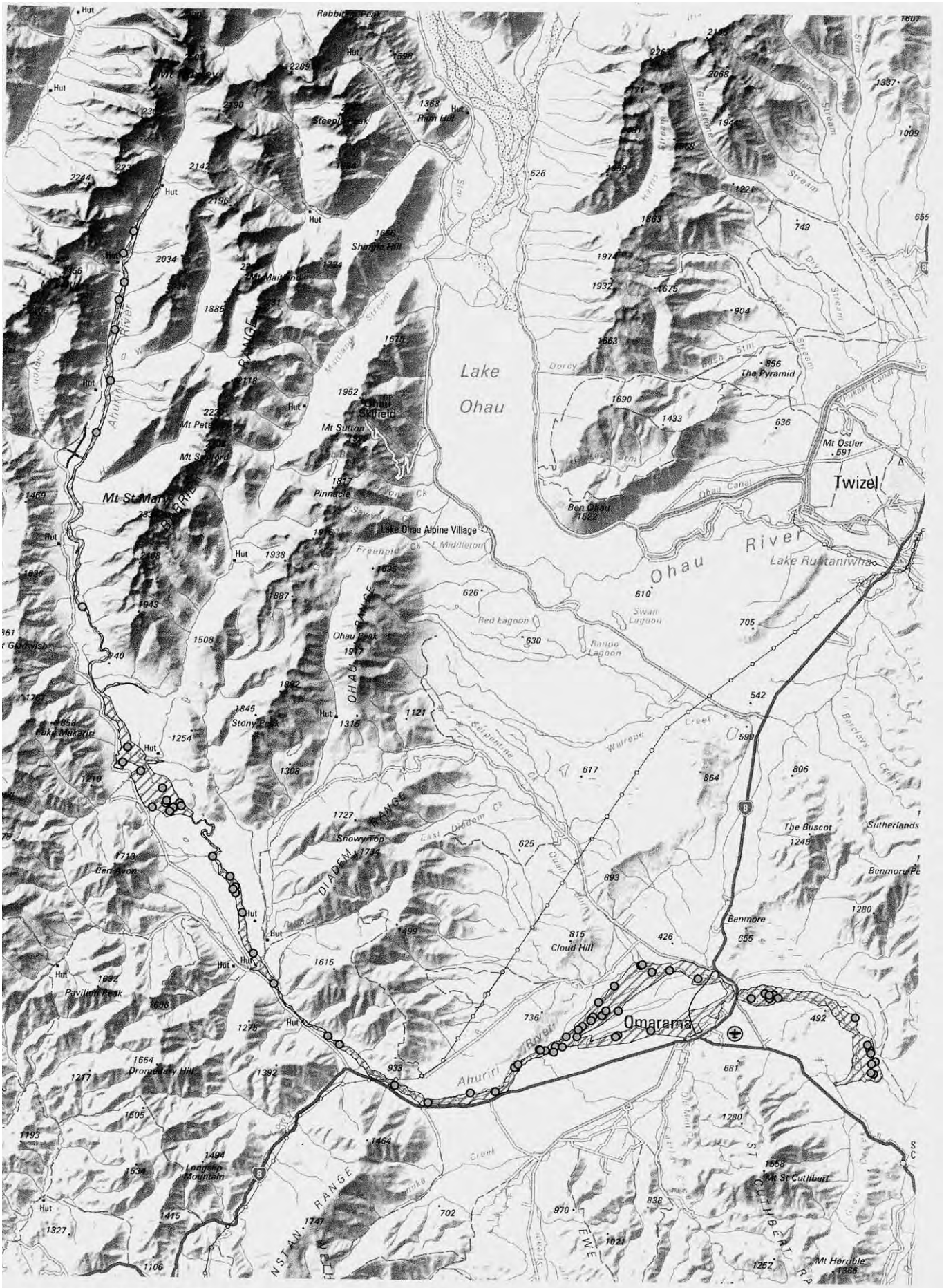
8. Appendices

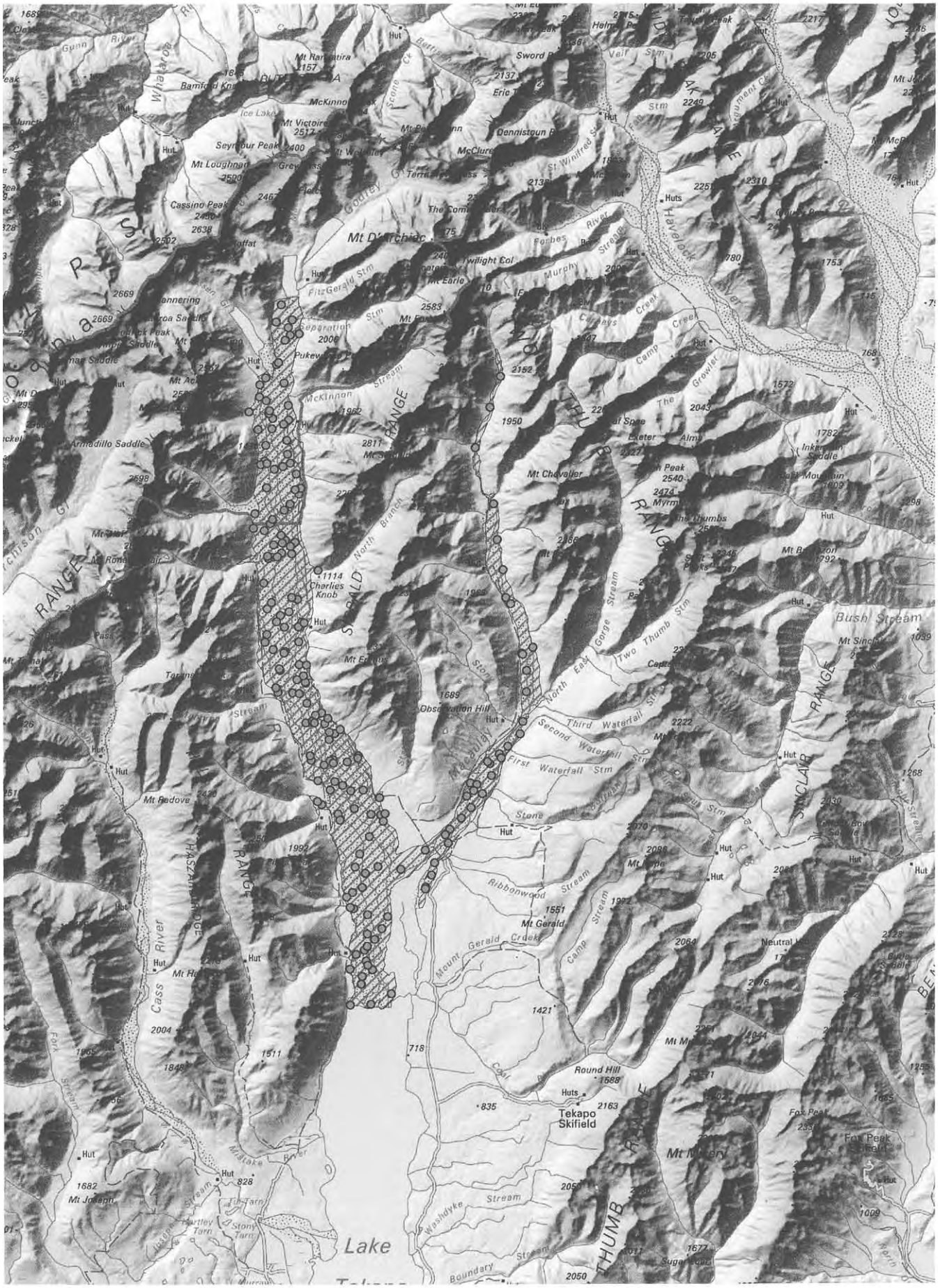
Appendix 1: Riverbed areas surveyed and plot locations



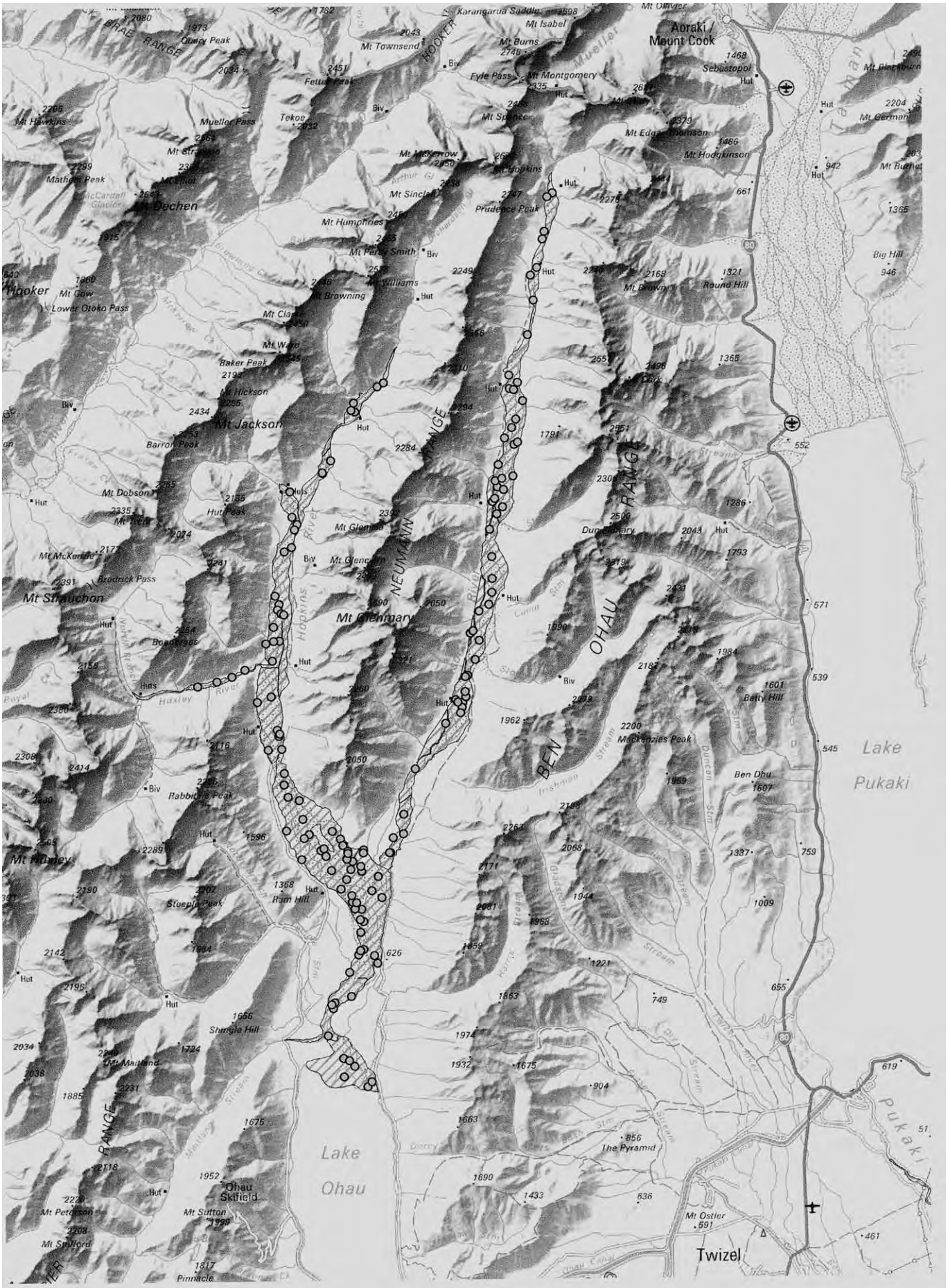
Tasman, Murchison & Cass Rivers



Ahuriri River



Godley & Macaulay Rivers



Hopkins & Dobson Rivers

Appendix 2: Species present and frequency of occurrence in plots. Exotic plants are marked with an asterisk (*).

CODE		GENUS	SPECIES	COMMON NAME	FAMILY	GROUP	# PLOTS	%
ACA	INE	*Acaena*	*inermis*	scarlet bidibidi	Rosaceae	Vascular plant	103	14.0
ACA	SAC	*Acaena*	*saccaticupula*	long-stalked bidibidi	Rosaceae	Vascular plant	22	3.0
ACA	FIS	*Acaena*	*fissistipula*	divided stipule	Rosaceae	Vascular plant	16	2.2
ACA	ENA	*Acaena*	species	bidibidi	Rosaceae	Vascular plant	14	1.9
ACA	CAE	*Acaena*	*caesiiglauca*	blueish bidibidi	Rosaceae	Vascular plant	5	0.7
*ACH	MIL	*Achillea*	*millefolium*	yarrow	Asteraceae	Vascular plant	73	9.9
ACI	AUR	*Aciphylla*	*aurea*	golden spaniard	Umbelliferae	Vascular plant	6	0.8
ACI	PHY	*Aciphylla*	species		Umbelliferae	Vascular plant	1	0.1
*AGR	CAP	*Agrostis*	*capillaris*	browntop	Poaceae	Vascular plant	447	60.7
*AGR	STO	*Agrostis*	*stolonifera*	creeping bent	Poaceae	Vascular plant	47	6.4
AGR	MUE	*Agrostis*	*muelleriana*		Poaceae	Vascular plant	3	0.4
AGR	PET	*Agrostis*	*petriei*	reddish agrostis	Poaceae	Vascular plant	3	0.4
AGR	MAG	*Agrostis*	*magellanica*		Poaceae	Vascular plant	1	0.1
*AIR	CAR	*Aira*	*caryophyllea*	hairgrass	Poaceae	Vascular plant	194	26.3
*ALN	GLU	*Alnus*	*glutinosa*	alder	Betulaceae	Vascular plant	2	0.3
*ALO	GEN	*Alopecurus*	*geniculatus*	marsh foxtail	Poaceae	Vascular plant	5	0.7
*ANA	ARV	*Anagallis*	*arvensis*	scarlet pimpernel	Primulaceae	Vascular plant	2	0.3
ANI	ARO	*Anisotome*	*aromatica*	kopoti	Apiaceae	Vascular plant	18	2.4
ANT	LAM	*Anthoceros*	*laminiferus*			Hornwort	2	0.3
*ANT	ODO	*Anthoxanthum*	*odoratum*	sweet vernal	Poaceae	Vascular plant	426	57.8
*APH	ARV	*Aphanes*	*arvensis*	parsley piert	Rosaceae	Vascular plant	1	0.1
*ARA	THA	*Arabidopsis*	*thaliana*	wall cress	Brassicaceae	Vascular plant	2	0.3
*ARE	SER	*Arenaria*	*serpyllifolia*	sandwort	Caryophyllaceae	Vascular plant	58	7.9
ARI	FRU	*Aristotelia*	*fruticosa*	mountain wineberry	Elaeocarpaceae	Vascular plant	2	0.3
*ARR	ELA	*Arrhenatherum*	*elatius*	tall oat grass	Poaceae	Vascular plant	9	1.2
ASP	RIC	*Asplenium*	*richardii*		Aspleniaceae	Fern	1	0.1
ASP	TRI	*Asplenium*	*trichomanes*	maidenhair spleenwort	Aspleniaceae	Fern	1	0.1
AZO	FIL	*Azolla*	*filiculoides*	floating fern	Azollaceae	Fern	1	0.1
*BAR	INT	*Barbarea*	*intermedia*	winter cress	Brassicaceae	Vascular plant	2	0.3
*BAR	STR	*Barbarea*	*stricta*	stout winter cress	Brassicaceae	Vascular plant	2	0.3
BAR	E	No plants					13	1.8
*BET	PEN	*Betula*	*pendula*	silver birch	Betulaceae	Vascular plant	2	0.3
BLE	PEN	*Blechnum*	*penna-marina*	little hard-fern	Blechnaceae	Fern	26	3.5
BRA	BEL	*Brachyglottis*	*bellidioides*		Asteraceae	Vascular plant	4	0.5
BRA	HAA	*Brachyglottis*	*haastii*	Haast's daisy	Asteraceae	Vascular plant	2	0.3
BRE	PEN	*Breutelia*	*pendula*			Moss	1	0.1
*BRO	TEC	*Bromus*	*tectorum*	barren brome	Poaceae	Vascular plant	81	11.0
*BRO	DIA	*Bromus*	*diandrus*	ripgut brome	Poaceae	Vascular plant	20	2.7
*BRO	HOR	*Bromus*	*hordeaceus*	soft brome	Poaceae	Vascular plant	18	2.4
*BRO	INE	*Bromus*	*inermis*		Poaceae	Vascular plant	1	0.1
*BRO	MOL	*Bromus*	*mollis*		Poaceae	Vascular plant	1	0.1
BRY	BLA	*Bryum*	*blandum*			Moss	1	0.1
BRY	LAE	*Bryum*	*laevigatum*			Moss	1	0.1
BRY	UM	*Bryum*	sp.			Moss	1	0.1
BUL	ANG	*Bulbinella*	*angustifolia*	Maori onion	Liliaceae	Vascular plant	4	0.5
BUL	GIB	*Bulbinella*	*gibbsii*		Liliaceae	Vascular plant	3	0.4
CAL	MNI	*Calyptopogon*	*mnioides*			Moss	3	0.4
CAM	PYP	*Campylopus*	spp.			Moss	24	3.3
CAM	CLA	*Campylopus*	*clavatus*			Moss	1	0.1
CAN	AUR	*Candelariella*	*aurella*			Lichen	44	6.0
CAR	AUS	*Carmichaelia*	cf. *australis*	N.Z. broom	Papilionaceae	Vascular plant	97	13.2
CAR	BRE	*Carex*	*breviculmis*	grassland	Cyperaceae	Vascular plant	60	8.1
CAR	COR	*Carex*	*coriacea*	rautahi	Cyperaceae	Vascular plant	40	5.4
*CAR	OVA	*Carex*	*ovalis*	oval carex	Cyperaceae	Vascular plant	22	3.0
CAR	PTR	*Carmichaelia*	*petriei*	stiff NZ broom	Papilionaceae	Vascular plant	19	2.6
CAR	DEC	*Carex*	*decurtata*	small stiff carex	Cyperaceae	Vascular plant	17	2.3
CAR	BER	*Carex*	*berggrenii*	small red carex	Cyperaceae	Vascular plant	16	2.2
CAR	SIN	*Carex*	*sinclairii*	grassy carex	Cyperaceae	Vascular plant	13	1.8

CAR	GAU	*Carex*	*gaudichaudiana*	short stiff carex	Cyperaceae	Vascular plant	11	1.5
*CAR	NUT	*Carduus*	*nutans*	nodding thistle	Asteraceae	Vascular plant	6	0.8
CAR	DEB	*Cardamine*	*debilis* complex	common cress	Brassicaceae	Vascular plant	5	0.7
CAR	KAL	*Carex*	*kaloides*	red tussock carex	Cyperaceae	Vascular plant	5	0.7
CAR	BUC	*Carex*	*buchananii*	pale carex	Cyperaceae	Vascular plant	4	0.5
CAR	CIR	*Carex*	*cirrhosa*	short curled-tip carex	Cyperaceae	Vascular plant	4	0.5
CAR	COM	*Carex*	*comans*	brown tussock carex	Cyperaceae	Vascular plant	4	0.5
CAR	COL	*Carex*	*colensoi*		Cyperaceae	Vascular plant	3	0.4
CAR	MUE	*Carex*	*muelleri*	Mueller's carex	Cyperaceae	Vascular plant	3	0.4
CAR	SEC	*Carex*	*secta*	makura	Cyperaceae	Vascular plant	3	0.4
CAR	UNI	*Carmichaelia*	*uniflora*	dwarf N.Z. broom	Papilionaceae	Vascular plant	2	0.3
*CAR	DEM	*Carex*	*demissa*	yellow-green carex	Cyperaceae	Vascular plant	2	0.3
CAR	DIA	*Carex*	*diandra*	sward carex	Cyperaceae	Vascular plant	1	0.1
CAR	FLA	*Carex*	*flaviformis*	yellow carex	Cyperaceae	Vascular plant	1	0.1
CAR	INV	*Carex*	*inversa*	Australasian carex	Cyperaceae	Vascular plant	1	0.1
CAR	LAC	*Carex*	*lachenalii*	bipolar carex	Cyperaceae	Vascular plant	1	0.1
CAR	MAO	*Carex*	*maorica*	Maori carex	Cyperaceae	Vascular plant	1	0.1
CAR	PET	*Carex*	*petriei*	long curled-tip carex	Cyperaceae	Vascular plant	1	0.1
CAR	VIR	*Carex*	*virgata*	small tussock carex	Cyperaceae	Vascular plant	1	0.1
CAR	ARB	*Carmichaelia*	*arborea*	South Island broom	Papilionaceae	Vascular plant	1	0.1
CEL	GRA	*Celmisia*	*gracilenta*	grassy celmisia	Asteraceae	Vascular plant	12	1.6
CEL	ANG	*Celmisia*	*angustifolia*	narrow-leaved celmisia	Asteraceae	Vascular plant	7	0.9
CEL	SEM	*Celmisia*	*semicordata*	big mountain daisy	Asteraceae	Vascular plant	2	0.3
CEL	DUR	*Celmisia*	*du-rietzii*	Du Rietz's celmisia	Asteraceae	Vascular plant	1	0.1
CEL	HAA	*Celmisia*	*haastii*		Asteraceae	Vascular plant	1	0.1
CEL	SES	*Celmisia*	*sessiliflora*		Asteraceae	Vascular plant	1	0.1
*CEN	ERY	*Centaurium*	*erythraea*	centaury	Gentianaceae	Vascular plant	49	6.6
CER	PUR	*Ceratodon*	*purpureus*			Moss	55	7.5
*CER	FON	*Cerastium*	*fontanum*	mouse-ear chickweed	Caryophyllaceae	Vascular plant	285	38.7
CHI	LOS	*Chiloscyphus*	sp.			Liverwort	3	0.4
CHI	RIG	*Chionochloa*	*rigida*	stiff snowgrass	Poaceae	Vascular plant	5	0.7
CHI	RUB	*Chionochloa*	*rubra*	red tussock	Poaceae	Vascular plant	5	0.7
CHI	PAL	*Chionochloa*	*pallens*	mid-ribbed snowgrass	Poaceae	Vascular plant	1	0.1
CHI	RSC	*Chionochloa*	*rubra* ssp. *cuprea*		Poaceae	Vascular plant	1	0.1
CHI	ONO	*Chionochloa*	*rubra* x *C. rigida*	hybrid snowgrass	Poaceae	Vascular plant	1	0.1
CHO	VIR	*Chondropsis*	*viridis*			Lichen	29	3.9
CHO	SEM	*Chondropsis*	*semiviridis*			Lichen	3	0.4
*CIR	ARV	*Cirsium*	*arvense*	Californian thistle	Asteraceae	Vascular plant	96	13.0
*CIR	VUL	*Cirsium*	*vulgare*	Scots thistle	Asteraceae	Vascular plant	48	6.5
CLA	DON	*Cladonia*	spp.			Lichen	98	13.3
CLA	AGG	*Cladonia*	*aggregata*			Lichen	46	6.2
CLA	CON	*Cladina*	*confusa*			Lichen	7	0.9
CLA	DIA	*Cladia*	species			Lichen	4	0.5
CLA	DIN	*Cladina*	species			Lichen	2	0.3
COL	STR	*Colobanthus*	*strictus*	stiff pincushion	Caryophyllaceae	Vascular plant	170	23.1
COL	ACI	*Colobanthus*	*acicularis*		Caryophyllaceae	Vascular plant	10	1.4
COL	BUC	*Colobanthus*	*buchananii*	pincushion	Caryophyllaceae	Vascular plant	6	0.8
*COL	CAV	*Collomia*	*cavanillesii*	trumpet flower	Polemoniaceae	Vascular plant	4	0.5
COL	BRE	*Colobanthus*	*brevisepalus*	pincushion	Caryophyllaceae	Vascular plant	3	0.4
COL	APE	*Colobanthus*	*apetalus*	lax pincushion	Caryophyllaceae	Vascular plant	2	0.3
CON	PEN	*Conostomum*	*pentastichum*			Moss	1	0.1
CON	VER	*Convolvulus*	*verecundus*	grassland convolvulus	Convolvulaceae	Vascular plant	5	0.7
*CON	MAC	*Conium*	*maculatum*	hemlock	Apiaceae	Vascular plant	1	0.1
COP	ATR	*Coprosma*	*atropurpurea*	bead berry coprosma	Rubiaceae	Vascular plant	93	12.6
COP	ACE	*Coprosma*	*acerosa*	blue berry coprosma	Rubiaceae	Vascular plant	37	5.0
COP	PER	*Coprosma*	*perpusilla*		Rubiaceae	Vascular plant	11	1.5
COP	PET	*Coprosma*	*petriei*	pale blue berry coprosma	Rubiaceae	Vascular plant	7	0.9
COP	PRO	*Coprosma*	*propinqua*	miki miki	Rubiaceae	Vascular plant	4	0.5
COP	RIG	*Coprosma*	*rigida*		Rubiaceae	Vascular plant	2	0.3
COR	SAR	*Coriaria*	*sarmentosa*	tutu	Coriariaceae	Vascular plant	28	3.8
COR	ANG	*Coriaria*	*angustissima*	narrow-leaved tutu	Coriariaceae	Vascular plant	10	1.4
COR	PLU	*Coriaria*	*plumosa*	tutu	Coriariaceae	Vascular plant	10	1.4

COR	SXP	*Coriaria*	*sarmentosa* x *Coriaria*. sp. aff. *plumosa*	small hybrid tutu	Coriariaceae	Vascular plant	2	0.3
COR	IAR	*Coriaria*	species	tutu	Coriariaceae	Vascular plant	2	0.3
COR	RIC	*Cortaderia*	*richardii*	toitoi	Cortaderiinae	Vascular plant	2	0.3
COR	AXS	*Coriaria*	*sarmentosa* x *Coriaria angustissima*	small hybrid tutu	Coriariaceae	Vascular plant	1	0.1
CRA	INC	*Craspedia*	*incana*	woolly-head	Asteraceae	Vascular plant	21	2.8
CRA	SPE	*Craspedia*	species	woolly-head	Asteraceae	Vascular plant	3	0.4
CRA	LAN	*Craspedia*	sp. cf. *lanata*	woolly-head	Asteraceae	Vascular plant	2	0.3
CRA	UNI	*Craspedia*	*uniflora*	complex woolly-head	Asteraceae	Vascular plant	1	0.1
CRA	SIE	*Crassula*	*sieberiana*	reddish succulent	Crassulaceae	Vascular plant	1	0.1
CRA	SIN	*Crassula*	*sinclairii*	tiny succulent	Crassulaceae	Vascular plant	1	0.1
CRE	CAP	*Crepis*	*capillaris*	smooth hawksbeard	Asteraceae	Vascular plant	137	18.6
*CUS	EPI	*Cuscuta*	*epithymum*	dodder (parasite)	Convolvulaceae	Vascular plant	14	1.9
*CYN	CRI	*Cynosurus*	*cristatus*	crested dogstail	Poaceae	Vascular plant	9	1.2
*CYT	SCO	*Cytisus*	*scoparius*	broom	Papilionaceae	Vascular plant	22	3.0
*DAC	GLO	*Dactylis*	*glomerata*	cocksfoot	Poaceae	Vascular plant	42	5.7
DER	LUR	*Dermatocarpon*	*luridum*			Lichen	1	0.1
DES	CAE	*Deschampsia*	*caespitosa*	tufted hairgrass	Poaceae	Vascular plant	2	0.3
DEY	YOU	*Deyeuxia*	*youngii*	stiff-head grass	Poaceae	Vascular plant	3	0.4
DEY	AVE	*Deyeuxia*	*avenoides*	small stiff-head grass	Poaceae	Vascular plant	2	0.3
*DIA	ARM	*Dianthus*	*armeria*	Deptford pink	Caryophyllaceae	Vascular plant	65	8.8
DIC	CRI	*Dichelachne*	*crinita*	floating sweet grass	Agrostidinae	Vascular plant	1	0.1
DIC	REP	*Dichondra*	*repens*	Mercury Bay weed	Convolvulaceae	Vascular plant	1	0.1
*DIG	PUR	*Digitalis*	*purpurea*	foxglove	Scrophulariaceae	Vascular plant	5	0.7
DIS	TOU	*Discaria*	*toumatou*	matagouri	Rhamnaceae	Vascular plant	138	18.7
DIT	RIC	*Ditrichum*	spp.			Moss	3	0.4
DRA	UNI	*Dracophyllum*	*uniflorum*	turpentine bush Dracophyllum	Epacridaceae	Vascular plant	6	0.8
DRA	KIR	*Dracophyllum*	*kirkii*		Epacridaceae	Vascular plant	1	0.1
DRA	LON	*Dracophyllum*	*longifolium*	inaka	Epacridaceae	Vascular plant	1	0.1
DRE	ADU	*Drepanocladus*	*aduncus*			Moss	11	1.5
*ECH	VUL	*Echium*	*vulgare*	vipers bugloss	Boraginaceae	Vascular plant	113	15.3
ELE	ACU	*Eleocharis*	*acuta*	club sedge	Cyperaceae	Vascular plant	13	1.8
ELE	GRA	*Eleocharis*	*gracilis*	small club sedge	Cyperaceae	Vascular plant	4	0.5
ELY	SOL	*Elymus*	*solandri*	bluegrass	Poaceae	Vascular plant	136	18.5
*ELY	REP	*Elytrigia*	*repens*	couch grass	Poaceae	Vascular plant	3	0.4
ELY	REC	*Elymus*	*rectisetus*	bluegrass	Poaceae	Vascular plant	1	0.1
EPI	MEL	*Epilobium*	*melanocaulon*	black-stem willowherb	Onagraceae	Vascular plant	392	53.2
EPI	MIC	*Epilobium*	*microphyllum*	small-leaved willowherb	Onagraceae	Vascular plant	333	45.2
EPI	ROS	*Epilobium*	*rostratum*	beaked willowherb	Onagraceae	Vascular plant	98	13.3
EPI	BRU	*Epilobium*	*brunnescens*	brownish willowherb	Onagraceae	Vascular plant	54	7.3
EPI	KOM	*Epilobium*	*komarovianum*	wrinkly leaf willowherb	Onagraceae	Vascular plant	46	6.2
*EPI	CIL	*Epilobium*	*ciliatum*	swamp willowherb	Onagraceae	Vascular plant	10	1.4
EPI	TEN	*Epilobium*	*alsinoides* subsp. *tenuipes*	willowherb	Onagraceae	Vascular plant	4	0.5
EPI	LOB	*Epilobium*	species	willowherb	Onagraceae	Vascular plant	3	0.4
EPI	CHI	*Epilobium*	*chionanthum*	snowy willowherb	Onagraceae	Vascular plant	2	0.3
EPI	GLA	*Epilobium*	sp. cf. *glabellum*	reddish willow herb	Onagraceae	Vascular plant	2	0.3
EPI	PAL	*Epilobium*	*pallidiflorum*	marsh willowherb	Onagraceae	Vascular plant	1	0.1
*ERO	CIC	*Erodium*	*cicutarium*	storks bill	Geraniaceae	Vascular plant	17	2.3
*ESC	CAL	*Escholzia*	*californica*	California poppy	Papaveraceae	Vascular plant	22	3.0
EUC	AUD	*Euchiton*	*audax*	grey cudweed	Asteraceae	Vascular plant	3	0.4
EUC	TRA	*Euchiton*	sp. cf. *traversii*	woolly cudweed	Asteraceae	Vascular plant	3	0.4
EUP	ZEL	*Euphrasia*	*zelandica*		Scrophulariaceae	Vascular plant	5	0.7
FES	RUB	*Festuca*	*rubra*		Poaceae	Vascular plant	310	42.1
FES	NOV	*Festuca*	*novae-zelandiae*	hard tussock	Poaceae	Vascular plant	99	13.4
FES	MAT	*Festuca*	*matthewsii*	small blue fescue	Poaceae	Vascular plant	9	1.2
*FES	COM	*Festuca*	*rubra* var. *commutata*	red fescue	Poaceae	Vascular plant	6	0.8
FES	TUC	*Festuca*	species		Poaceae	Vascular plant	3	0.4
FOS	SOM	*Fossombronia*	sp.			Liverwort	1	0.1
FRU	SOL	*Frullania*	*solanderiana*			Moss	1	0.1
GAL	APA	*Galium*	*aparine*		Rubiaceae	Vascular plant	11	1.5

GAL	PER	Galium	*perpusillum*	pygmy bedstraw	Rubiaceae	Vascular plant	9	1.2
GAL	PRO	*Galium*	*propinquum*		Rubiaceae	Vascular plant	1	0.1
GAU	CRA	*Gaultheria*	*crassa*	thick-leaved snowberry	Ericaceae	Vascular plant	17	2.3
GAU	DEP	*Gaultheria*	*depressa*	snow berry	Ericaceae	Vascular plant	11	1.5
GEN	COR	*Gentiana*	*corymbifera*		Gentianaceae	Vascular plant	3	0.4
GEN	GRI	*Gentiana*	*grisebachii*	marsh gentian	Gentianaceae	Vascular plant	3	0.4
GER	SES	*Geranium*	*sessiliflorum*	namu namu	Geraniaceae	Vascular plant	99	13.4
GER	DIS	*Geranium*	*dissectum*		Geraniaceae	Vascular plant	1	0.1
GER	MIC	*Geranium*	*microphyllum*		Geraniaceae	Vascular plant	1	0.1
*GER	ANI	*Geranium*	sp. cf. *molle*	dove's foot	Geraniaceae	Vascular plant	1	0.1
GEU	COC	*Geum*	*cockaynei*	NZ avens	Rosaceae	Vascular plant	1	0.1
GIN	DEC	*Gingidia*	*decipiens*	riverbed aniseed	Apiaceae	Vascular plant	13	1.8
GIN	MON	*Gingidia*	*montana*	aniseed	Apiaceae	Vascular plant	3	0.4
*GLY	AQU	*Glyceria*	*aquatica*		Poaceae	Vascular plant	1	0.1
GON	AGG	*Gonocarpus*	*aggregatus*	cutleaf	Haloragaceae	Vascular plant	33	4.5
GON	INC	*Gonocarpus*	*incanus*	sprawling cutleaf	Haloragaceae	Vascular plant	2	0.3
GON	MIC	*Gonocarpus*	*micranthus*	small-flowered cutleaf	Haloragaceae	Vascular plant	2	0.3
GUN	DEN	*Gunnera*	*dentata*	toothed-leaf gunnera	Gunneraceae	Vascular plant	38	5.2
HAE	BAB	*Haematomma*	*babingtonii*			Lichen	1	0.1
HEB	BUC	*Hebe*	*buchananii*	Buchanan's hebe	Scrophulariaceae	Vascular plant	5	0.7
HEB	EPA	*Hebe*	*epacridea*	heath-like hebe	Scrophulariaceae	Vascular plant	5	0.7
HEB	SUB	*Hebe*	*subalpina*	subalpine hebe	Scrophulariaceae	Vascular plant	5	0.7
HEB	ODO	*Hebe*	*odora*		Scrophulariaceae	Vascular plant	3	0.4
HEB	E	*Hebe*	species		Scrophulariaceae	Vascular plant	3	0.4
HEB	SAL	*Hebe*	*salicifolia*		Scrophulariaceae	Vascular plant	2	0.3
HEB	LYC	*Hebe*	*lycopodioides*		Scrophulariaceae	Vascular plant	1	0.1
HEB	PIM	*Hebe*	*pimeleoides*		Scrophulariaceae	Vascular plant	1	0.1
HEL	DEP	*Helichrysum*	*depressum*	sticks	Asteraceae	Vascular plant	119	16.1
HEL	FIL	*Helichrysum*	*filicaule*	slender everlasting daisy	Asteraceae	Vascular plant	33	4.5
HEL	BEL	*Helichrysum*	*bellidioides*	everlasting daisy	Asteraceae	Vascular plant	7	0.9
HEL	INT	*Helichrysum*	*intermedium*	cliff sungold	Asteraceae	Vascular plant	3	0.4
*HIE	PIL	*Hieracium*	*pilosella*	mouse ear hawkweed	Asteraceae	Vascular plant	445	60.4
*HIE	PRA	*Hieracium*	*praealtum*	king devil hawkweed	Asteraceae	Vascular plant	307	41.7
*HIE	LEP	*Hieracium*	*lepidulum*	tussock hawkweed	Asteraceae	Vascular plant	11	1.5
*HOL	LAN	*Holcus*	*lanatus*	Yorkshire fog grass	Poaceae	Vascular plant	375	50.9
*HOR	MUR	*Hordeum*	*murinum*	barley grass	Poaceae	Vascular plant	1	0.1
HYD	NOV	*Hydrocotyle*	*novae-zelandiae*	N.Z. pennywort	Apiaceae	Vascular plant	97	13.2
HYD	NZM	*Hydrocotyle*	*novae-zelandiae* var. *montana*		Apiaceae	Vascular plant	19	2.6
HYD	SUL	*Hydrocotyle*	*sulcata*	trifoliate pennywort	Apiaceae	Vascular plant	14	1.9
HYP	CUP	*Hypnum*	*cupressiforme*			Moss	55	7.5
*HYP	RAD	*Hypochoeris*	*radicata*	cats ear	Asteraceae	Vascular plant	213	28.9
*HYP	PER	*Hypericum*	*perforatum*	St John's wort	Clusiaceae	Vascular plant	208	28.2
ISO	AUC	*Isolepis*	*aucklandica*	dark-fruit spike sedge	Cyperaceae	Vascular plant	24	3.3
ISO	CAL	*Isolepis*	*caligenis*	tufted pike sedge	Cyperaceae	Vascular plant	3	0.4
ISO	BAS	*Isolepis*	*basilaris*	short-stem pike sedge	Cyperaceae	Vascular plant	2	0.3
*ISO	SET	*Isolepis*	*setacea*	two-head club sedge	Cyperaceae	Vascular plant	2	0.3
ISO	LEP	*Isolepis*	species		Cyperaceae	Vascular plant	1	0.1
*JUN	ART	*Juncus*	*articulatus*	jointed rush	Juncaceae	Vascular plant	82	11.1
*JUN	TEN	*Juncus*	*tenuis*	slender rush	Juncaceae	Vascular plant	47	6.4
*JUN	BUF	*Juncus*	*bufonius*	toad rush	Juncaceae	Vascular plant	42	5.7
*JUN	EFF	*Juncus*	*effusus*	soft rush	Juncaceae	Vascular plant	38	5.2
JUN	NOV	*Juncus*	*novae-zelandiae*	small rush	Juncaceae	Vascular plant	18	2.4
*JUN	CON	*Juncus*	*conglomeratus*	clustered rush	Juncaceae	Vascular plant	6	0.8
JUN	PUS	*Juncus*	*pusillus*	tiny rush	Juncaceae	Vascular plant	4	0.5
*JUN	CAN	*Juncus*	*canadensis*	Canadian rush	Juncaceae	Vascular plant	1	0.1
JUN	CUS	*Juncus*	species		Juncaceae	Vascular plant	1	0.1
KEL	DIE	*Kelleria*	*dieffenbachii*	dwarf daphne	Thymelaeaceae	Vascular plant	1	0.1
LAC	LYA	*Lachnagrostis*	*lyallii*	fine wind grass	Poaceae	Vascular plant	155	21.0
LAC	HNA	*Lachnagrostis*	species		Poaceae	Vascular plant	1	0.1
LAC	STR	*Lachnagrostis*	*striata*	purple windgrass	Poaceae	Vascular plant	1	0.1
LAG	PET	*Lagenifera*	*petiolata*	little daisy	Asteraceae	Vascular plant	3	0.4
LAG	CUN	*Lagenifera*	*cuneata*		Asteraceae	Vascular plant	1	0.1

*LAR	DEC	*Larix*	*decidua*	larch	Pinaceae	Conifer	2	0.3
LEC	BLA	*Lecanora*	*blanda*			Lichen	2	0.3
LEP	PUS	*Leptinella*	*pusilla*	dwarf bachelor's button	Asteraceae	Vascular plant	52	7.1
LEP	SER	*Leptinella*	*serrulata*	hairy bachelor's button	Asteraceae	Vascular plant	11	1.5
LEP	TIN	*Leptinella*	species		Asteraceae	Vascular plant	1	0.1
LEP	SCO	*Leptospermum*	*scoparium*	manuka	Myrtaceae	Vascular plant	1	0.1
LEU	FRA	*Leucopogon*	*fraseri*	patotara	Epacridaceae	Vascular plant	147	19.9
*LEU	VUL	*Leucanthemum*	*vulgare*	dog daisy	Asteraceae	Vascular plant	59	8.0
LEU	COL	*Leucopogon*	*colensoi*	red heath	Epacridaceae	Vascular plant	1	0.1
*LIN	CAT	*Linum*	*catharticum*	purging flax	Linaceae	Vascular plant	169	22.9
LIN	MON	*Linum*	*monogynum*		Linaceae	Vascular plant	2	0.3
*LIN	PUR	*Linaria*	*purpurea*	purple linaria	Scrophulariaceae	Vascular plant	1	0.1
*LOG	MIN	*Logfia*	*minima*	silver cudweed	Asteraceae	Vascular plant	14	1.9
*LOL	PER	*Lolium*	*perenne*	perennial ryegrass	Poaceae	Vascular plant	1	0.1
*LOT	PED	*Lotus*	*pedunculatus*	lotus	Papilionaceae	Vascular plant	49	6.6
*LOT	COR	*Lotus*	*corniculatus*	lotus	Papilionaceae	Vascular plant	6	0.8
*LUP	POL	*Lupinus*	*polyphyllus*	lupin	Papilionaceae	Vascular plant	52	7.1
LUZ	ALB	*Luzula*	*rufa* var. *albicomans*	hairy red woodrush	Juncaceae	Vascular plant	216	29.3
LUZ	CEL	*Luzula*	*celata*	dwarf woodrush	Juncaceae	Vascular plant	102	13.8
LUZ	RUF	*Luzula*	*rufa* var. *rufa*	red woodrush	Juncaceae	Vascular plant	61	8.3
LUZ	PIC	*Luzula*	*picta* var. *picta*	fine-stemmed woodrush	Juncaceae	Vascular plant	3	0.4
LUZ	ULA	*Luzula*	species		Juncaceae	Vascular plant	3	0.4
LUZ	TRA	*Luzula*	*traversii*	Traver's woodrush	Juncaceae	Vascular plant	2	0.3
LUZ	PUM	*Luzula*	*pumila*	dwarf woodrush	Juncaceae	Vascular plant	1	0.1
LYC	AUS	*Lycopodium*	*australianum*	stiff lycopodium	Lycopodiaceae	Lycopod	4	0.5
LYC	FAS	*Lycopodium*	*fastigiatum*		Lycopodiaceae	Lycopod	1	0.1
*MAL	DOM	*Malus*	x *domestica*	apple	Rosaceae	Vascular plant	1	0.1
*MAL	NEG	*Malva*	*neglecta*	common mallow	Malvaceae	Vascular plant	1	0.1
MAR	CHA	*Marchantia*	sp.			Liverwort	6	0.8
MAR	BER	*Marchantia*	*berteroana*			Liverwort	1	0.1
*MAR	VUL	*Marrubium*	*vulgare*	horehound	Lamiaceae	Vascular plant	1	0.1
MEL	ANE	*Melanelia*	sp.			Lichen	2	0.3
MEL	CAL	*Melanelia*	*calva*			Lichen	1	0.1
MEL	ALP	*Melicytus*	*alpinus*	wharekarara	Violaceae	Vascular plant	13	1.8
*MEL	ALB	*Melilotus*	*alba*	sweet melilot	Papilionaceae	Vascular plant	9	1.2
*MEL	OFF	*Melilotus*	*officinalis*	yellow sweet melilot	Papilionaceae	Vascular plant	2	0.3
*MEL	IND	*Melilotus*	*indicus*		Papilionaceae	Vascular plant	1	0.1
*MEN	SPI	*Mentha*	*spicata*	spearmint	Lamiaceae	Vascular plant	2	0.3
MEN	CUN	*Mentha*	*cunninghamii*	N.Z. mint	Lamiaceae	Vascular plant	1	0.1
MIC	UNI	*Microtis*	*uniflora*		Orchidaceae	Vascular plant	22	3.0
MIC	SCA	*Microseris*	*scapigera*	false dandelion	Asteraceae	Vascular plant	6	0.8
MIC	OLI	*Microtis*	*oligantha*		Orchidaceae	Vascular plant	2	0.3
*MIM	GUT	*Mimulus*	*guttatus*	monkey musk	Scrophulariaceae	Vascular plant	37	5.0
*MIM	MOS	*Mimulus*	*moschatus*	musk	Scrophulariaceae	Vascular plant	4	0.5
MOS	S	*Montia*	*fontana*	blinks	Portulacaceae	Vascular plant	4	0.5
MUE	AXI	*Muehlenbeckia*	*axillaris*	dwarf pōhuehue	Polygonaceae	Vascular plant	529	71.8
MUE	EPH	*Muehlenbeckia*	*ephedroides*	leafless pōhuehue	Polygonaceae	Vascular plant	21	2.8
MUE	COM	*Muehlenbeckia*	*complexa*	scrub pōhuehue	Polygonaceae	Vascular plant	2	0.3
MYO	UNI	*Myosotis*	*uniflora*	cushion forget-me-not	Boraginaceae	Vascular plant	137	18.6
MYO	LAX	*Myosotis*	*laxa*		Boraginaceae	Vascular plant	28	3.8
*MYO	LSC	*Myosotis*	*laxa* var. *caespitosa*	water forget-me-not	Boraginaceae	Vascular plant	4	0.5
MYO	ARV	*Myosotis*	*arvensis*		Boraginaceae	Vascular plant	2	0.3
MYO	AUS	*Myosotis*	*australis*		Boraginaceae	Vascular plant	2	0.3
MYO	SOT	*Myosotis*	species		Boraginaceae	Vascular plant	1	0.1
MYO	TVC	*Myosotis*	*traversii* var. *cantabrica*	Canterbury forget-me-not	Boraginaceae	Vascular plant	1	0.1
MYO	CAE						1	0.1
MYO	DIS						1	0.1
MYR	TRI	*Myriophyllum*	*triphyllum*	millfoil	Haloragaceae	Vascular plant	4	0.5
MYR	PRO	*Myriophyllum*	*propinquum*	millfoil	Haloragaceae	Vascular plant	2	0.3
*NAR	SQU	*Navaretia*	*squarrosa*	stinkweed	Polemoniaceae	Vascular plant	5	0.7
NEO	ADP	*Neofuscelia*	*adpicta*			Lichen	245	33.2
NEO	FUS	*Neofuscelia*	sp.			Lichen	37	5.0

NEO	AUS	*Neopaxia*	*australasica complex*	N.Z. portulaca	Portulacaceae	Vascular plant	16	2.2
NER	SET	*Nertera*	*setulosa*	ciliate nertera	Rubiaceae	Vascular plant	2	0.3
NER	BAL	*Nertera*	cf. *balfouriana*		Rubiaceae	Vascular plant	1	0.1
NOT	CLI	*Nothofagus*	*menziesii*	Silver beech	Fagaceae	Vascular plant	1	0.1
NOT	MEN	Nothofagus	*solandri* var. *cliffortioides*	mountain beech	Fagaceae	Vascular plant	1	0.1
OLE	BUL	*Olearia*	*bullata*	wrinkled-leaf daisy shrub	Asteraceae	Vascular plant	1	0.1
OLE	NUM	*Olearia*	*nummularifolia*	sticky-leaved olearia	Asteraceae	Vascular plant	1	0.1
OLE	ODO	*Olearia*	*odorata*		Asteraceae	Vascular plant	1	0.1
OPH	COR	*Ophioglossum*	*coriaceum*	adder's tongue	Ophioglossaceae	Fern	3	0.4
ORE	RIG	*Oreomyrrhis*	*rigida*	stiff mountain myrrh	Apiaceae	Vascular plant	6	0.8
ORE	COL	*Oreomyrrhis*	*colensoi*	mountain myrrh	Apiaceae	Vascular plant	3	0.4
ORE	PEC	*Oreobolus*	*pectinatus*	comb sedge	Cyperaceae	Vascular plant	2	0.3
ORE	RAM	*Oreomyrrhis*	*ramosa*		Apiaceae	Vascular plant	1	0.1
*ORO	MIN	*Orobanche*	*minor*	broom rape	Orobanchaceae	Vascular plant	1	0.1
OXA	EXI	*Oxalis*	*exilis*	yellow oxalis	Oxalidaceae	Vascular plant	3	0.4
OZO	LEP	*Ozothamnus*	*leptophylla*		Compositae	Vascular plant	7	0.9
PAR	CHI	*Parmotrema*	*chinense*			Lichen	1	0.1
PAR	DEC	*Parahebe*	*decora*	dainty parahebe	Scrophulariaceae	Vascular plant	27	3.7
*PAR	VIS	*Parentucellia*	*viscosa*	tar weed	Scrophulariaceae	Vascular plant	23	3.1
PAR	LYA	*Parahebe*	*lyallii*	Lyall's parahebe	Scrophulariaceae	Vascular plant	3	0.4
PEL	TIG	*Peltigera*	sp.			Lichen	2	0.3
PER	NAN	*Pernettya*	*nana*	pink dwarf snowberry	Ericaceae	Vascular plant	18	2.4
PHI	TEN	*Philonotis*	*tenuis*			Moss	4	0.5
PHI	PYR	*Philonotis*	*pyriformis*			Moss	2	0.3
*PHL	PRA	*Phleum*	*pratense*	timothy	Agrostidinae	Vascular plant	12	1.6
PIM	CAN	*Pimelea*	*oreophila*	mountain daphne	Thymelaeaceae	Vascular plant	150	20.4
PIM	TRA	*Pimelea*	*traversii*	Traver's daphne	Thymelaeaceae	Vascular plant	8	1.1
PIM	ORE	*Pimelea*	*prostrata* ("Canterbury")	riverbed daphne	Thymelaeaceae	Vascular plant	4	0.5
*PIN	CON	*Pinus*	*contorta*	lodgepole pine	Pinaceae	Conifer	10	1.4
*PIN	US	*Pinus*	species		Pinaceae	Conifer	5	0.7
*PIN	PON	*Pinus*	*ponderosa*		Pinaceae	Conifer	1	0.1
PLA	PER	*Placopsis*	*perrugosa*			Lichen	220	29.9
PLA	COP	*Placopsis*	sp.			Lichen	208	28.2
PLA	TRA	*Placopsis*	*trachyderma*			Lichen	3	0.4
*PLA	LAN	*Plantago*	*lanceolata*	narrow-leaved plantain	Plantaginaceae	Vascular plant	104	14.1
PLA	TRI	*Plantago*	*triandra*	toothed-leaf plantain	Plantaginaceae	Vascular plant	16	2.2
POA	LIN	*Poa*	*lindsayi*	riverbed poa	Poaceae	Vascular plant	375	50.9
POA	CIT	*Poa*	*cita*	silver tussock	Poaceae	Vascular plant	191	25.9
*POA	PRA	*Poa*	*pratensis*	meadow poa	Poaceae	Vascular plant	105	14.2
POA	COL	*Poa*	*colensoi*	blue tussock	Poaceae	Vascular plant	89	12.1
POA	MAN	*Poa*	*maniototo*	dwarf poa	Poaceae	Vascular plant	82	11.1
*POA	ANN	*Poa*	*annua*	annual poa	Poaceae	Vascular plant	12	1.6
POA	BUC	*Poa*	*buchananii*	scree poa	Poaceae	Vascular plant	8	1.1
POA	NOV	*Poa*	*novae-zelandiae*	mountain poa	Poaceae	Vascular plant	8	1.1
POA		*Poa*	species		Poaceae	Vascular plant	2	0.3
POA	BRE	*Poa*	*breviglumis*		Poaceae	Vascular plant	1	0.1
POD	NIV	*Podocarpus*	*nivalis*	snow totara	Podocarpaceae	Conifer	2	0.3
POL	JUN	*Polytrichum*	*juniperinum*			Moss	203	27.5
*POL	PER	*Polygonum*	*persicaria*	willow weed	Polygonaceae	Vascular plant	3	0.4
*POL	AVI	*Polygonum*	*aviculare*		Polygonaceae	Vascular plant	1	0.1
POL	VES	*Polystichum*	*vestitum*	shield fern		Fern	6	0.8
*POP	NIG	*Populus*	*nigra*	poplar	Salicaceae	Vascular plant	4	0.5
*POP	ALB	*Populus*	*alba*	silver poplar	Salicaceae	Vascular plant	3	0.4
POT	ANS	*Potentilla*	*anserinoides*	silverweed	Rosaceae	Vascular plant	8	1.1
*POT	ARG	*Potentilla*	*argentea*	cinquefoil	Rosaceae	Vascular plant	2	0.3
POT	CHE	*Potamogeton*	*cheesemanii*	red pondweed	Potamogetonaceae	Vascular plant	1	0.1
PRA	ANG	*Pratia*	*angulata*	pānakenake	Lobeliaceae	Vascular plant	26	3.5
PRA	COL	*Prasophyllum*	*colensoi*			Vascular plant	14	1.9
*PRU	VUL	*Prunella*	*vulgaris*	self-heal	Lamiaceae	Vascular plant	62	8.4
PSE	JAM	*Pseudocyphellaria*	*jamesii*			Lichen	6	0.8
PSE	ARD	*Pseudocyphellaria*	*ardesiaca*			Lichen	1	0.1

PSE	LUT	*Pseudognaphalium*	*luteoalbum*	woolly cudweed	Asteraceae	Vascular plant	3	0.4
PYR	EXI	*Pyrrhanthera*	*exigua*	pygmy twitch	Poaceae	Vascular plant	2	0.3
RAC	CRI	*Racomitrium*	*crispulum*			Moss	464	63.0
RAC	PRU	*Racomitrium*	*pruinosum*			Moss	297	40.3
RAC	CUR	*Racomitrium*	*curiosissimum*			Moss	10	1.4
RAM	GLA	*Ramalina*	*glaucescens*			Lichen	20	2.7
RAM	ALI	*Ramalina*	sp.			Lichen	8	1.1
RAN	MUL	*Ranunculus*	*multiscapus*	grassland buttercup	Ranunculaceae	Vascular plant	17	2.3
*RAN	REP	*Ranunculus*	*repens*	common buttercup	Ranunculaceae	Vascular plant	13	1.8
RAN	CHE	*Ranunculus*	*cheesemanii*	dwarf buttercup	Ranunculaceae	Vascular plant	9	1.2
RAN	MAC	*Ranunculus*	*maculatus*	chocolate blotch buttercup	Ranunculaceae	Vascular plant	5	0.7
RAN	GLA	*Ranunculus*	*glabrifolius*	small hairless buttercup	Ranunculaceae	Vascular plant	2	0.3
RAN	UNC	*Ranunculus*	species		Ranunculaceae	Vascular plant	2	0.3
*RAN	ACR	*Ranunculus*	*acris*	giant buttercup	Ranunculaceae	Vascular plant	1	0.1
RAN	REF	*Ranunculus*	*reflexus*	hairy buttercup	Ranunculaceae	Vascular plant	1	0.1
RAO	HOO	*Raoulia*	*hookeri*	Hooker's mat daisy, mat daisy	Asteraceae	Vascular plant	377	51.2
RAO	HAA	*Raoulia*	*haastii*	green mat daisy, mat daisy	Asteraceae	Vascular plant	281	38.1
RAO	AUS	*Raoulia*	*australis*	scabweed	Asteraceae	Vascular plant	267	36.2
RAO	TEN	*Raoulia*	*tenuicaulis*	thin-stemmed mat daisy	Asteraceae	Vascular plant	252	34.2
RAO	GLA	*Raoulia*	*glabra*	hairless mat daisy, dat daisy	Asteraceae	Vascular plant	37	5.0
RAO	PAR	*Raoulia*	*parkii*	dryland mat daisy, dat daisy	Asteraceae	Vascular plant	4	0.5
RAO	SUB	*Raoulia*	*subulata*		Asteraceae	Vascular plant	3	0.4
RAO	ULI	*Raoulia*	"black"	moraine mat daisy (species "M")	Asteraceae	Vascular plant	1	0.1
*RES	LUT	*Reseda*	*luteola*	mignonette	Resedaceae	Vascular plant	7	0.9
RHI	GEO	*Rhizocarpon*	*geographicum*			Lichen	102	13.8
RIC	CAR	*Riccardia*	sp.			Liverwort	2	0.3
*ROR	PAL	*Rorippa*	*palustris*	yellow cress	Brassicaceae	Vascular plant	6	0.8
ROR	MIC	*Rorippa*	*microphylla*	watercress	Brassicaceae	Vascular plant	1	0.1
*ROS	RUB	*Rosa*	*rubiginosa*	sweet brier	Rosaceae	Vascular plant	144	19.5
*RUM	ACE	*Rumex*	*acetosella*	sheep sorrel	Polygonaceae	Vascular plant	414	56.2
*RUM	CRI	*Rumex*	*crispus*	curled dock	Polygonaceae	Vascular plant	64	8.7
RUM	FLE	*Rumex*	*flexuosus*	N.Z. dock	Polygonaceae	Vascular plant	6	0.8
RYT	SET	*Rytidosperma*	species		Poaceae	Vascular plant	199	27.0
RYT	BUC	*Rytidosperma*	*buchananii*	black-stripe danthonia	Poaceae	Vascular plant	126	17.1
RYT	PUM	*Rytidosperma*	*setifolium*	needle-leaved danthonia	Poaceae	Vascular plant	25	3.4
RYT	THO	*Rytidosperma*	*thomsonii*	straight-awn danthonia	Poaceae	Vascular plant	8	1.1
RYT	IDO	*Rytidosperma*	*pumilum*	small black-stripe danthonia	Poaceae	Vascular plant	6	0.8
*SAG	APE	*Sagina*	*apetala*	pearlwort	Caryophyllaceae	Vascular plant	136	18.5
*SAL	FRA	*Salix*	*fragilis*	crack willow	Salicaceae	Vascular plant	59	8.0
*SAL	PUR	*Salix*	*purpurea*	purple osier	Salicaceae	Vascular plant	3	0.4
*SAL	ALB	*Salix*	*alba*		Salicaceae	Vascular plant	1	0.1
*SAL	GLA	*Salix*	*glaucophylloides*		Salicaceae	Vascular plant	1	0.1
*SAL	VIM	*Salix*	*viminalis*	osier	Salicaceae	Vascular plant	1	0.1
SAL	IX						1	0.1
*SAN	MIN	*Sanguisorba*	*minor*	sheep's burnet	Rosaceae	Vascular plant	13	1.8
SCH	PAU	*Schoenus*	*pauciflorus*	red sedge	Cyperaceae	Vascular plant	31	4.2
SCH	NIT	*Schizeilema*	*nitens*	false pennywort	Apiaceae	Vascular plant	8	1.1
SCL	UNI	*Scleranthus*	*uniflorus*	orange cushion	Caryophyllaceae	Vascular plant	32	4.3
SCL	BRO	*Scleranthus*	*brockiei*	green cushion	Caryophyllaceae	Vascular plant	10	1.4
*SED	ACR	*Sedum*	*acre*	stonecrop	Crassulaceae	Vascular plant	168	22.8
*SEN	JAC	*Senecio*	*jacobaea*	ragwort	Asteraceae	Vascular plant	55	7.5
SEN	DIS	*Senecio*	*glaucophyllus* subsp. *discoideus*		Asteraceae	Vascular plant	3	0.4
SEN	QUA	*Senecio*	*quadridentatus*	pekapeka	Asteraceae	Vascular plant	2	0.3
*SIL	GAL	*Silene*	*gallica*	catchfly	Caryophyllaceae	Vascular plant	1	0.1
*SIL	VUL	*Silene*	*vulgaris* ssp. *vulgaris*	bladder campion	Caryophyllaceae	Vascular plant	1	0.1
SIP	DEC	*Siphula*	*decumbens*			Lichen	14	1.9
*SOL	DUL	*Solanum*	*dulcamara*	bittersweet	Solanaceae	Vascular plant	1	0.1
SPE	MED	*Spergularia*	*media*		Caryophyllaceae	Vascular plant	26	3.5
*SPE	RUB	*Spergularia*	*rubra*	sand spurrey	Caryophyllaceae	Vascular plant	6	0.8
STE	REO	*Stereocaulon*	sp.			Lichen	2	0.3

STE	GRA	*Stellaria*	*gracilenta*	slender N.Z. chickweed	Caryophyllaceae	Vascular plant	226	30.7
*STE	ALS	*Stellaria*	*alsine*	stitchwort	Caryophyllaceae	Vascular plant	13	1.8
SYN	PRI	*Syntrichia*	*princeps*			Moss	1	0.1
*TAR	OFF	*Taraxacum*	*officinale*	dandelion	Asteraceae	Vascular plant	51	6.9
TAR	MAG	*Taraxacum*	*magellanicum*	tohetaka	Asteraceae	Vascular plant	3	0.4
TEL	VEL	*Teleoschistes*	*velifer*			Lichen	71	9.6
TEP	ATR	*Tephromela*	*atra*			Lichen	1	0.1
TRE	NTE	*Trentepohlia*	species			Algae	24	3.3
TRI	CHS	*Trichostomum*	sp.			Moss	2	0.3
TRI	PAP	*Triquetrella*	*papillata*			Moss	2	0.3
*TRI	REP	*Trifolium*	*repens*	white clover	Papilionaceae	Vascular plant	485	65.8
*TRI	ARV	*Trifolium*	*arvense*	haresfoot trefoil	Papilionaceae	Vascular plant	220	29.9
TRI	TEN	*Trisetum*	*tenellum*	delicate three-awn grass	Poaceae	Vascular plant	166	22.5
*TRI	DUB	*Trifolium*	*dubium*	suckling clover	Papilionaceae	Vascular plant	153	20.8
*TRI	PRA	*Trifolium*	*pratense*	red clover	Papilionaceae	Vascular plant	56	7.6
TRI	LEP	*Trisetum*	*lepidum*	small three-awn grass	Poaceae	Vascular plant	1	0.1
TRI	YOU	*Trisetum*	*youngii*		Poaceae	Vascular plant	1	0.1
*ULE	EUR	*Ulex*	*europaeus*			Vascular plant	19	2.6
UNC	FUS	*Uncinia*	*fuscovaginata*		Cyperaceae	Vascular plant	5	0.7
UNC	DIV	*Uncinia*	*divaricata*	small green hook-sedge	Cyperaceae	Vascular plant	3	0.4
USN	EA	*Usnea*	spp.			Lichen	53	7.2
USN	INE	*Usnea*	*inermis*			Lichen	51	6.9
UTR	MON	*Utricularia*	*monanthos*	bladderwort	Utriculariaceae	Vascular plant	1	0.1
*VER	THA	*Verbascum*	*thapsus*	woolly mullein	Scrophulariaceae	Vascular plant	152	20.6
*VER	VIR	*Verbascum*	*virgatum*		Scrophulariaceae	Vascular plant	13	1.8
*VER	CAT	*Veronica*	*catenata*	pink water speedwell	Scrophulariaceae	Vascular plant	12	1.6
*VER	SER	*Veronica*	*serpyllifolia*	turf speedwell	Scrophulariaceae	Vascular plant	12	1.6
*VER	ANA	*Veronica*	*anagallis-aquatica*		Scrophulariaceae	Vascular plant	9	1.2
VIO	CUN	*Viola*	*cunninghamii*	White violet	Violaceae	Vascular plant	9	1.2
*VIO	TRI	*Viola*	*tricolor*	heartsease	Violaceae	Vascular plant	2	0.3
*VIO	ARV	*Viola*	*arvensis*	field violet	Violaceae	Vascular plant	1	0.1
VIT	AUS	*Vittadinia*	*australis*	N.Z. fuzzweed	Asteraceae	Vascular plant	3	0.4
*VUL	BRO	*Vulpia*	*bromoides*	squirrel tail	Poaceae	Vascular plant	72	9.8
WAH	ALB	*Wahlenbergia*	*albomarginata*	N.Z bluebell	Campanulaceae	Vascular plant	159	21.6
XAN	THO	*Xanthoparmelia*	sp.			Lichen	46	6.2
XAN	GLA	*Xanthoparmelia*	*glareosa*			Lichen	29	3.9
XAN	REP	*Xanthoparmelia*	*reptans*			Lichen	13	1.8
XAN	ELE	*Xanthoria*	*elegans*			Lichen	1	0.1

Appendix 3: Total number of species and number of exotic species recorded in plant families.

FAMILY	# EXOTIC SPECIES	TOTAL # SPECIES
Agrostidinae	1	2
Apiaceae	1	11
Aspleniaceae		2
Asteraceae	13	52
Azollaceae		1
Betulaceae	2	2
Blechnaceae		1
Boraginaceae	3	8
Brassicaceae	4	6
Campanulaceae		1
Caryophyllaceae	8	17
Clusiaceae	1	1
Compositae		2
Convolvulaceae	1	3
Coriariaceae		6
Cortaderiinae		1
Crassulaceae	1	3
Cyperaceae	3	33
Dryopteridaceae		1
Elaeocarpaceae		1
Epacridaceae		5
Ericaceae		3
Fagaceae		2
Gentianaceae	1	3
Geraniaceae	1	5
Gunneraceae		1
Haloragaceae		6
Juncaceae	6	16
Lamiaceae	3	4
Liliaceae		2
Linaceae	1	2
Lobeliaceae		1
Lycopodiaceae		2
Malvaceae	1	1
Myrtaceae		1
Onagraceae	1	11
Ophioglossaceae		1
Orchidaceae		3
Orobanchaceae	1	1
Oxalidaceae		1
Papaveraceae	1	1
Papilionaceae	12	16
Pinaceae	4	4
Plantaginaceae	1	2
Poaceae	23	59
Podocarpaceae		1
Polemoniaceae	2	2
Polygonaceae	4	8
Portulacaceae		1
Potamogetonaceae		1
Primulaceae	1	1
Ranunculaceae	2	8
Resedaceae	1	1
Rhamnaceae		1
Rosaceae	5	12
Rubiaceae	1	11
Salicaceae	8	8
Scrophulariaceae	10	21
Solanaceae	1	1
Thymelaeaceae		4
Umbelliferae		2
Utriculariaceae		1
Violaceae	2	4

Appendix 4 Ordination variance and site-axis correlations

Coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space.

	R SQUARED	
AXIS	INCREMENT	CUMULATIVE
1	0.189	0.189
2	0.743	0.931
3	0.062	0.994

Increment and cumulative R-squared were adjusted for any lack of orthogonality of axes.

AXIS PAIR	R	ORTHOGONALITY % (100/(1-r^2)
1 vs 2	0.171	97.1
1 vs 3	-0.201	96.0
2 vs 3	-0.237	94.4

Site variable correlations

AXIS	1			2			3		
	R	R square	tau	R	R square	tau	R	R square	tau
Aspect	-0.002	0.000	-0.006	-0.007	0.000	-0.008	0.008	0.000	0.014
Slope	0.025	0.001	-0.003	0.035	0.001	-0.004	-0.033	0.001	0.003
Total surface bare rock	0.392	0.154	0.343	0.241	0.058	0.139	0.486	0.236	0.407
Mean fines depth	0.018	0.000	-0.067	-0.396	0.156	-0.152	-0.343	0.118	-0.245
October vapour deficit	-0.175	0.031	-0.120	-0.393	0.155	-0.278	0.330	0.109	0.243
Minimum annual temperature	0.751	0.564	0.403	0.470	0.221	0.198	-0.447	0.200	-0.222
Water balance ratio	0.419	0.176	0.291	0.644	0.415	0.494	-0.387	0.150	-0.311
Mean annual temperature	-0.351	0.123	-0.240	-0.524	0.274	-0.390	0.405	0.164	0.299
Average annual solar radiation	0.385	0.148	0.250	0.152	0.023	0.076	-0.125	0.016	-0.050
Winter solar radiation	0.442	0.196	0.252	0.527	0.277	0.341	-0.276	0.076	-0.160
Water deficit	-0.680	0.463	-0.400	-0.594	0.353	-0.467	0.483	0.233	0.321

Appendix 5: Threatened species recorded in plots and their frequency of occurrence in different river systems.

	THREAT CLASS	AHURIRI	OHAU	TEKAPO	PUKAKI	HOPKINS	DOBSON	CASS	TASMAN	GODLEY	MURCHISON	TOTAL # PLOTS
Carex berggrenii	at risk	1				4	2	3		6		16
Carex decurtata	at risk									17		17
Carex lachenalii subsp. *parkeri*	at risk									1		1
Carex muellerii	at risk							1		2		3
Convolvulus verecundus	at risk		2	3								5
Deyeuxia youngii	at risk							2			1	3
Muehlenbeckia ephedroides	at risk	1	4	15	1							21
Ranunculus maculatus	at risk	1				2		1	1			5
Raoulia species *M*	at risk							1				1
Carex cirrhosa	chronically threatened	1						1	1	1		4
Deschampsia cespitosa	chronically threatened	1				1						2
Epilobium chionanthum	chronically threatened	1				1						2
Isolepis basilaris	chronically threatened								2			2
Leptinella serrulata	chronically threatened					3	3	1	2	2		11
Luzula celata	chronically threatened					14	8		57	23		102
Colobanthus brevisepalus	data deficient		1	2								3
Myosotis uniflora	data deficient		2			13	5	9	39	51	18	137
Vittadinia australis	data deficient		1	1							1	3
Total number of threatened species		8	4	3	1	7	4	8	6	8	3	18
Total number of threatened species occurrences		8	8	20	1	38	18	19	102	103	20	327

Appendix 6. Means and standard errors of selected site variables and floodplain development stage.

Floodplain development stage	Number of species			% exotic species		Mean depth of surface fines (cm)		Bare rock cover (%)		Lichen cover (%)		Moss Cover (%)		Vascular plant cover (%)	
	Count	Mean	Standard error of mean	Mean	Standard error of mean	Mean	Standard error of mean	Mean	Standard error of mean	Mean	Standard error of mean	Mean	Standard error of mean	Mean	Standard error of mean
1	244	14	1	39.24%	1.73%	2	0	96	1	1	0	1	0	3	0
2	213	29	1	35.58%	1.48%	3	0	69	2	6	1	4	1	19	1
3	138	34	1	41.85%	1.85%	5	0	21	2	12	1	16	2	48	2
4	52	32	1	49.33%	3.38%	12	1	9	3	3	1	11	3	73	4
5	34	28	1	56.52%	3.31%	18	2	3	2	1	0	3	1	82	4
6	43	28	2	45.97%	3.56%	13	2	7	2	8	3	13	4	65	6

Appendix 7 Floodplain development stage indicator species

Genus	Species	Max grp	1 (N=257)	2 (N=213)	3 (N=138)	4 (N=52)	5 (N=34)	6 (N=43)	Indicator value	Mean	S. dev	p *
BAR	E	1	100	0	0	0	0	0	5.1	1.6	1.07	0.0192
EPI	MEL	2	28	50	16	4	0	3	40.4	11.9	1.61	0.0002
POA	LIN	2	24	40	22	8	0	6	32.1	11.3	1.52	0.0002
EPI	MIC	2	33	38	19	3	2	4	25.1	10.4	1.57	0.0002
RAO	HAA	2	10	39	30	12	2	7	25	9.3	1.67	0.0002
RAO	HOO	2	22	34	22	10	5	8	23.8	11.5	1.55	0.0002
RAO	TEN	2	19	45	26	8	1	0	23.5	8.6	1.68	0.0002
PLA	COP	2	6	40	36	8	1	9	20.5	7.5	1.64	0.0002
LAC	LYA	2	16	49	23	8	3	0	19.9	6.1	1.56	0.0002
MYO	UNI	2	12	45	19	10	3	10	16.4	5.6	1.48	0.0004
STE	GRA	2	11	32	29	8	4	16	15.8	7.9	1.62	0.0014
HEL	DEP	2	11	42	20	20	0	7	12.7	5.1	1.5	0.0014
EPI	ROS	2	9	43	33	3	0	11	11.2	4.5	1.39	0.0022
NEO	ADP	3	1	20	40	15	6	17	28.2	8.5	1.63	0.0002
RAC	CRI	3	8	21	33	19	6	13	27.9	13.4	1.53	0.0002
PLA	PER	3	3	21	36	16	6	17	20.2	7.8	1.62	0.0002
RAO	AUS	3	5	22	32	18	8	15	19.2	9	1.69	0.0002
RAC	PRU	3	5	16	31	20	4	24	18.7	9.9	1.76	0.001
MUE	AXI	3	9	17	23	21	14	17	18.2	14.7	1.42	0.0236
SED	ACR	3	5	17	42	18	10	8	18.1	6.5	1.56	0.0002
PIM	CAN	3	1	15	36	24	5	18	17	6	1.54	0.0002
COL	STR	3	7	34	40	7	3	10	17	6.5	1.56	0.0002
TRI	TEN	3	9	33	39	12	0	8	15.7	6.3	1.52	0.0004
CLA	DON	3	1	7	39	17	8	29	15.4	4.5	1.46	0.0004
TRI	ARV	3	5	17	30	21	16	11	14.6	7.9	1.67	0.0036
POL	JUN	3	5	18	28	20	15	15	13.5	7.3	1.55	0.0044
LUZ	ALB	3	5	28	29	14	5	19	13.5	7.7	1.59	0.0054
HYP	PER	3	6	15	28	22	17	12	12.2	7.6	1.68	0.0202
RYT	SET	3	6	26	30	19	7	12	12.1	7.3	1.65	0.0168
AIR	CAR	3	7	20	28	23	12	10	12	7.2	1.65	0.0162
POA	MAN	3	4	22	42	14	4	13	10.3	4	1.39	0.0034
FES	NOV	4	1	1	14	35	15	34	14.3	4.6	1.5	0.0006
COP	ATR	4	1	10	21	36	18	13	13.3	4.4	1.44	0.0008
LIN	CAT	4	2	7	24	28	18	21	13	6.6	1.62	0.0046
TRI	DUB	4	4	11	16	30	16	23	12.9	6.1	1.65	0.0042
CRE	CAP	4	5	8	13	26	22	26	11.7	5.7	1.56	0.0068
GAU	CRA	4	0	6	12	82	0	0	11	1.9	1.13	0.0002
POA	COL	4	1	5	23	35	8	27	10.1	4.4	1.49	0.0062

WAH	ALB	4	2	11	21	24	19	23	9.7	6.2	1.53	0.032
ELY	SOL	4	4	17	23	29	20	7	9.6	5.6	1.54	0.0276
ANT	ODO	5	3	6	16	22	29	24	25.3	12.8	1.7	0.0002
FES	RUB	5	3	7	17	23	29	20	21.4	10.1	1.7	0.0002
AGR	CAP	5	4	7	15	23	25	25	19.3	13.4	1.72	0.006
HOL	LAN	5	5	10	15	23	26	22	19.2	11.6	1.7	0.0018
HYP	RAD	5	3	11	15	20	32	20	18.7	7.6	1.59	0.0002
RAN	MUL	5	0	1	6	3	66	24	17.4	1.8	1.11	0.0002
CAR	OVA	5	1	4	4	30	57	4	15.1	2	1.09	0.0002
HIE	PRA	5	3	13	18	20	23	23	15	10	1.7	0.0146
JUN	EFF	5	0	2	10	29	44	16	14.3	2.6	1.23	0.0002
TRI	PRA	5	1	4	7	19	41	30	14.3	3.3	1.36	0.0004
GON	AGG	5	0	0	5	19	40	36	13.1	2.5	1.21	0.0002
HYD	NOV	5	2	7	11	22	32	25	12.3	4.5	1.48	0.0022
CAR	SIN	5	0	0	5	17	67	11	11.8	1.7	1.06	0.0002
HEL	FIL	5	1	1	7	26	44	22	11.6	2.4	1.2	0.0004
SCH	PAU	5	0	2	3	40	44	11	11.6	2.4	1.22	0.0006
SAL	FRA	5	4	5	17	9	47	18	11	3.4	1.38	0.002
PRU	VUL	5	2	7	10	21	37	24	10.8	3.5	1.37	0.0012
PLA	LAN	5	3	9	16	19	31	22	10	4.7	1.49	0.0094
HIE	PIL	6	5	11	22	20	18	24	19.5	13	1.55	0.002
RUM	ACE	6	7	14	22	18	12	27	19	12.3	1.58	0.003
CER	FON	6	9	9	9	22	24	26	15.8	9.4	1.67	0.006
ROS	RUB	6	2	5	22	16	23	32	15	5.9	1.64	0.0012
LEU	FRA	6	1	7	21	23	20	27	12.1	5.9	1.58	0.0066
DIS	TOU	6	1	9	19	21	19	31	11.4	5.9	1.68	0.0116
CAR	COR	6	1	1	4	29	23	43	11.1	2.7	1.25	0.0006
BLE	PEN	6	7	15	2	9	0	68	11	2.1	1.14	0.0004
RHI	GEO	6	1	7	28	26	7	32	10.4	4.6	1.41	0.0052
TEL	VEL	6	1	5	20	14	29	31	10.1	3.8	1.42	0.0046