Vegetation changes without grazing, Flat Top Hill, Central Otago

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Abstract

Permanent monitoring sites in Flat Top Hill Conservation Area in Central Otago were resurveyed in the spring of 1997, following a four-year interval in which rabbit numbers had been very low, and stock absent.

All study sites showed considerable vegetation change between 1993 and 1997. The most significant changes in the vegetation were large increases in overall vascular species richness and diversity, and particularly increases in the richness and abundance of exotic species. Exotic grasses (mainly *Anthoxanthum odoratum*, but also *Aira caryophyllea, Dactylis glomerata* and *Holcus lanatus* in particular communities) have increased dramatically, but there were also significant increases in native grasses *(Dichelachne crinita*, three *Elymus* species, *Festuca novae-zelandiae, Poa cita* and *Rytidosperma clavatum).* The woody exotic species *Thymus vulgaris* and *Rosa rubiginosa* increased significantly, but *Sedum acre* decreased markedly in abundance from 1993 to 1997.

Native species characteristic of `scabweed communities' in the driest habitats on Flat Top Hill (particularly *Raoulia australis* and *Poa maniototo*, but also *Colobanthus brevisepalus, Poa lindsayi, Raoulia beauverdii, Rytidosperma buchananii* and *Rytidosperma thomsonii)* have decreased in abundance and/or distribution over the four years. The three native ephemeral species recorded on Flat Top Hill in September 1993 *(Ceratocephalus pungens, Myosotis pygmaea* var. *minutiflora* and *Myosurus minimus* ssp. *novae-zelandiae)* all decreased in abundance from 1993 to 1997. Only *Myosotis pygmaea* var. *minutiflora* was recorded in study sites in September 1997. *Myosurtis minimus* ssp. *novae-zelandiae* was still present in the Conservation Area, but *Ceratocephalus pungens* was not found despite searches of previously known locations. Probably, the decrease in native ephemerals, and of the perennial native species characteristic of scabweed communities, is due to the increase of exotic grasses in the previously sparsely vegetated habitats preferred by these species.

Two different management regimes in different parts of Flat Top Hill Conservation Area are recommended to maintain the key conservation values of the area. If populations of native ephemeral species are to be maintained on Flat Top Hill, it is suggested that grazing be reintroduced in two peripheral areas, the low ridge west of Butchers Creek, and the gravel fan east of Butchers Dam. It is recommended that remainder of the conservation area should presently remain securely rabbit-fenced and free of stock, and that low rabbit numbers are maintained. There is an immediate and ongoing requirement for the control of *Rosa rubiginosa* and *Lupinus arboreus*, particularly east of the main ridge. The effects of management should be reappraised following vegetation monitoring at regular intervals in the future.

1. Introduction

Flat Top Hill is a flat-crested foothill of the Old Man Range in Central Otago, situated approximately 10 km to the south of Alexandra, to the east of State Highway 8. The hill is elongated from north to south, and lies between Lake Roxburgh in the east and Butchers Creek in the west. The northern half of Flat Top Hill, together with a low ridge between Butchers Creek and State Highway 8, was acquired by the Department of Conservation in 1992.

The acquisition of Flat Top Hill by the Department of Conservation was preceded by approximately 140 years of pastoral land use, over which time the area was grazed by sheep and (after c. 1870) by rabbits. In 1992, the conservation area was destocked, and control operations considerably reduced the numbers of rabbits. At this time, the flora and vegetation of the `dry core' of Central Otago had been little described, and it was not known how the semi-arid vegetation might change following the sudden removal of the continuous grazing regime. Flat Top Hill provided an opportunity both to describe the vegetation, and to monitor post-pastoral change in the driest part of New Zealand.

The natural values of the soils and vegetation of Flat Top Hill were first described by Johnson & Hewitt (1991). Subsequently, a detailed study of the vegetation was carried out in the conservation area in 1993 and 1994 (Walker 1994, Walker *et al.* 1995). In the course of the latter study, 118 permanent monitoring sites were established in the reserve. These permanent sites are distributed so as to include the great majority of habitats and plant communities present, and were initially surveyed three times, in autumn (March) and spring (September) 1993, and in summer (January) 1994, providing a baseline for the future monitoring of vegetation changes.

This report contains the results of a resurvey of the vegetation of Flat Top Hill in the spring (September) 1997, and it documents those changes which occurred in 88 of the permanent monitoring sites over the four years since the first spring vegetation survey of the sites, in September 1993. Of particular interest in this study were changes in the balance between native and exotic species, in the distribution and range of prominent exotic species, and in populations of native spring ephemeral species, which are of particular conservation value in the area. Suggestions are made regarding the management required to maintain the key values of Flat Top Hill.

2. Methods

2.1 SAMPLING

Eighty-eight of the permanent monitoring sites were relocated between 22 and 27 September 1997, and were resampled using the same method as in the 1993/94 surveys (Walker 1994; Walker *et al.* 1995); shoot presences of all vascular plant species, and the presence of lichen and bryophyte species were recorded in each of 100 1 cm x 1 cm subquadrats on a 10 cm grid, within each of four 0.5 x 0.5 m quadrats which were placed 50 cm apart along the long axis of the site. All vascular species that were present within the 0.5 x 2 m site, but not in one of the 1 cm x 1 cm subquadrats, were also recorded. Non-vascular species were not identified individually in this resurvey, but were recorded simply as lichens or mosses.

Sites from the three vegetation types (`communities') of the 1993 *Sedum acre* formation (A, B and C), three communities of the *Thymus vulgaris* formation (D, F and G), and the four communities of the *Anthoxanthum odoratum - Festuca rubra* formation (H, I, J and K) were resampled (these communities having been described in detail in Walker 1994 and Walker *et al.* 1995). However, those five sites on steep, shady slopes west of Butchers Creek, which made up Communities L, M and N of the *Anthoxanthum odoratum - Dactylis glomerata* community in 1993 were not resampled in 1997. The two sites (numbered 117 and 118) which were established inside fenced rabbit exclosures in December 1994 were included in the resurvey.

2.2 DATA HANDLING

Shoot presences of each species were summed over the 100 subquadrats to produce a percentage local frequency score (a crude approximation for percentage cover, referred to informally hereafter as abundance). Additional species recorded were assigned an arbitrary small local frequency value of 0.5%.

For each sample (i.e. each site in both 1993 and 1997) several vegetation characteristics were assessed which were though to be important in characterising vegetation changes. These included species richness, species diversity (the Shannon-Weaver Index H; Shannon & Weaver 1949) and evenness (the E' of Camargo 1993; low evenness equates to a high degree of dominance by one or a few species) and total (summed) abundance. Where percentage cover values are summed across species to produce a measure of summed abundance, it should be noted that this measure is not a good estimate of total cover (although it is the only one that may be obtained using this sampling method) because leaves of different species which occur in the same 1 cm x 1 cm subquadrat are added together, while leaves of the same species are not. This limitation should be borne in mind when trends in summed abundance of particular components of the vegetation are described hereafter in this report. Several measures were calculated to express the native species contribution to each site: these were the total number of natives species, the summed abundance of all native species, the percentage of native species in the total species richness, the percentage which native species contributed to the total (native + exotic) summed abundance, the summed abundance of native ephemeral species, of all native grasses, of the "short tussock" grass species *(Festuca novae-zelandiae, Poa cita* and *P, colensoi* and the three *Elymus* species *E. falcis, E. solandri* and *E. tenuis)* and of native mat species *(Raoulia australis, R. beauverdii* and *Colobanthus brevisepalus).* Five measures of the contribution of exotic species to each site were also calculated: i.e. the total number, diversity, and the summed abundances of all exotic species, of exotic annual grasses, and of exotic perennial grasses. The summed abundance of all tall (native + exotic) shrub species (i.e. excluding sub-shrubs such as *Thymus vulgaris* and *Vittadinia species*) was also calculated for each sample.

2.3 ANALYSES

The investigations in this report are presented in two sections. In the first section, changes in the vegetation between 1993 and 1997 are examined across all of the resampled sites, as well as within each of the resampled communities identified in 1993. In the second section, a classification of the vegetation of Flat Top Hill in 1997 is described, and related to the main environmental gradients in the study area. The analyses used in these two sections are detailed below.

Vegetation change between 1994 and 1997

Two indices of difference in the vegetation between the two sampling dates were calculated for each permanent monitoring site:

1. To express differences in the presence or absence of species in the site (i.e. species turnover), without consideration of their relative abundance, the Jaccard index was calculated (Podani, 1994). The index considers only mutual presences of species as a real expression of similarity, and ignores mutual absences of species, while giving equal weighting to mutual presences and to differences (i.e. a species present in one sample but not the other).

2. To indicate the dissimilarity in species abundance (i.e. total local frequency), the percentage difference index (or Marczewski-Steinhaus distance; Podani, 1994) was calculated. The index is the complement of the ratio of the sum of the shared contributions species to the total abundance, and therefore reflects both dissimilarity in the abundance of species in the community, and differences in species turnover (invasion and extinction). The index is divided by 100 to bring it into a range comparable with the Jaccard index.

Analyses of variance were used to determine whether the amount of change which occurred in the vegetation (expressed by these two indices) differed significantly among the ten resampled vegetation types.

The data were used to determine the number and proportion of native and of exotic species which increased, did not change, or decreased in distribution (i.e. the number of resampled sites occupied) and in abundance (i.e. the total percentage local frequency over all of the resampled sites) over the four years. `t' tests, using the 88 sites as replicates, were used to identify those species which were significantly more or less abundant in 1997 than in 1993. Further `t' tests were used to look for significant overall increases or decreases between 1993 and 1997 in each of the examined vegetation characteristics.

It was anticipated that changes in the abundance of individual species, and in vegetation characteristics, would be different in the different vegetation types ('communities') which were identified in the 1993 survey. Therefore, the significance of changes in individual species abundance, and in vegetation characteristics, were assessed, using 't' tests, separately for each of those ten 1993 communities which were represented in the 1997 resurvey. Duncan's New Multiple Range Test was used to determine whether changes in each of the examined vegetation characteristics differed significantly between the ten resampled communities.

Vegetation types present on Flat Top Hill in 1997

In order to describe the vegetation of Flat Top Hill as it was recorded in the spring of 1997, Indicator Species Analysis (ISA; Hill *et al.* 1975) was used to classify the 88 resampled sites into eight groups of more similar vegetation composition (i.e.'communities') on the basis of the quantitative vegetation data collected. Those environmental attributes of the sites (altitude, slope, north and east aspect, estimated incoming solar radiation, topsoil depth and total soil profile depth) which differed significantly between the different groups formed by the successive divisions of classification were identified using 't' tests. In order to compare the vegetation patterns and environmental correlations between the two sampling dates, similar analyses were performed using the data for the same 88 sites from the spring 1993 survey. It should be noted that the latter classification is based on only 88 of the 118 study sites, and lichens and mosses are not individually quantified, so that it differs from the classification of Walker (1994) which is referred to above.

3. Results

3.1 VEGETATION CHANGE BETWEEN 1994 AND 1997

Average change in the ten resampled communities over four years

There were considerable changes in the occurrence of species (i.e. species turnover, represented by the Jaccard index) and in the abundance of species (represented by the percentage difference measure) in all of the ten resampled communities (Appendix 1). Species turnover averaged more than 70% in the four years, but did not differ significantly between the communities. Dissimilarity in species abundance between the two sampling dates, represented by the percentage difference measure, was greatest (91.5%) in Community A (the *Marrubium vulgare* - *Trifolium arvense* community of 1993, represented by only one site), and least (46.2%) in Community G (the *Thymus vulgaris* - lichen community of 1993). Communities B and C of the *Sedum acre* Formation, and Community K of the *Anthoxanthum odoratum* - *Festuca rubra* Community also showed relatively large quantitative changes, while the three *Thymus vulgaris* Formation communities (D, F and G) and Community I (the *Agrostis capillaris* -*Anthoxanthum odoratum* Community) showed relatively little change.

Native and exotic species showing changes in distribution and abundance

A greater proportion of exotic species showed increases in range (*c.* 65%) and in total abundance (*c.* 72%) than native species (of which *c.* 39 and 59% increased in range and abundance, respectively) on Flat Top Hill from 1993 to 1997 (Appendix 2). Just over half of the native species were recorded in fewer study sites in 1997 than in 1993, while *c.* 41% of native species decreased in average abundance over the 88 resampled sites. Only *c.* 28% of exotic species occurred in fewer study sites in 1997 than in 1993, and the same proportion had a lower average abundance.

Native species

In 1993, *Raoulia australis* was the most widespread native species, occurring in *c.* 51% of sites, while *Geranium sessiliflorum* and *Poa maniototo* were each recorded in *c.* 43% of sites (Appendix 3a). By 1997, *Raoulia australis* occupied only *c.* 43% of sites, while *Geranium sessiliflorum* occupied 36% of sites, and *Poa maniototo* occupied just 19%. *Rytidosperma clavatum* was the most widespread native species in 1997, recorded in *c.* 49% of sites (an increase from 31% of sites in 1993). *Acaena novae-xelandiae* was recorded in 41% of sites in 1997, and *Stellaria gracilenta* in 38% (both increased from 36% site occupancy in 1993).

Three native grasses, *Dichelachne crinita, Elymus tenuis* and *Rytidosperma clavatum,* showed substantial increases in the number of resampled sites occupied (>10 sites) between 1993 and 1997 (Appendix 3a); *Dichelachne crinita* was not recorded in any site in 1993, but occupied *c.* 19% of sites in 1997, *Elymus tenuis* increased its occupancy from *c.* 7 to 22% of sites, while the distribution of *Rytidosperma clavatum* increased from *c.* 31 to 49% of sites. Somewhat smaller increases were shown by the tussock species *Elymus solandri, Poa cita* and *Festuca novae-xelandiae,* by two tiny tufted grasses of dry and saline soils (which bore no flower heads and are therefore not positively identified at this time; I refer to them as *Rytidosperma* cf. *maculattim* and *Poa* "tiny"), by the herbs *Acaena novae-xelandiae* and *Epilobium hectorii* and by the orchid *Microtis unifolia.* The distribution of *Celmisia gracilenta, Colobanthus strictus, Elymus falcis, Oreomyrrhis rigida, Thelymitra* sp., *Helichrysum filicaule, Melicytus alpinus, Raoulia subsericea* and *Stellaria gracilenta* increased by one or two sites. *Dichelachne crinita, Elymus falcis, Elymus solandri* and *Poa cita* and the unidentified short grass *Poa* "tiny" were not present in any of the 88 sites in 1993.

Of the native species, *Poa maniototo, Poa lindsayi* and *Oxalis exilis* showed the greatest reductions in their distribution; in 1997, all occurred in less than half the number of sites in which they were recorded in 1993 (Appendix 3a). Moderate reductions in distribution were also recorded in *Poa colensoi, Raoulia australis, Raoulia beauvardii, Acaena bucbananii, Geranium sessiliflflorumn, Gnaphalium ruahinicum, Colobanthus brevisepalus* and *Rytidosperma buchananii.* Several native species were present in a few sites in 1993, but were not recorded in any study site in 1997; these include the native ephemerals *Ceratocephalus pungens* and *Myosurus minimus* ssp *novae-zelandiae,* the fern *Asplenium flabellifolium* , the small herbaceous dicots

Epilobium alsinoides, Hydrocotyle novae-zelandiae and *Lagenifera cuneata,* the grasses *Lachnagrostis filiformis* and *Rytidosperma thomsonii,* and the hook sedge *Uncinia elegans.*

Raoulia australis was the most abundant native species in 1993 (on average, across the 88 sites), followed by *Rytidosperma clavatum, Poa maniototo* and *Stellaria gracilenta.* By 1997, *Rytidosperma clavatum* had increased significantly ($P<0.05$) to become the most abundant native species on average, followed by *Raoulia australis* (which had decreased in average abundance) and *Stellaria gracilenta* (which had increased in average abundance; Appendix 3a). *Elymus tenuis* (ranked 21st in the native species in 1993) had increased significantly ($P<0.05$) to become the fourth most abundant native species by 1997, closely followed by *Acaena novae-zelandiae,* while *Poa maniototo* had decreased significantly ($P<0.01$) to become only the fourteenth ranked native species in terms of abundance (Appendix 3a).

Most native species which increased in distribution also showed increases in average abundance over the eighty-eight sites (Appendix 3a). *Dichelachne crinita, Rytidosperma clavatum* and *Rytidosperma* cf. *maculatum* showed significant ($P<0.05$) increases in abundance across all sites (Appendix 3a) and in Community B (Appendix 4a), while the abundance of *Acaena novae-zelandiae* increased significantly overall ($P<0.05$) and in Communities B and C. *Elymus solandri* increased significantly overall ($P<0.05$), but not in any individual community. *Poa cita* showed an almost significant ($0.10>P>0.05$) increase overall, and a significant increase in abundance in the for-side Community K, while *Epilobium hectorii* showed an almost significant ($0.10>P>0.05$) increase in abundance over all communities, and in Community B. *Elymus falcis* increased significantly in one sunny, west-facing site (Site 25), while both the hard fern *Blechnum penna-marina* and the native herb *Leucopogon fraseri* increased noticeably in abundance, but remained confined to only one or two for-side sites.

Poa maniototo and *Raoulia australis* showed the greatest decrease in average abundance of all native species, and in the case of *Poa maniototo* this decrease was significant over all 88 resampled sites ($P<0.01$; Appendix 3a) and in two communities (Communities B and C; $P<0.05$; Appendix 4a).

Exotic species

Anthoxanthum odoratum (which occupied c. 57% of sites in 1993) was the most widespread of all (native + exotic) species in 1997, occurring in 87.5% of the sites resurveyed (Appendix 3b). *Sedum acre* was the next most widespread species in 1997, occurring in 75% of sites, whereas in 1993 it had been the most widely recorded of all species, recorded in *c.* 80.5% of the 88 sites.

Ten exotic species showed greater increases in the number of sites occupied than the most rapidly increasing of the native species (31 to 17 sites; Appendix 3b): in descending order of increase, these were the rosette-forming flatweeds *Hypochaeris radicata* (catsear) and *Crepis capillaris* (hawksbeard), the exotic spring annual grass *Aira caryophyllea* (which was not recorded in 1993), *Anthoxanthum odoratum* (sweet vernal), *Rosa rubiginosa* (sweet briar), *Trifolium arvense* (haresfoot trefoil), *Poa pratensis* (smooth meadow grass), *Hypericum perforatum* (St Johns wort), *Vicia sativa* (vetch) and *Holcus lanatus* (Yorkshire fog). Exotic species which increased their distribution by 5 to 15 sites were *Festuca rubra, Thymus vulgaris, Vittadinia gracilis, Dactylis glomerata, Taraxacum officinale, Agrostis capillaris, Trifolium repens, Cerastium fontanum* and *Veronica verna,* and smaller increases in distribution (<5 sites) were shown by *Acaena agnipila, Euphorbia peplus, Verbascum virgatum, Verbascum thapsus* and the annuals *Apbanes arvensis, Bromus tectorum, Erophila verna, Trifolium dubium* and *Vulpia bromoides.* Seven of these increasing species *(Aira caryophyllea, Bromus tectorum, Dactylis glomerata, Trifolium dubium, Taraxacum officinale, Vulpia bromoides* and *Veronica verna)* were not recorded in any of the 88 sites in 1993. Particularly large proportional increases in distribution of any exotic species were shown by *Vicia sativa* (recorded in one site in 1993 but in 18 sites in 1997) and by *Poa pratensis* (recorded in 3 and 23 sites in 1993 and 1997 respectively). *Vittadinia gracilis, Rosa rubiginosa* and *Hypericum perforatum* showed threefold increases in their distribution.

Anagallis arvensis, Reseda luteola, Erodium cicutarium and *Cirsium arvense* were the four exotic species which showed the greatest decreases in the number of sites occupied from 1993 to 1997 (Appendix 3b). *Myosotis stricta* and *Sedum acre* also decreased somewhat in their distribution, while *Rumex acetosella, Echium vulgare, Urtica urens, Rytidosperma racemosa, Marrubium vulgare* and *Cirsium vulgare* occurred in slightly fewer sites in 1997 than in 1993. Of these species, neither *Reseda luteola* nor *Urtica urens* was recorded at any site in 1997.

From 1993 to 1997, *Antho-xanthum odoratumn* showed a dramatic and highly significant (P<0.001) increase in abundance, equating to an average of almost 20% cover per site (Appendix 3b). However, the increase in *Anthoxanthum odoratum* was significant only in the three xeric communities B, C and D (Appendix 4b). A further ten exotic species showed significant increases in average abundance across the 88 sites. These were the annuals *Aira caryophyllea* and *Trifolium arvense,* the subshrubs *Thymus vulgaris* and *Vittadinia gracilis,* the perennial grasses *Holcus lanatus* and *Dactylis glomerata,* the flatweeds *Crepis capillaris* and *Hypochaeris radicata,* the herb *Hypericum perforatum* and the shrub *Rosa rubiginosa* (Appendix 3b). Both *Trifolium arvense* and *Hypochaeris radicata* were significantly more abundant in Communities B, C and D, while the increases in *Aira caryophyllea* and *Holcus lanatus* were significant in Community B, and the increase in *Crepis capillaris* was significant in Communities B and D (Appendix 4b). *Rosa rubiginosa* increased significantly between 1993 and 1997 in Communities B and C (Appendix 4b). The increases in *Thymus vulgaris* were not significant in any individual community, but were almost significant in Communities B and D (Appendix 4b). The increase in *Festuca rubra* was almost significant overall (0.10>P>0.05) and significant (P<0.05) in Community C (Appendix 4b), while the exotic ephemeral *Apbanes arvensis* was significantly more abundant in Community C in 1997 than in 1993 (Appendix 4b). *Poa pratensis* and *Vicia sativa* showed almost significant increases in average abundance over all 88 sites (0.10>P>0.05), and *Vicia sativa* showed almost significant increases in the mesic 1993 Communities H and I (Appendix 4b).

Sedum acre showed the largest decrease in average abundance of any species over the four years (*c.* 13% per site; $P<0.001$; Appendix 3b), and its decrease in abundance was significant in both Communities C and H (Appendix 4b). The annual species *Erodium cicutarium,* and the herbaceous perennial *Reseda luteola* (which was not recorded in any site in 1997) both also decreased significantly across all sites ($P<0.05$; Appendix 4b), while the overall decrease in the abundance of the thistle *Cirsium arvense* was almost significant ($0.10>P>0.05$). *Marrubium vulgare* decreased substantially in Community A (Site 7) over the four years (Appendix 4b).

Changes in vegetation characteristics

Species richness, species diversity (H') and the total abundance of all species showed highly significant increases over all of the 88 resampled sites, over the four years (Appendix 5). When examined at the level of individual communities, however, vascular species richness increased significantly only in Communities B and D, and almost significantly in Communities F and G ($0.10>P>0.05$; Appendix 6a). Species diversity (H') increased significantly in Communities B, C and D only ($P<0.001$; Appendix 6a), while the total (native + exotic) abundance increased significantly in Communities B, C, D, F and J (Appendix 6a). The summed abundance of annual species increased significantly overall, and in the individual Communities B, C and D ($P<0.01$; Appendix 6a), and there was an almost significant increase in the total abundance of tall woody species ($0.10>P>0.05$; Appendix 6a), which was significant in the individual Community C only (Appendix 6a).

There was no significant change in either the number or the diversity (H') of native species, overall, or in any particular community (Appendix 5; Appendix 6b). However, the total abundance of all native species did increase significantly overall, and in particular, the component of native grasses, and the subgroup of native short tussock grasses *(Elymus* species, *Festuca novae-zelandiae, Poa cita* and *Poa colensoi).* The total abundance of native species increased significantly in Community C only, and decreased significantly in Community D (Appendix 6b), while the abundance of all native grass species increased significantly in Communities B and G (Appendix 6b). There was no significant overall change in the average percentage which native species contribute to the total abundance of vascular species (Appendix 5); this decreased significantly in Communities B and D (Appendix 5), but increased significantly in Community G (Appendix 6b). There was, however, a significant decrease in the proportion of native species contributing to the total species richness across all resampled sites, although this was significant only in Communities B, C and D (Appendix 6b). In Community G, however, the proportion of native vascular species increased significantly. The average abundance of native ephemeral species decreased across all sites, but because the records of these species were few, this change was not shown to be significant overall, or in Communities B, C or D where these species occurred previously (Appendix 5).

Exotic vascular species richness, exotic species diversity (H') and the total abundance of exotic species all showed highly significant increases across all sites (Appendix 5c). At the level of individual communities, however, increases in exotic vascular species richness and diversity were significant in only Communities B, C, D, F and J, while the summed abundance of exotic species increased significantly only in Communities B, C and D (Appendix 6c). Exotic perennial grasses increased dramatically in abundance (Appendix 5), although again this increase was significant only in the individual Communities B, C and D (Appendix 6c). Exotic annual grasses also increased significantly overall in the four years (Appendix 5), but their increase was not significant in any individual community (Appendix 6c).

3.2 PLANT COMMUNITIES ON FLAT TOP HILL IN SPRING 1997

Vegetation types and environmental correlations in 1993 and 1997

In the analyses of data from both 1993 and 1997, Indicator Species Analyses separated the 88 sites into two main groups, which differ significantly in altitude, north aspect, in estimated solar radiation received, and in topsoil and total soil profile depth. Thus, in both 1993 and 1997, there were two main vegetation types on Flat Top Hill which could be described as `xeric' and `mesic'. `Xeric' vegetation occurred in relatively low altitude, north-facing sites, which receive high incoming solar radiation, and which have shallow soil profiles and absent or shallow topsoil horizons (Appendix 7a & b; Appendix 8). Mesic vegetation occurred at higher altitudes, in shady sites which receive lower incoming solar radiation and which have deep soils with relatively intact topsoils.

In 1993, xeric vegetation also tended to occur on slopes which were less steep than those supporting mesic vegetation, and the indicator species of this vegetation (which occurred in 56 of the 88 sites resampled in this survey) were the native species *Stellaria gracilenta, Poa maniototo, Vittadinia australis, Raoulia beauverdii* and the exotic species *Thymus vulgaris* and *Anagallis arvensis* (Appendix 7a). `Mesic' vegetation in 1993 tended to occur on deeper soils at higher altitudes and in more south-facing locations, which received lower incoming solar radiation, and was indicated by the species *Anthoxanthum odoratum, Hypochaeris radicata* and *Crepis capillaris,* as well as *Festuca rubra.* In 1997, only 50 sites were classified as xeric. Xeric plant communities were not found on significantly less steep slopes than mesic communities, and xeric sites were less distinctly separated from mesic sites on the criterion of north aspect than in 1993 (although the difference was significant; $P<0.05$; Appendix 8). As in 1993, the indicator species of xeric vegetation at this time included the native species *Stellaria gracilenta* and the exotic *Thymus vulgaris,* but the other indicator species in 1997 were the native grass *Rytidosperina clavatum* and the exotic herbaceous species *Rumex acetosella, Aira caryophyllea, Myosotis stricta* and *Aphanes arvensis* (Appendix 7b). *Sedum acre* was almost invariably present, and more abundant in xeric sites than in mesic sites in 1997 (Appendix 9). The indicator species which were identified for mesic vegetation in 1997, which comprised the remaining 38 sites, were *Festuca rubra* (as in 1993), as well as *Vicia sativa* and *Rosa rubiginosa.*

In 1993, xeric sites could be clearly separated into two groups, the one group containing more abundant *Thymus vulgaris,* and the other indicated by the presence of the native species *Poa lindsayi, Geranium sessiliflorum* and *Acaena novae-zelandiae,* and the exotics *Trifolium arvense, Erodium cicutarium, Myosotis discolor, Rumex acetosella, Cirsium vulgare* and *Crepis capillaris* (Appendix 7a). Sites with abundant *Thymus vulgaris* were significantly more east-facing, and had shallower topsoil horizons than those in the other group (Appendix 7a). In 1997, the first group (i.e.`Formation') of xeric sites occurred on shallower soils, in somewhat less north-facing sites at relatively high altitudes, and was indicated by the presence of *Stellaria gracilenta* (Appendix 7b; Appendix 8). The second group, the *Acaena novae-zelandiae* Formation, comprised somewhat more north-facing sites at slightly lower altitudes, where soil profiles were significantly deeper. A mixture of native and exotic species was characteristic of this second group; these included *Acaena novae-zelandiae* and *Cirsium vulgare,* as well as *Epilobium hectorii, Verbascum virgatum, Poa pratensis, Agrostis capillaris, Rosa rubiginosa, Anagallis arvensis* and *Myosotis stricta* (Appendix 7b). *Thymus vulgaris* was present in both formations, although it tended to be more abundant in sites of the *Stellaria gracilenta* Formation (Appendix 9).

`Mesic' vegetation in 1993 was divided into two types, one type which occupied more north-facing sites (indicated by the presence of the native grass *Poa maniototo,* and the exotic species *Erodium cicutarium* and *Cirsium arvense)* and a second type on more south-facing sites, indicated by the native grasses *Festuca novae-zelandiae* and *Rytidosperma clavatum,* and by the exotic species *Trifolium repens* and *Holcus lanatus* (Appendix 7a). In 1997, the division of the two primary mesic vegetation types was again significantly related to a difference in north aspect, but also to a difference in estimated incoming solar radiation (Appendix 7b; Appendix 8). More north-facing sites, receiving more incoming solar radiation (the *Rosa rubiginosa* Formation), were indicated by the presence of the exotic shrubs *Thymus vulgaris* and *Rosa rubiginosa,* and by the annual *Myosotis discolor,* while more shady, south-facing sites (the *Festuca novae-zelandiae* Formation) were indicated, as in 1993, by the presence of *Festuca novae-zelandiae* and *Trifolium repens,* as well as by the tall exotic grass *Dactylis glomerata,* and by more abundant bryophyte cover (Appendix 7b; Appendix 8).

As in 1993, the vegetation structure in 1997 was weak: as may be seen in the two-way table (Appendix 9), there was but one species *(Poa lindsayi* in Community 3) which was faithful to (i.e. found only in) a particular community) and there were few constant species (i.e. species present in all sites of any one community). Thus, each of the `communities' described below encompasses considerable vegetation variation.

Xeric communities in 1997

1. Thymus vulgaris - Trifolium arvense - Lichen Community

From B: Sites 59, 95, 98, 99, 100, 109
From C: Site 9
From D: Sites 43, 71, 72, 79, 110
From F: Sites 20, 46
From G: Sites 33, 37, 84

From H: Site 87
From I: Site 17

Sites with very shallow soil profiles, derived from a range of 1993 communities, tended to be dominated in the spring of 1997 by a shin-high canopy of *Thymus vulgaris,* with a mixed understorey of *Anthoxanthum odoratum, Trifolium arvense* and *Sedum acre.* One of the latter three species dominated the community where *Thymus vulgaris* was absent. A variety of lichen and moss species, as well as *Aira caryophyllea, Rytidosperma clavatum, Raoulia australis, Crepis capillaris, Hypochaeris radicata* and *Rumex acetosella* were common minor vegetation components, while *Dichelachne crinita* and *Elymus tennis* were occasionally present and infrequently abundant. *Myosotis discolor* and *Poa colensoi* were recorded occasionally in this community but were infrequent, and absent, respectively, in Community 2.

This community was the most species-poor of the xeric group, both overall and in native species, and had the lowest proportion of native species, and the lowest proportion of the summed abundance made up by native species, of the four xeric communities (Appendix 10).

2. *Trifolium arvense - Stellaria gracilenta* Community
From B: Site 34, 39, 49, 58, 85, 97, 103
From C: Site 89
From H: Site 117

The exotic annual *Trifolium arvense* and the native *Stellaria gracilenta* were constant species in this community, which occurred on somewhat deeper soils than the *Thymus vulgaris -Trifolium arvense - Lichen* Community, and which tended to be dominated by *Trifolium arvense, Sedum acre, Anthoxanthum odoratum* or *Raoulia australis,* rather than *Thymus vulgaris.* As in Community 1, *Aira caryophyllea, Rytidosperma clavatum, Crepis capillaris, Hypochaeris radicata, Rumex acetosella* and various mosses were common minor vegetation components, while the native grasses *Dichelachne crinita* and *Elymus tenuis* were recorded infrequently. However, *Acaena novae-zelandiae* and *Rytidosperma* cf. *maculatum* were present in this community, while absent in the *Thymus vulgaris - Trifolium arvense - Lichen* Community, and *Colobanthus brevisepalus, Epilobium hectorii, Geranium sessiliflorum* and *Vittadinia australis* were present more frequently on these deeper soils. *Aphanes arvensis, Carex breviculmis, Gnaphalium ruahinicum, Hypericum perforatum, Oreomyrrhis rigida, Poa maniototo* and *Raoulia beauverdii* were also more common than in Community 1.

This was the most species-rich of all of the 1997 communities, with an average of 20 species per site (Appendix 10). It contained the highest average number (*c.* 10) and proportion of native species (*c.* 50%) of all communities. The percentage of the total abundance made up by native species was also relatively high (*c.* 30%).

3. *Sedum acre - Trifolium arvense* Community
From B: Sites 5, 31, 35, 42, 50, 96, 104
From C: Sites 25, 28, 32, 36, 54, 55

The relatively gently sloping, north-facing sites in this community have moderately deep soils and the sites are derived from just two communities (B and C) of the 1993 *Sedum acre* Formation. *Sedum acre* was constant and abundant in 1997 (averaging 45% cover), and *Trifolium arvense* was a constant, but comparatively minor, vegetation component. *Anthoxanthum odoratum, Crepis capillaris* and *Acaena novae-zelandiae* were present in most sites, and were occasionally abundant, while *Rumex acetosella, Aphanes arvensis, Anagallis arvensis, Geranium sessiliflorum, Epilobium hectorii, Myosotis stricta* and various lichens were common minor species. *Poa pratensis* was frequently present, and *Rytidosperma racemosum* and *Agrostis capillaris* occasionally recorded, and all three exotic grasses were occasionally abundant (> *c*. 10% cover), while *Holcus lanatus* was present in a few sites, but only at low abundance. The native species *Raoulia australis, Rytidosperma clavatum* and *Stellaria gracilenta* were present in most sites, the tiny *Rytidosperma* cf. *maculatum* was recorded in some sites and was occasionally abundant, while *Elymus falcis* was present and abundant (*c.* 57% cover) at Site 25 only. The exotic shrubs *Thymus vulgaris* and *Rosa rubiginosa* were present at low abundance in a number of the sites.

This was a relatively species-rich community (containing an average of *c.* 18 species) but the proportion and number of native species were somewhat lower than in Community 2 (Appendix 10). However, native species made up *c.* 28% of the summed abundance, which was not significantly different from the average native proportion of abundance in Community 2.

4. *Sedum acre - Rytidosperma clavatum* Community

From B: Sites 29, 106, 116
From C: Sites 21, 24, 27, 30, 47
From F: Site 52

The vegetation of relatively steep, north-facing sites with little or no remaining topsoil layer had become dominated in 1997 by the native grass *Rytidosperma clavatum*, or, where this species was absent, by *Sedum acre, Trifolium arvense,* or *Rytidosperma racemosum*. There were no constant species in this community (although *Sedum acre* was almost so), but *Vittadinia gracilis* and *Verbascum thapsus* were more frequently recorded here than in any other community, while *Crepis capillaris, Holcus lanatus, Poa pratensis* and *Trifolium arvense* were less common than in the *Sedum acre-Trifolium arvense* Community. *Antboxantbum odoratum* was present in most sites and occasionally abundant (reaching c. 32%), while *Rumex acetosella, Acaena novae-zelandiae, Vittadinia australis, Cirsium vulgare, Epilobium hectorii, Geranium sessiliflorurra, Myosotis stricta* and various lichens and mosses were common minor species. *Thymus vulgaris* was present in most sites, but reached a cover value of > *c.* 10% in only one site.

Species richness in this community was similar to that in Community 3, but the average proportion and number of native species was marginally greater. Native species made up a larger proportion (*c.* 32%) of the summed abundance than in any other 1997 community (Appendix 10)

Mesic communities in 1997

5. Elymus tenuis - Rytidosperma clavatum Community

From A: Site 7
From B: Site 16
From C: Sites 2, 26
From D: Site 63
From H: Sites 62, 92
From I: Sites 3, 4, 6

This community is made up of those sites which received the greatest incoming solar radiation of all of those classified in the mesic vegetation group. Half of the ten sites were classified within xeric communities in 1993 (in communities A, B, C and D), and many lie west of Butchers Creek, or on, or near to the main ridge crest, rather than on the shady slopes above Lake Roxburgh. There were no faithful or constant species, although *Anthoxanthum odoratum* occurred in nine of the ten sites, and was the dominant species in most of these. The species composition of this `community' varied considerably between sites; *Festuca rubra* was recorded in 6 sites, and was abundant *(> c. 40%)* in four of these, while *Hypochaeris radicata* and *Rosa rubiginosa* were present at low abundance in 8 sites, and a variety of lichens in 7 sites. Several of the species present in this community are characteristic of more xeric plant communities; for example, *Trifolittm arvense, Thymus vulgaris* and *Poa pratensis* were each present in half of the sites, and *Thymus vulgaris* remained the dominant species in Site 63 in 1997. The three indicator species of this community, the native grasses *Rytidosperma clavatum* and *Elymus tenuis,* and the native sub-shrub *Vittadinia australis,* each occurred in less than half of the sites, and at relatively low abundance.

This was one of the most species-poor of the 1997 communities, with an average species richness of *c.* 11 species, and it contained the fewest native species of any community (*c.* 3 species; Appendix 10). Native species contributed an average of only *c.* 9% to the summed abundance, which was the lowest proportion in any 1997 community.

6. Anthoxanthum odoratum - Crepis capillaris Community

From B: Site 118
From C: Sites 38, 48, 56, 70, 81, 94
From H: Sites 78, 82
From I: Site 64
From J: Sites 86, 115

Anthoxanthum odoratum and *Crepis capillaris* were the only two constant species in this community in 1997, and, while the former tended to be dominant, the latter tended to be a minor component. *Festuca rubra* was present at low abundance in almost all sites, while other common species included *Hypochaeris radicata, Rosa rubiginosa* and a number of lichens and mosses. Relatively mesic environmental conditions (i.e. lower incoming solar radiation than in Community 5; Appendix 8) are indicated by the occurrence of *Trifolium repens* in some sites, the more frequent occurrence of such species as *Festuca rubra* and *Holcus lanatus,* and the occasional records of such native species as *Helichrysum filicaule, Poa cita, Raoulia subsericea* and the orchid *Thelymitra longifolia.* However, some species which are more characteristic of drier sites on Flat Top Hill, such as *Sedum acre, Trifolium arvense* and *Myosotis discolor,* were also present, at relatively low abundance, at some sites. As in the *Elymus tenuis - Rytidosperma clavatum* Community, there was substantial variation among the sites; *Thymus vulgaris* was abundant in two sites (*c*. 26 and 45% cover), *Poa pratensis* was abundant in two sites (at > *c.* 30% cover), both *Dichelacbne crinita* and *Vicia sativa* were abundant in Site 81 (> *c.* 30%), mosses and *Rytidosperma clavatum* were abundant at Site 86 (> *c.* 30%), and *Leucopogon fraseri* was abundant in the tor-side Site 115.

This community was marginally, but not significantly richer in all species and in native species than Community 5 on average, and native species tended to contribute only a small proportion (*c.* 13%) of the summed abundance (Appendix 10).

7. *Festuca rubra -Anthoxanthum odoratum* Community

From H: Sites 61, 67
From I: Sites 65, 73, 75, 80
From J: Site 11

Communities 7 and 8, which occupied the most south-facing slopes on Flat Top Hill in 1997, could not be distinguished between on any of the seven measured environmental characteristics. All of the sites in Community 7 were derived from mesic communities (1993 Communities H, I and J), and all are situated on moderately steep south- or east-facing slopes above Lake Roxburgh, except Site 11 on the low ridge west of Butchers Creek, and Site 61, in a gully head hollow on the upper western side of the main ridge. All sites contained both *Festuca rubra* and *Anthoxanthum odoratum* in 1997, and all were dominated by one or the other of these two species. A third exotic grass, *Dactylis glomerata,* which was not recorded in any of the 88 sites in 1993, was present in all Community 7 sites except Site 65, and reached >20% cover in two sites. The native hard tussock *Festuca novae-zelandiae,* the exotic flatweed *Hypochaeris radicata,* and a range of moss species, were present at most sites in this Community, but *Rosa rubiginosa* was absent in all but one site (Site 80), which also contained species more characteristics of mesic communities, such as *Raoulia australis, Rytidosperma clavatum, Stellaria gracilenta* and *Thymus vulgaris. Vicia sativa, Crepis capillaris* and *Sedum acre* were each present at low abundance in about half of the sites, while the native grasses *Elymus solandri* and *Elymus tenuis,* and the exotic grass *Holcus lanatus,* were each recorded in two of the sites in this community, and each was relatively abundant in one site.

This was another species-poor community, but it was slightly richer in native species than either of the preceding two mesic communities (Appendix 10). Native species contributed a low proportion to the summed abundance (c. 16%).

8. *Anthoxanthum odoratum - Trifolium repens* Community

From C: Site 51
From I: Site 53
From J: Sites 57, 60, 83, 111, 113
From K: Sites 112, 114

The four for-side sites on the crest of Flat Top Hill, and sites on high-altitude and/or relatively steep south- and east-facing slopes were included in this community. *Anthoxanthum odoratum* was the only species which was constant and consistently abundant, but *Crepis capillaris, Holcus lanatus* and *Trifolium repens* were each present in all but one site, while *Festuca rubra, Helichrysum filicaule, Festuca novae-zelandiae* and a range of lichens and mosses were present in most sites, and occasionally abundant. The native grass *Elymus tenuis* (which reached > *c.* 60% cover at Site 83), *Acaena novae-zelandiae,* and *Trifolium arvense* were present in five of the eight sites, while just less than half of the sites contained the native species *Geranium sessiliflorum, Poa colensoi, Raoulia australis, Rytidosperma clavatum,* or the exotic species *Rosa rubiginosa, Sedum acre* and *Vicia sativa. Poa cita* was present at >10% cover in the two shady for-side sites (112 and 114). The native mat species *Raoulia subsericea,* and the exotic grass *Dactylisglomerata* were each present in two sites, and abundant (> *c.* 10% cover) in one of those sites. Among the minor species recorded in two or three of these sites were the native species *Carex breviculmis, Celmisiagracilenta, Epilobium hectorii, Oreomyrrhis rigida* and *Raoulia beauverdii,* and the exotic species *Agrostis capillaris, Cerastium fontanum, Poa pratensis, Rumex acetosella, Taraxacum officinale, Trifolium dubium* and *Vittadinia gracilis. Thymus vulgaris* was absent from all Community 8 sites.

This mesic community was one of the most species-rich on Flat Top Hill in 1997 (*c.* 18 species; Appendix 10). Native species made up an average of *c.* 41% of the total species richness, and contributed an average of *c.* 30% of the total cover.

4. Discussion and conclusions

4.1 CAUSES OF VEGETATION CHANGE

The vegetation of Flat Top Hill changed considerably between 1993 and 1997, in which time stock were absent and rabbits numbers were controlled. It is not possible to attribute the vegetation changes solely to lack of grazing, because there exist no monitored sites which are closely comparable in vegetation and environment to Flat Top Hill which have been continually grazed, and which might act as a control. The period between 1993 and 1997 was both wetter and cooler than the long-term average in Central Otago, and these relatively favourable conditions for plant growth have led to considerable directional changes in some continually grazed Central Otago plant communities over this time (Walker 1997). In particular, significant increases in (predominantly exotic) perennial and tall annual grasses, and decreases in ephemerals and short dicot herbs have been described in grazed vegetation on the nearby Earnscleugh and Galloway Stations.

At the time of the 1997 resurvey of Flat Top Hill, there was a striking visible contrast between the short vegetation in the grazed paddocks adjacent to the conservation area, and the taller vegetation within the reserve, which does indicate that the removal of sheep and rabbits from Flat Top Hill has itself had a substantial effect. However, because dissimilarities in the species composition of the grazed and ungrazed vegetation remain undocumented, the effect of release from grazing alone on the vegetation of Flat Top Hill cannot be directly shown.

Most probably, the relatively cool, moist climatic conditions and the lack of grazing from 1993 to 1997 have both been responsible for the vegetation changes which are described in this report. Substantial changes might have occurred in the vegetation of Flat Top Hill between the two sampling dates, even without a reduction in grazing pressure, due to the relatively favourable climatic conditions for plant growth. However, it is also possible that some of the changes described in this report would not have come about if the climate had been hotter and drier in the intervening ungrazed years. Recent work in Central Otago (Walker 1997) has shown that vegetation response to the cessation of grazing may differ substantially depending on the date of release from grazing, and the climatic conditions around and after release.

4.2 GENERAL CHANGES IN XERIC COMMUNITIES

Those communities which occurred on sunny, gentle slopes on the crest and western face of Flat Top Hill in 1993, and which were previously the most heavily grazed by rabbits (Communities B and C of the *Sedum acre* Formation, and Community D of the *Thymus vulgaris* Formation) showed the most striking changes in vegetation characteristics between 1993 and 1997. The greatest increases in the number, diversity and abundance of all exotic species, in exotic annual grasses and exotic perennial grasses, and in the total abundance of all annual and monocot species, and the greatest decrease in the percentage of native species occurred in these three communities. The amount of vegetation change was slower in the communities dominated by the long-lived woody species *Thymus vulgaris* (thyme) than in the herbaceous communities. However, there were large increases in the abundance of native grasses in the thyme-dominated Communities F and G.

In 1993, sites with xeric vegetation could be clearly separated according to aspect, slope and topsoil depth into vegetation types dominated by thyme, *versus* those with little or no thyme. However, by 1997, the vegetation of gently sloping sites, which had been previously most greatly favoured by rabbits for grazing, was not as distinct from that on steeper slopes as it had been in 1993. Thyme had increased in, or invaded, more gently sloping, west-facing sites with deeper topsoils (e.g. sites of the xeric 1993 Communities B and C), while the three exotic species *Anthoxanthum odoraturn, Crepis capillaris* and *Hypochaeris radicata,* which were previously more restricted to steep, shady sites east of the main ridge, had shown highly significant increases on both steep and gentle sunny slopes. In 1997, total soil profile depth (rather than aspect, slope and topsoil depth) had become the environmental factor that most clearly distinguished between the main types of xeric vegetation. Thus, the overall pattern of vegetation of sunny, north-facing slopes of Flat Top Hill was related to different environmental factors in 1997 than in 1993. This may have come about because the cessation of grazing removed one of the primary influences on the distribution of species, although favourable climatic conditions for plant growth probably also promoted the change.

4.3 GENERAL CHANGES IN MESIC COMMUNITIES

Whereas some species previously indicative of steeper slopes and south-facing aspects (*Anthoxanthum odoratum*, *Hypochaeris radicata* and *Crepis capillaris)* had expanded their range by 1997 into sunnier, drier sites, *Festuca rubra* remained relatively faithful to mesic sites. Other species, such as *Dactylis glomerata* (cocksfoot), *Vicia sativa* and *Rosa rubiginosa* (sweet briar) increased considerably over the four year interval in sites which received lower incoming solar radiation, and these became the new indicator species of mesic plant communities on Flat Top Hill. However, it should be noted that sweet briar also increased significantly in two xeric 1993 communities (B and C) over the four years. Thyme, which had previously been mainly confined to xeric sites, invaded and increased in the mesic 1993 Communities H and I, as well as in drier sites. There was relatively little change in the grassy south facing sites which made up the 1993 *Agrostis capillaris - Anthoxanthum odoratum* Community (I). Here, *Festuca rubra* tended to increase over the four years to become the dominant species, but the dense exotic grass swards were more stable than most other communities.

4.4 NATIVE EPHEMERAL SPECIES

Populations of annual species may be expected to show some degree of interannual variability in a semi-arid environment such as Central Otago, where there are large climatic fluctuations from year to year. For example, the exotic annual *Trifolium arvense,* which was significantly more abundant in many sites on Flat Top Hill in 1997 than in 1993, is known to increase rapidly in response to particular combinations of environmental conditions, as well as in response to rest from rabbit grazing in other parts of Central Otago (Walker, 1997). However, it is of concern that the three native ephemeral species recorded in September 1993 *(Ceratocephalus pungens, Myosotis pygmaea* var. *minutiflora* and *Myosurus minimus* ssp. *novae-zelandiae)* had all decreased in distribution and in total abundance on Flat Top Hill between 1993 and 1997. *Myosurtis minimus* ssp. *novae-zelandiae* did not occur in any of the resampled study sites in 1997, but was present at the margins of the ephemeral pool on the crest, while *Ceratocephalus pungens* was not found at all despite a careful search of all of those locations at which its occurrence in 1993 was noted.

Native ephemeral species probably evolved in Central Otago in areas of high 'endogenous' or natural disturbance, such as beside regularly flooding streams. Probably much of the original habitat for these species in Central Otago has now been modified by pastoral practices or by the invasion of exotic species, so that the continuation of populations of native ephemerals now depends on the existence of areas of high 'exogenous' disturbance (e.g. the maintenance of open vegetation with much bare ground by heavy rabbit grazing). Almost certainly, the recent decline of these native ephemerals in Flat Top Hill is related to the increase in the vegetation cover (mainly of exotic grasses) in previously sparsely vegetated, heavily rabbit-grazed sites. A good example of this could be seen in September 1997 on the previously sparsely vegetated fan beside Butchers Dam (a significant saline site in Central Otago, described McIntosh *et al.* 1992). Here, the saline exposed patches of white tertiary sediments still supported a sparse cover of halophytic species (including *Atriplex buchananii),* but a relatively tall, dense sward of *Agrostis capillaris,* with few annual species, grew in the less saline soils right up to the margins of the salty patches.

4.5 NATIVE GRASSES

Despite a much greater increase in the distribution and abundance of numerous exotic species on Flat Top Hill between 1993 and 1997, several native grasses also increased considerably after 1993. The tiny tufted grasses *Rytidosperma* cf. *maculatum* and *Poa* "tiny" increased in dry, relatively sparsely vegetated sites,while *Rytidosperma clavatum* formed a short continuous tussock sward on parts of steep, sunny slopes west of the main ridge, between and amongst patches of thyme in 1997. *Dichelachne crinita* was present in many different vegetation types in 1997, for example beneath *Thymus vulgaris* canopies and within *Anthoxanthum odoratum* and *Festuca rubra* swards. Three native *Elymus* species were identified in the resurvey, and all had increased in abundance since 1993. *Elymus falcis* was abundant in the sunny, low-altitude Site 25, *Elymus tenuis* occurred across a range of sites, while *Elymus solandri* had increased particularly in relatively moist habitats. *Festuca novae-zelandiae* has increased in shady sites, while *Poa cita* was more abundant beside rock tors. *Poa colensoi* was the only native grass species that showed an almost significant decrease in abundance in one community (Community J), although it increased slightly in abundance in Communities B, C, H and I. It appears that none of these native grass species is at risk of being competitively excluded by the vigorous growth of taller exotic species, at least in the short term. However, the tiny xerophytic native grass *Poa maniototo* decreased significantly in abundance in the relatively dry sites in which it was present in 1993.

4.6 GAINS AND LOSSES

Grass cover on Flat Top Hill increased significantly over the four years between 1993 and 1997. The most dramatic increase was in the abundance of exotic grasses, but there were also significant increases in the abundance of a number of native grasses. The recovery of the tussock species *Festuca novae-zelandiae* and *Poa cita,* the increase in the abundance of three *Elymus* species, and the spread of *Rytidosperma clavatum* on sunny faces was particularly encouraging. Several visual observations supported the evidence from the permanent monitoring sites regarding the positive effect of grazing release on some native species. For example, small stands, and individual specimens, of apparently healthy, recovering short tussock species, were present within a matrix of shorter exotic species in many parts of Flat Top Hill in September 1997. Moreover, the woodrush *Luzula banksiana* var. *rhadina,* which was previously confined to grazing-sheltered rocky ledges, was observed establishing in grassy vegetation around rock tors and outcrops, and the native shrub *Ozothamnus leptophyllus* (previously *Cassinia leptophylla)* appeared to be regenerating freely around adult seed sources. These developments suggest that parts of Flat Top Hill might in the future support communities dominated by native short tussock grasses and native shrubs. Across a considerable area of Flat Top Hill, the decrease in the abundance of the invasive exotic succulent *Sedum acre* between 1993 and 1997 may also have been a positive result of the general increase in grass cover.

The increase in native tussock grasses from 1993 to 1997 was, however, accompanied by the decrease of a suite of native species which were previously abundant in the driest parts of Flat Top Hill. Of these species, the most dramatic decrease was seen in *Poa maniototo*, but *Raoulia australis* also decreased consistently (though not significantly) across most sites, while the small xerophytic grasses *Poa lindsayi*, *Rytidosperma thomsonii* and *Rytidosperma buchananii*, and the mat species *Colobanthus brevisepalus* and *Raoulia beauverdii*, were recorded in far fewer sites in 1997 than in 1993. It appears that these species, and the native ephemeral species, previously benefited from the maintenance of short, open vegetation (and in particular the suppression of exotic grasses such as *Agrostis capillaris* and *Poa pratensis)* by low rainfall or heavy grazing, or a combination of the two.

The range and abundance of thyme increased over the four years within the resampled sites, and the invasion of thyme on Flat Top Hill may not yet be complete. The cover of thyme increased markedly even in those sites where it was already dominant in 1993. However, many thyme-dominated sites were significantly richer in vascular plant species, and particularly in native grasses (particularly *Elymus* and *Rytidosperma* species) in 1997, than they were four years earlier. Because there was little evidence of rabbit grazing in the driest and most species-poor thyme-dominated sites in 1993, some of this increase in diversity must be attributable to the cooler, wetter climate in recent years. However, a much larger seed source for the dispersal of native (and exotic) grasses into these communities has probably been created by the general increase in grass cover across much of Flat Top Hill in the last four years.

The tall exotic shrub *Rosa rubiginosa* (sweet briar) has shown a marked increase in most plant communities on FlatTop Hill. This increase has undoubtedly been hastened by the decrease in rabbit numbers, which would have allowed the widespread establishment of palatable briar seedlings. In more mesic grassy communities east of the main ridge, it is possible that a window of opportunity for sweet briar establishment occurred immediately following grazing release and prior to the development of a dense grass sward, and that sweet briar recruitment might have since been suppressed to some extent by the grass cover. However, such suppression is unlikely to occur in more open grassy communities in drier parts of Flat Top Hill.

Some noteworthy new discoveries were made on Flat Top Hill in the spring of 1997. The large herbaceous dicot *Anisotome cauticola* was present amongst some rock outcrops. Because this species was not recorded in earlier surveys, either in that of Johnson & Hewitt (1991), or in the three surveys described by Walker (1994), it seems possible that this species has increased recently as a result of the reduced grazing regime, and particularly the eradication of goats. A single mature specimen of the locally rare native shrub *Olearia bullata*, which was undoubtedly present at the time of the earlier surveys, was identified in the southern lee of a rock outcrop. Lastly, in the extreme south-west corner of the conservation area, a new, relatively large saline area, supporting a number of native halophytes, was discovered adjacent to Butchers Creek.

4.7 THREATS

Although exotic species increased more rapidly than native species between 1993 and 1997, there was no significant change in the average number and diversity of native species at the permanent monitoring sites, and there was a significant increase in the average summed abundance of native species. However, particular exotic species in certain parts of Flat Top Hill may threaten native species and key values of the area.

The continuation of populations of native ephemeral species and the survival of native species-rich `scabweed' communities is threatened by an increase in exotic grasses and herbs in dry and saline parts of FlatTop Hill. This issue has been discussed in detail in earlier sections.

At the time of the 1997 resurvey, thyme still dominated mainly dry, sunny parts of the landscape with shallower soil profiles, but it did appear to be spreading into more mesic sites. In 1993, thyme-dominated sites were particularly poor in vascular plant species. Either:

1. thyme first invaded steep, rocky slopes with shallow soils which were initially species-poor, and has not significantly altered the species richness of these areas, or,

2. thyme reduced species richness and diversity where it invaded, possibly because thyme litter has allelopathic properties, as suggested by Wilkinson et al. (1979).

If the second explanation were correct, the spread of thyme might be a considerable threat to plant species diversity on Flat Top Hill. However, the adverse effect of thyme on species richness is not confirmed by the present study; in fact, where thyme increased, overall species diversity and richness also increased over the four years from 1993 to 1997. In some previously thyme-dominated communities on Flat Top Hill, grasses and thyme shrubs formed a dense and apparently competitive mixture in the spring of 1997. However, it is possible that the competitive balance might favour the long-lived, drought-resistant thyme shrubs over grasses in years of lower than average rainfall, or even that allelopathic effects are mitigated in years of relatively high rainfall. Therefore, *Thymus vulgaris* should still be seen as a potential threat.

While it appears little may be done to contain the widespread increase in thyme and in exotic grasses under a low-grazing regime on Flat Top Hill, it may still be possible to contain the spread of sweet briar. Little is known about the effects of this deciduous shrub on the functioning of semi-arid grassland ecosystems. However, sweet briar is clearly a major threat to the recovery and maintenance of open, short-tussock grassland vegetation on Flat Top Hill, and it has the potential to discourage recreational use of the area. Relatively dense, knee-high areas of sweet briar - presumably the consequence of rapid recruitment following rabbit control - were present on some of the grassy slopes above Lake Roxburgh in September 1997. These briar plants will significantly alter the appearance of the landscape if they are allowed to reach adult size, and there is an enormous potential for the further spread of briar if this cohort is allowed to flower and set fruit.

There was a marked increase in cocksfoot *(Dactylis glomerata)* in shady sites from 1993 to 1997. This species forms tall, long-lived, competitive near-monocultures on shady slopes elsewhere in Central Otago, and it may pose a threat to the persistence or recovery of native species-rich communities on the slopes above Lake Roxburgh. For example, the native tussock *Festuca novae-zelandiae* appears able to increase on the eastern face of Flat Top Hill within swards of the exotic grasses *Anthoxanthum odoratum* and *Festuca rubra,* but elsewhere on shady slopes in Central Otago (e.g. on Galloway Station; Walker 1997) *Festuca novae-zelandiae* and other native species have been suppressed by the development of a dense cocksfoot sward following the removal of grazing animals.

Lupinus arboreus was observed to have rapidly increased on the moister slopes of Flat Top Hill above Lake Roxburgh, although it was not recorded in any of the resurveyed monitoring sites. This tall, nitrogen-fixing species could spread across a considerable portion of the conservation area, and it may substantially modify the present plant communities.

5. Recommendations

Over much of Flat Top Hill, the cessation of grazing appears to have been beneficial for a some native species - particularly native grasses, but also some palatable forbs. At present, the continuation of rabbit control and the absence of stock appears the best management option to ensure the continued recovery of these native species.

Continued rabbit control will necessitate ongoing control of palatable weeds. In particular, the control of sweet briar *(Rosa rubiginosa),* tree lupin *(Lupinus arboreus)* and cocksfoot *(Dactylis glomerata)* by herbicides (or by biological control methods should these become available) is strongly recommended. Little is yet known of the effects of thyme and sweet briar on the vegetation, and research may help to predict the impacts and direct the management of these two woody weeds.

The paradox for the management of Flat Top Hill is that if rabbit numbers are to remain low, it is probable that the native ephemeral species, which are one of the key conservation values of Flat Top Hill, will decrease further, together with native species-rich `scabweed' vegetation. However, the restoration of high, or even moderate levels of grazing over the conservation area at this time would compromise or reverse the recovery of a wide range of other native species. It may be possible to impose two different management regimes on Flat Top Hill so that neither of these scenarios is realised. Native ephemeral species occurred in 1993 on the low ridge to the west of Butchers

Creek, on the gravel fan adjacent to and east of Butchers Dam, as well as in localised areas on the western face and the main ridge crest. The first two of these areas supported the largest populations of native ephemerals, and are conveniently situated on the periphery of the conservation area. With appropriate fencing, it may be possible to reintroduce grazing to the area west of Butchers Creek and to the gravel fan beside Butchers Dam, with the purpose of maintaining a short, open vegetation with much bare soil, while protecting the remainder of the conservation area from grazing. There are presently no experiments which indicate the type and number of herbivores which might be required to maintain a suitable habitat for native ephemeral species. The most practical solution might be to allow rabbit numbers to build up again in the grazed areas, and/or to graze the areas judiciously with sheep. Careful management and monitoring of the grazed areas, and some experimentation, would be necessary.

In view of the absence of *Ceratocephalus pungens* from its previous locations, and the decreases in the distribution and abundance of *Myosotis pygmaea* var. *minutiflora* and *Myosurus minimus* ssp. *novae-zelandiae* on Flat Top Hill over the last four years, it is strongly recommended that an attempt is made to locate, conserve and study other populations of native ephemerals in Central Otago and the eastern South Island. A better understanding of the ecology and population dynamics of these little-known species would help to direct conservation management.

The vegetation of Flat Top Hill will probably continue to change rapidly in the short and medium term. It is recommended that the vegetation should be remonitored, and management decisions reappraised, after another four years.

6. Acknowledgments

I would like to thank Brian Patrick for facilitating the resurvey, John Barkla for his patient assistance in the field, Matthew Sole for his enthusiastic input, and the staff of Department of Conservation Alexandra for logistic support.

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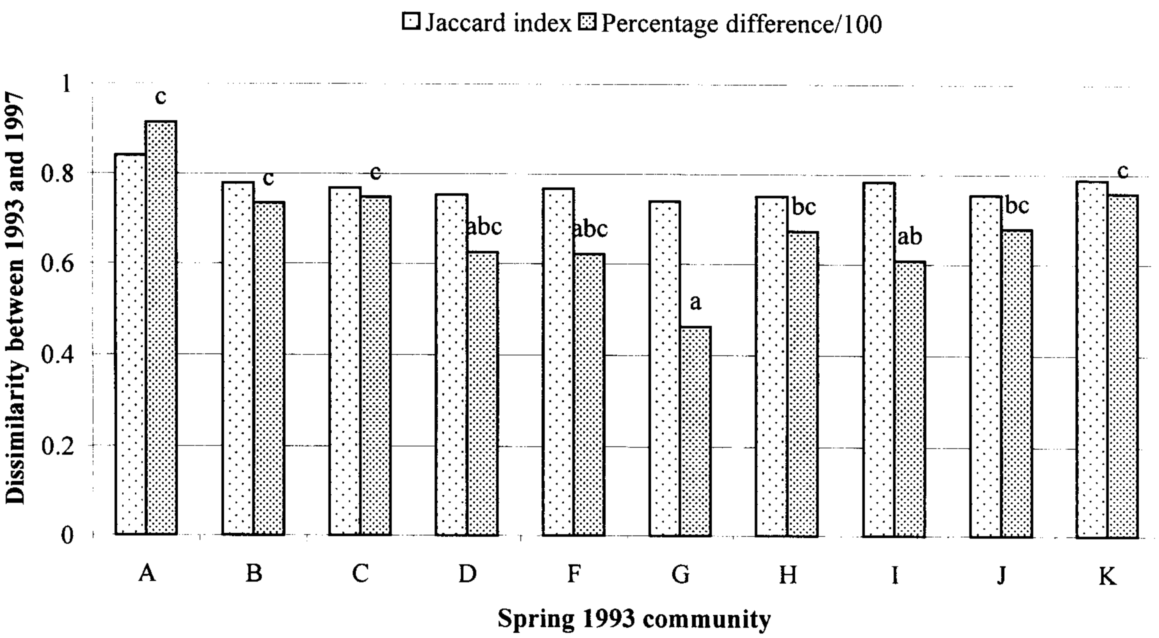
8. Appendices

Appendix 1 *Average dissimilarity between September 1993 and September 1997 in the ten resampled communities on Flat Top Hill. The Jaccard index represents turnover of species (which did not differ significantly between communities), while the Percentage Difference index represents quantitative change. For this index, lower case letters in common indicate that the value of that index is not significantly different between communities (P>0.05 by Duncan's New Multiple Range Test).*



Appendix 2 *Percentages (and number) of native and exotic vascular plant species which showed increases, decreases or no change in distribution (i.e in the number of study sites occupied) and in abundance (total frequency of occurrence) between September 1993 and September 1997 in the 88 resampled study sites on Flat Top Hill.*

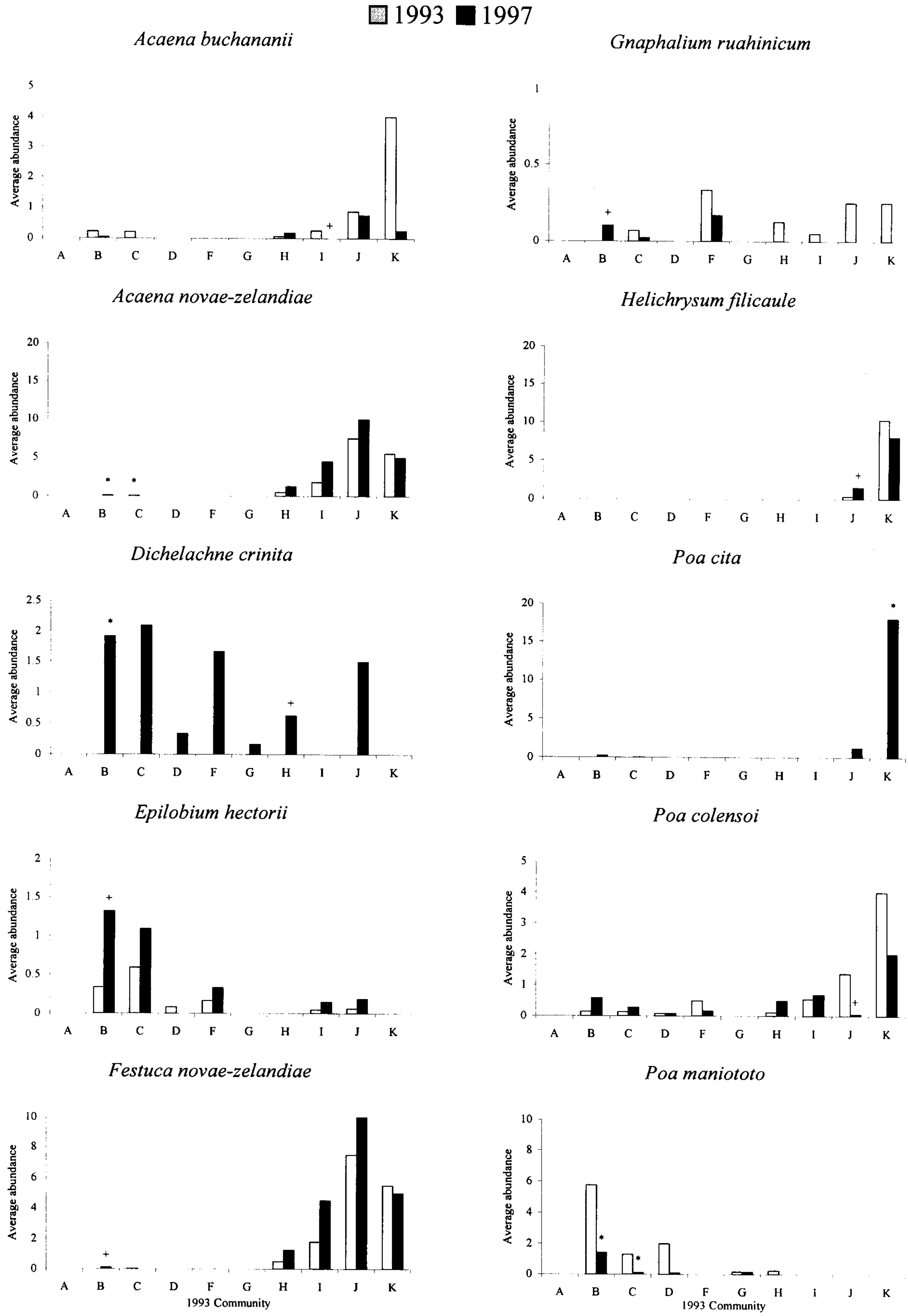
	Distribution		Abundance	
	Native	Exotic	Native	Exotic
Increase	39.22 (20)	65.12 (28)	58.82 (30)	72.09 (31)
No change	9.80 (5)	6.98 (3)	0.00 (0)	0.00 (0)
Decrease	50.98 (26)	27.91 (12)	41.18 (21)	27.91 (12)

Appendix 3a *Number of sites occupied, total frequency of occurrence and changes between the 1993 and 1997 spring sampling dates, in native vascular plant species, and lichens and mosses, over 88 study sites on Flat Top Hill.*

	Number of sites occupied			**Average abundance**		
	1993	1997	Change	1993	1997	Change
Acaena buchananii	13	6	-7	0.32	0.10	-0.22
Acaena caesiiglauca	2	2	0	0.02	0.02	0.01
Acaena novae-zelandiae	32	36	4	0.66	1.93	1.27*
Aciphylla aurea	1	1	0	0.01	0.01	0.01
Asplenium fabellifolium	3	0	-3	0.02	0.00	-0.02
Blechnum penna-marina	2	2	0	0.07	0.60	0.53
Carex breviculmis	18	14	-4	0.24	0.28	0.04
Celmisia gracilenta	1	3	2	0.01	0.07	0.06
Ceratocephalus pungens	3	0	-3	0.02	0.00	-0.02
Colobanthus brevisepalus	19	13	-6	0.33	0.40	0.07
Colobanthus strictus	1	3	2	0.01	0.02	0.01
Coprosma propinqua	3	2	-1	0.02	0.09	0.07
Dichelachne crinita	0	17	17	0.00	1.35	1.35**
Elymus falcis	0	2	2	0.00	0.69	0.69
Elymus solandri	0	6	6	0.00	0.40	0.40*
Elymus tenuis	6	19	13	0.19	1.97	1.77*
Epilobium alsinoides	2	0	-2	0.02	0.00	-0.02
Epilobium hectorii	22	31	9	0.27	0.69	0.43+
Festuca novae-zelandiae	12	16	4	1.07	1.68	0.61
Geranium sessiliorum	38	32	-6	0.48	0.47	-0.01
Gnaphalium ruahinicum	11	5	-6	0.07	0.04	-0.03
Helichrysum filicaule	6	7	1	0.27	0.32	0.05
Hydrocotyle novae-zelandiae	4	0	-4	0.11	0.00	-0.11
Lachnagrostis filiformis	2	0	-2	0.16	0.00	-0.16
Lagenifera cuneata	2	0	-2	0.03	0.00	-0.03
Leucopogon fraseri	1	1	0	0.01	0.58	0.57
Melicytus alpinus	3	4	1	0.20	0.22	0.02
Microtis unifolia	0	4	4	0.00	0.04	0.04
Myosotis pygmaea var minutiora	6	5	-1	0.09	0.06	-0.03
Myosurus minimus ssp *novae-zelandiae*	2	0	-2	0.01	0.00	-0.01
Oreomyrrhis ramosa	3	1	-2	0.06	0.01	-0.05
Oreomyrrhis rigida	5	7	2	0.03	0.10	0.06
Oxalis exilis	17	7	-10	0.25	0.08	-0.17+
Ozothamnus leptophyllus	1	1	0	0.01	0.02	0.02
Poa cita	0	5	5	0.00	0.60	0.60+
Poa colensoi	22	14	-8	0.39	0.42	0.03
Poa lindsayi	16	2	-14	0.24	0.06	-0.19+
Poa maniototo	38	17	-21	2.12	0.44	-1.68**
Poa "tiny"	0	4	4	0.00	0.11	0.11
Raoulia australis	45	38	-7	6.11	4.68	-1.44
Raoulia beauvardii	19	14	-5	1.02	1.03	0.01
Raoulia subsericea	3	4	1	0.25	0.33	0.08
Rytidosperma buchananii	5	0	-5	0.08	0.00	-0.08
Rytidosperma clavatum	27	43	16	3.00	6.19	3.19*
Rytidosperma cf *maculatum*	1	9	8	0.01	0.77	0.76*
Rytidosperma thomsonii	3	0	-3	0.02	0.00	-0.02
Rytidosperma unarede	3	1	-2	0.26	0.01	-0.24
Stellaria gracilenta	32	33	1	1.70	2.19	0.49
Thelymitra sp.	1	3	2	0.01	0.07	0.06
Uncinia elegans	2	0	-2	0.15	0.00	-0.15
Vittadinia australis	25	22	-3	0.38	0.34	-0.05
Lichens	76	60	-16	5.16	7.21	2.05
Mosses	52	46	-6	3.35	4.34	0.99

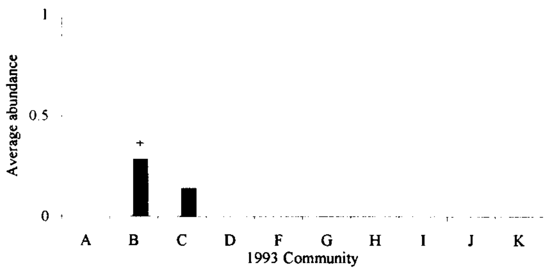
Appendix 3b *Number of sites occupied, total frequency of occurrence and changes between the 1993 and 1997 spring sampling dates, in exotic vascular plant species, over 88 study sites on Flat Top Hill.*

	Number of sites occupied			Average abundance		
EXOTIC SPECIES	1993	1997	Change	1993	1997	Change
Acaena agnipila	8	10	2	0.27	0.38	0.11
Agrostis capillaris	7	14	7	0.81	1.93	1.12
Aira caryophyllea	0	27	27	0.00	2.91	2.91
Anagallis arvensis	41	18	-23	0.59	0.45	-0.14
Anthoxanthum odoratum	50	77	27	13.39	33.01	19.63***
Aphanes arvensis	21	24	3	0.34	0.57	0.23
Bromus tectorum	0	2	2	0.00	0.01	0.01
Cerastium fontanum	4	10	6	0.06	0.13	0.07
Cirsium arvense	14	4	-10	0.63	0.08	-0.55+
Cirsium vulgare	15	13	-2	0.16	0.35	0.19
Crepis capillaris	33	63	30	1.39	4.89	3.50**
Dactylis glomerata	0	8	8	0.00	1.03	1.03
Echium vulgare	9	5	-4	0.24	0.05	-0.19
Erodium cicutarium	33	15	-18	1.09	0.23	-0.86*
Erophila verna	3	5	2	0.05	0.06	0.02
Euphorbia peplus	2	3	1	0.01	0.02	0.01
Festuca rubra	25	38	13	4.69	10.02	5.33+
Hieracium pilosella	3	3	0	0.02	0.07	0.05
Holcus lanatus	14	31	17	0.99	3.78	2.78*
Hypericum perforatum	9	27	18	0.13	0.90	0.77*
Hypocharis radicata	25	56	31	0.69	2.54	1.85***
Lolium perenne	2	2	0	0.14	0.16	0.03
Marrubium vulgare	10	8	-2	0.47	0.09	-0.39
Myosotis discolor	17	17	0	0.18	0.15	-0.03
Myosotis stricta	34	28	-6	1.23	0.55	-0.68
Poa pratensis	3	23	20	0.50	2.52	2.02+
Reseda luteola	18	0	-18	0.27	0.00	-0.27*
Rosa rubiginosa	11	34	23	0.09	0.54	0.45***
Rumex acetosella	45	41	-4	2.15	2.12	-0.03
Rytidosperma racemosa	7	5	-2	0.32	1.31	0.99
Sedum acre	71	66	-5	31.61	18.26	-13.35**
Taraxacum officinale	0	8	8	0.00	0.08	0.08
Thymus vulgaris	31	44	13	6.89	12.69	5.80*
Trifolium arvense	41	62	21	3.12	14.56	11.44***
Trifolium dubium	0	4	4	0.00	0.05	0.05
Trifolium repens	9	16	7	0.65	0.63	-0.02
Urtica urens	2	0	-2	0.01	0.00	-0.01
Verbascum thapsus	5	6	1	0.04	0.37	0.33
Verbascum virgatum	8	11	3	0.09	0.23	0.14
Veronica verna	0	6	6	0.00	0.32	0.32
Vicia sativa	1	19	18	0.01	0.80	0.80+
Vittadinia gracilis	5	16	11	0.03	0.33	0.30**
Vulpia bromioides	0	3	3	0.00	0.23	0.23

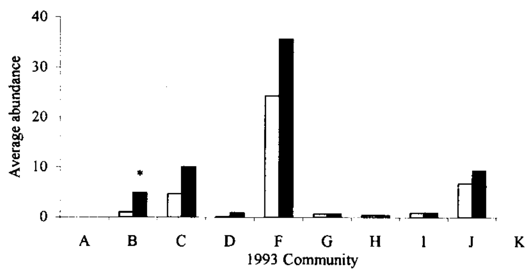


Appendix 4a *Native species which showed significant changes in average abundance between the September 1993 and the September 1997 sampling times, in one or more of the ten resampled 1993 communities. Significant changes are indicated thus:*
*+= 0.10>P>0.05; * = P<0.05; ** = P<0.01; *** = P<0.001*

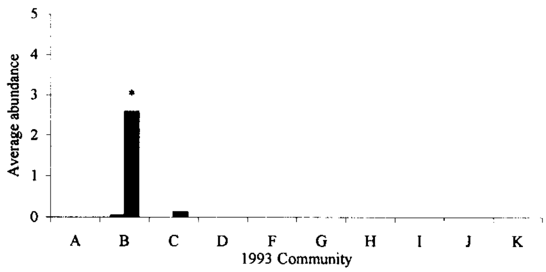
Poa "tiny"



Rytidosperma clavatum



Rytidosperma cf *maculatum*



Appendix 4a cont...

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