Environmental effects associated with snow grooming and skiing at Treble Cone Ski Field

Part 1. Vegetation and soil disturbance

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ABSTRACT

The expansion of ski facilities on public conservation land administered by Department of Conservation (DOC) is placing increased pressure on fragile sub-alpine and alpine ecosystems. Snow grooming in particular has the potential to disturb both soils and vegetation.

Field visits to three west Otago ski fields located on land managed by DOC showed that cushionfields are the most vulnerable to damage from snow grooming. To determine the nature and extent of damage to cushionfields 10 permanent 30 m transects were established across cushionfields in 1997 in areas that were groomed and skied, areas that were skied, and in undisturbed (control) areas at Treble Cone Ski Field. Data were collected at 0.3 m intervals to estimate percentage ground cover for six classes: live vascular plants, moss, lichen, dead vegetation and litter, bare ground, and rock and gravel. The frequency of each plant species was also recorded. Measurements of depth of A-horizon, soil bulk density, and penetration resistance were made at 3 m intervals along each transect.

There was a statistically significant difference in the cover of live vegetation among the three treatments. Cushionfields that were groomed had a lower cover of live vascular vegetation than the other treatments. Those cushionfields that had been groomed for only a year had the lowest cover of live vegetation. There were no significant differences in species richness and composition between the two treatments and the control, nor were there any statistical differences in soil bulk densities and penetration resistance.

While damage to cushionfields from snow grooming and skiing at Treble Cone is not excessive, it is widespread and ongoing. Transects should be re-monitored within 5 years to assess any long-term changes in plant cover, and selected transects should be surveyed for snow depths and densities in the winter to determine the degree and extent of snow compaction.

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1. Introduction

There has been an expansion of downhill ski facilities and ski-related activities in New Zealand's alpine areas in recent years. Superior snow conditions, together with improved reliability of snow cover through snowmaking, render such areas particularly attractive for development. However, there is a growing concern that these environmentally sensitive alpine ecosystems are suffering irreparable damage from such activities.

During the winter, snow is compacted by large tracked vehicles (snow groomers). Groomers are used to (a) make snow easier to ski, (b) prevent snow from blowing away, (c) fill in areas with thin snow coverage, and (d) even out hummocks (moguls). Moguls are the result of the carving action that skiers make, which redistributes and compacts the snow into hummocks. Skiers can remove snow cover and expose the vegetation, especially when the snow pack is thin, such as at the start and end of the ski season, and in low snow years. Where the snow cover is thin or absent, the passage of snow grooming vehicles can damage the vegetation and compact the soils. Compaction can reduce the size of macropores, thereby inhibiting root penetration, aeration, and infiltration capacity which can, in turn, lead to reduced seedling growth and accelerated surface erosion.

Studies have been carried out in Europe, North America, and New Zealand to determine the impacts of ski field activities. Some of these have focused on the impacts of ski area construction (e.g. Mosimann 1985, 1991; Cernusca 1987). Other studies have assessed the impacts of skiers and snow grooming machinery on vegetation and soil in Scotland (Bayfield 1971, 1980; Watson et al. 1970), in Russia (Baiderin 1980, 1983), and in Germany (Grabherr 1985; Newesly et al. 1994; Neugirg 1986; Ries 1996), whilst Meyer (1993) described their impacts on soil fauna. The impacts of ski-related activities on vegetation in North America have been documented by several workers (e.g. Price 1985; Hamilton 1981). Kattelmann (1985) investigated the hydrological implications of grooming. Most other studies which are relevant to the assessment of the impacts of snow grooming activities focus on the impacts of other over-snow vehicles, such as snowmobiles (e.g. Neumann & Merriam 1972) and arctic seismic vehicles (e.g. Emers et al. 1995).

In New Zealand, Rogers & Kimberley (unpublished report 1990) described the impacts of ski field management on vegetation at Turoa Ski Field, Tongariro National Park, while Wardle & Wardle (unpublished report 1992) assessed the impacts of snow grooming on tussock grasslands at Broken River Ski Field, Craigieburn Range, Canterbury. Vegetation monitoring programmes have also been established on The Remarkables ski field basin (Knight Frank, unpublished report 1994) and at Treble Cone Ski Field to investigate the implications of ski field development on succession in tussock grasslands (Jensen et al. 1997).

In west Otago, three of the four main downhill ski fields (Coronet Peak, The Remarkables, and Treble Cone) are located on land administered by the Department of Conservation (DOC). Concern was raised over the possible impacts ski field activities were having on fragile alpine vegetation. In 1995, DOC commissioned Landcare Research to conduct a literature review of the likely impacts of snow grooming and skiing on alpine vegetation and soils. The review (Fahey & Wardle 1998) drew mainly on overseas experience, and concluded that physical damage to plant communities is likely, particularly on exposed crests and hummocks. Woody and herbaceous plants as well as tussock species are also vulnerable to damage, especially where the snow pack is thin.

To determine whether the findings were applicable to the New Zealand environment, a vegetation and soil monitoring programme was proposed for all three ski fields. However, funding constraints meant that the full monitoring programme involving the establishment of vegetation transects was only feasible at one of these fields. Visits to all fields showed that cushionfield vegetation and wetland communities were more vulnerable to snow grooming damage than tussock grassland communities. However, wetlands tend to be in areas of deep snow accumulation, and are therefore less likely to be susceptible to damage than cushion vegetation. In addition, cushionfield vegetation is more widespread than wetland communities, and occurs in areas where ski field extension and proposals for cat skiing[1] ventures are likely to take place. Thus the impact of snow grooming and skiing on cushionfields was considered to be the highest priority for study. Treble Cone Ski Field, situated in the Harris Mountains 23 km north of Wanaka, was chosen as the study area as it has many cushionfields present, and the ski field staff were amenable to providing management information.

1.1 OBJECTIVES

- To determine the nature and extent of damage from skiing and snow grooming to sub-alpine and alpine cushionfield vegetation communities.
- To make recommendations on how the impact of snow grooming activities on cushionfield vegetation in sub-alpine and alpine areas can be minimised.
- To assess whether soil properties are also affected by frequent grooming and skiing.

2. Cushionfield vegetation

Cushionfields are dominated by low-growing tundra-like cushion and mat plants, such as *Dracophyllum muscoides*, *Hectorella caespitosa,* and *Raoulia hectori*. Cushion plants are often woody and compact, with a shell of close-set leaves and shoots, and an interior packed with stems and dead material. This life form has evolved probably in response to shoot activity being favoured only in the relatively calm, diurnally heated layer close to the ground, and because

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[1]Cat skiing involves the repeated use of a tracked over-snow vehicle, usually a snow groomer, in the back country to transport skiers from the bottom of a ski run to the top (in place of a ski lift).

nutrient and water uptakes are limited by the cold, raw soils (Wardle 1991). Cushionfields occur in penalpine to alpine areas, where soils are shallow and stony, especially on exposed knolls and ridges (Wardle 1991), on solifluction terraces, where exposure to strong winds often results in a distinct vegetation pattern (Mark & Bliss 1970), and where the snow pack is thin and melts earlier than at other sites (Körner & de Moreas 1979; Talbot et al. 1992). At Treble Cone Ski Field, the cushion vegetation is associated with mountain daisy *(Celmisia viscosa)*, slim-leaved snow tussock grassland (*Chionochloa macra)*, and snowbank and fellfield vegetation.

3. Constraints on site selection

A large number of transects should be established widely across the ski field, or preferably across several ski fields, to assess the effects of snow grooming on vegetation. However, the need to account for as much variation in vegetation as possible had to be balanced against the logistical constraints of time, money, the natural distribution and size of cushionfields, and the actual management pattern on the ski field.

Cushionfields are not evenly distributed over the ski field. Rather they tend to be concentrated on exposed sites, such as ridges or solifluction lobes. This has resulted in the groomed and skied treatment cushionfields being clustered on those ski runs which occur on exposed sites, although they did not necessarily show signs of vegetation damage.

Some cushionfields at Treble Cone were too narrow (< 10 m wide) or small for transects to be established on them, thereby further reducing the choice of suitable cushionfields for the monitoring programme.

It would have been preferable to sample cushionfields with very similar species composition. However, natural variability of species between cushionfields at Treble Cone, together with the other constraints mentioned, did not make this possible.

Since establishment in 1976, development at Treble Cone Ski Field has seen ski lifts change location, resulting in much of the mountain being affected by skiing and grooming activities. The variable nature of the snow pack each year has also dictated the location and frequency of snow grooming on the ski field. This factor especially has made it difficult to find suitable cushionfields to act as control sites, e.g. a cushionfield which appears to receive very little skiing traffic today is likely to have been skied on in previous years when the pattern of usage was different. Therefore the majority of control sites had to be located beyond the current ski field boundary.

4. Methods

4.1 VEGETATION SAMPLING PROCEDURES

A total of 30 cushionfields were sampled across the ski field in January 1997 (Fig.1). Ten sites are in areas that are groomed ("groom + ski"), ten are in skied areas which are not groomed ("ski"), whilst a further ten are in areas which are virtually never groomed or skied ("control").

A 30 m long transect, running across the slope, was established at each cushionfield. Where possible, transects included surrounding plant com-munities so that any changes in cushionfield boundaries through time could be monitored. Where cushionfields were narrower than 30 m, two parallel 15 m transects were established, 2 m apart. Each transect was permanently marked at both ends with labelled aluminium pegs, which were driven into the ground to avoid removal during the ski season. To aid relocation of the transects, a red or white fibreglass pole was placed 50 cm from the ends of the transect lines, and 5 mm diameter aluminium pegs were placed at 5 m intervals along each transect line. Information on the setup of transects is provided in Appendix 12.1. Additional details for each transect, including relocation notes, are held by Landcare Research, Lincoln.

At each transect, a tape measure was tightly secured between the aluminium end pegs. Transects were sampled at 0.3 m intervals, giving 100 sample points. At each sample point a 5 cm^2 quadrat was placed on the uphill side of the tape measure, and the percentage ground cover was estimated for each of the following six classes: live vascular vegetation; live moss; live lichen; dead vegetation and litter; bare ground (with or without filmy lichens growing on it); and rock and gravel. The presence of all live plant species rooted into the quadrat was recorded to give an estimate of percentage frequency for each plant species. Identifiable dead species were also recorded. (See Appendices 12.2, 12.3.)

For those sample points occurring in taller vegetation, such as tussock grassland, a height–frequency method (Scott 1965) was used to determine stature and biomass. A height pole marked off at 5 cm intervals was used, to which a movable open-ended frame (4.47 cm × 4.47 cm × 5 cm) which did not deflect plants, was attached. The frame was initially placed at the lowest height interval (i.e. 0–5 cm above ground level) and the presence of plant species within the frame was recorded. The frame was moved up the height pole and the procedure repeated at each height interval. Where tillers or leaves of *Chionochloa* and *Celmisia* species were rooted in the lowest height interval, the longest leaf was extended up the height pole to determine its maximum length. These data will be compared with future height frequency data to provide an indication of how grooming affects the biomass and height of taller vegetation.

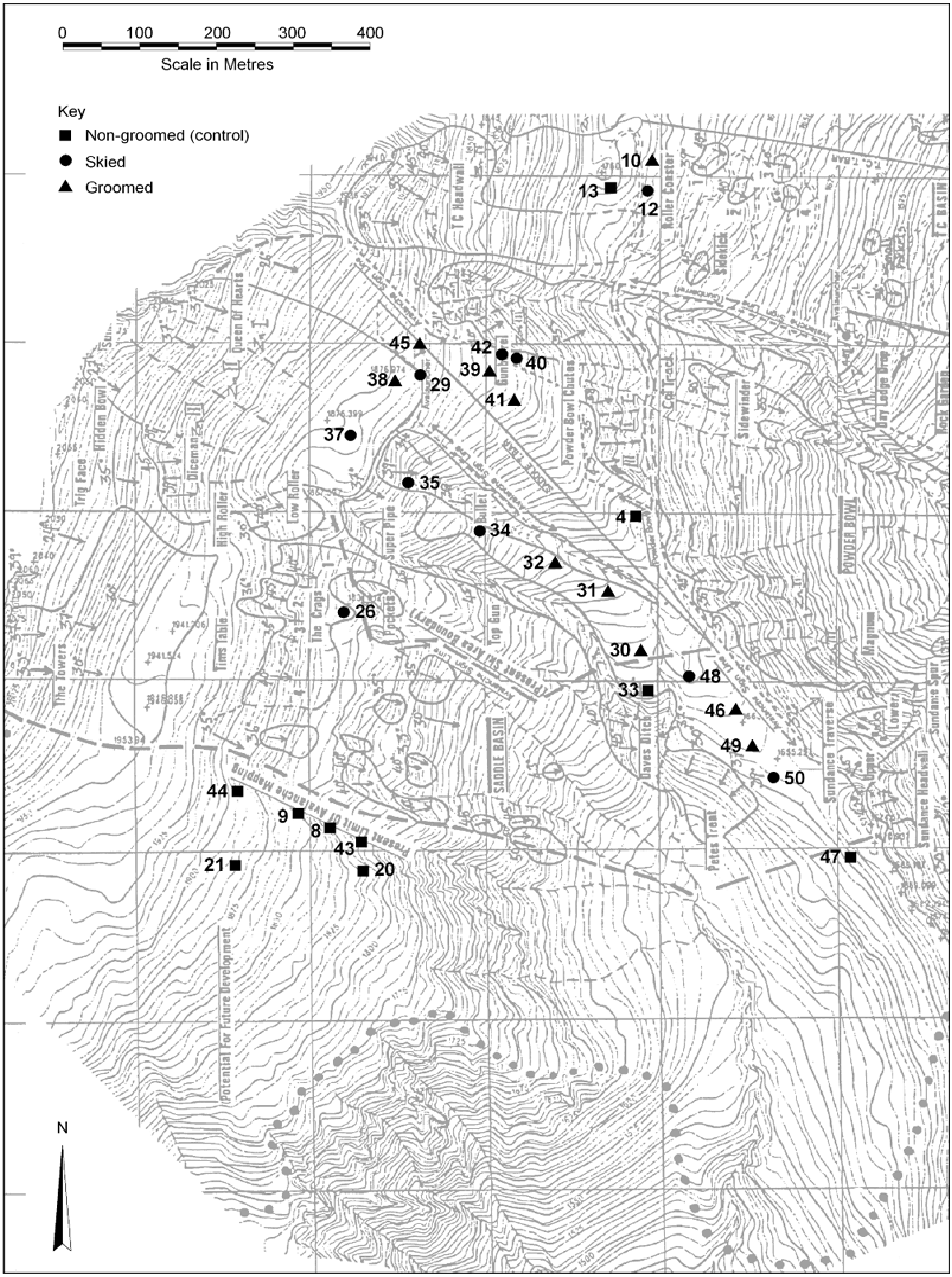

FIGURE 1. TRANSECT LOCATIONS USED IN THE 1997 SNOW SURVEY, TREBLE CONE SKI FIELD.

4.2 SOIL SAMPLING PROCEDURES

The depth of the A-horizon was estimated at each 3 m interval along all transects. Two samples were also collected for bulk density measurements, one at a depth of 0–3 cm and the other at a depth of 3–6 cm. These were identified and wrapped in microwave-resistant plastic bags in preparation for their return to the laboratory. Penetration resistance was also measured at 3 m intervals along the transects with a manually operated Rimik CP10 penetrometer with a 12.5 mm diameter 30° angle cone. It was not possible to measure penetration resistance at all sites because of rocks close to or at the surface. Full details on soil depth, bulk density, and penetration resistance are available at Landcare Research, Lincoln.

4.3 OBSERVATIONS AND SITE INFORMATION

At each transect, general observations were made regarding the extent and type of damage, patterns in vegetation, and presence of any weed species. Photos were taken along each transect and of adjacent damaged areas to assist in establishing how ground cover and species composition change through time. Some photo examples are included in Appendix 12.4 (Figs 2–11). The altitude, slope, aspect, and year the area was first groomed or skied were also recorded for each transect (Table 1). Additional information on visitor numbers for the winter of 1997, plus snow grooming patterns, and patterns of skier usage is provided in Appendix 12.5.

5. Data analysis

5.1 VEGETATION ANALYSES

Since many of the transects traversed patches of other plant communities in addition to cushionfield vegetation, it was necessary to classify the dominant plant community at each sample point. Four main plant communities were identified: cushionfield vegetation, *Celmisia viscosa* matfield, tussock grassland, or *Marsippospermum gracile* snowbank vegetation. Only data collected from cushionfield vegetation are analysed in this report.

Because of differences in the number of cushionfield vegetation sample points between transects, the results were converted into percentage data to facilitate comparison between transects.

Ground cover

For each transect, the average percentage ground cover was calculated for each ground cover class (i.e. live vascular vegetation; live moss; live lichen; dead vegetation and litter; bare ground (with or without filmy lichens growing on it); and rock and gravel). The average percentage ground cover data for each cover class were log-transformed to improve the normality of the data. The sites with different management treatments (i.e. groom + ski, ski, and control) were then

TABLE 1. ENVIRONMENTAL AND MANAGEMENT ATTRIBUTES OF THE TRANSECTS AT TREBLE CONE SKI FIELD.

TRANSECT NUMBER AND TREATMENT	ALTITUDE (m asl)	SLOPE (DEGREES)	ASPECT (DEGREES)	YEAR FIRST GROOMED/ SKIED
Control				
33	1655	13	158	n/a
47	1660	27	212	n/a
4	1705	12	145	n/a
13	1765	22	125	n/a
43	1800	20	108	n/a
20	1810	17	119	n/a
8	1825	20	100	n/a
9	1830	17	67	n/a
21	1880	13	116	n/a
44	1880	18	90	n/a
Ski				
48	1650	15	165	1996
50	1650	17	189	1996
34	1755	21	140	1989
12	1760	23	110	1976
26	1800	2	100	1989
35	1815	26	105	1989
40	1815	12	90	1989
42	1825	27	56	1989
29	1860	25	104	1989
37	1870	17	119	1989
Groom + ski				
46	1640	4	135	1996
49	1655	15	158	1996
30	1680	14	174	1989
31	1700	20	170	1989
32	1720	21	152	1989
10	1765	17	107	1976
41	1815	14	84	1989
39	1825	23	276	1989
45	1865	23	125	1989
38	1870	11	300	1989

compared using one-way analysis of variance (ANOVA). The results were robust with respect to the type of analysis used, and the same results were obtained using a non-parametric Kruskal–Wallis test.

An analysis of covariance (ANCOVA) was used to control for differences among transects in altitude, aspect, slope, and duration of treatment (i.e. number of years since treatment was first applied) before testing for management effects. Relationships between cover class and these environmental variables were investigated.

Species frequency

For each transect, the total number of occurrences for each species was expressed as a percentage of the number of possible occurrences, i.e. the total number of sample points with cushionfield vegetation in a transect. This procedure was repeated for identifiable dead species occurring in the cushionfield vegetation. A measure of percentage frequency of each dead species was calculated.

To simplify analysis of species frequency data, plant species occurring in cushionfield vegetation were grouped into functional groups (guilds) based on similar growth form, thereby enabling the examination of major structural shifts in the vegetation. Table 2 shows the plant species recorded in sampling and the life form categories used.

The effects of different management treatments on the percent frequency of each of the plant guilds was tested using one-way analysis of variance on raw data. Again, the results were robust to the type of analysis used, and the same results were obtained using a non-parametric Kruskal–Wallis test. Where the analysis of variance indicated a significant difference among treatments, analysis of covariance (ANCOVA) was used on log-transformed data to control for differences in altitude, aspect, and slope, before re-testing for management effects.

TABLE 2. PLANT SPECIES RECORDED IN SAMPLING AND THE LIFE FORM CATEGORIES USED IN TREBLE CONE SURVEY.

<u>Cushion plants</u> *Abrotanella inconspicua* *Anisotome imbricata* *Chionohebe thompsonii* *Colobanthus buchananii* *Dracophyllum muscoides* *Hectorella caespitosa* *Phyllachne colensoi* *Phyllachne rubra* *Raoulia hectorii*	<u>Woody dicot herbs (non-cushion habit)</u> *Aciphylla kirkii* *Celmisia haastii* *Celmisia laricifolia* *Celmisia lyallii* *Celmisia viscosa* *Chionohebe densifolia* *Dracophyllum pronum* *Hebe lycopodioides* *Melicytus alpinus* *Raoulia grandiflora*	<u>Other dicot herbs</u> *Anisotome flexuosa* *Anisotome languinosa* *Cardamine bilobata* *Epilobium tasmanicum* *Gentiana divisa* *Leptinella goyenii* *Ourisia glandulosa* *Schizeilema exiguum* *Viola cunninghamii*
<u>Grasses and monocot herbs</u> *Agrostis capillaris* *Agrostis muelleriana* *Carex pterocarpa* *Carex pyrenaica* *Chionochloa macra* *Koeleria* sp. *Luzula pumila* *Marsippospermum gracile* *Poa colensoi* *Rytidosperma pumilum*	<u>Lichens</u> *Alectoria nigricans* *Cetraria islandica* var. *antarctica* *Siphula dissoluta* *Thamnolia vermicularis*	<u>Mosses</u> Not identified

Species richness

The number of vascular plant species present in cushionfield vegetation along each transect was calculated.

5.2 SOIL ANALYSES

All samples were oven-dried then weighed and sieved to separate out the > 2 mm fraction, which was also weighed. The dry bulk density was calculated by subtracting the volume of stones (the weight of the > 2 mm fraction divided by an average particle density) from the total volume. Knowing the weight of the soil and the total volume enables the dry bulk density to be calculated (in weight/unit volume).

Soil bulk density

The Wilk–Shapiro/Rankit plot procedure was used to establish whether the 100 samples from each of the three treatments conformed to a normal distribution. Since these tests showed no significant departures from the Rankit plot, normality is assumed (average Wilk–Shapiro statistic = 0.9389). A 2-sample ‘t’test was then applied to the sets of data to test for differences between the means. The effects of the different management treatments on bulk density were also tested on the average values per transect (i.e. where n = 10) using analysis of variance (ANOVA). Finally, the data were tested for the effect of different management treatments after controlling for differences among transects in altitude, aspect, and slope using analysis of covariance (ANCOVA).

Soil penetration resistance

Penetration resistance or force (in kPa) was recorded at 2 cm depth increments down to 80 cm, but only data in the top 40 cm were used in the analyses. At each point on the transect three sets of measurements were made within a 20 cm radius, and the average for each set was computed. All soils were at or near field capacity. The data were arranged into the three treatments (control, ski, and groom + ski) and the data sets for each depth and each treatment were tested for normality. In all but one case the Wilk–Shapiro normality statistic was > 0.9100, indicating that these data for the most part conform to a normal distribution. The same sequence of statistical tests was applied to the soil penetration data, i.e. a 2-sample ‘t’ test, analysis of variance, and analysis of covariance.

6. Results

6.1 GROUND COVER

Data for percentage ground cover classes at each transect are presented in Appendix 12.3.

There was a lower cover of live vegetation on the groom + ski transects than on transects of the other two treatments (Table 3). Live vegetation was the only cover class that differed significantly among the three management treatments (ANOVA, $F_{2,29}$ = 5.24, P = 0.01).

TABLE 3. AVERAGE PERCENTAGE GROUND COVER (± STANDARD ERROR) FOR EACH COVER CLASS BY MANAGEMENT TREATMENT (GROOM + SKI, SKI, CONTROL) AT TREBLE CONE SKI FIELD.

COVER CLASS	MANAGEMENT (NO. OF TRANSECTS)		
	GROOM + SKI(10)	SKI(10)	CONTROL(10)
Live vegetation	32 (± 2)	41 (± 2)	40 (± 3)
Dead vegetation and litter	37 (± 4)	33 (± 3)	30 (± 2)
Bare ground	14 (± 2)	11 (± 1)	11 (± 2)
Rock and gravel	5 (± 2)	4 (± 1)	4 (± 1)
Moss	3 (± 1)	3 (± 1)	3 (± 1)
Lichen	10 (± 3)	12 (± 2)	15 (± 3)

This difference in live vegetation cover between management treatments was still significant after controlling for differences among transects in altitude, aspect and slope (ANCOVA, $F_{2,24}$ = 4.57, P = 0.021). None of the other cover classes differed significantly among management treatments, even after cont-rolling for differences in altitude, aspect and slope. However, the general trend was for increasing disturbance (i.e. groom + ski, ski) to result in an increase in cover of bare ground, dead vegetation and litter; and a decrease in lichen. Cover of moss remained the same irrespective of management treatment.

Live vegetation cover, which differed among the management treatments, also showed a significant inverse relationship with the number of years that a transect had been skied or groomed, although the small sample size for 1976 and 1996 transects should be noted. For the groom + ski and ski transects alone, after controlling for management effects, live vegetation cover tended to be higher on transects that had the longest history of grooming and/or skiing disturbance (Table 4). However, this relationship was weakened when altitude, aspect and slope, in addition to management were controlled for (regression $F_{1,14}$ = 3.37, P = 0.088).

TABLE 4. AVERAGE PERCENTAGE COVER (± STANDARD ERROR) OF LIVE VEGETATION BY YEAR OF FIRST USE FOR THE 20 TRANSECTS IN THE GROOM + SKI AND SKI TREATMENTS AT TREBLE CONE.

YEAR OF FIRST USE	AVE. % LIVE COVER (± SE)	NO. OF TRANSECTS
1976	45 (± 5)	2
1989	37 (± 2)	14
1996	32 (± 2)	4

The only cover class which varied significantly with any of the environmental variables was the dead vegetation and litter class. There was a greater cover of dead vegetation and litter at lower elevations (Pearson correlation r = 0.48, $P = 0.007$, n = 30) and on shadier sites (Pearson correlation r = 0.45, $P = 0.012$, n = 30).

6.2 SPECIES FREQUENCY

The raw data for mean percentage species frequency for cushionfield vegetation at each transect are presented in Appendix 12.2. Groomed sites had a significantly lower frequency of live cushion plants than other sites (Kruskal–Wallis chi-square = 11.1, $P < 0.01$; Table 5). This result remained significant when altitude, aspect and slope were controlled for (ANCOVA, $F_{2,24} = 7.44$, $P = 0.003$). The live cushion plant guild was the only one to exhibit a significant difference between management treatments.

6.3 SPECIES RICHNESS

There was no significant difference in the number of vascular species present between cushionfields with different management treatments.

6.4 OBSERVATIONS

Cushionfields that were groomed tended to look worn, with signs of physical damage, such as cuts in the cushions from groomer tracks, crushed stems, scalped off cushions, loose cushion plant pieces forming litter on the surface, dead vegetation, and exposure of bare ground or rock (Figs 3, 8, and 9, Appendix 12.4). In severe cases, this resulted in soil erosion (e.g. top of Saddle Ridge run). Cushionfields subject only to skiing had fewer obvious signs of disturbance, which usually consisted of cuts in the cushion plants from ski edges. Some cushion plants showed signs of being scraped, the outer stems and leaves having been sliced off (Figs 4, 6, and 7, Appendix 12.4). In both groomed and skied cushionfields, plants occupying the natural hollows tended to look healthy, often with a presence of *Cetraria islandica* var. *antarctica* lichen. It was the hummocks that had received most damage. Those cushionfields that received no skiing-related disturbance showed no signs of scraping or scalping (Figs

TABLE 5. MEAN PERCENTAGE FREQUENCY OF LIVE AND DEAD SPECIES GUILDS (± STANDARD ERROR) BY MANAGEMENT TREATMENT AT TREBLE CONE.

The ratio of dead/(live + dead) gives the proportion of the total frequency of species occurrences that were dead averaged over the 10 transects in each management treatment (expressed as a percentage).

SPECIES GUILD	MANAGEMENT (NO. OF TRANSECTS)		
	GROOM + SKI(10)	SKI(10)	CONTROL(10)
Cushion			
% live	32 (± 5)	55 (± 4)	45 (± 3)
% dead	27 (± 6)	41 (± 7)	29 (± 4)
% dead/(live +dead)	45 (± 4)	40 (± 3)	36 (± 2)
Woody herbs			
% live	25 (± 4)	21 (± 5)	26 (± 3)
% dead	17 (± 6)	9 (± 3)	17 (± 3)
% dead/(live +dead)	34 (± 7)	29 (± 5)	38 (± 4)
Non-woody herbs			
% live	4 (± 2)	4 (± 2)	5 (± 2)
% dead	1 (± 1)	1 (± 1)	0
% dead/(live +dead)	14 (± 6)	4 (± 1)	0
Monocot herbs, grasses			
% live	40 (± 5)	32 (± 5)	37 (± 4)
% dead	21 (± 5)	14 (± 4)	15 (± 3)
% dead/(live +dead)	31 (± 4)	26 (± 5)	30 (± 4)
SPECIES DIVERSITY *	12 (± 1)	13 (± 1)	13 (± 1)

* Number of vascular plant species in cushion vegetation

2 and 5, Appendix 12.4). At lower altitudes, the lichen *Cetraria* sp. was observed growing on top of, as well as in the hollows of, plants occupying undisturbed cushionfields. Dead vegetation was present on all cushionfields, irrespective of management treatment. The control cushionfields beyond the "New Boundary" sign line appeared to have a lower *Dracophyllum muscoides* presence, with more rocky ground present than elsewhere on the ski field. The actual species present and the proportions of cushion plants appeared to vary amongst transects, irrespective of management treatment (see Appendix 12.3).

A discrete amount of browntop (*Agrostis capillaris*) grass was found on one transect at the top of the Saddle Ridge T bar. No other exotic species were observed.

Celmisia viscosa occurring in hollows at the edges of cushionfields or tussocks generally appeared to be in good health. However, where grooming activity was heavy and snow cover variable, *Celmisia viscosa* mats showed some signs of damage (Fig. 10). At a transect on the lower Bullet groomed ski run, few live plants were seen, and dead plant matter formed a litter on the ground. On a steep slope used for access to Tim's Table above the ski field, *Celmisia viscosa* had been scalped, resulting in live plants being torn out of the ground, thereby revealing dead vegetation and bare ground (Fig. 11). This was the result of only a small number of passes by a snow groomer.

There was little sign of damage to tussocks, except in the vicinity of the damaged *Celmisia viscosa* on the lower Bullet groomed ski run. Here, individual tussocks amongst the *Celmisia viscosa* mats were severely crushed, resulting in the tussock centres being exposed.

6.5 SOIL BULK DENSITY

The application of a 2-sample 't' test showed no statistical difference in the means of the bulk densities for samples collected for the three treatments. The effect of different management techniques on bulk density tested using ANOVA (where n = 10) is summarised in Table 6. It shows that there is no significant difference in soil bulk density among treatments at either depth. Nor was there any statistically significant difference after using ANCOVA to control for differences among transects in altitude, aspect, and slope.

TABLE 6. MEAN VALUES (± SE) FOR BULK DENSITY BY MANAGEMENT TREATMENT (n=10 FOR EACH TREATMENT).

BULK DENSITY	GROOM + SKI	SKI	CONTROL	ANOVA RESULTS	
				F	*P*
0–3 cm	0.71 (±0.02)	0.67 (±0.03)	0.68 (±0.03)	0.48	0.63
3–6 cm	0.92 (±0.03)	0.89 (±0.03)	0.90 (±0.03)	0.22	0.81

6.6 SOIL PENETRATION RESISTANCE

The 't' test showed that the means of the penetration resistance measurements at 10, 20, 40, and 60 mm depth in the ski and groom + ski treatments were not statistically different from those at equivalent depths in the control transects. The effects of different management treatments were also tested on the three sets of mean values for each treatment using ANOVA (Table 7). Again they showed no statistical difference in soil penetration resistance at depths of 0–10 and 10–20 cm among treatments.

TABLE 7. MEAN VALUES (±SE) FOR PENETRATION RESISTANCE BY MANAGEMENT TREATMENT.

PENETRATION RESISTANCE	GROOM + SKI (n = 9)	SKI (n = 7)	CONTROL (n = 10)	ANOVA RESULTS	
				F	*P*
0 - 10 cm	237 (±30)	280 (±12)	246 (±12)	1.02	0.38
10 - 20 cm	526 (±46)	601 (±36)	535 (±26)	1.08	0.36

7. Discussion

At Treble Cone Ski Field, grooming and skiing significantly reduced total vegetation cover, and had a greater impact than skiing alone. The impact was greatest on cushion plants (see Table 5). The greatest reduction in live vegetation cover occurred on those cushionfields which had only been groomed for one year (Table 4), although it should be noted that sample size was small (n = 4). Other workers (e.g. Bell & Bliss 1973; Wanek 1971, 1974) have also observed that the impact on vegetation is worst in the first season, and that plants appear to recover in subsequent seasons. Table 5 indicates that, while vegetation will start to grow back after the initial skiing or grooming disturbance, it could take many years for pre-disturbance levels of total vegetation cover to be reached.

In a North American study, the species composition of arctic tundra vegetation changed with time following winter vehicle disturbance. Non-vascular plants and evergreen shrubs were reduced in cover, with replacement by sedges and grasses (Emers et al. 1995). However, at Treble Cone, no significant change in species composition resulted from grooming or skiing activity, irrespective of the number of years of disturbance. However, the reduction in total vegetation cover can be attributed to a reduction in the cover of cushion plants (see Table 5 and Appendix 12.3).

The removal of vegetation and exposure of bare ground has been reported in Australia (Keane et al. 1980) and in Austria (Meyer 1993). Although both these studies reported the complete destruction of the upper soil layer, at Treble Cone Ski Field visible erosion was only evident on a steep slope at the top of the Saddle Ridge ski run.

That grooming and skiing did not appear to affect bulk density and penetration resistance at Treble Cone is noteworthy. There is ample evidence in the literature of soil compaction associated with agricultural and forestry-related activities (e.g. Dickerson 1976; Lal et al. 1989; Smith 1987). Snow groomers have very low weight-to-track surface area relationships (~5 kPa), whereas contact pressures for forestry vehicles for example range between 30 and 125 kPa (Greacen & Sands 1980). However, while soil compaction may not be a problem on ski fields, when snow cover is thin or absent, each turn of a tracked vehicle will disturb the top few centimetres of soil and the associated plant cover.

Snow grooming and skiing can affect vegetation in two other ways: direct damage through scalping of plants by groomer blades or ski edges, or indirectly through compacting the snow.

7.1 DIRECT DAMAGE TO VEGETATION

The reduction in cushion plant cover is most likely to be the result of physical damage by groomer treads and blades scalping vegetation in areas of very little or no snow cover.

There were many visual signs of physical damage on groomed cushionfields, e.g. scalped hummocks, broken woody stems, sheared-off vegetation and areas of exposed bare ground. From observations, cushion plants such as *Dracophyllum muscoides* and *Chionohebe thompsonii* appeared to be particularly prone to stem breakage. Where skied, some cushion plants showed signs of scraping from ski edges, but there were few areas of extensive bare ground or rock resulting from severely scalped cushions.

Cushionfields tend to grow at sites which experience many freeze-thaw cycles during the short growing season (5 months) and have moist frost-active soils (Bliss & Mark 1974). They are commonly found on convex slopes and solifluction hummocks, where exposure to strong winds often results in a thin snow pack which readily melts (Körner & de Moreas 1979; Talbot et al. 1992). When snow grooming machinery is used in such locations, the treads and blades of the moving vehicle scalp the exposed cushion vegetation, thereby reducing both the total vegetation cover, and the cover of live cushion plant species.

This type of direct damage has been observed in Germany (Ries 1996), western North America (Price 1985; Hamilton 1981), and Alaska (Felix & Raynolds 1989; Felix et al. 1992). In Colorado, Greller et al. (1974) found that where snow was lacking in alpine tundra communities, the treads of snowmobiles scraped the soil away, removed the lichen, and damaged prominent rigid cushion plants. However, in New Zealand, Rogers & Kimberley (unpublished report 1990) found no clear evidence that skiing alone degraded the prostrate shrub vegetation growing on the gravelfields of Turoa Ski Field, Tongariro National Park.

In contrast to findings at Treble Cone Ski Field, some overseas studies (e.g. Mosimann 1985) have found that slope steepness has a bearing on the degree of direct damage experienced by the underlying vegetation.

7.2 INDIRECT EFFECTS ON VEGETATION

Overseas workers have found that snow grooming, and to a lesser extent, skiing, can result in a change in species composition due to snow compaction which brings about changes to the length of growing season and soil moisture availability (Price 1985; Baiderin 1980; Grabherr 1985; Emers et al. 1995). Snow compaction leads to changes in thermal and hydrological properties of the snow pack. Snow density, heat rates and length of snow retention have been found to increase, while porosity, permeability, and water-holding capacity are decreased (Neumann & Merriam 1972). These effects result in increased frost penetration, prolonging the time the soil remains frozen, and can alter soil microbial activity (Meyer 1993).

At Treble Cone Ski Field, no significant differences in species richness or species composition in terms of lifeform guilds, were detected when comparisons were made between groom + ski, ski, and control transects. This result can be interpreted in two ways. Firstly, grooming and skiing have not yet resulted in loss of species, just a reduction in frequency of some species. Secondly, natural variation in species composition of cushionfields within a particular management treatment is greater than any differences between management treatments, thereby masking any significant trends in the short term. To test whether grooming and skiing result in a significant change in species composition in the long term will therefore require a comparison of species frequency data for each transect over a period of time. Such changes in species composition of slow-growing mountain vegetation are, however, likely to take some time to become evident (Bayfield 1979). Roxburgh et al. (1988), for example, found evidence of significant changes in species composition of a high-alpine cushionfield 11 years after road-related disturbance on the Old Man Range, Central Otago. Smith et al. (1995) found that species composition of cushionfields on the Old Man Range had changed 32 years after the erection of a snow fence as a result of an increase in snow depth. Since the majority of transects established at Treble Cone Ski Field have experienced grooming or skiing impacts only since 1989, they should be re-monitored within the next five years.

Further study is required to determine whether grooming and skiing do affect snow pack characteristics and hence the sub-nival environment and length of snow lie through snow compaction at Treble Cone.

Other vegetation monitoring programmes established at Treble Cone (Jensen et al. 1997) and The Remarkables (Knight Frank, unpublished report 1984) ski fields reported that up to 73% of transects were lost as a result of major disturbances such as track building and terrain modification. It is important that the full set of cushionfield transect sites remain unmodified during the life of this study, and this condition should be included as part of the ski field's licence to operate on land managed by the Department.

8. Conclusions

Vegetation damage through snow grooming and skiing at Treble Cone is widespread and extensive, but cannot be regarded as excessive, nor are there large exposures of bare soil. Damage to cushion vegetation by scalping was visually obvious. However, we did not detect any relationship between skiing or grooming disturbance and changes in species composition of the cushionfields. Monitoring over a longer period of time is required to evaluate the impacts of snow grooming and skiing on species composition.

Physical changes are confined to the vegetation cover, and do not extend into the soil A-horizon.

The vegetation monitoring programme has revealed the following:

- Cushion plants are the most sensitive indicators of grooming- and skiing-related impacts.
- Snow grooming has more of an impact on total vegetation cover than skiing alone.
- Live vegetation cover was least on those cushionfields that had only been groomed for one year.
- There was no significant difference in species composition and richness between skied and groomed sites and undisturbed areas.
- Bare ground, and dead vegetation and litter were more extensive on skied and groomed sites than undisturbed sites.

9. Recommendations

- Where new developments take place in the ski field, over-snow vehicles should not be allowed in areas of, or at times of, shallow snow pack (e.g. exposed ridges; low snow years) until the minimum snow pack thickness required to buffer the vegetation has been determined.
- The vegetation transects should be re-monitored within the next 5–10 years to assess (a) changes in species frequency for cushion vegetation, (b) changes in the biomass and ground cover of adjacent taller plant communities, (c) the state of damaged areas recorded as photopoints, and (d) future re-monitoring needs.
- A commitment from Treble Cone Ski Field management not to modify any of the cushionfield transect sites (nor to remove any of the transect pegs during the life of the monitoring programme) should be sought and formalised in the operator's licence/lease agreement. The management should be provided with a map of the transect locations, and be familiar with their locations on the mountain.

- A study should be conducted in the winter to determine the snow pack characteristics at selected groomed, skied and control sites, and to determine how such activities influence snow compaction and length of snow lie.

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12. Appendices

12.1 TRANSECT INFORMATION

Standard transect setup

All transects were established in January 1997. Each is marked by a red or white fibreglass pole, located 50 cm away from the start and end of the transect. The start and end pegs of each transect are "L" shaped aluminium pegs, approximately 8 mm in width, and are engraved with the transect number.

Facing up-slope, the start peg of each transect is to the left (generally to the south) and the end peg to the right (generally to the north). The standard transect setup was for round aluminium pegs to be placed at 5 m intervals along the transect line to aid relocation. Each peg was marked so that if only one peg is found in the future, it will be known at what point along the transect the peg was placed.

For 30 m transects, the start "L" shaped peg at 0 m is labelled "#S". Along the transect, the following round pegs are placed at 5 m intervals: a peg with a single dash on it was placed at 5 m; 2 dashes at 10 m, 3 dashes at 15 m, 4 dashes at 20 m, and 5 dashes at 25 m. At 30 m, an "L" shaped peg is engraved with the transect number "#F" .

Where more than one transect line was established per site, the standard procedure was to place them 2 m apart down the slope. The upper transect is referred to as transect (a) the lower transect as transect (b), and, in the case of transect 42, the transect furthest downslope was transect (c). The standard transect setup for these transects is as follows

Transect (a): "L" shaped peg engraved with transect number "#S" at 0 m; a round peg with a single dash at 5 m; a peg with 2 dashes at 10 m; a blank "L" shaped peg at 15 m.

Transect (b): A blank "L" shaped peg at 0 m; a round peg with 3 dashes at 5 m; a round peg with 4 dashes at 10 m; and an "L" shaped peg engraved with transect number "#F" at 15 m.

Where transects have required a different peg arrangement due to presence of bedrock, for example, the setup is detailed under the heading"transect peg details" in the following pages.

Standard sampling procedure

Each transect was sampled at 0.3 m intervals**.** The quadrat and height pole were placed on the uphill side of the transect. One side of the sample quadrat was placed against the tape between, for example 0.3 m and 0.35 m.

A. CONTROL TRANSECTS

TRANSECT NO: **4 CONTROL**
Altitude: 1705 m
Slope (degrees): 12°
Aspect: 145°
Bearing (from start to end): 8°
Transect peg details: 2 × 15 m
Transect (b) is offset by 0.3 m, 2 m below transect (a)
Relocation notes:
Walk up Saddle Ridge run from Saddle T bar base to 3rd pylon. Go northwards over snowbank vegetation towards the sign line marking edge of bluffs. Transects end on edge of the gully
Photo references: E14-E18†

TRANSECT NO: **8 CONTROL**
Altitude: 1825 m
Slope (degrees): 20°
Aspect: 100°
Bearing (from start to end): 17.5°
Transect peg details: 2 × 15 m
Relocation notes:
New Boundary line: Go to S end of top traverse line from the top Saddle T bar. Climb up to New Boundary sign line. Go down to 6th pole down, and take a 244°bearing to the lower transect (b) peg, 30.9 m away.
Bearing from end peg to Trig on Towers Ridge: 306.5°
Bearing from end peg to bottom Saddle T bar shed: 32°
Photo references: C6 - C11

TRANSECT NO: **9 CONTROL**
Altitude: 1830 m
Slope (degrees): 17°
Aspect: 67°
Bearing (from start to end): 342°
Transect peg details: 2 × 15 m
Transect (a): 1 dash round peg at 4 m instead of 5 m. Rest normal
Relocation notes:
New Boundary area: Go to New Boundary sign line to south of ski area. Sited between 5th and 6th sign line post from top; opposite the 6th Tbar pylon.
Photo references: D0 - D8

TRANSECT NO: **13 CONTROL**
Altitude: 1765 m
Slope (degrees): 22°
Aspect: 125°
Bearing (from start to end): 32°
Transect peg details: 2 × 15 m transects.
1 dash aluminium round peg at 4 m rather than 5 m. Rest normal.
Relocation notes:
T2 area near top 6 seater chairlift
Go to Tower 12 below top chair station. End of transect (a) is 5.0 m from true right bottom of ladder on lower half of pylon leg; 131° bearing from ladder to transect (a) end peg.
Photo references: G2 - G10

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† All photographs listed in Appendix 12.1 are held at Landcare Research, Lincoln.

TRANSECT NO:	**20 CONTROL**
Altitude:	1810 m
Slope (degrees):	17°
Aspect:	119°
Bearing (from start to end):	9°
Transect peg details:	2 × 15 m transects

Relocation notes:

S of New Boundary area

From top NB sign line post (by Transect 44) traverse about 100 m to south crossing snowbank area to next shoulder. Drop down this shoulder, keeping the wee gully hard on your true left. Almost in line with Transect 43 near New Boundary sign line.

Photo references: B25 - B32

TRANSECT NO:	**21 CONTROL**
Altitude:	1880 m
Slope (degrees):	13°
Aspect:	116°
Bearing (from start to end):	14.5°
Transect peg details:	1 × 30 m transect

Relocation notes:

New Boundary sign line. From top New Boundary sign line post (at Transect 44), traverse southwards across snowbank depression, to cushionfield. Not far south from Transect 44.

Photo references: C18-C22

TRANSECT NO:	**33 CONTROL**
Altitude:	1640 m
Slope (degrees):	13°
Aspect:	158°
Bearing (from start to end):	59°30'
Transect peg details:	1 × 30 m Start peg is at 1 m, as 0 m is a flat rock.

Relocation notes:

From the top saddle chair station, cross wee creek/gully and follow downstream, passing 3 old sign line poles. T33 spans between this wee creek (end) and larger one to true left of transect.

End peg marked with red fibreglass pole just below large rock at edge of gully near chairlift

Photo references: A00 - A3

TRANSECT NO:	**43 CONTROL**
Altitude:	1800 m
Slope (degrees):	20°
Aspect:	108°
Bearing (from start to end):	21°
Transect peg details:	2 × 15 m transects Transect (a): normal arrangement Transect (b): 3 dash round aluminium peg at 4 m not 5 m; 4 dash peg is at 11 m not 10 m.

Relocation notes:

New Boundary sign line:

Go down NB sign line to 2nd post from bottom. From post take 165 bearing to bottom transect (b) peg, 18.8 m. Almost in line with Transect 20 to south across wee gully.

Photo references: B33 - B37; C0 - C5

TRANSECT NO: **44 CONTROL**
Altitude: 1880 m
Slope (degrees): 18°
Aspect: 90°
Bearing (from start to end): 346°
Transect peg details: 1 × 30 m transect
Normal peg arrangement, with extra plain round pegs placed at 1 m intervals to keep tape correct across solifluction lobes
Relocation notes:
New Boundary area:
Go along top traverse from top T bar station. Climb up to New Boundary sign line. Climb up spur to top post, below Tims Table. End peg is 4.9 m below this post; end red pole in line with sign line
Photo references: D9 - D15

TRANSECT NO: **47 CONTROL**
Altitude: 1660 m
Slope (degrees): 27°
Aspect: 212°
Bearing (from start to end): 126°
Transect peg details: 2 × 15 m transects
Relocation notes:
From Saddle T bar base follow 4WD track past snow fence until at lowest point on Saddle ridge. Walk up Sundance ridge walk below prominent crag above sign line. Transect 47 is first cushion on slope before track reaches ridge & sign line. Start (a) is 3.55 m downslope from foot track.
Photo references: F00 -F8

B: GROOMED TRANSECTS

TRANSECT NO: **10 GROOMED**
Altitude: 1765 m
Slope (degrees): 17°
Aspect: 107°
Bearing (from start to end): 2°
Transect peg details: 2 × 15 m transects
Relocation notes:
Main Mountain (T2):
From Triple Treat road under 6 seater chairlift line at top, drop down to first cushionfield. End peg of transect (a) is 1.5 m below the 3rd sign line post from top, almost directly below. Starts in tussock to south.
Year first skied/groomed: 1976
Photo references: G11 - G17

TRANSECT NO: **30 GROOMED**
Altitude: 1680 m
Slope (degrees): 14°
Aspect: 174°
Bearing (from start to end): 70°
Transect peg details: 1 × 30 m transect
Relocation notes:
Lower Saddle Area:
From top Saddle chair station, cross small gully. Head uphill on true right of gully for about 75 m to open celmisia area.
Starts in tussock, end peg on edge of stream gully.
Year first skied/groomed: 1989
Photo references: A4 - A8

TRANSECT NO: **31 GROOMED**

Altitude: 1700 m

Slope (degrees): 20°

Aspect: 170°

Bearing (from start to end): 70°

Transect peg details: 1 × 30 m long

Relocation notes:

Lower Saddle area:

From Saddle chair top station cross small gully. Walk up true right keeping close to gully side. In area of 3rd T bar pylon from bottom, close to gully.

Year first skied/groomed: 1989

Photo references: A9 - A11

TRANSECT NO: **32 GROOMED**

Altitude: 1720 m

Slope (degrees): 21°

Aspect: 152°

Bearing (from start to end): 65°

Transect peg details: 1 × 30 m transect

Relocation notes:

From top Saddle chair station, cross small gully. Head up true right of gully on shoulder. About 50 m above 3rd T bar pylon from bottom; right at edge of gully

Year first skied/groomed: 1989

Photo references: A12 - A14

TRANSECT NO: **38 GROOMED**

Altitude: 1835 m

Slope (degrees): 11°

Aspect: 300°

Bearing (from start to end): 16°30'

Transect peg details: 1 × 30 m

Relocation notes:

From top Saddle Tbar station, follow the traverse southwards about 20 m to Bullet sign line. Transect 38 is by almost the top sign line post. Starts in sedges, ends in tussock.

18 m point is in line with Bullet sign line post; 15 m peg is 6.10 m below sign line post at 66° bearing from sign.

Year first skied/groomed: 1989

Photo references: A24 - A25

TRANSECT NO: **39 GROOMED**

Altitude: 1825 m

Slope (degrees): 23°

Aspect: 276°

Bearing (from start to end): 355°

Transect peg details: 2 × 15 m transects

Normal peg arrangement, but end pegs = start pegs for T42.

Relocation notes:

Upper Saddle Ridge run. From top Tbar station drop down to 2nd sign line post from top, above upper Gun Barrel. Sited between 2nd and 3rd Tbar pylon from top. Starts in tussock, ends in line with posts.

Year first skied/groomed: 1989

Photo references: B0 - B2

TRANSECT NO: **41 GROOMED**

Altitude: 1815 m

Slope (degrees): 14°

Aspect: 84°

Bearing (from start to end): 357°

Transect peg details: 2 × 15 m transects

Transect a: 1 dashed round peg at 4 m not 5 m;

2 dash peg at 8 m not 10 m; 3 dash peg at 12 m

Transect (b): 4 dash peg at 4 m; 5 dash peg at 8 m; unmarked peg at 12 m.

Relocation notes:

From top Saddle Tbar, drop down Saddle Ridge run to slight table with small snowbank depression on true left.

20.60 m from 6th sign line post from top to start peg at 257° bearing.

23.30m from 6th sign line post to end of transect (a) at 297° bearing.

Year first skied/groomed: 1989

Photo references: B19 - B24

TRANSECT NO: **45 GROOMED**

Altitude: 1865 m

Slope (degrees): 23°

Aspect: 125°

Bearing (from start to end): 14°

Transect peg details: 2 × 15 m transects

Normal peg arrangement except transect (b) 4 dash peg at 9 m not 10 m

Relocation notes:

From top of Saddle Tbar, drop immediately below A frame hut on Side Saddle. Almost opposite (50 cm below post) 3rd upright of snowfence; 3.7 m to end of transect (b)

Year first skied/groomed: 1989

Photo references: D17 - D24

TRANSECT NO: **46 GROOMED**

Altitude: 1640 m

Slope (degrees): 4°

Aspect: 135°

Bearing (from start to end): 53°

Transect peg details: 2 × 15 m transects

Relocation notes:

Saddle Valley area: From top Saddle chair station, go east 50 m to blue ski trail sign. Transects are in upper part of the first cushionfield below this sign. Transects are approximately in line with Powderbowl sign line post (2nd from Tbar base), and ~ 20 m above the top chair lift pylon.

Both transects start/finish in tussock/celmisia.

Year first skied/groomed: 1996

Photo references: E19 - E23

TRANSECT NO: **49 GROOMED**

Altitude: 1655 m

Slope (degrees): 15°

Aspect: 158°

Bearing (from start to end): 103°

Transect peg details: 2 × 15 m transects

Relocation notes:

From top Saddle chair station, follow WD track down to end of snow fence (a) closest to Powder Bowl. Cushionfield is on R of both fences, and T49 follows bottom lip before it turns into tussock. Starts in cushion; end in tussock.

17.35m from end post of snowfence (a) to end transect (a) peg, bearing 187°.

Year first skied/groomed: 1996

Photo references: F9 - F17

C. SKIED TRANSECTS

TRANSECT NO: **12 SKIED**
Altitude: 1760 m
Slope (degrees): 23°
Aspect: 110°
Bearing (from start to end): 14°
Transect peg details: 2 × 15 m transects
Relocation notes:
Main Mountain (T2) area: To true right of 6 seater chairlift Tower 11; 13.30 m from bottom of Tower 11 to end peg of transect (a) on bearing 110°.
Year first skied/groomed: 1976
Photo references: G18 - G24

TRANSECT NO: **26 SKIED**
Altitude: 1800 m
Slope (degrees): 2°
Aspect: 100°
Bearing (from start to end): 355°
Transect peg details: 2 × 15 m transects
Relocation notes:
From top Saddle T bar station, follow traverse southwards, crossing 2 main gullies. T26 located under Crags 2, about 50 m south from 2nd post in sign line. On large flat rock in line with sign line post.
Year first skied/groomed: 1989
Photo references: D28; E0 - E5

TRANSECT NO: **29 SKIED**
Altitude: 1860 m
Slope (degrees): 25°
Aspect: 104°
Bearing (from start to end): 10°
Transect peg details: 2 × 15 m transects
Normal peg arrangement except that end peg of transect (b) is at 14.80 m as 15 m is right on edge of vegetation lobe.
Relocation notes:
From top Saddle Tbar, drop down T bar line towards the 2nd pylon form the shed. At bottom of snow fence traverse groomed slope to sign line post. T29 is located 3.7 m above sign post at 248° bearing.
Year first skied/groomed: 1989
Photo references: E6 - E11

TRANSECT NO: **34 SKIED**
Altitude: 1755 m
Slope (degrees): 21°
Aspect: 140°
Bearing (from start to end): 20°
Transect peg details: 2 × 15 m transects
Normal peg arrangement. Starts in tussock, ends in cushionfield
Relocation notes:
Saddle Mountain: On S side (true right) of Bullet Gully. From top Saddle Tbar, go south along traverse, crossing first wee gully/ snowbank (T37) and down spur (past T 29). T34 is located on prominent "table" cushion half way down spur to Chair top station. Looking across to Tbar line, T34 is between 5th and 6th pylons from bottom.
Year first skied/groomed: 1989
Photo references: A18 - A20

TRANSECT NO:	**35 SKIED**
Altitude:	1815 m
Slope (degrees):	26°
Aspect:	105°
Bearing (from start to end):	14°30'
Transect peg details:	2 × 15 m transects

Relocation notes:

Saddle Mountain: From top Saddle T bar, head southward crossing 1 snowbank/gully. Head down shoulder to scalped cushion area. Located on S side Bullet gully, ~ in line with 4th from bottom Bullet sign line post, just below Pylon 7.

Year first skied/groomed:	1989
Photo references:	A15 -A17

TRANSECT NO:	**37 SKIED**
Altitude:	1870 m
Slope (degrees):	17°
Aspect:	119°
Bearing (from start to end):	19°
Transect peg details:	1 × 30 m long transect

Relocation notes:

Saddle Mountain: From top Saddle Tbar, ~30 m S of A frame hut. About 10 m above signpost.

26 m point in line with Bullet sign line. 25 m peg is 7.5 m above 2nd from top Bullet sign line post; at bearing of 265°.

Year first skied/groomed:	1989
Photo references:	A21 - A23

TRANSECT NO:	**40 SKIED**
Altitude:	1815 m
Slope (degrees):	12°
Aspect:	90°
Bearing (from start to end):	3°
Transect peg details:	2 transects: (a) = 13 m; (b) = 12 m long Round pegs : transect (a):1 dash at 4 m; 2 dash at 8m, transect (b): 3 dash at 4 m; 4 dash at 8 m.

Relocation notes:

Saddle Mountain: From top Saddle Tbar, go down Saddle Ridge run on true left. Cushionfield is located on wee table above upper Gun Barrel. T40 is between 3rd & 4th Tbar pylon from top, and right beside a broken sign line post (5th from top).

Year first skied/groomed:	1989
Photo references:	B12 - B18

TRANSECT NO:	**42 SKIED**
Altitude:	1825 m
Slope (degrees):	27°
Aspect:	56°
Bearing (from start to end):	336°
Transect peg details:	3 transects: (a) = 8 m; (b) = 8 m; (c) = 7 m. Pegged at 5 m (1 dash); 8 m (end peg).Transect (b): 2 m (2 dash); 4 m (plain peg); 6 m(3dash); 8 m (end peg beside rock on top of gully) Transect (c): 2 m (plain peg); 4 m (4 dashes); 7 m (end peg at corner of flat rock)

Relocation notes:

Saddle Mountain: From top Saddle Tbar, drop down Saddle Ridge run on true left, to 2nd sign line post from top, where T39 is. i.e. between 2nd & 3rd sign line posts from top. Extends north to edge of rocky gully (upper Gun Barrel).

Year first skied/groomed:	1989
Photo references:	B3 - B11

TRANSECT NO: **48 SKIED**

Altitude: 1650 m

Slope (degrees): 15°

Aspect: 165°

Bearing (from start to end): 62°

Transect peg details: 2 × 15 m transects

Relocation notes:

Saddle Valley area: From top Saddle chair station, drop immediately below chair line towards 1st pylon. Transect ends are in tussock under eastern most chair wire and run back to Bullet Gully. 14.4 m above 1st chair pylon.

Year first skied/groomed: 1996

Photo references: E24-E25. G000-G1

TRANSECT NO: **50 SKIED**

Altitude: 1650 m

Slope (degrees): 17°

Aspect: 189°

Bearing (from start to end):

Transect peg details: 1 × 30 m transect

Relocation notes:

Saddle Valley area: From top Saddle chair station follow track down to snow fence nearest to Powder Bowl. Situated below T49; on long cushion at lip of steep slope. Between 2nd & 3rd chair pylon from top. 179° bearing from start peg to 3rd chair pylon from top

Year first skied/groomed: 1996

Photo references: F18 - F24

12.2 PERCENTAGE SPECIES FREQUENCY DATA

GROOMED TRANSECTS:	G10	G30	G31	G32	G38	G39	G41	G45	G46	G49	MEAN
n =	91	73	50	60	69	59	76	78	81	89	**%freq.**
Year first groomed:	**'76**	**'89**	**'89**	**'89**	**'89**	**'89**	**'89**	**'89**	**'96**	**'96**	**±STD**
Cushion plants											
Abrotanella inconspicua	0	0	0	5	45	2	14	33	0	4	10 ±15
Anisotome imbricata	7	0	10	2	0	2	4	3	16	28	7 ±8
Chionohebe thompsonii	1	0	8	0	16	0	17	17	2	0	6 ±7
Colobanthus buchananii	0	0	0	0	12	0	0	12	1	1	3 ±5
Dracophyllum muscoides	65	0	0	0	1	34	4	8	37	19	17 ±21
Hectorella caespitosa	0	0	0	0	4	0	0	5	1	3	1 ±2
Phyllachne colensoi	0	0	32	7	16	3	0	6	0	0	6 ±10
Phyllachne rubra	0	0	0	0	10	0	0	0	25	0	3 ±8
Raoulia hectori	0	0	0	0	0	3	0	0	21	0	2 ±6
Woody herbs(non-cushion habit)											
Aciphylla kirkii	2	0	0	0	0	0	0	0	0	0	0 ± 1
Celmisia haastii	0	0	0	0	1	0	0	14	0	0	2 ± 4
Celmisia larcifolia	5	0	18	8	4	0	11	14	4	33	10 ± 9
Celmisia lyallii	0	1	0	0	0	0	0	0	0	0	0 ± 0
Celmisia viscosa	0	30	14	5	0	14	0	0	0	0	6 ± 10
Chionohebe densifolia	0	0	0	0	1	0	0	0	1	0	0 ± 1
Coprosma perpusilum	0	0	0	0	0	0	0	0	0	0	0 ± 0
Dracophyllum pronum	0	0	0	0	0	0	0	0	0	0	0 ± 0
Hebe lycopodioides	0	0	0	0	0	0	0	0	0	0	0 ± 0
Melicytus alpinus	0	0	0	0	0	0	0	0	37	0	4 ± 11
Raoulia grandiflora	1	0	8	7	0	2	7	1	0	9	3 ± 3
Other dicot herbs											
Anisotome flexuosa	0	0	0	0	0	0	1	0	0	3	0 ± 1
Anisotome languinosa	0	0	0	0	0	2	0	0	0	0	0 ± 1
Brachyscome sinclairii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Cardamine sp.	0	0	0	0	0	0	0	0	0	0	0 ± 0
Epilobium tasmanicum	0	0	0	0	3	0	0	0	0	0	0 ± 1
Gentiana divisa	0	0	0	0	9	0	3	3	0	3	2 ± 3
Leptinella goyenii	0	0	0	0	0	0	0	3	2	0	1 ± 1
Myosotis pulvinaris	0	0	0	0	4	0	0	0	0	0	0 ± 1
Ourisia glandulosa	0	0	0	0	13	0	0	4	0	0	2 ± 4
Schizeilema exiguum	0	0	0	0	6	0	0	3	0	0	1 ± 2
Monocots											
Agrostis capillaris	0	0	0	0	0	0	0	5	0	0	1 ± 2
Agrostis muelleriana	5	8	22	3	25	0	9	14	21	20	13 ± 8
Carex pterocarpa	0	0	0	0	1	0	3	0	0	0	0 ± 1
Carex pyrenaica	2	0	0	0	0	0	5	0	0	0	1 ± 2
Chionochloa macra	0	11	4	13	0	3	0	1	0	0	3 ± 5
Chionochloa macra juvenile	0	3	0	0	0	0	0	0	0	0	0 ± 1
Koeleria sp.	0	0	0	0	0	0	0	0	0	0	0 ± 0
Luzula pumila	14	0	0	0	33	8	16	23	17	6	12 ± 11
Marsippospermum gracile	0	0	0	0	4	0	0	4	0	0	1 ± 2
Poa colensoi	11	37	48	50	43	36	54	28	31	24	36 ± 13
Rytidospermum pumilum	0	0	2	2	0	0	0	0	0	6	1 ± 2
Lichens											
Alectoria nigricans	5	0	4	22	20	3	32	23	63	47	22 ± 20
Lichen other	53	23	38	42	72	12	80	82	0	83	49 ± 29
Moss	32	51	78	23	78	27	82	49	0	46	47 ± 26

SKI TRANSECTS:	S12	S26	S29	S34	S35	S37	S40	S42	S48	S50	MEAN
n =	96	67	100	58	72	62	85	76	100	95	**% freq.**
Year first skied:	**'76**	**'89**	**'89**	**'89**	**'89**	**'89**	**'89**	**'89**	**'96**	**'96**	**±STD**
Cushion plants											
Abrotanella inconspicua	2	24	11	0	24	48	12	0	3	33	16 ± 15
Anisotome imbricata	17	13	0	9	3	0	6	8	14	0	7 ± 6
Chionohebe thompsonii	1	7	2	0	11	16	2	1	0	1	4 ± 5
Colobanthus buchananii	0	3	1	0	0	0	1	0	0	1	1 ± 1
Dracophyllum muscoides	72	0	79	69	0	16	72	82	30	34	45 ± 31
Hectorella caespitosa	1	0	16	2	4	13	2	0	1	1	4 ± 5
Phyllachne colensoi	0	1	5	2	7	19	1	0	0	0	4 ± 6
Phyllachne rubra	0	0	0	0	0	0	0	0	0	1	0 ± 0
Raoulia hectori	0	0	0	0	0	0	4	7	0	0	1 ± 2
Woody herbs(non-cushion habit)											
Aciphylla kirkii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Celmisia haastii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Celmisia larcifolia	4	28	21	2	36	26	6	0	11	17	15 ± 12
Celmisia lyallii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Celmisia viscosa	0	1	0	2	13	0	0	0	18	3	4 ± 6
Chionohebe densifolia	0	0	0	0	0	2	0	0	0	0	0 ± 0
Coprosma perpusilum	0	0	0	0	0	0	0	0	0	0	0 ± 0
Dracophyllum pronum	0	0	0	0	0	0	0	0	0	0	0 ± 0
Hebe lycopodioides	0	0	0	0	0	0	0	0	0	0	0 ± 0
Melicytus alpinus	0	0	0	0	0	0	0	0	0	0	0 ± 0
Raoulia grandiflora	4	15	0	0	15	2	4	0	3	16	6 ± 6
Other dicot herbs											
Anisotome flexuosa	0	3	3	0	4	0	0	0	0	1	1 ± 2
Anisotome languinosa	0	0	3	2	0	2	0	0	0	1	1 ± 1
Brachyscome sinclairii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Cardamine sp.	0	0	0	0	0	0	0	0	0	0	0 ± 0
Epilobium tasmanicum	0	0	0	0	0	0	0	0	0	0	0 ± 0
Gentiana divisa	0	0	1	0	0	3	1	0	0	1	1 ± 1
Leptinella goyenii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Myosotis pulvinaris	0	0	0	0	0	0	0	0	0	0	0 ± 0
Ourisia glandulosa	0	1	5	0	1	18	0	0	0	0	3 ± 5
Schizeilema exiguum	0	0	4	0	0	0	0	0	1	0	1 ± 1
Monocots											
Agrostis capillaris	0	0	0	0	0	0	0	0	0	0	0 ± 0
Agrostis muelleriana	11	33	6	0	1	18	11	11	3	11	10 ± 9
Carex pterocarpa	0	7	0	0	0	8	0	0	0	0	2 ± 3
Carex pyrenaica	0	0	0	0	0	0	0	0	0	0	0 ± 0
Chionochloa macra	1	0	0	0	1	0	0	0	10	0	1 ± 3
Chionochloa macra juvenile	0	0	0	0	1	0	0	0	0	2	0 ± 1
Koeleria sp.	0	0	0	0	0	0	0	0	0	0	0 ± 0
Luzula pumila	0	15	5	0	6	6	6	5	2	15	6 ± 5
Marsippospermum gracile	0	0	5	0	25	10	0	0	0	0	4 ± 8
Poa colensoi	9	52	7	16	43	39	16	22	14	26	25 ± 15
Rytidospermum pumilum	0	0	0	0	0	0	0	0	2	2	0 ± 1
Lichens											
Alectoria nigricans	17	6	43	0	0	37	14	9	36	5	17 ± 15
Lichen other	69	75	89	47	58	53	71	64	77	80	68 ± 12
Moss	29	88	40	19	63	53	44	22	43	59	46 ± 20

CONTROL TRANSECTS:	4C	8C	9C	13C	20C	21C	33C	43C	44C	47C	MEAN %
n =	90	47	68	95	100	65	58	44	100	85	freq.± STD
Cushion plants											
Abrotanella inconspicua	2	64	3	22	9	32	0	0	10	0	14 ± 19
Anisotome imbricata	12	6	6	13	3	2	0	9	9	1	6 ± 4
Chionohebe thompsonii	4	11	3	15	1	28	0	0	9	2	7 ± 8
Colobanthus buchananii	0	2	1	1	0	11	0	0	0	0	2 ± 3
Dracophyllum muscoides	52	2	35	46	41	0	34	41	26	51	33 ± 18
Hectorella caespitosa	1	6	7	7	0	0	3	0	3	1	3 ± 3
Phyllachne colensoi	3	13	0	1	0	15	0	0	0	3	4 ± 5
Phyllachne rubra	0	0	0	0	0	0	0	0	0	0	0 ± 0
Raoulia hectori	0	0	1	0	0	0	0	0	0	0	0 ± 0
Woody herbs(non-cushion habit)											
Aciphylla kirkii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Celmisia haastii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Celmisia larcifolia	13	38	24	26	18	25	7	2	18	4	18 ± 11
Celmisia lyallii	0	0	1	0	0	0	3	0	0	0	0 ± 1
Celmisia viscosa	4	11	13	1	1	2	7	11	3	8	6 ± 4
Chionohebe densifolia	0	11	0	0	0	0	5	0	0	0	2 ± 3
Coprosma perpusilum	0	0	0	0	0	0	0	0	0	0	0 ± 0
Dracophyllum pronum	0	0	0	0	2	0	0	0	0	0	0 ± 1
Hebe lycopodioides	0	0	0	0	0	0	0	0	0	0	0 ± 0
Melicytus alpinus	0	0	4	0	0	0	0	0	0	0	0 ± 1
Raoulia grandiflora	22	23	4	3	7	0	0	16	0	3	8 ± 9
Other dicot herbs											
Anisotome flexuosa	0	0	0	0	8	0	0	0	0	0	1 ± 2
Anisotome languinosa	0	0	0	2	1	2	0	0	0	0	0 ± 1
Brachyscome sinclairii	0	0	0	0	0	0	0	0	0	0	0 ± 0
Cardamine sp.	0	0	0	0	0	0	0	0	0	0	0 ± 0
Epilobium tasmanicum	0	0	0	0	0	0	0	0	0	0	0 ± 0
Gentiana divisa	0	9	0	0	0	12	0	0	1	0	2 ± 4
Leptinella goyenii	0	0	0	0	0	3	0	0	11	0	1 ± 3
Myosotis pulvinaris	0	0	0	0	0	0	0	0	0	0	0 ± 0
Ourisia glandulosa	0	0	0	0	0	2	0	0	0	0	0 ± 0
Schizeilema exiguum	1	0	0	0	0	9	0	0	0	0	1 ± 3
Monocots											
Agrostis capillaris	0	0	0	0	0	0	0	0	0	0	0 ± 0
Agrostis muelleriana	8	19	7	6	8	20	3	0	19	5	10 ± 7
Carex pterocarpa	0	4	0	0	0	2	0	0	0	0	1 ± 1
Carex pyrenaica	0	0	0	0	0	2	0	0	0	0	0 ± 0
Chionochloa macra	4	0	4	0	2	0	9	2	0	0	2 ± 3
Chionochloa macra juvenile	1	0	0	0	0	0	3	0	0	0	0 ± 1
Koeleria sp.	0	0	0	0	0	0	0	0	0	0	0 ± 0
Luzula pumila	2	28	10	12	5	35	2	5	15	1	11 ± 11
Marsippospermum gracile	0	0	0	0	7	0	19	0	0	0	3 ± 6
Poa colensoi	18	51	28	24	39	48	14	25	41	2	29 ± 15
Rytidospermum pumilum	7	0	0	0	0	0	0	0	0	0	1 ± 2
Lichens											
Alectoria nigricans	7	0	18	47	39	23	0	5	51	24	21 ± 18
Lichen other	63	70	82	86	88	78	43	73	91	72	75 ± 13
Moss	49	79	51	45	57	80	34	45	44	14	50 ± 18

12.3 PERCENTAGE GROUND COVER DATA

GROOM TRANSECTS: Year first groomed:	G10 '76	G30 '89	G31 '89	G32 '89	G38 '89	G39 '89	G41 '89	G45 '89	G46 '96	G49 '96	% cover (±STD)
Dead vegetation and litter	35	56	52	51	30	30	39	17	32	27	37 ± 12
Live vegetation	40	30	33	31	25	46	33	26	26	33	32 ± 6
Lichen	2	2	1	8	16	1	19	11	8	29	10 ± 9
Bare ground and filmy lichen	19	8	12	5	14	20	6	21	25	9	14 ± 7
Moss	1	4	2	2	8	1	6	5	2	1	3 ± 2
Rock and gravel	3	0	1	3	7	3	0	20	7	3	5 ± 6

SKI TRANSECTS: Year first skied:	S12 '76	S26 '89	S29 '89	S34 '89	S35 '89	S37 '89	S40 '89	S42 '89	S48 '96	S50 '96	% cover (±STD)
Dead vegetation and litter	26	39	32	43	40	21	39	19	32	37	33 ± 8
Live vegetation	50	35	40	40	34	45	44	53	35	36	41 ± 6
Lichen	4	14	17	6	7	24	10	8	21	7	12 ± 6
Bare ground and filmy lichen	14	7	11	9	10	7	10	10	11	18	11 ± 3
Moss	1	5	1	1	4	4	2	3	1	2	2 ± 1
Rock and gravel	5	2	4	1	6	1	2	12	1	1	4 ± 3

CONTROL TRANSECTS:	C4	C8	C9	C13	C20	C21	C33	C43	C44	C47	% cover (± STD)
Dead vegetation and litter	35	27	31	24	30	19	36	36	25	42	31 ± 7
Live vegetation	46	57	47	45	36	35	34	32	31	32	40 ± 8
Lichen	3	5	19	18	23	13	11	9	29	13	14 ± 8
Bare ground and filmy lichen	11	6	3	8	12	18	12	20	9	8	11 ± 5
Moss	0	2	5	1	2	7	3	2	4	2	3 ± 2
Rock and gravel	3	5	0	6	0	8	4	3	5	5	4 ± 2

12. 4 PHOTOGRAPHIC RECORD (taken January 1997)

FIGURE 2. RELATIVELY UNDISTURBED CUSHIONFIELD VEGETATION ALONG A SECTION OF TRANSECT 4 (CONTROL).

FIGURE 3. DAMAGE TO CUSHIONFIELD VEGETATION AFTER ONE YEAR'S GROOMING (TRANSECT 46).

FIGURE 4. A CUSHIONFIELD AFTER 7 YEARS OF SKIING. NOTE THAT THE CONDITION OF CUSHION PLANTS AND LICHENS APPEARS TO BE GOOD IN THE HOLLOWS (TRANSECT 34).

FIGURE 5. AN UNDISTURBED CUSHIONFIELD. NOTE THE DEAD CUSHION PLANTS AND THE PRESENCE OF LICHEN ON THE SURFACE OF CUSHION PLANTS AS WELL AS ABOVE GROUND (TRANSECT 44).

FIGURE 6. DAMAGE TO CUSHION PLANTS ONE YEAR AFTER SKIING COMMENCED. *Dracophyllum muscoides* CUSHION PLANTS HAVE BEEN SCRAPED WITH *IN SITU* LITTER PRESENT (TRANSECT 50).

FIGURE 7. DAMAGE TO CUSHION VEGETATION AFTER 20 YEARS OF SKIING. THE *Dracophyllum muscoides* CUSHION PLANTS HAVE BEEN SCALPED BACK TO REVEAL WOODY STEMS AND BARE GROUND (TRANSECT 12).

FIGURE 8. DAMAGE TO CUSHION VEGETATION AFTER ONE YEAR OF GROOMING. *Dracophyllum muscoides* HAS BEEN SCALPED AND THE RESULTING LITTER REMAINS *IN SITU* (TRANSECT 49).

FIGURE 9. DAMAGE TO CUSHION VEGETATION AFTER 20 YEARS OF GROOMING. STEMS AND LEAVES HAVE BEEN SCRAPED OFF EXPOSING ROOTS, WOODY STEMS AND BARE GROUND (TRANSECT 10).

FIGURE 10. DAMAGE TO *Celmisia viscosa* MATS IN AN INTENSIVELY GROOMED AREA (TRANSECT 30).

FIGURE 11. SEVERE DAMAGE TO *Celmisia viscosa* ON A STEEP SLOPE NEAR TIM'S TABLE AFTER A FEW GROOMER PASSES.

12.5 VISITOR NUMBERS AND SNOW GROOMING PATTERNS AT TREBLE CONE SKI FIELD

Visitor numbers

While the national trend in ski field usage is static, visitor numbers to Treble Cone Ski Field are gradually increasing. The 1997 ski season ran from 27 June to 12 October, and after a slow start attracted between 80 thousand and 100 thousand skiers and snow-boarders. Special events such as mountainbike races, and chairlift open days also attract visitors to the field during the off season.

Snow grooming patterns

Figure 12 shows the expected frequency of snow grooming for each ski run. However, actual patterns of snow grooming in a given season will be governed by the amount of snow present, the timing and frequency of snowfalls, the amount of snow which fell, and the pattern of usage as determined by which facilities on the ski field are open. For example, in 1997, the upper Rollercoaster ski run had insufficient snow to groom even once, whereas in past seasons it has been groomed regularly. Snow grooming frequencies and skier usage at transect sites for 1997 are listed in Table 8.

The snow arrived later than usual in 1997, and a thin pack at the start of the season prevented many areas being groomed. The mild winter compounded the problem. The pattern of snow groomer usage therefore is not the same as that shown in Fig. 12.

Patterns of skier/boarder usage

Much of Treble Cone Ski Field does not receive any snow grooming. The general level of skier and snow-boarder usage of the ungroomed parts of the ski field is highlighted in Fig. 13 and can be compared with transect positions in Fig. 14.

TABLE 8. SNOW GROOMING FREQUENCIES AND SKIER USAGE AT GROOMED TRANSECT SITES DURING THE WINTER OF 1997.

FREQUENCY OF SNOW GROOMING	LEVEL OF SKIER USAGE	TRANSECT NO.	NAME OF SKI RUN
Nightly	~500/hr	46G & 49G	Upper Saddle Valley Trail
Every 2–3 nights from mid August to end September	~500/hr	39G & 41G	Upper Saddle Ridge run
		38G	Traverse to Bullet
		30G, 31G & 32G	Lower Side Saddle
Every 4–5 nights	~500/hr	45G	Upper Side Saddle
None in 1997 (usually as required for mogul removal)	~250/hr	10G	Upper Rollercoaster

FIGURE 12. SNOW GROOMING KEY, TREBLE CONE SKI FIELD.

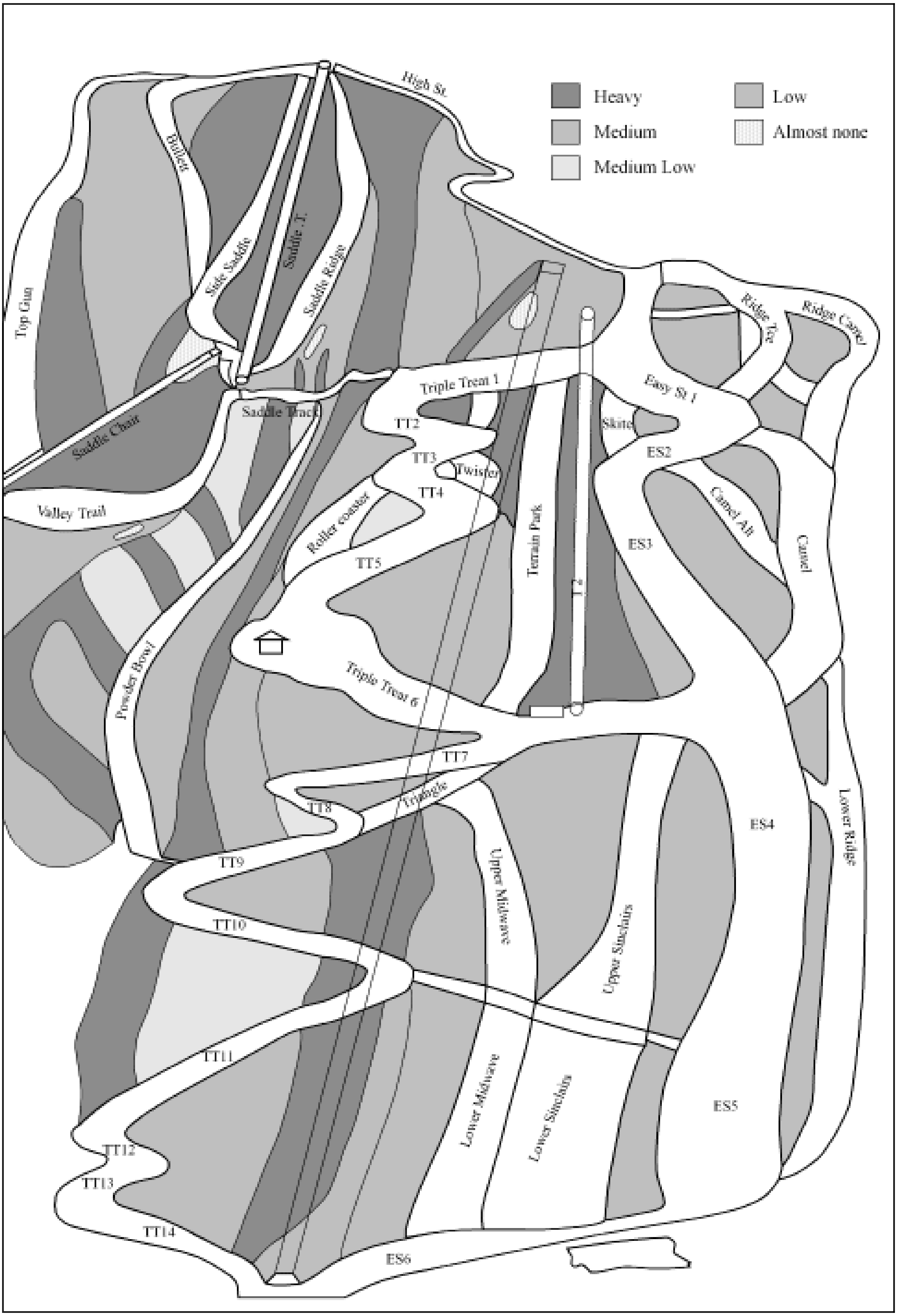

FIGURE 13. SKIER USAGE KEY, TREBLE CONE SKI FIELD.

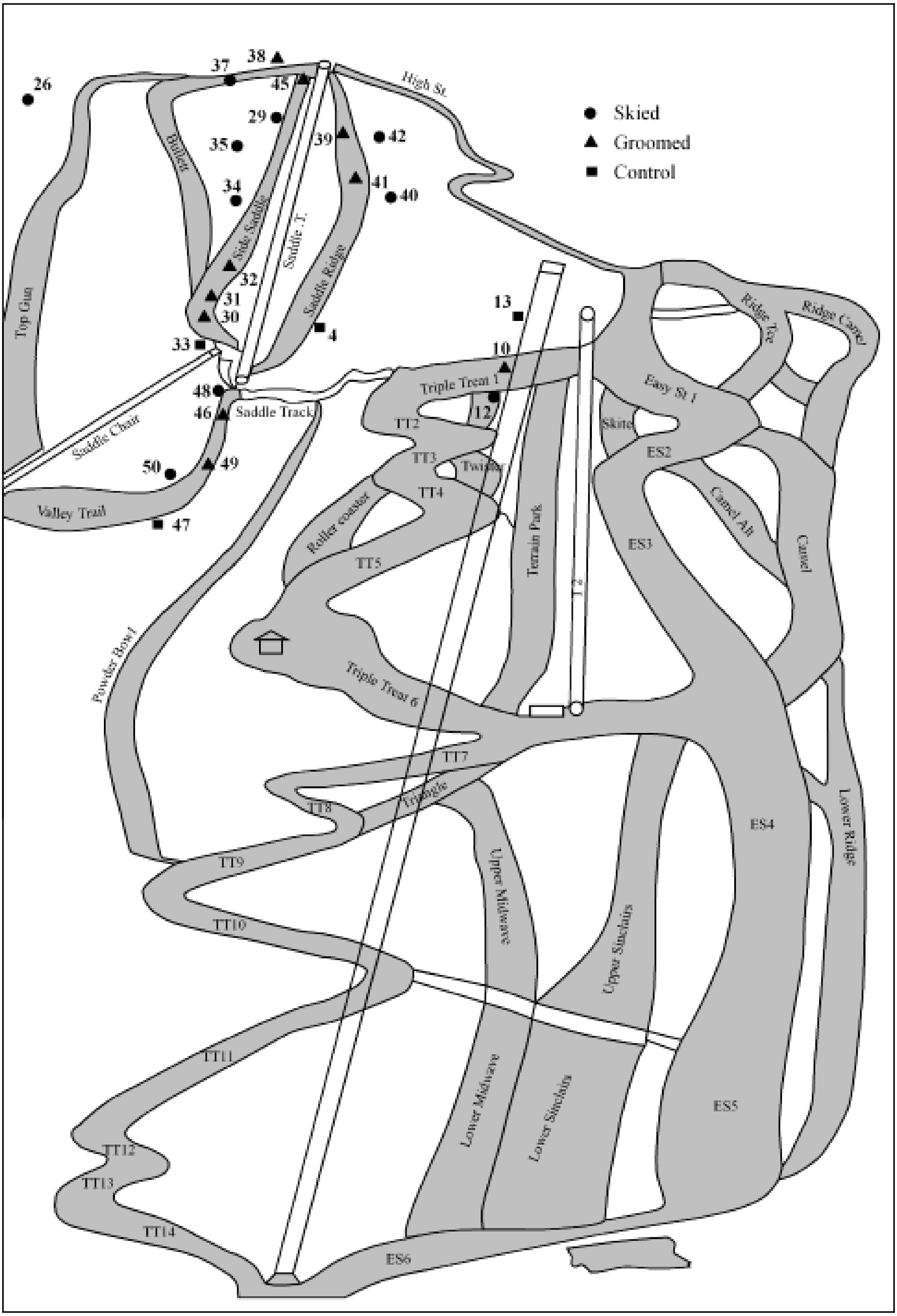

FIGURE 14. APPROXIMATE LOCATION OF TRANSECTS, TREBLE CONE SKI FIELD. SIX CONTROL SITES ARE BEYOND THE SKI FIELD BOUNDARY.