Environmental effects of the Manganui ski field, Mt Taranaki/Egmont

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Prepared for the Stratford Mountain Club

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Executive Summary

During May 2012, the environmental effects of the Manganui ski field were examined. Permanent quadrats first established in 1974 to monitor vegetation changes were re-measured, vegetation mapping was conducted, modifications to ground form and drainage were identified, soil compaction was examined, and stream water from the ski field catchment was tested for nutrient enrichment. This report focusses primarily on the lower Manganui ski field, as the upper Manganui ski field consists mostly of unmodified herbfield or gravelfield, protected by a sufficient snow base over the winter months. The lower Manganui ski field has a long history of modification spanning from the early 1900s. Vegetation types mapped on the lower field included unmown tussockfield, mown tussock-herbfield, shrubland and exotics. The re-measurement of vegetation in permanent quadrats on the lower field suggests that since the last re-measurement in 1994, several exotic species have increased in cover, including *Carex ovalis*, *Poa annua*, and *Agrostis capillaris* (percentage cover increases of up to 46.6%, 42.0% and 20.7% respectively). Vegetation mapping and historic photographs indicate that the lower ski field sits within the elevational belt of shrubland vegetation, little of which remains due to regular mowing conducted on the field since 1947. Shrubs which have been largely excluded from the field through mowing include *Brachyglottis elaeagnifolius*, *Hebe odora*, *Ozothamnus vauvilliersii*, *Dracophyllum filifolium*, *Pseudopanax colensoi*, *Raukaua simplex* and *Hebe stricta* var. *egmontiana*. Areas of the ski field dominated by exotic vegetation were predominantly associated with historic culvert construction and rock dynamiting. Compaction by machinery was confined to the sensitive mossfield area at the base of the lower field.

1 Introduction

Situated on the eastern slopes of Mt Taranaki, Egmont National Park, the Manganui ski field is managed by the Stratford Mountain Club and operates under a concession from the Department of Conservation. Provisions are made for the operation of the ski field in the Egmont National Park Management Plan (Department of Conservation 2002). The ski field can be separated into two main parts, the lower field and the upper field. The lower ski field is situated directly above the Stratford Mountain Club lodge between 1250-1360 m above sea level (asl), and is bounded by the Manganui Gorge to the south and the Ngarara Bluff to the north. It is of gentle gradient (<20°), approximately 5 ha in size, and is serviced by a modern T-bar ski-lift. The upper ski field, between 1400-1680 m asl, is serviced by a long rope tow referred to as the "top tow", and a number of steep (>25°) ski runs are available over an area of approximately 40 ha. The ski fields have been in existence since the 1920s when the first service hut was established near to the present day facilities. Vegetation of the lower ski field has a long history of modification spanning from the 1920s when vegetation was first slashed and pulled (Stratford Mountain Club 1984). At the time the lower ski field was established, snow depths were customarily greater than today. With the declining snow falls, the club has instituted further management of the field to remove shrubby vegetation from the favoured ski-runs to allow skiing on thinner snow-bases. Since 1947, tussock and low-growing shrubs have been regularly mown to improve the skiing conditions (Stratford Mountain Club 1984). The upper ski field is largely unmodified; experiencing lesser volumes of foot traffic and usually being protected by a thick covering of snow over the winter months.

1.1 Summary of previous vegetation reports

following the upgrade to a higher capacity T-bar tow on the lower ski field in 1974, concern was raised over what effects increased ski field use may have on the vegetation. This led to the Egmont National Park Board initiating a vegetation study (Popay & Ritchie 1975) which established a small network of permanent quadrats in high-use areas on the lower field in order to monitor vegetation changes. In addition to this, by comparing a combination of areas outside of the ski field, areas of the ski field which had been mown continuously, and others which had been mown and then left to regenerate, Popay & Ritchie (1975) concluded that mowing was having little effect on the vegetation, other than eliminating the larger shrubby species, and in a few restricted areas, wearing the vegetation down to the extent that some underlying soil had become exposed. They also noted that within 20 years, areas which had been previously mown and then left to regenerate had returned back to a 'normal' state. At the request of the Park Board, Popay & Ritchie (1977) conducted an additional botanical survey of an area between Warwick Castle and Ngarara Bluffs which was proposed as an extension of the existing Manganui ski field. To our knowledge, this proposal has since been abandoned or put on hold.

A re-measurement of the permanent quadrats on the lower field was first conducted in 1982 by Popay & Ritchie (1985). They concluded that overall, there had been little change in the vegetation cover within the quadrats. At this time, it was also noted that mowing had become less frequent and less rigorous than in the preceding years, and as a result, very little ‘scalping’ of the vegetation was occurring. Scalping occurs when the mower is set to mow too close, and as a result vegetation (particularly on humps) is completely removed, leaving only roots or bare soil behind. The permanent quadrats were again re-measured by Rapson et al. (1994), who observed that although the vegetation cover had increased within quadrats, some invasion of exotic species was occurring, and none of the plant communities present were in a stable state. In their report recommendations, Rapson et al. (1994) also suggested that fertiliser broadcasting on the field should cease. Concern over ‘scalping’, the abundance of exotics and fertiliser use on the field was again raised by Bruce Clarkson in an email to the Department of Conservation, 2007. At this time, it was thought that the portion of bare ground on the lower ski field was the highest it had been since the 1970s, probably as a result of a combination of scalping by the mower, the removal of plants from the field for planting around the new lodge, and the high numbers of hares/rabbits present on the field.

2 Objectives

In 2012, the Department of Conservation requested that the Stratford Mountain Club commission an assessment of the environmental effects of the Manganui ski field area, including a re-measurement of the permanent quadrats originally established in 1975, and re-measured most recently by Rapson et al. (1994). The work was subsequently contracted to the Environmental Research Institute, University of Waikato. The Department of Conservation provided a brief requiring that the cause and extent of the changes on the ski field be examined (as listed below), and provision of recommendations for mitigation.

- Damage or modification to the vegetation
- Introduction and dispersal of non-indigenous plant species present
- Damage or modification to ground form and drainage
- Soil compaction by machines and vehicles
- Contamination (nutrient enrichment) of water courses

3 Vegetation

This section addresses the first two points of the brief relating to the vegetation. At the altitudinal range of the lower ski field (1250-1360 m) elsewhere on the mountain, vegetation typically consists of a belt of tight-knit subalpine scrub and shrubland 1-2 m in height. Within this zone, the dominant species is usually *Brachyglottis elaeagnifolia*, intermixed with the shrubs *Pseudopanax colensoi*, *Raukaua simplex*, *Dracophyllum filifolium*, *Hebe stricta* var. *egmontiana*, *Coprosma pseudocuneata* and *Coprosma dumosa*. With increasing elevation, and on poorly drained sites, this shrubland gives way to shrub-tussockland, in which *Chionochloa rubra* is the most common tussock species. Between 1400-1600 m asl, dense mats of low growing alpine herbfield exist along with patches of moss-herbfield and mossfield. Common alpine herbs include *Celmisia gracilenta* var. (*C. major* var. *brevis*), *Celmisia glandulosa* var. *latifolia*, *Anaphalioides alpina*, *Anisotome aromatica*, *Forstera bidwillii* var. *densifolia*, *Coprosma perpusilla* and *Gaultheria depressa* var. *novae-zelandiae.* Above 1600 m asl, plant cover becomes patchy and the dominant surface is often bare substrate which is named gravelfield, stonefield, boulderfield etc. depending on the substrate size (Clarkson 1986).

The site of the Manganui ski field historically consisted of a mixture of shrub and tussock around 1 m in height before it was first cleared for skiing in the 1920s (Figure 1a). A photograph from the same location (Figure 1b) shows the full extent of shrub clearance which has occurred in the subsequent decades. Although tussock is still present, virtually all shrubby species have been removed to the extent that when viewed from a distance, the ski field is quite distinct from the surrounding belts of vegetation (Figure 2). The lower ski field is situated on a gently sloping debris fan distinct from surrounding areas, which inhibits drainage compared to on the steeper slopes. For this reason, prior to any vegetation clearance, this area would have probably supported a shorter shrub community than the surrounding areas, and the poorer drainage would have also permitted red tussock to be more common than elsewhere on the mountain at the equivalent elevation. The clearance of shrubs has had the effect of inducing a vegetation type not usually found at the elevation of the lower ski field, in which a carpet of alpine herbs (usually restricted to higher elevations) exists amongst tufts of tussock. Grasses of exotic species have also colonised and established.

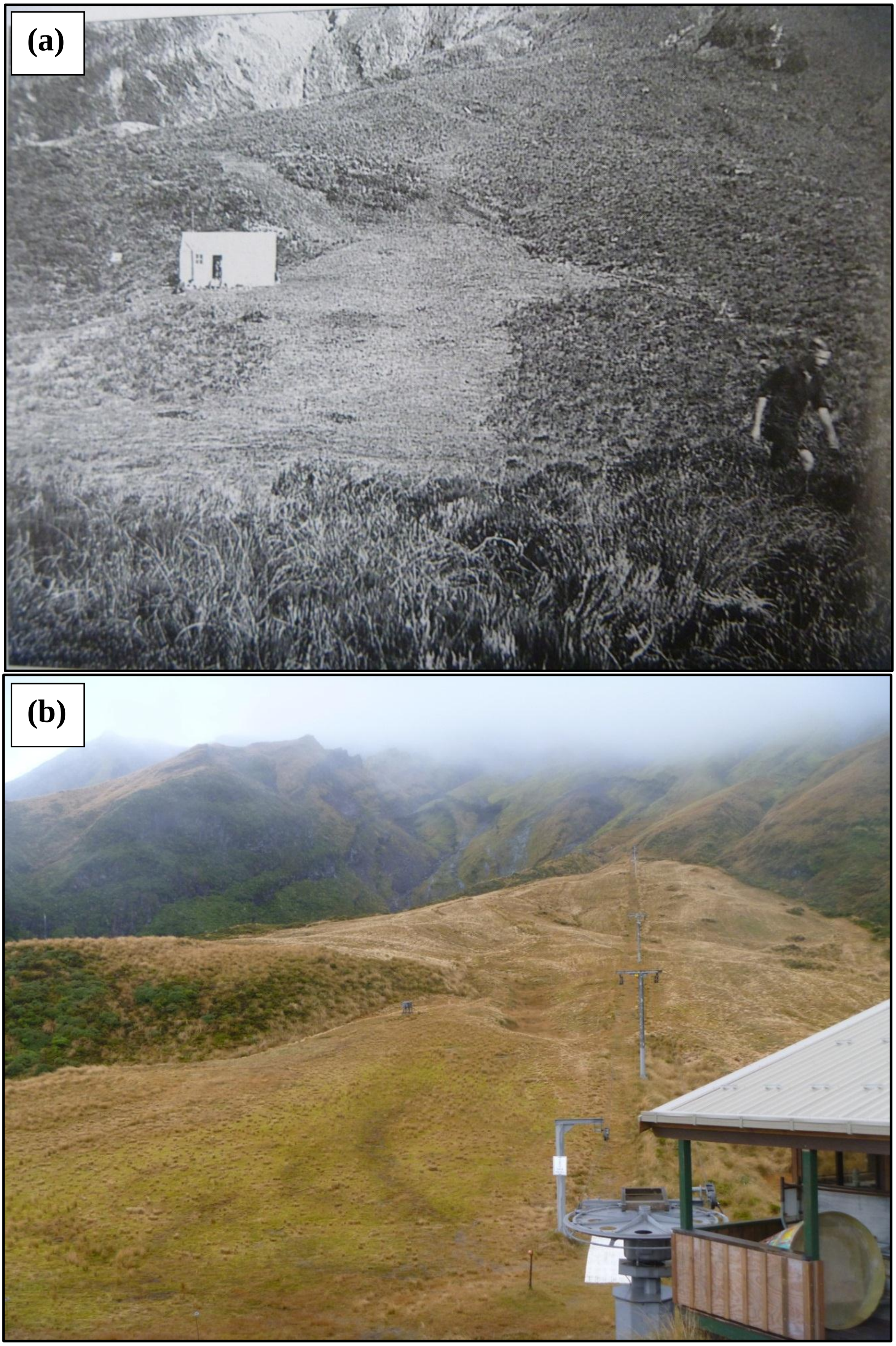

Figure 1: Historic photograph (Stokes & Stokes 2001) showing the vegetation of Manganui ski field in 1934 soon after clearing of shrubs had commenced (a), and from the same location in 2012 (b).

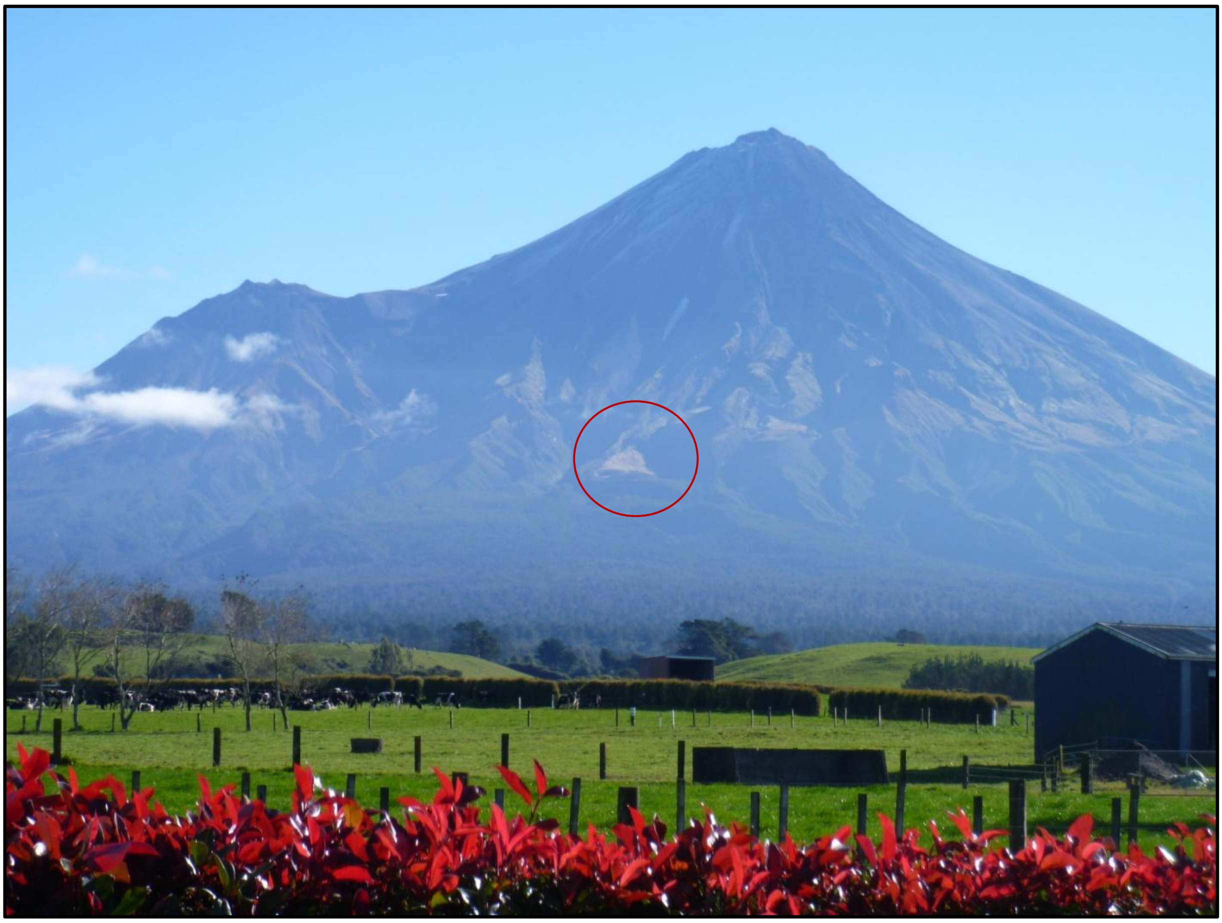

Figure 2: Extent of shrubland cleared for the Manganui ski field, as seen from Pembroke Road, 2012. A tussock field has been induced within the elevational belt of shrubland vegetation found elsewhere on the mountain.

3.1 Methods

3.1.1 Permanent quadrats

During May 2012, a thorough search was made for the wooden corner pegs of six 70 × 70 cm permanent quadrats originally established by Popay & Ritchie (1975) on the lower Manganui ski field area. Quadrat 1 is located on the site of the original Manganui hut and was largely un-vegetated when the quadrat was established in 1974. Quadrats 2-4 are in close proximity to the each other near the base of the T-bar towline, an area which experiences a high volume of foot traffic. Quadrats 5 and 6 are located near the offloading area at the top of the T-bar towline. These quadrats had previously been re-measured by Popay & Ritchie (1982) and Rapson et al. (1994). Both studies had mixed success at re-locating the quadrats, new corner pegs were installed for some of the quadrats in approximately the same location. This was in part due to insufficient detail being provided on the exact location of quadrats. An additional seventh permanent quadrat established by Popay & Ritchie (1975) was not re-measured by Rapson et al. (1994), and although we located one potential corner peg for this quadrat in the general area, it was not re-measured; this quadrat was larger (5 × 7 m) and was originally surveyed using only hand drawn sketch maps of vegetation types.

In the present study, corner pegs for three of the quadrats (1,4,6) were able to be re-located, while the remaining three (2,3,5) had to be re-established in approximately the original location because the corner pegs had probably decayed away or inadvertently been removed. In an attempt to ensure that quadrats can be more reliably located in the future, new corner pegs were put in place for all the quadrats; each quadrat now has 1 large wooden corner peg (clearly visible on the surface) with the remaining corners having a substantial copper or metal peg buried below the surface (a metal detector could relocate them if/when required). In addition, detailed measurements of each quadrats location in relation to permanent ski field fixtures such as T-bar supports were made (i.e., distances and compass bearings) such that in future, quadrats may be accurately relocated even if the pegs are no longer present.

The quadrat sampling method followed that of Rapson et al. (1994). Firstly a 70 × 70 cm sampling frame consisting of 5 × 5 cm grid divisions was placed over the corner pegs. At each non-peripheral grid intersection point, a needle was lowered vertically, and the species first touched was recorded. Litter was also recorded when it was intercepted, though this chiefly reflects the time since the last mowing; furthermore, in attempting to locate the corner pegs, litter was often required to be brushed away. This method gives species cover information from 169 grid intercept points in each quadrat. In addition to this, species cover was also quantified in a 50 × 50 cm subset of the quadrat using a random 200 point technique. The subset used was located in the lower right of each quadrat facing the mountain. Using random co-ordinates, a needle was lowered at 200 positions, and all species intercepted before the ground were recorded (as multiple layers of vegetation could exist). To improve the distribution of permanent quadrats over the lower ski field, five new quadrats were also established following the same methods described for the existing quadrats.

Unlike the original study (Popay & Ritchie 1975), sketch mapping of vegetation types within each quadrat was not conducted here. The use of such mapping may have been appropriate when quadrats encompassed large patches of bare ground, but given that all quadrats are now vegetated with mosaics of species, mapping at such a small scale would be difficult and provide little beneficial information.

3.1.2 Vegetation mapping

Using a handheld GPS, a vegetation map of the lower ski field was produced by traversing the main vegetation types present and creating digital ‘tracks’ of different areas. Within selected areas, vegetation information was collected using either point-intercept transects, the quadrat sampling frame, or general observations. It is the intention that if this type of GPS mapping is conducted again in a number of years, it will be possible to determine to what extent different vegetation types (for example weedy areas) have increased or decreased in extent. The point-intercept transect method used transects (mostly 10 m in length), with the first species intercepted at 10 cm intervals along the transect being recorded to give an estimate of species cover.

3.2 Results

3.2.1 Vegetation change in permanent quadrats

The permanent quadrats have been present on the lower ski field for 38 years. The location of permanent quadrats on the lower ski field is illustrated in Figure 3, and the new information collected on the exact position of each quadrat is presented in the Appendices (1-5). These records will ensure that in the event of the corner pegs being lost or removed, quadrats can be accurately repositioned, thus preserving the integrity of the long-term vegetation data. Table 1 summarises which quadrats' corner pegs were not able to be relocated during re-measurement studies, in which case quadrats were repositioned in approximately the same location. Consideration must be given to this limitation when interpreting the vegetation change in each quadrat over time.

Table 1: History of the 12 permanent quadrats present on the lower ski field. Quadrats which have been re-positioned due to the pegs not being located are shown.

✓ Permanent quadrat located
· Quadrat re-positioned (original pegs not found)
- Quadrat not sampled

	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study
	1974	**1975**	**1982**	**1993**	**1994**	**2012**
Quadrats est. 1974						
Quadrat 1	✓	✓	·	✓	✓	✓
Quadrat 2	✓	✓	✓	·	✓-	·
Quadrat 3	✓	✓	✓	·	✓	·
Quadrat 4	✓	✓	✓	·	✓	✓
Quadrat 5	✓	✓	✓	✓	✓	·
Quadrat 6	✓	✓	✓	✓	✓	✓
Quadrat 7	✓	✓	✓	✓-	✓-	✓-
Quadrats est. 2012						
Quadrat 8						✓
Quadrat 9						✓
Quadrat 10						✓
Quadrat 11						✓
Quadrat 12						✓

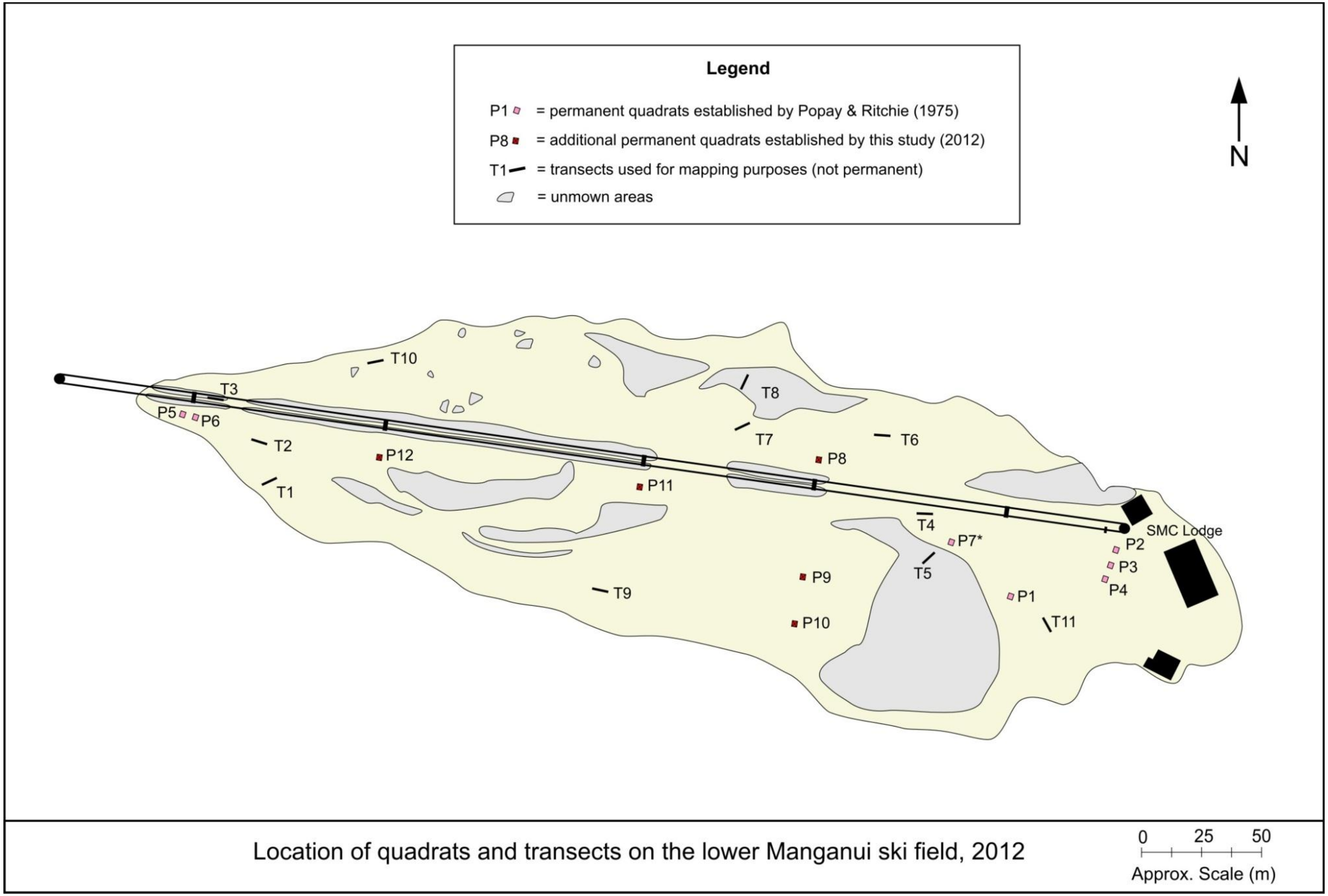

Figure 3: Location of quadrats and transects on the lower Manganui ski field. For more detailed descriptions of quadrat locations, see Appendix 1-5. Quadrat 7 (P7*) was not surveyed.

Within the permanent quadrats on the lower ski field, a total of 66 plant species have been recorded between 1974 and 2012 (Table 2); 40 indigenous vascular species, 10 exotic vascular species, and an additional 16 non-vascular species. By collating the data from the previous surveys in this way, it is immediately apparent which species have been present consistently throughout the monitoring period, and which have occurred sporadically, or have been lost from quadrats (assuming they were originally identified correctly). Some of the variability exhibited by species over the re-measurement period could relate to their annual life habit, and could also be influenced by the time of year the survey was conducted (some species are more conspicuous when in flower etc.). Table 2 serves as a quick reference point for those who are tasked with the re-measurement of these quadrats in the future.

Given the methods used, two types of results are available for the current re-measurement of permanent quadrats (and the new quadrats established); the grid intercept data, and the 200 random point data (both given in Table 3). Comparing the results obtained by these two methods, it is apparent that the percentage covers obtained for each species do not tend to differ by more than 5% within quadrats. The 200 random point method was found to be much more time consuming than the grid intercept technique, and given the similarities between results, it is our recommendation that in the future, only the grid intercept method need be used.

The grid intercept (species cover) data from the current and previous surveys illustrates changes in common species' abundance in the quadrats over time. It is apparent that none of the quadrats have reached a stable vegetation type, whereby portions of species are remaining constant. In comparison, unmodified tussock and herbfield vegetation in the vicinity of the ski field has remained relatively stable, with species abundances not varying from year to year (Rapson et al. 1994; Waikato University unpublished field trip data 2007-2012). The Vegetation changes that have occurred within the permanent quadrats since 1994 are summarised briefly here. Figure 4 and Figure 5 illustrate how the percent cover of the main species has varied within the quadrats over time, while Figure 6 summarises the total changes of native and exotic species present.

Species are referred to by their full scientific name in the first instance, and then by genus thereafter where possible; for full names, refer to the results tables.

Quadrat 1

Located on the site of the original Manganui hut, quadrat 1 (photograph in Appendix 7) was largely un-vegetated when first established in 1974. The marked reduction of lapilli within this quadrat over the monitoring period illustrates how it has now become fully vegetated. The re-vegetation has largely been by native species, with the current dominants being *Celmisia glandulosa* var. *latifolia, Gunnera monoica* and *Oreobolus pectinatus.* Since 1994, the cover of *Chionochloa rubra, Poa colensoi, Anaphalioides alpina* and the exotic *Hypochaeris radicata* has remained constant; *Celmisa gracilenta* var. (*C. major* var. *brevis*), *Celmisa glandulosa* and *Luzula* (*banksiana* var. *migrata*?) have increased in cover; *Gaultheria depressa* var. *novae-zelandiae* has decreased in cover; and *Coprosma perpusilla*, *Dracophyllum filifolium*, *Forstera bidwilllii* var. *densifolia, Gunnera, Hebe odora*, *Oreobolus* and *Pentachondra pumila* have been recorded in the quadrat for the first time. The original presence and recent disappearance of the pioneering genera *Raoulia* is to be expected, along with the reduction of lichen and moss cover, as these species are outcompeted by later successional species establishing at the site. There also appears to have been a loss of *Ourisia macrophylla* subsp. *macrophylla*, *Epilobium nerteroides*, *Zoysia* (erroneous record) and *Viola cunninghamii* from the quadrat.

Quadrats 2, 3 and 4

Quadrats 2, 3 and 4 are located in the moss field near the base of the T-bar bullwheel. Quadrat 2, the closest to the bullwheel, is situated within the moss field, but was largely dominated by the exotics *Carex ovalis* and *Agrostis capillaris*. Since 1994, *Carex, Agrostis* and *Lotus pedunculatus* have increased there, along with the cosmopolitan moss *Hypnum cupressiforme*. As well as several other species of moss, *Juncus antarcticus* was also present here, and both *Viola* and *Plantago novae-zelandiae* appear to have arrived in this quadrat. Quadrats 3 and 4 are currently dominated by the moss *Dicranoloma robusta*, and also *Oreobolus*. Since 1994, the cover of *Oreobolus* and *Chionochloa* has remained constant; *Juncus antarcticus* has appeared; and there has been a marked decrease or loss of natives *Anisotome aromatica*, *Coprosma perpusilla* and *Celmisia gracilenta*. This mossfield is of a fragile nature and very susceptible to compaction by both machine and foot traffic (see Section 5).

Quadrats 5 and 6

Quadrat 5 consisted mostly of *Chionochloa* and a mix of native herbs, although there was a small portion of the exotics *Poa annua* and *Hypochaeris* present. Since 1994, *Celmisia gracilenta*, *Anisotome*, and *Coprosma perpusilla* have shown a marked increase in cover; *Chionochloa* and *Celmisia glandulosa* have marginally decreased; *Poa colensoi* has dramatically decreased; and *Anaphalioides* has been lost. At present, quadrat 6 has a higher portion of exotics than quadrat 5, the most prominent being *Poa annua* which occupies almost half of the quadrat. Since 1994, the cover of *Chionochloa* has dramatically been reduced; *Anaphalioides* has also reduced; but there has been an appearance or increase in the natives *Anisotome*, *Coprosma perpusilla*, *Lobelia angulata*, *Viola*, and the exotics *Agrostis* and *Hypochaeris*.

Table 2: Vascular and non-vascular species present within permanent quadrats on the lower Manganui ski field (1974-2012). Note that quadrat 2 was only surveyed once by Rapson et al. (1994).

Species	Quadrat 1						Quadrat 2					Quadrat 3					
	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)	Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study
	1974	1975	1982	1993	1994	2012	1974	1975	1982	1993	2012	1974	1975	1982	1993	1994	2012
Agrostis capillaris*		+	+							+	+			+	+		
Aira*				+													
Anaphalioides alpina		+	+	+	+	+											
Anisotome aromatica	+	+	+										+	+		+	
***Breutelia pendula*~**																	
***Campylopus*~**						+											
Carex ovalis*									+	+	+						
Celmisia glandulosa* var. *latifolia	+	+	+	+	+	+						+	+	+	+	+	+
***Celmisia gracilenta* var. (*C. major* var. *brevis*)**				+		+											
Chaerophyllum																	
Chionochloa rubra			+	+	+	+						+	+	+	+	+	+
Coprosma depressa																	
Coprosma perpusilla* subsp. *perpusilla						+									+	+	
Coriaria plumosa																	
Coriaria pteridoides																	
Deyeuxia	+	+	+									+					
***Dicranoloma robusta*~**																	+
***Ditrichum difficile*~**		+	+									+	+	+			
***Ditrichum punctulatum*~**	+		+														
Dracophyllum filifolium						+											
Epilobium nerteroides	+	+		+	+		+		+								
Forstera bidwillii* var. *densifolia						+											
Gaultheria depressa* var. *novae-zelandiae			+	+	+	+											
Gentiana filicaule												+	+	+			
***Geranium* sp. "*microphyllum* mainland"**			+														
Gunnera monoica						+											
Hebe odora	+	+	+			+						+	+	+			
Hierochloe																	
Holcus lanatus*																	
***Hypnum cupressiforme*~**							+	+	+		+	+	+				+
Hypochaeris radicata*			+	+	+	+				+		+	+	+			
Juncus antarcticus							+	+	+		+						+
Juncus bufonius							+	+									
Kelleria dieffenbachii																	
Lichen!															+		

Species	Quadrat 4						Quadrat 5						Quadrat 6						New quadrats est. 2012				
	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Quadrat 8	Quadrat 9	Quadrat 10	Quadrat 11	Quadrat12
	1974	1975	1982	1993	1994	2012	1974	1975	1982	1993	1994	2012	1974	1975	1982	1993	1994	2012					
Agrostis capillaris*									+														
Aira*																+							
Anaphalioides alpina						+		+		+	+		+	+	+	+	+		+			+	
Anisotome aromatica	+	+	+	+	+		+	+	+	+	+	+				+			+	+	+	+	+
***Breutelia pendula*~**													+										+
***Campylopus*~**																							
Carex ovalis*																							
Celmisia glandulosa* var. *latifolia	+	+	+	+	+	+	+	+	+	+	+	+							+	+	+	+	+
***Celmisia gracilenta* var. (*C. major* var. *brevis*)**	+	+	+			+	+	+	+	+	+	+							+	+	+	+	+
Chaerophyllum																	+						
Chionochloa rubra	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
Coprosma depressa							+	+				+	+	+	+								
Coprosma perpusilla* subsp. *perpusilla		+	+		+	+	+	+	+		+	+				+			+	+	+	+	+
Coriaria plumosa	+							+	+					+					+			+	
Coriaria pteridoides											+												
Deyeuxia														+									
***Dicranoloma robusta*~**	+	+				+	+	+	+				+							+			
***Ditrichum difficile*~**																							
***Ditrichum punctulatum*~**																							
Dracophyllum filifolium									+														+
Epilobium nerteroides								+		+		+	+			+							
Forstera bidwillii* var. *densifolia		+				+									+				+	+		+	+
Gaultheria depressa* var. *novae-zelandiae				+						+						+			+		+		+
Gentiana filicaule								+						+									
***Geranium* sp. "*microphyllum* mainland"**									+	+					+								
Gunnera monoica												+					+					+	
Hebe odora	+	+	+						+								+			+	+		+
Hierochloe								+	+	+	+												
Holcus lanatus*																						+	
***Hypnum cupressiforme*~**	+						+	+	+			+	+							+	+	+	+
Hypochaeris radicata*	+	+	+						+			+			+	+			+			+	+
Juncus antarcticus						+																	
Juncus bufonius																							
Kelleria dieffenbachii							+	+	+											+		+	+
Lichen!										+	+												

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Species	Quadrat 1						Quadrat 2					Quadrat 3						Quadrat 4						Quadrat 5						Quadrat 6						New quadrats est. 2012				
	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)	Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Popay & Ritchie (1975)		Popay & Ritchie (1985)	Rapson et al. (1994)		Present study	Quadrat 8	Quadrat 9	Quadrat 10	Quadrat 11	Quadrat12
	1974	1975	1982	1993	1994	2012	1974	1975	1982	1993	2012	1974	1975	1982	1993	1994	2012	1974	1975	1982	1993	1994	2012	1974	1975	1982	1993	1994	2012	1974	1975	1982	1993	1994	2012					
Lobelia angulata							+		+	+				+													+		+			+								
*Lolium perenne**										+	+																												+	
Lophocolea biciliata~																		+																						
*Lotus pedunculatus**										+	+																													
Luzula				+	+	+																		+									+	+		+	+		+	
Lycopodium fastigiatum																		+	+	+																+	+			+
Moss!															+	+					+	+					+	+					+							
Muehlenbeckia axillaris															+			+	+				+						+	+	+	+		+		+				
Notodanthonia~			+											+						+																				
Oreobolus pectinatus						+						+	+	+	+	+	+	+	+	+	+	+	+					+								+	+	+	+	+
Ourisia macrophylla subsp. *macrophylla*				+	+																			+	+												+			+
Ozothamnus vauvilliersii	+	+	+																							+														+
Pentachondra pumila						+															+		+														+	+		
Plantago novae-zelandiae											+																						+	+		+		+	+	+
*Poa annua**	+	+	+				+	+	+	+					+														+				+						+	+
Poa cita										+																				+	+	+		+						
Poa colensoi			+	+	+	+						+	+	+				+	+	+				+	+	+	+	+	+			+	+	+		+	+	+	+	+
Poa pusilla																									+					+	+	+								
Polytrichadelphus magellanicus~	+	+	+				+	+	+		+																		+											+
Pseudodistichium buchanani~							+	+	+																															
Racomitrium crispulum~	+	+	+																																					
Racomitrium lanuginosum~						+						+	+								+																+	+		+
Racomitrium ptychophyllum~	+	+																																						
Raoulia australis	+	+	+	+	+		+	+																																
*Sagina procumbens**							+	+																																
Stereocaulon~						+							+																											
Tortula pteriei~	+	+	+																																					
*Trifolium repens**										+																														
Uncinia																														+	+	+	+							
Viola cunninghamii	+	+	+		+		+				+	+	+											+	+	+	+			+	+	+							+	
Wahlenbergia albomarginata																																	+							
Weisia lancifolia~		+	+																																					
Zoysia minima					+																																			

* Exotic

~ Non-vascular

! Rapson et al. (1994) did not differentiate between non-vascular species other than “lichen”, “moss” and “*Racomitrium lanuginosum*”

Table 3: Results of the present studies (2012) re-measurement of the six permanent quadrats on the lower Manganui ski field, plus the additional five new quadrats established. Data are expressed as percent cover calculated via (a) the random co-ordinate technique or the (b) grid intercept technique.

Species	Q 1		Q 2		Q 3		Q 4		Q 5		Q 6		Q 8		Q 9		Q 10		Q 11		Q 12	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
*Agrostis capillaris**			12.0	20.7								1.8										
Anaphalioides alpina	7.0	5.3									9.5	4.7	2.0	2.4					1.5	0.6		
Anisotome aromatica									7.5	12.4	3.5	5.9	4.0	3.0	1.5	2.4	5.5	4.7	1.0	0.6	3.5	1.2
Breutelia pendula~											4.5	5.9									3.0	1.2
Campylopus~	14.0	9.5									14.5	7.1										
*Carex ovalis**			31.0	34.3																		
Celmisia glandulosa var. *latifolia*	15.0	17.2			4.5	1.8	10.0	5.9	1.5	3.0	0.5		26.5	30.2	11.5	14.8	9.0	11.2	17.5	20.1	13.0	21.3
Celmisia gracilenta var. (*C. major* var. *brevis*)	4.5	4.7						4.7	10.0	11.8			1.0			0.6	6.5	7.7	2.0	1.2	0.5	
Chionochloa rubra	7.5	6.5			7.5	5.3	7.0	3.6	28.5	19.5	0.5	5.3	9.0	5.3	7.0	3.0	5.0	3.0	16.0	10.1	3.5	3.6
Coprosma depressa									6.5	1.8												
Coprosma perpusilla	0.5	0.6					2.0	1.8	17.5	21.3	4.0	1.8	12.0	11.8	6.0	7.7	12.5	25.4	7.0	8.9	8.0	6.5
Coriaria plumosa													2.0	3.0						0.6		
Dicranoloma robusta~					48.5	50.3	47.5	53.3							4.0	1.2						
Ditrichum difficile~												0.6										
Dracophyllum filifolium		0.6																			1.0	1.2
Epilobium nerteroides									1.0													
Forstera bidwillii var. *densifolia*	2.0	1.8					1.0	0.6					3.0	1.8	7.0	2.4			3.5	3.0	5.5	4.7
Gaultheria depressa var. *novae-zelandiae*	4.5	4.1									0.5			1.2			0.5	3.6			2.5	1.2
Gunnera monoica	8.0	15.4								0.6		0.6							1.0			
Hebe odora	1.5	1.2													2.5	3.0	5.5	1.8			4.0	1.2
*Holcus lanatus**																			0.5	0.6		
Hypnum cupressiforme~			39.5	32.5	12.5	10.1			4.5	6.5					0.5		1.5	1.2	1.5	1.8	4.0	3.0
*Hypochaeris radicata**	2.0	0.6								2.4	2.0	4.1		0.6					3.5	0.6		0.6
Juncus antarcticus			4.5	4.7	13.0	12.4	4.0	2.4														
Kelleria dieffenbachii															5.0	4.1			2.0	3.0	4.5	1.8
Lapilli		0.6																				
Litter	5.5	3.0					1.0			4.7	5.0	5.3							3.5	1.8		
Lobelia angulata											6.5	5.3										
*Lolium perenne**				0.6															4.0	4.1		
*Lotus pedunculatus**			5.5	4.1																		
Luzula	8.0	6.5											3.5	1.8		0.6			0.5	2.4		
Lycopodium fastigiatum													0.5	2.4	2.0	1.8					2.0	0.6
Muehlenbeckia axillaris							4.0	1.8	5.0	1.8	6.5	5.9		1.2								
Oreobolus pectinatus	6.0	14.2			14.0	20.1	23.5	26.0				0.6	26.5	33.1	25.0	33.1	3.5	1.2		3.0	33.5	45.6
Ourisia macrophylla subsp. *macrophylla*															1.0							0.6
Ozothamnus vauvilliersii																					0.5	
Pentachondra pumila	0.5														14.0	17.8	15.0	12.4				
Plantago novae-zelandiae			5.0	2.4									1.0	0.6				0.6	1.5	0.6	4.0	1.2
*Poa annua**									4.5	6.5	36.5	42.0							22.5	26.0	0.5	0.6
Poa colensoi	8.5	4.1							1.0	0.6			9.0	1.8	10.5	6.5	18.5	8.9	10.5	10.1	1.0	1.2
Polytrichadelphus magellanicus~			2.5						12.5	7.1												0.6
Racomitrium lanuginosum	5.0	3.0													2.5	1.2	17.0	18.3			5.5	2.4
Soil											2.0	0.6										
Stereocaulon~		1.2																				
Viola cunninghamii				0.6							4.0	2.4							0.5	1.2		

*** Exotic**
~ Non-vascular

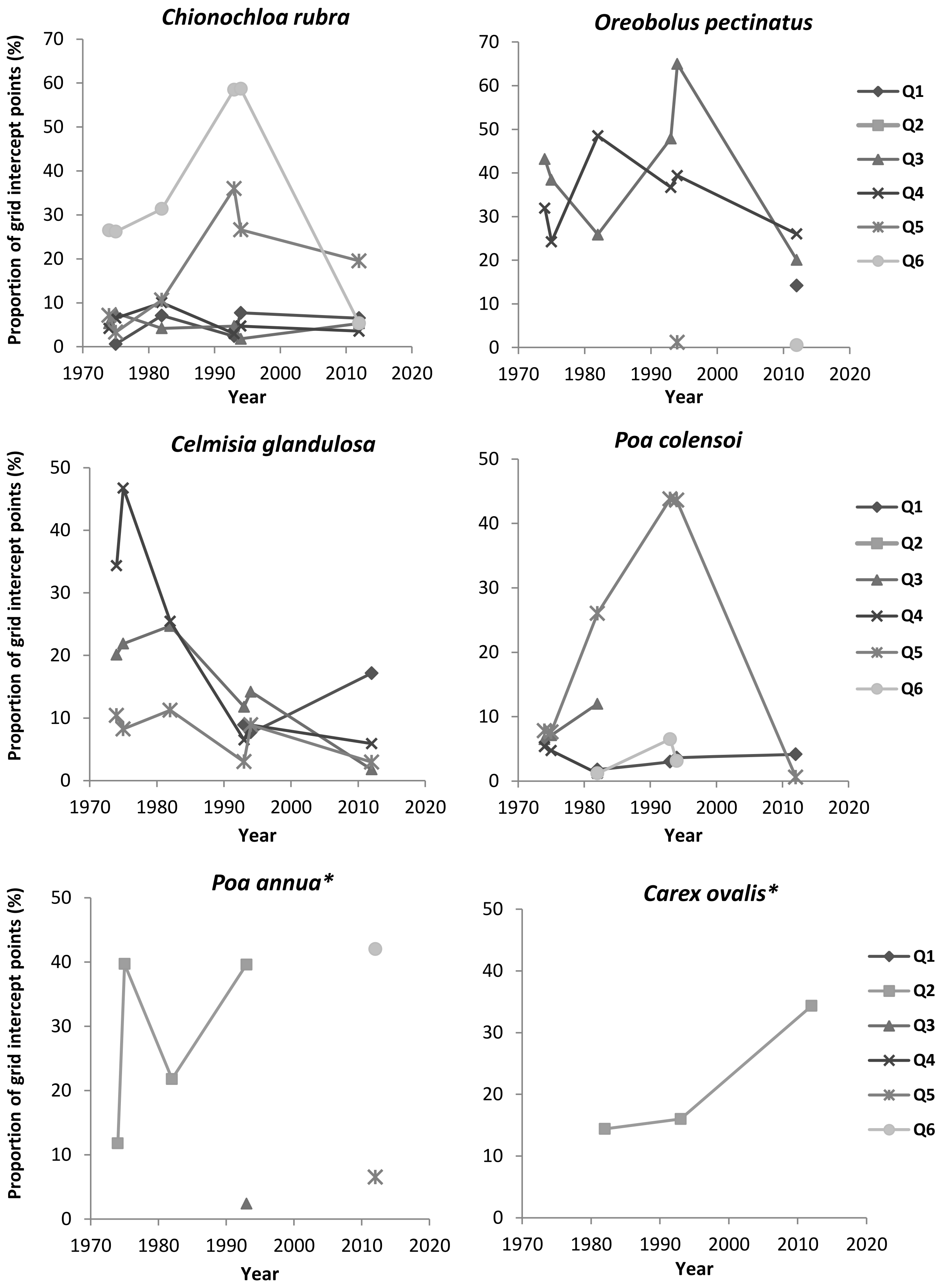

Figure 4: Changes in percent cover for main species in permanent quadrats (1974-2012).

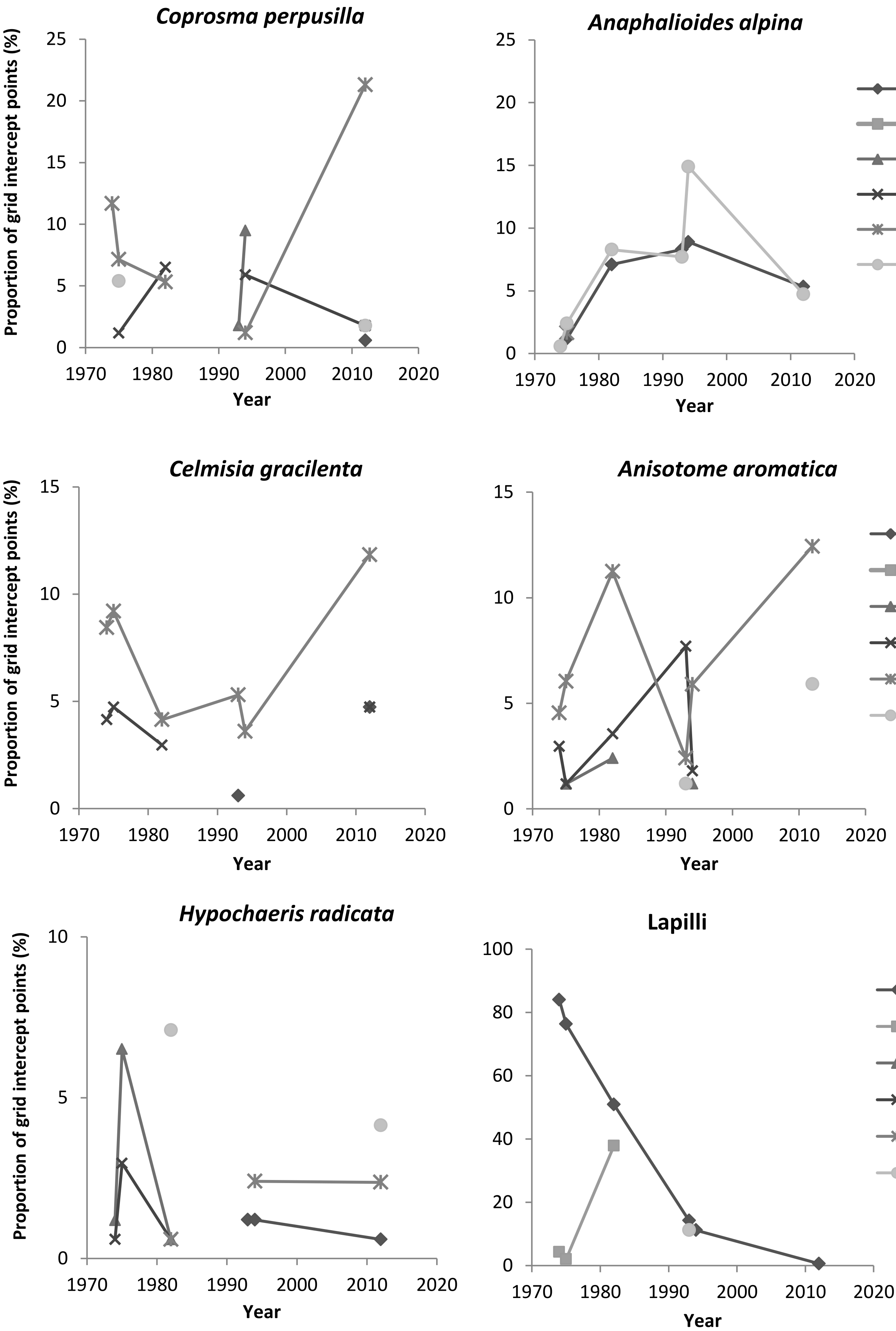

Figure 5: Changes in percent cover for main species in permanent quadrats (1974-2012).

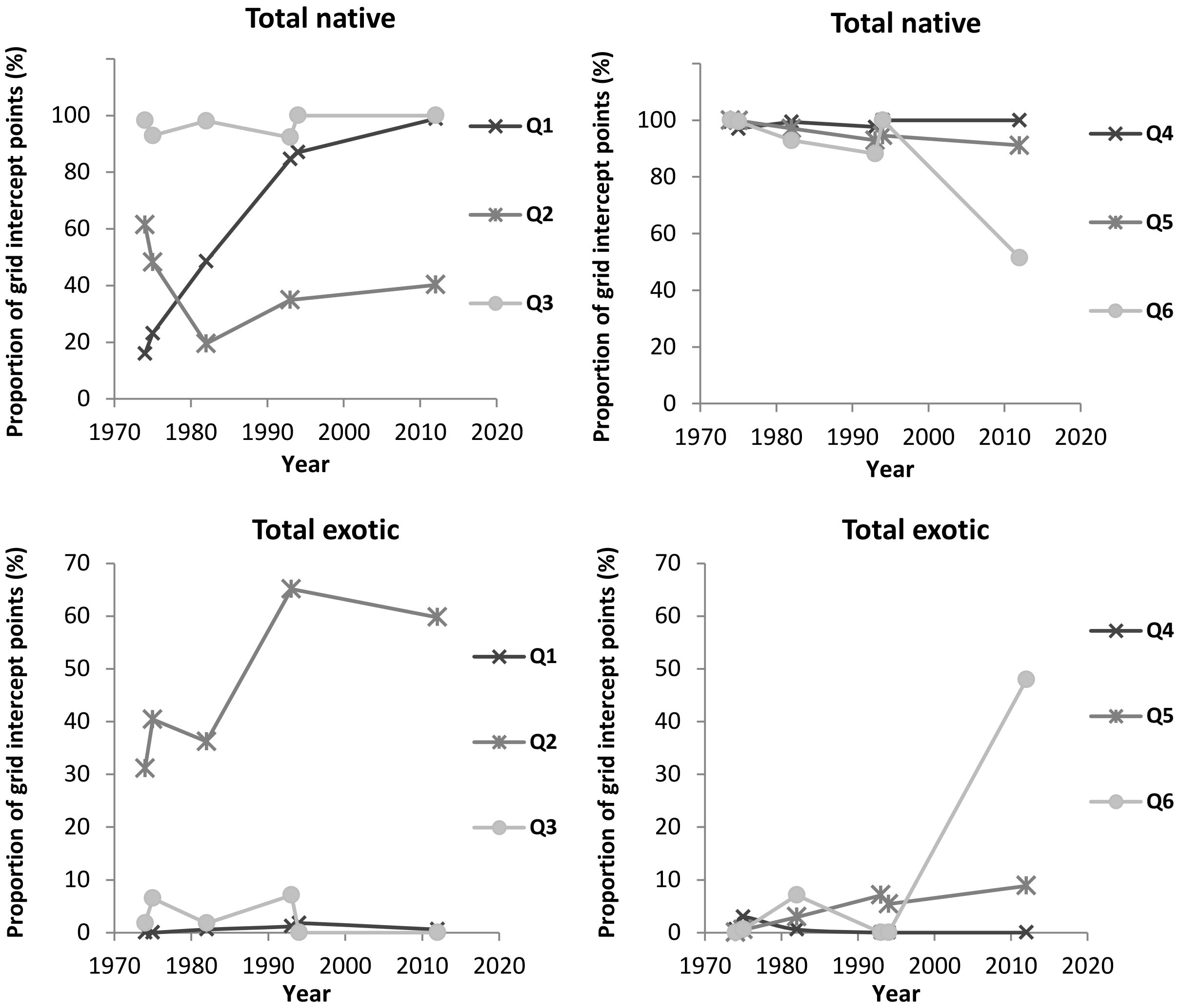

Figure 6: Changes in relative portions of native and exotic species in permanent quadrats (1974-2012).

3.2.2 Vegetation map of lower ski field

The vegetation map of the lower ski field (Figure 7) identifies eleven main vegetation types, each of which is described in detail in Appendix 6. These descriptions are based on quantitative data from both permanent quadrats and transects, as well as qualitative descriptions made in the field.

3.2.3 Distribution of exotic species

The vegetation map and permanent quadrat data have indicated that in some areas of the lower ski field, exotic species have increased in abundance and become predominant in the vegetation (e.g., Figure 8). Common exotic species present on the lower ski field include *Carex ovalis*¸ *Agrostis capillaris*, *Poa annua*, *Hypochaeris radicata*, *Holcus lantus*, *Lolium perenne*, *Anthoxanthum odoratum* and *Lotus pedunculatus.* When native vegetation is in an unmodified state, it is generally considered to be quite resilient to invasion by exotic species. However, the long history of human activity on the ski field, including some questionable practices such as sowing bare areas with exotics and the addition of fertiliser (Rapson et al. 1994), has left its mark on the ski field. Fortunately, there is little evidence that these exotics have spread beyond the extent of the lower ski field boundaries. Our observations have indicated that the distribution of exotics appear to closely relate to land form modification which has occurred on the field. The proportions of exotics in the vegetation are highest in areas where underground drain pipes have been historically laid (See Section 4), or where re-contouring has occurred (dynamiting of rocks etc.). An illustration from the 1984 Stratford Mountain Club Management Plan (Figure 9) identifies two areas where dynamiting of rock was to occur, and assuming that this was conducted, these areas were identified on our vegetation map as being dominated largely by exotics; the same is true for the culvert section shown. Section 4.2 (Figure 11) identifies other areas where drainage has been modified (grated drains etc.), and these areas mostly correspond to exotic dominated areas illustrated on the vegetation map.

In the past, management of the ski field appears to have been focused more on preventing erosion from areas where vegetation had been removed for drain pipes etc., with less concern given to what species were re-vegetating these bare areas. Exotic grasses are assumed to have been sown because they were considered more capable of rapid re-vegetation than native species, which are inherently slower-growing; with additions of fertiliser being used to further speed up the process. Unfortunately, the native vegetation adapted to the area is unlikely to have been nutrient limited, and fertiliser would therefore have been of no benefit to the native plants. Rapson et al. (1994) commented that any sowing of exotic seed and addition of fertiliser to the ski field should cease, though unfortunately fertiliser granules have been seen on the field as recently as 2007 (Bruce Clarkson, pers. comm.); it is hoped that this practice has now finally ceased, and under no circumstance should it be repeated. If no further fertiliser additions are to occur, the nutrient levels in the modified areas of the ski field will gradually decrease over time, and at some stage, the native species more adapted to low nutrient regimes may regain some of their former dominance. The presence of the efficient nitrogen-fixing exotic herb *Lotus pedunculatus* may to some extent counter this trend, but the site is marginal compared to its preferred habitat. Other than being deliberately sown, exotic species may have also arrived opportunistically on the clothing of visitors or as wind-borne seed, and then taken hold on areas of bare ground where the native vegetation cover had been breached. The vegetation map produced here will be useful for monitoring changes in the exotic dominated areas.

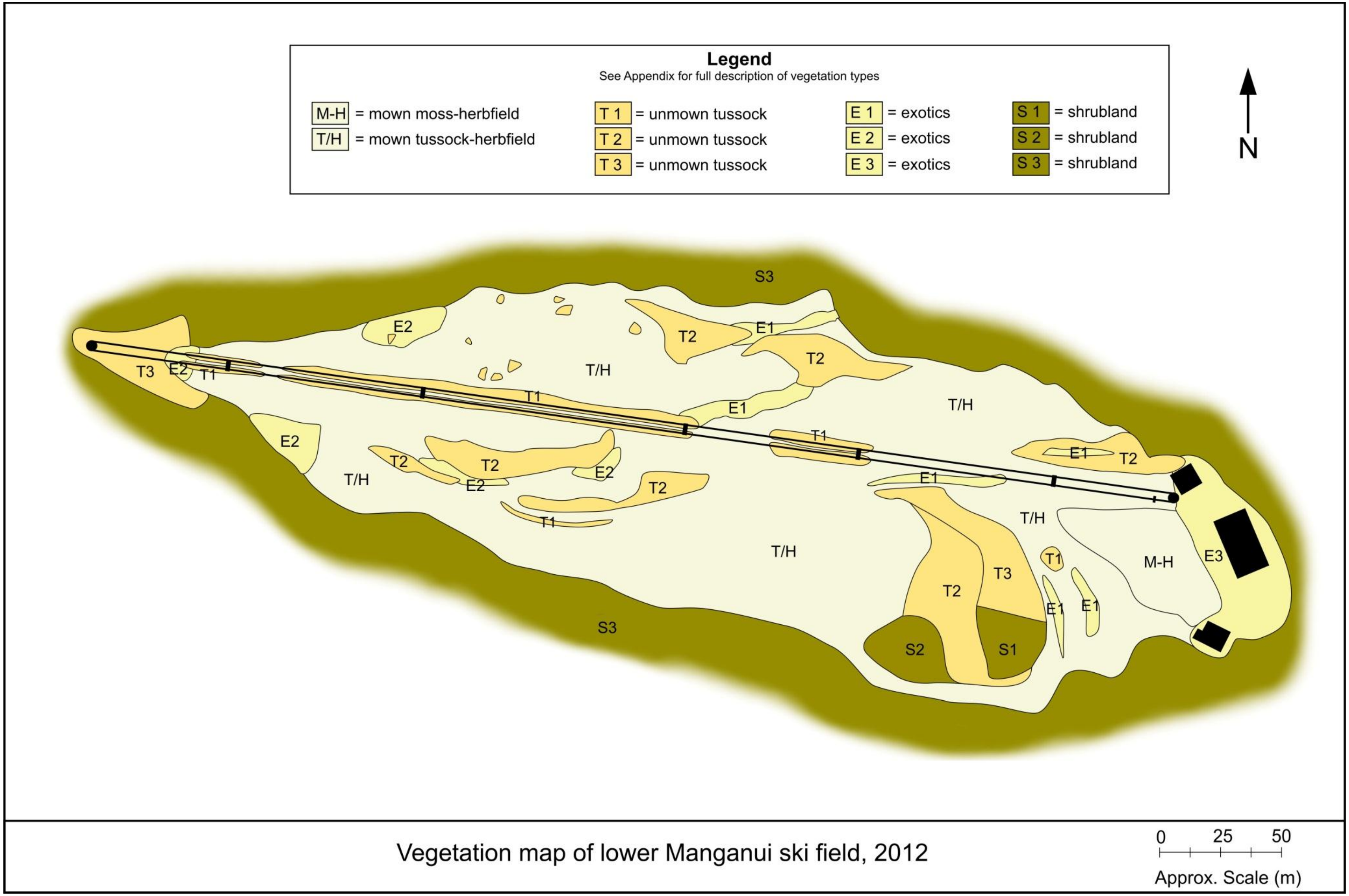

Figure 7: Vegetation map of lower Manganui ski field. For full descriptions of mapped vegetation types, see Appendix 6.


Figure 8: Examples of areas dominated by exotic species on the lower Manganui ski field.

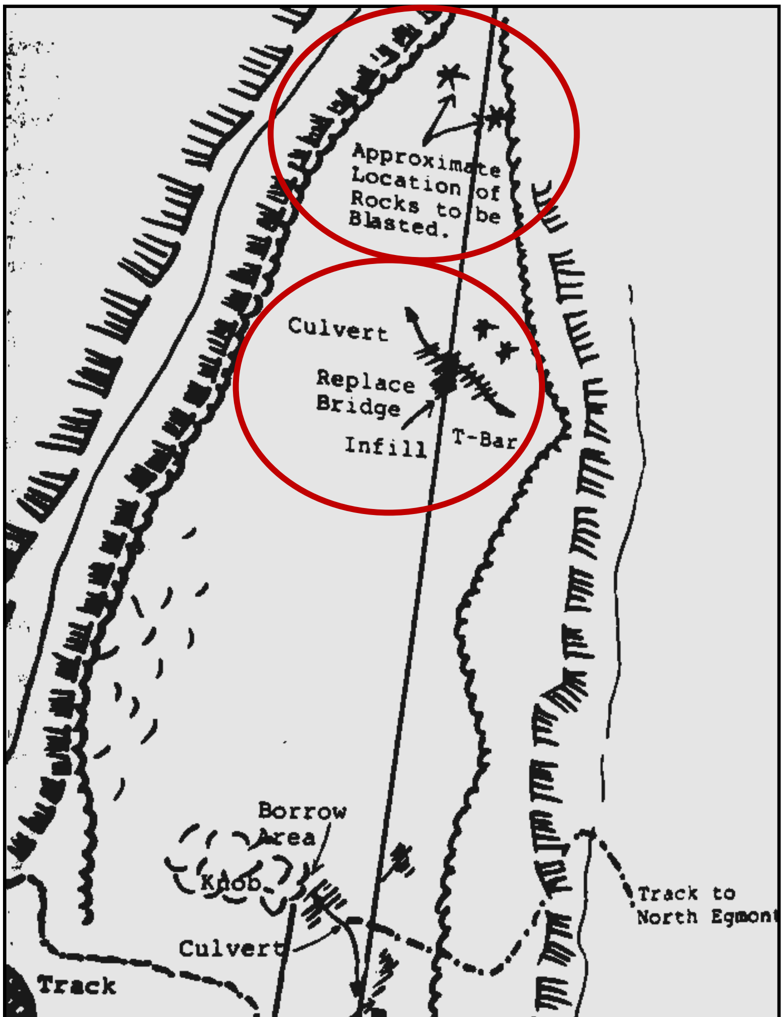

Figure 9: Excerpt from the 1984 Stratford Mountain Club Management Plan showing areas where dynamiting and drainage was to be conducted. These areas now have a high portion of exotic species present.

3.3 Recommendations

- A re-measurement of the permanent quadrats should be conducted again in five years from now.
- At this stage, removing exotic species either mechanically or with herbicide is not considered appropriate because of the increased risk of erosion and the high likelihood that exotics will simply reinvade. Five-yearly monitoring of the distribution of exotics is considered the best practice.
- Although unlikely, if any future re-contouring or drainage modification is to be undertaken on the lower ski field, consultation on use of appropriate native species is recommended to ensure that exotic species do not increase their dominance on the field further.
- No fertiliser or seed should be broadcast on the field in future.
- The high numbers of visitors to the Plateau and ski field area each year have probably been an inevitable source of exotic seed introduction. A sign in the car park reminding visitors to check that their boots and clothing are clean and free of any seed may be appropriate.
- The mower should continue to be set at a height at which no scalping of the vegetation can occur.
- Exclusion of the mower from the sensitive moss area at the base of the ski field should continue.

4 Ground form and drainage

This aspect of the brief requested that we examine damage or modification to ground form and drainage, and recommend actions to minimise or correct any damage or modification. It would appear that very little baseline information on the historic ground form and drainage of the ski field is in existence.

4.1 Methods

Visual observations and mapping (with the aid of hand held GPS) were conducted along with the examination of some historic data (management plans etc.) of limited scope.

4.2 Results

Modification of ground form and drainage appeared to be confined to the lower ski field only. The location of the main grated drains (e.g., Figure 10), open drains and culverts that have been constructed on the ski field have been preliminarily mapped (Figure 11), and if necessary, this map could now severe as a reference point for determining any future modifications. The main locations where significant water courses exit off the ski field have also been indicated on the map. According to Stokes & Stokes (2001), the majority of the drainage network on the lower field was constructed between 1987-1992, and it would appear that there have probably been no significant modifications to ground form or drainage since that time. At least one of the culverts installed was quite extensive (Figure 12), and as described in Section 3.2.3, areas around culverts such as this one are now largely dominated by exotic vegetation due to the ground disturbance during construction and subsequent remediation practices.

Historically, along with the clearance of shrubs, depressions on the lower ski field have been in-filled to smooth the ski runs. According to the Stratford Mountain Club (1984) development plan, a comparison of aerial photographs from 1956 and 1967 revealed that during that period, constant mowing (beginning in 1957) had caused minor alterations to the contour of the ski field, with small eroded channels gradually becoming in filled. They also noted that some larger rocks on the field were dynamited in 1983-84, with the material then being used to both infill depressions and back fill around culverts (See Figure 9). “Minor slope re-contouring” is also reported to have occurred at other unspecified locations on the field (Stratford Mountain Club 1984). The lower ski field is now largely void of any rocky outcrops and the ground form is distinctively smooth compared with other areas of the mountain at similar elevations.

In recent years, efforts have been made to stabilise actively eroding areas on the lower field, particularly under the T-Bar line, a popular walking route for many visitors to the area. Wooden retaining boards held in place with pegs have been used successfully by the club to stop erosion both along the T-Bar line and at other locations on the field (e.g., Figure 13). This practice could probably continue successfully when required. The use of snow mat tiles around the T-Bar loading/unloading areas also appears to have been quite successful at stabilising areas and preventing erosion (Figure 14). No attempts should be made to remove any older snow matting, within which plants have now become established. Presently, there are no significant actively eroding areas on the ski field. Of most concern is the numbers of hares present. Hares often dig in areas where the herb layer is already breached; this in turn inhibits natural re-vegetation (Figure 15). The effect of machinery (quad bike, tractor etc.,) on the ski field mostly relates to compaction rather than modification to ground form, and is therefore discussed in Section 5.

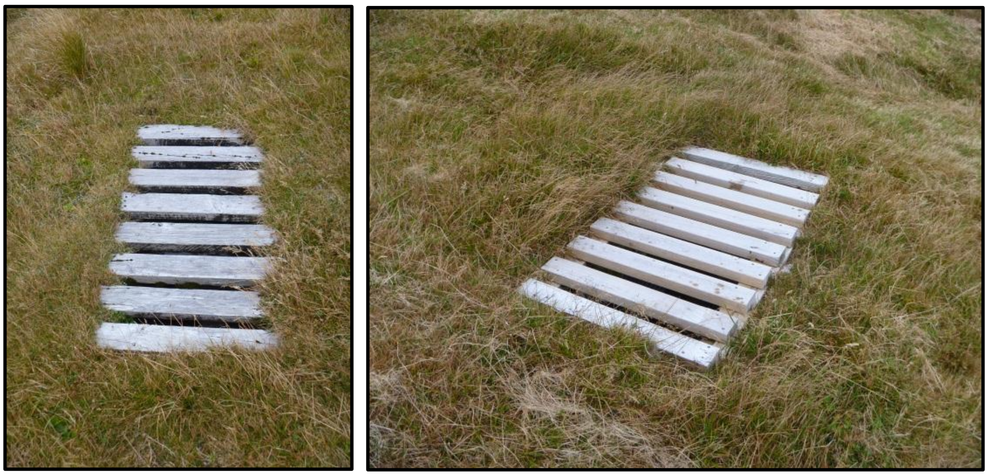

Figure 10: Grated drains present on the lower ski field. Note that exotic grasses dominate at these areas where the ground has been disturbed.

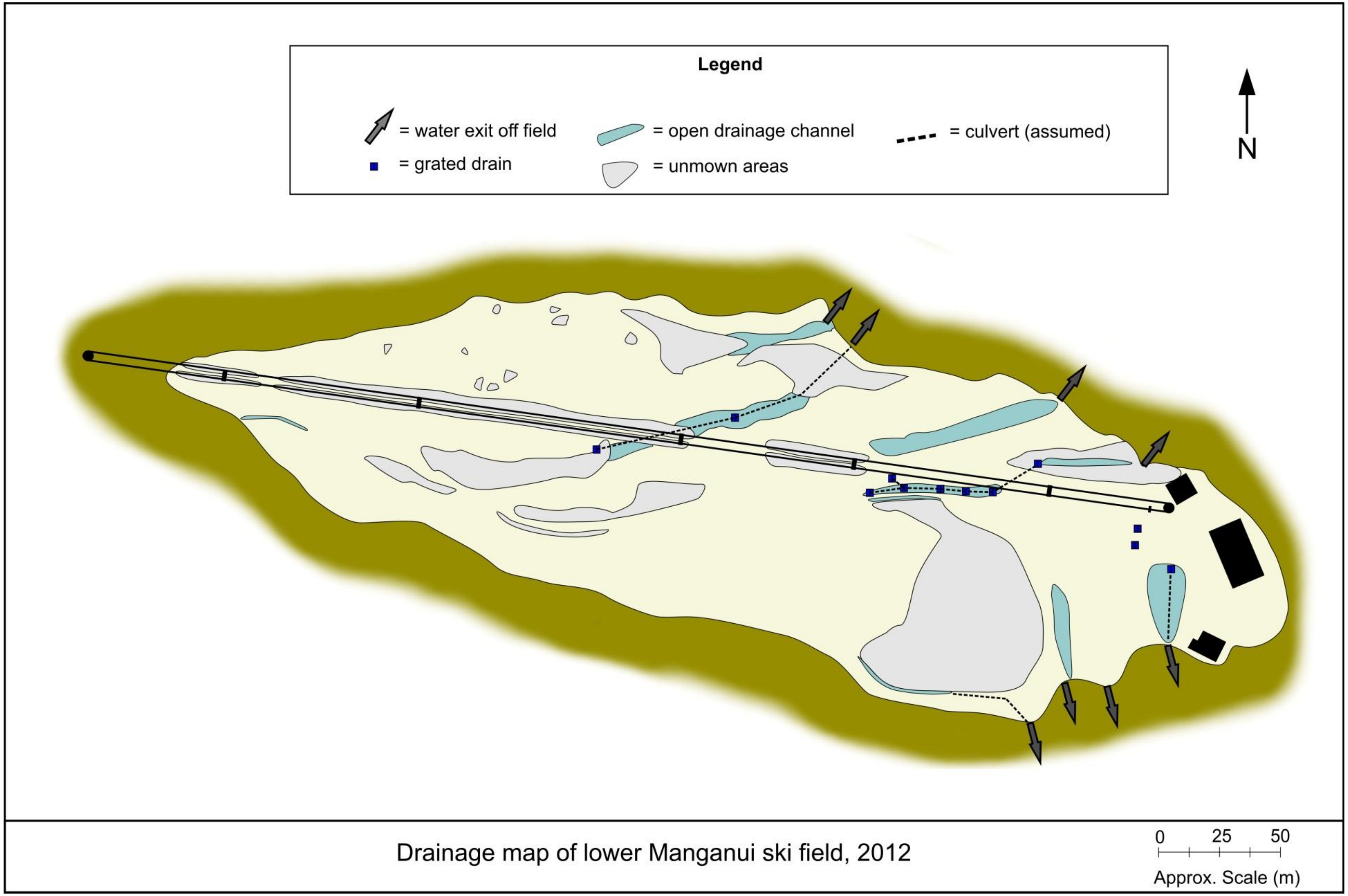

Figure 11: Map showing some of the main drainage features on the lower Manganui ski field.

Figure 12: Photograph showing one of the large culverts being installed on the lower ski field in the 1980s (Stokes & Stokes 2001).

Figure 13: Retaining boards used by Manganui Ski Club to stabilise actively eroding areas on the lower ski field.

Figure 14: Snow mat tiles used under the T-bar tow line on the lower ski field.

Figure 15: Hare damage on the lower ski field.

4.3 Recommendations

- Increased hare control on the ski field would be beneficial.
- There is little that can be done to rectify historic modifications to the ground form and drainage on the ski field, but no further major developments (re-contouring, drains etc.) should be permitted without consultation.

5 Soil compaction

The Manganui Ski Club currently uses several items of machinery capable of causing compaction in the ski field area: a quad bike with trailer, a tractor with mowing attachment, a skidoo and a snow groomer. With the exception of the skidoo, this equipment is probably confined to operating on the lower ski field only. To a lesser extent, people walking across some sensitive areas would also be capable of causing a degree of compaction on the ski field.

5.1 Methods

The lower ski field area where machinery is known to have operated was visually examined for signs of soil compaction. Quantitative measures of compaction, such as those obtained from a soil penetrometer or via calculation of soil bulk density were not practical at the site because of the high proportion of lapilli (pumice fragments) present in the soil. Such fragments are intercepted by the probe of a soil penetrometer giving false readings, and are also known to distort true bulk density values; a visual observation was thus the most feasible option (Dr Megan Balks, Earth and Ocean Sciences Department, University of Waikato, pers. comm. 2012). To supplement the visual observations, reports of compaction issues on other ski fields were also briefly reviewed.

5.2 Results

A visual observation of the lower ski field suggests that poorly drained areas dominated by moss are probably the most susceptible to compaction. The largest area of poorly drained moss exists in the hollow at the base of the ski field around the path of the learners tow (Figure 16). In this area, a peaty soil derived from this moss is soft to the extent that foot prints can be visible for several days after people cross it, particularly during wet conditions. This occurs as the peat is compressed and the interlaced moss is scuffed out of place. It is our understanding that the Department of Conservation has recently instructed that no machinery (including the mower) be used on this fragile portion of the ski field; this is currently being adhered too, with hand-held hedge pruning shears being used as an alternative to trim the tussocks in this area.

Our inspection identified several areas where recent use of the tractor had caused some minor scuffing of the moss and compaction of soil (Figure 17), but this is probably unavoidable as the tractor must cross over a portion of the mossfield to access the rest of the ski field. Elsewhere on the lower ski field the drainage is better and peat is uncommon; these areas are more resilient to compaction and vegetation scuffing is not such an issue (Figure 17). Being the largest of the machines at the ski field, the snow groomer probably has the greatest potential to cause damage to vegetation and soil. Damage could occur via its caterpillar tracks, and through the blade being set to an inadequate height above the vegetation. It is our understanding that the snow groomer has been out of operation during the last three ski seasons, but in the past it has been known to cause some minor damage to vegetation when it has been used on an insufficient snow base. We did not detect any evidence of historic damage caused by the snow groomer, and it is assumed that staff are instructed to operate the groomer only when the snow base is sufficient to protect the vegetation below. The skidoo would also have considerable potential to scuff ground with its tracks, and thus it is important it is not used over bare areas (without sufficient snow cover) where damage could occur. It is positive to see that the other machinery has been suitably equipped with large tires to distribute weight and reduce damage to soil and vegetation.

Review of other studies of compaction

Both national and international studies have investigated the impacts of vehicles on the snowpack and alpine soils (e.g., National: Bamford & Lenart 1978, Fahey & Wardle 1998, Wardle & Fahey 1999, International: Felix et al. 1992, Pintar et al. 2009, Kangas et al. 2009). Research shows that although over-snow vehicles, such as snow groomers, are designed to have large track surface area to distributed weight ratios, they still have substantial and lasting impacts on both ski field soil and vegetation (Keane et al. 1980). These effects may be direct, where vehicles have made contact with the vegetation and/or soil, or indirect through snow compaction (Wardle & Fahey 1999).

Snow compaction has potential to influence the thermal and hydrological regimes, ultimately impacting the ski field soil, vegetation and water courses (Fahey & Wardle 1998). The use of over-snow vehicles is known to initiate and/or accelerate the metamorphic processes of snow densification and hardening; mechanical disturbance breaks off the small points where new crystals form, destroys weak inter-grain bonds and brings the large grains into much closer contact (Kattlemann 1985). This reduces porosity, permeability and water holding capacity of the snow pack, while heat flow rates and length of snow retention are generally increased. Combined, these contribute to longer and deeper frost penetration into the soil, causing negative effects on the underlying vegetation and soil. Keddy et al. (1979) have shown that roughly 75% of total snow compaction results from the initial pass of an over-snow vehicle.

According to Wardle & Fahey (1999), the possible effects of snow compaction are:

1. Increased snow density
2. Decreased snow permeability
3. Increased heat flow out of the soil and snow, leading to colder snow and soil temperatures
4. Decreased snow pore spaces reducing water holding properties, thus higher run-off rates during spring snow melt.
5. All effects are greatest in the first pass of the vehicle

A thick snow pack acts as a buffer, protecting the underlying soil/vegetation from the weight and shearing effect of over-snow vehicle tracks, wheels and blades (Wardle & Fahey 1998). However, as snowpack depth decreases (at the beginning and end of the ski season and on exposed crests and hummocks), the magnitude of disturbance to the soil and vegetation below increases. Where the snowpack layer is thin or absent soil is compacted and vegetation may be removed. Soil compaction can reduce the size of the macropores, thereby inhibiting root penetration, aeration and infiltration capacity, which in turn reduces plant growth and can lead to accelerated surface erosion (Wardle & Fahey 1999). Erosion is increased and intensified by frequent freeze thaw cycles, high rainfalls and strong winds common in the alpine environment (Felix et al. 1992). This coupled with the short growing season makes regeneration of these damaged areas slow (decades to centuries), and wetter soils are considerably more susceptible to such soil and vegetation disturbance than drier soils.

According to Wardle & Fahey (1999), the possible effects of soil compaction are:

1. Decreased infiltration rates resulting in more surface runoff
2. Increased bare ground and soil erosion
3. Increased bulk densities
4. Increased soil temperature
5. Accelerated and deeper soil thaw
6. Lower moisture percentages
7. Reduction in soil fauna

5.3 Recommendations

- The current practise of hand mowing the sensitive mossfield at the base of the lower ski field should continue because compaction is more prevalent in waterlogged soils.
- Mowing of the wider ski field should continue to be conducted in summer, when the soil is at its driest and thus least susceptible to compaction.
- Because prior research has found the first pass of over-snow vehicles causes the most compaction, localisation of over-snow traffic should reduce its impact on the soil and vegetation. Encouraging the use of tracks and trails is more appropriate than attempting to diffuse use.
- During the snow season, over-snow vehicles should not be allowed in areas of, or at times of, shallow snow pack (e.g. exposed ridges; low snow years). Wardle & Fahey (1999) have suggested a snow pack depth of 20 cm is sufficient to protect underlying vegetation from damage, however a greater snow depth of 50 cm may be required to avoid impacting the soil below (Felix & Raynolds 1989).

Figure 16: Mossfield (light green vegetation) at the base of lower ski field; a poorly drained area susceptible to compaction by people and machinery.

Figure 17: Example of the extent of compaction and scuffing as a result of tractor use on the mossfield (left) and elsewhere on the ski field (right).

6 Contamination of water courses

6.1 Methods

To investigate potential contamination (nutrient enrichment) of water courses in the ski field area, water samples were collected from seven locations (Table 4, Figure 18) and analysed for nitrogen (N) and phosphorus (P) fractions. Five of the sampling locations were known to directly drain the ski field area (Sites 1-5), while the remaining two sites (Sites 6,7) were collected in close proximity to, but outside of the ski field catchment (and thus act as a form of reference point). On the 8/5/2012 (one day prior to water sampling) the nearby North Egmont visitor centre rain gauge recorded a total rainfall of 26.5 mm in a 24 hour period. Sampling was conducted on the 9/5/2012, at which time 50 mm of rain was recoded in the 24 hour period. Given the porous nature of volcanic sediments at the ski field, the streams in the area tend to flow only during periods of rainfall and then dry up a short time after. It was therefore only possible to collect stream water samples during wet weather. At each site, two 15 ml water samples were collected, one unfiltered, and one filtered. Filtering was undertaken in the field immediately after sample collection using acid-washed syringes and 0.45 µm Advantec GC filters. Samples were stored on ice in the dark until return to the laboratory where they were frozen until analysis. Samples were analysed by the University of Waikato (limnology lab) on an Aquakem 200 discrete analyser. Simultaneous persulphate digestion (Ebina et al. 1983) was used for total nitrogen and total phosphorus analyses based on EPA Methods 353.1 and 365.3 respectively. Ammonia was analysed for using Methods for the Examination of Waters and Associated Materials Ammonia in Waters 1981 ISBN 0117516139 and for Phosphate using Methods for the Examination of Water and Associated Materials Phosphorus in Waters, Sewage and Effluents 1981. ISBN 011751582.5 and EPA Method 365.1.

Table 4: Location of water sample collection points around lower ski field.

Site number	GPS (NZTM)	
	Easting	Northing
1	1694011	5649026
2	1694051	5649026
3	1693902	5649054
4	1694037	5648931
5	1693982	5648860
6	1693822	5648763
7	1693926	5648740

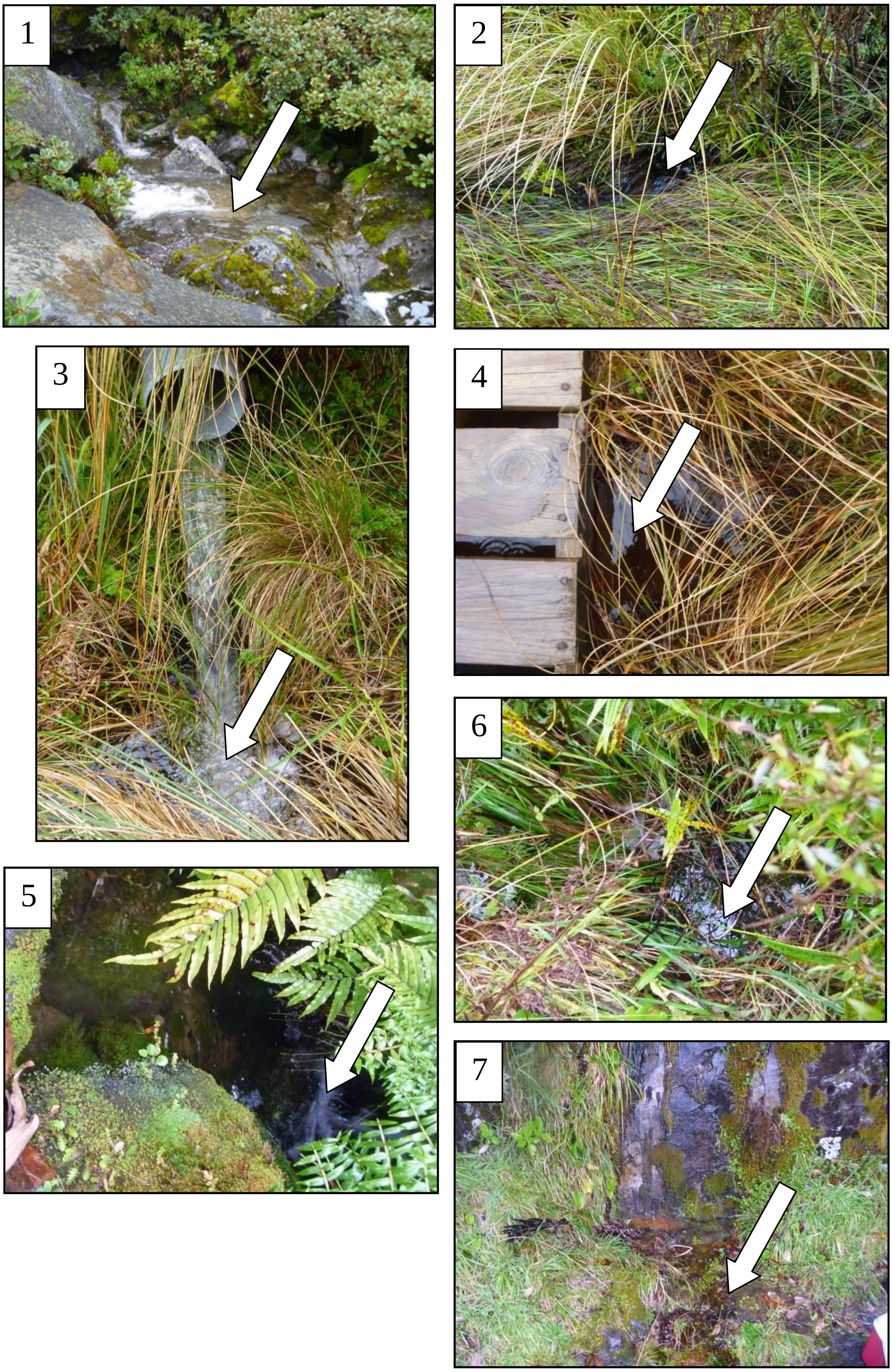

Figure 18: Photographs of locations around lower ski field where water samples were collected.

6.2 Results

Results of the water nutrient analysis from the ski field area are presented in Table 5 and Figure 19. No previous data on water nutrient levels were available from the area for comparison. Both nitrogen and phosphorus levels were found to be extremely low, and no major differences between the sites were apparent. It is therefore unlikely that stream nutrient levels in the area have increased as a result of ski field management practices such as mowing or historic fertiliser addition. If required, these nutrient results could serve as a baseline for future studies.

Table 5: Results of nutrient analysis of water from the skifield area. Results are expressed in units of mg/l or parts per million (ppm). Nutrients: NH_4 ammonium; NO_2 nitrogen dioxide; NOx nitric oxide and nitrogen dioxide; NO_3 nitrate; PO4 phosphate; TN total nitrogen; TP total phosphorus.

Site #	NH_4	NO_2	NOx	NO_3	PO4	TN	TP
1	<0.001	<0.001	0.0362	0.0362	0.0013	**0.05715**	**0.0599**
2	0.0011	<0.001	0.04	0.04	0.0004	**0.0711**	**0.0053**
3	0.0015	<0.001	0.044	0.044	0.0007	**0.06675**	**0.0518**
4	0.0023	<0.001	0.021	0.021	0.0004	**0.1061**	**0.0046**
5	<0.001	<0.001	0.0586	0.0586	0.0058	**0.0804**	**0.0455**
6	0.0049	<0.001	0.0719	0.0719	0.0054	**0.1176**	**0.0512**
7	0.004	<0.001	0.0894	0.0894	0.0062	**0.11385**	**0.0590**

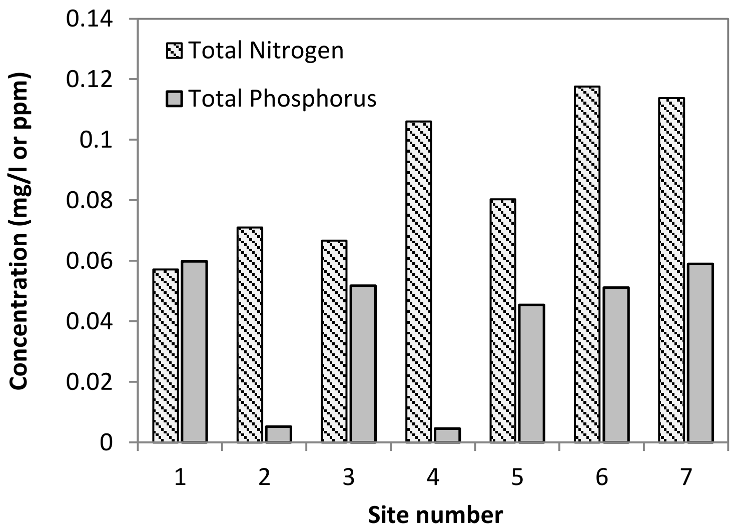

Figure 19: Results of nutrient analysis of water from the skifield area (total nitrogen and total phosphorus).

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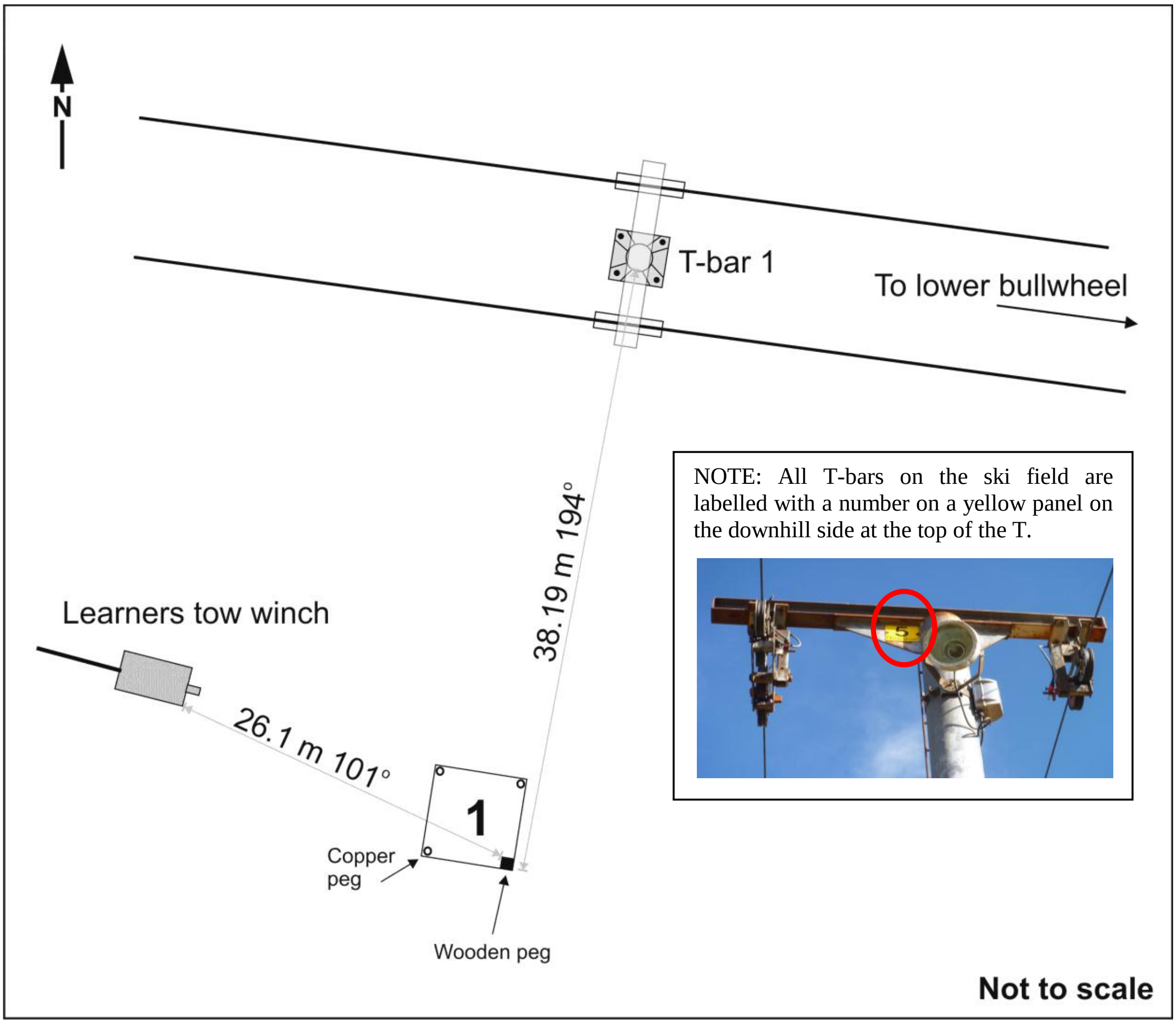
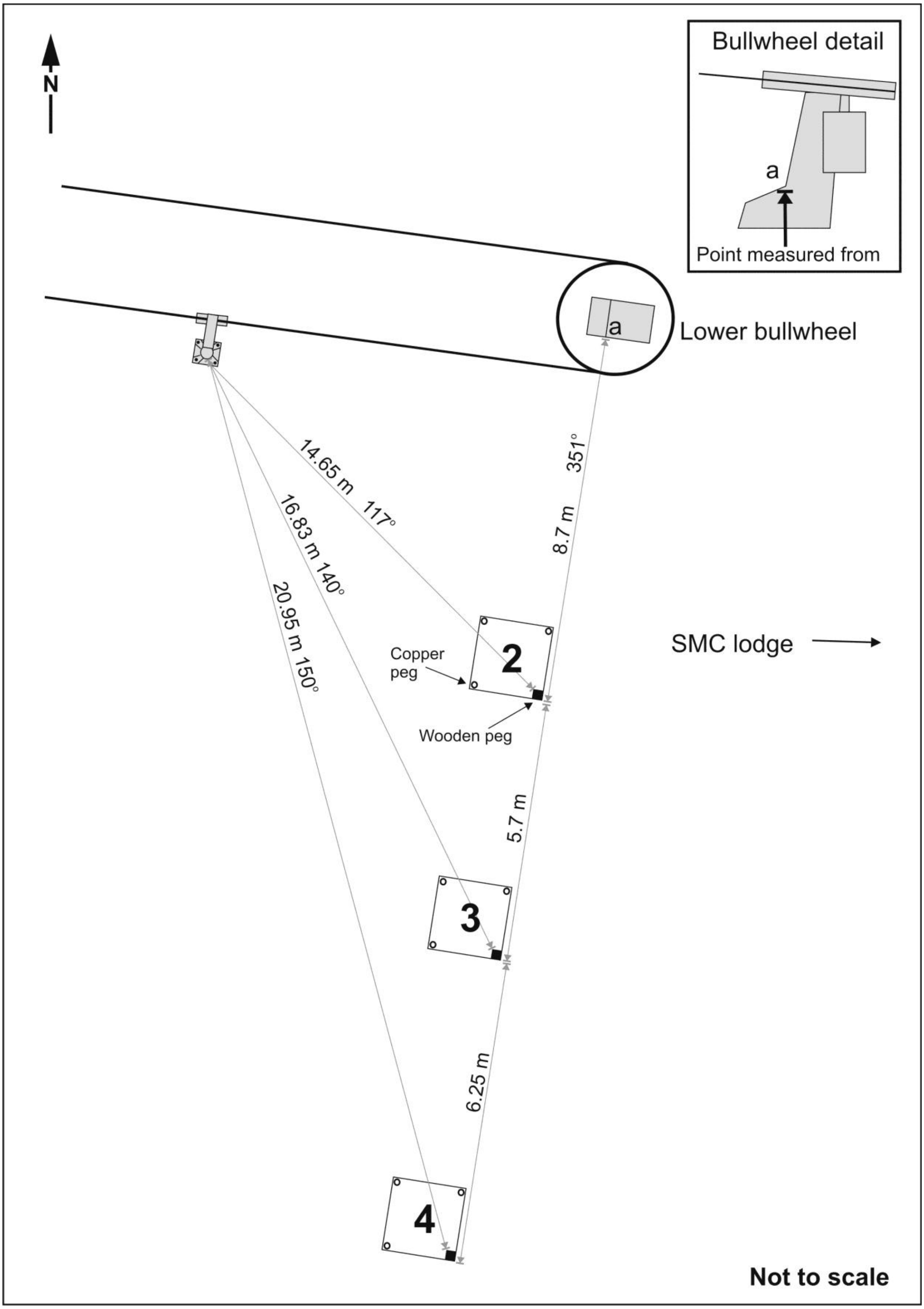
8 Appendices

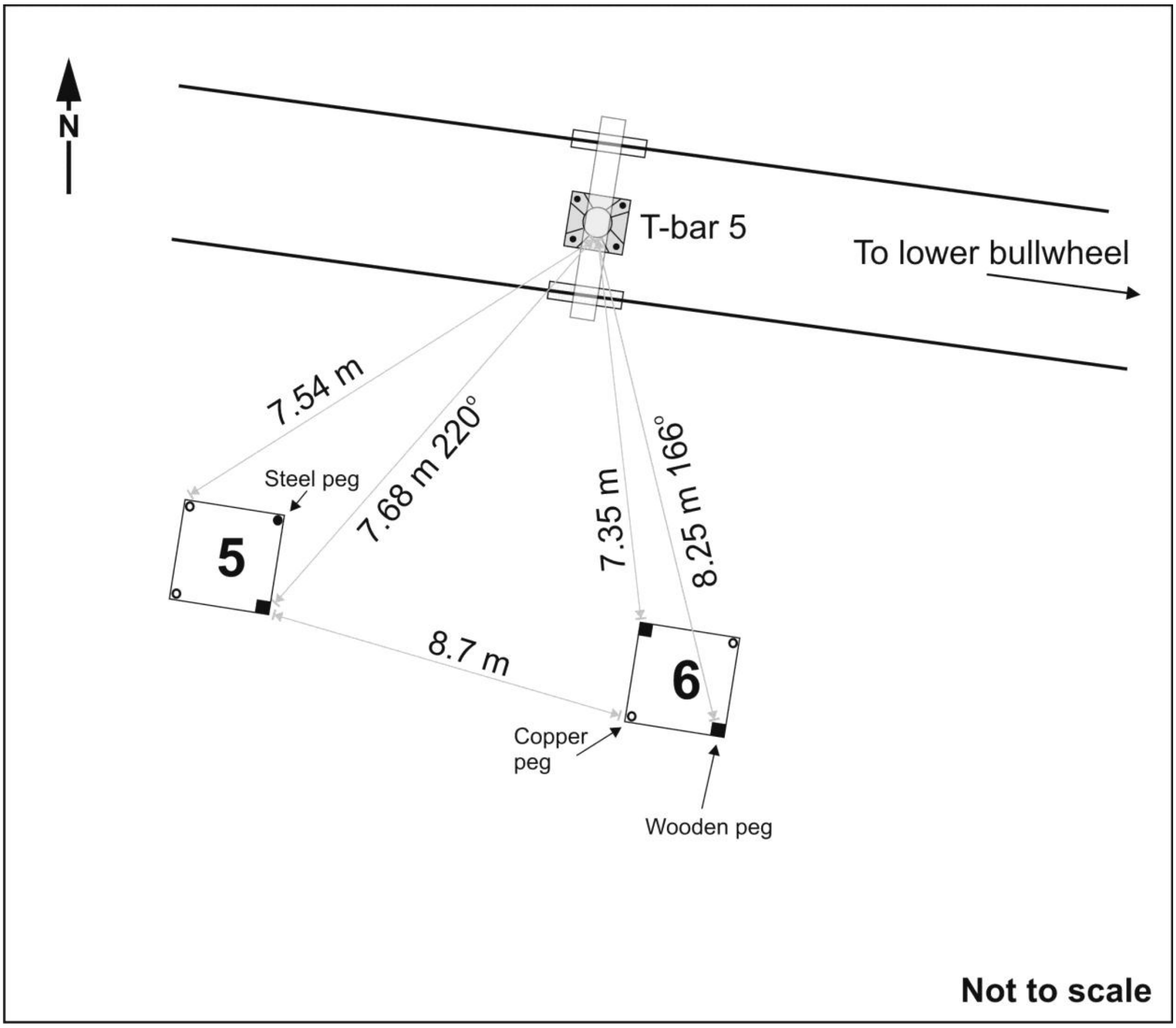
Appendix 1: Location of quadrat 1



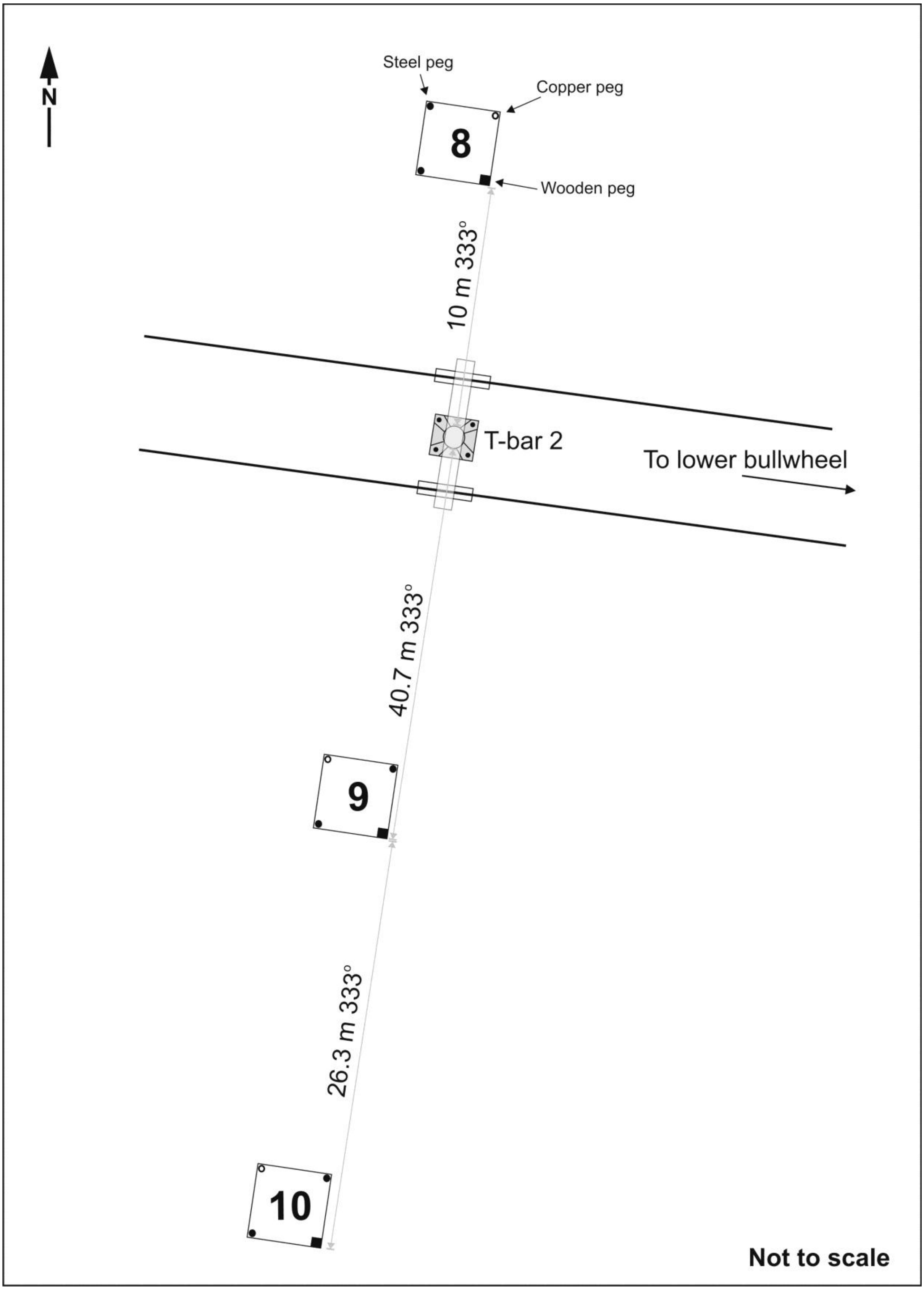
Appendix 2: Location of quadrats 2, 3 and 4



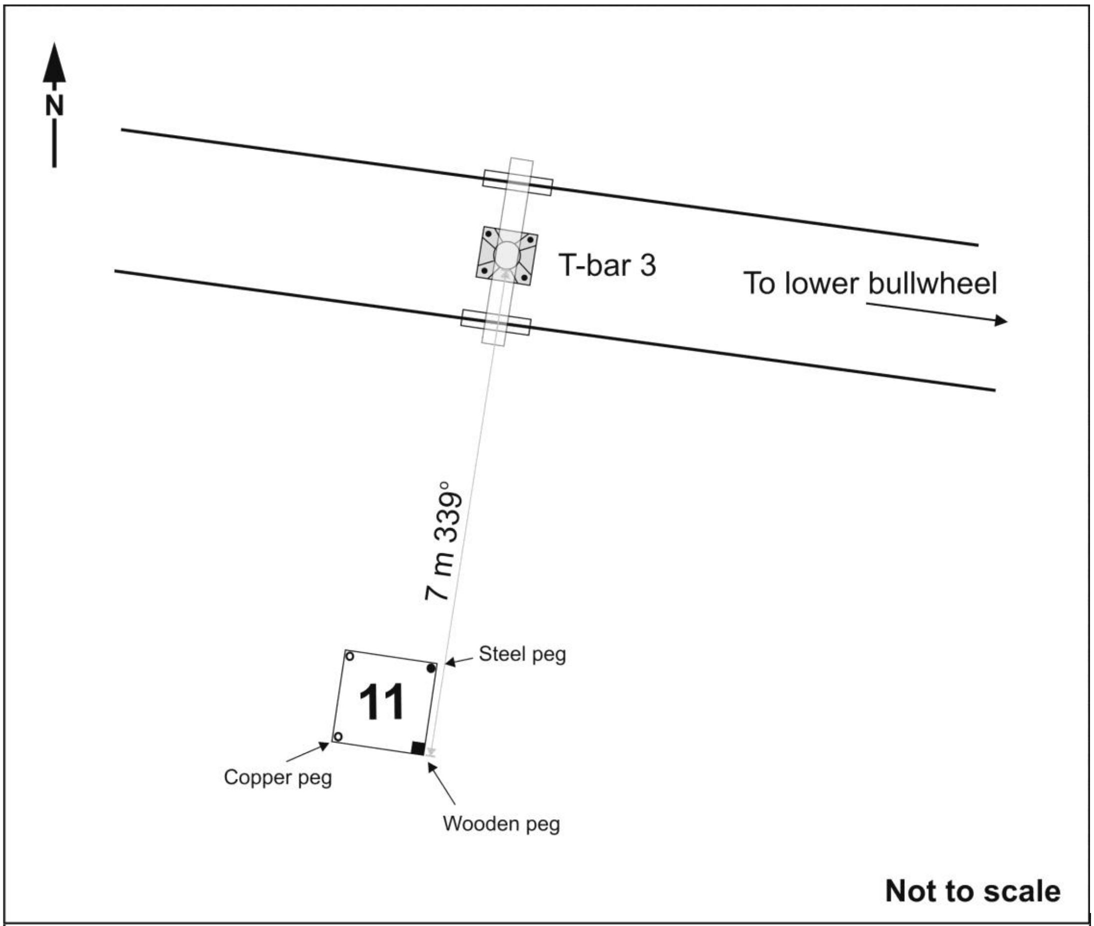
Appendix 3: Location of quadrats 5 and 6

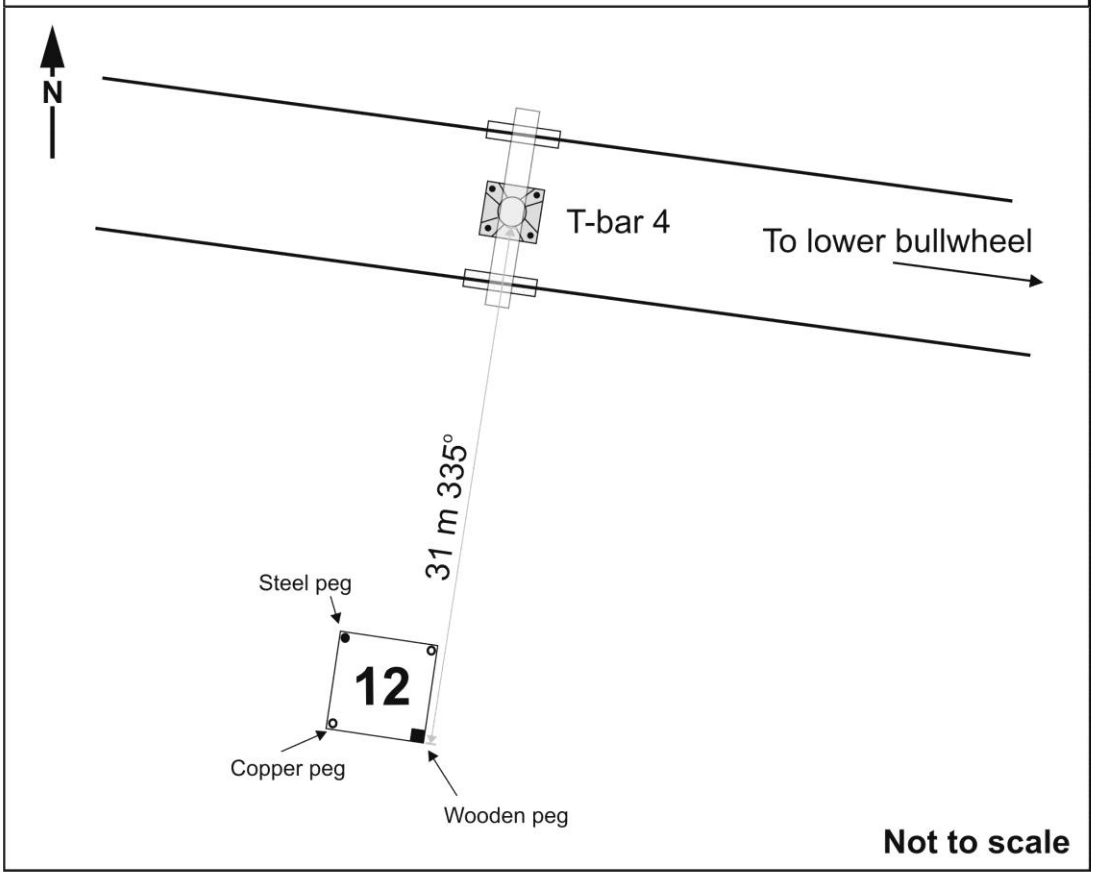


Appendix 4: Location of quadrats 8, 9 and 10



Appendix 5: Location of quadrats 11 and 12





Appendix 6: Descriptions of mapped vegetation types

Herbfield

Mown moss-herbfield (M-H)

This vegetation type occupied the boggy region at the foot of the ski field near the Stratford Mountain Club lodge. Permanent quadrats 2, 3 and 4 were located within this vegetation zone. The vegetation here formed a low moss-herbfield, not exceeding 5 cm in height. Vegetation cover was dominated by two moss species *Dicranoloma robustum* and *Hypnum cupressiforme* and the comb sedge *Oreobolus pectinatus*. Native species including *Juncus antarcticus*, *Plantago novae-zelandiae*, *Celmisia glandulosa* var. *latifolia*, *Muehlenbeckia axillaris* and *Coprosma perpusilla* subsp. *perpusilla* commonly grew amongst the moss and sedge. Trimmed *Chionochloa rubra* individuals were also scattered throughout this zone and overtopped the shorter turf forming species. Nearer to the bullwheel and lodge, where past disturbances have probably been greater, the proportion of exotic species increased; amongst the most common were *Agrostis capillaris, Carex ovalis, Hypochaeris radicata* and *Lotus pedunculatus.*

Mown tussock/herbfield (T/H)

This vegetation type was widespread on the lower ski field, particularly on moderate to well drained slopes. Although this vegetation type has been induced by the practices associated with the ski field management (mowing etc.), the species were predominantly native. Permanent quadrats 8, 9, 12 and transects 2, 6, 9 were located within areas dominated by this vegetation type. Typically, scattered mown *Chionochloa rubra* individuals (<25 cm tall) were emergent over the shorter herbfield turf (<6 cm tall) which was dominated by *Oreobolus pectinatus* (ranging from 25.7-45.6% cover) and *Celmisia glandulosa* var. *latifolia* (ranging from 11.4-40.2% cover). Other common species included *Poa colensoi*, *Celmisia gracilenta* var., *Coprosma perpusilla* subsp. *perpusilla, Forstera bidwillii, Anaphalioides alpina, Muehlenbeckia axillaris* and *Pentachondra pumila*.

Unmown tussock (T1)

This vegetation type existed in thin discontinuous “no-mow” bands, with the majority being adjacent to the T-bar line. Transect 3 is located within one of these bands (near T-bar 4) and represents the vegetation in these zones. *Chionochloa rubra* was the dominant species (82% canopy cover) and formed a dense canopy up to 1 m tall. Other species associated with this zone that also contributed to the canopy foliage were *Hebe odora* (10% canopy cover) and *Ozothamnus vauvilliersii* (2% canopy cover). Beneath this canopy, the ground layer was more diverse, hosting many of the common herbfield species; the most abundant were *Muehlenbeckia axillaris*, *Celmisia glandulosa* var. *latifolia* and *Anisotome aromatica*. In contrast to the larger tussock dominated zones on the ski field, exotic species such as *Agrostis capillaris*, *Poa annua* and *Carex ovalis* were also commonly present.

Unmown tussock (T2)

This vegetation type occupied the north-western region of a hummock on the lower ski field, adjacent to shrub vegetation types “S1” and “S2”. Smaller zones dominated by this vegetation type were also present in various “no-mow” localities of the lower ski field; these areas are represented by transect 8. *Chionochloa rubra* was the dominant species and formed a discontinuous canopy up to 0.5 m tall. Other species also reaching 0.5 m included *Hebe stricta* var. *egmontiana*, *Ozothamnus vauvilliersii* and *Dracophyllum filifolium*. Beneath this, species such as *Celmisia glandulosa* var. *latifolia*, *Coprosma perpusilla* subsp. *perpusilla*, *Anaphalioides alpina* and *Forstera bidwillii* var. *densifolia* were common.

Unmown tussock (T3)

This vegetation type was adjacent to type “T2”, occupying a north east facing bank and differing from “T2” in both vegetation composition and structure. Data from transect 5 is representative of this vegetation zone. *Chionochloa rubra* was the dominant canopy species (50% total cover), contributing to a canopy up to 1.0 m tall. Other canopy species in a descending order of dominance were *Blechnum montanum* (16% canopy cover), *Coriaria pteridoides* (10% canopy cover), *Dracophyllum filifolium* (6% canopy cover) *Ozothamnus vauvilliersii* (6% canopy cover), *Hebe odora* (4% canopy cover) and *Gaultheria antipoda*. These species were never taller than 0.7 metres. Beneath the canopy layer, turf forming species formed a tight ground layer, including *Celmisia glandulosa* var. *latifolia*, *Celmisia gracilenta* var., *Coriaria plumosa*, *Muehlenbeckia axillaris*, *Anisotome aromatica*, *Ourisia macrophylla*, *Coprosma perpusilla* subsp. *perpusilla*, *Anaphalioides alpina* and *Oreobolus pectinatus*. A number of weedy species were also present, however at low densities; these were *Agrostis capillaris*, *Poa annua* and *Hypochaeris radicata*.

Shrubland (S1)

This vegetation type was present on an east facing slope, located on the lower ski field. Vegetation consisted of shrub species 1.5-2.0 m tall, overtopping a ground layer with species comparable to that found in “T3”. *Brachyglottis elaeagnifolia*, *Coprosma pseudocuneata*, *Hebe stricta* var. *egmontiana* and *Ozothamnus vauvilliersii* formed the majority of the canopy. Ferns species *Blechnum montanum* and *Polystichum vestitum* were also present, however generally did not exceed 0.6 meters in height.

Shrubland (S2)

This vegetation type was present on a south facing slope on the lower ski field and shared many similarities to “S1”. Vegetation consisted of shrub species 0.5-1.0 metre tall, overtopping a ground layer with species comparable to that found in “T3”. Canopy species in descending order of dominance were *Dracophyllum filifolium*, *Brachyglottis elaeagnifolia*, and *Chionochloa rubra*.

Shrubland (S3)

The slopes surrounding the lower ski field were predominantly vegetated in shrubs up to 1.5 meters tall. The most common canopy forming species here were *Brachyglottis elaeagnifolia*, *Coprosma pseudocuneata*, *Dracophyllum filifolium, Raukaua simplex*, *Olearia arborescens*, *Hebe stricta* var. *egmontiana*, *Coriaria pteridoides* and *Myrsine divaricata*. These species overtopped and formed mosaics with *Astelia nervosa*, *Chionochloa rubra*, *Blechnum montanum* and *Ozothamnus vauvilliersii*. The ground layer was predominantly comprised of litter, however scattered individuals of *Ourisia macrophylla*, *Celmisia glandulosa* var. *latifolia*, *Celmisia gracilenta* var., *Coriaria plumosa* and *Muehlenbeckia axillaris* were also common. The shrubland bordering the ski field, just north of the Mountain Club Lodge has been monitored annually since 2007 by the University of Waikato and since this time species composition and structure has remained in a steady state.

Exotics (E1)

This vegetation type generally occupied shallow north east draining depressions and was dominated by exotic grass species (c. 90% cover) not exceeding 20 cm in height. Data from quadrat 11 and transects 7 and 4 typify the vegetation in this area. Exotic species included *Carex ovalis* (0-50.9% cover), *Poa annua* (20.9-47.6 % cover), *Agrostis capillaris* (0-12.7% cover), and *Lotus pedunculatus* (0-8.1% cover); *Holcus lanatus*, *Cerastium fontanum*, *Lolium perenne* and *Hypochaeris radicata* were also common. Native herbs and mosses were also present; however no native species contributed more than 2% of total cover. Native species included *Celmisia glandulosa* var. *latifolia, Poa colensoi*, *Epilobium nerteroides, Celmisia gracilenta* var., *Anaphalioides alpina* and *Oreobolus pectinatus*.

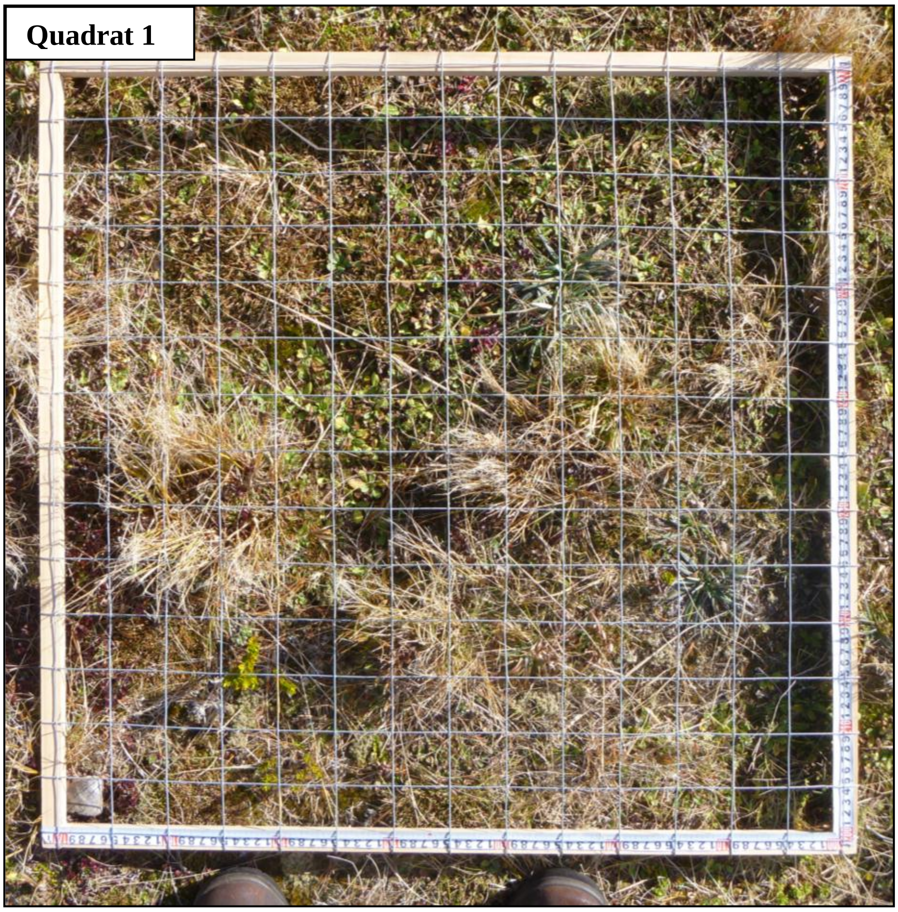
Exotics (E2)

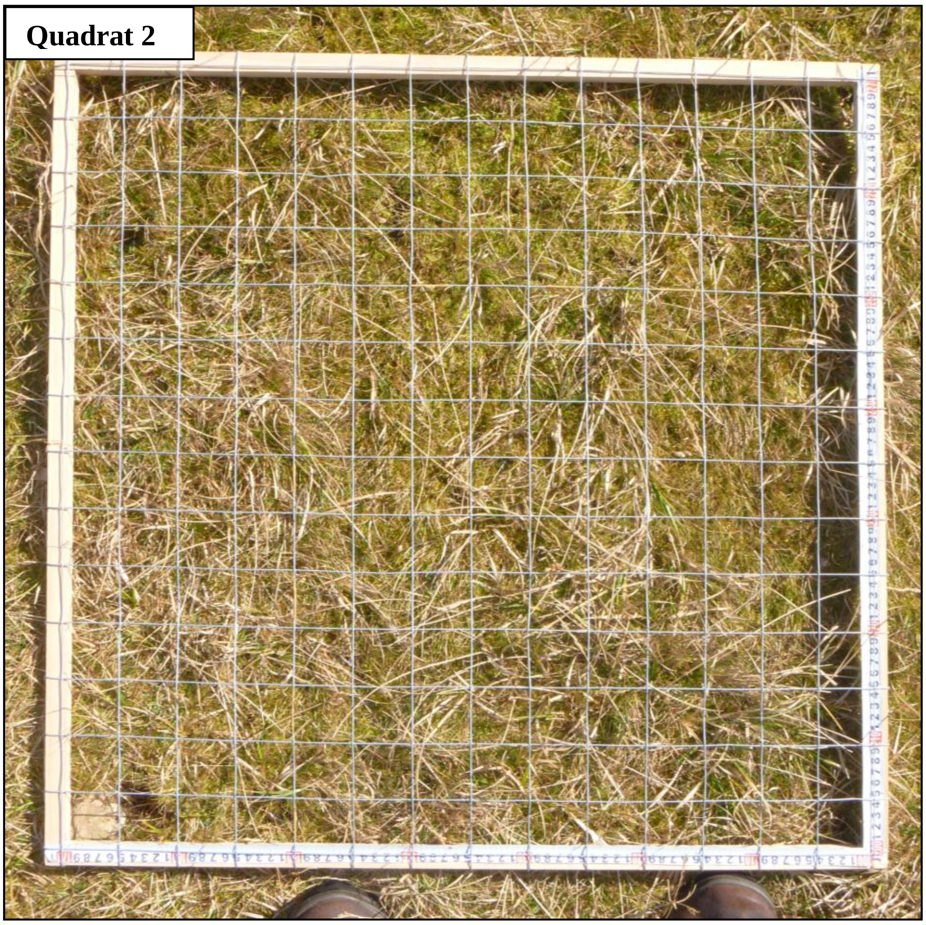
The vegetation in this area was similar to "E1", and was generally restricted to areas where ground has been historically disturbed. Transect 1 and 10 represent the vegetation within these areas. In the drier regions the dominant species included *Poa annua* and *Lotus pedunculatus*, together contributing up to c. 70% of cover. However, in the damper regions *Carex ovalis* was much more prevalent. Other exotic species included *Holcus lanatus*, *Cerastium fontanum*, *Lolium perenne* and *Hypochaeris radicata*. Native species were also scattered amongst the weeds, with the most common being, *Chionochloa rubra* and *Poa colensoi*.

Exotics (E3)

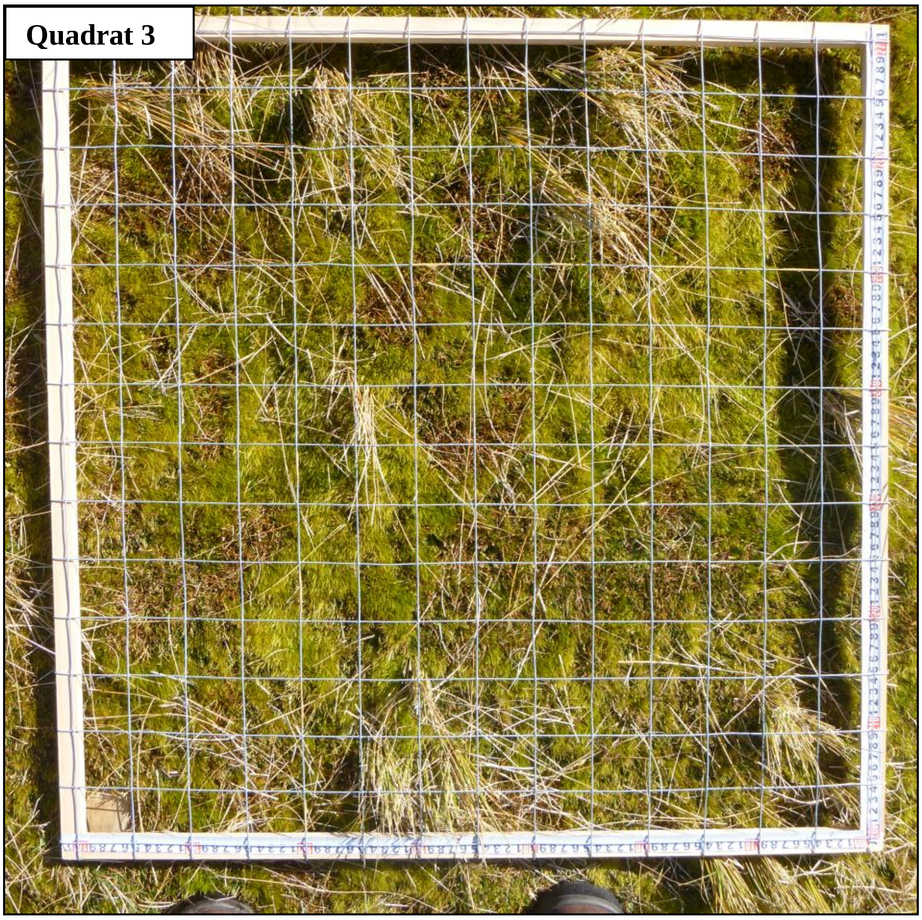
This vegetation type was present on the bank in front of the Stratford Mountain Club lodge; an area subject to a high amount of foot traffic and with a history of modification. No permanent quadrats or transects were located within this zone, however the vegetation was qualitatively described. A mosaic of exotic grasses and herbs dominated, including *Carex ovalis*, *Holcus lanatus*, *Lolium perenne*, *Agrostis capillaris* and *Hypochaeris radicata*. The exotic rush *Juncus effusus* was also present, particularly in damper regions. Native herbfield species such as *Viola cunninghamii*, *Muehlenbeckia* *axillaris*, *Oreobolus pectinatus*, *Gunnera monoica*, *Plantago novae-zelandiae* and *Celmisia glandulosa* were common amongst and beneath the exotic species. Scattered *Chionochloa rubra* became more common with increased distance from the lodge.

Appendix 7: Photographs of permanent quadrats


Quadrat 1


Quadrat 2

Quadrat 3



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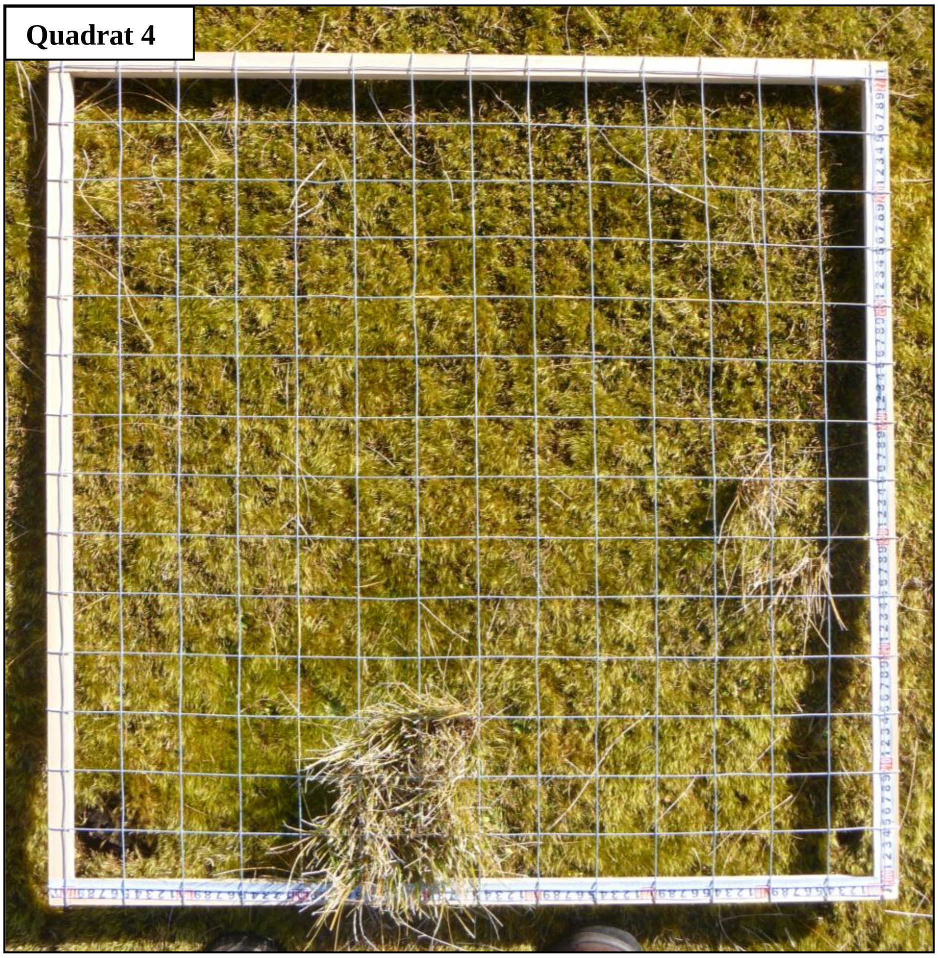

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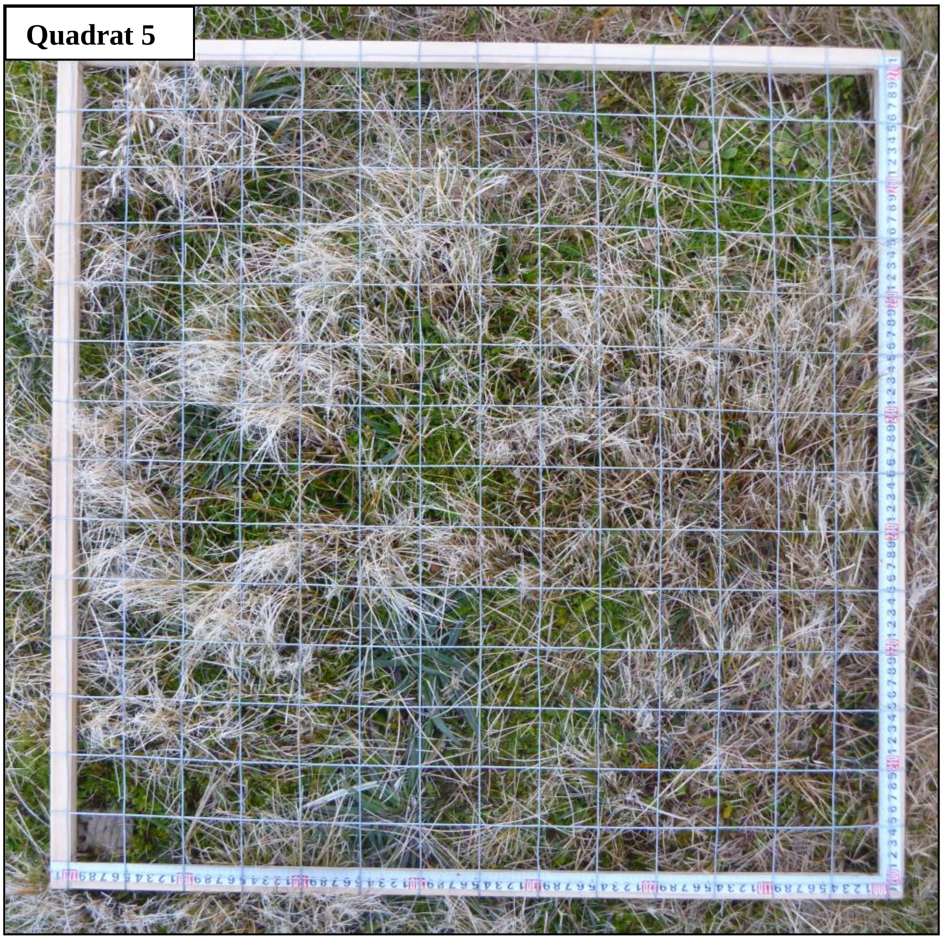

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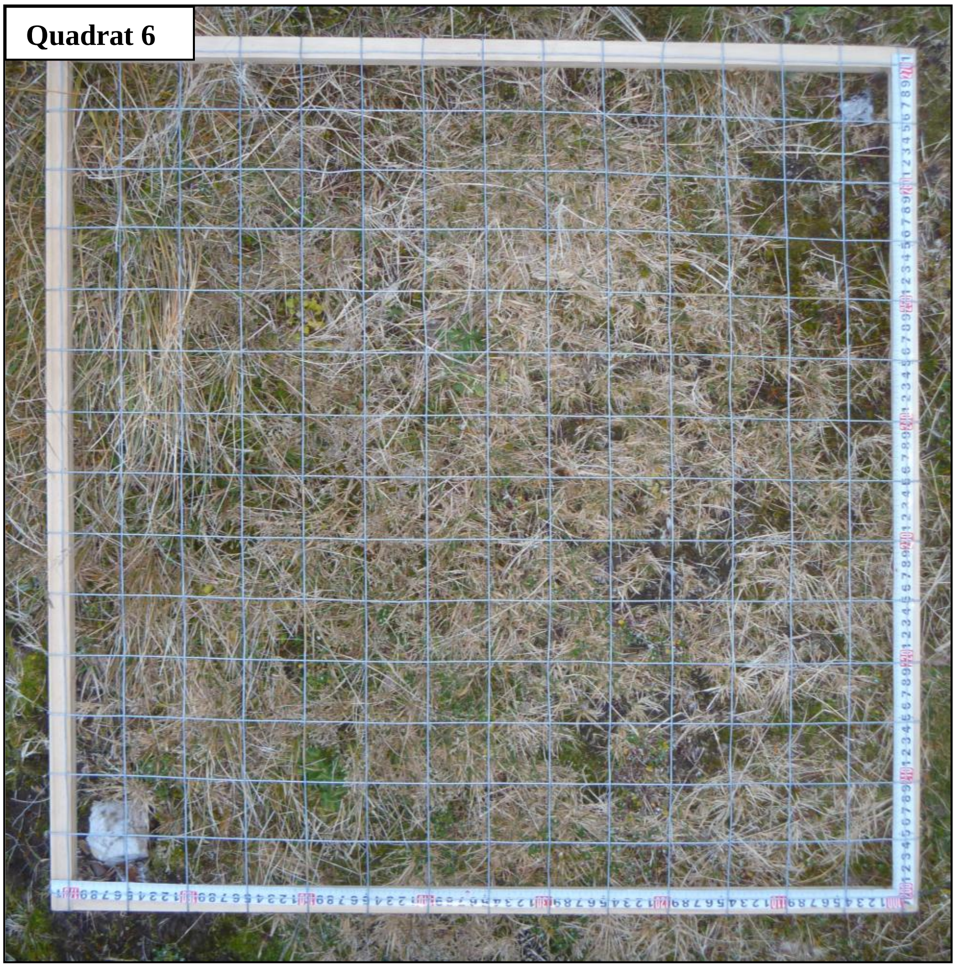
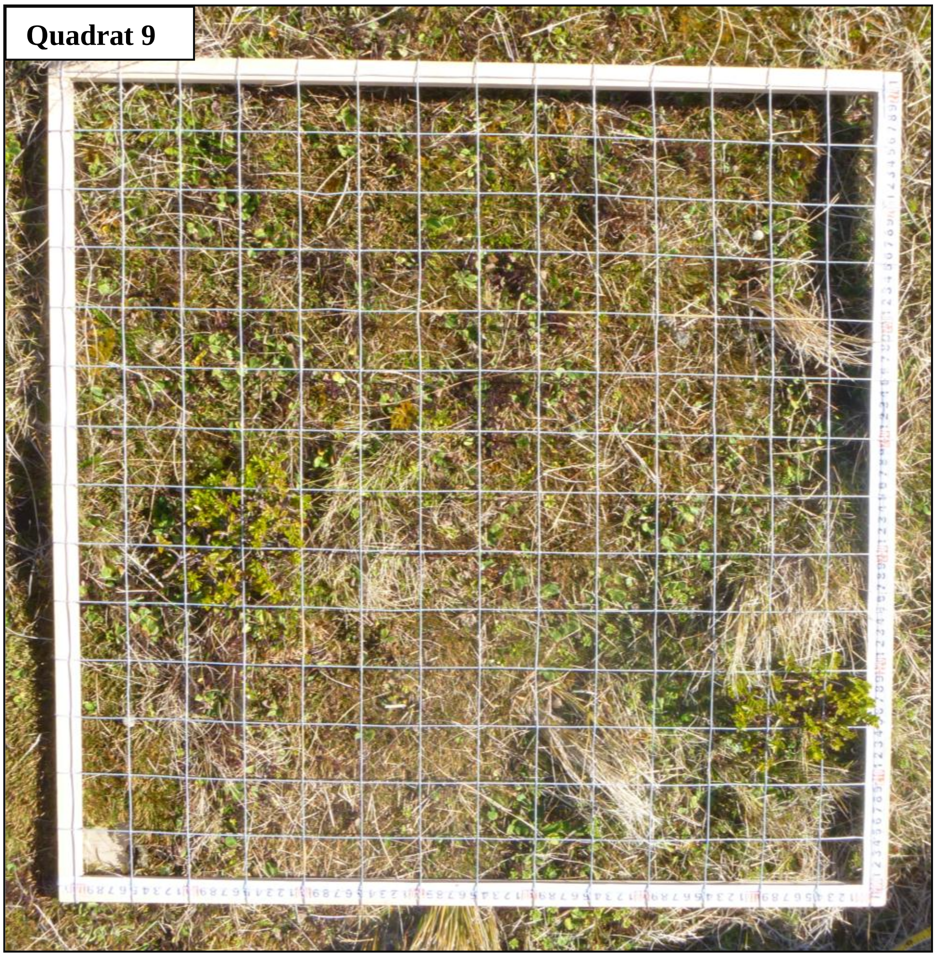
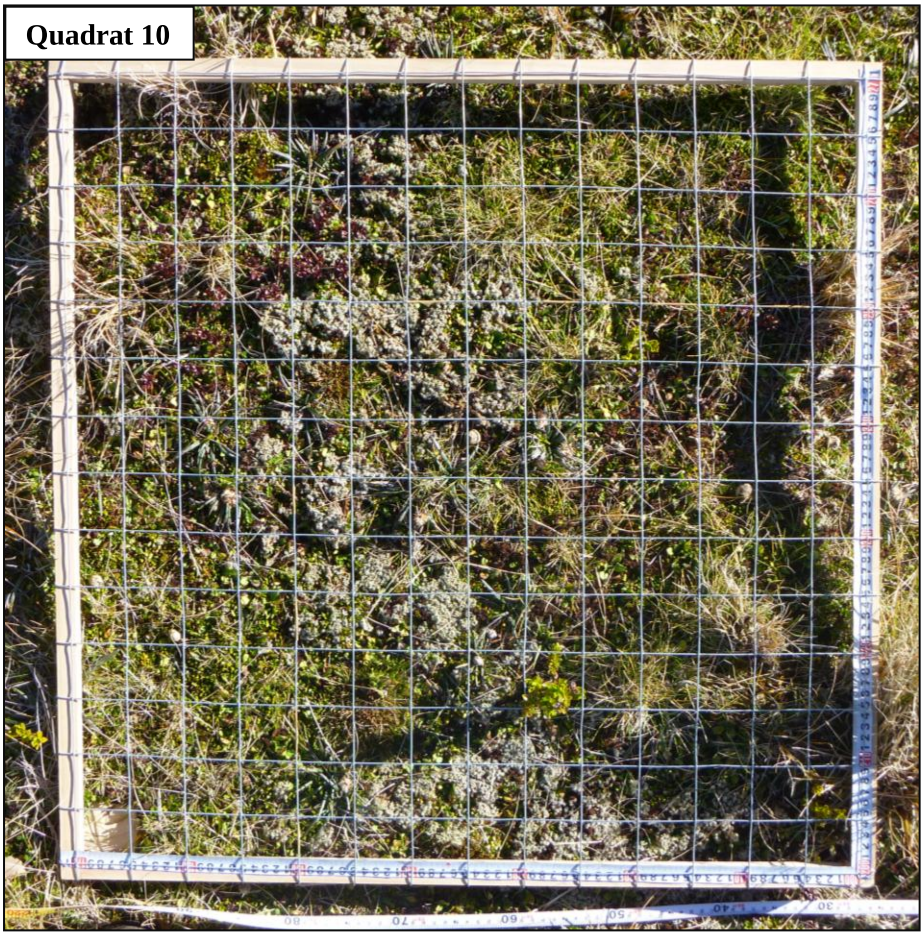


Quadrat 8

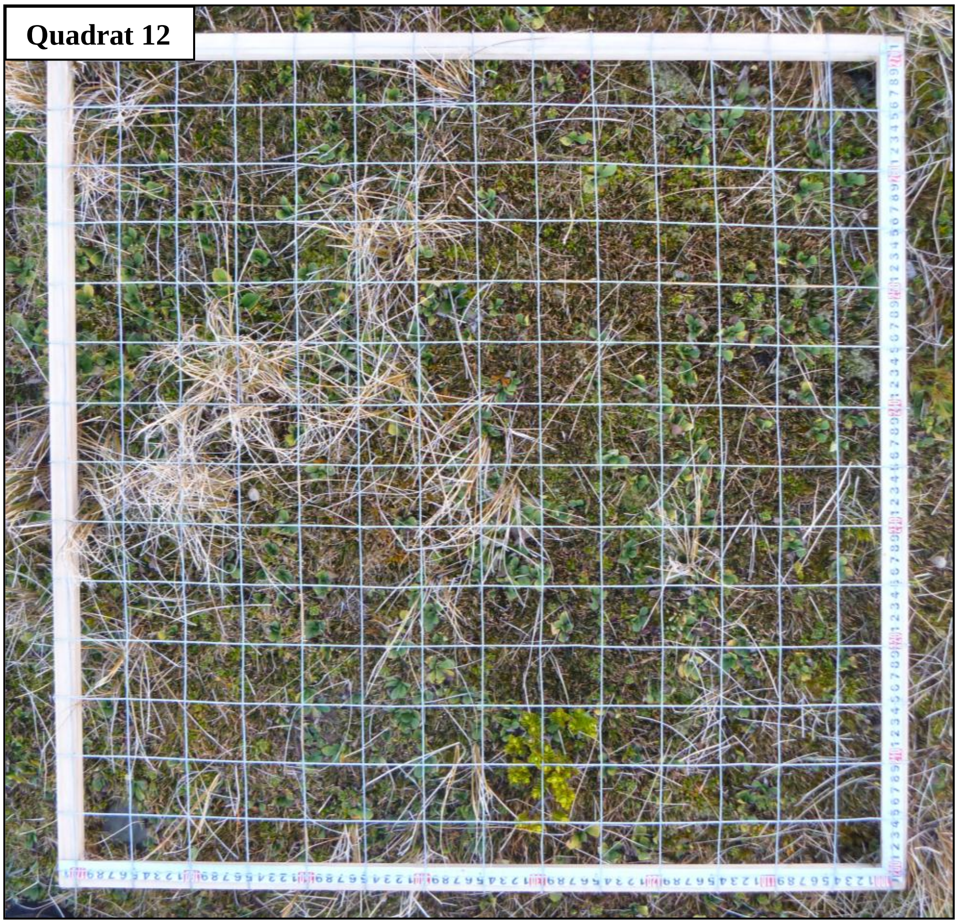
Quadrat 9



Quadrat 10



Quadrat 11



Quadrat 12