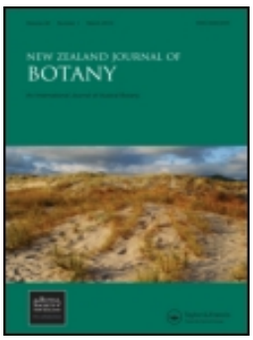

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The conservation status of New Zealand's indigenous grasslands

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Abstract The conservation status of New Zealand's indigenous grasslands was assessed against an 1840 baseline, immediately prior to European settlement, when they were of maximum extent. Five major types were recognised, four of them tussock grasslands. The assumed baseline extent of areas with at least some grassland dominance was mapped on the basis of the best available information. Their current extent was derived from the "tussock" category in Land Cover Data Base 1 map (typed as for the baseline map) and the areas formally protected (as at September 2002) from Department of Conservation records. Ecological region boundaries were added and the map information scanned and compiled using ArcGIS. North Island areas were also assessed as one unit while South Island was divided into three geographic regions based on general land use patterns: western wet non-rangeland, rain-shadow rangeland, and eastern lower altitude non-rangeland regions.

Of the total baseline extent of indigenous grasslands (82 432 km^2 or c. 31% of the land area), about 13% was low-alpine snow tussock grassland, 18% montane to subalpine snow tussock grassland, 23% montane to low-alpine tall red/copper tussock grassland, 44% montane to subalpine short-tussock grassland, and c. 2% lowland sward grassland. Most grassland (57%) was in the South Island rangeland region which also had the greatest extent of all four major tussock grassland types. Remaining areas of each grassland type vary largely with altitude and climate, the drier lower-elevation grasslands showing the greatest reduction. Protection of the remaining indigenous grasslands, with various degrees of modification and/or degradation, is greatest in the South Island wet western region (89% of the 98% which remained as of September 2002), with less in the North Island (40% of the remaining 17%), and eastern South Island non-rangeland region (11% of the remaining 3%). Grassland protection in the rangelands (12% of the remaining 76%) is currently increasing through tenure review of the Crown-owned pastoral leases in this region.

Indigenous temperate grasslands, claimed to be the world's most beleaguered biome (currently 4.59% protected), attain about 12.3% protection of the baseline area in New Zealand (or 28% of the 44% of remaining baseline extent), though biased towards the uplands. Data sets are available as ArcGIS shape files for indigenous grasslands at both 2002 and 1840, on an ecological region basis, as well as for high-alpine and nival areas for the same periods and regions.

Keywords conservation; indigenous grasslands; land use; pastoral leasehold; preservation; protected areas network

INTRODUCTION

The conservation status of New Zealand's indigenous grasslands has been assessed as part of a global exercise. This is largely in response to a general impression that conservation of the indigenous temperate grasslands requires promotion since they are considered collectively to be perhaps the world's most beleaguered biome: only 0.69% of the total area of such grasslands were under some kind of protective status in the mid 1990s, according to

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Henwood (1998a). The major examples of this biome, the prairies of North America, the pampas of South America, the steppes of eastern Europe-northern Eurasia, and the grassveld of South Africa, are considered to be among the most biodiverse and productive of all the earth's terrestrial biomes (Henwood 1998a). Despite this, it is claimed that, "without exception, [they] have received very low levels of protection: ranging from a low of 0.08% for the Argentine pampas to "very modest highs of 2.01% for the lowland grasslands of south-eastern Australia and 2.2% in the South African grassveld" (Henwood 1998a,b). This degree of protection apparently is the lowest, by several orders of magnitude, among the world's 15 recognised major biomes, according to Henwood, who asked "what is it about temperate grasslands that has failed to inspire governments to protect them?" and "what can we do to improve this situation?" The parlous state of the North American prairies is currently being addressed with a tri-national co-operative programme involving Mexico, the USA, and Canada which is attempting to address both sustainable management and conservation needs (Gauthier et al. 2003). Given the relatively small size of New Zealand (267 840 km^2) it is not surprising that the situation of indigenous grassland conservation here was not assessed in Henwood's (1998a,b) brief world review.

New Zealand's indigenous grasslands have been and remain a significant component of its plant cover. They are generally dominated by grasses with a bunch or tussock form, mostly in three genera, the largely endemic genus *Chionochloa* which dominates the tall-tussock grasslands and the cosmopolitan *Festuca* and *Poa* which characterise the short-tussock grasslands. *Chionochloa* is the largest of three indigenous genera in the tribe Danthonieae of the subfamily Arundinoideae. Subsequent to Edgar & Connor's (2000) recognition of 22 species, with many subspecific taxa and interspecific hybrids, another has been described by Connor & Lloyd (2004). Of these species, some 17, mostly tussock-forming, may be dominant in grassland communities on the mainland, but only four of them occur in the North Island. These community patterns will be discussed only briefly. At the time of European settlement, tussock grasslands dominated the low-alpine zone above the natural (climatic) treeline and some valley floors in the higher rainfall, mostly forested regions but were most extensive in the rain-shadow region to leeward of the Southern Alps in the South Island (Mark 1993). These indigenous grasslands have been classified traditionally on the basis of the form, height, and composition of the dominant grasses, plus general altitudinal and geographic distributions of these species (Cockayne 1928; Wardle 1991; Mark 1993). The extent of the high-alpine zone, occupied by generally dwarfed plants beyond the upper limits of snow tussock grassland, plus the nival zone of permanent ice and snow, have been included for completeness but mapped separately.

Despite humans having settled New Zealand relatively recently, Polynesian Maori from about AD1000–1100, and the possibility of reconstructing a pre-human baseline, we have assessed the distribution of the indigenous grasslands as at the time of European settlement in the 1840s. Prior to European settlement, Maori fires reduced the extent of a largely woody cover on the main islands from about 80% to near 50%, and shifted the dominant cover to tussock grasslands, particularly in the South Island rain-shadow region (Molloy et al. 1963; McGlone 1989; Anderson & McGlone 1992; McGlone & Wilmhurst 1999) but also in the central North Island (Rogers 1994). These transformations, however, were perhaps no more drastic than occurred in many other parts of the world at much earlier times, associated with human occupation.

The maximum extent of areas where indigenous grasses were dominant thus occurred immediately prior to European settlement (Holloway 1959), before there was extensive modification associated with agricultural and pastoral developments and the introduction of a wide range of plants and animals, both wild and domestic (Thomson 1922). An 1840 baseline is not only easier to establish than a pre-human one, it is also considered more relevant to the present exercise. Similarly, an 1840 baseline was considered appropriate for the Protected Natural Areas Programme (Myers et al. 1987), particularly where extensive areas of indigenous grasslands were involved. Human, particularly European, effects on the New Zealand landscape and biota were obviously accentuated by the generally archaic nature of its indigenous biota which has a strong Gondwanan element that has been retained through prolonged isolation (Stevens et al. 1988). An emerging view, however, based on molecular phylogenic and other information, is that much of the indigenous flora, particularly that of the non-forest and mountain components, is Gondwanan only in the sense that its antecedents arrived long after the separation of New Zealand from Gondwana, largely by trans-oceanic dispersal from or via other Gondwana fragments (Pole 1994, 2001; Winkworth et al. 2002).

The situation with indigenous grassland conservation in New Zealand, until the last decade, generally followed the global pattern of having been largely overlooked. Only the low-alpine snow tussock grasslands of the more remote mountainous regions, particularly the main axial ranges of both islands, and the red tussock grasslands of the North Island volcanic mountains, were mostly conserved as part of the "protection" vegetation and in the absence of any alternative economic uses (Anon. 1980; Mark 1985), as national parks and other protected areas.

METHODS

Despite extensive development of the indigenous grasslands for agriculture or rangeland purposes, the general pattern as at 1840 can still be deduced from the persistence of remnants or extensive plant cover in various degrees of intactness, or from early records. We invited four other plant ecologists with appropriate knowledge of major regions to contribute to the exercise of deducing the baseline distribution of indigenous grasslands at the time of European settlement, as well as its current extent where this varied from that shown in the New Zealand Land Cover database. Mapping was done at a 1:50,000 scale or smaller. Some arbitrary decisions were made in relation to mixed shrub-grasslands, particularly in the South Island rain-shadow region, where periodic natural but mostly human-induced fires largely determined the extent of grass dominance at this time. We mapped as grassland all areas where indigenous grasses were assumed to have attained at least local dominance at 1840.

The bioclimatic zones described by Meurk (1983) were adopted for the exercise, as were the ecological regions outlined by McEwen (1987). Five major types of indigenous grassland were recognised. Lowland sward grassland, apparently of limited extent in 1840, was accepted as a relevant category even though only traces now remain. Amongst the bunch or tussock grasslands, four types were recognised: short-tussock grassland of the montane and subalpine zones in the drier regions; tall red or copper tussock grassland also of the montane to subalpine zones (with very limited areas in the low-alpine zone of the North Island volcanic mountains: Atkinson 1981; Clarkson 1986; and western South Island); tall snow tussock grassland from the montane to subalpine zones, but also occurring above the climatic treeline in the low-alpine zone. These last two were mapped separately so as to distinguish between the entirely natural low-alpine grassland from those of the montane to subalpine zones below treeline elevation, which have become much more extensive through fire, largely of human origin. Both the red/copper and snow tussock grasslands are dominated by various species of the largely indigenous genus *Chionochloa*.

The baseline (1840) map supplied by each of the four collaborators identified the five indigenous grassland types as outlined. It was agreed that some or all of the four major tussock grassland types in the montane to subalpine zones may have been mixed in certain areas, in which case only the assumed predominant type would be shown. Also, as discussed above, some grasslands may have contained variable amounts of co-dominant woody species, or occurred as grassland-shrubland mosaics, in which case the areas assumed to have had at least local dominance of grassland would be shown as grassland. The mapped information supplied by the four collaborators as paper maps was then scanned into digital form and registered to New Zealand Map Grid coordinates for use in ArcGIS™ (Environmental Systems Research Institute (ESRI), Redlands, California) geographic information system software. A separate layer of digital geographic data was compiled for each major tussock grassland type by digitising the boundaries of each type contained in the scans of the original paper maps. Maps supplied by the collaborators intentionally made no distinction between low-alpine and montane to subalpine types of snow tussock grassland; the boundary between these types was computed with ArcGIS using elevation data obtained from the New Zealand topographic database (see below). At this stage both these snow tussock grassland types were represented as a single class designated as "snow tussock". When digitising was complete the component layers representing each tussock grassland type were merged into a single layer for further processing, and for use as a basis for developing data representing the current status of indigenous grasslands.

The map showing current status of the indigenous grasslands was derived from (1) additional paper maps provided by the four collaborators (using the same techniques as described above), (2) relevant data from paper vegetation maps provided by Atkinson (1981), Clarkson (1986), and Rogers (1994) for various regions of the North Island, and (3) data contained in the Land Cover Data base Version One (LCDB 1). This showed the extent of "tussock" cover (1 of 9 "natural landscapes" depicted among 16 cover types). This land cover information has

been derived mainly from SPOT satellite imagery c. 1996–7, but also from ancillary data, and has a minimum mapping unit of 1 ha, a target classification accuracy of >90%, and a positional accuracy of ±25 m (S. Thompson pers. comm. 2002). It should be noted that a Version Two of the LCDB, recognising 70 cover types, including three tussock grassland types plus high-alpine and permanent ice/snow cover, is being compiled but was not available.

The tussock grassland information from the LCDB 1 map was extracted to a separate ArcGIS layer. This layer contained only one homogenous class of data, that of "tussock", which represented all tussock grassland types considered in this exercise. This layer was used to "clip" a copy of the baseline (1840) layer to provide the current extents of the five major indigenous grassland types. We considered this approach was appropriate since the total extent of these grasslands has decreased, although the boundaries between adjoining types have remained largely unchanged, at least based on the scale being used.

Ecological region boundaries, based on McEwen (1987) and obtained from the Department of Conservation in ArcGIS format, were intersected with both the baseline and current status layers. Prior to this operation the geographic data within these layers contained a single attribute denoting the tussock grassland type. After the intersection, polygons representing tussock grasslands lying across ecological region boundaries were split at these boundaries, and an attribute identifying the ecological region that contained this grassland was appended to each polygon.

The boundary between the low-alpine and montane to subalpine snow tussock grasslands was derived in the generally non-forest regions of central and eastern South Island on the basis of elevation of the nearest natural treeline or from the elevation associated with bioclimatic information for the lower boundary of the alpine zone (10°C mean summer isotherm). This elevation varied regionally from 1500 m in central North Island and inland Marlborough-Nelson to 1200 m in the southern North Island and central South Island, 900 m in southern South Island, and 800 m on Stewart Island, with some increase at a particular latitude associated with distance from the coast, i.e., increasing continentality. The relevant elevations for a region were extracted from an electronic version of the current 1:50,000 New Zealand topographic database. These elevations, represented as contour lines of varying height, were extracted from this database to form an ArcGIS layer containing closed polygons representing the boundary between low-alpine and montane to subalpine snow tussock grasslands. Both baseline and current status layers were intersected with this boundary layer. Regions of the single snow tussock class occurring above this boundary were reclassified as low-alpine snow tussock grassland, those below as montane to subalpine snow tussock grassland. The high-alpine zone, above the limits of low-alpine snow tussock grassland, was added from the "bare ground" class on the LCDB 1 maps, while the nival areas of permanent ice and snow (included in the "bare ground" class on the LCDB 1 maps) were derived from electronic data provided by T. Chinn (pers. comm. 2002), based on 1978 records (Chinn 2001). Each of these two additional land cover types was also divided along ecological region boundaries and an attribute identifying ecological regions was appended.

Of the 78 ecological regions covering the three main islands (Fig. 1), 60 were presumed to have contained indigenous grassland at the time of European settlement. Both the baseline information and current situation were analysed for each of these 60 regions. The ecological region data were also grouped into four major geographic categories on the basis of the general pattern of land use and indigenous grassland exploitation. The North Island was treated as one unit embracing 19 ecological regions, since the grasslands here were of more limited extent and have been either developed for agriculture or managed for nature, soil, and water conservation, and are now mostly formally protected. The second category comprised the tussock grasslands of the South Island hill- and high-country, rain-shadow region which have been retained as rangeland (i.e., indigenous grassland used for extensive pastoral farming); 19 ecological regions are involved. The third category, the South Island western non-rangeland region, embraces the main divide of the Southern Alps and the wet western mountains, and involves 10 ecological regions. Apart from some limited areas in the lowlands, the grasslands here remain essentially intact and are mostly managed as conservation land. The fourth category, eastern South Island lowlands and lower hills, beyond the rangelands, including Stewart Island, account for the remaining 12 ecological regions (Fig. 1). Separate summaries were derived for each of these four major regions.

The Department of Conservation's National Conservation Unit dataset, which contains information on areas formally protected (records as of September

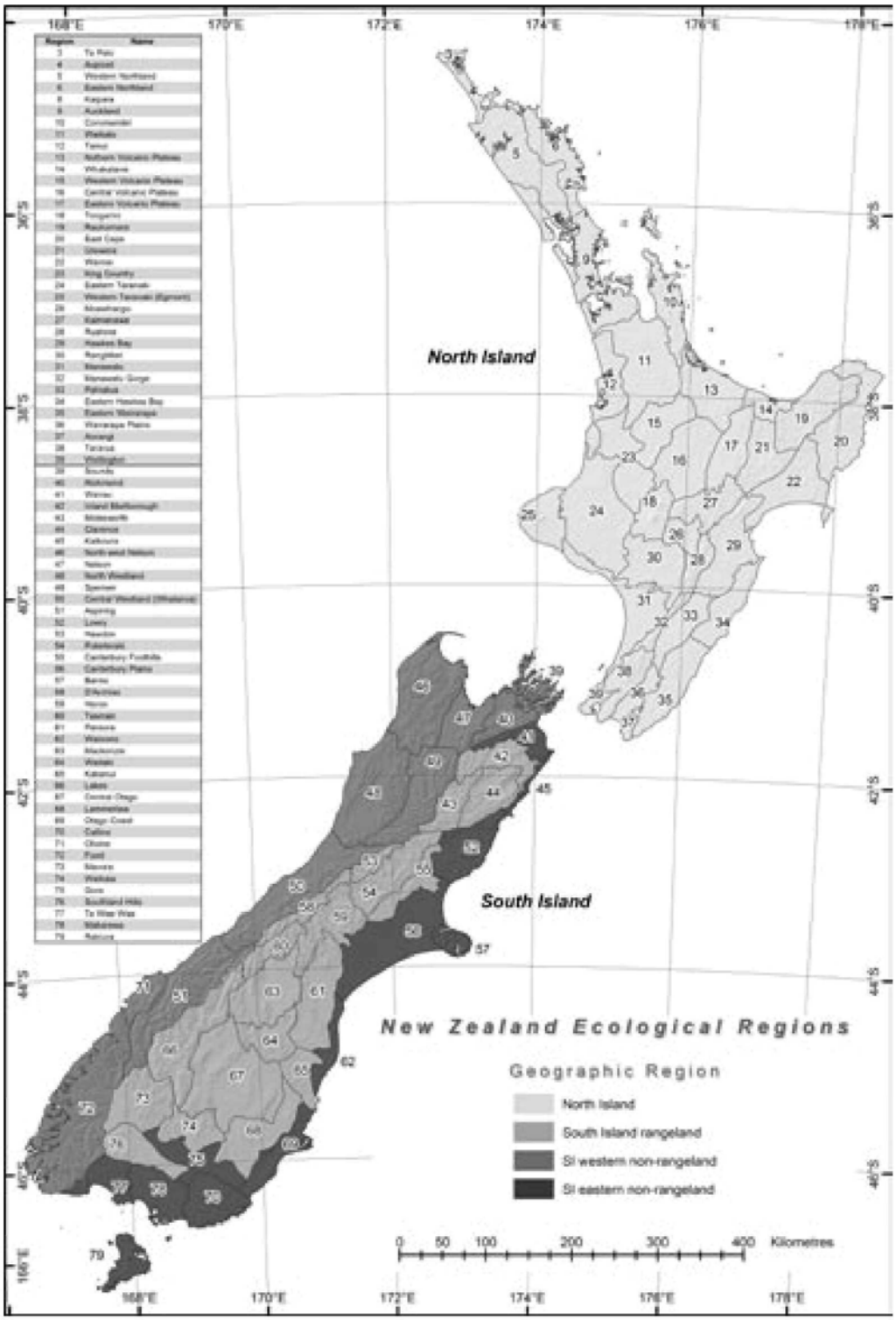


Fig. 1 New Zealand's mainland ecological regions showing their separation into the four major geographic areas used in this exercise.

2002 were used), was made available in ArcGIS format for the exercise. The ArcGIS layer for the current status of indigenous grasslands was intersected with these conservation unit data, resulting in grassland polygons being further split and an attribute appended designating the protection status of each polygon (i.e., either protected or non-protected). Values for areas formally protected were calculated as a percentage of the area of each indigenous grassland type remaining at this time (September 2002). Given the increased areas of indigenous grasslands and associated mountain land plant communities currently being formally protected through the tenure review process in the South Island rangeland region (Mark & Dickinson 2004), this date is significant for future reviews. These records were applied to the map of current extent of indigenous grasslands and associated high-alpine and nival areas. Land covenanted with the Queen Elizabeth II National Trust has not been included since only relatively small areas of tussock grassland have been protected to date with this procedure.

RESULTS

The baseline situation: Pre-European grassland pattern of 1840

While several attempts have been made to reconstruct the immediately pre-human plant cover in many parts of New Zealand (McGlone & Basher 1995; McGlone 2001), there has been only one published account of grassland vegetation patterns at the time of European settlement presented in sufficient detail to be relevant to the present exercise. Rogers (1994) attempted to reconstruct the indigenous seral grasslands of the North Island on the basis of a field reconnaissance of existing indigenous vegetation, combined with an understanding of relationships between this vegetation, landforms, and soils, together with some historical accounts. Tall red tussock and short-tussock grasslands, as well as non-tussock (sward) "lowland plains and maritime grasslands" of summer-dry lowlands and coastal plains, were recognised on areas that had been deforested in pre-European (Maori) times. Rogers mapped these grasslands at two scales with the two tussock grassland types being shown in relation to 10 ecological districts and 4 ecological regions in the central North Island. The areas of red tussock grassland mapped for Tongariro National Park (Atkinson 1981), including the limited area of low-alpine grassland above the local treeline at c. 1500 m here, and in Egmont National Park (Clarkson 1986) have been included in the baseline record.

The grasslands which occupied lowlands on the Heretaunga/Ahuriri and Takapau/Ruataniwha plains of Hawke's Bay, the sand plains of the Manawatu along the west coast, and the Wairarapa Plains in the south, were apparently composed of mostly low, sward-forming species, with only occasional tussock grasses according to Rogers (1994). He reported *Chionochloa beddei* as having been important on the Wairarapa Plains, although today this tussock grass is confined to steep, rocky ground in forested areas of southern North Island. Giant tussocks of *Cortaderia* spp. probably formed colonies along drainage channels and on wet slips but most of the cover was formed by grasses that are either rhizomatous or at least not conspicuously tussocky according to Rogers (1994). Wardle (1991) and Rogers (1994) indicated that *Poa anceps*, *Microlaena stipoides*, *Festuca rubra*, and *Echinopogon ovatus* probably formed swards on slopes while *Hierochloe redolens* would have dominated widely in damp grassland and *Deschampsia cespitosa* tussocks may have occupied floodable ground around the margins of swamps. *Rytidosperma* spp. would have dominated mainly on dry or stony ground while other common grasses would have included species of *Elymus*, *Stenostachys*, *Dichelachne*, *Trisetum*, *Agrostis*, *Lachnagrostis*, *Deyeuxia*, and sward-forming species of *Poa* and *Festuca* according to Hill (1963) and Rogers (1994). Rogers mapped the presumed 1840 extent and also estimated the total area of each seral grassland type present at the beginning of organised European settlement, including short-tussock grassland which was widespread in the central part of the island (Fig. 2A; Table 1).

Montane to low-alpine red tussock grassland, dominated by forms of the tall tussock species *Chionochloa rubra*, up to 1.5 m tall, with distinctive reddish hues, occurred on the North Island volcanic mountains where the limited areas above the natural treeline have largely persisted as a dominant or co-dominant in the low-alpine zone on Mt Egmont (Clarkson 1986) and on the central volcanic mountains (Atkinson 1981). In the central region there has been limited cultivation at lower altitudes and invasion by shrubs in the absence of site disturbance (Rogers & Leathwick 1994). The low-alpine grasslands occur on recent volcanic soils (inceptisols) while elsewhere in the North Island this grassland appears to be mostly seral, occupying permanently wet often peaty histosols, generally where fire had

removed forest during the Polynesian phase of human occupation (Rogers 1994).

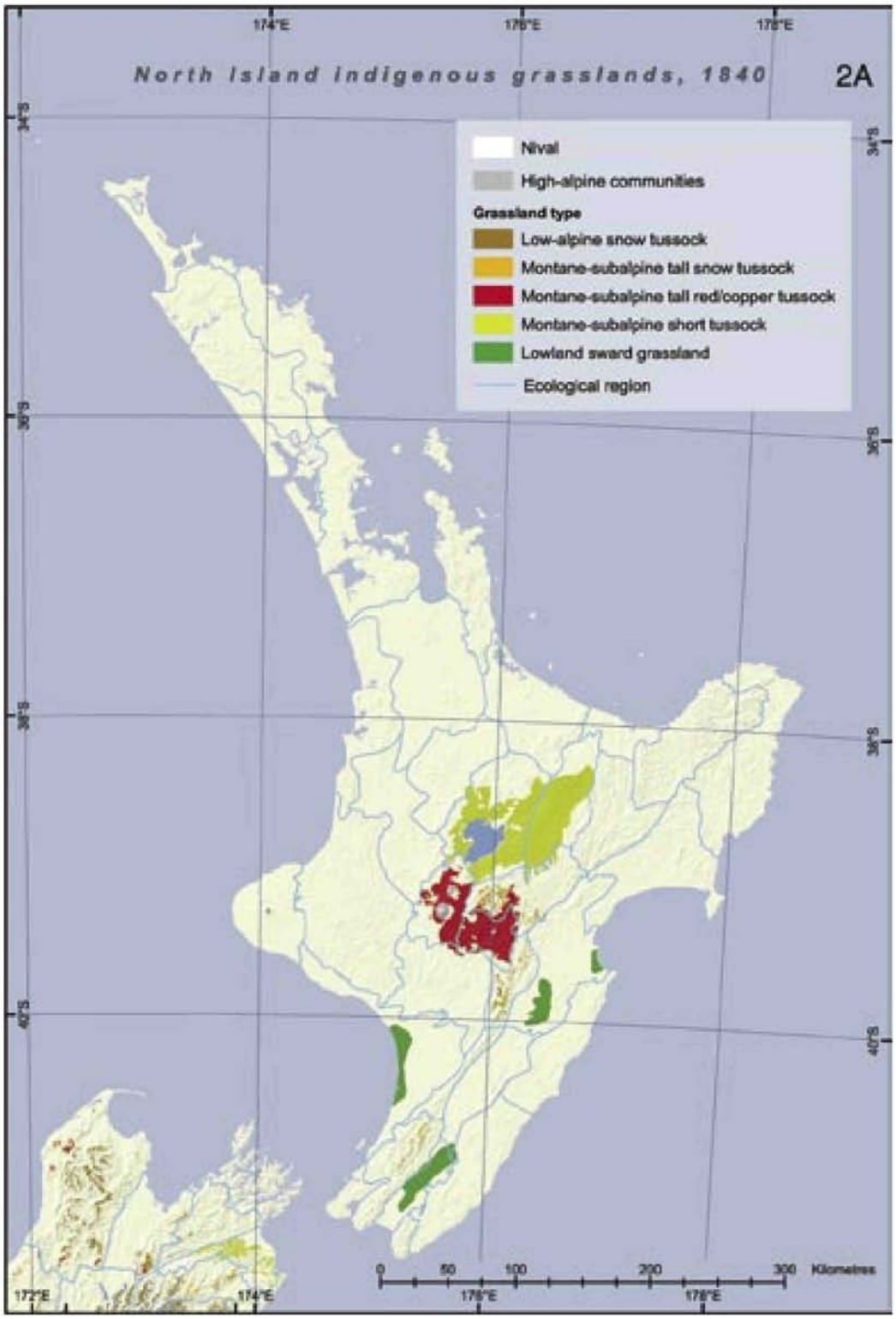
On the main axial ranges of the North Island the low-alpine tall snow tussock grasslands have generally persisted. Here the ecological roles of the relatively few dominant species are determined by elevation and locally also by soil conditions as affected by the history of site disturbance, as described for the Tararua Range by Williams (1975a,b). Limited areas of high-alpine and nival communities in the North Island are confined to the volcanic mountains (Fig. 2A; Table 1). There were relatively extensive areas of short-tussock grassland in the central and eastern North Island at the time of European settlement (Fig. 2A), apparently generally similar to those of the central and eastern South Island, according to Rogers (1994).

In the South Island all of the major indigenous grassland types were represented at the time of European settlement. Of these, there is evidence for only very limited areas of sward grassland, containing in particular *Rytidosperma gracile*, *Lachnagrostis lyallii*, and species of *Elymus*, *Hierochloe*, *Trisetum*, and *Deyeuxia*, plus a range of turf-forming herbs (Wardle 1991). Only two sites on the extensive outwash fluvio-glacial plains of North Westland were of mappable extent (Fig. 2B). Their remnants are characterised by several indigenous grasses including species of *Rytidosperma*, *Trisetum*, and *Lachnagrostis*. Small unmappable areas still persist here, on recent soils, avalanche tracts, etc. in the mountain valleys, according to Wardle (1991).

Among the four major tussock grassland types in the South Island, montane to subalpine short-tussock grassland occupied the extensive outwash plains and lower hills from North Otago to Marlborough, as well as the intermontane basins and associated lower mountain slopes in the drier rain-shadow regions of the South Island. Occurring at elevations below about 800 m, this short-tussock grassland occupied areas receiving less than 700 mm annual precipitation, and was characterised by sitiform (brown-grey to yellow-grey) soils or aridisols. No adequate accounts were given of the original composition of this grassland in either island but it is assumed to have been generally similar to the short-tussock grasslands that still persist on some sites in the South Island and for which there are generalised botanical descriptions dating from the late 1860s onwards. Short-tussock grassland is generally less than 50 cm tall, and was probably dominated chiefly by silver tussock (*Poa cita*), but hard or fescue tussock (*Festuca novae-zelandiae*) may also have been important, though less so than today. By contrast, the highly palatable blue wheat grass (*Elymus solandri*) may have been more important than early records or current abundance indicate according to O'Connor (1986) and Mark et al. (1989). Co-dominant shrubs and some extensive areas of shrubland and woodland would have featured in many areas with such grassland, particularly inland Marlborough and the Canterbury Plains where extensive stands of kanuka (*Kunzea ericoides*) were recorded. Emergent or co-dominant, microphyllous small trees or shrubs of this species but also of *Leptospermum*, *Coprosma*, *Ozothamnus*, *Melicytus*, *Corokia*, and *Olearia*, together with the thorny nitrifying rhamnaceous shrub *Discaria toumatou*, would have been scattered through this grassland and probably dominated along riparian areas, some valley floors, and rocky ground. Scattered trees and groves of cabbage tree (*Cordyline australis*) and kowhai (*Sophora microphylla*) probably occurred widely while nitrifying tutu (*Coriaria* spp.) was probably more abundant than at present, with the rhizomatous *C. sarmentosa* being an integral part of much of this grassland. The upper limit of this grassland was undoubtedly lower in pre-European times than to-day, by up to 200 m, since the unpalatable *Festuca* and *Poa* tussocks have been progressively displacing the more palatable or grazing-sensitive tall snow tussocks (*Chionochloa* spp.) at higher elevations, as a result of pastoral farming (Connor 1964; Mark 1993). Among the earliest botanical records Buchanan (1868) described the use of fire to curb the invasion of these grasslands by woody species in parts of the South Island rain-shadow region, specifically Otago. In parts of inland Marlborough this practice resulted in replacement of shrubland by short-tussock grassland over extensive areas but particularly on the drier north-aspect slopes, and the transition from short- to tall-tussock grasslands here was assumed to be at about 1000 m elevation (S. Courtney pers. comm. 2002).

Red tussock grassland dominated poorly drained often peaty and acidic soils in the northern South Island where, as in the North Island, it occupied

Fig. 2 Assumed North Island (**A**) and South Island (**B**) baseline distribution and extent of the five major indigenous grassland types, associated high-alpine communities, and permanent ice and snow at the time of European settlement in the early 1840s. Ecological region boundaries are also shown. ➤


North Island indigenous grasslands, 1840
2A
Nival
High-alpine communities
Grassland type
Low-alpine snow tussock
Montane-subalpine tall snow tussock
Montane-subalpine tall red/copper tussock
Montane-subalpine short tussock
Lowland sward grassland
Ecological region
174°E
176°E
178°E
172°E
34°S
36°S
38°S
40°S
0 50 100 200 300 Kilometres

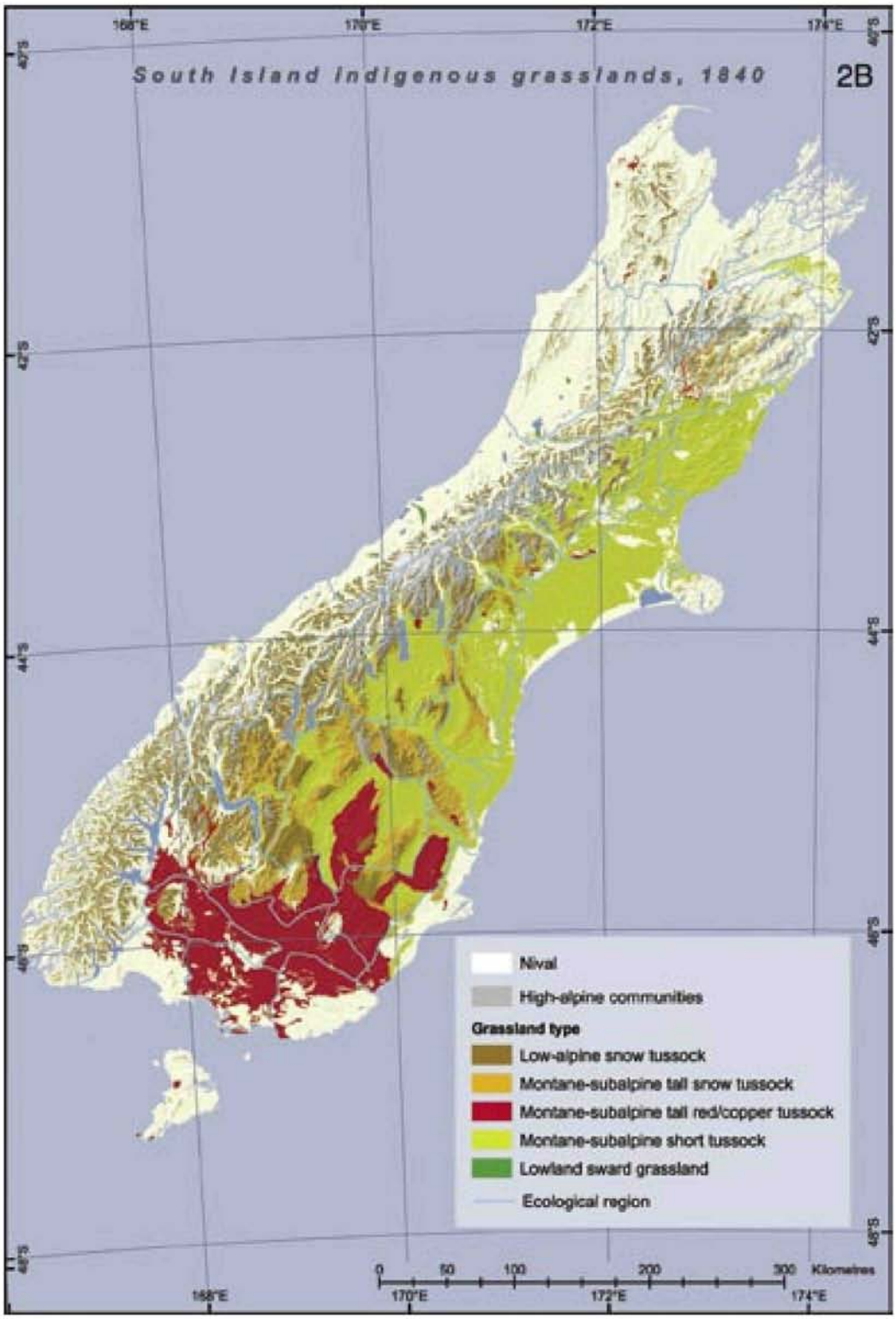

South Island indigenous grasslands, 1840
2B
168°E
170°E
172°E
174°E
47°S
46°S
45°S
44°S
43°S
42°S
41°S
Nival
High-alpine communities
Grassland type
Low-alpine snow tussock
Montane-subalpine tall snow tussock
Montane-subalpine tall red/copper tussock
Montane-subalpine short tussock
Lowland sward grassland
Ecological region
0 50 100 200 300 Kilometres

Table 1 Assumed extent (km^2) of the five major indigenous grassland types, and associated high-alpine and nival cover types in 1840, with percentage of each type remaining in 2002 (%R), and the percentage of the latter formally protected (%P), as of September 2002.

Region	Nival			High-alpine communities			Low-alpine snow tussock			Montane-subalpine snow tussock			Montane-subalpine red/copper tussock			Montane-subalpine short tussock			Lowland sward grassland			Total grassland		
	km^2	% R	% P	km^2	% R	% P	km^2	% R	% P	km^2	% R	% P	km^2	% R	% P	km^2	% R	% P	km^2	% R	% P	km^2	% R	% P
North I.	5.41	100	100	143.85	100	98	42.92	100	82	325.98	100	72	2314.46	45	27	4191.77	1	65	1616.25	0	-	8491.38	17	40
S.I. western non-rangeland	717.74	100	99	2664.18	100	82	3910.79	100	90	2756.25	100	91	164.13	61	93	72.53	106	7	94.50	0	-	6998.21	98	89
S.I. eastern non-rangeland				0.08	100	100	4.91	100	58	143.10	41	64	7409.32	1	33	12103.54	4	1				19660.87	3	11
S.I. rangeland	515.19	100	94	5888.39	100	46	6973.52	96	27	11978.42	81	12	8830.66	28	8	19503.38	42	3				47285.97	76	12
Total	**1238.33**	**100**	**97**	**8696.50**	**100**	**58**	**10932.14**	**98**	**50**	**15203.76**	**84**	**31**	**18718.56**	**20**	**16**	**35871.22**	**25**	**3**	**1710.75**	**0**	**-**	**82436.43**	**44**	**28**

locally wet, often frosty, depressions, particularly valley floors below treeline. The more copper-coloured variant, subspecies *cuprea* (copper tussock), occupied generally similar habitats from Canterbury and North Westland southwards in the South Island and on Stewart Island. On the infertile, generally damp Buller coal plateau in North Westland, the similarly coloured subspecies *occulta* often occurs in association with the somewhat shorter, reddish endemic *C. juncea* (P. Knightbridge pers. comm. 2004). Subspecies *occulta* also dominated locally in permanently damp basins to well above treeline along and west of the main divide, from Nelson to South Westland, where it still persists (P. Wardle pers. comm. 2003). Copper tussock was widespread and dominant on the Southland Plains, extending northward onto the often poorly drained uplands of the Manorburn Ecological District in eastern Central Otago where it largely displaced forest destroyed by Polynesian fires. At higher elevations copper tussock often formed mosaics or shared dominance with narrow-leaved snow tussock (*C. rigida*), with copper tussock being more prominent on wetter, often peaty slopes and depressions, mostly below the original treeline (Mark et al. 2003a). Similar situations occurred along the western fringes of the Canterbury Plains and further inland (Connor 1964, 1965). Co-dominant shrubs also played a variable role in copper tussock grassland with periodic fires generally restricting their role, at least temporarily.

Snow tussock grassland, dominated by one or more of the several alpine species of *Chionochloa*, up to 1.5 m tall, occupied much of the low-alpine zone above the climatic treeline throughout the South Island mountains in pre-human times (Mark 1993). Important regional differences in distribution of some of the 14 alpine species of snow tussock are assumed to reflect the vagaries of Pleistocene survival (Wardle 1963, 1988, 1991; Burrows 1965) or perhaps are related to tectonic events (McGlone 1985). One such species, *C. australis*, confined to the North Canterbury-Nelson region of north-western South Island, forms dense carpets rather than tussocks (though usually occurring with tussock-forming species). Altitudinal and more localised ecological patterns among the alpine snow tussock species have been related to variations in topography, especially as it affects duration of snow-lie (Burrows 1977), or specific preferences for particular soil physical and chemical factors associated with site disturbances (Connor 1965; Williams et al. 1976), or both (Mark et al. 2000). These local patterns still persist but are not amenable to mapping at the scale used for this

exercise. In the low-alpine zone the snow tussock grassland was associated with permanently moist, strongly leached and acidic fulviform soils (upland yellow-brown earths) or highly leached eldefulvic soils (podzolised yellow-brown earths) or, on steep slopes, weakly developed steepland soils (inceptisols or lithosols). Limited areas of snow tussock grassland also occur on exposed, particularly rocky sites within the forest and, in the absence of forest or tall shrubland, as on ultramafic outcrops or on peaty benches, such grassland descends to lower elevations, even locally to sea level as in western Fiordland (Wardle et al. 1973). The snow tussock species dominating some such habitats, particularly *C. juncea*, *C. defracta*, and *C. acicularis*, are perhaps more akin, ecologically, to red tussock but, being generally scattered and of relatively limited extent, have been included within snow tussock grassland in this exercise.

In the South Island rain-shadow region, areas of montane to subalpine snow tussock grassland may have occurred as part of vegetation mosaics related to physiography (Mark & Dickinson 2003, 2004) but extensive areas were largely the result of human destruction of woody vegetation through fire, both before and during the first (Polynesian) phase of human occupation (McGlone 1985; McGlone et al. 2003). Tall snow tussock grassland probably extended down-slope from above treeline and also expanded from mosaics and local habitats within the woody cover (Mark & Dickinson 2003) to become widespread in this region (Mark 1993). From the Rakaia catchment southwards the tussock species involved are narrow-leaved snow tussock (*Chionochloa rigida*) in the montane to lower low-alpine zones and slim snow tussock (*C. macra*) at higher elevations, with some additional western species (*C. crassiuscula*, *C. pallens*) involved towards the western limits of the rain-shadow region. North of the Rakaia valley, however, *C. rigida* is generally absent and here slim snow tussock descends to much lower altitudes but with *C. crassiuscula* and *C. pallens* again involved further west.

High-alpine plant communities, above the limits of low-alpine snow tussock grassland, include fellfields, boulderfields, herbfields, talus (scree) slopes, cushionfields, and snowbanks, usually with small tussocks of *Chionochloa oreophila* and/or *C. macra*, within their geographic ranges, and with considerable regional variation in plant distribution (Mark & Adams 1995). These communities were mapped as a single unit and are assumed to be essentially unchanged from the baseline (1840) situation. This assumption is partly a function of the mapping scale being used, since considerable areas of high-alpine communities are known to have been induced through destruction of a snow tussock cover with pastoral farming practices in the South Island rangeland region (Mark & Bliss 1970; Mark 1993; Mark et al. 2003a; Mark & Dickinson 1997, 2004).

Baseline distributions and extent of the main grassland types

The map (Fig. 2) represents the baseline pattern and extent assumed for each of the five main indigenous grassland types, plus the associated high-alpine plant communities and the nival zone of permanent ice and snow, immediately preceding European settlement (1840). Values for the extent of each of the four major geographic regions recognised, based on generalised land use categories, are presented in Table 1 while comparable values for each of the 60 ecological regions involved are given in Appendix 1. The detail shown is considered appropriate for the scale of 1:1 000 000 used in the exercise. The datasets for indigenous grasslands, both 1840 and 2002, as well as for the extent of high-alpine and nival areas (1840 and 2002), as ArcGIS shape files (compressed as zip archives), using the New Zealand Map Grid (NZMG49) coordinate system, are available for downloading from the University of Otago Botany Department's website (http://www.botany.otago.ac.nz/tussockconservation)*.

The total extent of indigenous grasslands in New Zealand at the time of European settlement (the 1840 baseline) is assumed to have been about 82 432 km^2 or c. 31% of the total land area of 267 840 km^2, with another 8697 km^2 (c. 3.3%) being of various high-alpine plant communities, above the limits of tussock grassland, and 1238 km^2 (c. 0.5%) occupied by permanent ice and snow of the nival zone. Of the indigenous grasslands, some 13% was various types of low-alpine snow tussock grassland, c. 18% was montane to subalpine snow tussock grassland, 23% was montane to subalpine tall red/copper tussock grassland, c. 44% was montane to subalpine short-tussock grassland, and about 2% was lowland sward grassland. In relation to the four major geographic regions (Table 1), the greatest extent of indigenous grasslands was in the South Island rangeland region (47 286 km^2 or 57% of the total grassland area),

*ArcGIS users should note that the default projection files supplied by ERSI for New Zealand are erroneous. Corrected projection files are also available for downloading at this site.

followed by the eastern South Island non-rangeland region (19661 km^2 or 24% of the grassland area), both substantially greater than for the North Island (8491 km^2 or 10%) and the western South Island non-rangeland region (6998 km^2 or 9%).

The main occurrence of the low-alpine snow tussock grassland was in the South Island rangeland (64%) and South Island western non-rangeland (36%) regions (Table 1). Most of the montane to subalpine snow tussock grassland (79%) was in the South Island rangeland region with another 18% in the western non-rangeland region of the South Island. For the montane to subalpine red/copper tussock grasslands there were generally similar areas in the South Island rangeland (47%) and eastern non-rangeland (40%) regions, with some 12% in the North Island, including relatively small areas in the low-alpine zone on the volcanic mountains. The most extensive grassland type, the montane to subalpine short-tussock grassland, was most extensive in the South Island rangeland region (54%) with smaller areas in the eastern South Island non-rangeland region (34%) and the North Island (12%). The limited areas of sward grassland were almost all in the North Island (94%), the remainder being in the western South Island non-rangeland region. Equivalent values for each ecological region are given in Appendix 1.

The current conservation status of New Zealand's indigenous grasslands

With European colonisation from the 1840s there was considerable and almost immediate modification of the indigenous grasslands in many areas, particularly the lowland sward grassland and lower altitude montane tussock grasslands, regardless of type. Agricultural development was most extensive on the lower hills and plains which, virtually regardless of their plant cover, were soon cultivated and planted in crops. The moderate slopes were also eventually cultivated and sown to exotics while all but the most inaccessible uplands were used for pastoral farming with extensive grazing (Mark 1994; Pawson & Brooking 2002).

Analysis of the current (2002) conservation status of the grasslands (Fig. 3; Table 1; Appendix 1) shows a highly variable situation in relation to both the extent and proportions of each grassland type remaining. We emphasise that the current values are based on records extracted from the LCDB 1, information which does not record the degree of modification or degradation of the vegetation from the assumed baseline state. Distinction between tussock grassland and shrubland or even unimproved pasture may be somewhat arbitrary (S. Thompson pers. comm. 2002). Mosaics may also involve various exotic and/or indigenous woody species as well as different grassland types. Values for the area of each major grassland type, plus high-alpine and nival areas still remaining, have been presented as percentages of their presumed baseline (1840) extent, for each of the four major geographic regions (Table 1) and also for each of the 60 ecological regions which contained indigenous grasslands (Appendix 1). Three ecological regions show an increase in the extent of tussock grassland from the baseline state. All are in Marlborough where short-tussock grassland apparently has increased from its baseline extent in the Inland Marlborough Ecological Region about 11-fold, by displacing manuka-kanuka shrubland through burning, and in the Clarence E.R. about 3.3 times, while on Mt Stokes in the Sounds E.R. an original 1 ha area of low-alpine tall snow tussock (*C. pallens*) grassland has been extended by c. 10 ha through burning of subalpine silver beech forest in post-European times, according to our collaborator for this region (S. Courtney pers. comm. 2002). In nearby Spenser E.R. there has been limited increase in the extent of short-tussock grassland which is also the case in Mavora E.R. Here in northern Southland a limited area of short-tussock grassland has replaced tall copper tussock grassland on a valley floor, according to our collaborator for southern South Island (B. Rance pers. comm. 2002).

Lowland sward grassland, being mostly on sites that could be readily developed, has been virtually all converted to intensive agriculture. The traces which remain are not mapable. Similar fates were met by the short-tussock grassland of the North Island and on most of the Canterbury Plains, and also by the tall copper tussock grassland on the Southland Plains. The montane to low-alpine red tussock grasslands on the volcanoes and other areas of the North Island uplands has largely persisted (Atkinson 1981; Clarkson 1986; Rogers 1994), though some substantial areas have been cultivated and there has been a general invasion by shrubs with the reduction in frequency of fire or other site disturbances according to Rogers & Leathwick (1994). The exotic heather (*Calluna vulgaris*) has become a very serious invader on the central volcanic plateau since it was introduced in 1912 (Chapman & Bannister 1990). The most palatable indigenous grassland species such as *Elymus rectisetus*, *Gingidia montana*, and *Hierochloe redolens* were apparently quickly eliminated from the accessible hill slopes, contemporary

with the naturalisation of pasture species and alien weeds. On the hill country in particular, there was also invasion by a range of woody plants, both native, as reported in Otago by Buchanan (1868) and then increasingly by exotics, particularly gorse (*Ulex europaeus*), European broom (*Cytisus scoparius*), and briar (*Rosa rubiginosa*) (Wardle 1991). The eastern South Island non-rangeland indigenous grasslands mostly followed this course and much has now been developed for intensive agriculture. The South Island rangelands and the low-alpine snow tussock grassland of the wet western South Island and the North Island axial ranges, by contrast, still largely persist, albeit in variously modified forms, for pastoral farming and conservation/recreation, respectively, and will be discussed separately.

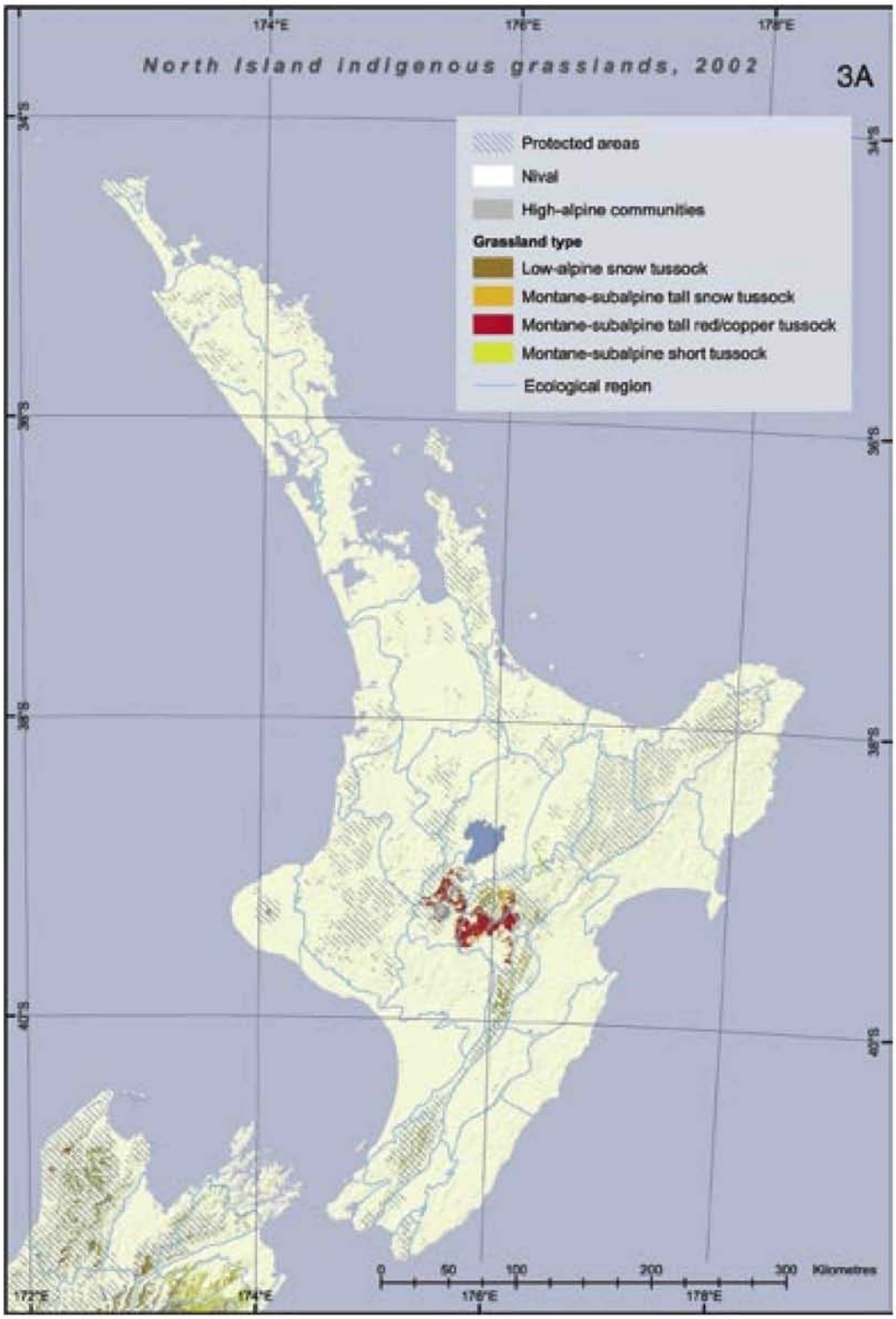
Rangelands of the South Island rain-shadow region

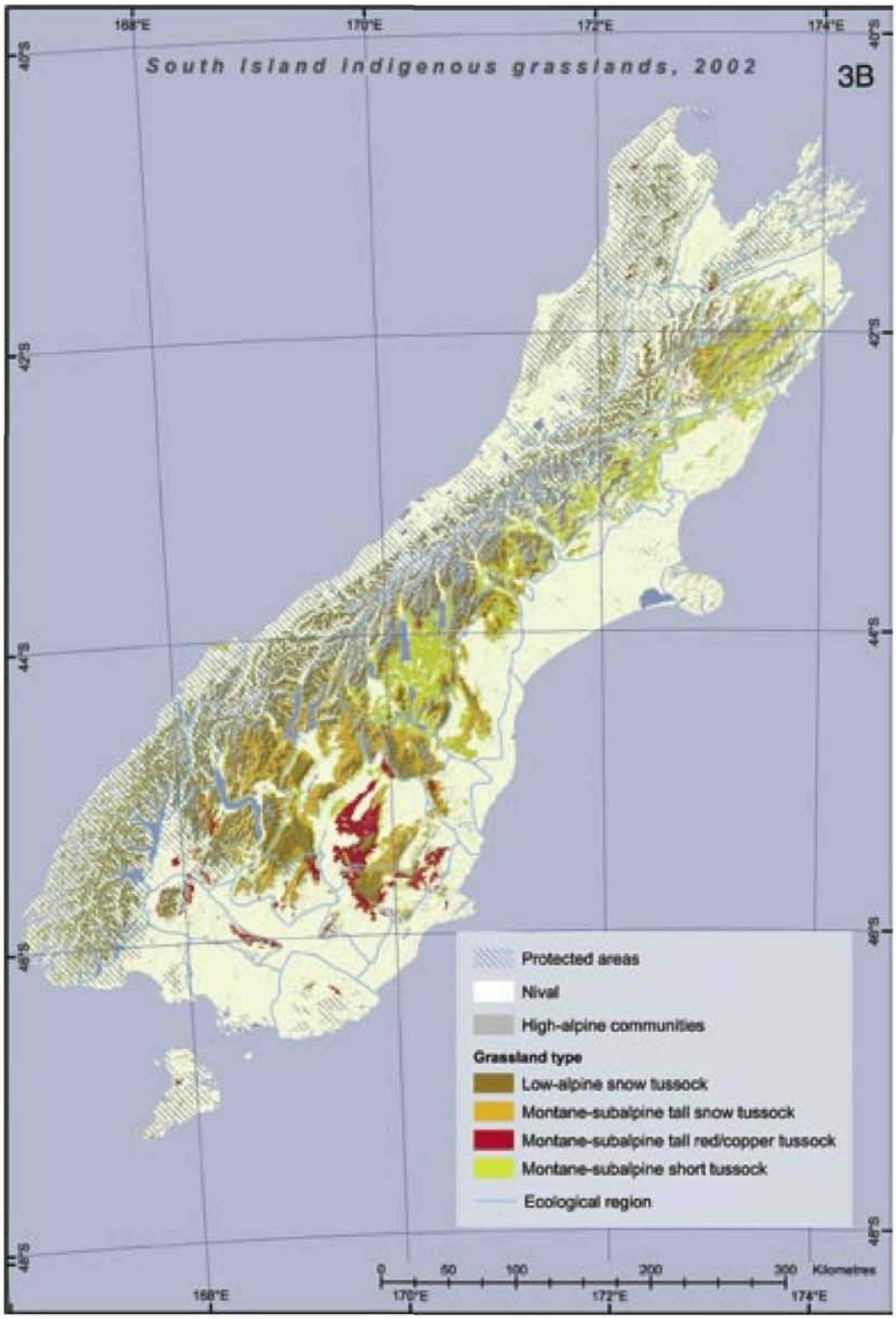
Almost all of the tussock grasslands in the hill and high country of the interior South Island rain-shadow region were retained in Crown ownership and leased out in large blocks for combined pastoralism (extensive grazing without inputs) and pastoral farming (more intensive farming with fertilizer inputs) (Allen et al. 1994), as rangeland. The more amenable low elevation areas, however, were generally freeholded and developed, mostly for more intensive agriculture. The rangeland was generally allocated in altitudinal corridors from lower slopes to mountain crests, to provide for both summer and winter grazing. Initially the Crown leases were on an 11-year term with no right of renewal, which encouraged aggressive farming with generally high stock numbers and frequent uncontrolled fires, a phase referred to by O'Connor (1982) as "exploitative pastoralism." This phase was also associated with major plagues of introduced rabbits (*Oryctolagus cuniculus*) and, inevitably, significant land degradation. This situation persisted (Tussock Grassland Research Committee 1954) until the conditions of leasehold tenure were reviewed through legislative amendments in 1948, which made provision to replace the short-term leases with much more secure 33-year renewable leases (Mark 1994; O'Connor 2003). There were also rights of occupancy and to the pasturage, as well as *de facto* trespass control. Significantly, there were no rights to soil, water, trees, feral animals, scenery, or commercial recreation.

At this time there were some 360 pastoral leases occupying about 2.6 million ha (c. 10% of the land area), an average of 7200 ha per lease. Some runs, however, were much larger, in excess of 50 000 ha. The 1948 legislation vested certain discretionary constraints, associated with management and development activities, in the bureaucracy: stock type and number, cultivation, fencing, burning, tree planting, etc. The whole package was obviously designed to encourage more sustainable use of the indigenous grasslands. This was further promoted with Government subsidies for innovative aerial oversowing and topdressing at lower altitudes, as well as subdivision and retirement fencing at higher altitudes. These soil conservation measures were administered by regional catchment boards that were established in the 1940s under special soil and water conservation legislation (McCaskill 1973).

Subsequent ecological research on the two dominant upland rangeland species of snow tussock (*Chionochloa rigida* and *C. macra*) indicated a general tolerance of fire but an obvious intolerance of heavy grazing, particularly during the early period of recovery from burning (Payton & Mark 1979), when the regrowth foliage is both palatable and relatively nutritious (Payton et al. 1986; Mark 1994). The relevance of this information to the management of pastoral farming has been applied to a limited extent by regional government authorities charged with the responsibility of management oversight. However, grassland degradation has continued, manifest in particular by continued rabbit plagues plus an explosion of several introduced species of hawkweed (*Hieracium* spp.) which have become serious weeds over extensive areas of rangeland as well as in some recently protected areas (Hunter 1991; Espie 2001). The continued degradation has been described as "a large-scale systems failure in the management of one of New Zealand's largest land resources – the mountains", caused by "the failure of all the unconnected resource management decisions to be considered in the light of ecological reality" (Kerr 1992, p. 35). Reviews by the Parliamentary Commissioner for the Environment of sustainable land use of the dry short-tussock grassland (1991) and also of the system for managing the burning of upland snow tussock grassland for pastoral use (1995) were both generally critical of prevailing practices. More recently, a special committee established by the Ministers of Conservation, Agriculture, and the

Fig. 3 Distribution and extent of the land cover categories of Fig. 2 in the North Island (**A**) and South Island (**B**) as at September 2002, together with the areas managed at this time by the Department of Conservation. ➤


North Island indigenous grasslands, 2002
3A
Protected areas
Nival
High-alpine communities
Grassland type
Low-alpine snow tussock
Montane-subalpine tall snow tussock
Montane-subalpine tall red/copper tussock
Montane-subalpine short tussock
Ecological region
174°E
176°E
178°E
172°E
34°S
36°S
38°S
40°S
0
50
100
200
300
Kilometres


South Island indigenous grasslands, 2002
3B
168°E
170°E
172°E
174°E
40°S
42°S
44°S
46°S
48°S
Protected areas
Nival
High-alpine communities
Grassland type
Low-alpine snow tussock
Montane-subalpine tall snow tussock
Montane-subalpine tall red/copper tussock
Montane-subalpine short tussock
Ecological region
0 50 100 200 300 Kilometres

Environment to review sustainable land management of the South Island rangelands, with a submission from 14 practising scientists (Allen et al. 1994) amongst others, reported (Martin et al. 1994) that the 80% of rangeland which is unimproved, through receiving no inputs, is unlikely to be able to sustain traditional pastoral use.

Given this situation, plus other concerns among the main stakeholders, the Government facilitated a tenure review process in the mid 1990s, inviting the pastoral lessees to review their leases. Described by the Government as a "win, win" situation, the farmers could initiate a review of their leasehold tenure and obtain a "win" through free-holding the more developed and productive, usually lower elevation parts of their properties, and thereby also remove the constraints of a Crown pastoral lease. The Government could also "win" through resuming control of those mostly higher altitude areas that contain significant conservation/recreation values, but have limited productive potential, while also being relieved of the substantial costs of administering the leases. Areas relinquished from the leases were to be managed by the Department of Conservation, for the benefit of the general public who would, thus, also "win" by now having freedom of access to such areas. Facilitating legislation was provided in 1998 (Crown Pastoral Land Act), which promotes ecologically sustainable land management through the tenure review process while also providing the Government with greater discretion over various forms of land use and development on leasehold land prior to, or in the absence of, tenure review. This discretion was aimed at "protecting the inherent values of the land" particularly as it applies to "indigenous plants and animals, and natural ecosystems and landscapes".

Tenure review is currently an on-going exercise under the Crown Pastoral Land Act 1998: by August 2003, 162 of the remaining 306 leasehold properties had entered the process. Only 12, however, were at or near completion of the exercise by this time, resulting in some 107 515 ha (61%) being free-holded and 69 577 ha (39%) allocated to full Crown ownership and control, to be managed by the Department of Conservation. Some 41 public access easements had been negotiated. Of the free-holded land some 12.9% has been constrained by formal covenants to provide for certain historic (c. 8%) and conservation (c. 5%) values, while about 18% of the land, which had been returned to full Crown control, had provisions for grazing under certain conditions for varying periods. This was largely to facilitate adjustment of farm management. A range of concerns had been expressed by conservation/recreation advocates up to this time, particularly regarding the disproportionate amount of land being free-holded, the loss of important indigenous biodiversity values, particularly invertebrates, through the very limited areas of low- to mid-altitude ecosystems being conserved, the general lack of altitudinal corridors to provide for possible effects of global warming, provision for stock grazing in perpetuity in many covenanted areas, particularly remnants of woody vegetation, which would inhibit ecological restoration, inadequate and/or unsuitable public access on some properties, inadequate attention to landscape values, and the lack of recognition given public submissions on the "preliminary proposals". A statement released by the Minister of Land Information at this time further clarified the objectives of tenure review as a process to "balance the interests of farming communities, conservation, public access and outdoor recreation groups". The objectives were described as being: (1) To promote the management of the Crown's high country land in a way that is ecologically sustainable; (2) To enable reviewable land (i.e., leasehold land subject to tenure review) capable of economic use, to be freed of current management constraints; (3) To protect significant inherent values on reviewable land by the creation of protective measures, or preferably by restoration of the land concerned to full Crown ownership and control; (4) To secure public access to and enjoyment of high-country land; (5) To take into account the principles of the Treaty of Waitangi; (6) To take into account any particular purpose for which the Crown uses, or intends to use, the land. Additional "complementary objectives" for the South Island high country announced at this time included: (a) Ensure that conservation outcomes for the high country are consistent with the New Zealand Biodiversity Strategy; (b) Progressively establish a network of high-country parks and reserves; (c) Foster sustainability of communities, infrastructure, and economic growth and the contribution of the high country to the economy of New Zealand; and (d) Obtain a fair financial return to the Crown on its high-country land assets.

The piecemeal approach to tenure review, consequent on initiatives being vested in individual lessees, has also meant that co-ordination of the outcomes through strategic planning by the government agencies has not been possible. Evidence to date indicates that rangeland which has been free-holded through tenure review will soon lose much of its nature conservation, including landscape, values

through various development options which mostly result in land-use intensification and often subdivision, constrained only by resource management legislation administered by local authorities. A separate concern has been the recent acquisition of several pastoral leases by mostly overseas buyers, usually at inflated prices and often involving changed use (e.g., life-style areas or tourism), for which the trespass rights of a pastoral lessee are advantageous and sometimes being exercised. Nevertheless, the potential conservation outcomes of tenure review, in terms of overcoming the long-recognised deficiency of formally protected non-forest ecosystems of the South Island rain-shadow region, are clearly being addressed with tenure review. The first high-country conservation park, Korowai/Torlesse (c. 21 000 ha) on the Puketeraki Range in mid Canterbury was achieved in 2001, largely through tenure review, as was Te Papanui Conservation Park (20 882 ha) on uplands of the Lammerlaw-Lammermoor Ranges in eastern Central Otago, which was opened in 2003. A wide spectrum of views prevails, even among grassland ecologists (O'Connor 2003; Mark & Dickinson 2004), on the merits of tenure review.

Non-pastoral indigenous grasslands of the high mountain high rainfall regions

Early in the country's European history most of the indigenous grasslands and associated high mountain lands of the generally inaccessible Southern Alps and its outlier ranges, as well as the more limited area of the North Island's axial ranges and higher mountains, were designated as unoccupied (unalienated) Crown land (UCL). Some of the more accessible areas, and even some relatively inaccessible areas, such as the head basin of the Hokitika catchment on the western slopes of the Southern Alps, that are now formally protected, were grazed by domestic stock in earlier times. Once formally protected, areas were used mainly for recreation, including ecotourism and recreational hunting, particularly of introduced red deer (*Cervus elaphus*) and more locally other species of deer as well as chamois (*Rupicapra rupicapra*) and thar (*Hemitragus jemlahicus*). First liberated in the 1860s, red deer spread virtually throughout the mountainous country and reached pest proportions in the more remote areas before very effective commercial hunting using helicopters, from the late 1960s, essentially eliminated them from the tussock grasslands and associated high mountain areas. Chamois were similarly hunted while thar have been managed to retain a herd of about 10 000 animals in the central Southern Alps. Subsequent recovery of the low-alpine snow tussock grassland and herbfields has been spectacular in most regions and, where monitored in the two southern national parks, has indicated a return to a near-natural state (Rose & Platt 1987; Mark 1989, 1993, 2000). Extermination of these feral ungulates, even if possible, seems unlikely in relation to the strong recreational hunting lobby, while the demand for feral deer will probably be a factor in determining their future numbers in more remote areas.

Remaining areas of indigenous grasslands

The proportion of the major indigenous grasslands and associated high mountain areas which still persist varies considerably among the various types. Essentially all of the baseline high-alpine and nival areas persist (Table 1; Appendix 1), which is also the case with the low-alpine snow tussock grassland and for the limited areas of montane to subalpine snow tussock grassland on the North Island and western South Island mountains. In the South Island rangeland region, however, where tussock grasslands were originally most extensive, about 81% of this latter type still persists, albeit with varying levels of modification, while for the more limited lower elevation areas in the eastern South Island it is much less (41%).

Of the montane to low-alpine red/copper tall-tussock grassland, some 45% persists in the North Island but only 28% in the South Island rangeland region and a mere 1% in the Island's eastern non-rangeland region, reflecting, in particular, its virtual elimination from the Southland Plains (Fig. 3B). Some 61% of it persists in the western South Island mountains where it was of much more limited extent (Table 1).

Of the montane to subalpine short-tussock grassland, some 42% still persists in the South Island rain-shadow rangeland region, generally in a much modified and/or degraded condition. However, it has virtually disappeared from the eastern non-rangeland South Island (c. 4% remaining) and the North Island (c. 1%). The limited areas of sward grassland in the North Island and western South Island have all virtually disappeared through land development.

Conservation status of the indigenous grasslands: 2002

Indigenous grassland conservation in New Zealand has generally followed the global pattern. Up to the early 1980s, formal conservation in New Zealand was achieved largely by default, despite strong public support on the basis of scenic and recreational

values of the most spectacular landscapes: some 16% of the land area was formally protected at this time but less than 0.5% had been reserved in deference to some form of development (Anon. 1980; Mark 1985). Traditionally, the protected natural areas network was based on the more spectacular areas of steep, mostly forested mountain lands and associated higher peaks in the high rainfall regions. These areas were keenly sought for recreation and were assumed to have negligible potential for alternative economic development. The plant cover here was appropriately referred to as "protection vegetation" in contrast to "production vegetation"on less extreme sites with potential for some form of economic development without undue risk of serious land instability. The steep wet, western tussock grasslands outside of national parks became the responsibility of the Forest Service in conjunction with extensive areas of adjoining protection forest, and was transferred to the Department of Conservation when the management of Crown lands was reorganised in the late 1980s.

A series of national parks, most of which embrace tussock grassland and associated high mountain areas, have been established periodically over time from 1887 to the present. Tongariro National Park, now of 78 651 ha, the first established, included extensive areas of tall red tussock grassland and mixed tussock grass-shrubland (Atkinson 1981). Ten of the 13 other national parks established since then contain indigenous tussock grasslands. In chronological order these are Mt Egmont in 1900 (33 534 ha) with red tussock grassland and tussock-shrubland, and associated high-alpine volcanic areas (Clarkson 1986), Arthur's Pass in 1929 (114 500 ha), with extensive areas of snow tussock and small areas of copper and short-tussock grasslands, Fiordland in 1952 (1 257 000 ha), with extensive areas of snow tussock grasslands and high-alpine communities, with limited areas of copper tussock grassland, Aoraki-Mt Cook in 1953 (70 696 ha), with limited areas of short-tussock grassland, but extensive snow tussock grassland and mixed tussock-shrublands, and high-alpine/nival areas (Wilson 1976), Nelson Lakes in 1956 (102 000 ha), also with extensive areas of snow tussock grassland, Westland in 1960 (117 547 ha), also with extensive snow tussock grassland and tussock-shrubland plus high-alpine and nival areas, and limited areas of red tussock grassland (Wardle 1979), Mt Aspiring in 1964 (355 518 ha), similarly with large areas of snow tussock grassland and high mountain areas (Mark 1977), Paparoa in 1987 (30 327 ha), with extensive snow tussock grassland and some high-alpine areas, Kahurangi in 1996 (452 002 ha), also with extensive areas of snow tussock grassland and high-alpine areas, and, most recently, Rakiura-Stewart Island in 2002 (157 000 ha) with limited areas of snow tussock and copper tussock grasslands (Wilson 1987). Other extensive areas of snow tussock grassland and limited areas of red/copper tussock grassland in both North and South Islands, mainly on the axial ranges, that were transferred from the Forest Service to the Department of Conservation in 1987, are now variously classified as forest parks, conservation parks, or conservation areas, with some limited additions to adjoining national parks.

In the South Island rain-shadow region the upland indigenous grasslands were retained in Government ownership and all allocated to pastoral farming, as rangeland. Reserves for scenic/landscape values, for nature conservation or scientific research as baseline reference areas, were slow to be established. Reserve surveys of Canterbury (Kelly 1972) and Otago (Allen 1976), the main rangeland provinces, highlighted the lack of representative protected natural areas at this time. For Canterbury, Kelly (1972) revealed that tussock grasslands covered some 68% of the pre-European landscape but only 5.7% of the total area then reserved. Similarly in Otago, Allen (1976) found that tussock grasslands covered some 71% of the pre-European landscape but contributed less than 13% to the reserves system, mostly in the uplands. The situation in the other two rangeland provinces, Marlborough and Southland, was similar (Mark 1985). The first scenic reserve established in the rangeland region, Lindis Pass (403 ha in 1976), on the uplands between Otago and Canterbury, was justified on landscape values. Indeed, pastoral farming has been allowed to continue on this reserve and it was not included among the areas recommended for protection in the Protected Natural Areas survey of the Lindis Ecological District by Ward et al. (1994). The first fully protected reserves of tussock grassland and associated communities were established in the late 1960s, but all as scientific reserves since they were promoted by ecologists and considered by the authorities to lack scenic value. Fully protected scenic reserves in the rangeland region were first recognised only in the late 1980s. Since then several have been established, some through retirement of high-altitude or degraded rangeland, with government-subsidised soil and water conservation plans, and, more recently, through tenure review as discussed above. According to an announcement by the Minister of Land Information (18 August 2003), tenure review is likely to result in up to 1.3 million

ha of rangeland, or about half the total area in the South Island rain-shadow region, being added to the network of parks and reserves.

The situation as at September 2002 is shown in Fig. 3 and is presented on the basis of the percentage of the areas of each vegetation type remaining at this time which is formally protected and managed by the Department of Conservation. Values for each of the four major geographic regions are shown in Table 1 while equivalent values for individual ecological regions are given in Appendix 1. Dealing with each of the seven cover types in turn, the nival areas of permanent ice and snow are virtually all formally protected; only some 6% of the 515 km^2 in the South Island rangeland region is not so protected. For the high-alpine communities, the biggest deficiency is in the South Island rangeland region where only 46% of the remaining area is formally protected, with a value of 82% for the western South Island region, giving a national value of 58%. For the low-alpine snow tussock grassland the national value is 50% protected with the greatest deficiency again being in the South Island rangeland region where only 27% (of the remaining 96%) is protected. Some 90% of this tussock grassland type is formally protected in the only other region where it is of importance, the South Island western non-rangeland region. Similarly with the montane to subalpine snow tussock grassland, only 12% (of the 81% remaining) is formally protected in the rangeland region but values exceed 70% in the other two regions where it is of some importance (North Island and South Island western non-rangeland regions), to give a national value of 31% (of the 84% which still remains) formally protected (Table 1).

For the red/copper tussock grassland the national value is a relatively low 16% of the limited areas remaining (20%), due mostly to the low value (8%) for the rangeland region. Of the mere 1% remaining in the South Island eastern non-rangeland region, where it originally comprised 47% of the total extent, only 33% is formally protected. The situation is rather better in the North Island where 27% is protected (of the 45% which still remains). Apart from the limited original areas of sward grassland, which have been essentially developed, the montane to subalpine short-tussock grassland has fared the worst. Nationally, only 3% of what remains (some 25% of the baseline area) is formally protected with the smallest values in the two South Island sectors where it was originally most important: the rangeland (47% of the total) and eastern (40%) regions (Table 1; Appendix 1).

DISCUSSION AND CONCLUSIONS

Globally, the temperate indigenous grasslands have been assessed as the most beleaguered biome with only some 0.69% of the total natural extent under some type of formal protection in the 1980s according to Henwood (1998a). The latest official figure, 4.59%, is still far short of the 10% target set by the World Conservation Union (IUCN) for each of the world's 14 terrestrial biomes, and remains the poorest protected (Chape et al. 2003). Given its relatively small size, New Zealand was not included in Henwood's (1998b) world assessment. Similarly, its contribution to the IUCN value for the extent of protection of the world's temperate grasslands would also be minor. Nevertheless, it would be appropriate to include the formally protected indigenous grasslands and associated mountain lands in the IUCN biome category of Temperate Grasslands rather than in Subtropical/Temperate Rainforests/Woodlands to which all of New Zealand's protected natural areas are currently assigned by the Department of Conservation, and the need to review the IUCN listings is accepted by the Department (A. Bignell pers. comm. April 2004). This is particularly so since it is clear from the results of this exercise that the situation in New Zealand, with some 12.3% of the baseline area of indigenous grasslands (82 432 km^2) now formally protected, is much better, percentage-wise, than for the world in general, or for any of the major temperate grasslands: North American prairies, South American pampas, eastern European-Eurasian steppes, South African grassveldt, and, particularly, Australia where more than 99% of its temperate native grasslands apparently have been lost since European development (Mark et al. 2003b). There has been a recent tri-national initiative aimed at developing a conservation strategy for the prairie grasslands of North America (Gauthier et al. 2003).

This assessment of the conservation status of New Zealand's indigenous grasslands (to September 2002) indicates that some 36 047 km^2 or 44% of the 82 432 km^2 of indigenous grasslands assumed to have been present at the time of European settlement in 1840 (the baseline state) still persists, albeit in a variously modified or degraded condition. The baseline extent of grassland has been depicted on maps for all areas where indigenous grassland species were assumed to have attained at least local dominance; some such areas may have contained co-dominant woody species or formed grassland-shrubland-forest mosaics, as still occurs in some areas to-day (Mark & Dickinson 2004). Of this baseline extent,

some 10 127 km^2 (12.3%) of the original baseline area is formally protected, representing 28% of the remaining areas of indigenous grassland. The level of protection, however, varies greatly among the five major grassland types recognised for this exercise. Montane to subalpine short-tussock grassland which had the greatest extent (44% of the baseline area) has been reduced to 25% of its baseline extent and, of this, a mere 3% is formally protected. Montane to subalpine tall red/copper tussock grassland (with very limited areas in the low-alpine zone on the North Island volcanic mountains) is about as seriously depleted; from a baseline extent of 23%, only 20% of it remains and, of this, only 16% is formally protected. Some 18% of the baseline grasslands were montane to subalpine tall snow tussock grasslands but, of this, about 84% persists with some 31% of it now formally protected. Tall snow tussock grassland occurring above the climatic treeline in the low-alpine zone comprised some 13% of the baseline extent and most of this (98%) still persists with half of it (50%) formally protected. The remaining 2% of the baseline extent was of lowland sward grassland, of which only very scattered remnants remain. Above the low-alpine snow tussock grassland, the high-alpine zone had a baseline extent of about 8697 km^2 (3.3% of the land area), all of which remains, with some 58% of it formally protected. The extent of the nival zone of permanent ice and snow, determined from Chinn's (2001) information to be 1238 km^2 (0.49% of the land area) is assumed to have remained essentially unchanged from 1840 and it is virtually all protected (97%). This estimated extent is smaller than the 1586 km^2 given in Leathwick et al. (2003) and 1570 km^2 in Leathwick et al. (2002).

There is also considerable geographical variation in the extent of indigenous grasslands that remain and also in the proportions which are formally protected. Three broad regions have been distinguished in the South Island in this regard, while the North Island, where indigenous grasslands were of more limited extent, has been treated as a whole. Here the limited areas of snow tussock grassland still persist whereas the somewhat larger areas of tall red tussock and short-tussock grasslands have been more seriously reduced and given more limited protection, while the lowland sward grassland has virtually disappeared through land development for agriculture. A generally similar situation prevails in the eastern non-rangeland region of the South Island whereas the western non-rangeland region, apart from the very limited area of lowland sward grassland, reveals relatively high levels of both persistence and protection. This reflects the extensive areas that have been progressively added to the public conservation lands, mostly as national parks. In the hill and high country of the South Island rain-shadow rangeland region, where tenure review of pastoral leasehold land is currently progressing, areas of tussock grasslands continue to be protected. By September 2002, when reviews of 36 of the 306 leases had been completed, the montane to low-alpine snow tussock rangeland mostly persisted and 27% (low-alpine) to 12% (montane to subalpine) of the remaining areas had been protected, while for the red/copper and short-tussock grasslands, both the levels of persistence and protection were relatively low. Comparable values have been calculated for each of the 60 ecological regions which contained some type of indigenous grassland in 1840, out of the 78 recognised for the three main islands (McEwen 1987). In five ecological regions we have recorded an increase in one of the major grassland types. A limited area of tall snow tussock grassland has displaced subalpine beech forest following fire on Mt Stokes in the Sounds Ecological Region of Marlborough while short-tussock grassland has apparently increased in extent in Inland Marlborough, Clarence, and Spenser Ecological Regions in Marlborough, at the expense of manuka-kanuka shrubland according to S. Courtney (pers. comm. 2003). Short-tussock grassland has also established in limited areas on valley floors, at the expense of copper tussock grassland, in the Mavora Ecological Region of northern Southland, where it is now mostly protected, according to B. Rance (pers. comm. 2003).

This information can be accessed on a website (http://www.botany.otago.ac.nz/tussockconservation) and, thus, is readily available for interrogation and further refinement. Given the somewhat limited information currently available from the Land Cover Data Base 1 used to map the current extent of "tussock" grassland, further refinement may be possible with the completion of the LCDB 2 map which, in contrast to one type among nine "natural landscapes", will distinguish three tussock grasslands (short, tall, and degraded) among 70 cover types.

Under the high country policy of the present government, the conservation status of New Zealand's indigenous grasslands has changed somewhat from the situation as at September 2002, the cut-off point used in this exercise. Most significant has been the purchase, in early 2004, of Birchwood Station (23 783 ha) in the Mackenzie Ecological Region, South Canterbury, which comprises a wide range

of indigenous vegetation types but mostly low-alpine snow tussock and montane to subalpine snow tussock and short-tussock grasslands, as well as several high-alpine communities: talus, fellfield, and snowbanks, plus limited nival areas. Government's announcement of its planned transfer in July 2005 of Molesworth Station (180476 ha), spanning the Clarence, Tarndale, and Spenser Ecological Regions of southern Marlborough, to be managed as a high-country park by the Department of Conservation, will add substantially to the protected area network of short-tussock and snow tussock grasslands when formalised. Grazing of cattle by LandCorp will continue here, under licence, as in the past. These two areas will form an important component of the network of parks and reserves, which is part of the current government's objectives, announced in 2003, for the tussock grasslands of the South Island high country.

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Appendix 1 Assumed extent (km²) of the five major indigenous grassland types, associated high-alpine and nival cover types in 1840, based on each of the 60 mainland ecological regions which are assumed to have contained indigenous grassland at the time of European settlement, in 1840, the baseline situation. The percentage of each type r□

			Nival			High-alpine communities			Low-alpine tall snow tussock			Montane-subalpine tall snow tussock			Montane-subalpine tall red/copper tussock			Montane-subalpine short tussock			Lowland sward grassland		Total (Tussock & Grassland)		
ID	Ecological Region	km²	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	Area (ha)	% R	% P
	North Island																								
15	Western Volcanic Plateau	3354																2527	0	-			2527	0	-
16	Central Volcanic Plateau	4898													354	52	5	208045	<1	0			208399	<1	4
17	Eastern Volcanic Plateau	3070																193988	2	80			193988	2	80
18	Tongariro	2124	541	100	100	12206	100	100							91275	39	68	5057	0	-			96333	37	68
19	Raukumara	4474				3	100	0																	
21	Urewera	3117																707	0	-			707	0	-
23	King Country	4043													339	0	-						339	0	-
25	Western Taranaki (Egmont)	2678				1143	100	100							758	100	100						758	100	100
26	Moawhango	1355							18	100	98				109743	50	1						109761	50	1
27	Kaimanawa	2790				886	100	68	2466	100	68	16024	100	61	22921	52	15	8853	12	5			50263	63	42
28	Ruahine	1386				146	100	100	1808	100	100	11538	100	82	366	62	0						13713	99	83
29	Hawkes Bay	4511										6	100	100							48681	0	48686	<1	100
30	Rangitikei	4058													5690	1	0						5690	1	0
31	Manawatu	4201																			43139	0	43139	0	-
32	Manawatu Gorge	873										96	100	100									96	100	100
33	Pahiatua	2532																			3712	0	3712	0	-
35	Eastern Wairarapa	3943																			2907	0	2907	0	-
36	Wairarapa Plains	1323																			59711	0	59711	0	-
38	Tararua	2410										4934	100	89							3474	0	8409	59	89
	Total	57141	541	100	100	14385	100	98	4292	100	82	32598	100	72	231446	45	27	419177	1	65	161625	0	839138	17	40
	South Island Western non-rangeland																								
39	Sounds	1529							13	100	0	0	>100	0									13	>100	-
40	Richmond	2113				455	100	100	343	100	100	15	100	100				517	0	-			875	41	100
46	North-west Nelson	7356				3660	100	100	30353	98	100	8057	100	95	10938	57	100						49384	89	99
47	Nelson	2628				1081	100	100	2684	100	94	5373	100	92	2572	100	89						10629	100	92
48	North Westland	7593				25	100	100	11582	100	100	16537	100	98	471	100	0				2959	0	31550	91	97
49	Spenser	5276	187	100	1	43495	100	12	43279	99	39	38797	98	78	657	61	0	6735	>100	7			89468	100	53
50	Central Westland	6945	29504	100	100	69832	100	100	49353	100	100	21465	100	100							6492	0	77301	92	100
51	Aspiring	6914	35426	100	98	85488	100	90	113928	100	87	68206	100	81	992	18	99						183125	100	85
71	Olivine	1488	394	100	100	5445	100	100	9434	100	100	7777	100	99									17211	100	100
72	Fiord	11966	6262	100	100	56937	100	100	130120	100	100	109397	100	99	784	14	98						240301	100	100
	Total	53808	71774	100	99	266418	100	82	391079	100	90	275625	100	91	16413	61	93	7253	>100	7	9450	0	699821	98	89

Appendix 1 (*Continued*)

ID	Ecological Region	km²	Nival			High-alpine communities			Low-alpine tall snow tussock			Montane-subalpine tall snow tussock			Montane-subalpine tall red/copper tussock			Montane-subalpine short tussock			Lowland sward grassland		Total (Tussock & Grassland)		
			Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	% P	Area (ha)	% R	Area (ha)	% R	% P
	South Island Eastern non-rangeland																								
41	Wairau	1620										20	87	0				38654	14	0			38674	14	0
45	Kaikoura	496																7656	13	0			7656	13	0
52	Lowry	3831																353425	11	0			353425	11	0
56	Canterbury Plains	7878																622689	<1	3			622689	<1	3
57	Banks	1032										1959	10	0				17829	14	11			19788	13	10
62	Wainono	1482																135228	0	-			135228	0	-
69	Otago Coast	2690							443	100	64	9568	33	49	45006	2	6	34872	4	12			86889	7	35
70	Catlins	3333													137699	2	18						137699	2	18
75	Gore	2972										156	0	-	289008	1	0						289163	1	0
77	Te Wae Wae	2347				8	100	100				621	82	100	39480	0	-						40101	1	100
78	Makarewa	3170										15	0	-	227959	<1	89						227974	<1	89
79	Rakiura	1770							48	100	0	1973	100	86	4779	38	82						6800	56	83
	Total	32619				8	100	100	491	100	58	14310	41	64	740932	1	33	1210354	4	1			1966087	3	11
	South Island rangeland																								
42	Inland Marlborough	2665				23916	100	0	8473	95	0	11187	81	1				3413	>100	0			23073	>100	0
43	Molesworth	2142				32363	100	4	14695	89	5	31963	89	1	13046	47	1	41075	70	2			100778	76	2
44	Clarence	3117	141	100	0	47143	100	6	7011	99	1	44901	95	4				26520	>100	3			78433	>100	3
53	Hawdon	874	628	100	100	22493	100	98	12316	92	100	6874	74	98				1919	100	72			21109	87	96
54	Puketeraki	3891				51411	100	43	34215	79	43	20253	46	11				207228	46	6			261696	50	14
55	Canterbury	2068				16	100	10				2263	91	0	4163	0	-	159367	33	2			165792	33	2
58	D'Archiac	1653	40336	100	99	68333	100	91	11683	100	89	8233	100	65									19916	100	79
59	Heron	3741	991	100	89	94003	100	42	59084	98	35	75095	83	9	1804	87	9	96378	69	3			232360	81	15
60	Tasman	1886	6034	100	79	80449	100	62	30097	100	42	26926	99	33	47	100	0	8686	64	12			65756	95	35
61	Pareora	5207				3333	100	0	16242	100	18	73988	99	7	954	89	0	385143	24	0			476327	38	4
63	Mackenzie	4928	45	100	0	25630	100	47	40341	99	21	65657	84	9	3449	73	0	321236	73	3			430684	77	6
64	Waitaki	2591				24139	100	38	63767	99	26	108359	87	12	1743	66	0	61071	56	2			234939	82	15
65	Kakanui	1908				114	100	19	5157	98	2	69414	27	3	5576	44	0	92908	1	0			173055	16	3
66	Lakes	6189	3216	100	67	73555	100	37	152371	98	27	207175	87	12				32850	11	13			392397	85	18
67	Central Otago	9611				1281	100	15	129458	97	6	217035	90	1	168916	62	1	443804	15	1			959214	51	2
68	Lammerlaw	4341							32224	94	21	43930	54	6	272312	28	8	68739	7	0			417205	32	10
73	Mavora	4304	127	100	56	38396	100	50	55543	97	42	80741	83	29	97548	19	37		>100	93			233832	60	35
74	Waikaia	2569				268	100	46	15196	95	16	92680	64	17	111630	13	6						219506	40	15
76	Southland Hills	2813				1997	100	100	9477	99	100	11168	78	99	201880	12	18						222525	19	53
	Total	66499	51519	100	94	588839	100	46	697352	96	27	1197842	81	12	883066	28	8	1950338	42	3			4728597	76	12
	TOTAL	**210068**	**123833**	**100**	**97**	**869650**	**100**	**58**	**1093214**	**98**	**50**	**1520376**	**84**	**31**	**1871856**	**20**	**16**	**3587121**	**25**	**3**	**171075**	**0**	**8243643**	**44**	**28**