Effects of removing grazing from native grasslands in the eastern South Island of New Zealand: a literature review

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CONTENTS

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A B S T R A C T

An increasing number of areas of native grassland, formerly used for extensive pastoralism, are being protected as public conservation lands in the eastern South Island of New Zealand. Information on the effects of grazing cessation on indigenous grasslands is required to inform management of these areas. This report reviews the published literature on this study area. A variety of studies examining grazing removal in short and tall tussock grasslands, spanning 4–45 years from Marlborough to Southland, are reviewed. Most studies focused on the removal of domestic sheep from montane to low alpine tussock grasslands. Removal of grazing by domestic stock is mainly beneficial to native grasslands, particularly less modified tall tussock grasslands, but can have highly variable results in more modified tall and short tussock grassland communities. A range of factors influence the response of grassland communities to grazing cessation. These include vegetation type, environmental factors, and the degree of modification by exotic species at the time of grazing removal. Ongoing monitoring will generally be required to ensure conservation objectives are being met.

Keywords: Tussock grasslands, grazing, retirement, exclosure, research, monitoring, conservation, New Zealand.

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1. Introduction

The indigenous grassland communities of the eastern South Island of New Zealand are subject to widespread grazing from both domestic and feral ungulates. Prior to European settlement, indigenous grasslands were browsed only by flightless indigenous birds and invertebrates and evolved without grazing from ungulates (Rose & Platt 1987; Mark 1992). For the last 150 years the most important grazer of indigenous grasslands in the eastern South Island has continued to be the domestic sheep (*Ovis aries*), used for widespread extensive pastoralism. The impact of European pastoralism on the indigenous grasslands of the eastern South Island has been well documented (e.g. O'Connor 1982; Mark 1994). Currently, few areas of indigenous grassland remain without some degree of modification (Mark 1992).

Retirement of indigenous grasslands from sheep grazing began in the 1940s and expanded in the 1960s and 1970s with the primary aim of soil conservation. Extensive areas of the eastern South Island high country were retired from grazing by domestic stock during this period (Scott et al. 1988; Allan et al. 2000). More recently, the conservation of inherent natural values has been the primary reason for the removal of grazing from indigenous grasslands (Mark 1985; Dickinson et al. 1998). Large areas of indigenous grassland previously managed for production are now managed as conservation land by the Department of Conservation (DOC). Some of these areas were identified and recommended for protection under the Protected Natural Areas Programme (PNAP) (Kelley & Park 1986). More recently, outcomes from the Tenure Review process set up under the Crown Pastoral Lease Act (1998) have resulted in large areas of indigenous grassland being formally protected.

The protection of indigenous grasslands from previous disturbances may not necessarily result in the community returning to an original or desirable state (Lord 1990; Walker et al. 1995). Therefore, information on the effects of release from grazing on indigenous grasslands is required to inform management of these areas, particularly in relation to introduced plant species (Grove et al. 2002). It is in this context that this report reviews research into the effects of grazing cessation on indigenous grasslands in the eastern South Island of New Zealand.

2. Background

The indigenous grasslands of the eastern South Island comprise both natural and anthropogenic grasslands ranging in condition from intact tall tussock ecosystems to severely depleted short tussock communities dominated by introduced *Hieracium* spp. Prior to European pastoralism, indigenous grasslands were dominated by caespitose (tufted) tussock growth forms that evolved in the absence of mammalian grazing. The tussock form still dominates the native component of indigenous grasslands and a range of communities are present throughout the eastern South Island. Broadly, major indigenous grassland types in the eastern South Island include lowland, montane to subalpine, and intermontane short tussock grasslands (*Festuca*, *Poa*, *Elymus* spp.); lowland to low alpine tall red/copper tussock grasslands (*Chionochloa rubra*); and montane to high alpine tall snow tussock grasslands (*Chionochloa* spp.). Nationally, approximately 43% of the pre-European indigenous grassland land area remains, with the majority of this area in the eastern South Island (A. F. Mark, pers. comm.).

Many indigenous grassland communities have undergone substantial geographical, compositional and structural changes since the arrival of humans. The main drivers of vegetation change have been periodic burning, grazing animals (domestic and feral), introductions of exotic plant species, and the addition of fertilizer inputs (Molloy et al. 1963; O'Connor 1982; McGlone 2001; Walker et al. 2003b). Several long-term studies indicate that ongoing change is widespread and, over the last four decades, has generally been towards increased dominance by exotic weeds and reductions in the diversity and abundance of native species, particularly in short tussock grasslands (e.g. Scott et al. 1988; Treskonova 1991; Rose et al. 1995; Hunter & Scott 1997; Jensen et al. 1997; Duncan et al. 2001).

The impacts of ungulate grazers other than domestic sheep on indigenous grasslands in the eastern South Island is generally more localized but can be no less destructive (Mark 1992). Such grazers include Himalayan thar (*Hemitragus jemlahicus*) and chamois (*Rupicapra rupicapra*) in the alpine zone along the Main Divide, with red deer (*Cervus elaphus scoticus*) more widespread at higher altitudes. Cattle (*Bos taurus*), feral sheep, and goats (*Capra hircus*) are present at a range of altitudes (Fenner et al. 1993). Rabbits (*Oryctolagus cuniculus*) and hares (*Lepus europaeus*) are also important grazers of indigenous grasslands east of the Main Divide (Norbury & Norbury 1996; Wong & Hickling 1999; Parkes 2001) but are treated only in combination with ungulates in this report. Possums and wallabies also graze indigenous grasslands in the eastern South Island but are not included here.

Little monitoring was undertaken to determine ecological change after land retirement under Soil and Water Conservation Plans in the 1960s and 1970s (Allan et al. 2000). A review of 56 completed vegetation monitoring studies in tussock grasslands found that 45% of the studies were intended to monitor changes in vegetation resulting from management of, and changes to, grazing regimes of sheep (including grazing cessation), and control of feral ruminant numbers (Allen 1993). A variety of methods were used and some of the studies are included in this report. However, many studies were considered to lack the appropriate experimental design required to increase understanding of natural processes or management effects (Allen 1993), and a large amount of data remains unpublished (Dickinson et al. 1992; Allen 1993; Floate 1994).

Protection of indigenous grasslands from grazing by domestic and feral ungulates is important for conservation values and to provide ecological baselines to assess the impacts of different management and/or land use regimes (O'Connor 1982; Mark 1985). The response of exotic species to the removal of grazing from indigenous grasslands is of particular interest to conservation managers (Grove et al. 2002). Dry ecosystems such as the indigenous grasslands of the eastern South Island have been identified as particularly vulnerable to weed invasion after animal control. Various naturalised tree, shrub, grass, and herb species have been reported to increase after goat, stock or rabbit control (Timmins & Geritzlehner 2003).

The extent of eastern South Island indigenous grasslands below the natural treeline during pre-human times is uncertain (see McGlone 2001; Mark & Dickinson 2003; Walker et al. 2003a; 2003b). Most lower elevation tussock grasslands either are, or are presumed to be, seral in nature and have generally undergone more extensive modification than those at higher altitudes. This has raised questions regarding the maintenance of tussock dominance and community diversity in the absence of prior disturbance factors such as grazing (Meurk et al. 1989; Norton & Miller 2000). The results of studies such as those reviewed here are of importance to inform sound conservation management.

3. Objective

The objective of this report was to provide a comprehensive review of the published literature on the effects of grazing cessation on the indigenous grasslands of the eastern South Island of New Zealand.

4. Methods

The literature relating to the specific topic of this review is relatively recent. The search for material to include was limited to published works. These were initially located by searching the ISI Web of Science provided online by the University of Otago using a range of search terms. References in published works of particular relevance were then scrutinized for further relevant literature. Specific websites were searched for relevant literature, namely those of Landcare Research, DOC, and the Royal Society of New Zealand, and further web searches were conducted to locate information on the topic in general. Several local researchers were consulted for advice on current information or material pertinent to the particular study area.

5. Results

Most studies focused on the effects of removing grazing sheep from montane to low alpine hill country tussock grasslands. However, grazing removal was also studied in a range of other communities and land systems including lowland reserves, intermontane valleys and basins, semi-arid areas, and high alpine grasslands. A variety of techniques were used to assess the effects of grazing cessation. These included monitoring of retired areas, comparative monitoring of adjacent retired and grazed areas, fenced exclusion of sheep (and/or rabbits), and fenceline comparisons. Study length ranged from 4–45 years after initial grazing cessation.

Little research on the responses of eastern South Island indigenous grassland communities to the removal or control of feral ungulates was found. Apart from Himalayan thar, no government-funded monitoring of ungulate pest impacts (and thus vegetation responses to their removal) in the central Southern Alps is being undertaken currently (Forsyth et al. 2000). Two studies from the southwestern South Island on the response of alpine grasslands to the control of feral ungulates are included below.

5.1 GRAZING REMOVAL IN MONTANE TO ALPINE TUSSOCK GRASSLANDS

Most of the indigenous grasslands in the eastern South Island are montane, subalpine, or alpine tussock grasslands. These communities make up most of the run country used for extensive pastoralism. It is important to note that retirement from sheep grazing does not necessarily remove all grazing effects as feral animals are generally still present and may have significant impacts on grassland vegetation (see Rose & Platt 1992).

5.1.1 Studies in either tall or short tussock grasslands

Rose et al. (1995) examined different grazing histories (continually grazed v. retired since, or prior to, 1968) in short tussock grassland between 700 m and 1350 m altitude in the Harper-Avoca catchment between 1965 and 1990. Earlier results from these transects were reported in Rose (1983). The overall trend was towards invasion by exotic species such as *Agrostis capillaris* and *Hieracium* spp. and declines in indigenous grassland species such as short tussock grasses and intertussock herbs. However, the effects of grazing history were variable with aspect and elevation. On sites of equivalent aspect and elevation, the total cover of exotic species was greater on grazed rather than retired blocks, and most of eight common indigenous species (such as *Festuca novae-zelandiae*, *Chionochloa flavescens* ssp. *brevis*, *C. macra*, *Rytidosperma setifolium*) were significantly more abundant on retired blocks than on grazed blocks.

Mark & Dickinson (2003) monitored narrow-leaved snow tussock (*Chionochloa rigida*) grassland protected from grazing for 30 years in the mid-altitude (690–770 m) Black Rock Scientific Reserve in upland eastern Otago. Initial results after 16 years were reported in Dickinson et al. (1992). Significant increases in the cover and height of snow tussock were recorded over the period, with co-dominant shrubs increasing non-significantly except for *Dracopyllum longifolium* which increased significantly. Biomass indices of the sub-dominant shrubs *Coprosma cheesemanii*, *Leucopogon colensoi*, *Gaultheria macrostigma* and several cryptograms increased significantly, while some native rosette herbs such as *Brachyglottis bellidioides*, *Oreomyrrhis colensoi*, *Plantago novae-zelandiae*, and the exotic *Hypochoeris radicata*, declined significantly. The exotic flatweed, *Hieracium pilosella,* remained a minor component in the system. An overall decline in vascular species diversity was recorded for the study period.

Allan et al. (2000) report that on one Canterbury property, vegetation monitoring revealed that 40 years of retirement had resulted in an increase in tall-statured snow tussocks and *Dracophyllum* shrubs especially at mid-altitude and in areas adjacent to local seed sources. This general pattern was also noted on two sites retired from grazing in either 1974 or 1989 in the Waimakariri River basin. Increases in cover were reported for the tall tussock *Chionochloa flavescens*, and the shrubs *Dracophyllum* spp., and *Leptospermum scoparium* (Hunter & Scott 1997).

Tall tussock (*Chionochloa* spp.) can recover from non-lethal burning or grazing by vegetative growth, however reproduction by seed production is the only means for re-establishing populations or colonising bare surfaces (Rose & Platt 1990). Two studies have examined the effects of different levels of grazing on tall tussock regeneration.

Rose & Platt (1992) studied montane to subalpine *Chionochloa macra* and *C. flavescens* ssp. *brevis* grasslands on previously forested sites (at 900–1500 m altitude) retired from grazing for 34 or 21 years in the Harper-Avoca catchment, Canterbury. Retirement had led to the recovery of snow tussock populations and the onset of increases in tussock abundance with low proportions of senescent tussocks and high proportions (> 60%) of seedlings and juveniles. Seedlings were most frequent within 70 cm of mature tussocks. This contrasted with sites subjected to grazing for c. 80 years where the remaining tussocks were mostly senescent and seedlings infrequent. These results suggested the probable long-term invasion of retired sites by snow tussock. However, results from one 10 year-old exclosure in *C. macra* grassland retired from sheep grazing for 34 years suggested that browsing from European hares alone may be capable of inhibiting recovery of this species (Rose & Platt 1992).

Lee et al. (1993) examined the effects of different grazing intensities (not grazing cessation) over an 8 year period on the regeneration of subalpine tall tussock (*Chionochloa rigida* ssp. *rigida*) at 1200–1300 m altitude on the Carrick Range, Central Otago. Low grazing intensity resulted in higher recruitment than at the moderately grazed site (4 v. 9 immature plants per tussock), higher mean seedling height and a higher proportion of seedlings in the smallest size class. The highest densities of recruits were found between 0.5–1 m from tussock centres and 72% of all immature plants occurred downhill or downwind from the tussock.

5.1.2 Studies covering tall and short tussock grasslands

Jensen et al. (1997) studied vegetation changes at mid-altitude (655–1870 m) sites in mostly tall tussock grasslands in Otago, Canterbury and Marlborough retired from stock grazing since the late 1970s. A highly significant increase in overall vegetation cover was recorded during the study period although the specific effect of retirement was uncertain. Overall, tall tussock (*Chionochloa* spp.) cover was generally low (under 50%) to begin with at the sites studied and a highly significant increase in percentage frequency was found for this group. Short tussock species either showed no clear trends (*Poa cita*, *Rytidosperma setifolium*) or their percentage frequency decreased significantly overall (but not at all sites) (*Festuca novae-zelandiae*, *Poa colensoi*). Other grasses including both indigenous and exotic species were among the main species to show increases (percentage frequency) in specific areas. Seventeen of 27 shrub species showed an overall increase in mean frequency (but remain a minor component of the studied communities) while combined native and exotic herbs decreased (excluding *Hieracium* spp.).

Grove et al. (2002) undertook permanent, height-frequency, vegetation monitoring at a range of mostly tall tussock grassland communities located in four conservation areas recently formally protected in Otago (Bain and Lauder Conservation Areas, and the Rock and Pillar Scenic Reserve) and Southland (Eyre Conservation Area). Monitoring sites ranged from 550–1580 m in altitude, with a monitoring interval of between 5 and 6 years, and included 10 paired grazed-ungrazed sites and 8 sites where grazing had ceased prior to the initial measurements. Overall, there was no significant increase in the abundance of exotic perennial pasture grasses following grazing cessation in these areas after 5–6 years.

In alpine grasslands in the Bain Conservation Area there was a general recovery (increase in height and cover) of the dominant snow tussocks (*Chionochloa rigida*, *C. macra*), with the recovery being greatest at lower elevations. A decline in bimas indices was recorded in intertussock species at some sites with little change in higher altitude tussock-cushionfield and tussock-herbfield communities over the period. Exotic species were uncommon in the alpine zone and generally declined where present. There was no indication of an increasing shrub component in the low alpine vegetation which is presently lacking woody seed sources. In low alpine tall tussock grassland in the Lauder Conservation Area, the dominant *C. macra* tussock biomass indices increased significantly at the ungrazed site although they still increased under light grazing nearby. No other plant species showed any grazing effects in this area (Grove et al. 2002)

Biomass indices increased in dominant *C. rigida* in both lightly grazed and ungrazed sites were recorded in montane to subalpine tall tussock grassland in the Bain Conservation Area with greater increases within stock exclosures. A significant increase in biomass indices of *C. rigida* at two ungrazed sites, and a decline under adjacent grazing, was recorded in montane to subalpine tall tussock in the Rock and Pillar Scenic Reserve. A corresponding decline in the abundance and diversity of intertussock herbs and grasses (native and exotic) at the ungrazed sites was found in the Rock and Pillar Scenic Reserve sites, with the opposite effect at the grazed Rock and Pillar site (Grove et al. 2002).

In ungrazed montane shrub-tussockland and short tussock (*Festuca matthewsii*) grassland at 550–660 m altitude in the Eyre Conservation Area, there was an increase in height and abundance of both native and exotic species but little change in species composition. The exotic grasses *Agrostis capillaris* and *Anthoxanthum odoratum* increased at ungrazed sites, as did palatable native grasses such as *Elymus solandri*. Grazing cessation aided the recovery of intertussock herb species and no decline in species diversity at the Eyre sites was recorded in response to grazing cessation. Overall, increased shrub growth was more prominent within exclosures but inconsistent between species (Grove et al. 2002).

Meurk et al. (2002; 2003[1]) studied changes in vegetation states of a range of tussock grassland communities over 10 years in the MacKenzie Basin. Sites were located in four grassland types and between 423 m and 944 m in altitude, with fescue tussock grassland (*Festuca novae-zelandiae*) at four localities, snow tussock grassland (*Chionochloa rigida*) at two localities, red tussock grassland (*C. rubra*) at two localities, and silver tussock grassland (*Poa cita*) at one locality. Three grazing treatments were established at each location: sheep and rabbit grazed, rabbit only grazed, and no grazing. Grazing levels were light over the study period. Overall, vegetation states in quadrats where *Hieracium pilosella* was initially dominant (> 50% cover) changed little regardless of grassland type or grazing treatment, and tall tussock vegetation states were generally more stable than short tussock states.

In fescue tussock grassland sites, the number of quadrats showing transitions to different states differed significantly among localities, as might be expected given their different initial compositions, but were independent of grazing treatment. Most quadrats in *Hieracium pilosella*-dominated states initially remained in these states, while many quadrats in states where *H. pilosella* cover was low (State A) or in which a number of native species were retained (State B) had changed to more *H. pilosella*-dominated states, with a corresponding decrease in many native species present initially in State B quadrats. Some early sign of recovery was noted for some native shrub species (*Carmichaelia petriei*, *C. vexillata*) in ungrazed treatments, while *Discaria toumatou* seedlings were noted in all treatments probably due to reduced grazing over the 10-year study period (Meurk et al. 2002).

In silver tussock grassland, *Poa cita* decreased across all treatments. In four ungrazed and five rabbit-grazed quadrats, the average cover of *Poa cita* decreased significantly (eliminated in three rabbit-grazed quadrats) reflecting substantial increases in the exotic grass *Dactylis glomerata* and the exotic forb *Echium vulgare*, and smaller increases in the native grasses *Dichelachne crinita* and *Rytidosperma unarede* (Meurk et al. 2002).

In snow tussock grasslands with average *Chionochloa rigida* cover ranging between 3% and 27%, gradual recovery of *C. rigida* stature and consequent suppression of *Hieracium pilosella* was recorded in the locality with overall higher snow tussock cover, while state transitions were few and inconsistent at the locality where initial *C. rigida* cover was lower and more patchy (Meurk et al. 2002).

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1 Although Muerk et al. (2003) is unpublished, it is included in this review, as it provides additional detail to Meurk et al. (2002).

In red tussock grasslands, state transitions reflecting increasing *Hieracium pilosella* dominance and decreasing *Chionochloa rubra* cover were seen in some ungrazed and rabbit-grazed treatments, as was the opposite trend towards *C. rubra* dominance in ungrazed and grazed treatments. Overall, *H. pilosella* cover was increasing while *C. rubra* cover remained similar over the 10 years and the observed state changes could not be attributed to particular grazing treatments (Meurk et al. 2002).

Overall, tall tussocks generally increased in cover with *Chionochloa rigida* increasing more often than *C. rubra*. Three-quarters of ungrazed tall tussock sites showed an increase in cover compared to 63% that showed a decline among the rabbit and fully grazed treatments. Short tussocks generally declined in cover and biomass over the study period, with increases occurring evenly in both fully grazed and ungrazed quadrats. Other native grasses increased or decreased with almost equal frequency by treatment, or there was a slight bias towards better performance in the ungrazed blocks (Meurk et al. 2003).

Duncan et al. (2001) measured vegetation change over 10–15 years on 142 permanently marked transects located in tussock grasslands in Otago and Canterbury. Thirty-eight transects were in areas retired from stock grazing prior to transect establishment. Sites managed for conservation purposes with no stock grazing over the study period showed a decline in species richness similar to that of grazed sites on pastoral lease land. Data from inside and adjacent to four fenced exclosure plots established for 7–9 years at between 960 m and 1500 m altitude showed a greater decline in mean quadrat species richness in ungrazed transects compared to grazed transects for three of four sites.

Widespread compositional change occurred in these grasslands over the study period independent of recent management history such as grazing or retirement (Duncan et al. 2001). Their observation concurs with that of Hunter & Scott (1997) who found no clear relationships between grazing levels and vegetation trends. Overall, Duncan et al. (2001) recorded a significant decline in species richness of both native and exotic species. With the exception of *Hieracium* spp. and *Chionochloa* spp. (which increased significantly in mean quadrat species richness reflecting their greater abundance along the transects) herbs, ferns, rushes, sedges and grasses all declined significantly in species richness (reflecting their decreasing abundance along the transects). Significantly declining species included short tussocks, *Poa colensoi* and *Festuca novae-zelandiae*, and the native intertussock species *Anisotome flexuosa* and *Raoulia subsericea*. The rate of decline in species richness was also apparently unrelated to either changes in the abundance of either *Chionochloa* spp. or *Hieracium* spp. or an overall increase in total vegetation cover on transects (Duncan et al. 2001).

5.2 LOW- TO MID-ALTITUDE GRASSLANDS

The indigenous grassland communities in this section are generally moderately to highly modified, and have been considered vulnerable to increasing exotic plant species after grazing cessation (Meurk et al. 1989; Walker et al. 1995; Walker et al. 2003b). Semi-arid grasslands such as those in Central Otago are among the most modified grassland ecosystems in New Zealand and have proved particularly susceptible to over-exploitation and invasions by exotic plant and animal species (Walker et al. 1995). Lowland and alluvial grasslands are generally more fertile than semi-arid areas and are, therefore, more highly prized for pastoral production. These communities have been subject to more intensive modification for agricultural purposes (Lord 1990; Walker et al. 2003b).

5.2.1 Semi-arid grasslands

Highly modified grassland/shrubland dominated by exotic species, but with a higher number of native species than exotic species was described by Walker et al. (1995) at Flat Top Hill (140–545 m altitude) in Central Otago shortly after it was acquired for conservation. Walker (2000) reported on vegetation changes 4 years after sheep and rabbit grazing ceased in the area.

There was significantly higher species richness in 1997 as compared to 1993 for exotic annual and perennial grass species, exotic perennial forbs, exotic woody species and native tussock grasses. A significant decrease in the proportion of native species contributing to total species richness was recorded, reflecting a significant increase in average per-site exotic species richness and diversity but no significant change in the per-site native species richness of. The exotic herbs *Hypochoeris radicata* and *Crepis capillaris* showed the greatest increase in distributional range, while the exotic grass *Anthoxanthum odoratum* showed the greatest increase in total local frequency (Walker 2000).

However, the average number of native tussock grasses (e.g. *Festuca novae-zelandiae*, *Poa colensoi*, *Elymus tenuis*) per-site increased significantly. Seven of eight 'tall' native grasses increased with little evidence of their exclusion by exotic perennial grasses in competitive-sorting or successional processes. Absence of grazing was considered by Walker (2000) to be the best option for continued recovery of the remnant native tussock grassland, although different management strategies might be required for some species. For example, grazing cessation and the subsequent increase in exotic grasses may have been impacting on rare native annual forbs and some native perennials such as the dwarf xerophytic grasses *Rytidosperma buchananii* and *R. thomsonii*, which decreased in local frequency over the study period. Also, native tussock grasses on shady slopes were considered to be at risk from the increasing exotic grasses *Festuca rubra* and *Dactylis glomerata*. (Walker 2000).

The local frequency of the exotic woody species *Thymus vulgaris* and *Rosa rubiginosa*, also increased rapidly in the absence of grazing at Flat Top Hill (Walker 2000). After 8 years at the same site, a number of native woody species such as *Carmichaelia compacta*, *Kunzea ericoides*, *Pimelea aridula*, *Ozothamnus leptophyllus* and *Hebe pimeleoides* var. *rupestris* have been observed regenerating in the absence of sheep and rabbits. In short tussock grassland at Luggate in Central Otago, the exclusion of mammalian grazing combined with annual fertilizer addition resulted in native shrub dominance within 12 years. The cessation of grazing may encourage regeneration of a range of woody species in depleted or mixed short tussock grassland communities in the absence of fire and grazing and in the presence of seed sources (Walker et al. 2003a).

Allen et al. (1995) compared vegetation change over 6 years in sheep-excluded, sheep- and rabbit-excluded, and control (low to zero sheep grazing) areas, in depleted semi-arid grassland at Galloway and Earnscleugh Stations in Central Otago. The vegetation was dominated by exotic species but retained a residual native component. Substantial changes in the structure and composition of the vegetation were recorded in the absence of grazing, however the only general trends to emerge were an increase in the frequency of perennials (such as the exotic grass *Dactylis glomerata*) and year-to-year changes becoming smaller with time. Total vegetation cover values generally followed year-to-year changes in species frequency and seldom changed as a result of grazing cessation.

After 14 years of grazing cessation at Galloway Station, *Dactylis glomerata* had increased at the expense of *Festuca novae-zelandiae*, while at Earnscleugh Station native species were excluded from short annual grassland by increases in *D. glomerata* and *Festuca rubra* in response to grazing cessation and high rainfall. The replacement of low growing native species by exotic pasture grass (*Anthoxanthum odoratum*) in response to high rainfall and grazing cessation was also recorded at Luggate (see Walker 2000).

Walker et al. (2003c) investigated the responses of semi-arid short tussock grassland at Luggate to different grazing management and the addition of fertiliser and irrigation treatments between 1988 and 2000. The cover of native tussock grasses and *Carmichaelia petriei* decreased under grazing, remained steady with no grazing, and increased with resource enrichment (irrigation or fertiliser) plus no grazing. Native species richness and native forb cover decreased, while exotic grass cover increased in all treatments, and exotic species richness decreased in all ungrazed treatments. Overall, there was limited recovery of taller native species with grazing removal alone, but the addition of irrigation or fertiliser to ungrazed treatments promoted the growth of native tall shrubs and tussocks without resulting in physiognomic dominance by exotic species. In the 'ungrazed plus fertiliser' treatment, *Hieracium pilosella* was almost completely excluded by a dense sward of native tall shrubs and tussocks and exotic grasses.

5.2.2 Alluvial grasslands of intermontane valleys and basins

The present-day vegetation of intermontane valleys and basins of the eastern South Island comprises mostly modified indigenous grassland communities, with a high level of exotic species, and a minor woody component. These are among the few, natural, non-forest ecosytems that exist below the treeline in New Zealand (Walker et al. 2003b). Walker et al. (2003b) studied indigenous grassland communities in 56 alluvial catchments throughout the South Island east of the Main Divide in Marlborough, Canterbury, Otago, and Southland. Vegetation patterns are described in detail for 47 of these catchments in Walker & Lee (2000, 2002). Eight alluvial vegetation types were identified in three plant community categories: *Festuca novae-zelandiae* grasslands, *Festuca matthewsii* grasslands, and *Chionochloa rubra* grasslands.

Thirteen exclosures or grazing-retirement fences were sampled (all positioned in relatively modified vegetation types) to examine the effects of grazing cessation and different management histories, representing only a small proportion of the intermontane valleys and basins sampled overall. No relationship between ungrazed v. grazed differences in native species richness and biomass proportions was found at the exclosure sites, with the results almost evenly split over the 10 sites. This was not unexpected as baseline data for the exclosures was unavailable, and the size of the sample relative to the range of communities present was limited. At retirement fenceline sites, the precise causes of contrasts (e.g. management regimes such as burning and/or grazing) were not known but suggested a loss of structural tussock dominance and that the replacement of native species by exotic species may be continuing in intermontane valleys and basins under pastoral use regimes (Walker et al. 2003b).

The competitive exclusion of native species by exotic species was not a universal outcome of grazing cessation in the exclosures despite the vegetation being relatively modified and considered vulnerable to invasion by exotic species. Results from the 10 exclosures cannot be readily extrapolated to indicate potential effects of grazing cessation in less modified vegetation types. It is likely that predictions of vegetation changes following grazing cessation in intermontane valleys and basins will involve a high degree of uncertainty. However, grazing cessation is likely to be appropriate to increase the biomass and stature of tussocks (Walker et al. 2003b).

5.2.3 Lowland grasslands

Meurk et al. (1989) reported on changes in modified short tussock grassland in three small lowland reserves in Canterbury, released from grazing for between 10 and 20 years. Overall, the cover of naturalized species increased, generally at the expense of indigenous species, and indigenous species richness mostly declined.

This trend was most pronounced in silver tussock grassland on the Port Hills (highly modified, moderately fertile soils), where *Poa cita* short tussock density was markedly lower in ungrazed sites while that of exotic grasses such as *Dactylis glomerata* and *Agrostis capillaris* increased (Meurk et al. 1989; Lord 1990). In this instance, cessation of grazing led to a decrease in the number and abundance of indigenous species (particularly intertussock forbs), and fewer adventive species but higher adventive cover. The clear trend was towards dominance of a few exotic species, particularly *Dactylis glomerata*, when grazing pressure was removed (Lord 1990).

5.3 SOIL AND VEGETATION RESPONSES

Basher & Lynn (1996) compared soil characteristics from within and adjacent to two vegetation exclosures retired from stock grazing for 45 years, and located in grazed blocks of mixed short tussock grassland at 810–870 m altitude near Porters Pass in Canterbury. Prior to exclosure, both sites were short tussock grassland dominated by *Festuca novae-zelandiae*, *Poa colensoi*, and one or both exotic grasses, *Agrostis capillaris* and *Anthoxanthum odoratum*. At both sites there were few significant differences in soil tests comparing exclosure and adjacent sites, despite vegetation recovery, suggesting a slow rate of change of soil properties following the cessation of grazing.

Both exclosure sites showed a recovery in the vegetation in the absence of grazing with bare ground reduced from 17–18% to 5–8% within 5 years of exclosure. However, vegetation recovery was variable between the sites. One exclosure site became dominated by the tall tussock *Chionochloa flavescens*, with *Dracophyllum acerosum*, *Poa colensoi*, and *Aciphylla aurea* common, while the adjacent grazed area consisted mostly of exotic grasses and *Hieracium* spp. with scattered short tussocks. The other exclosure site became dominated by exotic grasses with some *Hieracium* spp. and scattered or rare short and tall tussocks and shrubs, while the adjacent grazed area was similar but without scattered tall tussocks (Basher & Lynn 1996).

McIntosh & Allen (1998) also compared soil and vegetation changes within and outside two exclosures (sheep plus rabbit). The exclosures had been present for 15 years on steep and shady slopes at 770 m altitude in the upper Waitaki Valley. Grazing cessation resulted in greater plant cover, close to double the biomass of standing vegetation, greater root biomass, and more biomass nutrients compared with grazed areas. However, native species were not favoured by grazing cessation with little change in the diversity or abundance of the dominant native grasses (*Festuca novae-zelandiae*, *Poa colensoi*) and forbs, but increases in the cover of major exotic perennials such as *Anthoxanthum odoratum*. Grazing cessation had little effect on soil nutrients or soil carbon on either sunny or shady aspects.

Changes in soil properties in response to grazing removal have not been particularly consistent or marked. Both Basher & Lynn (1996) and McIntosh & Allen (1998) reported little change in soil properties after 45 years and 15 years respectively. The slow rate of change in soil properties following grazing cessation is probably because the total nutrient pool is relatively constant in the absence of fast-weathering or parent material inputs, and because plants take up most surplus nutrients (McIntosh & Allen 1998).

5.4 FERAL UNGULATES

Reliable information about the influence of feral ungulates on indigenous communities and ecosystems (including indigenous grasslands) is required to guide and justify management (Forsyth et al. 2002). Research on feral ungulates has generally focused on their general impact on ecosystems and aspects of diet (see King 1990; Fenner et al. 1993; Forsyth et al. 2002). Parkes & Thomson (1999) assessed alpine grassland vegetation condition (mostly snow tussock) in relation to densities of Himalayan thar but found thar density was not a consistent predictor of vegetation condition, although a lack of experimental controls in the study meant that any conclusions were tentative.

The impacts of the feral ungulates such as red deer, chamois and Himalayan thar on indigenous grasslands were most severe for the several decades preceding commercial helicopter hunting in the mid 1960s, and included the local elimination of some plant species (Fraser 2000). There is little published research quantifying post-control vegetation responses of these species, although recovery of alpine grasslands is generally noted (see King 1990).

Currently, there is a general lack of quantitative information on the impact of some species such as chamois on indigenous grasslands, and of ecosystem responses to feral ungulate control in the eastern South Island.

Recovery of mostly alpine grasslands in western high-rainfall areas such as Fiordland and Mt. Aspiring National Parks was, however, reported during a period of when high deer numbers were reduced substantially by sustained hunting pressure (Rose & Platt 1987; Mark 1989).

In Northern Fiordland alpine grasslands, vegetation recovery between 1969 and 1984 was most prominent on more fertile sites where deer preferentially browsed *Chionochloa pallens*, *C. flavescens* and associated large herbs which are major components of deer diet in alpine grasslands. Prolific establishment of snow tussock seedlings in these areas was recorded in response to deer control. Vegetation recovery was relatively rapid on fertile sites, particularly at lower elevations, making them sensitive sites for monitoring responses of these grasslands to different grazing pressures by red deer (Rose & Platt 1987).

During a similar period in Mt. Aspiring National Park, grassland condition was most improved in low alpine snow tussock grassland dominated by *Chionochloa pallens* with increases in height and cover of the dominant tussock and increases in the most palatable large herbs. Areas of valley grassland had noticeably improved plant size and floristic richness, whereas low alpine snow tussock grassland dominated by *C. crassiuscula* had only marginally improved (Mark 1989). Recovery was such that these grasslands were considered to be returning to a condition approximating to their natural state (Mark 1992).

6. Discussion

A number of factors have made it difficult to establish causal links between vegetation change and environment or management in New Zealand tussock grasslands. These include ecological lag effects, the presence of multiple types of grazers, diverse natural disturbances and unknown management practices (Walker et al. 2003b). While some general trends are beginning to emerge, physiographic and bioclimatic diversity and a heterogenous landscape make predictions of post-pastoral vegetation changes difficult. Early trends in vegetation composition and structure can be variable and unpredictable after management for conservation purposes is introduced (Mark & Dickinson 2003), with highly modified areas being more unpredictable than relatively unmodified areas with few if any exotic species.

6.1 GRASSLAND COMMUNITIES

Recovery of tall tussock and establishment of snow tussock seedlings was recorded after grazing cessation and control of feral animals in many studies in tall tussock grassland (Rose & Platt 1987; Mark 1989; Rose & Platt 1992; Lee et al. 1993; Duncan et al. 2001; Grove et al. 2002; Meurk et al. 2002; Mark & Dickinson 2003). In relatively unmodified naturally occurring ecosystems, protection from grazing can result in increased abundance and/or diversity of native species; and controlling feral animals and woody weeds such as wilding pines may be enough to meet conservation objectives.

Short tussock grasslands are mostly semi-natural because they are generally seral in nature and modified by pastoral practices and introduced species (Grove et al. 2002). The practice of opening up tall tussock grasslands and their transformation to short tussock grasslands has reduced the stability of these grassland communities (Meurk et al. 2002). The effects of grazing cessation on these communities is mixed, and complicated by their instability.

In fescue tussock grasslands, trends such as invasion of *Hieracium pilosella* and the loss of intertussock herbs (and sometimes of fescue tussock) appear to be occurring after the cessation of grazing in some studies (Rose et al. 1995; Meurk et al. 2002), but not in others (Grove et al. 2002). While cover and/or frequency of fescue tussock decreased after grazing cessation in some studies (e.g. Jenson et al. 1997), it increased in other situations (see Rose et al. 1995), and has decreased under grazing too (Scott et al. 1988). Vegetation recovery towards native species-dominance after grazing cessation in fescue tussock grasslands has generally been slow and limited where it has occurred (Walker et al. 2003c).

Semi-arid vegetation that is managed for pastoral use has been shown to be inherently unstable, with species composition fluctuating from year to year (Allen et al. 1995). In depleted grassland, or where invasive exotic species occur, native species tend to decrease in abundance without grazing but show a more positive response in areas with a higher tussock cover (Rose 1983; Scott et al. 1988). Many studies of short tussock grassland following stock removal show that cover and species richness of annual and short-lived species have decreased, and that vegetation has become dominated by a few tall exotic perennial species over time (e.g. Meurk et al. 1989; Lord 1990; Allen et al. 1995). However, many studies also report the continued decline of short tussock grasslands under grazing regimes (e.g. Walker et al. 2003c).

6.2 *HIERACIUM* SPP. AND INTERTUSSOCK HERBS

Many studies report increases in frequency and/or cover of *Hieracium* spp. (mostly *H. pilosella*) independent of grazing regimes. Large tussocks and associated thick litter layers provide the greatest resistance to *Hieracium* spp. invasion in tussock grasslands while tall tussock recovery and increased tall tussock seedling abundance may reduce *Hieracium* spp. in many areas in the long term (Rose & Frampton 1999; Meurk et al. 2002; Mark & Dickinson 2003). The current spread of *Hieracium* spp. in short tussock grasslands in the eastern South Island suggests that transitions to *Hieracium* spp.-dominated states are likely to continue in fescue tussock grasslands at least, with or without grazing (Meurk et al. 2002).

Many studies also reported a decline in species richness and abundance of intertussock herb species (Duncan et al. 2001; Grove et al. 2002; Meurk et al. 2002; Mark & Dickinson 2003). Duncan et al. (2001) found that the loss of intertussock species richness was unrelated to increases in the abundance of the competitive dominants *Hieracium* spp. and *Chionochloa* spp. However, Meurk et al. (2002) reported that an increase in *H. pilosella* cover coincided with the decrease in native, low-growing species, as did an increase in cover and/or biomass indices for *Chionochloa* spp. with a decline in intertussock herbs in other studies (Grove et al. 2002; Mark & Dickinson 2003). Walker et al. (2003c) also reported a simultaneous increase in the cover of exotic grasses and *H. pilosella* with decreasing cover of native forbs, which is consistent with the occurrence of competitive exclusion.

Meurk et al. (2002) considered that options for maintaining diverse intertussock floras in induced tussock grasslands were elusive, particularly in light of the continued spread of *Hieracium* spp. Similarly, Walker et al. (2003c) suggested there may be few measures that will maintain high numbers of the early-seral, light-demanding native herbs that contribute to native species richness in *Festuca novae-zelandiae* short tussock grasslands. Native intertussock herbs may continue to decline regardless of management and/or successional trajectory in short tussock grasslands. However, low-intensity stock grazing may be appropriate in some montane to subalpine communities to maintain native species diversity (Grove et al. 2002).

6.3 SUCCESSION BY WOODY SPECIES AND COMPETITION FROM EXOTIC GRASSES

In many areas where short tussock grassland is present exotic species are a major component of the vegetation. Further spread of palatable grasses in the absence of grazing has been identified as a threat to native grassland species in modified grasslands (Meurk et al. 1989; Lord 1990; Walker et al. 1995). In these situations, the recovery of native grassland vegetation depends largely on the presence and vigour of the exotic species present. Fertile and/or high rainfall environments favour *Festuca rubra* and *Dactylis glomerata* which can form dense swards and exclude native short tussocks, particularly when tussocks are widely spaced; whereas drier, cooler and less fertile sites support *Anthoxanthum odoratum*, *Agrostis capillaris*, and *Hieracium pilosella*.

Competition from exotic grasses after the removal of grazing is more apparent in mesic situations and fertile sites. Walker (2000) reported no evidence of competitive suppression of native grassland species by exotic grasses in the dry grasslands at Flat Top Hill but suggested it may occur on the shady slopes in the area. Similarly, apart from one fertile *Poa cita* grassland site, Meurk et al. (2002) found no evidence of prolific establishment of palatable exotic species due to the absence or reduction of grazing in short tussock grassland in the MacKenzie Basin.

The exclusion of native species by *Dactylis glomerata* was recorded from Central Otago in response to high rainfall and grazing cessation (Allen et al. 1995; Walker 2000), and is recorded in several studies in *Poa cita* tussock grassland (Meurk et al. 1989; Lord 1990; Meurk et al. 2002). Where *Dactylis glomerata* is present in short tussock grassland, it appears to respond consistently to the removal of grazing and will competitively exclude or suppress native species in more fertile and mesic situations. However, the competitive exclusion of native species by exotic species was not a universal outcome in the short tussock grasslands studied. Where environmental factors limit plant growth there may little or no change in species composition due to grazing cessation, but where plant growth is not severely limited the response to grazing cessation appears to depend on the initial condition of the vegetation (Lord 1990).

In the Mackenzie Basin there was no evidence that grazing removal led to increased weed invasion in the tall snow or red tussock grasslands studied by Meurk et al. (2002). The regeneration of native shrubs in both tall and short tussock grasslands was reported in several studies (Grove et al. 2002; Meurk et al. 2002; Walker et al. 2003a). However, it was not a universal result of grazing cessation, relies on the presence of nearby seed sources, and may be occurring over long time frames (Mark & Dickinson 2003).

A range of factors may complicate the effects of grazing cessation in indigenous grasslands and responses were often variable within discrete study areas. For example, differences between grazed and ungrazed sites were sometimes more apparent on north-facing sites in two studies (Rose 1983; Grove et al. 2002). A decline in *Poa cita* short tussock in the grazed treatment at one site in Meurk et al. (2002) was attributed to drought, and an increase in forb cover following reduced grazing due to high natural fertility enhanced by top-dressing. An unusually good growing climate with more than average rainfall was present during the period of study in Walker (2000), and this may have added to the effects of grazing cessation. Significant declines of total biomass indices and maximum height in *Chionochloa macra* at two sites in Otago after grazing cessation were considered to most probably reflect the effect of late snow-lie on the vegetation (Grove et al. 2002).

7. Conclusions

The reported effects of grazing cessation are variable, and may be seen as a function of a site's physical environment, or its degree of modification, or both (Lord 1990). Removal of grazing was generally considered appropriate for tall and short tussock grassland, although low-intensity grazing may be appropriate in both tall and short tussock grasslands in some situations. Long-term research and monitoring are required to better understand potential and actual successional processes and the recovery of indigenous grasslands from grazing by domestic/feral animals and previous management regimes.

The effect of grazing cessation on the indigenous grasslands of the eastern South Island is variable on a range of scales. Vegetation responses are influenced by vegetation type, the stature and density of the native physiognomic dominants at the time of grazing cessation, environmental factors, and by the competitive abilities of the exotic species present (Walker et al. 2003b). There is no single management regime that fits all scenarios. However, the removal of grazing has generally been considered beneficial to the indigenous components of native grasslands, although results are variable and must be considered in context.

There are important differences between the response to grazing cessation of natural grasslands (e.g. alpine grasslands above the treeline along the main axial range), induced but relatively stable grasslands, and seral grasslands changing rapidly through successional processes. It seems likely that communities currently dominated by tall native tussock and/or shrub species will retain native dominance following grazing cessation or control of feral herbivores. In areas where native biomass is lowest and exotic species are most vigorous, responses to grazing cessation are generally more unpredictable. They will require ongoing monitoring and a range of management options to achieve conservation gains.

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