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KAIMANAWA FERAL HORSES AND THEIR ENVIRONMENTAL IMPACTS

Summary: Feral horses *(Equus caballus* L) occupy 64 000 ha of montane-subalpine tussock grassland in the south-western Kaimanawa Mountains, an area zoned for military training. Since 1979, the population has increased at 16.7% per annum, reaching 1102 in 1990. The most extensive habitat, red tussock *(Chionochloa rubra)* grassland, was variably affected by horses; tussocks in restricted mesic sites were heavily grazed and mostly eliminated, but those in extensive xeric grasslands showed little impact. The mixed hard tussock *(Festuca novae-zelandiae)*/red tussock grasslands on basin floors and plateaux, which had already been degraded by early European farming, were suffering further depletion from horse grazing. The restricted, high altitude *Chionochloa pallens* tussock communities were being eliminated rapidly through preferential grazing. Oligotrophic bogs, on the summits and basin floors were largely intact, whereas high nutrient flushes were severely affected by trampling and grazing. Horses appeared to have had little impact upon *Nothofagus* forest understoreys. Ten plant species, several of which are vulnerable nationally, occur in the North Island only within the wild horse range. The habitats of five of them were damaged by horses. Throughout the wide basins and plateaux of the north, horses compromised floristic, rare plant habitat, and landscape nature conservation values. Their numbers may therefore have to be controlled.

Keywords: feral horses; *Equus caballus;* population density; fecundity; grazing damage; tussock grassland; threatened plants.

Introduction

Free-ranging horses *(Equus caballus* L) once occurred over much of the central North Island, but on the Tongariro volcanic uplands and on the Kaingaroa Plains they have progressively disappeared since the 1950s. The only surviving population is now restricted to 64 000 ha of the south-western Kaimanawa Mountains, largely on land administered by the Ministry of Defence. The Kaimanawa population is broadly confined to the Moawhango River headwaters (Fig. 1), a region bounded by State Highway 1 in the west, Waipakihi Stream in the north, Rangitikei River in the east, and sheep stations east of Waiouru in the south. Since the 1930s, horses have survived in the region because Army tenure has restricted public access and exploitation.

With the exception of managed Przewalski horses in Russia, all free-ranging horses throughout the world are derived from domestic breeds (Berger, 1986). Feral horses were first recorded in the Kaimanawa Mountains on 15 March 1876 (R.A.L Batley, *pers. comm.)*. The genetic origins of the Kaimanawa horses were diverse (Wright, 1989) and include input from Sir Donald Maclean's "Comet" breed at Maraekakaho, Hawke's Bay, which was based on mares of Exmoor pony descent crossed with Welsh stallions. Other likely sources were cavalry horses released in 1941, and horses introduced by Maori in the 19th century.

Horse numbers in the Moawhango region were low in the 1950s (R.A.L Batley, *pers. comm.)* and early 1970s (C.C. Ogle, *pers. comm.)*. After investigating aspects of the population biology and the social organisation of wild horses at Motumatai (Fig. 1) in 1979, Aitken *et al*. (1979) estimated the total population at 174. The present estimate of 1102 is based on an aerial census in April 1990.

Feral horses represent a complicated problem in contemporary wildlife management. Protection was afforded them by a Special Order in Council enacted in 1981 under the provisions of the Wild Animal Control Act 1953, and numbers have so increased, that there is now a need to resolve conflicts between maintaining them and protecting other nature conservation values. However, management is hampered by a lack of reliable information on their ecology (particularly demography), and will probably be influenced by the demands of special interest groups and the emotional issues involved.

The present study sought to assess the impact of horses on their adopted habitat, particularly in relation to the fragile, open vegetation communities and the biogeographically special plants. More specifically, the study aimed to:

1. assess the level of grazing compatible with maintaining the viability of various tussock populations;
2. determine the changes in vegetation structure and composition after grazing had ceased;
3. monitor impacts on vulnerable, and/or biogeographically important plant species and their habitats;
4. prepare preliminary horse distribution and reproduction statistics from aerial surveys.

Study area

Moawhango resembles most wild horse habitat throughout the world in its savanna appearance. The region is dominated by a peneplain of subdued greywacke relief with broad convex ranges separated by wide shallow basins. Deeply incised antecedent gorges occur where the Rangitikei and Moawhango Rivers have down-cut the greywacke peneplain during uplift in the Kaikoura Orogeny. There are thin discontinuous remnants of Cenozoic marine sediments overlying parts of the basement greywacke. Soils are derived from 2-3m of Holocene andesitic ashes. However, Taupo Pumice is interbedded with the andesitic ash in the north where it forms 10-20m deep deposits on basin floors and a thin veneer on rolling uplands (Rogers and McGlone, 1989).

Much of. the region was deforested by Polynesian fires 400-600 years ago (Rogers, 1987), but in more broken greywacke topography about the Moawhango and Rangitikei Rivers, remnants of the mixed *Nothofagus*[1] forests persist on south-facing, mid-valley slopes. The wide basins have both arid pavements of Taupo Pumice with sparse *Raoulia* vegetation and more mesic pavements of andesitic ash supporting red tussock *(Chionochloa rubra)* and hard tussock *(Festuca novae-zelandiae)* grassland with scattered monoao *(Dracophyllum subulatum)*. The basins and deep valley floors are important horse habitat. Evidence that these sites have not supported forest during the post-glacial is:

1. a pronounced, inverted treeline of both *Nothofagus* forest and, on burnt valley slopes, successional manuka *(Leptospermum scoparium);*
2. no pedological evidence of past forest such as moroid profiles and buried charcoal (Rogers, 1987);
3. rare and widely disjunct plant species characteristic of open vegetation (Rogers, 1989).

[1]Plant nomenclature follows Cheeseman (1925), Allan (1961), Connor and Edgar (1987) and Webb, Sykes and Garnock-Jones (1988) unless otherwise indicated.

The extensive rolling uplands, which have been deforested, support mainly red tussock grassland with a lower proportion of hard tussock. Manuka and monoao are invading the grasslands on most hillslopes but only monoao invades on the basin floors. Above the original treeline, several subalpine shrubs including *Hebe tetragona, Brachyglottis bidwillii* and *Dracophyllum recurvum* are important in the grasslands of red tussock and *Chionochloa pallens*.

Bogs of three types are also widespread within the wild horse range:

1. restricted, high fertility flushes fed by groundwater seeping from the underlying marine sediment;
   extensive blanket bogs capping rounded greywacke ridges dependent directly on rainfall (Taylor and Pohlen, 1962);
3. extensive basin bogs fed by catchment drainage which have developed where deep Taupo Pumice overlies andesitic ash.

The Moawhango River headwaters has the highest concentration of plants with unusual distributional limits of any region in New Zealand (A.P. Druce, *pers. comm.,* 1989; Rogers, 1989). Ten species occur only there in the North Island and a further 21 occur no further south in the North Island and appear again in the South Island. The region is now important as one of only three major landscape refuges for red tussock grassland below treeline in the North Island.

Red deer *(Cervus elaphus scoticus* Lonnberg) and sika deer *(Cervus nippon* Temminck) are present in the study area. Their numbers are low where isolated forest pockets occur in a matrix of tussock grassland, but moderate where more or less continuous forest flanks the Rangitikei River and its tributaries.

Methods

Horse population census

Four aerial surveys of the entire horse population were conducted between 1986 and 1990. Both fixed-wing aircraft and helicopters were used (B. Fleury, *pers. comm.*). Positions of the individual bands or family groups were marked on 1:50000 maps with numbers of adults and juveniles in each band recorded. Body size was used to identify juveniles. For assessing local variations in horse distribution and reproduction, the study region was classified into 6 distinct ecological sectors (Fig. 1) based on geology, landforms, vegetation, and degree of naturalness. Estimates of the reproduction rates in the various sectors were based on adult/juvenile ratios. There was one ground-based survey of total horse numbers in 1979 (Aitken *et al.,* 1979).

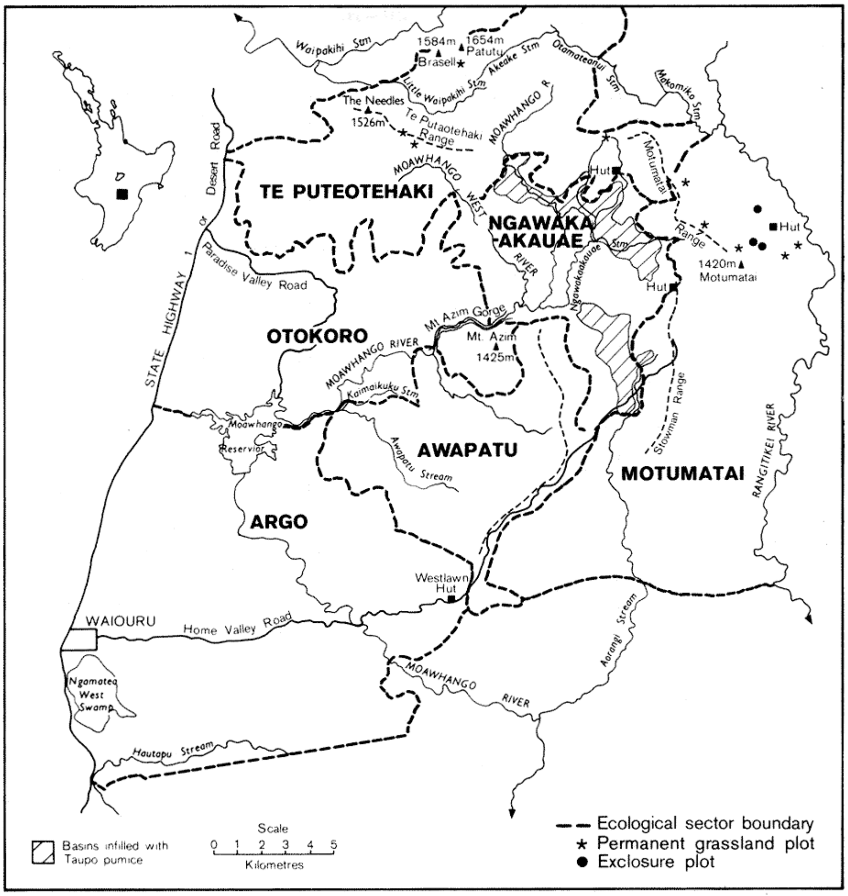

Figure 1: *Salient topographical features of the wild horse range in the south-western Kaimanawa Mountains, North Island, New Zealand.*

Horse impact

The impact of horses was assessed from an existing network of permanent grassland plots and three ungulate exclosure plots established in 1982 to assess vegetation condition and the impact of large grazjng herbivores.

Permanent grassland plots

A large number of permanent grassland plots (Allen, Rose and Evans, 1983) were established by staff of the New Zealand Forest Service (B. Fleury, *pers. comm.)* in the southern Kaimanawa Mountains. Nine of these plots, where horses were the only major grazing influence, were remeasured in 1989 (Fig. 1). Remeasurement involved recording the frequency of plant species at 100 points along a 40m transect, assessing the top cover of vegetation using stereo pairs of colour photographs, and recording tussock stature at 8 permanent points in each plot (Rose and Platt, 1987, pp. 24-25). Species frequency was compared for the 1982 and 1989 surveys using the Student's t-test, paired samples, after arcsine square root transformation. The categories used for cover analysis from the photographs were:

- Red tussock
- *Chionochloa pallens*
- Hard tussock
- *Poa colensoi*
- *Rytidosperma setifolium*
- *Celmisia spectabilis*
- Moss: mainly *Racomitrium lanuginosum* and *Hypnum cupressiforme*.

Mat: low growing inter-tussock species including *Acaena microphylla, Hieracium pilosella, Hypochoeris radicata, Leucopogon fraseri, Uncinia rubra, Wahlenbergia albomarginata,* and several adventive grasses including *Anthoxanthum odoratum* L., *Agrostis capillaris* L., *Festuca nigrescens* L. *(F. rubra), Festuca tenuifolia* L., and *Holcus lanatus* L.

Shrubs: mainly *Cassinia vauvilliersii, Coprosma cheesemanii, Coprosma* sp. (0) (Eagle, 1982), *Dracophyllum recurvum, Dracophyllum subulatum, Hebe tetragona,* and *Leucopogon suaveolens.*

Bare ground: bare soil or rock.

Litter: dead plant material not attached to plants.

The data from the 1982 and 1989 cover analyses formed a 2 x c (cover classes, up to six) contingency table for each vegetation and bare ground category. Significant changes in cover and bare ground were then tested for using the algorithm of Pagano and Halvorsen (1981).

Fenced exclosure plots

Three fenced exclosure plots, 20 x 20m, were established in 1982 at Motumatai (Fig. 1), two in mountain beech *(Nothofagus solandri* var. *cliffortioides)* forest, and one in hard tussock grassland. Equivalent unfenced control plots were located within twenty metres of each exclosure.

Forest exclosures

In the forest exclosures, tree diameter, sapling, and understorey plot data were collected as in Allen and Mclennan (1983). Saplings were recorded as the number of stems of each woody species taller than 135cm and less than 3.0cm diameter at base (d.a.b.) in the folluwing height tiers; < 15cm, 15-135cm, 135cm. In the understorey, the presence of all vascular species was recorded in 30 circular subplots of 49cm radius. Because of the limited time interval, and the apparently negligible impact of horses on canopy tree foliage, tree diameter data are not presented here.

Grassland exclosure

For the grassland exclosure, species frequency in 1982 and 1989 was measured in 100 circular subplots of 15cm diameter spaced at 40cm intervals along the two diagonals. Stereo pairs of colour photographs were used to record cover. Tussock stature was also measured at the points of the photographs. In 1989, the Scott height frequency method (Scott, 1965) was used to record the vertical distribution of species in 5cm height classes at 100 points along both diagonals. For each species, the sum of all intercepts in all height classes was calculated, and the height class with the maximum frequency was noted. Diameter and height at full extension were recorded for all tussocks in 20 subplots, of 1 x 2m, randomly located in each plot. These data were used to calculate diameter class distributions, and mean height, cover, and density estimates for each tussock species. To obtain an index of tussock health, a random sample of ten tillers was collected from each of approximately 50 plants of both red and hard tussock. Dead sheaths, rhizomes and roots were removed; tillers were then oven dried at 70C for 48 hours and weighed. Before oven-drying, the extended tiller length of each sample was measured to provide a tiller weight/length index.

Rare and/or vulnerable plants

The presence of all the biogeographically important plant species and their habitats in the wild horse range were recorded. The impact of grazing and trampling upon the plant habitats was assessed qualitatively.

Results

Horse population census

There were consistently high densities of wild horses in the south, in the Auahitotara and Awapatu sectors, where populations were concentrated in the Moawhango and Awapatu River basins (Table 1). Density was also high in the Motumatai sector where dispersal to the east is restrained by the deeply incised Rangitikei River. Since 1987, density has substantially increased in the Ngawakaakauae where most of the biogeographically unusual plants occur. Although population density increased in the region as a whole, it fluctuated in 5 of the 6 sectors. It varied most at Te Puteotehaki, the remote northern sector, and was more stable in the high population sectors of the south. Because the 1987 census was conducted in a different season to the others, both seasonal and yearly fluctuations are revealed. The size of the fluctuations suggested band home ranges were quite unstable. In addition, military training activities substantially influenced dispersion *(pers. obs.).*

An exponential regression function fitted to data from five surveys between 1979 and 1990 (Fig. 2) indicates a remarkably steady rate of population increase in the last 11 years (r = 0.167, 95% CI = 0.015). Between 1988 and 1990, the exponential rate of r (Caughley, 1977) was 0.20 or a population doubling time of 3.43 years. There was also a dramatic increase in the number of herds and in the juvenile:adult ratio (Table 1). Consistently higher reproduction rates were estimated for the higher density southern sectors; however, the higher incidence of bachelor bands in the north *(pers. obs.)* will depress reproduction rates in that area. A recent rapid increase of horse numbers was recorded in the Ngawakaakauae sector, and it is thought that this sector functioned as habitat for horses emigrating from the higher density southern and Motumatai sectors.

Table 1: *Dispersion and demographic statistics derived from four aerial surveys for the wild horses in the south-western Kaimanawa Mountains (see Fig. 1). (*=standard deviation)*

Ecological sector	Adults	Juveniles	Total	Juvenile Adult Ratio	Area per Horse (ha)
		July 1986			
Auahitotara (18066 ha)	149	33	182	0.22	99
Awapatu (6815 ha)	126	21	147	0.17	46
Motumatai (13381 ha)	122	3	125	0.02	107
Otokoro (8927 ha)	25	4	29	0.16	308
Ngawakaakauae (5713 ha)	34	2	36	0.06	159
Te Puteotehaki (10673 ha)	11	2	13	0.18	821
Summary (63575 ha)	467	65	532	0.14	120
band mean	4.72	0.66	5.38		
band s.d. *	2.92	0.91			
number of bands	99				
		December 1987			
Auahitotara	288	57	345	0.20	52
Awapatu	82	10	92	0.12	74
Motumatai	104	20	124	0.19	108
Otokoro	29	5	34	0.17	263
Ngawakaakauae	15	2	17	0.13	336
Te Puteotehaki	44	6	50	0.14	213
Summary	562	100	662	0.18	96
band mean	5.56	0.99			
band s.d. *	5.11	1.37			
number of bands	101				
		April 1988			
Auahitotara	202	45	247	0.22	73
Awapatu	116	19	135	0	50
Motumatai	210	37	247	0	54
Otokoro	38	8	46	0.21	194
Ngawakaakauae	62	10	72	0.16	79
Te Puteotehaki	15	1	16	0.06	667
Summary	643	120	763	0.19	83
band mean	5	0.90			
band s.d. *	3	1.04			
number of bands	133				
		April 1990			
Auahitotara	426	94	520	0.22	35
Awapatu	201	27	228	0.13	30
Motumatai	171	28	199	0.16	67
Otokoro	26	4	30	0.15	298
Ngawakaakauae	78	17	95	0.22	60
Te Puteotehaki	26	4	30	0.15	356
Summary	928	174	1102	0.19	58
band mean	4.30	0.81			
band s.d. *	3.06	1.06			
number of bands	216				

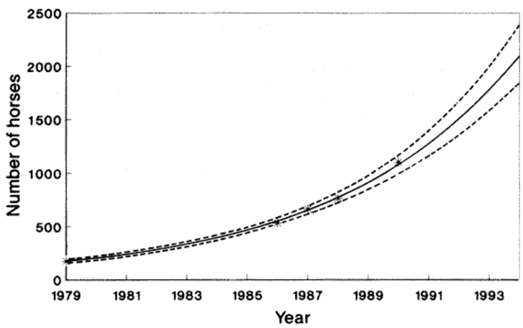

Figure 2: *An exponential curve and 95% confidence intervals fitted to data from 5 horse surveys in the south western Kaimanawa Mountains. The equation of the regression curve* is $y= 171.9^{e5.147X}$ $(r^2= 0.998)$.

Permanent grassland plots

Species frequency

Seven of the nine grassland plots were located in red tussock grassland in the far north. Hard tussock, silver tussock *(Poa cita),* and the shrubs, *Hebe tetragona, Dracophyllum recurvum,* monoao, and *Brachyglottis bidwillii* were locally important. Between 1982 and 1989, the mean frequency of seven small prostrate species declined significantly (Table 2). The adventive species, *Hieracium pilosella,* increased significantly, particularly on heavily grazed sites.

One of the remaining two plots was located in a terraced gravelfield with less than 5% vegetation cover; there was no significant change in species frequency between 1982 and 1989. The other plot, on a basin floor, was in a heavily grazed grassland abutting a forest pocket and, because native tussocks were mostly eliminated, was dominated by adventive grasses. Here the frequency of prostrate plants such as *H. pilosella, Leucanthemum vulgare* and *Hypnum cupressiforme* and the adventive grasses sweet vernal *(Anthoxanthum odoratum* L.) and browntop *(Agrostis capillaris* L.) did not change. Observation suggested that concentrated browsing and trampling of *Nothofagus* saplings on the margins of the forest appears to have prevented forest expanding into the bordering grassland.

Photocentres and tussock stature

There were no significant changes in the cover of any species, although that for *Chionochloa pallens* came close to a significant change (Fig. 3). There was, however, a highly significant decrease in mean height of *C. pallens* (mean height in 1982=33.8cm, mean height in 1989=11.2cm, Student's t-test, paired sample, P<0.001). No *C. pallens* seedlings were seen. Mean height of red tussock increased at three plots, but declined at three others. Shrubs cover did not increase, but the observation interval was short.

Table 2*: Changes in mean specific frequency (%) of species with >5% mean frequency in anyone year in 8 permanent grassland plots measured in 1982 and 1989. n = number of plots the species was recorded in; P = Students t-test (paired samples) of significant differences in mean frequency at p<0.05 and p<0.01.*

Species	Mean frequencies			
	n	1982	1989	P
Anisotome aromatica	7	40.9	28.9	0.05
Anthoxanthum odoratum	5	37.8	35	NS
Celmisia gracilenta	5	24	15.8	NS
Celmisia spectabilis	8	31.8	22.3	NS
Chionochloa rubra	8	28.4	25.3	NS
Coprosma cheesemanii	4	25.3	21	NS
Coprosma perpusilla	5	35.4	27	NS
Deyeuxia avenoides	4	36	14.8	NS
Dracophyllum recurvum	6	54.5	47.3	NS
Epilobium alsinoides	4	12.3	10.8	NS
Euphrasia cuneata	7	11.1	9.4	0.05
Gentiana bellidifolia	7	19	13.6	0.01
Geranium sessiliflorum	8	12	8.9	0.01
Hebe tetragona	6	34.2	27.7	NS
Hieracium pilosella	6	2.8	15.7	0.05
Hypnum cupressiforme	7	54	38.4	0.05
Hypochoeris radicata	6	18	14.3	NS
Lepidothamnus laxifolius	5	15.4	13.4	NS
Leucopogon fraseri	5	30.2	31.8	NS
Linum catharticum	4	10.8	7.8	NS
Luzula migrata	7	5.4	3.4	0.01
Lycopodium fastigiatum	6	12.3	9.5	NS
Poa colensoi	8	34.6	26.9	NS
Uncinia rubra	5	25.6	16.6	NS
Wahlenbergia albomarginata	8	33.9	25	0.01

The permanent grassland plots, which showed no overall change in the cover of red tussock, did not include moist gullies and stream-beds. There observation suggested that the red tussock community was heavily grazed and wrenched tillers littered the ground. This was to the advantage of adventives such as *Hieracium pilosella,* catsear *(Hypochoeris radicata),* hair *fescue (Festuca tenuifolia),* Yorkshire fog *(Holcus lanatus),* sweet vernal, and browntop *(pers. obs.).*

Fenced exclosure plots

Nothofagus *forest*

One exclosure and its control were located in a small, wind-swept forest pocket on a plateau and the other pair within extensive forest on a steep valley midslope (Fig. 1, Table 3). The small number of subplots sampled and the lack of true replication (because of the limited number of exclosures) made statistical testing for differences between exclosures and control plots uninformative. There appeared to be an increase in *Griselinia littoralis* seedlings in both exclosures, and an increase in *Poa anceps* in the forest pocket exclosure. Several small herbs such as sweet vernal,

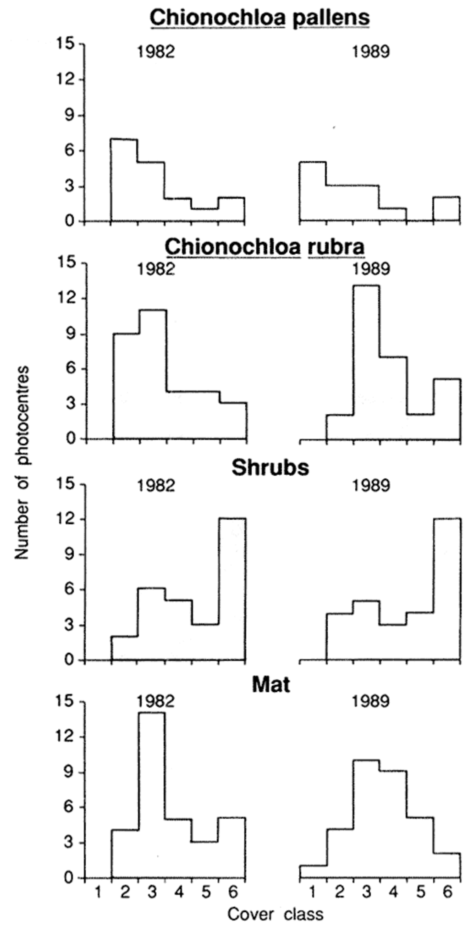

Figure 3*: Comparison of cover in 1982 and 1989 estimated from photocentre analysis of selected species in red tussock grassland. Cover classes are: 1 = 1%; 2=1-5%; 3=6-25%; 4=26-50%; 5=51-75%; 6= 76-100%.*

Lagenifera strangulata, Oreomyrrhis colensoi, and *Uncinia silvestris* declined in the forest pocket exclosure, perhaps due to a decrease in understorey light levels.

Hard tussock grassland

This exclosure was in a degraded hard tussock grassland on a small plateau at Motumatai (Fig. 1), where horse numbers are high. After grazing ceased in the exclosure, the frequency of the dominant inter-tussock grass, hair fescue increased significantly

Table 3*: Number of stems of woody species <3.0 cm diameter at base in three height classes and the frequency of important herb species in 1982 and 1989 from two exclosure plot pairs at Motumatai. Height classes are: 1 = <15 cm; 2=15-135 cm; 3= >135 cm.*

Extensive forest	Exclosure						Control					
Year	1982			1989			1982			1989		
Height class	1	2	3	1	2	3	1	2	3	1	2	3
Griselinia littoralis	9	2		9	8		12	6		17		
Lagenifera strangulata				1			5			2		
Nothofagus solandri var. *cliffortioides*	25	41	7	28	90	1	19	15		3	22	21
Uncinia silvestris				2			1			2		

Forest pocket	Exclosure						Control					
Year	1982			1989			1982			1989		
Height class	1	2	3	1	2	3	1	2	3	1	2	3
Acaena anserinifolia	23			26			20			23		
Anthoxanthum odoratum	6											
Aristotelia fruticosa	2			3			1	1			1	
Agrostis capillaris	2			7								
Blechnum penna-marina	4			4						7 6		
Chiloglottis cornuta							4			1		
Coprosma mierocarpa	2	1		4								
Coprosma sp. (t) (Eagle, 1982)		4			2	2	1				2	
Festuea nigrescens				4						6		
Griselinia littoralis	11			21	3		14			12		
Hymenophy/lum multifidum	21						3					
Hypoehoeris radicata	4			2			2			1		
Lagenifera strangulata	21			8			18			17		
Myrsine divarieata	1				2	1		1		1	2	
Nothofagus solandri var. *cliffortioides*	12	2	6	13	1	2	17	8	5	17	8	
Oreomyrrhis ceolensoi	24			16			14			15		
Phyllocladus alpinus				2			2			4		
Poa anceps	8			18						1		
Ranuneulus membranifolius	8			9			1			1		
Rytidosperma gracile	2				1		2			9		
Sehizeilema colensoi				9						6		
Uncinia silvestris	24			16			17			19		
Viola filicaulis	20			22			15			15		

(Table 4). The frequency of 12 low stature species, e.g., sweet vernal, *Deyeuxia avenoides, Leucopogon fraseri,* and *Stackhousia minima,* and total species diversity declined significantly because of overtopping by hard tussock and hair fescue.

In the control plot, continued grazing pressure led to a significant decline in individuals of the highly palatable grass, hair fescue, and also in *Festuca nigrescens, Geranium sessilif1orum,* Yorkshire fog, *Rytidosperma gracile, Stackhousia minima,* and *Wahlenbergia albomarginata*. Other prostrate and/or unpalatable species increased significantly in the low turf, notably *Hydrocotyle microphylla, Hypnum cupressiforme, Leontodon taraxacoides, Leucopogon fraseri,* and *Oreomyrrhis colensoi*.

Total intercepts (Table 4) and height frequency (Table 4 and Fig. 4) revealed substantial differences in stature of both adventive and indigenous grasses. Without grazing, adventive grasses, particularly hair fescue, expanded to dominate the vegetation. By contrast, in the grazed plot, both species biomass and stature were low for all the potentially taller, palatable grasses such as hard tussock, *Festuca nigrescens,* hair fescue, Yorkshire fog, silver tussock, and *Poa colensoi*. Although red tussock was much more important inside the exclosure, it was more abundant there when the plot pair was established in 1981. The species with greater biomass in the control were all low-growing turf species such as *Acaena microphylla, Leucopogon fraseri,* and *Wahlenbergia albomarginata,* that escape heavy horse grazing. Overall, when horses were removed, adventive fescues proliferated at the expense of the native, low stature, inter-tussock flora.

The tussock diameter class distributions indicated that hard tussock was being recruited in both plots (Fig. 5). The recruitment of red tussock was substantially reduced by grazing. There was no silver tussock in the control plot, probably because it had been browsed out.

The mean diameter of hard tussock in the exclosure was significantly smaller than in the control plot (Table 5), suggesting a younger population.

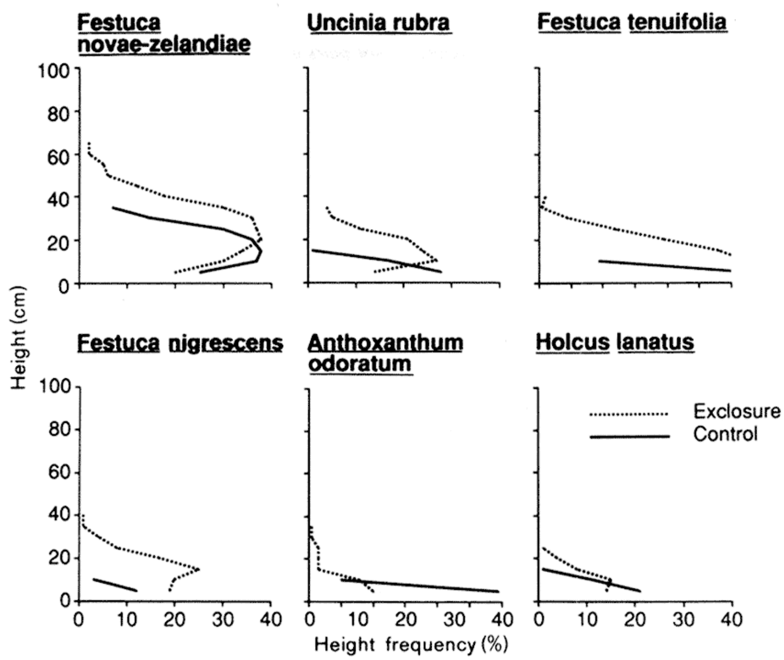

Figure 4: *Height frequencies of physiognomically important species in an exclosure and control plot at Motumatai.*

Hard tussock in the exclosure was, however, significantly taller than in the control, probably due to the combined effects of a release from grazing pressure in the exclosure and an increase in grazing pressure on the control population during the observation period (see horse population statistics, Table 1). For red tussock, the mean diameter was significantly greater in the control plot, indicating reduced recruitment, but there was no significant difference in the height of the two red tussock populations. Hard tussock in the control had a significantly lower tiller weight, tiller length, and tiller weight/length ratio than that in the exclosure (Table 5). The lower tiller weight/length ratio was the reverse of what was expected because grazing removes the blade tips where the dry, less heavy dieback tissue is concentrated. Nevertheless, the effects of heavy grazing clearly reduce tiller biomass.

The tiller weight/length ratio for grazed red tussock was, however, significantly greater than the ungrazed. The other parameters, tussock height, tiller weight, and tiller length showed that horses did not significantly graze the established, older population of red tussock, but that recruitment in this degraded community was inhibited.

Rare and vulnerable plants and habitats

Rogers (1989) highlighted the plant species of biogeographical importance in the Moawhango Ecological Region, and, in particular, the Moawhango River headwaters. The present study recognised 31 species in four distribution categories (Table 6). Many of the species are of precarious status in the North Island; for instance, *Carex petrei,* of which only two plants are currently known; *Gnaphalium ensifer, Luzula* sp. *(L rufa* var *albicomans), Koelaria* sp. *(K. novozelandica* agg.) *[K. kurtzil]* for which only one small population is known for each species; and *Carex uncifolia* which has become extinct recently in the Moawhango and for which only one other small population is known (Mt Hauhungatahi).

Some species suffered grazing and trampling damage; for instance, *Agrostis imbedlla, Carex berggrenii, Gnaphalium ensifer, Koelaria* sp., and *Rytidosperma pumilum.* Another species of restricted distribution in the North Island, *Deschampsia caespitosa,* may have been browsed out by horses because it has not been recorded in recent surveys. Trampling damage is particularly severe in fragile, high-nutrient flushes, thereby threatening *Carex*

Table 4: *Species frequency and Scott height frequency for species in a grassland exclosure (Exc) and in a control (Con) plot at Motumatai. Total intercept is the sum of all intercepts in all height classes and height frequency (freq) is the height class (cm) at which each species attains its maximum frequency. P = significant differences in mean frequency from Pagano and Halvorsen* (1981) *contingency tables at p<0.05* (*) *and p<0.01(**).*

	Frequency							Total intercept		Height freq	
	Exclosure			Control			Exe/Con	Exe	Con	Exe	Con
	1982	1989	P	1982	1989	P	P	1989	1989	1989	1989
Acaena microphylla	9	46	**	60	63		*	27	43	2.5	2.5
Anthoxanthum odoratum	83	36	**	82	77		**	47	69	2.5	2.5
Chionochloa rubra	9	16		1				75		20	
Deyeuxia avenoides	21	6	**	22	31		**	9		7.5	
Epilobium alsinoides	16	5	*	10	4						
Festuca nigrescens	16	15		23	11	*		95	15	12.5	2.5
Festuca novae-zelandiae	34	44		51	53			270	188	22.5	15
Festuca tenuifolia	63	88	**	60	39	**	**	251	86	7.5	2.5
Galium propinquum	13	9					**				
Gentiana bel/idifolia				7	1						
Geranium sessiliflorum	32	9	**	34	17	**		4	6	2.5	2.5
Helichrysum bellidioides	15		**	4							
Hieracium pilosella	11	9		12	15			9	7	5	2.5
Holcus lanatus	20	22		39	16	**		42	33	7.5	2.5
Hydrocotyle microphylla	21	12		20	37	*	**				
Hypochoeris radicata	31	12	**	18	15			8	8	2.5	2.5
Hypnum cupressiforme	80	83		78	91	*		64	79	2.5	2.5
Leontodon taraxacoides				1	8	*	**				
Leucopogcm fraseri	65	17	**	28	41		**	10	39	2.5	2.5
Linum catharticum	16	5	*	4	4						
Luzula migrata	2			1	7		*				
Lycopodium fastigiatum	7	2									
Oreomyrrhis colensoi	4	1			8	**	*		10		2.5
Poa cita								18	5	17.5	15
Poa colensoi								25		10	
Ranunculus multiscapus	3	7		1	4						
Rytidosperma gracile	12	2	**	10		**		35	24	7.5	2.5
Rytidosperma setifolium				1							
Stackhousia minima	21		**	13	1	**		3	8	2.5	2.5
Trifolium sp.	16		**	15	15		**		6		2.5
Uncinia rubra	52	48		42	43			106	46	7.5	2.5
Wahlenbergia albomarginata	62	26	**	64	46	*	**	18	41	2.5	2.5

Table 5: *Differences in mean diameter, height, density, and mean tiller weight for tussock species in an exclosure and control plot at Motumatai. s.d. = standard deviation; df = degrees of freedom; P = Student's t-test (paired samples) of significant differences in mean frequency at p<0.05 and p<0.01.*

	Exclosure		Control			
	mean	s.d.	mean	s.d	df	P
Festuca novae-zelandiae						
diameter (cm)	6.96	6.63	8.98	6.92	572	P =0.01
height (cm)	33.35	11.3	23.38	5.78	572	P<0.001
tussock density (no. ha^{-1})	64500		78750			
tiller weight (g)	0.87	0.24	0.71	0.18	109	P<0.01
tiller length (cm)	27.07	5.36	24.17	4.46	109	P<0.01
tiller weight/length (g cm^{-1})	0.032	0.007	0.029	0.005	109	P<0.01
Chionochloa rubra						
diameter (cm)	7.9	9.28	13.5	11.28	76	P<0.05
height (cm)	45.8	15.73	34.6	24.91	76	NS
tussock density (no. ha^{-1})	13750		5500			
tiller weight (g)	7.13	3.85	8.23	4.85	105	NS
tiller length (cm)	44.16	11.68	42.88	20.93	105	NS
tiller weight/length (g cm^{-1})	0.15	0.04	0.18	0.04	105	P<0.001

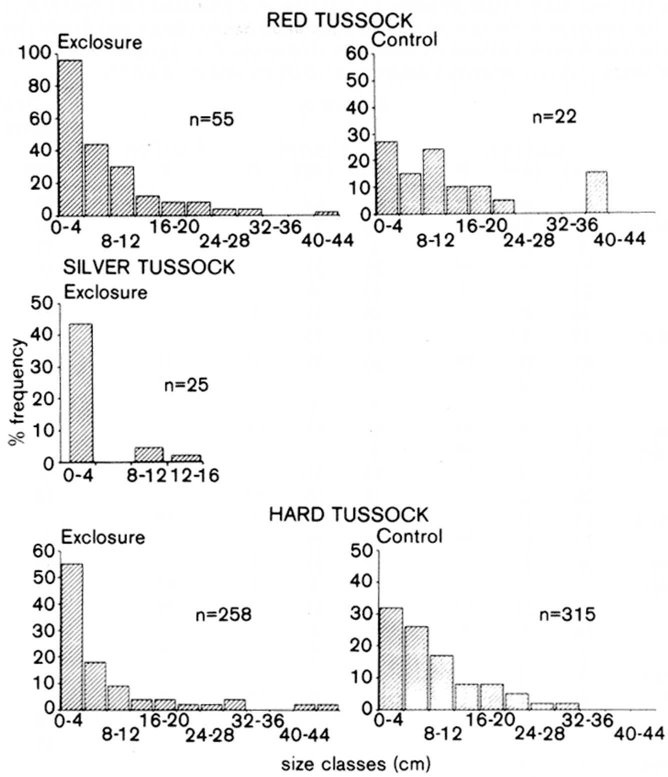

Figure 5: *Diameter class distributions for three tussock species in an exclosure plot pair at Motumatai.*

berggrenii. Furthermore, smothering weeds, the spread of which is enhanced by horse disturbance, ultimately threaten many species. The likely invasion of heather *(Calluna vulgaris* (L.) Hull) and further spread of *Hieracium pilosella* pose a threat to 18 of the biogeographically unusual species which are principally low stature components of tussock grassland and low herbfields. *H. pilosella* invaded damp depressions within tussock grassland where many of the biogeographically unusual plants occurred, including *Ranunculus recens* var. (Ogle, 1978) which is particularly vulnerable to trampling damage.

Flush zones were highly degraded by horse trampling and grazing irrespective of local variations in horse density and habitat abundance. As trampling was the main agent of damage, the vulnerability of bogs increased with the wetness. Not only did this disrupt water-flow and increase downstream siltation, but a wide range of weedy rushes, sedges and herbs benefited by colonising the fresh substrates and dung heaps. Most prolific amongst the weeds were *Juncus articulatus,* Yorkshire fog, and *Trifolium repens*. The more eutrophic flushes suffered greatest damage because their elevated fertility provided preferred fodder.

The oligotrophic peat bogs which blanket the convex greywacke ridges at high altitude were not a preferred habitat for horses, and, although some trampling damage was evident, the hydrological regime and the surface vegetation were largely intact. The fertility status of the bogs on basin floors was probably no higher than that of the blanket peats but because horses favoured basins, some areas of these bogs were modified. Nevertheless, these systems appeared resilient to damage probably because their hydrology was relatively stable and their oligotrophic and stagnant states were inhospitable to many weeds.

Table 6: *Local abundance and threats to plant species with unusual distribution limits coinciding with the wild horse range. The biogeographic groups are: 1, local endemic; 2, southern limits of a central North Island endemic; 3, species that occur only in the Moawhango River headwaters in the North Island and are then disjunct to the South Island; 4, more widespread species in the upper North Island that have southern North Island limits in the Moawhango River headwaters and are then disjunct to the South Island. Threats are: h = horses; f = fire; he = heather; A = Army training activities.*

Group	Species	Abundance	Threats
1	*Logania depressa*	probably extinct	
2	*Carex astonii*	frequent	he
	Raoulia sp. (*R. australis* "north" of Ward, 1982)	rare	he
	Anaphalis sp. (aff. *A. keriensis)*	frequent	
	Prasophyllum suttonii	rare	
	Ranunculus nivicola	frequent	
3	*Acaena inermis*	rare	f, he
	Agrostis imbecilla	rare	f, he, A
	Carex berggrenii	very rare	he
	Carex petriei	very rare	
	Gnaphalium ensifer	very rare	h, he, A
	Koelaria sp. *(K. novozelandica* agg.) *[K. kurtzi,]*	very rare	h, f, he
	Luzula sp. *(L. rufa* var. *albicomans)*	very rare	h, f, he
	Myosotis sp. *(M. pygmaea* var. *glauca)*	very rare	h, f, he, A
	Nertera sp. (aff. *N. balfouriana)*	very rare	
	Ranunculus recens var.	rare	h, he
4	*Carex rubicunda*	frequent	he
	Carex uncifolia	possibly locally extinct	h, f, he
	Deschampsia novae-zelandiae	frequent	he
	Lagenifera montana	rare	
	Myosotis sp. *(M. australis* agg.)	very rare	
	Oreomyrrhis sp. *(0. colensoi* var. *delicatula)*	frequent	he
	Pernettya macrostigma	abundant	he
	Pimelea microphylla (P. prostrata in part)	frequent	he
	Pittosporum anomalum	very rare	
	Rytidosperma pumilum	rare	h, he
	Raoulia sp. *(R.* sp. K of Ward, 1982)	rare	
	Selliera microphylla	frequent	he
	Hydrocotyle sulcata	frequent	
	Pterostylis humilis	rare	
	Ranunculus simulans	frequent	

Discussion

Horse biology

The relative accuracy of aerial censuses of horses must be assessed on a site specific basis, but in the central USA, observer experience, and terrain and vegetation type had the greatest influence on reliability (Wolfe, 1986). Counts in gentle to moderate terrain with low steppe vegetation accounted for up to 93% of horses present. In the Moawhango region, helicopters, a continuity of observers, low relief terrain, and open vegetation probably gave comparable reliability. Because these influences were constant, it seems likely that the actual population has been underestimated by a similar amount on each of the biennial counts.

Horses are not territorial and do not defend grazing or watering areas (Berger, 1977). Berger (1977) also concluded that social behaviour or organisation did not substantially regulate population levels, but that food availability was the principal factor. The exponential growth model was used for the Kaimanawa population on the assumption that the population was increasing without any density dependent effects; i.e., it is in the exponential phase of a logistic growth curve (Wolfe, 1980). Accordingly, horse numbers will probably continue to increase even in the higher density sectors because food resources appear abundant. Nevertheless, horses appeared to have responded to higher population density in the south by ranging more widely into the three northern sectors as shown by marked population increase and many bachelor bands. Both male and female horses leave their natal bands within the first few years of life, but males migrate further, probably to enhance their prospects for mating by emigrating to lower density areas (Berger, 1986). In 1989, horses attempted to establish new home ranges west of State Highway 1 on the Whangaehu lahar fan.

Management intervention thwarted these attempts. The population increase in peripheral sectors and the attempts to establish new home ranges west of State Highway 1 also suggested that population pressure was expanding the total range.

Because the density statistics apply to large geographical sectors, they do not show local variation in density. In preferred habitats such as basin floors or elevated plateaux, several bands had overlapping home ranges (Aitken *et al.,* 1979) which resulted in local densities very much higher than the total for the entire sector.

Berger (1986) found that reproduction rates for bands utilizing high quality habitats were significantly higher than for animals occupying inferior habitats. It is possible that habitat quality, particularly soil fertility and altitude, markedly influenced productivity in the Moawhango region. In the north, the relatively lower nutritional status of Taupo Pumice substrates and the higher elevations possibly contributed to lower reproductivity.

Because of the protracted foaling period from late November to March *(pers. obs.),* future aerial inventories should be made after mid-April and before late October if reproduction statistics are to be compiled. For the purposes of this study, the April 1988 count was arbitrarily treated as a post-breeding inventory. Wolfe (1986) in the central-western USA showed that survival rates among foals and older animals probably approached 90% and 95% respectively in normal years, which accords with reproduction rates approaching 20% (Wolfe, 1980). Census work showed that rates of increase of approximately 20% were also attained in Oregon (USA) wild horse populations (Eberhardt, Majorowicz and Wilcox, 1982). However, disproportionately high losses among foals and very old animals in harsh winters would be expected to reduce this figure substantially. Wintcrs in the last 3 years in the Moawhango region have been particularly mild, the years in which the reproduction rate approached 20%. A relaxation in hunting and capture pressure following formal protection in 1981 may well have contributed to the rapid increase in numbers in the 1980s.

Grassland habitat

The recent impact of high horse numbers must be placed against a background of substantial earlier, and in some parts continuing, European modification. Grazing, particularly by cattle, sheep, and horses, has acted continuously, and burning intermittently, in modifying the Moawhango grasslands since the 1880s. Numerous accounts of South Island grasslands (e.g., Connor, 1964; Connor and MacRae, 1969) highlight the depletion of tall tussock through repeated burning and grazing and its conversion to short tussock grassland. The condition of the plateaux and basin grasslands in the Moawhango indicated that the pre-European red tussock grasslands had undergone three retrogressive successional shifts. In the more remote north, before the region became a military reserve in 1939, a shift from closed tall tussock to depleted short tussock accompanied the era of exploitative pastoralism as in the South Island (O'Connor, 1982). In the southern horse range, as farmers continued to burn and graze after 1939, there were two further successional changes away from hard tussock grassland. First, open hard tussock grassland degraded to an adventive grass sward dominated by sweet vernal, browntop, Yorkshire fog, and hair fescue. Second, there was a further transition to closed *Hieracium pilosella* vegetation which presently shows no indications of change. In the Harper-Avoca catchment in Canterbury, Rose (1983) reported similar grassland successions over periods of 15-25 years. It can be assumed that most of the hard tussock grasslands of the Moawhango were secondarily induced in the period of European pastoralism.

It is clear from the permanent grassland plots in the north where horse numbers are low that, at this level of grazing, red tussock on extensive undulating topography will generally continue its slow recovery from the period of early European farming. The only exception is that red tussock will continue to be lost from moist habitats such as those bordering high nutrient flushes, and from grasslands bordering *Nothofagus* forest. By contrast, *Chionochloa pallens* grasslands are heavily grazed. Williams *et al* (1976) showed that *C. pallens* has a markedly higher content of soluble sugars, protein and sodium than red tussock and selective horse grazing may reflect this nutritional difference. From artificial defoliation experiments of *C. pallens,* Lee, Mills and Lavers (1988) predicted that C. *pallens* will need two decades to recover, even in the absence of grazing. Although horse numbers are low in the north, *C. pallens* will be eliminated in the foreseeable future because of its restricted occurrence and the heavy selective grazing pressure.

Hughes (1975) reported that hard tussock is not highly palatable to sheep *(Ovis aries* L.), probably because of its low levels of digestible nitrogen and organic matter (Dryden and Archie, 1980). Nevertheless, the decline in tussock height, and tiller weight and length of hard tussock outside the grassland exclosure plot suggests that it is moderately palatable to horses. Because there was no significant difference in the height of the two red tussock populations in the grassland exclosure, and a significantly shorter population of hard tussock in the control, horses appear to graze hard tussock in preference to red tussock in mixed communities. The grassland exclosure also demonstrated that neither heavy grazing pressure nor competition from a dense inter-tussock sward was curtailing the recruitment of hard tussock. Even so, substantially more recruitment is occurring in the absence of grazing because the frequency of hard tussock in 1982 was much less in the exclosure plot, and because hard tussock density was only slightly less in the exclosure than the control in 1989.

Overall, the grassland exclosures demonstrated that when grazing pressure stopped the highly modified hard tussock grasslands on basin and valley floors can, in the short-term, become physiognomically dominated by adventive grasses. Light grazing pressure by horses might therefore be a desirable management measure for maintaining the physiognomic dominance of hard tussock in intact grasslands on basin floors. On the other hand, red tussock is expected to be less susceptible to competition from unrestrained growth of adventive grasses because it grows taller. In the absence of grazing, or with light grazing, I predict a progressive increase of red tussock over hard tussock in mixed tussock communities.

The grassland exclosure showed that at the present horse density in the Motumatai sector (one horse per 50-70 ha), the hard tussock grasslands on both the elevated plateaux and on the basin floors will continue to degrade to adventive grasslands or herbfields. In the Awapatu basin, the hard tussock grassland has already degraded to *Hieracium* herbfield in places. Because this remote northern sector was only lightly grazed by sheep until the 19305, horses must be viewed as the main agent of this change.

Red tussock and hard tussock reproduce only by seed but silver tussock also reproduces by rhizomes. Despite this, silver tussock was not common in the Moawhango region. Since most plants encountered were heavily grazed, the species must be highly palatable to horses, as well as cattle and sheep, and was probably more common in pre-European grasslands.

Austin, Williams and Belbin (1981) analysed long-term changes in Australian mediterranean grasslands. Differences between grazed and ungrazed conditions were small compared with changes during successions. In the present study, the short period did not reveal significant invasion of the seral grasslands by shrubs either above or below the regional treeline. Nevertheless, below the regional treeline, monoao seres, then manuka seres were common on previously forested hillslopes, and there, succession from grassland to shrubland is expected to be rapid. The only areas of the study above the regional treeline were in the Motumatai and Te Puteotehaki sectors where shrubs such as *Brachygloltis bidwillii, Dracophyllum recurvum,* and *Hebe tetragona* appear to be increasing after early 20th century burning.

Forest habitat

Because of the short observation interval, there was little change in the smaller size classes of *Nothofagus* within the forest exclosures. Moreover, there were very few *Nothofagus* juveniles probably because light levels were low in these dense, apparently even-aged stands. Because browsing pressure was not evident on *Nothofagus* juveniles in the forest pockets, it seems that horses will not influence natural regeneration of *Nothofagus*. In the forest pocket exclosure, the close proximity of a tussock grassland and the slightly higher light levels of a small forest produced greater species diversity.

Evidence from the forest exclosures and the low incidence of faeces suggested that horses avoided extensive tracts of forest, e.g., those in the Otokoro sector and about the Rangitikei River. On the other hand, horses frequently used the smaller forest pockets, presumably for shelter. Nevertheless, in concentrating their grazing on the adventive grass sward and tussock grasslands bordering forest, horses retard the advance of *Nothofagus* into the seral grasslands, in the same way deer do in Canterbury (Dick, 1956).

Special plants and habitats

Any small population is vulnerable to extinction, especially through habitat modification or loss. Some of the 10 plant species which are known only from the horse range in the North Island suffered habitat damage by horses. The species most vulnerable were those that occurred at only one or two sites and those in flush zones and on tarn margins - *Amphibromus f1uitans, Carex berggrenii, Carex petrei, Carex uncifolia, Gnaphalium ensifer,* and *Koelaria* sp. Although none of these plants are in danger of local extinction, the rapid increase in horses in the Ngawakaakauae zone where most of them occur, will accelerate habitat modification, and possibly transfer their status from rare to vulnerable (Lucus and Synge, 1978).

In general, flush zones were grossly modified by horses and many were dominated by adventive grasses and rushes. This is of great concern because. ecologically, these sites have no equivalent elsewhere in the North Island. Because flush zones also harboured some of the special plants they are indicator sites for excessive horse damage. Gravel levees, which supported two of the special plants, received little attention from horses.

Heather

It is now inevitable that heather will spread into the Moawhango red tussock grasslands from adjacent Tongariro National Park. Chapman and Bannister (1990) documented its vigorous colonization of open communities, in particular red tussock grassland. Below 1550m, only saturated substrates restricted its spread. Rapid spread of heather south along the Desert Road to within 5 km of Waiouru has been helped by soil disturbance during road maintenance and Army training activities. Heather is actively invading the Moawhango region as a wave of colonization in an easterly direction from the Desert Road, and scattered outlier nuclei occurred throughout the tussock grasslands as far east as the Rangitikei River in 1989.

Extrapolation from the performance of heather in Tongariro National Park suggests that in the Moawhango region all the short and tall tussock grasslands, flushes and bogs with water content less than 90% will, in time, be dominated by heather. The rates of population growth of heather in Tongariro National Park suggest that heather will become physiognomically dominant in the western Moawhango tussock grasslands within three decades, and in eastern districts within five decades. Anything which exposes fresh mineral soil including fire, military training activities, and grazing and trampling by horses, will help the spread of heather. However, heather may accelerate rates of invasion by indigenous shrubs and trees into the tussock grasslands (Chapman, 1984, p. 337). Tussock grasslands are largely inhospitable to the establishment of *Nothofagus* seedlings (Burrows, 1977), but heather may function as a future shrubland nurse. Because most of the Moawhango grasslands are seral, the management challenge is not for community stasis, but rather, to plan for a transformation to shrubland and forest in much of the present horse habitat. There is no information on the palatability of heather to feral horses, however, transformation of grasslands to shrublands (either indigenous or adventive shrublands) will substantially reduce the regions' carrying capacity.

Guidelines for management

An integrated approach to management must seek to enhance the considerable wildland conservation values of the region whilst maintaining a viable population of horses. Many botanical and landscape features in the north (for instance, flush zones, riparian sites, and basin grasslands) are compromised by horses. The landscape conservation values of the south are less at risk to increased horse numbers, by virtue of earlier European modification. Because conservation options are few for the more sensitive features of the north, sectors could be recognized where horse numbers are severely restricted for the benefit of wilderness and special-plant habitat preservation. A sustainable management regime for the region should recognise horse grazing as compatible with nature protection values only in areas with an inherent resilience to grazing. In the south, therefore, substantial horse preserves or sanctuaries could be recognised where horse numbers might be manipulated for the benefit of horses and indigenous landscapes. To minimize management costs, sanctuary boundaries could coincide with natural barriers to dispersal such as forested gorges and the Moawhango reservoir.

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