CHARACTERISTICS OF PATCHES OF SHORT GRASSES AND HERBS IN THE FALKLAND ISLANDS AND THEIR MANAGEMENT FOR SHEEP GRAZING.

CARACTERÍSTICAS DE SECTORES DE PASTOS CORTOS Y ESPECIES HERBÁCEAS EN LAS ISLAS FALKLAND (MALVINAS) Y SU MANEJO PARA EL PASTOREO OVINO.

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ABSTRACT

Patches of short grasses and herbs (Greens) are important grazing resources for sheep in the Falkland Islands. Little was known of their origins or diversity making it difficult to select management options for sustainable grazing.

The floristic, physiographic, biotic and edaphic attributes of 131 Greens were surveyed. They occurred widely, were mainly <5 ha, had variable shapes and physiography and were used frequently by livestock. The most dominant plant species were *Agrostis* spp, *Juncus scheuchzerioides*, *Gunnera magellanica* and *Poa pratensis*.

Greens were classified into eight communities that differed floristically, physiographically, edaphically and in herbage quality. For management purposes two main types were identified. The first type, dominated by *Agrostis* spp. and *G. magellanica*, occurred on relatively wet and infertile soil and was mainly associated with inland valleys and small paddocks. The second type, dominated by *Poa* spp., occurred on relatively dry and fertile soil and was mainly associated with coastal sites, ponds and penguin rookeries.

Ordination of sites showed that Greens were floristically similar as no wholly distinct groups were found on any axes combination. Differences were principally in species frequency rather than in diversity. The first ordination axis was positively related to soil Mg and P and dung cover and negatively related to soil moisture. The second axis was positively related to soil Ca and negatively related to K and dung cover. These corresponded generally with the soil features of the classification groups.

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Variation between Greens was due mainly to the type and degree of disturbance caused by combinations of livestock, penguins and sheldgeese. As Greens were more similar than dissimilar and inter-Green variation was more continuous than discrete, it is expected that management strategies for sustainable grazing would also be similar. Special management may be needed only for overgrazed Greens.

Key words: grassland management, patches, sheep grazing, sheldgeese, penguins.

RESUMEN

Sectores de pastos cortos y especies herbáceas (*Greens*) son importantes recursos forrajeros para la ganadería ovina de las islas Falkland (Malvinas). Como su origen y diversidad eran poco conocidos, se hacía difícil elegir opciones de manejo para un pastoreo sustentable.

Se muestrearon los atributos florísticos, fisiográficos, bióticos y edáficos de 131 sectores con tales características. Éstos se distribuyeron ampliamente, y eran principalmente menores a 5ha, con formas y fisiografía variable y usados frecuentemente por el ganado. Las especies de plantas más dominantes fueron *Agrostis* spp, *Juncus scheuchzerioides*, *Gunnera magellanica* y *Poa pratensis.*

Estos sectores fueron clasificados en ocho comunidades que diferían florística, fisiográfica y edáficamente y en calidad herbácea. Se identificaron dos tipos principales para efectos de manejo. El primer tipo, dominado por *Agrostis* spp. y *G. magellanica*, estaba en un suelo relativamente húmedo e infértil y principalmente asociado a valles interiores y pequeños potreros . El segundo tipo, dominado por *Poa* spp., estaba en un suelo relativamente seco y fértil, principalmente asociado a sitios costeros, aguadas y colonias de pingüinos.

El ordenamiento de los sectores mostró que estas áreas eran similares florísticamente ya que no la totalidad de los distintos grupos fueron encontrados sobre la combinación de los ejes. Las diferencias eran principalmente en cuanto a frecuencia de especies más que en diversidad. El primer eje de ordenamiento se relacionó positivamente con Mg y P del suelo y cobertura de heces, y negativamente con la humedad del suelo. El segundo eje se relacionó positivamente con el Ca del suelo y negativamente con K y cobertura de heces. Éstos correspondieron generalmente con las características del suelo de los grupos de clasificación. La variación entre sectores se debió principalmente al tipo y grado de perturbación causado por las combinaciones de ganado, pingüinos y gansos silvestres. Dado que estos sectores fueron más similares que distintos y que la variación entre ellos fue más continua que discreta, se espera que las estrategias de manejo para un pastoreo sustentable debieran ser también similares. Un manejo especial podría ser necesario sólo en aquellos sectores sobrepastoreados.

Palabras clave: manejo de praderas, parches, pastoreo por ovejas, gansos silvestres, pingüinos.

INTRODUCTION

The vegetation of the Falkland Islands (51° 53° S; 57° 62° W) has been described as oceanic heath with two associations; those in which the grass *Cortaderia pilosa* is dominant and those in which dwarf shrubs *e.g. Empetrum rubrum,* are dominant (Moore 1968). The *Cortaderia* associations tend to be found on areas where the drainage is poor to moderate whereas the dwarf shrub heath usually occurs on drier ground. The vascular flora of the islands consists of 348 species, 171 of which are believed to be native (Broughton & McAdam 2002).

Agriculture is confined to extensive sheep farming in large enclosures (89% > c. 2000 ha (Davies *et al.* 1971). Traditionally, pasture improvement through reseeding and fertilising was practiced only on a very small scale. Recently the development of pastures with improved grasses and legumes has received much greater priority than previously.

The nutritional quality of the native pastures is low with *C. pilosa*, the dominant species, typically having 29 - 73 % of dead matter in the herbage and consequently low organic matter digestibility (32 - 45 %) (McAdam *et al.* 1989). Where *C. pilosa* occurs as separate tussocks intermingled with more productive and better quality grasses, the overall value of the pasture is higher (Summers & McAdam 1993).

Throughout the oceanic heath formations numerous patches of short, dense hard grazed turf occur near streams, valleys and ponds. Similar vegetation formations can be found in coastal areas and around settlements in small paddocks. For most of the year the patches appear bright green which contrasts with the straw-brown colour of the surrounding *Cortaderia* grassland. Consequently, these formations are referred to locally as Greens.

Greens have long been recognised as an important grazing resource (Davies 1939). Davies *et al.* (1971) estimated that Greens and tussock *C. pilosa* occupied 15 % of farms on East and West Falkland and up to 25 % of the pastures on the smaller, outer islands and regarded them as 'the most valuable grazings on the islands'. Summers (1985) estimated that Greens composed 9.5% (11,828 ha) of one farm and supported 81.7% (35,381 ha) of the total wild sheldgeese (*Chloephaga* spp.) population on the farm. Although such data did not exist for sheep, casual aerial observation suggested that a similar pattern of grazing occurred.

The productivity and nutritional value of herbage from Greens was higher than from the surrounding pasture (Kerr & McAdam 1993). Given the opportunity for free ranging behaviour and grazing selection that the herbivores (sheep, cattle, horses and sheldgeese) can exhibit, utilisation of Greens is much higher than that of the surrounding pasture. Thus the value of a particular large grazing paddock is often assessed on the extent of Greens that it contains.

One of the current thrusts of agronomic research in the islands is directed towards improved management and utilisation of the native pastures. Within this broad framework, more detailed knowledge of Greens was essential. Little was known about their underlying features and the inherent differences and similarities between Greens in terms of their origin, floristic composition, physiography and edaphic characteristics.

This paper presents information that describes ordinates and classifies Greens and determines their environmental gradients. Such information will ultimately be of value in;

(a) Predicting change within and between Green types,

(b) Assessing their contribution to the grazing resources and,

(c) Prescribing options for their sustainable management.

MATERIAL AND METHODS

Sample selection

From an earlier land system analysis (King *et al.* 1969), a vegetation distribution map (Davies 1939) and examination of aerial photographs, a stratified sampling strategy was adopted based on the main categories of Greens recognised by farmers viz.; 'Penguin', 'Valley', 'Pond', 'Settlement' and 'Paddock'. Due to the lack of a surfaced road network and difficult terrain as many Greens of each type as possible were sampled on a series of journeys between isolated settlements and into the surrounding countryside between December 1987 and March 1988 i.e. over one austral summer. The routes chosen ensured that Greens were sampled areas that represented the main soil types and geographic regions. In each locality sampling of Greens was random. In all, 35 farms were traversed and a total of 131 Greens were surveyed (Fig. 1).

Data collected for each Green;

(i) Environmental features

Geographic: Latitude and longitude, located on East or West Falkland or the smaller outlying islands.

Physiographic: Area, altitude, proximity to coast, topographic position, slope, aspect, shelter (degree and direction), proximity to freshwater stream or pond.

Biotic: Information from farmers on; the type of livestock carried, the likely stock density in the overall paddock, the type of use of each Green by livestock and the history of fire at each Green. The presence or absence of penguins was recorded.

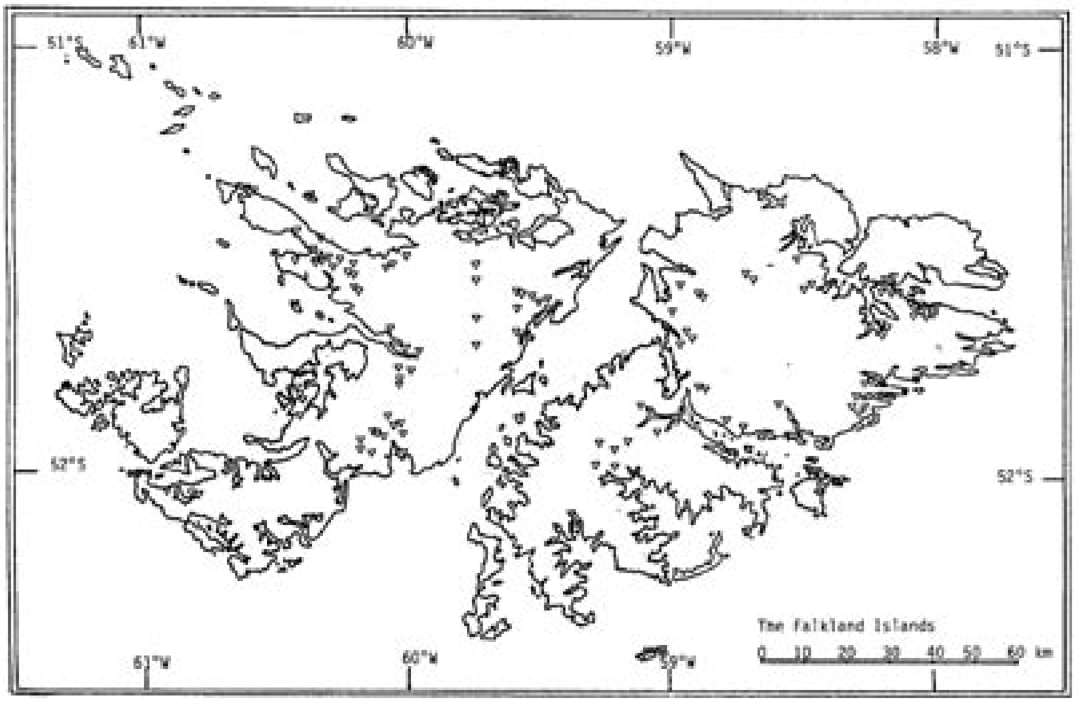

Fig. 1. The distribution of patches of short geasses and herbs (Greens) surveyed in the Falkland Islands.

(ii) Floristic composition

Floristic composition in five 50 cm x 50 cm quadrats randomly located in each Green was estimated using the Domin scale (Kershaw 1973) of cover/abundance. Where species identification was occasionally difficult *e.g.* in the absence of flowers, specimens were grouped at the genus level.

(iii) Surrounding vegetation

The surrounding vegetation was classed according to Moore (1968) with slight modification as follows:

Grass heath (*C. pilosa* dominant);

Dwarf shrub heath (either *E. rubrum* and or *Baccharis magellanica* dominant);

Large shrub (*Chiliotrichum diffusum* dominant);

Cushion plant (e.g. *Bolax gummifera* dominant);

Fern (*Blechnum penna-marina* dominant);

Fen and bog (e.g. *Juncus* spp. or *Rostkovia magellanica* dominant);

Other grass types (e.g. *Hierochloë redolens* dominant).

(iv) Herbage

The herbage in each of the five quadrats was clipped to ground level and bulked to give one sample per Green. This herbage was dried at 80°C for 24 hours and weighed to determine the standing crop. A dried sub-sample was analysed for the proportions of N (total), Ca, K, Mg, and P using standard analytical techniques (MAFF 1987).

(v) Soil

One soil core, 2.5 cm in diameter, was sampled to a depth of 15 cm in each of five quadrats and bulked to give one sample per Green. Samples were taken fresh to the laboratory where moisture content (oven dry %), pH, C:N, nitrate-N and ammonium-N, Ca, Mg, P and K were determined using standard analytical techniques (MAFF 1987).

(vi) Other

The area of bare ground and the cover/abundance of all faecal material in each quadrat were estimated using the Domin scale.

Data analysis

The floristic data were averaged over the five quadrats recorded from each Green.

Four separate data matrices were created each of 131 Greens by the following attributes: 43 species and bare ground cover/abundance, nine environmental (geographic, physiographic and biotic) features, nine soil chemical and dung cover/abundance, five herbage biomass, species diversity and chemical composition.

Where appropriate the soil chemical, herbage biomass and P composition, dung and bare ground were transformed to their natural logarithms (ln) prior to statistical analysis. Data matrices were edited as recommended by Gauch (1982). "Rare" species (see Appendix I), that occurred in less than about 5% (7) of the Greens sampled, were deleted from the floristic matrix before classification and ordination.

Classification

To characterise the vegetation and to provide a classification that could be used during other studies on Greens, the floristic and bare ground cover/abundance data were divided into groups using a divisive hierarchical classification, the two-way indicator-species analysis "TWINSPAN" (Hill *et al*. 1975). The default values were used, except as follows:

a. The number of pseudospecies cut off levels was set to four. These were 0.1, 4.0, 6.0, 8.0 on the Domin scale and represented the typical species cover/abundance categories of "present, a little, a lot, and more or less dominant" as suggested by Hill (1979a),

b. The maximum level of divisions was set to three. This produced eight groups, beyond which clear ecological interpretation was not readily obtained.

Analyses of variance compared species, soil and herbage attributes between the communities of Greens identified by the classification and dominance between species within each community. Chi-square tests, with Yates' correction, were conducted to test for associations between the environmental features and the groups of Greens. Tables were constructed in which the environmental features, either binary or categorical, were the columns and the community groups were the rows. Tests were conducted only for groups formed at the first and second level of division. Beyond this level table entries were too small (<1) for valid tests to be conducted.

Ordination

To examine inter-site and inter-species relations the floristic data were ordinated using the detrended correspondence analysis program "DECORANA" (Hill 1979b). To facilitate interpretation of possible environmental gradients, the communities formed in the classification were superimposed on the ordination co-ordinates. Additionally, arbitrary boundary lines were drawn in ordination space to highlight discrete communities.

Step down predictive regression

To examine relations between the vegetation and the soil and dung factors step down predictive regression equations were calculated for the first four ordination axes. Ordination positions of the sites were regressed against the soil chemical variables.

RESULTS

Geographic

Greens occurred widely on West Falkland (62), East Falkland (53) and on the three outlying islands (16) that were surveyed (Table 1a).

Physiographic

The size of individual Greens ranged from about 0.01 ha to 136 ha with a mean of 10.7 ha. 64%, 29% and 7% were <5 ha, 5-20 ha and >20 ha, respectively. They varied greatly in shape, although on valley bottoms, the most common position (46%) (Table 1b), they often followed the shape of the valley. Greens on open plains (33%), mid-slopes (17%) and hill crests (4%) generally had irregular shapes. However, where Greens were associated with fence lines, paddock corners, or small paddocks (26%) their shapes often followed those of the fences. Greens found near penguin rookeries often followed the shape of the coast and sometimes

TABLE 1. Geographic, physiographic and biotic features of short grass and herb communities (Greens) in the Falkland Islands. Only those with significant ($P<0.05$) χ^2 associations are presented. Key: O = observed frequency, E = expected frequency, C = cell χ^2.

a. Geographic

Communities		Location: East Falkland	Location: West Falkland	Location: Smaller islands	Latitude South: Northern, 51°-51°30'	Latitude South: Central, 51°30'- 52°	Latitude South: Southern, 52°- 52°30'	Proximity to the sea: Coastal	Proximity to the sea: Inland, (>3km from sea)
I-II	O	8	12	1	4	15	2	8	13
	E	8.5	9.94	2.56	4.97	14.11	1.92	9.14	11.86
	C	0.03	0.43	0.95	0.19	0.06	<0.01	0.14	0.11
III-IV	O	18	21	1	3	34	3	14	26
	E	16.18	18.93	4.89	9.47	26.87	3.66	17.4	22.60
	C	0.2	0.23	3.09	4.42	1.89	0.12	0.67	0.51
V-VI	O	21	17	6	13	28	3	17	27
	E	17.8	20.82	5.37	10.41	29.56	4.03	19.15	24.85
	C	0.57	0.7	0.07	0.64	0.08	0.23	0.24	0.19
VII-VIII	O	6	12	8	11	11	4	18	8
	E	10.52	12.31	3.18	6.15	17.47	2.38	11.31	14.69
	C	1.94	0.01	7.33	3.82	2.39	1.10	3.95	3.04
Total O		53	62	16	31	88	12	57	74
		χ^2 = 15.56, P = 0.0163, d. f. = 6			χ^2 = 14.98 P = 0.0204, d. f. = 6			χ^2 = 8.85 P = 0.0313, d. f. = 3	

b. Physiographic

Communities		Landscape position: Open plain	Landscape position: Valley	Landscape position: Mid-slope/ crest	Proximity to fresh water: Not near	Proximity to fresh water: Near stream	Proximity to fresh water: Near pond	No. of directions sheltered: 0-1, exposed	No. of directions sheltered: 2-4, sheltered	Shelter to the South: Absent	Shelter to the South: Present
I-II	O	4	15	2	4	15	2	7	14	13	8
	E	6.89	9.78	4.33	5.93	11.86	3.21	9.94	11.06	14.27	6.73
	C	1.21	2.79	1.25	0.63	0.83	0.45	0.87	0.78	0.11	0.24
III-IV	O	12	23	5	10	29	1	17	23	29	11
	E	13.13	18.63	8.24	11.30	22.60	6.11	18.93	21.07	27.18	12.82
	C	0.10	1.03	1.28	0.15	1.82	4.27	0.20	0.18	0.12	0.26
V-VI	O	12	17	15	12	26	6	18	26	24	20
	E	14.44	20.49	9.07	12.43	24.85	6.72	20.82	23.18	29.89	14.11
	C	0.41	0.59	3.88	0.01	0.05	0.08	0.38	0.34	1.16	2.46
VII-VIII	O	15	6	5	11	4	11	20	6	23	3
	E	8.53	12.11	5.36	7.34	14.69	3.97	12.31	13.69	17.66	8.34
	C	4.90	3.08	0.02	1.82	7.78	12.45	4.81	4.32	1.61	3.42
Total O		43	61	27	37	74	20	62	69	89	42
		χ^2 = 20.55 P = 0.0022, d. f. = 6			χ^2 = 30.34 P < 0.0001, d. f. = 6			χ^2 = 11.89 P = 0.0078, d. f. = 3		χ^2 = 9.38 P = 0.0246, d. f. = 3	

c. Biotic

Communities		Type of occupancy by livestock: Non-camp area	Type of occupancy by livestock: Camp area	Type of occupancy by livestock: Fence line effect	Type of occupancy by livestock: Small paddock	Occupancy by penguins: Absent	Occupancy by penguins: Present
I-II	O	4	14	1	2	21	0
	E	5.61	9.94	1.92	3.53	17.47	3.53
	C	0.46	1.66	0.44	0.66	0.71	3.53
III-IV	O	3	18	6	13	40	0
	E	10.69	18.93	3.66	6.72	33.28	6.72
	C	5.53	0.05	1.49	5.88	1.36	6.72
V-VI	O	11	23	4	6	35	9
	E	11.76	20.82	4.03	7.39	36.61	7.39
	C	0.05	0.23	0	0.26	0.07	0.35
VII-VIII	O	17	7	1	1	13	13
	E	6.95	12.31	2.38	4.37	21.63	4.37
	C	14.55	2.29	0.8	2.6	3.45	17.07
Total O		35	62	12	22	109	22
		χ^2 = 36.94, P <0.0001, d. f. = 9				χ^2 = 33.25, P <0.0001, d. f. = 3	

extended up to several hundred metres inland. 69% of the Greens were well sheltered (i.e. from at least two directions) and most commonly from the west (Table 1b). 57% were close to streams and 15% to ponds, where the green often surrounded the pond (Table 1b). All Greens were low lying (<83 m.a.s.l.) and 55% of sites were sloping.

Management and Utilisation

Accurate histories of fire in each paddock were difficult to obtain as many farms had changed ownership since sub-division of large farms began in 1980. However 18% of Greens had been burned within five years and at least another 13% in the previous five years. 72% of Greens were in large paddocks in which the annual stocking rate was low (<0.4 sheep/ha) (Table 1c). Sheep alone were present at 56% of Greens, while at the rest cattle and/or horses were also present, particularly at Greens on the outlying islands (Table 1c). 74% of Greens had been used frequently by livestock (Table 1c). Well-worn tracks and abundant deposits of dung of varying age were present. These Greens were probably either bedding areas, or areas where livestock regularly congregated, were herded, or confined temporarily e.g. before and after sheep shearing.

Floristics

Of the 43 species or groups of species of higher plants identified, 23 were dicotyledons (forbs), 16 were monocotyledons (graminoids) and 4 pteridophytes (Appendix 1). The species were mainly herbaceous as only three species of shrubs were found. There were more forbs species than graminoids, but the graminoids occurred more frequently and had greater cover than the forbs. The average number of species per green was 11. The species or groups comprised c. 12% of the vascular flora of the Falkland Islands (Broughton & McAdam 1999) and c. 29% was alien to the Islands (Moore 1968, Broughton & McAdam 2002) (Appendix I). The most dominant species were *Agrostis* spp, *Juncus scheuchzerioides*, *Gunnera magellanica*, and *Poa pratensis*. At least one of these species occurred in all Greens. Some *Agrostis* spp and *P. pratensis* are alien species. *Lycopodium* spp. was the most common pteridophyte. Greens were surrounded most frequently by grass and dwarf-shrub heath.

APPENDIX I. Abbreviated and botanical names, taxonomic groups, origins, frequency of occurrence and mean Domin value of species found in a survey of patches of short grasses and herbs (Greens) in the Falkland Islands. Key: Group; D = dicotyledon, M = monocotyledon. All species are herbaceous except S = shrub and P = pteridophyte (Moore, 1968). Origin; I = introduced, N = native (Moore, 1968). Frequency; R = rare species, (present at <5% of sites).

Abbreviation	Botanical name	Group	Origin	Frequency (%)	Domin Value
Ac lu	*Acaena lucida*	D	N	1 R	<0.1
Ac ma	*Acaena magellanica*	D	N	3 R	<0.1
Ag sp	*Agrostis* spp.	M	N, I	81	3.6
Ai pr	*Aira praecox*	M	N	63	1.3
Am ar	*Ammophila arenaria*	M	N	1 R	<0.1
As pu	*Astelia pumila*	D	N	1 R	<0.1
Az sp	*Azorella* spp.	D	N	15	0.2
Ba ma	*Baccharis magellanica*	D, S	N	11	<0.1
Be pe	*Bellis perennis*	D	N	17	0.2
Bl pe	*Blechnum penna-marina*	P	N	18	<0.1
Bryo	Bryophytes	P	N	5 R	<0.1
Ca sa	*Caltha sagittata*	D	N	8	0.1
Ca sp	*Carex* spp.	M	N	2 R	<0.1
Ce fo	*Cerastium fontanum*	D	I	31	0.1
Co qu	*Colobanthus quitensis*	D	N	50	0.6
Co pi	*Cortaderia pilosa*	M	N	24	0.2
Em ru	*Empetrum rubrum*	D, S	N	2 R	<0.1
Fe sp	*Festuca* spp.	M	N, I	50	1.0
Ga pu	*Gaultheria pumila*	D, S	N	14	<0.1
Gn lu	*Gnaphalium luteoalbum*	D	N	2 R	<0.1

APPENDIX I. Continued.

Gu ma	*Gunnera magellanica*	D	N	70	2.6
Hi re	*Hierochloë redolens*	M	N	12	0.1
Ho la	*Holcus lanatus*	M	I	24	0.5
Hy fa	*Hymenophyllum falklandicum*	P	N	2 R	<0.1
Ju sc	*Juncus scheuchzerioides*	M	N	88	3.0
Le sc	*Leptinella scariosa*	D	N	20	0.5
Lich	Lichens	P	N	5 R	<0.1
Li ma	*Lilaeopsis macloviana*	D	N	30	0.8
Lu al	*Luzula alopecurus*	M	N	10	<0.1
Ly sp	*Lycopodium* spp.	P	N	67	1.5
Ma gr	*Marsippospermum grandiflorum*	M	N	2 R	<0.1
Ne gr	*Nertera granadensis*	D	N	5 R	<0.1
Or ob	*Oreobolus obtusangulus*	M	N	1 R	<0.1
Or ho	*Oreomyrrhis hookeri*	D	N	37	0.3
Po an	*Poa annua*	M	I	58	1.4
Po pr	*Poa pratensis*	M	I	78	2.0
Po ro	*Poa robusta*	M	N	4 R	<0.1
Pr re	*Pratia repens*	D	N	68	1.4
Ra sp	*Ranunculus* spp.	D	N, I	50	0.5
Ro ma	*Rostkovia magellanica*	M	N	4 R	<0.1
Ru ac	*Rumex acetosella*	D	I	63	1.0
Sa pr	*Sagina procumbens*	D	I	11	0.2
Sp me	*Spergularia marina*	D	N	1 R	<0.1
Tr re	*Trifolium repens*	D	I	2 R	<0.1
Unid	Unidentified species	-	-	5 R	<0.1

APPENDIX II. Values, means, minima, and maxima for soil, dung and herbage factors of short grass and herb communities (Greens) in the Falkland Islands. Dv = Domin value of abundance/ cover.

Soil and dung factors				
Factor	Number	Mean	Minimum	Maximum
pH	131	4.7	4.0	6.7
H_2O (%)	131	49	9	85
Dung cover (Dv)	129	1.9	0	5.2
Ca (mg/l)	131	510	90	3200
K (mg/l)	131	163	13	521
Mg (mg/l)	131	305	71	870
P (mg/l)	131	28	4	171
NH_4 N (ppm)	111	35	0	222
NO_3 N (ppm)	111	1.4	0	46.7
C : N	131	31	3	220
Herbage factors				
Ca (%)	128	0.35	0.16	1.03
K (%)	128	1.36	0.61	2.47
Mg (%)	131	0.33	0.16	0.54
P (%)	128	0.20	0.06	0.57
N (%)	128	2.36	1.32	3.78
Biomass (g DM/m^2)	129	24	2	105
Species (n)	131	11	3	16

Soils

Soil type ranged from highly organic, acidic peat on wetter sites to less acidic mineral clay loam on drier sites and occasionally sandy loam at coastal sites. The ranges and the means of soil pH, moisture content, exchangeable Ca, K, Mg, P, NH_4-N, and NO_3-N, C: N and dung cover are shown in Appendix II.

Herbage

The range and means for the amounts of standing crop, bare ground cover, species diversity and the levels of N, K, Mg, Ca, and P in the dried herbage are shown in Appendix II.

Wildlife

Penguins were present, often in large populations, at 22 sites. Magellanic penguins (*Spheniscus magellanicus*) and Gentoo penguins (*Pygoscelis papua*) were the most common species. King penguins (*Aptenodytes patagonicus*) were present at fewer

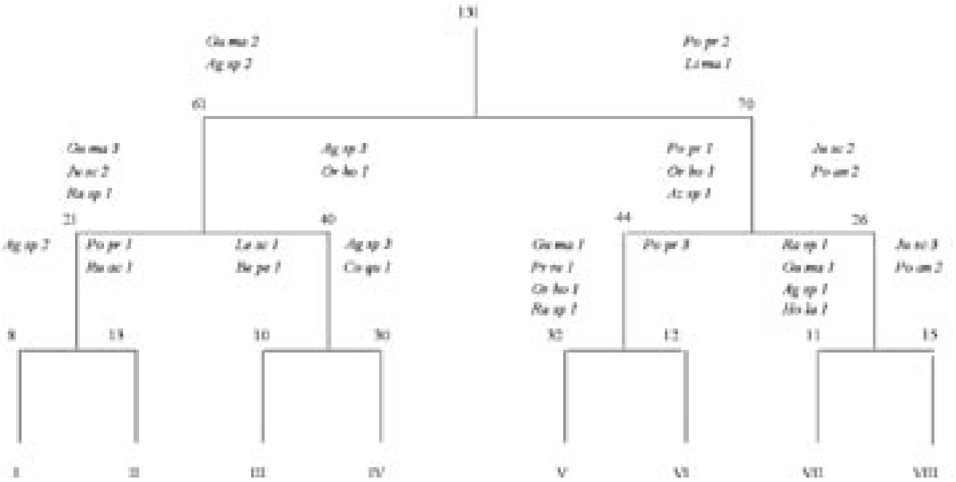

Fig. 2. Twinspan classification of patches of short grasses and herbs (Greens) in the Falkland Islands. At each division the indicator pseudospecies and the number of species on each side are shown. Species names are the first two letters of the genus and species, see Appendix I for full names. Roman numerals represent communities.

sites. Native sheldgeese (*Chloephaga rubidiceps*, *C. picta* and *C. hybrida*) were frequently observed at sites near to ponds and in valleys but population densities were not recorded.

Classification

Eight plant communities (I -VIII) were recognised (Fig. 2). They differed significantly ($P<0.05$) in standing crop, the levels of Mg and P in the dried herbage (Table 2), the number of species and the cover/abundance of 16 of the main species (Table 3), the cover of dung and the levels of K, Mg, P, NH_4-N in the soil (Table 4). The main environmental features of each community were summarised in Table 5.

Ordination

The eigenvalues for the four axes of the ordination of sites were 0.268, 0.236, 0.167 and 0.139 respectively. The best separation occurred along axis one and was between communities I-IV to the left and VI and VIII to the right (Fig. 3). Also communities I-IV were almost distinct from VIII. The separation of the communities was not improved when the Greens were ordinated on the other axes combinations. Separation between the groups of communities also occurred at the first level of division in the classification. However, the separation was not as clear as that between the communities formed at the third level. Communities I-IV had relatively lower values on axis one than communi-

TABLE 2. The mean concentrations of Mg and P in the herbage and the herbage biomass of short grass and herb communities (Greens) in the Falkland Islands. Communities were formed at the third level of division in a hierarchical classification. Real and natural log means with the same letter below them were not significantly ($P > 0.001$) different.

	Communities							
	I	II	III	IV	V	VI	VII	VIII
Mg (%)	0.35	0.40	0.34	0.30	0.32	0.31	0.34	0.30
	ab	a	ab	b	b	b	ab	b
P (%)	0.13	0.16	0.18	0.17	0.19	0.27	0.21	0.33
(ln)	0.13	0.15	0.17	0.16	0.17	0.24	0.19	0.28
	c	c	bc	c	c	ab	bc	a
Herbage biomass (g DMm^{-2})	37	33	35	23	22	11	22	18
(ln)	3.82	3.63	3.51	3.24	3.20	2.52	3.17	2.94
	a	ab	ab	ab	ab	c	abc	bc

TABLE 3. The mean number of species and Domin values of abundance/cover of the main species in short grass and herb communities (Greens) in the Falkland Islands. Communities were formed at the third level of division in a hierarchical classification. Only species with significantly ($P<0.05$) different Domin value means between communities are shown. Significance is indicated as follows; *** $P<0.001$, * $P<0.05$. Means with the same letter below them were not significantly different between communities.

Species	Sig.	I	II	III	IV	V	VI	VII	VIII
N° Species	***	8.1 d	11.4 abc	10.4 bc	11.7 ab	13.4 a	8.5 cd	12.1 ab	8.2 d
Agrostis spp.	***	5.9 ab	2.8 c	3.6 bc	6.9 a	2.5 c	1.4 c	2.6 c	1.3 c
Aira praecox	***	0.1 c	0.5 bc	0.4 bc	0.9 bc	2.4 a	2.2 ab	1.7 abc	0.6 bc
Azorella spp.	***	0	0	0	<0.1 c	0.5 b	0.7 a	0	0
Colobanthus quitensis	***	0.2 bc	0.3 bc	0	0.3 c	0.7 abc	1.3 ab	0.7 abc	1.5 a
Leptinella scariosa	***	0	0.4 b	2.9 a	0.1 b	0.5 b	0.4 b	0.8 b	0.2 b
Festuca spp.	*	0.1 c	1.0 bc	1.8 ab	0.5 c	0.9 bc	0.9 bc	2.5 a	1.1 bc
Gunnera magellanica	***	5.6 ab	6.3 a	3.0 bc	2.9 c	2.3 c	<0.1 d	1.8 cd	0.3 d
Holcus lanatus	*	0.8 ab	0.9 a	0.6 ab	0.8 a	0.1 b	0	0.5 ab	0.1 b
Juncus scheuchzerioides	***	3.7 abc	4.5 ab	2.6 bcd	2.0 cd	2.2 cd	1.1 d	4.7 ab	5.2 a
Lilaeopsis macloviana	*	0.3 abc	0.2 bc	0	0.2 c	1.0 ab	0.7 abc	1.5 a	1.1 ab
Lycopodium spp.	***	0.7 ab	0.4 ab	1.6 ab	1.8 ab	2.1 ab	2.9 a	1.0 ab	0.5 b
Oreomyrrhis hookeri	***	0	0.2 ab	0.4 ab	0.3 ab	0.7 a	0.2 ab	0	<0.1 b
Poa annua	***	0.2 b	0.9 b	0.6 b	0.7 b	1.5 b	1.3 b	1.5 b	4.4 a
Poa pratensis	***	0.1 c	1.4 bc	1.4 bc	1.5 c	2.8 b	5.7 a	1.3 c	1.3 c
Pratia repens	***	2.0 ab	2.7 a	0.8 bc	1.4 abc	1.8 ab	<0.1 c	1.7 abc	0.5 bc
Rumex acetosella	***	0	0.8 ab	0.8 ab	0.5 b	1.4 ab	2.2 a	0.5 ab	1.6 ab

ties V-VIII (Fig 3). About 30% of all the sites were closely ordinated in an intermediate zone near the middle of axis 1.

In the ordination of species on axes 1 and 2 (Fig. 4) four species (*H. lanatus, L. scariosa, Sagina procumbens* and *B. magellanica*) had relatively extreme values compared to the rest and were regarded as outliers. Bare ground cover was ordinated centrally. The other species ordinated into three groups (labelled X, Y and Z, Fig 4). Although the species groups formed in the ordination did not exactly match those formed by the classification the order of species was similar in both methods.

Multiple regression

The soil and dung factors explained low proportions (20-32%) of the variation in the first four axes of the ordination (Table 5). Explanatory gradients that included the soil and dung factors were slight and difficult to define from these factors alone. However, axis 1 represented positive gradients of Mg, P and dung cover and a negative gradient with soil moisture. Axis 2 represented a positive gradient with Ca and negative gradients with K and dung cover. Axis 3 represented positive gradients with NH_4-N and a negative gradient with pH. Axis 4 represented a positive gradient with P and a negative gradient with Ca.

TABLE 4. Mean levels of soil chemical, dung and bare ground factors for groups of short grass and herb communities (Greens) in the Falkland Islands. Significant differences between means are indicated as follows; *** = $P<0.001$, ** = $P<0.01$, * = $P<0.05$, ns = not significant. The units for the exchangeable cation and nitrogen factors are mg kg^{-1}, dv = Domin value.

Community groups formed at the first and second levels of division

Factor	Sig	I-IV	V-VIII	Sig	I-II	III-IV	V-VI	VII-VIII
pH	ns	4.7	4.8	ns	4.7	4.7	4.8	4.7
Ca		455	558		430	468	504	648
(ln)	ns	5.9	6.1	ns	5.86	5.93	5.99	6.23
K	ns	152	174	***	112 b	172 ab	195 a	137 ab
Mg	ns	281	325	ns	268	288	329	318
P		21	35		22	20	28	48
(ln)	***	0.15 b	0.21 a	***	3.02 ab	2.89 b	3.12 ab	3.55 a
NH_4 -N		27	41		21	31	48	29
(ln)	ns	3.1	3.3	*	2.82 b	3.22 ab	3.48 a	2.99 b
NO_3 -N		0.55	1.96		0.27	0.71	1.33	3.1
(ln)	ns	0.33	0.56	ns	0.17	0.41	0.55	0.58
C:N	ns	32	30	ns	27	35	29	33
(ln)	ns	3.39	3.40	ns	3.32	3.43	3.33	3.50
H_2O (%)	*	53 a	46 b	ns	55	52	45	48
Dung cover (dv)	**	1.6 b	2.1 a	**	1.1 b	2.0 ab	2.4 a	1.6 ab
Bare ground (dv)	**	1.1 b	2.0 a	*	1.0 b	1.2 b	2.0 a	2.0 a

Communities formed at the third level of division

Factor	Sig	I	II	III	IV	V	VI	VII	VIII
pH	ns	4.8	4.7	4.8	4.7	4.7	4.9	4.8	4.7
Ca		404	446	523	450	393	802	430	808
(ln)	ns	5.94	5.81	6.03	5.90	5.89	6.24	5.96	6.42
K	***	124 bc	106 bc	190 abc	166 abc	178 abc	241 a	89 c	172 abc
Mg	**	266 b	269 b	320 ab	278 b	289 b	435 a	278 b	348 ab
P		19	23	19	20	24	38	24	66
(ln)	***	2.91 b	3.08 ab	2.91 b	2.88 b	2.99 b	3.45 ab	3.11 ab	3.86 a
NH_4-N		22	21	49	26	39	70	33	27
(ln)	*	2.69 c	2.95 bc	3.73 ab	3.10 bc	3.35 abc	3.78 a	2.72 c	3.21 abc
NO_3-N		0.49	0.07	1.85	0.44	0.94	2.24	0.30	5.2
(ln)	*	0.30 abc	0.06 c	0.88 a	0.30 bc	0.50 abc	0.67 ab	0.21 bc	0.86 a
C:N		26	27	36	35	29	27	32	33
(ln)	ns	3.31	3.33	3.49	3.41	3.37	3.23	3.46	3.53
H_2O (%)	ns	55	55	52	52	48	36	48	48
Dung cover (dv)	**	0.8 b	1.4 ab	1.7 ab	1.9 ab	2.5 a	2.1 ab	1.4 ab	1.8 ab
Bare ground (dv)	ns	1.1	0.9	1.2	1.2	2.1	2.0	1.9	2.1

TABLE 5. Summary of the main environmental features of short grass and herb communities (Greens) in the Falkland Islands. The letters L (Low), M (Medium) and H (High) are comparative levels and are based on differences between the community means for each variable. Full species names are given in Appendix I.

Community	I	II	III	IV	V	VI	VII	VIII
Dominant species	*Ag* sp. *Gu ma*	*Gu ma* *Ju sc*	*Ag* sp. *Le sc* *Ju sc*	*Ag* sp.	-	*Po pr*	*Ju sc*	*Ju sc* *Po an*
Indicator species	5% *Ag* sp.	*Po pr* *Ru ac*	*Le sc* *Be pe*	33% *Ag* sp. *Co qu*	*Gu ma* *Pr re* *Or ho* *Ra* sp.	33% *Po pr*	*Ra* sp. *Gu ma* *Ag* sp. *Ho la*	33% *Ju sc* 5 % *Po an*
Herbage; Biomass	H	M	M	M	M	L	M	M
Mg	M	H	M	L	L	L	M	L
P	L	L	M	L	L	M	M	H
Soil; K	M	M	M	M	M	H	L	M
Mg	L	L	M	L	L	H	L	M
P	L	M	L	L	L	M	M	H
NH_4-N	L	L	M	L	M	H	L	L
NO_3-N	M	L	H	M	M	M	M	H
Dung cover	L	M	M	M	H	M	M	M
Associations; Geographic	-		51°30' - 52° S		-		Outlying islands < 51° 30'S & > 52 °S Coastal	
Physiographic	Valley		Valley Near stream		Mid-slope Crests Shelter to S		Open plains Near ponds Exposed sites	
Biotic	Livestock camp areas		Fence line effect Small paddocks		-		Penguins present	

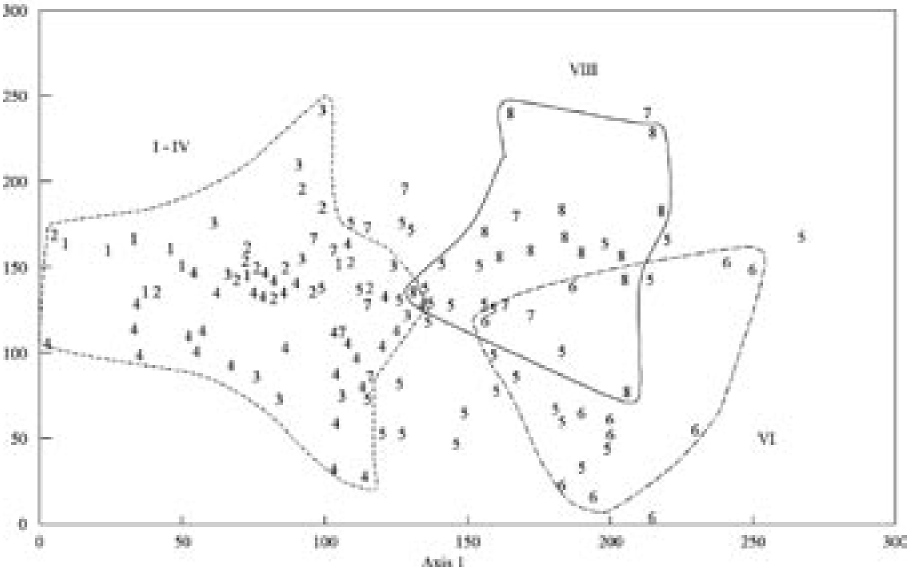

Fig. 3. Axes 1 and 2 of the ordination of patches of short grass and herbs (Greens) in the Falkland Islands. Numbers indicate classification communities at the third division level. Boundaries indicate the approximate ordination space of the most discrete communities.

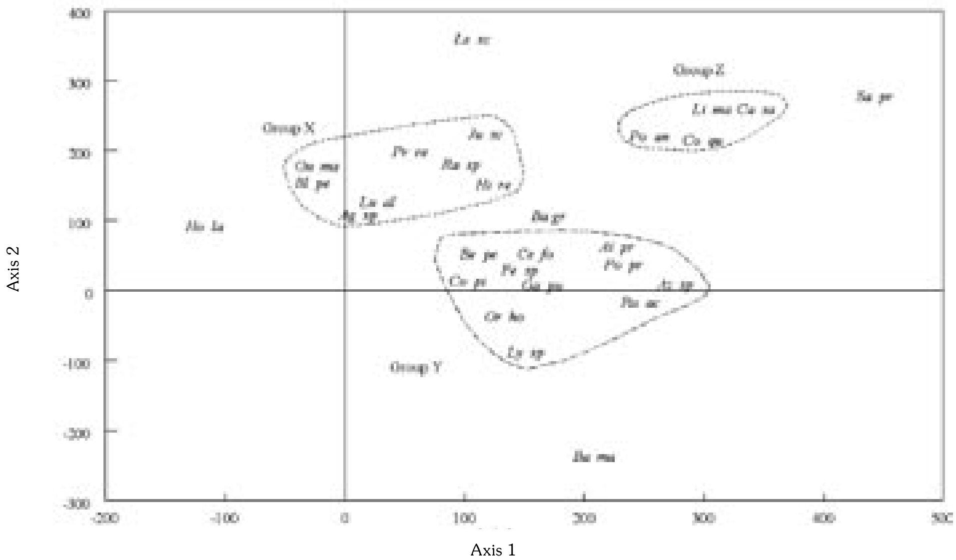

Fig. 4. Axes 1 and 2 of the DCA ordination of the main species and bare ground found in patches of short grasses and herbs (Greens) in the Falkland Islands. Boundaries highlight species groups. See Appendix I for full species names.

DISCUSSION

Floristics

Several short-growing graminoids and forbs, some of which were alien species, dominated Greens. Generally Greens classified as *Agrostis* spp.- *G. magellanica* - *J. scheuchzerioides* - *Poa* spp. grassland. Although many of the species were common to the *Cortaderia* and *Empetrum* associations (Davies 1939, Moore 1968) the shortness of the swards and the paucity of both tussock forming and dwarf shrub plants were distinctive floristic features of Greens.

Greens had many species in common with other grassland communities at similar latitudes. Greens were most similar to the Mesic grassland "meadows" of the Patagonian Steppe in Tierra del Fuego; dominated by *J. scheuchzerioides* and *G. magellanica* and which occurred in valleys or alongside watercourses (Moore 1983). Greens were similar to the Fuegian Alpine "meadows" which had poor drainage and supported grassy vegetation, often dominated by *Agrostis magellanica* (Moore 1983). The co-dominance of *P. pratensis* also occurred on grazing lawns in the steppe of Tierra del Fuego (Posse *et al.* 2000). In the Northern Hemisphere, Greens were similar to the *Agrostis/ Festuca* ve-

TABLE 6. Slopes of the step-down predictive equation in the multiple regression between significant soil factors and values of the first four axes of the DCA ordination of short grass and herb communities (Greens) in the Falkland Islands. Significance is indicated as follows; **** = $P<0.0001$, *** = $P<0.001$, ** = $P<0.01$, * = $P<0.05$.

	Axis							
Factor	1		2		3		4	
pH	-	-	-	-	-34.844	***	-	-
Ca	-	-	22.442	***	-	-	-21.443	***
K	-	-	-0.211	****	-	-	-	-
Mg	0.113	**	-	-	-	-	-	-
NH_4-N	-	-	-	-	12.000	**	-	-
P	25.814	***	-	-	-	-	27.013	****
H_2O	-0.952	***	-	-	-	-	-	-
Dung cover	9.950	**	-7.382	*	-	-	-	-
r^2	0.324		0.284		0.201		0.204	

getation types in Scottish (Frame *et al.* 1985) and Welsh hills (Hughes 1958).

Floristically two main types of Greens could be distinguished viz. a. those with high cover of the forb *G. magellanica* in association with the grass *Agrostis* and b. those dominated by the grasses *P. annua* and *P. pratensis*. When the communities classified at level three were superimposed on the ordination (Fig. 3) the separation between communities was generally restricted to those at the extremes of the classification and dominated by these four species. Despite this simple distinction, the high constancy of a few species, especially *J. scheuchzerioides*, across most communities (Table 3) suggested that floristically Greens were more alike than they were different. It also suggested that the variation between Greens was more continuous than it was discrete. The floristic composition of the two largest communities, IV and V, which together contained 47% of all sites, supported this conclusion in that they both contained all the main species found in the other communities. Our data were typical of the "fuzzy" data sets which Equihua (1990) and other authors (reviewed in Belbin & McDonald 1993) regarded as suitable descriptions of the continuous (non-discrete) distribution of species along environmental gradients.

The floristic similarity of Greens and their distinctness from the dominant native grasslands suggested that they were specialised communities. A few dominant species have become adapted to a specific set of environmental factors. Greens occurred in a variety of topographic positions, most of which had relatively high levels of livestock occupancy in comparison to the other heath communities. The consequent disturbance, mainly through the grazing, treading and manuring by sheep was common to most Greens and was probably the primary cause of vegetative change from the *Cortaderia/Empetrum* dominant vegetation.

Soils

The soils of all Greens were acidic. While most had pH values in the expected range (4.1 5.0) for the land systems in the Falkland Islands (King *et al.* 1969) 23% of the soils had pH ranges which were more favourable for plant growth. These soils were from valley, pond or penguin Greens.

Most land facets had adequate levels of K and Mg in their soils and all had very low values for total P and exchangeable Ca, except soils from marine terraces and valley bottoms, which had higher than average values (King *et al.* 1969). Our results confirmed that soils from Greens on these land facets had high values for all these minerals.

Herbage

The range in standing crop on Greens (Appendix IIb) was lower than for *Cortaderia* communities (2 - 22 t/DM/ha) (Davies *et al.* 1990). This was probably due more to differences in utilisation by herbivores than to differences in the herbage productivity between the two communities. Annual productivity of Greens was 4 - 14 t DM/ha of which 65 - 94% was utilised (Kerr & McAdam 1993). As well as the differences in utilisation between different plant communities, they also found that utilisation was greater on coastal Greens, occupied by penguins, than on inland valleys, which were not.

The chemical composition of Greens herbage (Appendix II) may have encouraged their selective grazing by livestock in preference to other communities. N levels in herbage from Greens (1.3 - 3.8%) were higher than those found in a range of herbaceous species (0.7 - 2.5%) selected from other pastures in the Falkland Islands (Davies 1988). The levels of Ca (0.1-0.5%), Mg (0.1 - 0.6%), and K (0.9 - 2.8%) found by Davies (1988) were similar to those found in Greens, (0.2 - 1.0%, 0.2 - 0.5% and 0.6 - 2.5%, respectively) in our survey. He also found that the forb *Gunnera magellanica*, an abundant species in Greens, had relatively higher levels of N, Ca and Mg than the other species sampled, which were not abundant in Greens. This species may have been the source of the higher levels of Mg found in herbage from community II.

The chemical composition of herbage from Greens also compared favourably with that from similar communities in other cool temperate grasslands. The average N level (2.4%) of Greens was higher than that from grasslands on Soay (2.2%) (Milner & Gwynne 1974), an extensively grazed Scottish island, and from upland grasslands in Wales (2.3%) (Hughes *et al.* 1964). The latter herbage had slightly higher levels of K (1.7%) and similar levels of Ca (0.4%), P (0.2%) and Mg (0.25%) to those from Greens.

Relationships with animals

Disturbance by animal grazing, treading and defecation influenced the ecology of Greens to a great extent. Communities I-IV had probably been disturbed to a lesser extent than V-VIII since the latter had a greater cover of dung, more bare ground and generally less standing crop. Communities V-VIII also contained a greater proportion of species typically found in disturbed environments. *Rumex acetosella* (Davies & McAdam 1989) and *Poa pratensis* (Davies 1939) are known colonisers of disturbed grasslands. Davies (1939) regarded *J. scheuchzerioides* as "highly resistant to grazing". *P. annua* was a characteristic species of overgrazed tussock grassland in South Georgia (Walton & Smith 1973) and *P. pratensis* had the same status in the steppe of Tierra del Fuego (Posse *et al.* 2000) and in the Scottish uplands (King & Nicholson 1964). *Colobanthus quitensis*, a common species in community VIII, was associated with maritime tussock grassland in Tierra del Fuego, which was often disturbed by penguins, albatrosses and seals (Moore 1983). Exotic plant species were associated with highly disturbed grasslands in temperate areas of Australia (McIntyre & Lavorel 1994).

Inputs of nutrients from biotic sources probably had the greatest influence on the floristic and the chemical composition of Greens herbage and soils. Small deposits of calcareous shells exist and their potential to enhance Ca levels for agricultural purposes has been investigated by Miller (2000) and more recently by Radic & McAdam (2008). Additionally, the traditional remoteness of the Falkland Islands from markets has, for economic reasons, resulted in little use of imported lime and fertilisers. Inputs of N via fixation in sown introduced legumes have been provisionally estimated as 66-69kg N/ha (Radic & McAdam 2008). Only two greens contained a legume, viz. *Trifolium repens.* There are no native legumes. Furthermore it is only since 2000 that significant areas have been sown with introduced species (Miller *et al.* 2000).

Penguins

The main input of nutrients to coastal Greens was from penguins. Their rookeries were exclusive to communities V-VIII and were associated strongly with communities VII-VIII. Treading and manuring by penguins may have contributed to the better soil fertility of communities V-VIII compared to that of I-IV. Community VIII had the highest level of soil and herbage P. In an associated study, one of the penguin Greens in community VIII produced about 14 t dm/ha in one year (Kerr & McAdam 1993). This is one of the highest herbage production rates reported for any pasture in the Falkland Islands. The Green was grazed almost continuously and heavily by sheep and sheldgeese and was dominated *by J. scheuchzerioides, P. annua* and *L. scariosa.*

There were similarities in soil chemical status between Greens and some of the sub-Antarctic islands. Smith & French (1988) found 11 - 93 ppm of available P on Marion Island. One sample from a community heavily influenced by seal and penguin excreta measured 179 ppm P. This was close to the maximum for Greens in our survey, which was sampled from a pond Green near to a penguin colony. Smith & French (1988) also found higher levels of Ca, (120 - 460 ppm), K (117 - 627 ppm) and Mg (106 - 3086 ppm) than those found in our study.

Superior plant productivity related to enhanced soil fertility associated with penguin rookeries has been reported for other south Atlantic islands. On Marion Island, penguin excreta were composed of 80 % uric acid, which was rapidly converted to ammonia (Lindeboom 1984). The soils, enriched in NH_4-N, NO_3-N (Smith 1978) and inorganic-P (Smith 1976), sustained the improved vitality of many plants, such as *Agrostis magellanica*. The plants also had high levels of N and P in their leaves.

Sheep

Communities I-IV had similar floristic compositions associated with high levels of treading, manuring and grazing by sheep. *Agrostis* spp., *G. magellanica* and *J. scheuchzerioides* were common co-dominants of these communities. Their association with Greens where sheep habitually congregated or were herded suggests that the activities of sheep also had a major influence on Green ecology. Floristic differences between these communities were minor and confined to the relatively high abundance/cover of *Leptinella scariosa* in community III. This may have been related to flock management and the higher level of disturbance associated with the heavily stocked small paddocks in which these Greens occurred. Their soils had high levels of NH_4-N and NO_3-N compared to those of the other communities in this group.

Occupancy of Greens by sheep may also have been related to site exposure. The availability of shelter from the seasonally severe chilling winds (McAdam 1985) may have influenced the densities of sheep between exposed and sheltered sites, particularly in the large, low-lying and extensively managed paddocks. Sheltered Greens, such as those in communities V-VI, may have been frequented more often by livestock and consequently disturbed to a greater extent than more exposed Greens. A comparable mechanism also controlled the distribution of sheep on Soay. There, the weather, plant growth and animal heat loss in winter interacted to control sheep population densities on similar communities (Milner & Gwynne 1974).

Floristic composition may also have been related to site drainage. The soils of the communities V-VIII were drier than those of communities I-IV and this may have favoured the higher abundance/cover of *Poa pratensis* and *Aira praecox*. The dryness of these sites may also have encouraged sheep to lie down more often there. In turn this may have concentrated the return of nutrients via excreta to these more fertile sites. Similarly, the composition of *Festuca-Agrostis* grasslands on Scottish hills was closely related to soil base status and moisture regime (King 1962). There the effects could not be separated from those of grazing pressure and other environmental factors that influenced the selective grazing of species.

Cattle and horses

Other livestock may also have influenced the floristic composition of Greens communities through their selective preference for particular species and the subsequent dispersal of the seeds in excreta. The establishment of *P. annua, P. pratensis, Agrostis* spp., *Juncus* spp. and *Rumex acetosella* graminoids in cattle and sheep dung on Scottish moorland was favoured over that of dicotyledons (Welch 1985). He proposed that cattle, through their defecation, enhanced the spread of grasses that attracted them. Thus cattle had a homogenising influence on the vegetation within their range. We did not find any difference in floristic composition between Greens occupied by mixed livestock and sheep alone. However the homogenising effect of cattle may have been true for all Greens in that, they were generally species-poor, dominated by short-growing graminoids (Table 3) and had abundant deposits of faeces (Appendix IIa) from cattle, horses and sheep.

Sheldgeese

The native sheldgeese (*Chloephaga* spp.) may also exert a considerable effect on Greens. The high constancy of *J. scheuchzerioides* in Greens may have been due to its preferential selection by the sheldgeese (Summers & Grieve 1982) and its ability to reproduce clonally (Moore 1983). The sheldgeese may have encouraged the adventive spread of *J. scheuchzerioides*, particularly on pond and coastal Greens that they grazed frequently (Summers 1985). Similarly, on tundra vegetation in Canada, the foraging activities of native sheldgeese (*Anser caerulescens*) enhanced the establishment of stoloniferous graminoids from vegetative propagules (Chou *et al.* 1992).

Overall, sheldgeese may benefit the grazing value of Greens. Sheldgeese selectively graze Greens in preference to *C. pilosa* communities, but they consume (15% of the herbage with minimal adverse effects on pasture production (Summers 1985). Additionally, the high productivity of Greens (Kerr & McAdam 1993) may be attributed to close grazing of the sward by sheldgeese. Jefferies *et al.* (1986) found that grazing by sheldgeese increased the net aboveground primary production of stands of *Puccinellia phryganodes* in Canadian tundra. This was attributed to the maintenance of high relative growth rates of axillary shoots of *P. phryganodes* in grazed areas. We found that the more productive Greens contained species that were preferentially grazed by sheldgeese, such as *P. annua* and *P. pratensis* (Summers & Grieve 1982).

Sheldgeese may also have influenced Greens vegetation through their defecation. Summers & Grieve (1982) estimated that the daily output of faeces was 115 - 253 g dm/bird with N levels of 3.5 - 5.3 % OM. Given that geese population densities on Greens averaged 0.1 - 7.8 birds/ha, the output of N was calculated to be 4 - 718 kg ha/yr. As about 66% of N in the faeces of Canadian geese was estimated to be ammonia (Jefferies *et al.* 1986) it was probable that sheldgeese may have also positively affected N cycling on Greens.

The effects of the activities of each of sheep, cattle, horses, penguins and sheldgeese were difficult to separate. The effects of sheldgeese may only have been important around pond and coastal Greens where they gathered in large numbers. Defecation by penguins may have improved soil fertility and in turn enhanced herbage nutrient levels and greater herbivore activity. This agrees with the conclusion of Summers & Grieve (1982) that the main mechanisms of *Poa* Greens development were intensive grazing, trampling and manuring.

Management

Greens were floristically more similar than they were dissimilar and their management may now be easier to plan than if discrete floristic groups had been found. The species composition was a continuum in which the ubiquitous *J. scheuchzerioides* was associated with *G. magellanica* and *Agrostis* spp. on relatively wetter, infertile and undisturbed sites and with *Poa* spp. on drier, fertile and disturbed sites. Also, the variation in species composition was not associated strongly with the traditional distinctions between Greens based on landscape position or use by livestock. Although communities I-IV were most frequently located in valleys and holding paddocks and communities V-VIII were most frequently coastal and found near ponds, Greens at these four locations occurred in all community groups.

The high productivity and nutritive value of *Poa* Greens has long been recognised but as they composed only about three per cent of the land, mainly along coasts and around settlements, their contribution to sheep diets was limited due to severe uncontrolled grazing (Davies 1939). Kerr & McAdam (1993) confirmed their high productivity and utilisation by sheep and sheldgeese. This study showed that communities V and VIII, which were dominated by *Poa* spp. were barer than communities I-IV (Table 3) and had fewer species than most other communities, except community I. Additionally, community VI had the highest cover/abundance of club mosses (*Lycopodium* spp.). These have little grazing value for livestock. Thus the productive potential of these Greens was degraded. Many of these Greens occurred on slopes and crests where the shallow soils had been eroded by frequent treading by livestock.

To minimise further degradation of Greens the heterogeneous patterns of grazing and utilisation that exist between Greens and the surrounding pastures need to be evened out. In the extensive hill pastures in the south island of New Zealand, Thorrold *et al.* (1985) found that increased stocking rates produced more even distributions of sheep grazing and dung than sub-division alone, although sub-division may have enhanced the effect of stocking rate. In the Falkland Islands land sub-division since 1980 has resulted in higher stocking rates than before (Summers *et al.* 1993). Additionally, greater utilisation by sheep of *C. pilosa* pastures was achieved in summer by adjusting stocking rates in small (3 ha) paddocks according to changes in leaf length (Davies *et al.* 1989).

Recent research to improve the sustainability of sheep grazing in the Islands has demonstrated the potential of rotational grazing compared to continuous grazing, to improve sheep productivity on native pastures (Kerr & McAdam 2000, Kerr 2002) and to use hay made from *Cortaderia pilosa* and fortified with supplements (Miller *et al.* 2005). Under rotational grazing, areas containing Greens and the associated tussock *C. pilosa* were rested during summer and reserved for grazing during winter. Over three successive winters rotationally grazed wethers continued to gain weight in contrast to continuously grazed sheep, which lost weight (Kerr 2002[1]). Consequently, annual production from rotational grazed sheep was also superior. The superior productivity of the rotational sheep was due mainly to improved availability and utilisation of Greens forage by the sheep during winter. This improvement was attributed to the four-month rest from grazing these pasture types received during late summer.

It is also suggested that the forage content of *Poa* Greens, the preferred grazing areas in the drier *Empetrum* heaths in the Islands, could be enhanced through controlled mixed grazing and nutrient input, particularly P. In Scotland cattle grazing and defecation depressed the growth of the *Calluna vulgaris* in favour of palatable graminoids *e.g. Agrostis, Festuca* and *Juncus* (Welch 1985). P fertilisation to improve grass composition over that of the shrubs has been advocated for the *Empetrum* heaths in Tierra del Fuego (Mendoza *et al.* 1995) and in the Falkland Islands (Broughton 1999).

In conclusion, the characteristics of the Greens studied reflected the combined effects of defoliation, defecation and treading of the sheep, cattle, horses, sheldgeese and penguins that frequented them. Their value for sheep grazing would be improved and sustained using management strategies that utilise and integrate the beneficial effects of the livestock and birds.

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