Environmental Conservation

7 201-202 (1980)

... to remain ... d only by small arrows. The first ten-years' management plan is nearing its completion, and a new plan, based upon our experience, is now in preparation. At first our objective was to conserve a typical chalk woodland, but we now realize that we are owners of a very special woodland which is not at all typical.

A study of the weather is beginning in 1980—we are lucky to have a Trust member living on the edge of the Reserve, at the top of the hill, who is a meteorologist and has an official weather station in his garden. A comparison with results obtained in the valley where the Warden's house is situated should be very interesting.

Land prices in England in 1980 place the value of this Reserve at more than a quarter of a million pounds sterling. Naturalists' Trusts must, however, continue to try to save these rich pockets of wildlife.

Vera N. Paul, OBE
Overdale
Peppard Common
Nr Henley-on-Thames
Oxon, U.K.

Uncontrolled Grazing and Vegetation Removal in the Falkland Islands

The Falkland Islands (Latitude 51°S, Longtitude 60°W), an isolated archipelago in the South Atlantic ocean, have long been recognized for their relatively untouched wildlife potential (Strange, 1971). The predominant vegetation of the Islands is an oceanic heath that is notable for its uniformity, while there is a total lack of any natural tree-growth. As described by Moore (1968), there are only seven at all obviously different plant associations on the Islands, and, of these, two occupy almost 70% of the land area. Habitat diversity is very limited, and the main concentrations of flora and fauna are to be found in the coastal areas.

The two main plant associations of the coastal areas are:

(i) The *Poa flabellata* (Tussock-grass) fringe, which is not as extensive as it was before the introduction of grazing stock, when uncontrolled grazing of the palatable leaves resulted in its present diminished area status. The problems associated with the decimation of the Tussock-grass area have been fully discussed and described elsewhere (Strange, 1976).

(ii) The *Ammophila/Elymus* association. *Ammophila arenaria* and *Elymus arenarius* were introduced to the Islands in the 19th century, and one of the most extensive areas of cover of this association is on the Cape Pembroke peninsula (Fig. 1), which is approximately 7 km from the only sizeable human settlement on the Islands, Port Stanley (population *ca* 1,000). The history of the Cape Pembroke area reflects a successful *Ammophila/Elymus* establishment exercise and has been summarized by Hubbard (1937) as follows:

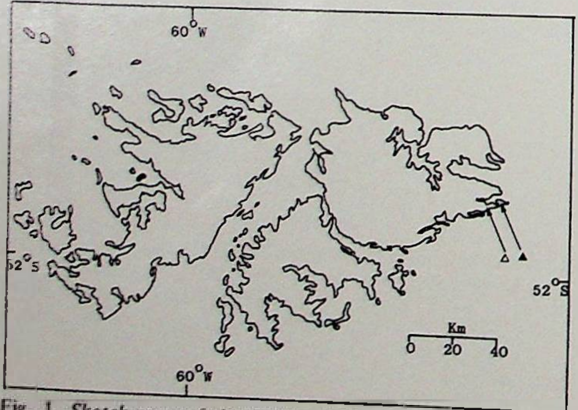

Fig. 1. Sketch-map of the Falkland Islands, with positions of Stanley (○) and Cape Pembroke peninsula (▲) indicated.

'The Board of Trade lighthouse at Cape Pembroke was situated in dismal surroundings, and sand, drifting from a source 4 or 5 miles [6.4 or 8 km] from the lighthouse, had destroyed practically all the vegetation on the peninsula and laid waste an area of about 1,800 acres [730 ha]. In addition it had almost buried the first floor of the light-keeper's quarters. Marram Grass (*Ammophila arenaria*) and Lyme Grass (*Elymus arenarius*) were imported and planted in 1923. The planting was most successful, and the whole area had [become] covered over by 1937 with sand-binding grasses.'

The area was securely fenced and used as common grazing for the Islanders' cows and horses, being carefully managed so as to provide valuable late summer and winter feed. This stocking pattern, with controlled grazing and removal of stock in the spring, was found to have no detrimental effect on the vegetation cover, and the encouragement of stock to eat poorer vegetation on the rest of the common-land outside the Cape Pembroke area for certain periods, was having a beneficial effect on the feeding quality and quantity of the vegetation in that area. The area was photographed in 1956 (Fig. 2), at which time the Cape area was considered to be well vegetated, with no reported problems from blown sand. The dunes had become stabilized, and breeding colonies of Gentoo Penguins (*Pygoscelis papua*) and Magellanic Penguins (*Spheniscus magellanicus*) had established themselves on parts of the area. A sand-dune-associated flora had also developed.

The Cape Pembroke peninsula supports one of the most extensive areas of sand-dune ecosystem on the entire Falkland Islands, and because of its proximity to Port Stanley it has considerable tourist and recreational potential. However, in 1972 work commenced on the construction of a 1,250-m-long airstrip on the Cape Pembroke peninusla (*see* Fig. 3), and the vegetation cover was removed over considerable areas. Fences were also removed to allow access for construction vehicles, and the grazing pattern of the area reverted to one of year-round uncontrolled grazing, with stock preferring to remain in the area in spring-time rather than graze the less-attractive pastures outside. As a result, the vegetation in the area at present does not have an opportunity to recover in the spring-time and this, coupled with the damage done to the vegetation by construction equipment in what is essentially a fragile and unstable ecosystem, has led to a reduction in the vegetation cover and a recurrence of the blown-sand problem.

The lighthouse keepers had, in 1978, noticed a considerable increase in the quantity of blown sand in the lighthouse buildings, and the airport contractors

Ecological and Agronomic Studies

Carried Out in The

Falkland Islands, from 1976 to 1978.

A REPORT

by

J.H.McADAM

Pasture Agronomist

Grassland Trials Unit

For :-

The Overseas Development Administration,

London.

1980

The Following Report is Presented to the Ministry of Overseas Development

The author was appointed by the Ministry of Overseas Development in January 1976 to act as Pasture Agronomist to the Grassland Trials Unit in the Falkland Islands.

The terms of reference were, in summary:-

a. Differentiate and define the range of vegetation communities of agricultural significance and assess their extent.

b. Measure the total and seasonal dry matter production and quality of the main vegetation species and communities, including the reseeded areas.

c. Carry out vegetation improvement studies

d. Carry out grazing studies.

The over riding consideration of the work was its integration into the Unit's programme of investigation aimed at increasing animal production in the Falkland Islands.

The period of the study covered 2½ years.

It is hoped that this report will be of value to the continuing programme of work by the Grasslands trials Unit and to all sectors of the agricultural community in the Islands.

J H McAdam BSc, BAgr, MAgr

November 1980

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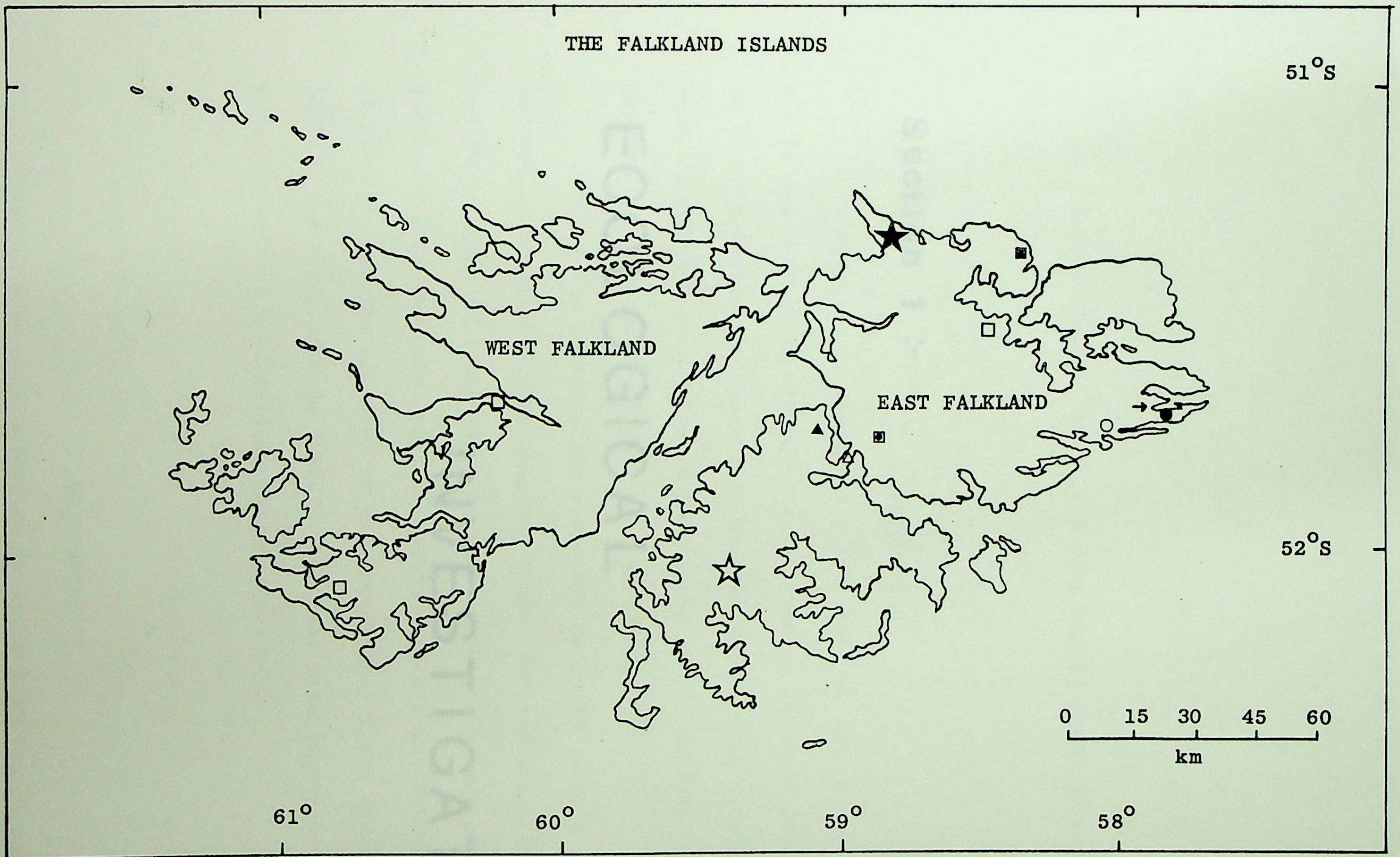

Map of the Falkland Islands illustrating the position of sites referred to in the text.

● Stanley (GTU Headquarters; Meteorological station; 1Bd)
▲ Brenton Loch (2 pasture system expt; Botanical cages; tatter flags)
■ Ronda (2 pasture system expt; Botanical cages; tatter flags)
△ Darwin (Reseed renovation expt; fertilizer on hayfields 2Bb2&3)
▣ Arroyos (2Bc)
○ Rolon Cove (IBe)
→ Moody Brook (IBc)
★ Cape Dolphin (Botanical cages)
☆ North Arm (Botanical cages)
□ Reseed Renovation expts (2Bb2)

Section 1 :-

ECOLOGICAL INVESTIGATIONS

PART A. CLIMATIC STUDIES

a. METEOROLOGICAL CONDITIONS OVER THE DURATION OF THE STUDY

INTRODUCTION

In attempting to define the interactions and performances of plants and animals in agricultural systems, a detailed knowledge of relevant climatic variables must be available. This information has been accumulated and published jointly by the Grasslands trials Unit and the Meteorological Office, Stanley (1977).

Many of the patterns and responses detailed in this report will be seen to be climatically induced, hence, for reference purposes and for the purpose of providing a background to the nature of the work carried out in the programme, the meteorological conditions prevailing at Stanley over the duration of the investigation are presented in Table 1 and summarised in Table 2. All the investigations reported were carried out between June 1976 and May 1978.

DISCUSSION

From the mean data presented in Table 1 it can be seen that the Falkland Islands have a cool oceanic climate, with a relatively modest seasonal variation. The mean winter temperatures are comparable with those experienced in Britain but the summer mean is more similar to conditions in Scotland. Air frosts are uncommon in summer but no month is frost-free and ground frosts can occur throughout the year.

Overcast conditions are frequent, and at Port Stanley more than half the sky is free of cloud on about 18 days in the year (Pepper 1954) so that sunshine levels are low.

The mean annual precipitation at Port Stanley during the period 1944-1978 was 640.3 mm. Rain can fall on an average of 150 days in the year and the monthly means indicate a markedly greater rainfall during the summer. It has been suggested by Skottsberg (1913) that the relatively low spring rainfall imposes strictures on plant growth.

At Stanley snow falls on about 55 days during the year and it may occur in any month, although usually in small amounts which do not lie for long on low ground.

Pressure generally decreases steadily from north to south over the Falkland Islands, giving gradients for Westerly winds; thus about 50 per cent of the winds are between SW and N-W and these can occur in any month. There is a high frequency of strong winds but the proportion of gales is low (2.5%). The strongest winds occur in November, thus probably emphasising the effects of low spring precipitation on plant growth (Moore 1968).

The rainfall and temperature data from other parts of the Falklands, although incomplete, show several departures from the conditions at Stanley (see Fig 1). Stanley is in one of the wetter parts of the Islands, the drier settlements generally lying in the southern part of the archipelago, while those with the higher rainfall occur in the north and are generally situated immediately north and east of high ground. In view of the prevailing westerly air streams across the area, it has been suggested (Moore 1968) that unstable air masses are warmed by their passage over the southern part of the Islands which, together with the uplift caused by the high ground to the north, accounts for the observed distribution of rainfall. There is a tendency of increasing temperatures towards the west and south of the Islands and this may well be an important factor affecting the distribution of some plants within the archipelago.

Growing Season

There has been considerable discussion on the factors affecting the onset of plant growth and the length of the growing season (Taylor 1967). Alcock et al (1968) demonstrated that temperature was responsible for the poorer growth in upland areas in spring and autumn and Munro and Davies (1973) found that in the uplands of Wales temperature remains the dominant factor throughout the year. General acceptance of temperature as a defining factor must be modified by consideration of wind speed (Warren Wilson 1959), soil type (Alcock et al 1968), precipitation (Hurst & Smith 1967) and altitude (Hunter and Grant 1971).

Alcock et al (1968) correlated a number of factors with plant growth on peaty soils and found that 10 cm soil temperature was the most highly correlated variable. The 10 cm soil temperature is a complex factor and it has been suggested that wind speed, particularly in spring, may be an important factor determining habitat differencesin soil temperature and plant regrowth.

The generally accepted temperature threshold for plant growth is 5.5 ^{o}C (Grass minimum temperature). The relation between this temperature and that in the soil at 10 cm has not been clearly defined due to the complex interaction of many factors.

However, data from the Falkland Islands show that the grass minimum reaches 5.5 ^{o}C concomitant with or slightly later than the 10 cm soil temperature. It was decided to adopt, as a general guide to the definition of growing season a 5.5 ^{o}C 10 cm soil temperature threshold. On this basis the mean duration of the growing season (1954-63) was 176 days (16th October to 23rd April). The duration of the growing period in 1976/77 was 185 days and in 1977/78 was 187 days.

The period of the investigations reported spanned two growing seasons. In 1976/77 the first part of the growing season was average with the growing conditions in the second part being ameliorated by warm, drier and less windy conditions than average. The winter in 1977 was, overall, more severe than usual being cooler, duller and wetter though less windy than average. The first part of the 1977/78 season was above average with conditions better than those found in the early part of the previous growing season. The second part of the season was warmer than average, with rain and wind being typical for that period.

In Summary, the growing conditions over the two seasons which these investigations spanned were better than average with the winter being more severe.

ACKNOWLEDGEMENTS

The supply of data and information by Mr D Borland, Senior Meteorological Officer, Stanley is gratefully acknowledged.

	MEAN HOURLY W SPEED (KTS)				AIR TEMPERATURE (°C)				10CM SOIL TEMP (°C)			
MONTH	1976	1977	1978	10 YR MEAN	1976	1977	1978	10 YR MEAN	1976	1977	1978	10 YR MEAN
J		15.1	17.1	16.2		9.5	9.5	8.5	9.6	9.9	10.2	9.5
F		14.7	14.7	16.8		10.0	9.7	8.9	9.2	10.0	9.8	9.6
M		15.2	16.4	17.2		8.3	8.5	8.1	8.3	8.6	8.5	8.2
A		14.0	17.6	15.7		6.7	5.9	5.7	6.3	6.4	6.4	6.0
M		16.1	13.4	16.9		4.5	3.6	4.0	4.2	4.1	4.1	4.1
J	12.4	14.4		17.1	2.0	3.6		2.5	2.9	3.3	2.7	2.7
J	13.3	10.5		17.0	1.5	1.0		2.4	2.3	1.6	1.4	2.0
A	15.1	13.9		16.7	3.0	1.9		2.3	2.5	1.8	2.4	2.1
S	16.2	14.5		16.9	2.9	3.0		3.3	3.4	3.1	4.2	3.4
O	18.3	16.8		17.4	5.2	5.4		5.3	5.4	5.5	6.3	5.5
N	18.3	17.8		18.0	7.0	7.1		7.0	7.6	8.3	7.8	7.7
D	16.1	17.4		16.9	6.3	9.8		7.7	9.4	10.3	9.6	9.0

Table 1 Meteorological data recorded at Port Stanley for the duration of the period over which the investigations reported were carried out. Long-term mean data are presented for comparison.

	RAINFALL (MM)				REL HUM (%)				MEAN HOURS SUNSHINE/DAY			
MONTH	1976	1977	1978	35 YR MEAN	1976	1977	1978	10 YR MEAN	1976	1977	1978	10 YR MEAN
J	89.9	30.0	81.5	74.4		84	87	81		7.6	6.6	6.2
F	33.5	31.6	43.0	56.1		85	89	81		6.1	5.5	6.0
M	73.5	80.2	42.9	50.5		86	91	82		4.3	4.1	5.3
A	56.9	56.4	73.7	51.1		95	91	87		3.1	2.5	3.9
M	53.5	70.1	29.8	54.8		94	91	88		3.1	1.6	2.6
J	63.4	59.6		50.7	93	94		89	1.6	2.2		1.9
J	52.2	42.7		44.9	90	93		89	3.1	2.0		2.2
A	20.8	38.3		45.1	87	93		88	3.7	2.5		3.0
S	30.2	46.5		34.9	87	87		85	4.5	3.9		4.2
O	77.1	29.8		42.0	89	85		80	4.1	5.7		6.3
N	62.3	61.3		69.1	84	83		79	6.0	7.9		6.5
D	90.1	19.1		66.7	89	86		80	4.8	7.7		6.4

Table 1 (contd.)

Table 2. Summary of conditions prevalent over the duration of the investigation. All conditions expressed relative to 10 year mean.

			SEASON 1976-77	SEASON 1977-78
GROWING SEASON	Oct-Dec	Rain	Above	Below
		Sun	Below	Above
		Wind	Slightly Above	Slightly Below
		Air Temp	Average	Above
		Soil Temp	Average	Above
	Jan-April	Rain	Considerably Below	Average
		Sun	Above	Above
		Wind	Below	Average
		Air Temp	Above	Above
		Soil Temp	Above	Above
WINTER	May-Sept	Rain	Slightly Above	
		Sun	Below	
		Wind	Below	
		Air Temp	Below	
		Soil Temp	Slightly Below	

1.A.

b COMPARITIVE ESTIMATES OF EXPOSURE TO WIND FROM THREE SITES USING THE RATE OF TATTER OF STANDARD FLAGS AS AN INDEX

INTRODUCTION

The term 'exposure' has often been ill-defined and no satisfactory quantitative definition of the term has been produced (Grace 1977). It may well be impossible since 'exposure' almost always relates to the response of some physical or biological system to various elements of the atmospheric environment, both acting singly and in different combinations. Exposure will be used in this report in the context of exposure to wind.

Lines and Howell (1963) gave detailed consideration to the problems of exposure on plant growth. In their work, (on trees) they analysed the combined effects of a number of variables, including elevation, rainfall, proximity to the sea and the rate of disintegration of cotton flags which contribute to the generalised concept of 'exposure'. There is evidence that on certain sites the rate of disintegration (tatter) of cotton flags may well be governed by that combination of atmospheric influences which inhibits plant growth and it is in this context flags may be better indicators of exposure than would purely wind measuring devices (Savill 1974).

The use of tattering of standard flags appears to be an inexpensive technique giving a general impression of wind-speed over a large area.

The performance of flags under controlled conditions has been investigated by Rutter (1966) who found that for dry flags the relationship between wind-speed and tatter was linear over a wide range of wind-speeds. For wet flags exposure to wind-speeds in excess of 30 knots resulted in an exaggerated degree of tatter. Rutter (1968) also studied tattering of flags at different sites in relation to wind and weather and found that they may be used within similar topographic situations to compare the exposure at different sites and on very exposed sites untrimmed (i.e. without the frayed edge cut off) flags were as reliable as those trimmed weekly. Rutter has concluded that intra-site comparisons using rate of tatter of untrimmed flags are valid and allow a considerable degree of substitution for anemometers, flag tatter corresponding well with time variations of exposure.

In view of the fact that measurements need only be taken at relatively widely spaced time intervals (4-8 weeks) and the isolation of the sites it was envisaged that the use of the tatter flag would give some comparison of exposure to wind at the sites of the two main sheep management experiments being carried out by the Unit. The placing of flags at Stanley would give a standard both for comparison with the two sites and correlation with meteorological data recorded on the same site. Calculated rates of tatter could be compared with those obtained in Britain and the results of such a comparison used to give some indication of the potential of plant growth on comparable sites.

MATERIALS AND METHODS

The flags were prepared in a similar fashion to those used by the Forestry Commission and described by Lines and Howell (1963). Flags were erected in triplets at each of 3 sites (see Fig 1). The top of each flag was at a height of 1.5 m above ground level and flags were free to rotate. Anomalous tatter values mentioned by Rutter (1968) (mainly due to ribbon fraying) occurred on at least one of the flags on some occasions and were discarded. Flags were untrimmed and changed at approximately 6-8 week intervals where this was convenient. After each change the area of solid weave lost by tattering was calculated using the formula Y=1179.4 -28.2x where Y is the area of flag lost in square cm and X is the length of flag remaining in cm, as measured horizontally from the pole to the centre of the frayed edge (Savill 1974).

RESULTS

The mean tatter rate per day was calculated from the 3 recorded flags at each site and the data presented in Table 1 and illustrated in Fig. 2. There was little variation between flags on any one site. It can be seen that there is a variation in rate of tatter with time, this variation being closely replicated on all 3 sites. Generally the rate of tatter was lower at Ronda than the other two sites. The data indicate that the tatter rate and hence exposure to wind was considerably higher over the 1977/78 growing season than the 1976 season.

DISCUSSION

The mean tatter rates for several localities in the British Isles are presented in Table 2. It can be seen that tatter rates are higher in the Falklands than in almost all other areas of the northern British

Isles, the levels at Stanley and Brenton Loch being higher than those recorded at two Shetland sites. The tatter rate at Ronda was lower than that recorded in the Shetland Islands but higher than those recorded from the Orkney Islands and other northern British sites. Mean wind-speeds are generally higher in the Falkland Islands than the sites listed for the British Isles where, however, rainfall is considerably higher. The complex interaction of rain and wind means that an unstable combination of linear and curvilinear relationships replaces the relatively simple functions determined for wet and dry conditions separately (Rutter 1966). Hence, with the wide rainfall differences recorded between the Falkland Islands and British Isles, direct comparison of the results as simple exposure to wind is not valid. There are more complex interactions resulting in generally more unfavourable climatic conditions in the Falkland Islands than Northern Britain as estimated by the rate of tatter of standard flags.

Rainfall varies considerably over the Falkland Islands (see section 1.A.a) generally being higher in the east of the archipelago. Measurements were not taken at the actual flag sites, but some information was available from nearby settlements:-

Tatter flag site	Distance from rainfall gauge (km)	Mean annual rainfall (mm)	No. of years recorded
Stanley	0	610.3	32
Ronda	6.2	494.9	4
Brenton Loch	7.5	470.9	25

The lower rainfall from Ronda and Brenton Loch could indicate that the tatter results from these sites are a better indication of actual exposure to wind. As the rainfall was similar near both sites and the tatter rate was, on average, lower at Ronda than Brenton Loch, it can be assumed that exposure to wind is greater at Brenton Loch than Ronda with the results from Stanley being slightly confounded by the higher rainfall.

No seasonal pattern in the change of tatter rate was detected, peaks occurring in all 3 sites in spring 1976, autumn 1977 and summer 1977/78.

SUMMARY

The use of the rate of tatter of standard flags has been shown to give a measure of comparison of the exposure to wind at different sites in Britain.

A series of tatter flags were erected at 3 sites (Ronda, Brenton Loch and Stanley) in the Falkland Islands. Inter-site variation between flags was small, consistent differences being detected between sites. The overall exposure to wind was lower at Ronda than Brenton Loch, the rainfall probably being similar on both sites. At Stanley the recorded rate of tatter was higher than on the other two sites.

The levels of tatter recorded in the Falkland Islands were generally higher than those for northern Britain.

Care must be taken in the interpretation of the results. The comparison between Falkland and British sites must be especially suspect in view of the different rainfall of the areas. Intra site comparisons between areas which are topographically similar are possible and the results from the Falklands probably do reflect differences in the sites.

ACKNOWLEDGEMENTS

Mr. R. Lines, Forestry Commission and Dr. P. Savill, Forestry Division, Department of Agriculture for Northern Ireland gave helpful information and advice. Mr. and Mrs. A. McBain at Brenton Loch and

Messrs. H. McLeod and T.P. Maitland at Ronda kindly changed flags on occasions when I was unable to visit sites. Mr. D. Borland, Senior Meteorological Officer, Stanley, permitted flags to be sited at the meteorological station.

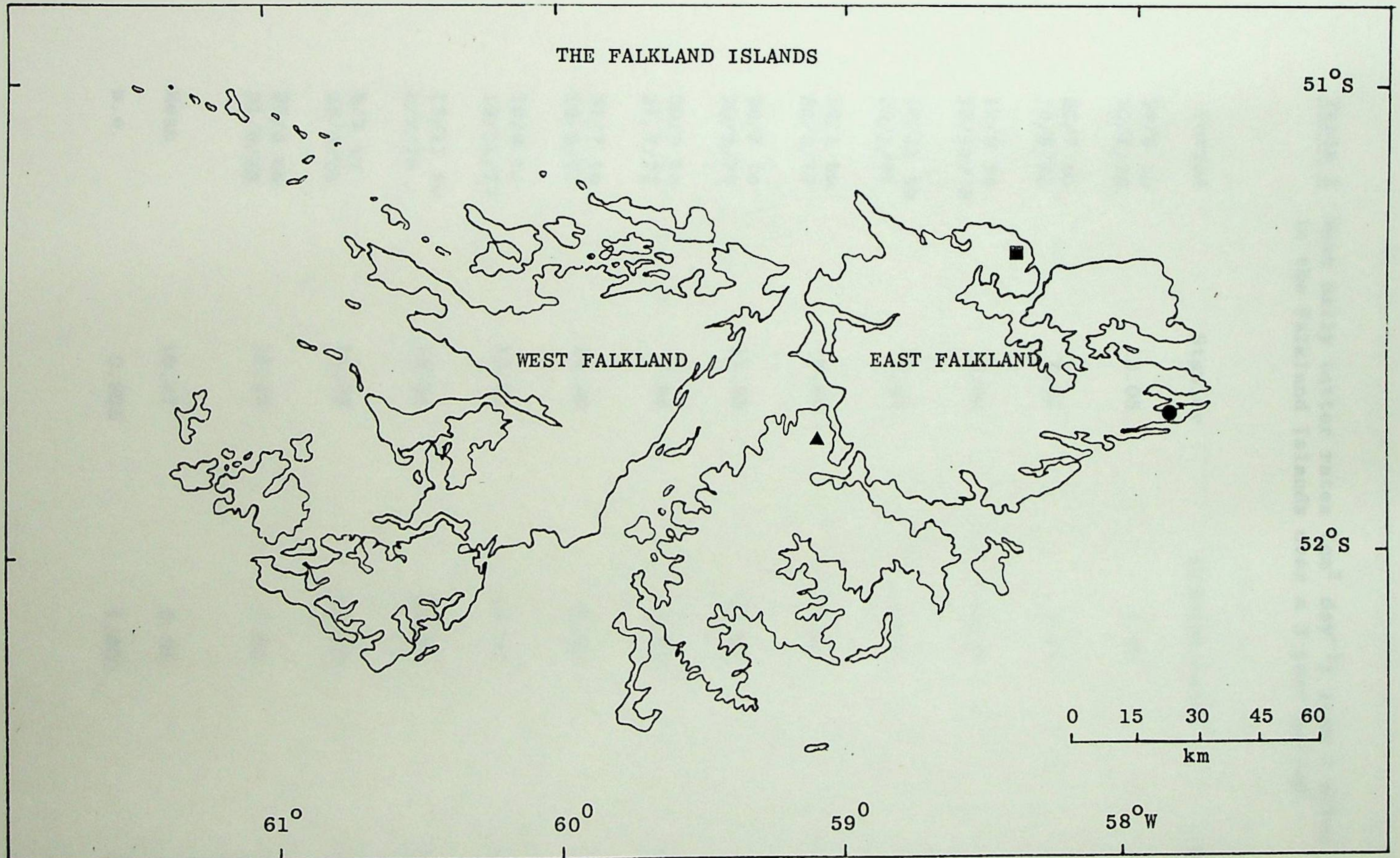

Fig.1. Tatter flag sites: Stanley (●); Brenton Loch (▲); Ronda (■).

Table 1 Mean daily tatter rates (cm^2 day^{-1}) from 3 sites in the Falkland Islands over a 2 year period.

Period	Stanley	Brenton Loch	Ronda
18/5 to 20/7/76	12.05	8.86	8.48
20/7 to 19/9/76	7.41	7.51	7.26
19/9 to 18/11/76	9.59	10.17	8.72
18/11 to 19/1/77	7.47	5.47	5.04
19/1 to 22/3/77	6.68	5.41	6.26
22/3 to 20/5/77	11.35	11.53	7.67
20/5 to 21/7/77	7.37	9.32	6.52
21/7 to 19/9/77	12.40	8.34	8.37
19/9 to 19/11/77	15.61	14.37	15.16
19/11 to 8/2/78	13.34	16.31	13.29
8/2 to 25/3/78	11.27	13.83	13.34
25/3 to 21/5/78	11.13	7.95	6.46
Mean	10.47	9.92	8.88
s.e.	0.805	1.001	0.939

Table 2 Tatter flag data from the Falkland Islands compared with means from British sites (all over 2 year period). Number of stations per site: 1 - 2; 2 - 4; 3 - 4; 4 - 6; 5 - 6; 6 - 4.

Site	Mean area lost per day (cm^2) over two year period
FALKLAND IS.	
Stanley	10.47
Brenton Loch	9.92
Ronda	8.88
SCOTLAND	
Shetland[1]	9.16
Orkney[2]	7.32
Caithness[3]	6.95
Wester Ross[4]	5.41
Kincardineshire	8.32
N. ENGLAND	
Kielder[5]	7.64
S. Pennines[6]	7.02
N. IRELAND	
Fermanagh	6.83

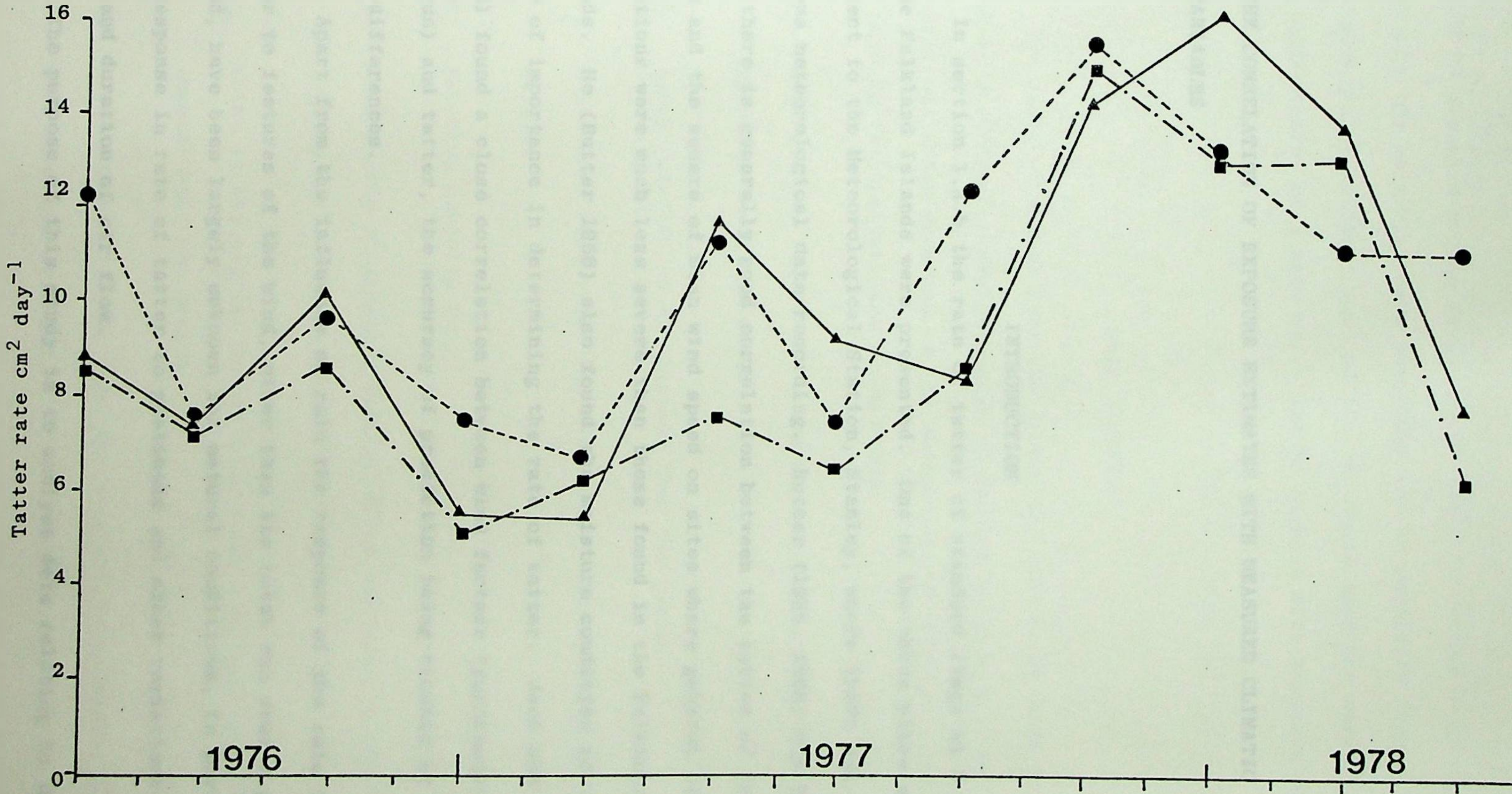

Fig 2. Temporal variation in tatter rate from 3 Falkland Island Sites - Stanley (●—●), Brenton Loch (▲—▲), and Ronda (■—■).

C. THE CORRELATION OF EXPOSURE ESTIMATES WITH MEASURED CLIMATIC VARIABLES

INTRODUCTION

In section 1.A.b the rate of tatter of standard flags at 3 sites in the Falkland Islands were presented. One of the three sites was adjacent to the Meteorological Station, Stanley, where there was continuous meteorological data recording. Rutter (1966, 1968) has shown that there is generally good correlation between the tatter of trimmed flags and the square of mean wind speed on sites where general climatic conditions were much less severe than those found in the Falkland Islands. He (Rutter 1966) also found the moisture condition of the flag to be of importance in determining the rate of tatter. Jack and Savill (1973) found a close correlation between wind factors (gustiness and windrun) and tatter, the accuracy of prediction being clouded by inter-site differences.

Apart from the influence of rain the response of the rate of tatter to features of the wind, other than its total run over a given period, have been largely unknown for natural conditions, in particular the response in rate of tatter to gustiness and other variations in the rate and duration of air flow.

The purpose of this study is to analyse data relating to the tatter of standard cotton flags and 12 climatic variables in order to determine how reliably these variables can be predicted from measurements of tatter. Many of the variables used are measures of the wind-weather of a site which may be equated with exposure to wind.

DATA RECORDED

The rates of tatter over the period May 1976 - May 1978 for flags sited at Port Stanley are presented in Table 1 of Section 1 Ab. The climatic variables recorded at the Meteorological Station, Stanley, and used in the analysis, are shown below.

V_1 Mean rate of tatter in square centimetres per day over an approximate 60 day period.

V_2 Total Rainfall in millimetres over the period.

V_3 Total days rain (over one millimetre) recorded during the period.

V_4 Relative Humidity (%).

V_5 Mean hourly windspeed (Nautical miles per hour) 1 knot = $0.514\ m\ sec^{-1} = 1.852\ km\ hr^{-1}$.

V_6 Total of the highest hourly windspeeds recorded each day (knots) over the period.

V_7 Total number of hours when the mean hourly windspeed was between 0 and 10 knots.

V_8 Total number of hours when the mean hourly windspeed was between 10 and 20 knots.

V_9 Total number of hours when the mean hourly windspeed was between 20 and 33 knots.

V_{10} Total number of hours when the mean hourly windspeed was between 33 and 47 knots.

V_{11} Total number of gusts between 33 and 47 knots over the period.

V_{12} Total number of gusts over 47 knots in each 60 day period.

V_{13} The maximum gust (knots) recorded during the period.

A summary of the data collected is presented in Table 1.

ANALYSIS AND RESULTS

In the past the selection of the climatic variables to be used for correlation has been a subjective choice. The more variables included, the more sophisticated the correlation, but the more difficult it was to determine. To simplify the process, the classification was usually based on only a few of the available variables and useful information was therefore discarded. The method used here, principal component analysis, discards a minimal amount of information but at the same time reduced the amount of data to workable proportions.

The basic technique of principal component analysis is well described by Kendall (1957) Seal (1964) and many others. Practical examples of particular relevance to this study have been given by Jeffers (1967), Alcock <u>et al</u> (1968), Newnham (1968) and Jack and Savill (1973).

The analysis reduces a relatively large number of original variables into a set of new variables (or components) the first 2 or 3 of which usually account for most of the variation in the original variables.

The remaining components can safely be discarded without an important loss of information.

The eigenvalues and the corresponding eigenvectors (weighting factors) for the first 4 components are shown in Table 2. Jeffers (1967) has suggested that only components with eigenvalues of 1.00 or more should be regarded as having practical importance. Hence, in the example presented here the first 3 components account for 84% of the variation described by the original 12 variables. If the next component (4) is considered, 92% of the variability is considered. The inclusion of subsequent components only slightly increases the amount of variation accounted for.

An interpretation of the components in terms of weightings (eigenvectors) given by each of the original variables was made. The pattern was not straightforward, however, component 1 (accounting for 39.8% of the variation) appeared to be an index of wind when the windspeeds were relatively low (Factors having the greatest weightings:- windspeed; hours 0 - 10 kts; and 20 to 33 kts). Component 2 (accounting for 29.3% of the variation) appeared to be an index of the higher windspeed, the inclusion of the H 10 - 20 kts being slightly anomalous (hours 10 to 20 knots; hours 33 to 47 knots; maximum gust; and gusts over 47 knots). Component 3 (14.6% of the variation) was almost entirely an index of rainfall and strong gusts (rain; days rain, gusts over 47 knots) as was component 4 (8.4%). Apart from component 1, the incidence of strong gusts has a high weighting factor in the other components and is contributing considerably to tatter.

These results are in general agreement with Jack and Savill (1973) who investigated the causes of tattering of flags under natural conditions in Northern Ireland. They found the first component (51% of the variation) to be largely an index of windspeeds over 15 knots and the second component (20%) to be an index of the effect of less strong winds on tatter. Their third component (9%) was also an index of rainfall.

If flag tatter is correlated with the original variables (Table 3) it can be seen that none of the correlations are significant although the highest correlations are obtained for the strong gust factors and there is a negative correlation with the precipitation variates (rainfall, days rain and humidity).

In contrast, Jack and Savill (1973) found a high positive correlation with all variates except where windspeeds were below 15 knots.

REGRESSION ANALYSIS

A number of regressions were calculated using tatter as the independent variable and the best equation obtained relating tatter to a progressively increased number of variates obtained (Table 4). The selection of any more variables than 4 was not merited, further variables contributing to only a small increase in the multiple correlation.

The prediction equation for tatter including, say, 2 variables would therefore be:-

$$\text{TATTER} = 34.58 - 0.17V_3 - 0.03\ V_8$$

TATTER = 34.58 - 0.17 (total days with rain) - 0.03 (total hours with windspeed 10 - 20 knots).

DISCUSSION

The correlation of tatter to climatic variables in the Falkland Islands yields different results to those found in Britain. The most significant is the effect of rainfall. Rutter (1968) and Jack and Savill(1973) found significant positive correlations with rainfall, whereas this investigation revealed an insignificant slightly negative correlation with tatter. Rainfall was lower in the Falkland Islands than in N. Ireland over the period when Rutter, Jack and Savill exposed their flags. All facets of windspeed were, however, very much higher than those recorded in N. Ireland by Jack and Savill (1973) and this is especially pronounced at the higher windspeeds. For example there was a x 50 factor difference in variable V_{10} (hours when wind was 33 to 47 knots). Hence, the effect of wind will be considerably masking any effect of rain and this may explain the different results obtained.

The principal components analysis indicated that tatter is largely accounted for by wind - compenents 1 (index of low windspeeds) and 2 (index of high windspeeds accounting for 70% of the variance - with rainfall also being of some importance).

The positive contribution of the strong gusts (over 47 knots) to tatter may be of significance in comparison of tatter rates in the Falkland Islands and Britain. It appears that the use of the term "exposure to wind" is therefore justified in relation to flag tatter in the Falkland Islands.

The prediction equations showed that it was not possible to predict very accurately any of the variables with which tatter is well correlated. It will be seen that the equations are not particularly useful for prediction purposes.

SUMMARY

The method of Principal Components Analysis was used to correlate a number of climatic variable to the rate of tatter of standard flags. The analysis indicated that wind factors primarily were accounting for tatter with rainfall secondarily. Both low (0 - 20 knots) and high

(20 - 47 knots) windspeed factors appeared to be contributing equally with an indication that very strong gusts may be causing high tatter values.

Although contributory factors to tatter could be identified, their accurate prediction was not possible.

Comparison of results with those from Britain indicated that rainfall was not as significant a factor in the Falklands Islands, its effects probably being masked by the wind.

It is reasonable to assume that rate of tatter is an indication of exposure to wind.

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Table 1. Summary of data collected at Port Stanley during 12 eight-week periods, 1976 - 1978

Variable	Mean value	Minimum value	Maximum value	Standard error of the mean
TATTER	10.47	6.68	15.61	0.805
V_2	102.7	51.0	139.4	6.67
V_3	42.6	32.0	57.0	2.13
V_4	88.9	84.0	94.5	0.95
V_5	15.4	12.0	18.3	0.49
V_6	1396.5	1224.0	1632.0	37.50
V_7	414.3	198.0	780.0	45.35
V_8	660.5	548.0	786.0	21.56
V_9	366.3	222.0	600.0	31.18
V_{10}	29.3	10.0	84.0	6.15
V_{11}	218.3	112.0	282.0	16.67
V_{12}	35.8	10.0	86.0	5.86
V_{13}	61.8	53.0	88.0	2.77

Table 2. Eigenvalues and their associated eigenvectors for the first four components of the correlation matrix

Variable	Eigenvector for Components 1	2	3	4
V_2	0.029	0.116	0.596	0.580
V_4	0.355	-0.216	0.362	-0.319
V_5	-0.453	0.022	0.142	-0.027
V_6	-0.315	-0.318	0.220	-0.245
V_7	0.393	-0.292	-0.024	0.081
V_8	0.066	0.524	-0.114	0.142
V_9	-0.410	-0.080	0.333	-0.211
V_{10}	-0.252	-0.424	-0.262	0.077
V_{11}	-0.350	0.086	0.087	0.364
V_{12}	-0.103	-0.381	-0.392	0.460
V_{13}	0.241	-0.373	0.302	0.282
Eigenvalue or component variance	4.375	3.223	1.599	0.930
Accumulated value as % of total variance	39.77	69.07	83.62	92.07

Table 3 Coefficients of correlation (r) between flag tatter and climatic variables

Variable	r	Variable	r
V_2	-0.0443	V_8	-0.5143
V_3	-0.2231	V_9	0.1671
V_4	-0.0477	V_{10}	0.4751
V_5	0.2926	V_{11}	0.0498
V_6	0.1813	V_{12}	0.5094
V_7	0.1764	V_{13}	0.3044

Degrees of freedom = 11 ($r = 0.576$ necessary for $P = 0.05$)

Table 4 Regression of tatter on a number of variates to find best equation to fit recorded data.

Best equation with n variables in set	Multiple Correlation	Intercept term	Regression coefficient for each variate considered
n = 1	0.514	23.167	$-0.019(V_8)$
n = 2	0.671	34.585	$-0.175(V_3)-0.025(V_8)$
n = 3	0.826	9.082	$-0.436(V_3)+0.028(V_7)+0.022(V_9)$
n = 4	0.906	87.293	$-0.493(V_3)-0.079(V_8)-0.298(V_{10})+0.141(V_{12})$

1.B. VEGETATION STUDIES

a. CLASSIFICATION AND DESCRIPTION OF VEGETATION COMMUNITIES.

In an attempt to facilitate the calculations of pasture production (see Section 1B b) it was decided to classify the vegetation of the Falklands into a number of relatively subjective groups based on their integration into a planned programme of pasture production estimates and grazing studies as carried out by the Unit as a whole.

The classification is based on the types of vegetation found on a hypothetical transect from sea level to a high altitude (see Table 1). Along such a transect there is a natural progression of differing vegetation types each merging to a greater or lesser extent, their distribution being related to a number of factors the principal ones of which appeared to be soil moisture and organic matter content. Associated with these two factors is soil pH and the availability of soil nutrients and this, in turn, tended to determine the distribution of species.

This pattern is somewhat obscured on coastal areas where the presence of large numbers of sea birds and marine mammals has led to a nutrient-rich plant environment and its associated distribution of species.

Coastal Areas

The coastal vegetation can be classified into three main groups - areas dominated by _Poa flabellata_ and areas of _Gunnera magellanica_, _Juncus scheuzerioides_, _Poa pratensis_, _Poa annua_ etc. being the most important. These areas, although more widespread in the past (Hooker 1847) than at present, are still of considerable significance in many localities. _Poa flabellata_ has been greatly reduced by overgrazing since human settlement and the association is now well developed in relatively few localities, largely on small offshore islands. The species commonly found on coastal greens have a high proportion of photosynthetic matter in the DM and are relatively nutritious to stock. The _Ammophila_ association is not widespread and cannot be considered to be of great importance in an agricultural context.

River valleys

The valley greens, areas on the floors and lower sides of often slow-moving, meandering streams and rivers tend to be more productive and to contain species of relatively greater nutritive value than the surrounding areas. This is probably due to a combination of factors namely:-

1. The high moisture content of the soils at all times of the year associated with good drainage and the prevention of anaerobiosis.
2. Increased shelter from the persistent winds which tend to cause desiccation at the time of maximum growth (see section 1A a).
3. Some leaching of nutrients down the sides of the valleys may be occurring.
4. The congregation of grazing stock and birds and the continual defoliation of the herbage plus the accumulated

nutrients from droppings may contribute to the nature of the valley greens. This increased grazing pressure prevents the growth of dense Cortaderia tussocks which would shade out smaller, often more nutritious species.

These valleys and the coastal greens are the areas of most value to grazing stock.

Typical vegetation of the sides of these valleys is tussock-forming Cortaderia plants and their associated species Cp(B). The presence of these tussocks creates a micro environment in which more nutritious and finer grass species such as Poa pratensis, Deschampsia flexuosa and Festuca magellanica are found. Stock are attracted to these areas and although the grazing preference is for the finer species, the Cortaderia is heavily grazed. This leads to a decrease in the fund of Cortaderia standing dead matter and an increased utilisation of the Cortaderia and the area as a whole.

On level and undulating country with poorly drained soils the vegetation is dominated by a uniform cover of non-tussock forming Cortaderia. With decreasing drainage properties the percentage of Cortaderia in the sward decreases giving rise to a range of herbaceous species dominated by Blechnum penna-marina on drier ground and Baccharis magellanica and Oreobolus obtusangulus on wetter ground.

The utilisation of the Cortaderia on these areas is very low and the plants have a high proportion of standing dead material.

Mountain and rocky areas

On areas at higher altitude with severely impeded drainage and high water table bog associations are found which are dominated by Oreobolus obtusangulus, Rostkovia magellanica and Astelia spp. The nutritional quality of this herbage is poor and such associations are of little agricultural significance.

On comparatively dry ground, rocky ridges, stony areas or places where the subsoil is of relatively coarse material so that drainage is good, a hard dry peat is found, the vegetation being dominated by Empetrum rubrum and Pernettya pumila. Also associated with these species and occasionally forming dense cover of its own on rocky, drier areas is Blechnum magellanicum. Above 600 m a dry mountain top association is found comprising Bolax gummifera, Festuca erecta and Azorella spp. with a high proportion of bare soil and rock.

Reseeds

Holcus lanatus has been widely sown in the past. These associations tend to have a high proportion of bare ground with the Holcus plants forming individual rosettes on a small 'island' of uneroded soil. Associated plant species tend to be related to the amount of regeneration occurring and hence the plants present before reseeding. The most common associates are Baccharis magellanica and Rumex acetosella.

Vegetation classification of this type is of value in studies of land utilization and the interpretation of aerial photographs. The classification can also be widely used in theoretical planning of the management of specific areas in association with the Unit's development work on grazing systems and studies on competition by the Upland goose Chloeophaga picta picta.

For some of the vegetation types listed a full description was obtained by selecting typical sites and assessing the number and cover of species present based on the Braun-Blanquet system of rating (Poore 1955) (see below).

A quantitive approach to this classification of vegetation is presented in the section 1B b.

Notes and brief descriptions of vegetation types discussed above and summarised in Tables 1 & 2 (Coding as in Table 2).

1. FORESHORE ASSOCIATION

Vegetation dominated by *Ammophila arenaria* with much bare sand and some *Elymus arenarius* and *Senecio candicans*.

2. TUSSOCK ASSOCIATION

Varying amount of *Poa flabellata* cover often decimated by fungal attack (Gunn 1974). Associated species are *Apium graveolens* and *Poa annua*.

3. COASTAL GREEN

Based on analysis of an area behind the foreshore at Bertha's Beach, East Falkland (51°53'S 58°23'W).

Species	Cover
Gunnera magellanica	3
Juncus scheuzerioides	2
Poa pratensis	2
Poa annua	1
Agrostis magellanica	1
Aira praecox	+
Pratia repens	+
Colobanthus sp.	+
Euphrasia antarctica	+

Estimated percentage area of whole Falklands 2.91% (Davies 1939).

4. VALLEY GREEN

Based on analysis from a valley near Spit Ridge, Island Harbour, East Falkland (51°49.49'S 58°22.95'W).

Poa pratensis	3
Gunnera magellanica	2

Blechnun magellanicum	2
Festuca magellanica	1
Deschampsia flexuosa	1
Juncus scheuzerioides	2

6A TUSSOCK-FORMING WHITEGRASS Cp(B)

Based on analyses from Cape Dolphin (51°20.75'S 58°50.39'W) and Ceritos Arroyo, Darwin, East Falkland (51°45.54'S 58°55.56'W).

Cortaderia pilosa	3
Poa pratensis	2
Juncus scheuzerioides	2
Gunnera magellanica	1
Blechnum penna-marina	1
Festuca erecta	1
Aira praecox	+

5. RESEEDED AREAS

Settlement fields (for detailed analyses see Davies 1939) and relatively large areas of *Holcus lanatus*.

6B WHITEGRASS ASSOCIATIONS Cp Bpm/Gm

Based on analysis from Rolon Cove East Falkland (51°44.01'S 58°03.84'W).

Cortaderia pilosa	4
Gunnera magellanica	1
Myrteola nummularia	2
Blechnum penna-marina	1
Agrostis canina	+
Festuca sp.	1
Bryophytes	+

The *Cortaderia* tends to be aggregated into small tussocks, this aggregation being much less pronounced than group 6A.

6C Cp

Based on analysis from near Bertha's ditch, East Falkland (51°52.26'S 58°22.9'W).

Cortaderia pilosa	4
Luzula alopecurus	1
Blechnum penna-marina	1
Festuca ovina	+
Oxalis enneaphylla	+
Ranunculus sp.	+
Rostkovia magellanica	+
Myrteola nummularia	+
Viola maculata	+
Lichen	+
Bryophytes	+

The Cortaderia is not formed into clumps or tussocks but provides a uniform cover.

6D Cp Bm/Rm

Based on analysis of an area near Rolon Cove, East Falkland, (51°44.01'S 58°03.02'W).

Cortaderia pilosa	4
Baccharis magellanica	1
Rostkovia magellanica	1
Oreobolus obtusangulus	+
Myrteola nummularia	+
Pernettya pumila	*
Viola maculata	+
Bryophytes	+

6E Cp Bm/Oo

Based on an analysis near Cave Arroyo, Rolon Cove, East Falkland.

Cortaderia pilosa	3
Oreobolus obtusangulus	1
Baccharis magellanica	1
Blechnum penna-marina	+
Myrteola nummularia	+
Bryophytes	2

7. BOG ASSOCIATION Cp Oo Rm

Based on an analysis from an area near Moody Valley, Stanley E Falkland ($51^{o}40.78$'S $57^{o}58.84$'W).

Cortaderia pilosa	2
Oreobolus obtusangulus	4
Rostkovia magellanica	+
Baccharis magellanica	1
Myrteola nummularia	+
Blechnum penna-marina	+
Lycopodium confertum	+
Lichen	1

8. Oo Ast Cp.

Based on an analysis from Moody Valley, Stanley ($51^{o}40.69$'S $57^{o}59.53$'W) and near Cave Arroyo, East Falkland ($51^{o}43.54$'S $58^{o}00.86$'W).

Cortaderia pilosa	2
Oreobolus obtusangulus	2
Astelia sp.	1
Baccharis magellanica	1
Myrteola nummularia	+
Lycopodium confertum	+
Rostkovia magellanica	+

Table 1 A classification of Falkland Island vegetation

ASSOCIATION		PRINCIPAL SPECIES	MAIN ASSOCIATED SPECIES
DRY MOUNTAIN ASSOCIATION		Bolax gummifera Lichens	Pernettya pumila Bare ground
DIDDLE-DEE ASSOCIATIONS	1	Empetrum rubrum Bolax gummifera	Azorella sp. Festuca erecta Blechnum magellanicum
	2	Empetrum rubrum	Festuca erecta Pernettya pumila Cortaderia pilosa
	3	Empetrum rubrum Cortaderia pilosa	Festuca erecta Baccharis magellanica
MOUNTAIN ASSOCIATION		Oreobolus obtusangulus Astelia pumila	Poa alopecurus Bolax gummifera
BOG ASSOCIATION		Oreobolus obtusangulus Cortaderia pilosa	Rostkovia magellanica Myrteola nummularia Astelia sp.
WHITEGRASS ASSOCIATIONS (NON-TUSSOCK FORMING)	1	Baccharis magellanica Cortaderia pilosa	Rostkovia magellanica Oreobolus obtusangulus Pernettya pumila
	2	Cortaderia pilosa Baccharis magellanica	Rostkovia magellanica Myrteola nummularia
	3	Cortaderia pilosa	Cortaderia pilosa
WHITEGRASS ASSOCIATIONS (TUSSOCK FORMING)	4	Cortaderia pilosa	Blechnum penna-marina Gunnera magellanica
	5	Cortaderia pilosa	Festuca magellanica Agrostis magellanica Gunnera magellanica Poa pratensis
RESEED ASSOCIATIONS		Holcus lanatus	Rumex acetosella
VALLEY GREEN ASSOCIATIONS		Poa pratensis Juncus scheuzerioides Cortaderia pilosa	Gunnera magellanica Aira praecox Deschampsia flexuosa
COASTAL GREEN ASSOCIATIONS		Juncus scheuzerioides Poa annua	Gunnera magellanica Poa pratensis Agrostis magellanica
TUSSOCK GRASS ASSOCIATION		Poa flabellata	Apium graveolens Poa annua
FORESHORE ASSOCIATION		Ammophila arenaria	Elymus arenarius Senecio candicans

Table 2 <u>Vegetation classification - Summary</u>

<u>For species coding see Appendix</u> (p 190)

CAMP TYPE	ASSOCIATION		CODE	REFERENCE NUMBER
Hard	DRY MOUNTAIN ASSOCIATION		BG	
Hard	DIDDLE-DEE ASSOCIATIONS	1	Er/Bg	
		2	Er	
		3	Er/Cp	
Soft	MOUNTAIN ASSOCIATION		Oo/Ast	8
Soft	BOG ASSOCIATION		Oo/Cp	7
		1	Cp/Bm/Oo	6E
		2	Cp/Bm	6D
		3	Cp	6C
		4	Cp(B)/Bpm	6B
		5	Cp(B) Pp Am	6A
Hard	RESEED ASSOCIATION		R	5
Hard	VALLEY GREEN ASSOCIATION		VG	4
Hard	COASTAL GREEN ASSOCIATION		CG	3
Hard	TUSSOCK GRASS ASSOCIATION		T	2
Hard	FORESHORE ASSOCIATION		F	1

1.B.

B. ASSESSMENT OF THE ANNUAL DRY MATTER PRODUCTION, COMPOSITION AND QUALITY OF A RANGE OF VEGETATION COMMUNITIES

INTRODUCTION

In the previous section of this report the vegetation of the Falkland Islands was classified into a number of subjective groups based on the presence and cover of certain species. It is desirable that some form of quantitative data be attached to these qualitative delineations. Such data are essential for the planning of grazing study experiments and overall pasture productivity in a context of grazing management and land improvement.

There are two methods which have been used by agronomists and ecologists for the measurement of net primary productivity of grassland. The first of these is the difference method whereby the biomass of the plant community at the beginning of the study period and again at the end is measured and the increment calculated by subtraction. This method has been widely used on slow growing and extensively grazed plant communities (eg Smith and Stephenson, 1975; Bliss, 1966). Under conditions found in the Falkland Islands this method is probably more suitable than the other which involves pre-trimming the grass sward and measuring re-growth - a drastic treatment which may modify subsequent growth to such an extent that measurement may not be valid (Milner and Hughes 1968). The difference method, however, involves a considerable degree of replication to detect biomass changes where a. growth is slow b. the inherent natural variation within the sward is high. It was decided to use the method of pretrimming incorporating grazing enclosure cages. Due to the difficulties imposed by transport, the availability of time and experimental equipment, cages were erected on a wide range of vegetation types with as much replication between sites and season carried out as possible.

There has been little previous quantitative work done on pasture production in the Falkland Islands. Davies (1939) published no results on pasture production whereas Davies et al. (1971) measured approximately 1800 kg ha^{-1} on uniform Cortaderia and 2000 kg ha^{-1} on 'Greens'. This estimate was based on results from 1969-70.

It was hoped to collect data over 3 seasons and obtain an estimate of pasture production on as many of the vegetation communities described in Section 1.Ba as possible.

MATERIALS

1. Design

Cages were designed to exclude, where appropriate, a. sheep b. cattle and horses, c. geese and other grazing birds.

The exclusion of groups a and c could be relatively effectively achieved by the use of 5 cm mesh heavy guage netting wire. A roof of netting wire was also placed over the cage to prevent intrusion by grazing animals and birds. It proved much more difficult to effectively exclude cattle and horses. These animals frequently trampled down wire netting cages. The only permanent solution was to erect a barbed wire barrier fence around the exclusion cage at a distance of not less than 1 m all round.

The corner posts of each cage generally consisted of 2 m long galvanised steel fencing standards driven in to the ground to a depth of at least 0.6 m. The cages were 1 m high and 2.5 x 2.0 m in dimension.

Prefabricated cages consisting of 4 sides constructed from plastic coated netting wire on a wood frame were also constructed. These had the advantage of being easily moved but suffered from large bulk (transport problems), expensive construction and susceptibility to wind blow.

2. Sampling equipment

A quadrat size of 150 cm x 25 cm was used, these dimensions being found to give the lowest coefficient of variation in this type of vegetation. (HFRO unpubl.). The quadrat was constructed of aluminium framing and the plots were marked inside the cage by stiff wire pegs.

The samples were cut using battery powered hand shears.

3. Siting of cages

Due to logistic limitations cages were sited convenient to tracks and were widely dispersed throughout most of the Units' large scale grazing studies and extension sites on East Falkland (see Table 1).

METHODS

a. Timing of sampling

Cages were normally sited during the winter months when growth had stopped. On siting and erecting the cages, the quadrat area within the cages was trimmed to ground level. Cages were, whenever possible, cut once during the growing season and once in the early winter after growth had stopped and before severe losses from wind damage had occurred.

The first cut was generally carried out in late January/early February to coincide with other experimental work. By this time approximately 14 - 15 weeks of growth had occurred with 11 - 12 weeks of the growing season remaining (based on a 10 cm soil temperature minimum of 5.5°C (Taylor 1967). Details of cutting dates are shown below. The second cut was taken on the same quadrat position as the first and was taken in May or June.

Cutting dates of plots in grazing exclosure cages

Treatment	1975/76	1976/77	1977/78
Pretrimming	November	August	July
1st cut	Mid January	Early February	Mid January
2nd cut	Early June	Late May	Mid May

b. Sample handling

Samples were stored in labelled polythene bags and deep frozen until required for analysis.

c. Sample analyses

Sample fresh weight was recorded prior to mixing and sub-sampling. The sub-sample was separated into three components:-

1. The 'green' i.e. photosynthetic graminaceous fraction
2. The 'dead' i.e. non-photosynthetic graminaceous fraction
3. The 'herb' fraction

These were then dried in a fan oven for 48 hours at 90°C and weighed. The samples were bulked into different vegetation types for organic matter digestibility analyses (OMD).

RESULTS

Production results have been amalgamated for vegetation types and are presented in full for 3 seasons in Table 2. The means of these, including the sample components analysis are illustrated in Fig 1. The total DM production between cuts per vegetation type (means of 3 seasons) are expressed in Table 3. These are presented on a per season basis in Table 4. Organic Matter Digestibility values (OMD) are presented in Table 5.

The total annual dry matter production was higher than that recorded by Davies <u>et al</u>. (1971) on corresponding vegetation types.

There is considerable variation between seasons, the yields in 1977/78 being lower than those obtained from the same areas in 1976/77. The results for 1975/76 are generally lower than those for the other two seasons.

On three vegetation types (VG, CG, and Cp(B)) the yields of both total annual DM production and green matter production were higher than all the other sites. The OMD of herbage sampled from these valleys and coastal areas was significantly higher than on all the other areas.

On all vegetation types production was greater for the first cut than the second. This effect is more prounounced in the higher production vegetation types (CG, VG and Cp(B)) than those on lower production types.

The sward component analyses indicated that there was considerable variation between sward components within sward types. On the higher production pastures the green and herb fractions are the main sward components whereas on the poorer production pastures, the proportion of sward components are similar with the proportion of green matter in the sward being lower than in the higher production pastures. On these lower production pastures there is little variation in OMD, among pasture types, the values obtained being similar to those by Davies et al. (1971) ie in the range 30 - 40%. During the second part of the growing season, the contribution of the individual components to the overall growth of the swards were similar for all vegetation types.

When considering the OMD of the pasture types measured it is apparent that, as with herbage production, there is a clear distinction into two main groups. The first group comprises the coastal and valley areas with OMD values of 43 - 45%. In July in upland Wales, Munro, Davies & Thomas (1973) measured OMD values of 42% for a Nardus/Molinia sward and 48% for an Agrostis/Festuca. The OMD's for the other group of vegetation types (Mainly the low-production Cortaderia associations) range from 35 - 39%, lower than recorded for hill pasture types in Britain during July.

DISCUSSION

It is of significance that annual DM production yields on three of the vegetation types (VG, CG, Cp(B)) are higher than those indicated for upland pasture in Britain where Agrostis/Festuca pastures yield 2200 - 2750^{-1} kg. DM ha^{-1} annum^{-1} with some types approaching 3200 kg ha^{-1} annum^{-1}. Yields from pasture dominated by Molinia and Nardus in Britain are lower, with production levels of 1300 - 1750 kg DM ha^{-1}annum^{-1} (Eadie 1970). These coastal and valley areas do not constitute a large proportion of the total area of the Falklands, however their potential for high quality herbage production is high and they are of considerable importance when properly integrated into a controlled management system aimed at improving utilization. The estimated total area of these vegetation types cannot be accurately calculated from Davies (1939) as he does not differnetiate the Cortaderia types. From Davies et al. (1971) the percentage of tussock-forming Cortaderia and Valley Greens is 4.76 (W Falkland) 15.71 (E Falkland) and 25.40 (Islands) Davies (1939) quotes 3.02% (E Falkland) 2.79% (W Falkland) as percentage areas of coastal greens.

The high percentage of green matter and low per cent of dead in these swards is contributing to their high digestibility. The correlation between stock carrying capacity and vegetation type was carried out on some farms by Davies et al. (1971). From this analysis the stocking rate for "greens" was 1.2 ha per ewe equivalent. This compared favourably with Oo/Cp (group 7) - 2.1 ha per ewe equivalent and 1.9 for Cp with mountain associations (group 8) having a negative value.

Pasture production data for the Cortaderia types (other than the tussock-forming Cortaderia) range from 1250 - 2900 kg dm. ha^{-1} this range encompassing that of most of the hill pasture types in Britain. This range of vegetation types includes a significantly large area of the islands and hence they are of importance. Estimates of area covered are:-

	East Falkland	West Falkland
Davies (1939)	53.12	33.17
Davies et al. (1971)	52.59	44.64

The proportion of dead Cortaderia in these swards at all times of the year contributes to a low OMD and rate of utilization and a severe dilution of the small amount of high quality vegetation present.

It should, however be borne in mind that the OMD value calculated for the whole sward is probably lower than the digestibility of herbage eaten by the sheep, the OMD of the green ie photosynthetic matter providing a closer approximation to the quality of herbage ingested.

It is conceivable that the utilization of these poorer pastures could be increased by decreasing the fund of standing dead vegetation. This could be achieved by increased stocking rates at certain times in the year in association with initial controlled burning. Large areas of this poorer pasture could be utilized in association with areas of the better vegetation types as found in green valleys and on the coast. Grazing patterns on these pastures could then be concentrated on integration into the seasonal energy demand pattern of the ewe following the guidelines of the two-pasture system (Eadie 1970). Hence the better areas should be reserved for the pre-lambing and pre-mating period. Alternatively a modified system involving wether stocking on the predominantly <u>Cortaderia</u> pastures (with the ewe production being reserved for the better areas or areas with a higher proportion of better pasture) could be considered.

The main limitations to adoption of these management principles may lie in the distribution of the areas of better pasture. There may not be sufficient areas of good pasture to allow for any increase in utilization of the poorer pastures or the areas of good pasture may be too widely fragmented to enable reasonable delimitation by fencing of poor and good pasture. This is not likely to be a problem in coastal areas, where it is envisaged that the two-pasture system could be carried out with significant effect. The improved and integrated utilization of valley greens and tussock-forming <u>Cortaderia</u> areas on the valley sides may not prove to be feasible due to the wide dispersion of these areas throughout many differing vegetation types.

In the absence of further information on their palatibility digestibility and trace element content it is not possible to assess the significance of the herb content of the sward. In view of the high herb content in all the vegetation types sampled this area merits further research.

SUMMARY

A series of grazing enclosures cages were erected on a range of vegetation types over three growing seasons.

Three of the vegetation types were more productive had a higher percentage green matter and higher OMD% than the other types.

Production on these three 'better' vegetation types was much higher than that reported for hill land in Britain and OMD values were similar. Production on the other five types was similar to British hill swards whereas OMD values were generally lower.

With the poorer pasture types, the proportion of dead matter was considerably higher than that found in the better pasture types. This is probably contributing to the low overall OMD values obtained for these poorer pastures.

The significance of these results is discussed in relation to improved pasture utilization and the implementation of the two pasture system . The wide dispersion and fragmentation of the areas of better pasture isseen as a serious limitation to improvement.

ACKNOWLEDGEMENTS

Mr C D Kerr set up the prefabricated cages in November 1975. My wife assisted greatly in assembling and sampling of subsequent cages. Messrs N Knight and S Whitley erected some cages at North Arm and Mr P Maitland kindly cut the plots in 1977/78 at Salvador. Mr A Miller cooperated by taking winter cuts from Cape Dolphin. Thanks are also due to farms on whose land cages were sited.

The digestibility analyses were carried out by the Hill Farming Research Organisation.

Table 1 Siting of grazing exclosure cages

Code	Site	Site Details	No of cages
F	A series along the Stanley-Fitzroy track. East Falkland	Sites cover a wide range of vegetation types from very poorly drained deep peat near Stanley to Coastal sites beyond Fitzroy.	7
MV	Moody Valley (to West of Stanley)	An East-West shallow sided valley with gradually increasing rainfall and soil OM content up the valley and hence a broad spectrum of *Cortaderia* vegetation types.	4
BL	Brenton Loch Goose Green, East Falkland	Site of a large grazing study covering a wide range of vegetation types on a variety of soils.	8
S	Ronda, Salvador East Falkland.	As above	8
KC	Port San Carlos East Falkland	Site of the Unit's extension scheme involving strict management control of existing paddocks. Many coastal areas.	6
NA	North Arm, Lafonia, East Falkland	Site of the Unit's dry sheep experiment where wool growth of wethers is monitored. Typical *Cortaderia* vegetation on undulating ground.	5
WGE	Whitegrass growth Experiment, Rolon Cove, near Stanley	Cages on a site adjacent to a detailed study of annual growth pattern of a *Cortaderia* sward (section 1 Be).	2
RT	Rolon Cove, East Falkland	A south facing hill with a series of cages sited to form a transect from sea level to the top of a hill (160 m).	3
YF	a. Fitzroy b. Darwin	A series of cages on areas previously reseeded with *Holcus lanatus*.	10

Table 2 Total annual dry matter production data (kg ha^{-1}) from individual cages for each season. Each horizontal row represents the results from one cage.

VEGETATION TYPE	CODE	1975/76	1976/77	1977/78	CAGE MEAN
		2273	6145	3938	4119
		-	7347	5126	6237
CG	3	-	7299	7604	7451
		-	4431	3673	4052
		2493	-	-	2493
		-	11124	7783	9453
		-	7023	5297	6160
VG	4	-	6090	7257	6673
		-	4939	5692	5315
		-	-	5166	5166
		-	6788	-	6788
		2219	-	-	2219
		-	6150	5112	5631
Cp (B)	6A	-	5298	5240	5269
		-	4112	5172	4642
		-	-	3140	3140
		-	-	3984	3984
		-	3794	2588	3191
		-	3061	2170	2165
		-	-	1778	1778
Cp (Bpm)	6B	1546	-	-	1546
		-	-	1254	1254
		-	5245	4109	4677
		1747	1915	1322	1661
Cp	6C	-	2095	1651	1873
		1266	-	-	1266
Cp Bm	6D	-	2289	1781	2035
		-	3201	1671	2436
		-	1759	1206	1482
		-	-	1753	1753
		-	885	787	836
Cp Bm O_0	6E	-	-	1621	1621
		-	-	1579	1579
		-	-	947	947
		1092	876	-	984
		-	-	498	498
		-	702	415	558
		912	337	-	627
O_0/Cp	7	348	686	-	517
		941	788	-	864

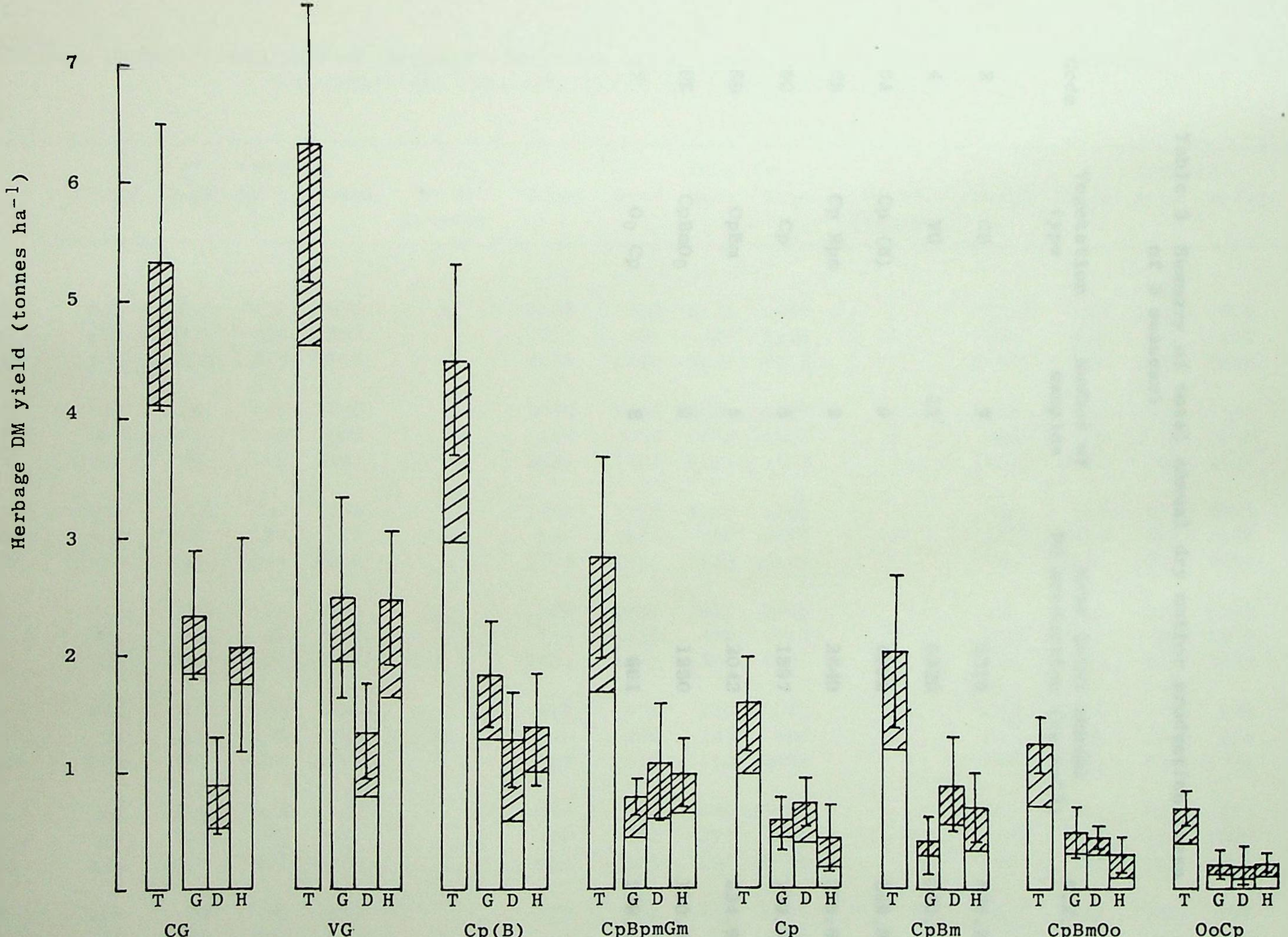

FIG. 1. Mean annual DM yields of different vegetation types expressed as total (T) production and component photosynthetic graminaceous (G)- Non-photosynthetic graminaceous (D): & Herb (H) fractions. Shaded portion represents growth Feb - Apl. Attached 95% confidence Limits to total annual DM production

Table 3 Summary of total annual dry matter production (mean of 3 seasons)

Code	Vegetation type	Number of samples	Mean total annual DM production (kg ha^{-1})	S.E.
3	CG	9	5315	536.2
4	VG	11	6332	570.0
6A	Cp (B)	9	4992	349.9
6B	Cp Bpm	9	2840	376.6
6C	Cp	5	1597	139.9
6D	CpBm	5	2042	234.9
6E	$CpBmO_0$	9	1250	110.3
7	O_0 Cp	8	661	279.5

Table 4 Detailed analysis of component and total sward production per part and total season, per vegetation type (all yield data expressed as kg ha^{-1}).

Vegetation Type		1975/76 Green	Dead	Herb	Total	No of Samples	1976/77 Green	Dead	Herb	Total	No of Samples	1977/78 Green	Dead	Herb	Total	No of Samples
CG	Part 1	964	200	251	1415	1	2138	818	2111	5067		1824	352	1720	3896	
	Part 2	231	304	324	859		351	461	427	1239	4	663	246	277	1186	4
	Total	1195	504	575	2274		2489	1279	2538	6306		2487	598	1997	5082	
VG	Part 1	780	420	733	1933	1	2540	1258	2025	5823		1618	618	1711	3947	
	Part 2	290	111	159	560		419	448	502	1369	5	703	553	1036	2292	5
	Total	1070	531	892	2493		2959	1706	2527	7192		2321	1171	2747	6239	
Cp (B)	Part 1	1001	96	311	1408		1499	1006	1607	4112		1312	470	825	2607	
	Part 2	148	373	290	811	1	234	575	265	1073	3	487	734	464	1685	5
	Total	1149	469	601	2219		1733	1581	1872	5185		1799	1204	1289	4292	
Cp Bpm	Part 1	164	583	56	803	1	869	1079	1018	2966		322	302	559	1183	
	Part 2	274	404	65	743		164	432	472	1068	2	262	553	355	1170	5
	Total	538	987	121	1546		1033	1511	1490	4034		584	855	914	2353	
Cp	Part 1	928	301	133	1362		4815	571	320	1372		223	319	90	632	
	Part 2	71	210	105	386	1	145	345	143	633	2	141	269	444	854	2
	Total	999	511	238	1748		627	916	463	2005		364	588	534	1486	
Cp Bm	Part 1	174	230	105	509		574	913	578	2065		163	354	204	721	
	Part 2	62	355	240	657	1	120	300	261	681	2	73	368	564	1005	2
	Total	236	575	345	1266		694	1213	839	2746		236	722	768	1726	
Cp Bm O_0	Part 1	249	99	55	403		672	362	108	1142		329	259	137	725	
	Part 2	73	312	304	689	2	92	179	85	356	3	173	164	227	564	5
	Total	322	411	359	1092		764	541	193	1498		502	423	364	1289	
O_0 Cp	Part 1	168	111	90	369		179	196	168	543		120	28	126	274	
	Part 2	62	194	108	364	3	67	59	89	214	3	71	17	94	182	2
	Total	230	305	198	733		246	255	257	757		191	45	220	456	

Table 5 Organic matter digestibility (OMD) values for a range of vegetation types from herbage cut in January and February 1976, 1977 and 1978.

Vegetation Type	Mean OMD	s.e.	% Green matter in total DM	OMD of green matter	s.e.	No of samples
CG	45.8	3.01	43.6	53.9	2.12	7
VG	43.1	2.98	39.3	48.8	3.21	10
Cp (B)	44.0	1.44	39.7	49.9	1.45	8
Cp Bpm	39.9	2.01	34.1	47.5	1.97	9
Cp	36.8	2.32	33.2	43.6	2.97	4
Cp Bm	35.3	2.87	19.1	42.9	3.11	3
Cp Bm O_0	38.1	1.64	39.9	45.3	1.92	8
O_0 Cp	36.7	0.88	33.2	41.7	0.96	8

1.B

C. EXTENSION MEASUREMENTS ON A POPULATION OF MARKED *Cortaderia pilosa* LEAVES

INTRODUCTION

The technique of using labelled leaves and tillers had been widely used to give information on plant growth and defoliation (Scott 1960, Hodgson & Ollerenshaw 1969). The method has been little used in production studies (Milner & Hughes 1968).

Methods of marking leaves and tillers have varied considerably. Hodgson (1966) used small coloured rings around tillers while it has been recommended (Anon 1961) that red paint, when carefully applied, can be satisfactorily used. The marking and labelling method employed does not seem to influence the result, the method adopted being that found most convenient to the operator.

In conjunction with other work carried out on *Cortaderia* presented in this report it was decided to measure seasonal changes in the linear growth of parts of leaves from a population of *Cortaderia* plants. No information was available on variation in leaf growth between *Cortaderia* leaves or on seasonal changes in leaf growth.

It was envisaged, however, that as well as information on the seasonal growth pattern of the *Cortaderia* leaves being obtained from such a study some indication of the pattern of senescence and dieback from the tip of *Cortaderia* leaves would also be found. This feature is of importance in the overall picture of *Cortaderia* growth and, as shown from section 1Bb, vegetation communities dominated by Cortaderia are characterised by a high fund of standing dead matter at all times of the year.

MATERIALS AND METHODS

Site

Approximately 0.06 ha of tussock forming Cortaderia were fenced off at the outlet of Moody Brook, to the west of Stanley, East Falkland.

Leaf Marking

100 randomly selected leaves were marked in October, before growth had commenced.

The leaves were labelled with a numbered plastic sheep ear tag pushed into the ground near the base of the leaf under observation. Leaves were then marked with bright coloured lipstick on the adaxial surface and the interface between the green and dead portions of the leaf marked with Indian ink applied with a 1 cm^3 syringe and fine needle.

A wire nail was pushed into the ground at the bottom of each leaf to give a constant base line measurement.

Measurements

The total leaf length, length of the leaf from base to the green/dead interface and the length from the base to the Indian ink mark (see Fig 1) were recorded on as many labelled leaves as could be found on each of the following dates:- 1977 - 28/10, 7/11, 18/11, 20/12; 1978 - 15/1, 10/2, 2/3, 29/3, 24/4.

TABLE 1. Seasonal changes in the linear extension of the measured components of *Cortaderia* leaves

Date	Green component (mm) (G)		Total leaf length (mm) D		Dieback from original dead/ green interface (mm) X		Number of samples
	Length	s.e.	Length	s.e.	Length	s.e.	
28.10.77	132	5.1	152	6.3	0	0	100
7.11.77	134	5.5	152	6.1	0.1	0.04	83
18.11.77	151	7.0	178	9.4	3.0	0.42	45
20.12.77	188	7.1	232	9.1	11.5	1.35	50
15. 1.78	197	7.2	243	9.0	11.2	1.38	50
10. 2.78	178	7.7	244	10.2	29.3	2.21	51
2. 3.78	170	7.3	271	9.9	40.1	2.64	49
29. 3.78	151	6.7	268	9.9	57.7	3.63	47
24. 4.78	138	6.4	264	9.7	71.3	3.81	49

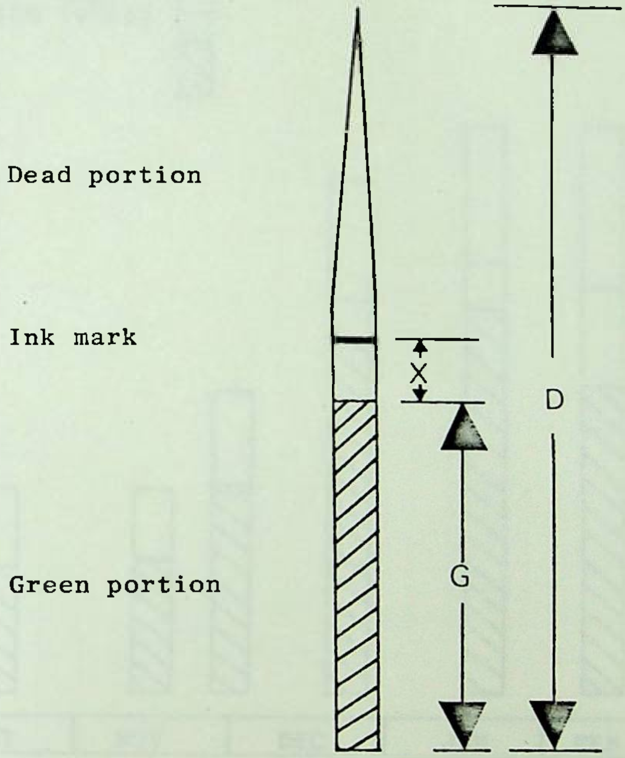

Fig. 1 Measurements recorded on <u>Cortaderia</u> leaves

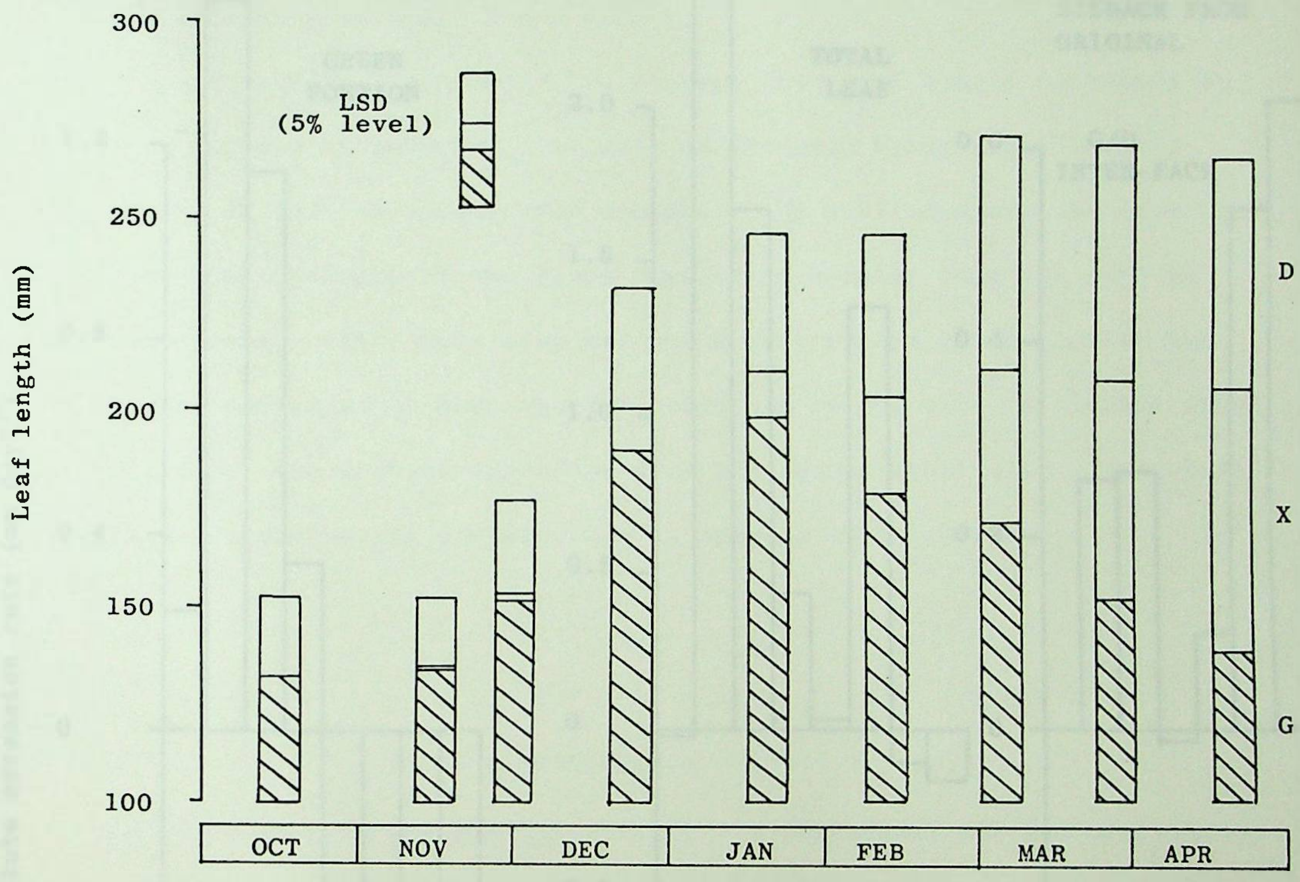

Fig. 2 Change in leaf length and components over the growing season. Green (photosynthetic) portion shaded. For explanation of symbols (G, X & D) see Fig. 1.

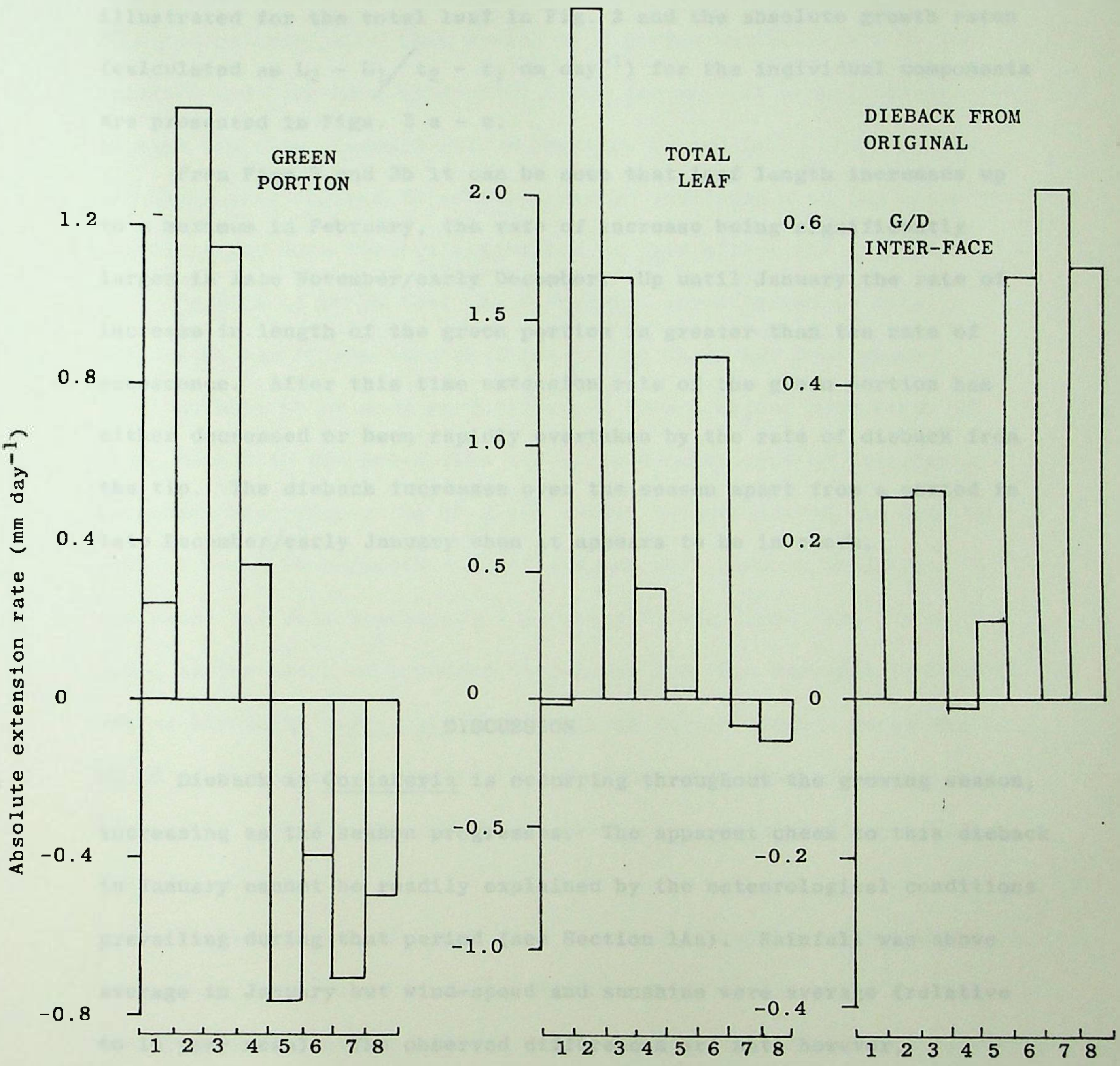

Fig. 3 Absolute extension rates for total and components of Cortaderia leaves over the growing season. For intervals between recordings see text.

RESULTS

Seasonal changes in the linear growth of the measured parts of the leaves are shown (with standards errors) in Table 1. These data are illustrated for the total leaf in Fig. 2 and the absolute growth rates (calculated as $L_2 - L_1 / t_2 - t_1$ mm day^{-1}) for the individual components are presented in Figs. 3 a - c.

From Figs 2 and 3b it can be seen that leaf length increases up to a maximum in February, the rate of increase being significantly larger in late November/early December. Up until January the rate of increase in length of the green portion is greater than the rate of senescence. After this time extension rate of the green portion has either decreased or been rapidly overtaken by the rate of dieback from the tip. The dieback increases over the season apart from a period in late December/early January when it appears to be in check.

DISCUSSION

Dieback in Cortaderia is occurring throughout the growing season, increasing as the season progresses. The apparent check to this dieback in January cannot be readily explained by the meteorological conditions prevailing during that period (see Section 1Aa). Rainfall was above average in January but wind-speed and sunshine were average (relative to 10 year mean). The observed differences are not, however, statistically significant ($P = 0.05$) and it seems more likely that the rate of senescence should increase as the season advances.

Although there was no rapid increase in leaf length in the early spring the rate of leaf extension (attributable mainly to the increase in the green portion) was highest in December. This was slightly earlier than observed from other experiments (see Section 1 Bd & e), but is in accordance with the general pattern of Cortaderia growth observed ie there is an absence of early spring growth (October and November). The available meteorological data (from a more exposed site 4 km to the east) show that spring is a period characterised by low rainfall and high mean windspeed, hence the rate of evapotranspiration is high and this, coupled with a shortage of available water in the immediate near-surface rhizosphere may be providing a spring check to growth. (For more precise discussion of this effect see section 1Bc).

It must be noted that the Cortaderia investigated in this experiment was of the tussock-forming type which has been shown (Section 1Bb) to be more productive and have a higher proportion of green matter in the sward than the uniform-cover type of Cortaderia. Hence the high proportion of green matter accumulated in the leaf by January would be expected and this agrees with pasture production estimated for this vegetation type where it was found that 75% of the green matter had been produced by January and this was contributing to 70% of the total Cortaderia production by then. These figures are based on dry matter production and the data from this experiment is comparable with 79% (by length) of the Cortaderia consisting of green matter in January.

These data are of importance in a consideration of Cortaderia management. The check to early season growth - a time when ewe energy demand is at a maximum - imposes a severe limitation on improving animal production. The levels of sheep nutrition are critically low during this period and unless the 'good' pasture types (in valleys and coastal sites) can be shown to produce sufficient herbage early in the season the only pathway to increased production may be in land improvement. The dieback of the plant resulting in a high proportion of standing dead material adversely affects utilization of the sward and further work on the effects of heavy grazing pressure on the sward during February and March is essential if improved Cortaderia management is sought.

This work indicates the seasonal pattern of leaf growth or plant vigour and provides information on dieback. It does not follow that the information obtained is directly applicable to the pattern of production or to leaf extension in any other Cortaderia dominant vegetation community.

SUMMARY

A series of linear measurements were carried out on a population of Cortaderia leaves to detect seasonal growth patterns and the nature of dieback from the leaf tip.

There was an observed check to early season growth, maximum leaf extension occurring in December, with the green portion contributing most to overall leaf length extension until January. This is in close agreement with pasture production data for this vegetation type and the significance of the variation in range of Cortaderia types as discussed.

The rate of dieback increases with time leading to a high fund of standing dead matter in the sward during the second part of the season.

The implication of these findings are discussed in relation to improved Cortaderia management and increased animal production.

ACKNOWLEDGEMENTS

Mr P Maitland assisted with fencing and recording. Miss H Rodgers also assisted with recording. Thanks are due to the Officer-in-charge, Naval Party 8901, Royal Marines for permission to use Admiralty ground for the experiments.

1B

d. A PRELIMINARY EXPERIMENT TO MEASURE THE SEASONAL PATTERN OF PRODUCTION OF AN INTRODUCED PASTURE

INTRODUCTION

In planning grazing programmes involving optimum year-round utilisation of herbage it is essential that some information is available on the seasonal pattern of growth of the herbage. Information concerning the seasonal pattern of herbage growth in the Falkland Islands has not been quantified and the present experiment was set up as preliminary to more detailed investigations on the subject.

MATERIALS

Site

Rough pasture adjacent to a dwelling house, Stanley. Principal sward species: *Poa pratensis*, *Holcus lanatus*, *Dactylis glomerata*.

METHODS

The site was pre-trimmed to ground level in September 1976.

A grid of 12 x 4 (48) plots each 61 x 30.5 cm was pegged out and 2 random plots cut from alternate rows at specified time intervals as follows:

Cut	Date
1	9.10.76.
2	14.11.76.
3	15.12.76.
4	15. 1.77.
5	29. 1.77.
6	22. 2.77.
7	23. 3.77.

The samples were dried at 90 ^{o}C for 48 hours and weighed. Samples were milled and sent to the United Kingdom for digestibility analysis.

RESULTS

The mean total dry wt. per cut is expressed in Table 1. Between-cut differences were divided by the elapsed time interval to give an estimate of net DM accumulation rate over the period of the experiment (see Table 2 and Fig. 1)

It can be seen from Fig. 1 that there is a peak of net DM accumulation rate in January.

Organic matter per cent and per cent digestibility are presented in Table 3. The values obtained for OMD are comparable to those found for hill pastures in Britain (HFRO 1979) although the December value (65.35%) is lower than that commonly found in hill pastures in June in Britain.

DISCUSSION

In contrast to the normal sward growth pattern observed in lowland pastures in the United Kingdon (Anslow and Green 1967) and to a lesser extent - hill pastures (Alcock et al 1968) no spring peak of growth is seen in Falkland Island pastures. This can be best explained by the prevalent spring meteorological conditions. This period is characterised by strong frequent winds and a marked depression in rainfall (see Section 1Aa). This leads to increased transpiration rates and associated water stress due to a low soil water potential. Hence, the lack of growth in spring appears to be environmentally induced. Such a lack of growth may be partially overcome in areas where ground water supply is adequate and some measure of shelter is available eg in valley greens.

Although only 3 digestibility values were available for this material it was felt that, in view of the lack of basic information on pasture quality in the Falklands, these deserved inclusion. If any inference can be drawn from them it is that the shifting of the peak of vegetation production to later in the season than would be found in Britain is matched by a shift in the digestibility peak. This further exacerbates the lack of early season growth as there is an indication that herbage which does grow in the spring is of low Organic Matter Digestibility compared to herbage growing later in the season.

It is proposed that the nature of the herbage growth and digestibility pattern found in the Falklands has several important consequences.

1 In planning year-round grazing systems studies, the lack of a spring flush of grass growth must be seen as a serious limitation to sheep production. Fundamental to any programme of increased sheep production is a fulfilment of the high energy demands of the ewe in the <u>pre partum</u> period. With the apparent lack of spring growth the area of better pasture conserved for ewe flushing must represent a correspondingly larger proportion of the total area and contain a high proportion of coastal and valley areas. Such an allowance may seriously affect the balance of the ratio of poor to better pasture and further complicate grazing management.

On many enclosures it is doubtful whether sufficient good pasture is present to provide the necessary pre-lambing nutritional boost.

2 The three main areas of high nutritional quality herbage production are valley floors, valley sides and coastal greens (this report section 1Bb). From observation the inhibition of spring growth is much more pronounced on the coastal greens than in the valleys. The areas of coastal greens are generally exposed and overlie sandy soils which are prone to desiccation whereas the valleys are typically more sheltered and have sufficient water supply to compensate for the low rainfall. Hence, in planning controlled grazing management in order to provide a late pregnancy nutritional boost it would be better to utilise areas with a high proportion of green valleys as opposed to coastal greens.

3 In planning areas of pasture improvement considerable care should be given to site selection. High priority should be given to the production of high quality herbage as early in the season as possible and hence site selection should orientate towards areas where exposure is minimal and ground water is available during the period September to November.

SUMMARY

Due to the absence of available information a small scale experiment was laid down to investigate the seasonal growth pattern of herbage.

It was found that growth rate was very low in the first half of the season and was characterised by a high peak in late January.

It was thought that this growth pattern was climatically induced, being due to strong winds and low rainfall in the spring. The consequences of this pattern of growth are discussed in relation to grazing systems planning and pasture improvement considerations.

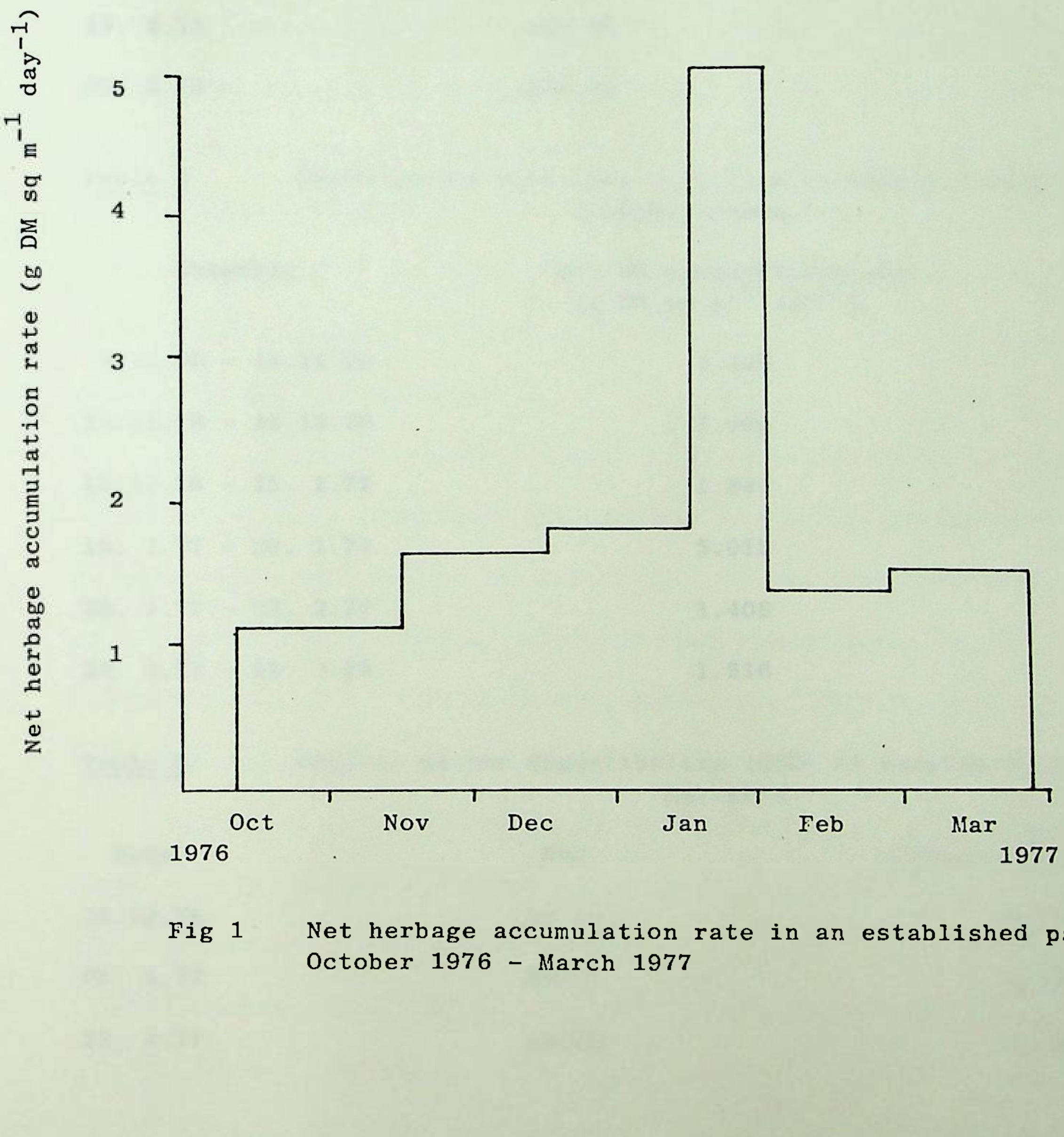

Fig 1 Net herbage accumulation rate in an established pasture. October 1976 - March 1977

Table 1 Herbage dry matter at each harvest.

Date	Mean DM (g sq m^{-1})
9.10.76	51.64
14.11.76	92.50
15.12.76	144.15
15. 1.77	201.31
29. 1.78	271.52
22. 2.78	305.31
23. 3.78	349.28

Table 2 Sward growth rate over specified intervals during the growing season.

Interval	Net DM accumulation rate (g DM sq m^{-1} day^{-1})
9.10.76 - 14.11.76	1.135
14.11.76 - 15.12.76	1.666
15.12.76 - 15. 1.77	1.844
15. 1.77 - 29. 1.77	5.015
29. 1.77 - 22. 2.77	1.408
22. 2.77 - 23. 3.77	1.516

Table 3 Organic matter digestibility (OMD) of samples from three harvests

Date	OMD	Organic Matter (%)
15.12.76	65.35	91.84
29. 1.77	68.17	91.89
22. 2.77	60.83	92.58

1.B.

e. ECOLOGICAL STUDIES ON THE SEASONAL GROWTH PATTERN IN A WHITEGRASS (Cortaderia) SWARD

INTRODUCTION

The most important component of the native vegetation is Cortaderia pilosa (Whitegrass). It is a gynodioecious (Conner 1965) perennial herb which seems to exhibit a range of forms dependent on habitat. In shallow sided valeys (sheltered areas with a continuous ground water supply) the plant tends to form tussocks whereas on level and undulating ground with poorly drained soils the Cortaderia produces a uniform cover with a relatively lax growth habit.

Most of the Falklands are covered by some facies of the communities included in these formations (Moore 1968) and it is the dominant element in most plant communities (Davies 1939). It has been estimated (Davies et al. 1971) that Cortaderia dominant communities comprise, by area, approximately 65% of West Falkland, 63% of East Falkland and 41% of the scattered Islands.

Estimates of total annual dry matter production have been obtained using a pre-trimming technique over three growing seasons (1975-1978) (Section 1.B.b.). Considerable variation between seasons and sites were found with mean annual production of tussock forming Cortaderia being 4500 kg DM ha^{-1} and yield on the uniform-cover communities ranging from 1250 - 2800 kg DM ha^{-1}. The latter production figures corresponds with those widely reported for Molinia-Nardus vegetation in upland Britain (Eadie 1970). Davies et al. (1971) report a mean D-value for Cortaderia as 37.3%.

There are few reported soil analyses from the Falkland Islands. From Davies (1939), King et al. (1969), Davies et al. (1971) and this report Section 2.B.c. pH values range from 3.9 to 4.7. Phosphorus levels on unimproved ground were low, Davies et al. (1971) and King et al. (1969) measuring levels from 0.0009 - 0.0070% and Potassium and Magnesium levels from 0.073 - 0.48% and 0.125 - 0.712% respectively. Characteristics of soils of this type are low levels of decomposition, poor mineralisation and limited plant nutrient cycling (Floate 1970).

The present system of year-round set stocking of pastures imposes limitations on the levels of production. Principally these are poor nutrition and low pasture utilisation, herbage intake being low in relation to production with a large proportion of standing dead matter diluting the quality of feed available. This is most limiting during the pre-lambing period when the energy demand of the ewe is at a maximum. Improvement in sheep production from this type of system depends on increasing pasture production and improving the efficiency of utilisation (Eadie 1970). This improvement is realised by differentiating and fencing off areas of good pasture from poorer pasture and integrating the grazing on these to ensure that the sheep's energy demands are met at critical periods in the cycle.

Fundamental to any programme of this nature is information on the seasonal pattern and quantity of production of the native pastures. When this quantitative information is combined with data on the change in quality of the pasture with time, grazing management decisions can be made with a greater degree of precision and development and improvement practices can be approached on a less speculative basis.

The current investigation was aimed at studying the changes occurring in a Cortaderia dominant community throughout the period October - May and attaching more precision to the available data on production in this type of community, (Section 1.B.c.).

SITE

As sampling had to be carried out regularly a site was chosen which could be relatively easily reached overland from Stanley.

Site aspect and position are shown in Fig. 1. On the study area approximatley 1.8 m of undifferentiated peat overlaid upper carboniferous Lafonian tillite (Greenway 1972). The study area chosen was representative of a Cortaderia community which covered a large area of the Falkland Islands. The site vegetation was described using the Braun-Blanquet cover abundance system (Poore 1955) and this is presented in Table 1.

The experimental site was fenced from stock.

MATERIALS AND METHODS

a. Meteorological data

This was collected from Port Stanley to the east of the study area and Fitzroy settlement an equal distance (14 km) to the west of the area. Rainfall and 10 cm soil temperatures were available for Fitzroy; Rainfall, 10 cm soil temperatures, grass minimum temperature, mean wind speed, and hours sunshine for Stanley.

b. Herbage sampling

Measuring primary productivity by calculating biomass of the plant community at the beginning of, end of, and at selected intervals throughout the growing season allows the calculation of increment by subtraction. This is a method which has been widely used by ecologists and is particularly suitable for slow growing and extensively grazed plant communities (eg Bliss 1966; Tormala and Raatikainen 1976). It has also been used in studies on sub-antantic grasslands (Smith and Stephenson 1975; Walton, Green and Callaghan 1975). In many grasslands pre-trimming is a very drastic treatment which is likely to modify subsequent growth considerably (Milner and Hughes 1970).

The sampling area, measuring 9.6 m by 9.6 m was subdivided with string into a grid of 30 cm x 30 cm squares.

Harvesting occurred at 3 week intervals starting in October 1977 just before the onset of growth based on a 10 cm soil temperature of 5.5 °C being attained (Taylor 1967). Harvesting ceased in May 1978, by which time the soil temperature had fallen below 5.5 °C and visiting the site was becoming increasingly more difficult.

Samples were taken only from alternate horizontal and vertical rows in the grid thus preventing any two adjacent samples being taken during the same or between different harvests. In this way any edge effect was eliminated. At each harvest twenty random 30 cm by 30 cm squares were removed as shallow turves and taken to the laboratory. This procedure was adopted to overcome some of the difficulties experienced in trimming samples in the field in conditions of almost continuous wind.

Subsequently samples were sub-sampled and sorted into various above ground fractions. The <u>Cortaderia</u> present in the subsample was divided into photosynthetic ('Green') and non-photosynthetic ('Dead') fractions. The culm of the grass was included in the non-photosynthetic fraction while the green panicle was included in the photosynthetic fraction. During the latter part of the season the entire inflorescence was treated as non-photosynthetic material. The non-<u>Cortaderia</u> fraction of the above-ground herbage was termed the 'Herb' fraction. The component fractions of the sub-sample and the remainder of the total sample were oven dried at 90 °C for 48 hours before weighing.

c. Root sampling

The root systems of grassland ecosystems constitute an important proportion of the primary production and standing crop of the community. Their measurement presents considerable sampling problems due to the ramifications of the roots and their adherence to soil particles. These difficulties tend to be exacerbated in peaty soils. It was therefore impractical to consider the detection of root growth patterns in peat by the difference method because of the amount of replication required. A useful technique consisting of the removal of a core from the sward to an appropriate depth and replacing it with soil containing no roots has been suggested by Troughton and used successfully by Milner and Perkins (unpubl.) on mountain grasslands in Britain (Milner and Hughes 1968). After a given period, the identical core is again sampled and roots which have grown into the soil weighed.

In this investigation a square grid of sixtyfour (8 x 8) 1257 cm^3 cylindrical cores at 0.5 x 0.5 m spacings were filled with moistened inert peat mould prior to commencement of herbage growth. Subsequently ten of these cores were removed every six weeks. The roots were washed from the peat, their volume found by water displacement and their dry weight measured.

d. Soil sampling and chemical analyses

Soil samples were removed from a depth of 2.5 cm in each of the twenty turves samples and the following analyses carried out:-

Factor analysed	Method of analysis	Time interval between sampling (weeks)	Number of samples
pH	(Anon 1973)	3	20
Extractable-PO_4^{3-}	Molybdenum blue (Allen 1974)	6	10
Total Phosphorus	Acid digestion and spectro-photometric molybdovanado-phosphate method (AOAC 1970)	6	10
Extractable-K	Flame photometer (Allen 1974)	6	10
Total Potassium	Wet Digestion Method (AOAC 1970)	6	10
Total Nitrogen	Acid micro-digestion method (Anon 1973)	6	10
Total Carbon	Sample Ashing at 500 ^{o}C for 10 hrs	6	10
Dry Matter	Oven dry for 48 hrs at 90 ^{o}C	6	10

e. Herbage digestibility analyses

After drying and weighing the separated herbage samples from each harvest were bulked and subsampled to give five samples for herbage digestibility analysis. The organic matter content and organic matter digestibility of these samples was determined (Tilley and Terry 1963).

f. Numbers and biomass of bacteria

In order to obtain an indication of the rate of decompositon of leaf litter and soil in the Cortaderia grassland ecosystem under study an attempt was made to assess the numbers and biomass of bacteria by the dilution plate count technique (Clark 1965). Samples of Cortaderia litter and of soil from about 0.5 cm depth were taken. Ten grams fresh weight of each sample was shaken for 10 min in 95 cm^3 sterilised water.

10 cm^3 aliquots of the suspension were diluted by a factor of 10^2, 10^3, 10^4 and 10^5 with sterilised water. Four 1 cm^3 replicates of each dilution were pipetted onto petri dishes into which 12 cm^3 of egg-albumen agar at 42 ^oC was poured. The dishes were then incubated in semi-darkness at 28 ^oC. After 14 days the numbers of bacterial colonies per plate were counted.

Litter and soil samples were analysed at three times during the 1977-78 season, namely in spring (October), summer (January) and in autumn (May).

RESULTS

a. Meteorological conditions (Table 2)

(The term 'average' is used with respect to the ten year mean (1954-1963).

The winter preceeding the 1977/78 growing season was more severe than usual. Air temperature, soil temperature and sunshine levels were below average with rainfall above average. The growing season was warmer and sunnier than average with windspeed and rainfall average in the latter part of the season (February - May) and below average in the first part of the season (February - May) and below average in the first part of the season (October - January). Abnormally high and low rainfalls were recorded at Stanley in November and December respectively. The high November rainfall was not recorded at Fitzroy.

Overall, growing conditions in the 1977/78 season were more suited to plant growth than average. It was estimated that the experimental period (209 days) included the complete growing season, the last harvest being taken in the period when growth had ceased.

b. Herbage production

Significant changes ($P<0.001$) were recorded in each sward component and in the total standing herbage over the growing season (Fig 2, Table 3). Levels of total standing herbage were relatively constant in the first part of the season, the peak of production ocurring in January with little further increase. The relative growth rate (RGR) (Table 4) was higher between harvests 5 (5.1.78) and 6 (26.1.78) than between any other adjacent pair of harvests.

Cortaderia remained the principal component in the herbage throughout the season, contributing an average of 71% to the total standing crop DM. The January peak of total standing crop production was due to an increase in the photosynthetic (PS) and non-photosynthetic (non-PS) *Cortaderia* components (Fig 3). A large proportion of the herbage at any time consisted of herbs and the non-PS *Cortaderia* fraction, the PS *Cortaderia* fraction contributing an average of 23.3% of the standing crop DM at any one time. The PS to non-PS ratio in the *Cortaderia* plants (Fig 4) increased uniformly to a constant level in January - February declining rapidly after the cessation of growth (harvest 10 - 19.4.78).

There was a significant loss of non-PS matter from the *Cortaderia* early in the season with the peak of production occurring in January and, to a lesser extent, in April. The production of PS matter by *Cortaderia* was confined to a peak in January.

The contribution of herbs to the overall herbage composition remained relatively constant with two periods of DM loss in the latter part of the season.

Calculation of Net Aerial Primary Production

Characteristic of the very extensively grazed vegetation under study is a large amount of standing dead plant material at all times of the year. Numerous studies of the primary production of grasslands of this type have been undertaken and in the majority of these data on the time series of harvest of biomass form the basis of computing the net production. However no single standard technique of computation is available which would give comparable estimates across grassland types and hence various authors have used different techniques. Singh, Lauenroth and Steinhorst (1975) have reviewed and assessed the various techniques for estimating net aerial primary production (NAP) in grasslands from harvest data.

Utilizing data representing a grazed and ungrazed treatment on ten sites of six grassland types in the USA (IBP Grassland Biome sites) they calculated NAP for the growing season using thirteen different methods. They found that although all of the methods used in the computation of NAP were significantly correlated ($r<0.61$) they yielded significantly different estimates when applied to the same set of data. Estimates from principal methods were, however, interconvertible and conversion factors were presented in their paper.

Of all the methods they tested, the trough-peak analysis on total biomass categories appeared the most logical choice from both a theoretical and utilitarian point of view. In this method significant concurrent positive increments (which were significantly different at $P = 0.1$) in total live and total standing dead components were summed. The use of this method is thought to be particularly suited to veget-ation types where one species is dominant and there is a high standing dead biomass at any time in the season because:-

a Individual species biomass measurements are not required.

b More than one growth peak per season can be considered.

c It can be applied to sites where 'recent dead' and 'old dead' components have not been separated.

A slight modification of this method is proposed for the analysis of data presented in this investigation. It is proposed that the NAP of the Cortaderia (live and dead) and of the herb component be computed separately and summed.

Singh et al. (1975) recommend some statistical constraint on the method suggested. They summarised positive differences in standing biomass with the following constraints:-

1 No constraints.

2 Only increments summed which were significant at the 80% level ($P = 0.2$).

3 Only increments summed which were significant at the 90% level ($P = 0.1$).

4 Only increments summed which were significant at the 95% level ($P = 0.05$).

On analysis of the results from the grassland sites studied, they (Singh et al. 1975) found that 90% or 80% levels of confidence were very close to the means of all methods tested.

Positive increments were summed assuming different levels of significance between increments (Table 5) to give estimates of total NAP and of Cortaderia NAP for the growing season.

Hence, from the detailed comparisons of methods recommended by Singh et al. (1975) the NAP of this type of Cortaderia dominant vegetation community was found to be $254 gm^{-2}$ over the period October to May, 66% of this production being Cortaderia ($167 gm^{-2}$)

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c. Root production

Mean cumulative root weight and root volume (Table 6) are closely correlated. A highly significant linear ($P<0.001$) increase in root weight and volume was detected over the growing period. The RGR (Table 7) decreased over the growing season.

Over the period of the experiment the mean total root production was 818 gm^{-2} (to a depth of 25 cm) representing a mean root production of 3.92gm^{-2} day^{-1}.

Root production has been calculated for a wide range of sites. Wiegert and Evans (1964) report 2.23 gm^{-2} day^{-1} from an ungrazed field in Michigan, USA. Walton et al. (1975) measured 3.05 gm^{-2} day^{-1} on South Georgia and Tormala and Raatikainen (1976) quote total annual root production from a Finnish field at 343 gm^{-2}. Troughton (1957) quotes many sources ranging from 250 - 620 gm^{-2} $annum^{-1}$ in rough upland pasture. Hence the root production measured in this experiment (3.92 gm^{-2} day^{-1} and 818 gm^{-2} growing $season^{-1}$) would indicate that production in the Falklands is considerably higher than that recorded for other areas.

d. Soil analyses

Soil pH and dry matter changed significantly over the growing period (Fig 5). The pH was at a maximum in December rapidly increasing by almost 0.5 pH units from October. A secondary pH peak was noted in March and the soil DM content was at a maximum in January.

The levels of extractable P and K and total N, P and K did not change significantly over the growing period (Table 8). The Organic matter content (% carbon) changed significantly ($P = 0.01$) over the season, reaching a maximum in mid April.

Levels of total P and total K were within the range quoted for hillsoils in Britain, with the Organic Matter content and total N levels being higher than commonly recorded (Floate 1977). Levels of available P and K were higher than reported by Davies et al. (1971)

for the Falklands, Gwynne et al. (1974) on St Kilda and Walton et al. (1975) on South Georgia.

e. Herbage Digestibility (Fig 6)

The herbage digestibility showed a slight but significant ($P<0.05$) increase over the growing period, reaching a maximum in late January, approximately coincident with the period of maximum DM increase .

However a closer examination of the factors contributing to the overall digestibility is of considerable importance. The OMD of the green matter increased highly significantly in the spring period and then declined steadily over the summer again reaching a peak in autumn. The relatively high digestibility of the green matter in spring did not contribute to a rapid increase in total herbage digestibility because of the low digestibility of the dead matter which was the major herbage component at that time (Fig 2). The dead matter OMD does not change significantly over the growing period, however it does reach a maximum in February and this contributes to the peak in total herbage digestibility. The values obtained for OMD from the Falklands are considerably lower than those obtained for even the poorest quality hill pastures in the UK where values of 60-70% are recorded for Nardus and Molinia dominant pastures in spring and early summer and 35-40% for Nardus in late winter (HFRO 1979)

f. Bacterial numbers and biomass

Since the mean number of bacteria in the higher dilutions (10^{-4} - 10^{-5}) when multiplied by the dilution factor, provided comparatively similar results, a sample mean was calculated and converted to total number of bacteria per gram dry weight (Table 9). The fresh-weight biomass per gram fresh-weight of sample has been estimated on the basis that the fresh weight of an average bacterium is 1.5×10^{-2}g. (Alexander 1961).

Bacterial activity was considerably greater in the litter than the soil. The bacterial biomass increased by a factor of 7.3 over the season in the litter and by 1.8 in the soil. Bacterial biomass was considerably higher at all times than that from soil and litter in Festuca contracta grassland and Poa flabellata litter in South Georgia (Smith and Stephenson 1975) and at the lower end of the range commonly quoted for soil (10^6 - 10^8 per gram soil) as measured by serial dilution (Mason 1976).

DISCUSSION

Above ground quality and quantity of herbage production.

The end-of-season standing crop - 600 gm^{-2} - was considerably lower than that reported for Festuca contracta dominant grassland on South Georgia (1141 gm^{-2}, Smith and Stephenson 1975) and on a herb-grass community in the USSR (Schamurin et al. 1972 - approx 550 gm^{-2}). The estimated total herbage produciton over the growing season of Cortaderia grassland on the Falkland Islands (254.4 gm^{-2}) was lower than recorded for Festuca grassland (vascular component) in South Georgia (612.6 gm^{-2} Walton et al. 1975) within the range recorded in a field in mid Finland (045 - 415 gm^{-2}; Tormala and Raatikainen 1976) and greater than recorded for alpine tundra ecosystems (20 - 200 gm^{-2} reviewed in Bliss 1966) and sedge meadows in alpine microenvironments (67 - 176 gm^{-2} Bliss 1966). This production (2544 kg ha^{-1}) is equivalent to the upper reported range for Molinia - Nardus grassland in upland Britain (HFRO 1979).

For most of the above quoted vegetation communities the estimated length of the growth season is shorter than that estimated for the Falkland Islands, hence the production rates must be considered as low. Polunin (1960) classified the Falkland Islands' vegetation as grassy tundra with lichens and mosses, whereas data from other regions would indicate that in terms of production many widespread communities could be classified as alpine tundra. The closest (geographically) recorded sites to the Falklands are those on South Georgia. The work reported in this paper (where production was considerably lower than recorded from South Georgia) supports the view of Walton et al. (1975) that communities on some South Georgian sites might be considered as being more similar to low-altitude alpine rather than sub-arctic polar sites - as the Falkland Islands vegetation communities cannot be considered as similar to those found on sub-arctic polar sites.

The lower levels of bacterial activity found in South Georgian sites than on those in the Falkland Islands may be attributable to temperature differences, air and soil temperatures being much lower over the growing season in the former area.

The most significant component of the standing herbage at any time is the high proportion of herbs and Cortaderia dead matter. This is the primary contributory factor to the low digestibility of the herbage and hence the low levels of herbage utilisation and animal production recorded from such areas. The green matter in the sward which is able to be utilised is being considerably diluted by this high fund of standing dead matter.

The dead matter digestibility peak in February suggests that the die-back effect may be more rapid on the outside of the leaves, some photosynthesis continuing within the outer sheath of dead cells. Hence, it may appear that 'recent dead' material has a higher digestibility than 'older dead' material and it is the high digestibility of this recent dead material plus the relatively large standing crop of green material which is contributing to the peak of digestibility noted in February.

The application of improved grazing management practices is dependent on the seasonal pattern of herbage production, especially of the photosynthetic graminaceous component of the herbage. It is evident from the work reported here that there is a marked absence of early season production, a large proportion of the P/S matter being produced in a relatively narrow time interval in mid-season. The onset of anthesis in December/January may be partially contributing to the standing crop of P/S matter, however the density of culms was very low. The culms may be contributing to the rapid dry weight gain of the non P/S Cortaderia fraction in the January period.

The general pattern of herbage growth noted was thought to be largely climatically induced. The October - November period generally has low rainfall and high mean windspeeds. It has been suggested (Skottsberg 1913) that the relatively low spring rainfall imposes strictures on plant growth, these being amplified by the strong winds. The reluctance of wet, peat soils to warm up in spring (Taylor 1967) leads to an early season check to growth, the temperature affect being exacerbated by the wind (Grace 1977).

The primary components of the herb fraction (Table 1) are native woody herbs which appear to grow slowly and be capable of growth at low temperatures. Increase in herb standing crop did not appear to commence until late in the season. This may not imply an absence of growth, the rate of senescence and loss of dead matter possibly being compensated by an approximately similar rate of accumulation of live matter. A net dry weight gain of the herb component was recorded in May, after the Cortaderia component showed a reduction in growth. The two periods where there is a net DM loss recorded coincide with the period of seed dispersal of Baccharis magellanica and Rotkovia magellanica and ripening and loss of berries of Myrteola nummularia, Pernettya pumila and Nertera depressa.

The most critical periods in the annual energy demand cycle of the ewe are late pregnancy and early lactation. In the Falklands this is from late August to early November. It can be seen therefore that the observed check to early season growth imposes limitations on pasture and animal production. It must be noted that the vegetation type chosen in this experiment, although the most widespread in extent, is not the most productive, coastal areas and river valleys producing up to four or five times as much DM per annum. The check to early season growth although not so marked here due to the presence of some shelter and ground water supply, is still evident as experiments on leaf extension of Cortaderia and on production of improved pasture (Sections 1.B.d. & 2.B.c.) indicated. Hence, even though better areas are available, they are often fragmented and dispersed among much larger areas of pasture of the types studied in this experiment. This further contributes to the low utilization rate of the Cortaderia, stock preferentially grazing the valleys.

Implications on Cortaderia management

The implications of these results on the management and increased utilization of Cortaderia dominant grassland are seen to be:-

1 In early spring (Oct - Nov) net DM accumulation is limited and although the digestibility of the Cortaderia green matter is high, considerable dilution of this quality occurs because of the high proportion of 'old dead' Cortaderia in the sward.

The energy requirements of the pregnant ewe are at a maximum at this time and as no supplementary feed in being provided the shortage of availability of high quality herbage at this time is imposing severe limitations on ewe lactation and lamb birth weights. the removal of the high fund of standing dead matter in early spring would result in higher quality herbage being made available and increased utilisation of the herbage produced.

Burning in early spring or heavy stocking by dry sheep in late winter may be the best way of achieving this. Because of the variation in vegetation types generally encountered in any large, stocked enclosure, herbage from better sites such as stream valleys and the coast will most probably be available during this period. However, the grazing pressure on these, often widely dispersed, areas is generally so severe that the creation of more extensive areas of relatively higher quality pasture would be very advantageous especially over this critical period.

2 In the summer (Dec - Feb) although the digestibility of the green matter is decreasing, overall herbage digestibility is increasing because of

a the removal of 'old dead' material and its replacement by more 'recent dead' material and

b a peak in green-matter production.

Heavy grazing at this time would not be desirable the aim being to maintain a high proportion of standing green-matter in the herbage prior to a late season significant increase in herbage digestibility. Most of the 'old dead' vegetation seems to have been blown off or removed and the more recent dead is contributing to a build up in the overall pasture digestibility which should be allowed to proceed.

3 Increased grazing pressure in April and May would then remove some of the standing dead matter which would have accumulated. Stock would then have maximum benefit from this increased digestibility herbage and greater utilisation of the standing herbage would occur. Pasture would then enter the winter period with a reduced fund of standing dead matter and sufficient quantity of relatively high quality herbage. This would also provide the desirable pre-mating nutritional boost for the ewes.

It may be, however, that enclosures which contain a high proportion of the Cortaderia community described will be used primarily for dry sheep production. In this instance the high spring energy demand of the sheep is not so critical and the stock can be subject to greater pressure with less risk of severe nutritional problems arising.

Hence, it is thought that two periods of severe pasture defoliation, one in Oct/Nov/Dec and one in March/April would be a management practice best suited to increasing the utilisation and overall herbage digestibility of Cortaderia grassland of this type. The early season severe grazing pressure on low production Cortaderia would serve to relieve the pressure on better areas for breeding sheep and nutritional disorders are less likely to occur because of the relatively high digestibility of the growing herbage. The March/April heavy grazing pressure period is also unlikely to be severely limiting in that maximum herbage accumulation has occurred (Jan/Feb) and the digestibility of the material is still relatively high by March/April.

The problem of limited early season growth and low herbage digestibility may only be finally overcome by reseeding and controlling the grazing on areas of Cortaderia dominant vegetation where the drainage is not severely impeded and some degree of soil mineralisation is evident.

A management programme incorporating this improved pasture integrated with a substantially larger area of the type of grass community studied in this experiment could result in increased utilization of the Cortaderia and subsequently increased animal production on the area as a whole.

Below ground production

In view of the related low level of measured above-ground production it seems unlikely that the below-ground production in the Falklands, especially under the soil conditions prevalent should be higher than in other, similar, regions of the world. Hence some doubt must be cast on the method adopted suggested by Troughton (in Milner and Hughes 1968) - but no definitive criticism can be made in the absence of a detailed comparison with the method of measured difference in the current root crop. Possibly initial severing of the roots stimulated growth or, in the absence of competition (as would occur in this case), Cortaderia roots developed at an unusually fast rate. The decrease of RGR as the season progressed may also indicate a competition effect, the increasing root production leading to increasing competition and a decrease in RGR.

Soil mineral levels

It is difficult to account for the significant ($P<0.001$) increase in pH early in the season. This may be due to a drying-out effect, although if this were the case one would expect the soil DM peak (Fig 5) to precede the pH peak, not follow it, as was the case. During December windspeed was at a maximum and this, coupled with the very low December rainfall, may have been contributing to the increase in pH. Little work has been published on the cyclic pattern of pH level in soil and it is not certain whether the measured pattern in 1977/78 would be repeated in other growing seasons. An amelioration of pH of this magnitude (4.0 - 4.5) may be of ecological significance in that conditions would be slightly more favourable for plant growth, mineralization, trace element release, and bacterial activity in the rhizosphere during this period.

Because of the wet undecompsed nature of the soils the low DM% and relatively high OM content are to be expected. Only a small fraction of the total-P is in the extractable form and anomalous results have been obtained for determination of available-P in peaty soils (Floate and Pimplasker 1976). It may be of more relevance to consider the total-P values and in this respect total-P values from the Falklands are similar to those found in upland British soils, hence the same problems of plant phosphorous nutrition will probably be encountered in both areas.

Due to the low levels of decomposition (Table 9) and the undifferentiated nature of the peat; the methods adopted for standard soil analysis may not be applicable and the high P and K values obtained may be reflecting the higher P and K levels generally recorded in plant tissue.

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SUMMARY

Climatic and edaphic conditions in the Falkland Islands result in species - poor low productivity grassland communities dominated by Cortaderia pilosa. The severe limitations imposed on animal production by these communities and this species in particular are outlined and presented as the background to a study aimed at investigating the production and growth pattern over the growing period of above and below ground components of a Cortaderia dominated grassland community.

A typical sward of lax, uniform Cortaderia was sampled at regular intervals over the growing season. The above-ground herbage was separated into herb, photosynthetic - and non-photosynthetic - Cortaderia fractions. Standing DM and organic matter digestibility of the sward fractions were measured.

Root growth was investigated by a sugested method whereby growth into previously removed soil cores was measured at regular intervals. Soil, pH, moisture content, total and extractable P and K, organic matter content and total N levels were monitored and estimates of bacterial numbers were made at the beginning, middle and end of the season. The above-ground production was dominated by Cortaderia and characterised by a high proportion of standing dead matter at all times of the year. This influenced the method of calculation of net aerial production which was estimated as 254 g m^{-2}. Comparison with data from other localities indicated that productivity was low, being similar to levels for sites classified as alpine tundra.

The pattern of production was characterised by a marked check to early season growth, most of the dry matter being produced in a short period in mid season.

The results obtained for Cortaderia root production were high and cast doubt on the method of measurement used, further information being required to support this criticism.

Levels of available P and K were higher than found in British hill soils whereas levels of total N, P and K were comparable. The problems associated with measuring extractable - P are referred to. Soil pH and DM reached a pronounced peak in mid season and a correlation with recorded climatic variables was discussed. The peat sampled was characterised by a high OM and low DM content.

The implications of these findings, especially the low level of production, the digestibility of the herbage, the high proportion of standing dead matter and absence of early season growth were discussed in relation to the pattern and quality of vegetation communities found, the increased utilisation of Cortaderia by improved management and increased pasture production.

It was concluded that improvement could best be realised in many situations by reseeding areas of known high pasture potential and integrating the grazing of these with a larger area of the type of pasture studied. The importance of the removal of the large fund of standing dead matter was emphasised.

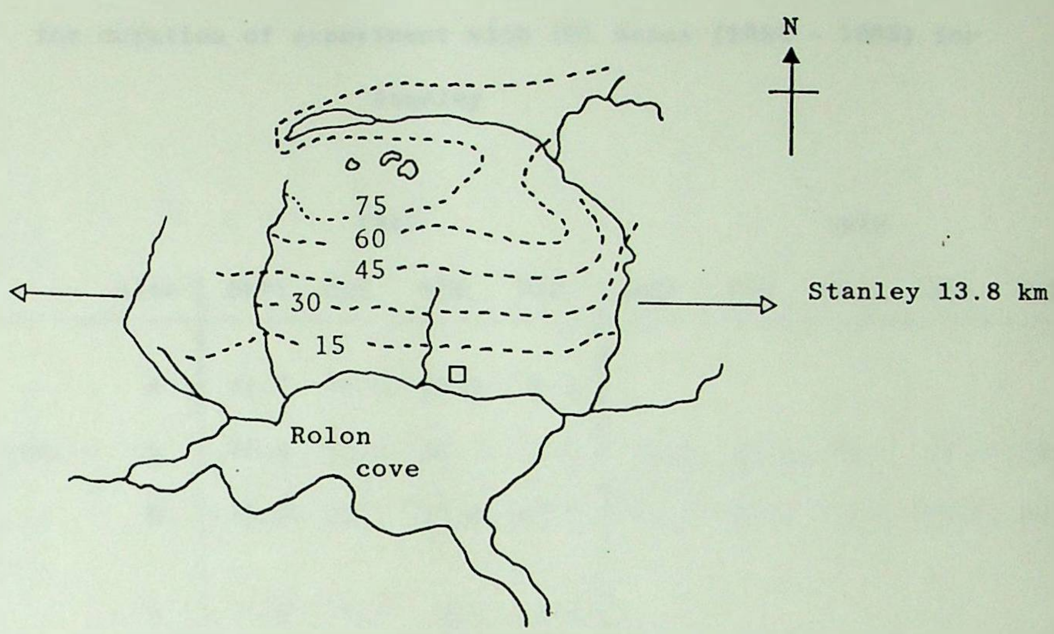


Fig 1 Relative Position of experimental site (51°44.03'S; 58°03.06'W). Altitudes above msl in metres.

Table 1 Vegetation community description, based on cover abundance analysis (Scale + - 5)

Species	Rating
Cortaderia pilosa (D'Urv) Hack	4
Baccharis magellanica (Lam.) Pers.	1
Rostkovia magellanica (Lam.) Hook. f.	1
Oreobolus otrunsangulus Gaudich	+
Myrteola nummularia ((Poir). Berg	+
Pernettya pumila (L.f.) Hook	+
Viola macuita Cav	+
Byrophytes	+

Table 2 Climatic data recorded at Fitzroy (A) and Port Stanley (B) for duration of experiment with (M) means (1954 - 1963) for Stanley

	Site	1977 SEPT	OCT	NOV	DEC	1978 JAN	FEB	MAR	APR	MAY
Rainfall (mm)	A	41.7	39.0	27.6	30.7					
	B	46.5	29.8	61.3	19.1	81.5	43.0	42.9	73.7	29.8
	M	32.0	30.7	39.6	69.1	75.1	45.9	41.5	49.1	56.1
Soil temp 10 cm (^{o}C)	A	2.9	5.3	8.1	11.2					
	B	3.1	5.5	8.3	10.3	10.2	9.8	8.5	6.4	4.1
	M	3.4	5.5	7.7	9.0	9.5	9.6	8.2	6.0	4.1
Windspeed (km hr^{-1})	B	25.5	29.6	31.3	30.6	30.1	25.9	28.9	31.0	23.6
	M	29.7	30.6	31.7	29.7	28.5	29.6	30.3	27.6	29.7
Daily Sunshine (hrs)	B	3.9	5.7	7.9	7.7	6.6	5.5	4.1	2.5	1.6
	M	4.2	6.3	6.5	6.4	6.2	6.0	5.3	3.9	2.6

Table 3 Mean dry weight per harvest (g m^{-2}) for aerial fractions of components of a Cortaderia grassland community

Harvest Number	Date	Cortaderia		Other sward components (H)	Total above ground biomass
		Green fraction (G)	Dead fraction (D)		
1	12.10.77	106.0	217.2	129.0	452.2
2	3.11.77	121.3	219.8	125.4	466.5
3	20.11.77	114.2	191.1	104.9	410.2
4	15.12.77	114.4	154.1	113.8	382.3
5	5. 1.78	121.5	162.2	156.4	440.1
6	26. 1.78	179.5	237.3	182.9	599.7
7	15. 2.78	193.9	240.5	122.6	556.9
8	8. 3.78	177.7	217.4	167.1	562.2
9	29. 3.78	178.1	223.3	119.7	521.1
10	19. 4.78	198.9	257.5	143.0	599.4
11	10. 5.78	130.7	227.1	174.5	532.4
s.e.d.		12.89	18.01	20.96	35.28

Table 4 Relative growth rates (RGR) for principal aerial components of *Cortaderia* grassland

RGR units:- g g^{-1} day^{-1}

Between Harvests	Cortaderia green fraction	Total above ground vegetation
1 & 2	0.006	0.001
2 & 3	-0.003	-0.007
3 & 4	0	-0.003
4 & 5	0.003	0.007
5 & 6	0.020	0.015
6 & 7	0.003	-0.004
7 & 8	-0.004	0.001
8 & 9	0	-0.004
9 &10	0.005	0.006
10 &11	-0.020	-0.006

Table 5   Estimates of Net Aerial Production(NAP) in g DM m^{-2} for various components of the *Cortaderia* community, assuming different levels of significance between postive increments.

	No statistical constraints between Increments	Increments significantly different at level:- p = 0.2 80%	p = 0.1 90%	p = 0.05 95%
1 *Cortaderia* component	245.0	188.1	167.3	133.1
2 Herb component	177.3	87.1	87.1	87.1
3 Total above ground biomass	422.3	275.1	254.4	220.2

Table 6 Mean cumulative root weight and volume in *Cortaderia* grassland throughout the growing season

	Harvest number and date						
	H3 20.11.77	H5 5.1.78	H7 15.2.78	H9 29.3.78	H11 10.5.78	s.e.d.	level of significance
Root wt (µg cm^{-3} soil)	9.6	212.2	667.0	1611.3	3273.3	153.22	P<0.001
Root wt (g sq m^{-1})	2.4	53.1	166.8	402.9	818.4	27.08	P<0.001
Root vol (µl cm^{-3}soil)	0.07	1.37	5.25	12.46	21.48	0.96	P<0.001
Root vol(µl sq m^{-1})	18.1	343.9	1313.0	3115.5	5371.5	239.91	P<0.001

Table 7 Relative growth rates for root component of *Cortaderia* grassland

	20.11.77-5.1.78	5.1.78-15.2.78	15.2.78-29.3.78	29.3.78-10.5.78
Root volume (cm^3 cm^{-3} day^{-1})	0.064	0.033	0.021	0.013
Root weight (µg $cm^{-3}day^{-1}$)	0.067	0.028	0.021	0.017

Harvest Number	Date	DM%	%P Extractable	%P Total	%K Extractable	%K Total	%C	%N
1	12.10.77	12.2	0.0054		0.0798			
3	20.11.77	13.4	0.0037	0.09	0.0741	0.10	48.8	2.1
5	5. 1.78	15.7	0.0072	0.09	0.0970	0.10	50.5	2.3
7	15. 2.78	13.9	0.0056	0.09	0.0777	0.11	50.9	2.2
9	29. 3.78	13.4	0.0076	0.09	0.1027	0.13	52.2	2.2
11	10. 5.78	11.2	0.0060	0.09	0.0783	0.12	50.6	2.2
Mean		13.3	0.0059	0.09	0.0849	0.12	50.8	2.2
s.e.d.		0.59	0.0015	0.004	0.0124	0.110	0.79	0.07
Level of significance of difference		***	NS	NS	NS	NS	**	NS

Table 8 Levels of C, N, P, K and DM in soil associated with *Cortaderia* grassland

Table 9 Total number and biomass of bacteria in litter and soil from *Cortaderia pilosa* grassland

Sampling date	Substrate	Mean total number of bacteria ($10^6 g^{-1}$ dry wt)	Estimated fresh weight of bacteria ($\mu g\ g^{-1}$ fresh wt)
OCTOBER			
	soil	2.88	0.525
	litter	6.98	1.275
JANUARY			
	soil	3.18	0.750
	litter	15.29	3.600
MAY			
	soil	5.61	0.937
	litter	55.6	9.300

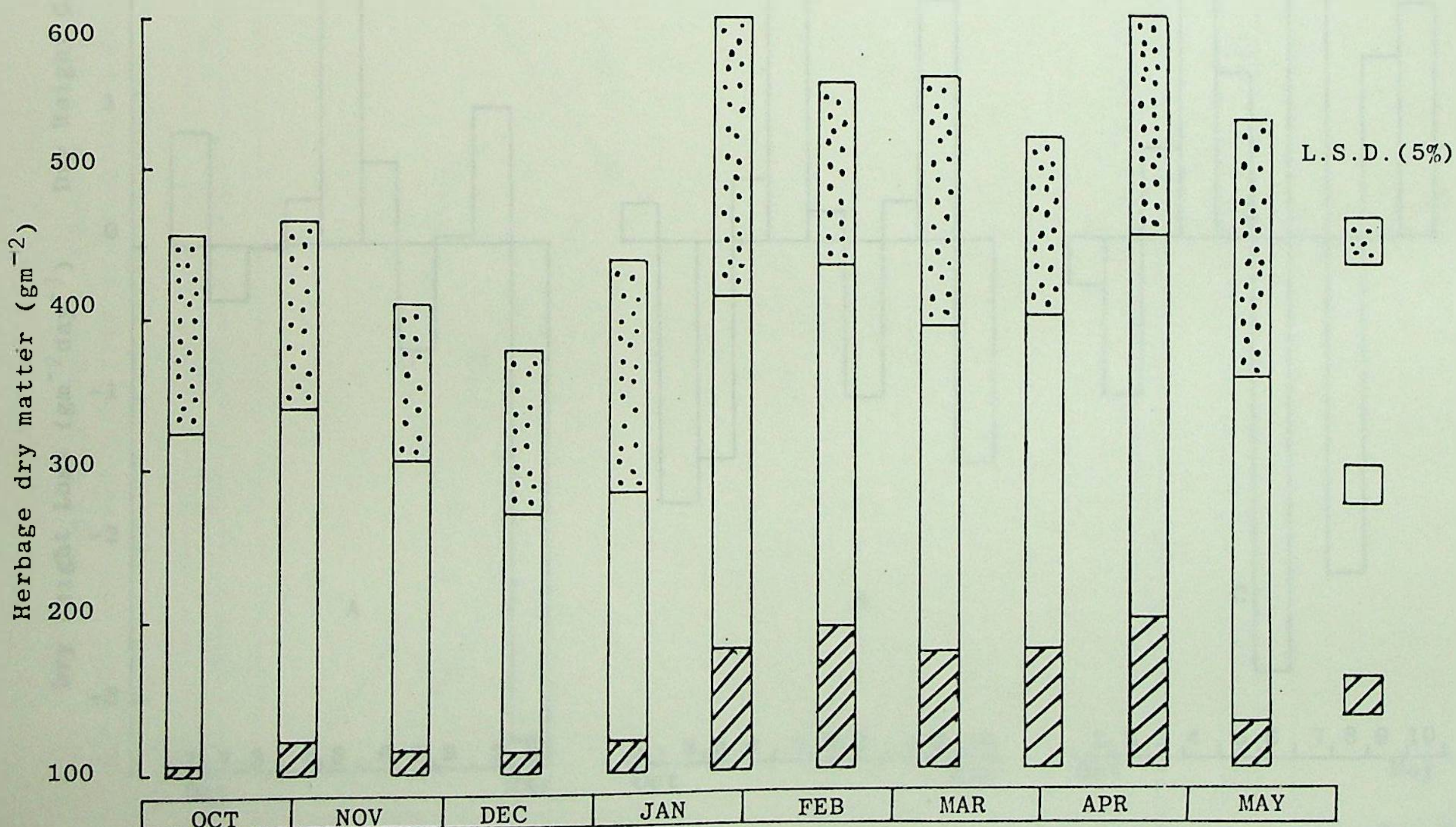


Fig 2 Seasonal change in the total and component standing herbage in a *Cortaderia* grassland. *Cortaderia* fractions Photosynthetic ▨ non-photosynthetic □ herb fraction ⛆

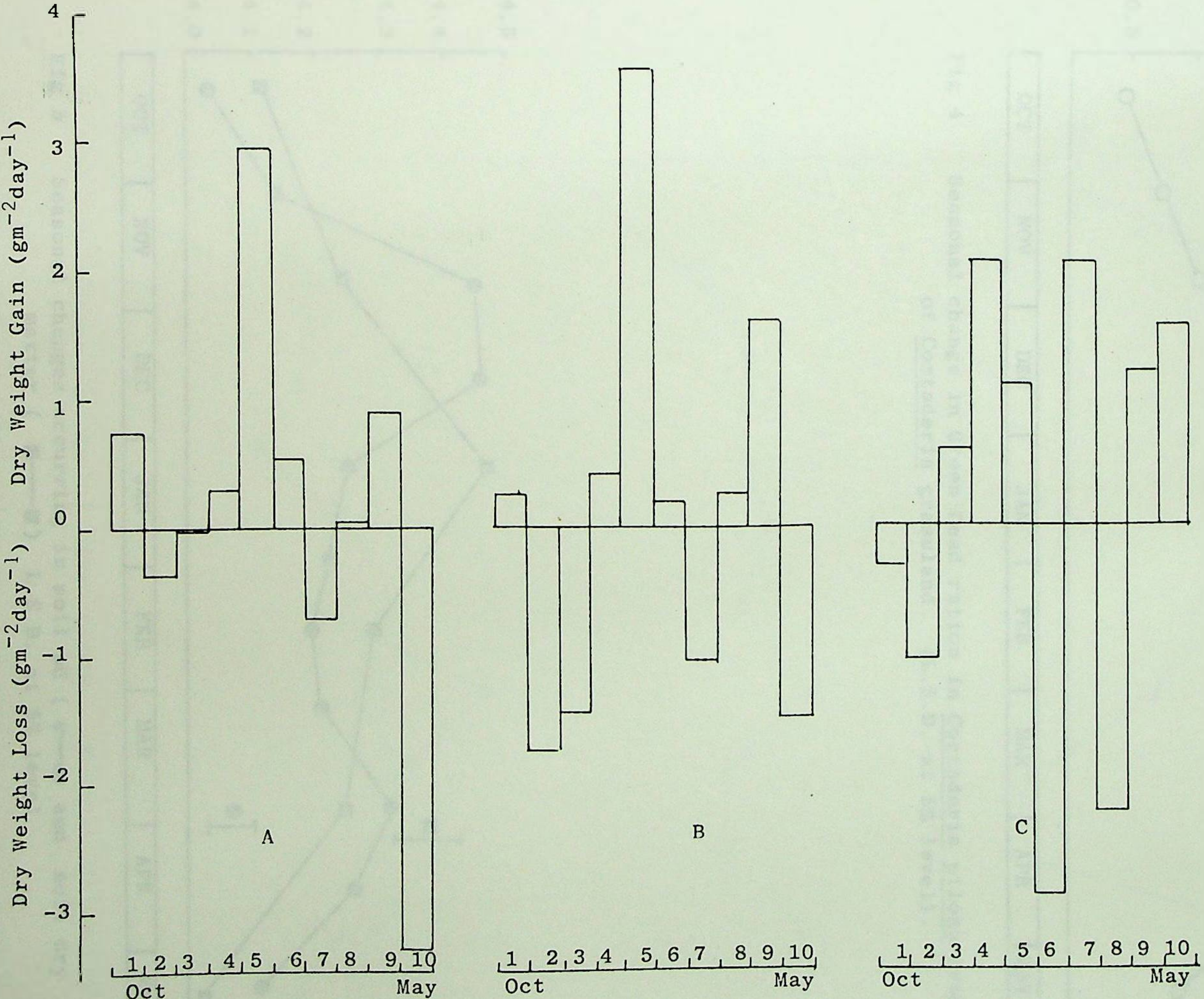


Fig 3 Seasonal changes in dry weight production of the principal components of a Cortaderia pilosa grassland. A. Photosynthetic Cortaderia fraction; B. Non-photosynthetic Cortaderia fraction; C. Herb fraction. Growing periods as detailed in text.

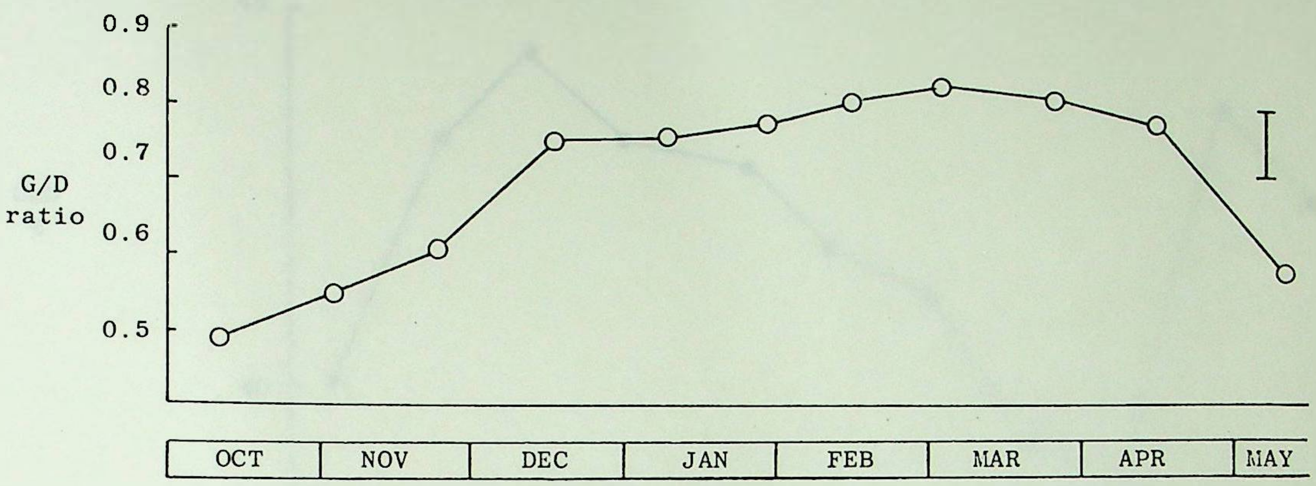


Fig 4 Seasonal change in Green:Dead ration in Cortaderia pilosa fraction of Cortaderia grassland. (L.S.D. at 5% level).

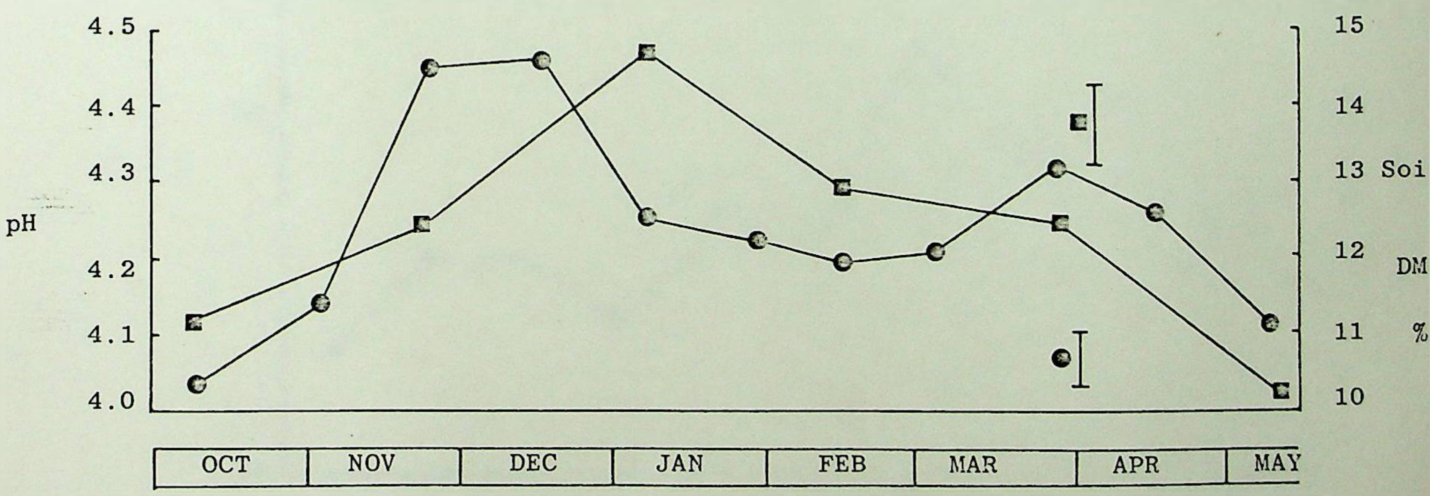


Fig 5 Seasonal changes occurring in soil pH (●—●) and soil dry matter (■—■) L.S.D. at 5% level

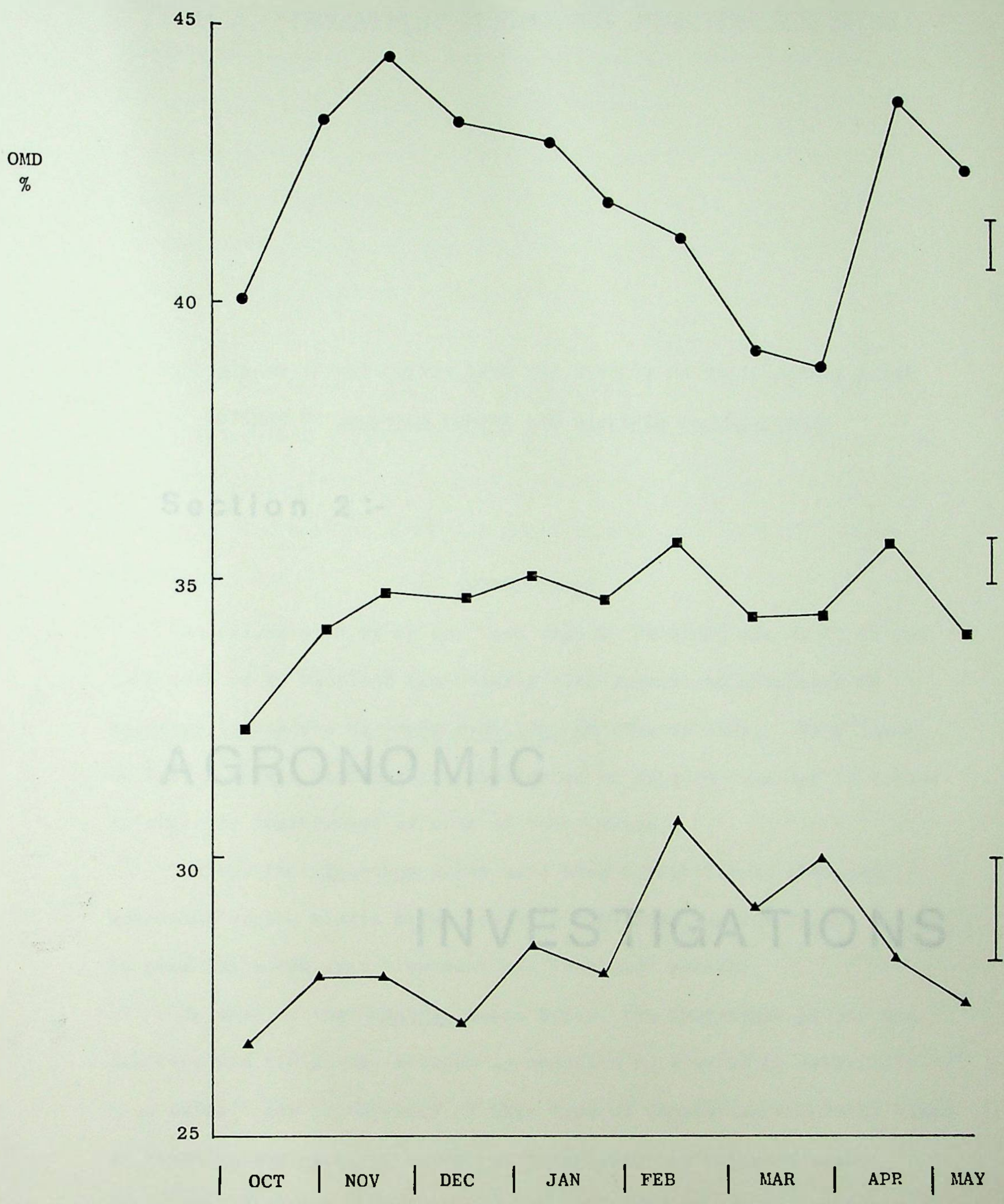


Fig 6 Organic matter digestibility (OMD %) of Cortaderia components (Live matter ●—●); Dead matter ▲—▲) and of Total above ground vegetation (■—■). The vertical bars represent standard errors of the differences between means.

Section 2 :-

AGRONOMIC INVESTIGATIONS

PART A. IMPROVEMENT STUDIES NOT INVOLVING RESEEDING

PRELIMINARY INVESTIGATION INTO THE EFFECTS OF FLAIL MOWING DENSE STANDS OF Empetrum rubrum AND Blechnum magellanicum

INTRODUCTION

An estimated 2.9% of the land area E. Falkland and 23.4% of the land area of W. Falkland are covered with vegetation dominated by Empetrum rubrum and Blechnum magellanicum (Davies 1939). Many farms on West Falkland have considerable areas of Empetrum and may be forced to consider improvement of some of these areas.

In the past Empetrum areas have been either burnt, ploughed, rotavated or the plants broken up with home made angular frame 'rollers'. In some instances this treatment has preceded seeding.

On some of the Empetrum heath types, the individual plants are distinct and the ground between is occupied by a sward of relatively high value. Any improvement of this type of vegetation should be aimed at reducing the Empetrum cover yet conserving the adjacent sward. Davies et al (1971) recommend that the Empetrum be checked by mechanical means, the flail mower giving more reliable results than roller breaking of plants. Heavy discing has been carried out at Douglas Station (Reid 1967) with reported stimulation of the growth of the finer grasses. It is generally considered that further treatment of these areas in the form of reseeding is not necessary in view of the quality of the herbage between the Empetrum shrubs and the favourable microclimate created by the presence of the shrubs.

Improvement of areas of dense Empetrum cover necessitates the removal of a large proportion of the plants followed by consolidation and reseeding. Davies (1939) and Davies et al (1971) stress the danger in burning such areas and the use of mechanical means is advocated. Trash removal is of critical importance. Davies et al have suggested that the flail mower reduces the Empetrum to a fine dust which subsequently blows away. It is thought, however, that the reseeding of areas of high Empetrum cover would be expensive and, in view of the difficulties encountered in establishment and consolidation, would merit further experimentation.

Observations on heather (Milne and Grant 1978) have shown that sheep eat a smaller part of new season's shoot in the summer than the winter and in late summer will select previously grazed shoots which have regrown in preference to those shoots with flowers on them. It has been observed that sheep will eat Empetrum shoots on some occasions and in some localities and one pathway of improvement may be to make fresh young growth more attractive and available to the sheep.

Hence, one aim of the management of Empetrum, if it responds in the same fashion as heather, is to achieve the maximum possible area in the most productive growth phase. The vegetative regeneration of heather has been found to be more vigorous after cutting than burning (Gimingham 1975). It is reported that the digestibility of heather declines from around 60% in mid summer after flower initiation to 40% by late winter (Milne and Grant 1978).

The technique of flail mowing has been found to be of value in the improvement of rough grazing in Britain (Chippindale and Davies 1962). In view of the information presented above it was thought that flail mowing of Empetrum would -

(a) in areas where the shrubs were spaced, encourage the growth of better herbage species and produce palatable nutritious regrowth of the Empetrum

(b) in areas of dense cover achieve some measure of improvement by encouraging fresh regrowth. The technique is relatively rapid and has a low labour demand.

The above proposals are based on the assumption that Empetrum will respond to defoliation in a similar manner to heather. In view of the similarity in growth habit of the two species this assumption does not seem unreasonable. The only published analysis of Empetrum (based on one sample) quotes a digestibility value of 38.1% in autumn (Davies et al, 1971). No information is available on the digestibility of fresh regrowth of the species.

Associated with Empetrum in certain areas is the dense upright fern Blechnum magellanicum. This species is estimated to cover 0.11% of the land area of East Falkland and 0.33% of West Falkland (Davies 1939) hence its importance is minimal. It may however be desirable to eradicate Blechnum where it is present in high density and in association with Empetrum on areas where improvement is being contemplated.

A preliminary trial using the flail mower on area of dense Blechnum and Empetrum was designed to assess the performance of the mower and assess the regrowth of both species under a range of mower settings.

MATERIALS

Site

South side of Whalebone bay, Cape Pembroke, East Falkland 51^{o} 41.35'S, 57^{o} 47.8'W (See Fig 1).

Machinery

Bomford 'Bandit', P.T.O. operated, horizontal bar type flail mower driven by a Ford 6600 two wheel drive tractor (75 hp).

Plots were unfenced and boundaries were delimited by wooden stakes.

Management

The Cape Pembroke area was continually grazed by horses, dry dairy cows and geese. There was no evident grazing pressure on the trial area, stock preferring the adjacent more attractive areas of coastal green and marram grass.

METHODS

The trial was carried out on 10th May 1977. The plot layout is shown in Fig 1 and treatments detailed in Table 1.

The plots were carefully studied in May 1978. A visual assessment was made of the effect of the treatments with some measurements taken of the length of shoot regrowth.

RESULTS

May 1978

10 cm cut (Plot 1) - There was considerably less Blechnum remaining on this area which was cut to 10 cm than on Plot 2 which was cut to 25/30 cm. The Blechnum had been killed out in several places and much of the heavy

trash caused by the initial flail mowing still remained. The Empetrum initially present on the site had been killed out. Where the Blechnum had recovered the regrowth of leaves was 8-14 cm.

25/30 cm cut (Plot 2) - The Blechnum on this site which was subject to mowing at 25/30 cm had recovered considerably and regrown shoots were approximately 18-30 cm long.

With the high mowing height much of the initially present Empetrum, which was prostrate, was untouched and hence was still present on the site. There was no obvious increase in the Empetrum cover due to the reduction in Blechnum cover.

30 cm cut (Plot 3) - Recovery of the Empetrum after cutting to 30 cm was evident with shoot regrowth of approximately 6-8 cm.

15 cm cut (Plot 4) - Shoot regrowth of Empetrum was 3-4 cm after cutting to 15 cm.

5 cm cut (Plot 5) - At the low mowing height the Empetrum had not recovered and appeared to have been killed. An increase in the cover of Juncus scheuzerioides was observed but otherwise the site appeared barren.

5/10 cm cut (Plot 6) - Poor regrowth of Baccharis magellanica and Empetrum shoots to approximately 2 cm and of tussocks of Cortaderia to about 10 cm was the feature of this plot which was cut to 5/10 cm.

DISCUSSION

Empetrum appears to be killed out by low cutting with the flail mower. Against this, the complete pulverisation of the Empetrum can only be achieved by operating the machine at very high revolutions and low ground speed. Hence the operation is relatively slow and expensive. Following pulverisation the site is left with a deep layer of chopped up Empetrum trash. As an alternative to burning for Empetrum eradication, flail mowing need only be considered where the risk of peat burning and severe erosion is great.

High mowing of the Empetrum is an operation which can be carried out at high ground speed and hence a large area can be cut in a given time. The regrowth of the Empetrum shoots is greatest at the highest cutting height and if grazing sheep could utilise these young shoots then this treatment could be considered as a means of achieving a small amount of improvement and increased utilisation of Empetrum areas.

High cutting appeared to enhance the growth of Blechnum. Complete eradication of the Blechnum was not possible even at close cutting and, due to the dense nature of the tussocks, operation of the machine was more difficult than in Empetrum cover. It was concluded that areas of dense Blechnum cover were not amenable to improvement by flail mowing.

It is felt that the results of the present study indicate that further work on the use of the flail mower could be of benefit. The following topics are suggested:-

1 Trash removal and reseeding techniques following the killing out of Empetrum by low cutting.

2 Qualitative and quantitative measurements of regrowth of Empetrum following higher cutting (if it could be conclusively demonstrated that sheep will eat Empetrum shoots).

SUMMARY

Empetrum rubrum can be completely killed out using the flail mower set at a low cutting height. However this is expensive and further treatment of the area is necessary.

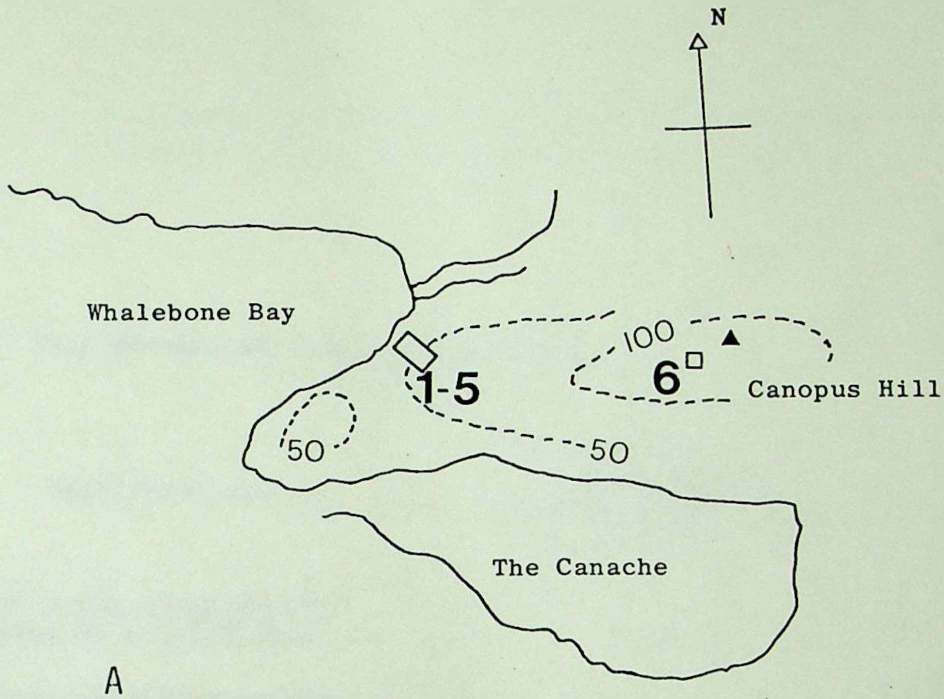
At high cutting height the Empetrum is encouraged to produce fresh new regrowth shoots.

Improvement of areas of high Blechnum magellanicum cover with the flail mower is not considered to be practical.

Further work in this field should concentrate on reseeding following Empetrum removal and an assessment of the quantity and quality of Empetrum regrowth.

ACKNOWLEDGEMENTS

The loan of a tractor by the Falkland Islands Government is gratefully acknowledged.



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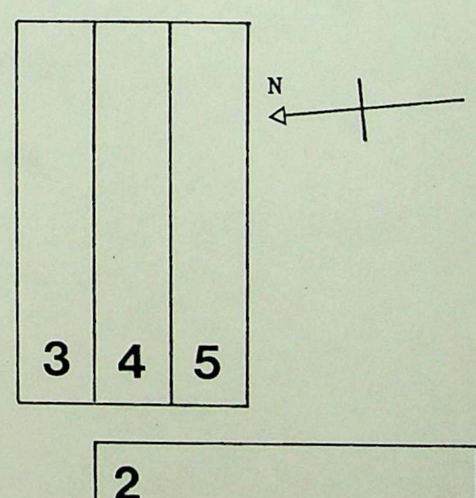

B

Fig. 1 A. Position of plots 1-5 and plot 6, flail mowing investigation.
B. Detail of layout of plots 1-5. Altitudes in feet above mean sea level.

Table 1 Plot details of flail mowing trial

Plot No.	Vegetation cover	Mower Height setting (approximate)
1	Blechnum magellanicum with Empetrum on rough ground	10 cm
2	Blechnum magellanicum with Empetrum on rough ground	25 - 30 cm
3	Dense uniform cover of Empetrum on flat ground	30 cm
4	Dense uniform cover of Empetrum on flat ground	15 cm
5	Dense uniform cover of Empetrum on flat ground	5 cm
6	Sparse cover of Empetrum with Baccharis magellanica and Cortaderia pilosa	5 - 10 cm

2A

d. A PRELIMINARY INVESTIGATION INTO THE REGROWTH OF Cortaderia DOMINANT VEGETATION FOLLOWING BURNING

INTRODUCTION

The use of fire as a tool in upland grassland and heath land management is a widespread practice, (Gimingham 1975). In Britain heather is frequently burned either as a precursor to reseeding or to create conditions required for uniform regeneration leading to even-aged stands, having high productivity, of edible new shoots (Milne and Grant, 1978).

Burning of both Empetrum rubrum and Cortaderia pilosa has been widely practised on some farms in the Falkland Islands for a long time (Davies 1939). Empetrum areas often overlie dry peat and the high risks involved in burning have been clearly outlined by Davies (1939), Davies et al. (1971) and many local farmers. The burning of areas of Cortaderia dominant vegetation (usually overlying wet peat) incurs fewer risks if carried out correctly. Current policy among farms concerning this issue varies considerably, some managers arguing that the detrimental effect on more nutritous graminaceous species (found interspersed within the Cortaderia) outweighs the benefit obtained by the reduction in the large fund of standing dead matter, the principal advantage put forward by the protagonists of burning.

In the past a large amount of the burning carried out has had little beneficial effect on the overall productivity of the native pasture. This may be due to the misconception that burning per se leads to a direct increase in animal production whereas it is widely known that burning must be carried out in association with attempts to increase utilization if burning of Cortaderia is to be used as a positive management tool (Eadie J unpublished).

It has been demonstrated (Section 1 Bb, 1 Bd, 1 Be) that Cortaderia grassland is characterised by a high fund of standing dead vegetation. This tends to considerably dilute the quality of feed available and lead to severe under-utilization of large areas of native grassland. Increases in animal production on this type of vegetation depend on increased pasture utilization and amended partition of grazing pressure on areas of varying quality to coincide with the sheep's annual cycle of energy demand (Eadie 1970). It is envisaged that as a precursor to this programme of improvement, the standing dead component of the Cortaderia vegetation must be removed.

Davies et al (1971) have suggested the use of flail mowing as a means of reducing the standing dead content of the herbage and the performance capability of this machine under Falkland Islands conditions had been adequately demonstrated (eg this report Section 2Aa). The use of the flail mower may have application in confined or high risk situations where defoliation must be controlled. However, it is difficult to envisage it competing successfully on a widespread scale with as inexpensive a management practice as burning.

Hence, an investigation into the response of Cortaderia to defoliation by burning and the subsequent benefits obtained by controlled grazing and increased utilization is of particular interest. The results presented here must be regarded mainly as a precursor to a more detailed investigation into the response of Cortaderia to burning.

MATERIALS AND METHODS

The site chosen (Orqueta Park, Goose Green, East Falkland) had been unevenly burned the previous season (October 1975) and the sampling was carried out in February 1977. The vegetation cover was tussock-forming Cortaderia with Blechnum penna-marina and Baccharis magellanica and the area had been almost continually grazed since burning.

The uneven nature of the burn enabled almost adjacent plants to be sampled from both burned and non-burned areas, hence minimising differences attributable to soil type. Ten random Cortaderia tussocks were removed from each area. The plants were harvested at ground level, tightly bound to preserve their shape, cut into 2 cm long sections and each section sorted into photosynthetic (P/s) and non-photosynthetic (non-P/s) matter and oven dried.

Six randomly placed 150 x 25 cm quadrats were cut from both the burned and non-burned areas. Sub samples of these were separated into (1) P/s graminaceous ('Green'), (2) non-P/s graminaceous ('Dead') and (3) remaining sward components ('Herb') fractions. These were oven dried and weighed.

RESULTS

1. The detailed partitioning of P/s and non-P/s matter in burned and non-burned Cortaderia plants (mean of 10 samples) calculated on a dry weight basis and expressed as percentage distribution of each component is illustrated in Fig 1. It can be seen that in the non-burned plants the distribution of both P/s and non-P/s matter was similar in pattern and quantity.
   In the burned plants above the bottom 4 cm there was a greater percentage of P/s than non-P/s matter throughout the plant.

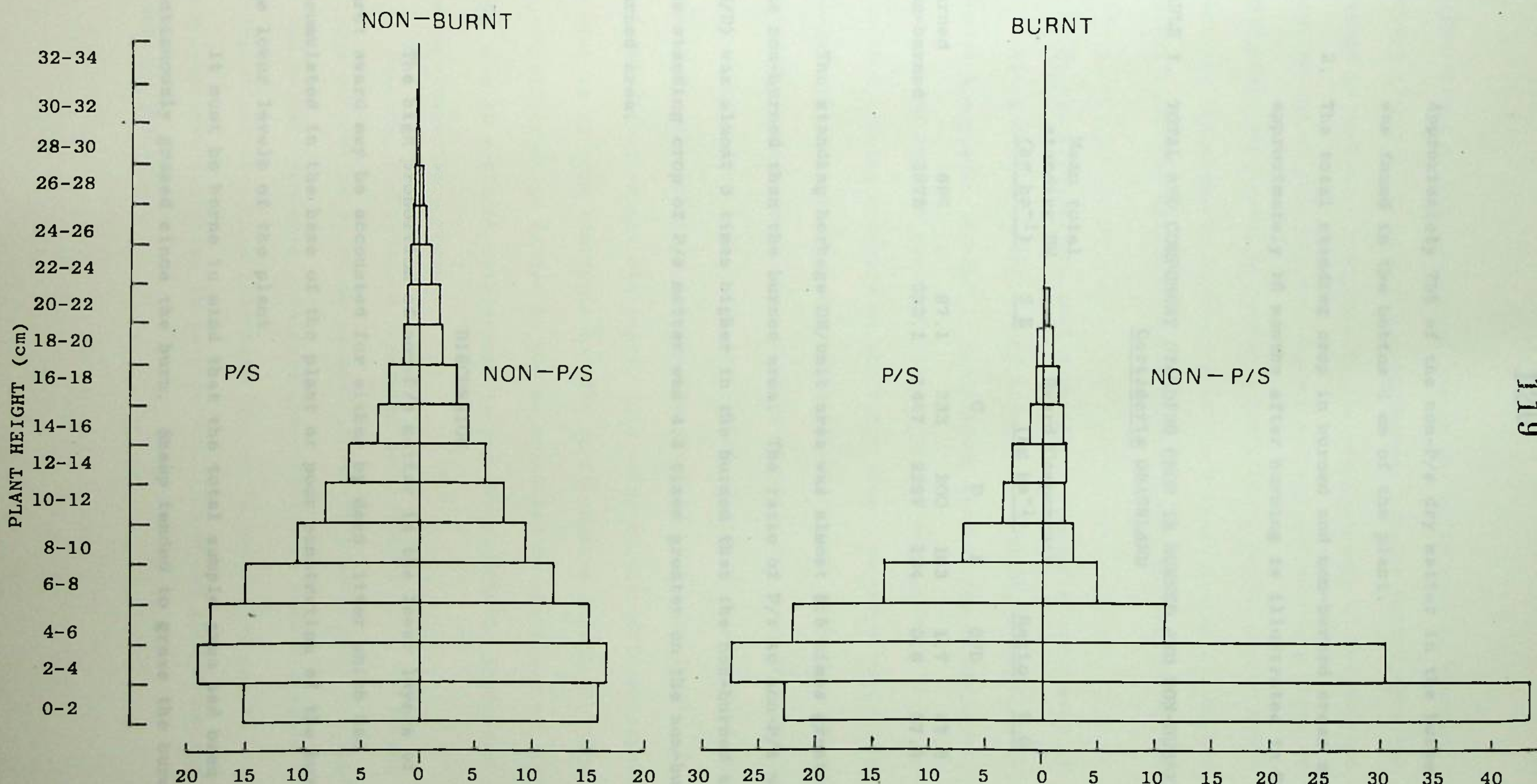

Fig. 1 Percentage distribution (by weight) of photosynthetic (P/S) and non-photosynthetic (Non-P/S) matter in burnt and non burnt <u>Cortaderia</u> plants. Burning occurred approximately 18 months previously. Means of 10 plants.

Approximately 75% of the non-P/s dry matter in the burned plants was found in the bottom 4 cm of the plant.

2. The total standing crop in burned and non-burned areas sampled approximately 16 months after burning is illustrated in Table 1.

TABLE I. TOTAL AND COMPONENT STANDING CROP IN BURNED AND NON-BURNED *Cortaderia* GRASSLAND

	Mean total standing DM (kg ha^{-1})	S E	Sward Components (kg ha^{-1})			Ratio	% G
			G	D	H	G/D	
Burned	696	97.1	333	200	163	1.7	47.8
Non-burned	3878	322.1	1447	2297	134	0.6	37.3

The standing herbage DM/unit area was almost 5.5 times greater in the non-burned than the burned area. The ratio of P/s to non-P/s matter (G/D) was almost 3 times higher in the burned than the non-burned area and the standing crop of P/s matter was 4.3 times greater on the non-burned than burned area.

DISCUSSION

The high proportion of non-P/s matter in the lower layers of the burnt sward may be accounted for either by dead litter which had accumulated in the base of the plant or poor penetration of the burn to the lower levels of the plant.

It must be borne in mind that the total sample area had been almost continuously grazed since the burn. Sheep tended to graze the burned area in preference to the non-burned, hence the difference in standing crop of herbage (Table 1) is probably exaggerated. On the burned area the material present is much more available to the sheep because of the absence of a large amount of standing dead matter masking the standing green matter. The sheep will have tended to remove a significant amount of the green matter, hence the low measured difference in the % Green matter in the two treatments. The P/s : non-P/s ration reflects the increased utilization on the burnt area.

It can be concluded that burning has removed a large part of the fund of standing dead material - many fragments of which have fallen into the base of the plant. Almost 1½ years after burning the quantity of standing green matter has not recovered to the pre-burning level. This is due to increased grazing pressure on the burnt area. In the situation where burning *per se* is used as a management improvement technique and where *Cortaderia* commences to die back from the leaf tip soon after regrowth it would be of value to discover the period of time elapsed before the standing green fund of vegetation reaches its original, pre-burn level. It may be that this level is not attained. This being so, it could be argued that burning is of some immediate benefit as it enables relatively high digestibility green matter to become available to the sheep but in the long term it would be detrimental to the photosynthetic productivity of the vegetation as a whole.

However, the evidence presented demonstrated that, following burning, a large proportion of standing-dead matter is removed from the upper layers of the canopy, and more palatable green matter is made available. It is of importance that this immediate benefit is not wasted and is translated into long-term increases in pasture utilization and production and hence animal production.

SUMMARY

The background to burning in the Falkland Islands is presented and its potential as a management improvement technique discussed. It was demonstrated that a large part of the fund of standing dead material in a Cortaderia sward could be removed. In the burned areas the ratio of P/s to non-P/s matter was higher than in the non-burned area especially in the upper layers of the sward canopy where sheep are most likely to graze.

The increased grazing pressure on the burned plants exaggerated the difference in standing herbage yield in the two areas.

Burning per se as a management tool does not produce long term changes in the sward, but considered with improved utilization brought about by maintaining the Cortaderia in a condition where the sward contains a high level of available green matter, animal production could be increased.

PART B. IMPROVEMENT STUDIES INVOLVING THE USE OF RESEEDS

A. THE USE OF DIRECT DRILLING AS A PASTURE IMPROVEMENT TECHNIQUE

INTRODUCTION

The concept of minimal cultivation by drilling seed and fertiliser directly into pre-formed slits has received considerable attention and support. The relevant advantages quoted for this technique are:-

1. Insignificant depression in yield
2. The conservation of soil moisture.
3. The prevention of erosion where wind blown cultivated topsoil is a problem.
4. A beneficial effect on soil structure where the open matrix built up by interwoven roots is conserved and compaction is avoided.
5. A reduced energy input. Direct drilling:- 12 - 30 HP ha^{-1}. Conventional cultivations:- 75 - 135 HP ha^{-1} (Finney 1974).
6. A reduced labour requirement.

Conventional cultivations (Nix 1978)

Rotary cultivations	1.3 - 1.8 ha day^{-1}
Seeding following cultivation	6.4 - 9.5 ha day^{-1}
Fertiliser distribution	11.3 - 17.0 ha day^{-1}

i.e., One can take 71 - 101 days to cultivate, sow and fertilise

100 ha.

In relation to the Falkland Islands the system may have several disadvantages:-

1. The relatively wide drill spacing (18 cm) couples with slow plant growth may contribute to a delay in establishing adequate ground cover. Fertiliser placement may further discourage this spread of sown plants from the rows.
2. The ability of sown species to compete with the native vegetation is still not fully investigated.
3. The machinery involved must be of robust manufacture and require a high powered tractor for operation.
4. If herbicides are used to kill the native sward, the accumulation of trash and toxic chemical residues may present problems.
5. Introduced plants may be more susceptible to insect pest attack (c.f. frit fly larva in UK).
6. The acid conditions found in the upper vegetation mat may be detrimental.
7. The direct or indirect harmful effect by one plant on another through the production of chemical compounds that escape into the environment (allelopathy) is still not documented from the Falklands.

It was envisaged that in situations where topography was not limiting and the indigenous vegetation was a uniform cover of low tussocks of Cortaderia overlying peat with not severely impeded drainage direct drilling might significantly improve the quality of the herbage. This improved area could then be utilised in conjunction with a more extensive area of lower quality herbage in an integrated grazing management programme.

Alternatively, direct drilling of leguminous species into already established reseeded pasture may be a means of establishing a legume in a system where rate of nitrogen mineralization is higher than in the indigenous vegetation.

Previous reseeding work in the Falklands has been carried out when the labour demand imposed by the annual sheep production cycle was lowest. The speed of operation and low labour requirement of the operation of the direct drill would enable farms to carry out land improvement when the likelihood of successful establishment was greatest.

The use of a Bettinson 3D direct drill was available to the Unit for experimentation. A preliminarly trial was carried out on improved pasture on Stanley Common to gain experience with the operation of the machine and to investigate the performance of sown species under a range of fertiliser applications. Subsequently a more extensive trial was carried out on native Cortaderia pasture in Lafonia.

1. A preliminary trial on direct drilling seeds and fertilisers into improved pasture.

SITE

Location

Short's Paddock, Stanley Common - to SW of town 57°51.59'W; 51°41.43'S.

Geology

Port Stanley beds, Devono-Carboniferous group (Greenway 1972).

Topography

Level site exposed to the South and approximately 25m above mean sea level.

Sward composition

Poa pratensis, *Holcus lanatus*, *Agrostis tenuis*, *Festuca rubra*, *Gunnera magellanica* and *Trifolium repens*.

MATERIALS

Drill

Bettinson 3D Direct drill with 15 rows at 18 cm spacings.

Tractor

A Ford 6600 rear wheel drive tractor was used to pull the drill.

Fencing

The drilled area was fenced from cattle using two strands of electrified 16 gauge steel wire stretched between wooden posts at 10m spacings.

Fertiliser type

A compound grassland fertiliser, composition 20N; 15P; 10K, was used.

Seeds mixture (all plots)

Species (cultivar)	Quantity (kg ha^{-1})
Cocksfoot (S143)	5
(S37)	5
Red fescue ('Novorubra')	4
Smooth stalked meadow grass. (Dutch origin)	4
Timothy (S48)	1.5
Tall Fescue (S170)	8
Perennial ryegrass (S23)	6
White clover (S100)	2
Birdsfoot trefoil (4701)	0.5
	36.0 kg ha^{-1}

METHODS

Treatments

The plots were drilled with fertiliser at the following rates:- 0; 125; 250; 375 kg ha^{-1} and the seeds mixture detailed above.

Drilling date

11th November 1976.

Plot layout

Due to the absence of a functional hydraulic lift system on the tractor it was decided to drill the area in a series of concentric circles. The plot layout was as follows (from outer to inner circles).

Treatments 1. 250 2. 125 3. 375 4. 0 kg ha^{-1} 5. Control (no seeds or fertilisers)

The area of each plot was approximately 0.8 ha. There was no replication of plots.

Sampling

Four quadrats (each 150 x 25 cm) were cut from random positions in each plot on 21/2/77 and the total drilled area opened up to allow access by grazing cattle.

The herbage samples were visually inspected for presence of sown species, fan oven dried at 90°C for 48 hrs and weighed.

Observations

Ground penetration by the drill discs seemed to be satisfactory and once the drawbar position was altered (hence altering the relative positions of the front and rear discs) the seed and fertilisers were correctly placed in the slits. Where the drill passed over local ground depressions penetration was poor and seed and fertiliser were deposited on the surface of the ground.

The responses of the existing sward to the fertiliser was rapid and after a few weeks the whole of the experimental area was noticeably greener than the rest of the paddock.

Germination of the sown seeds was slow, taking 3 - 4 weeks. Seedlings of all sown species were seen and a high percentage of clover seed appeared to have germinated. Competition from the existing sward was observed to be severe.

Following sampling in February 1977 the area was grazed until May 1977 and was rested over the winter. Grazing recommenced in October 1977 (spring) and in January 1978 a visual assessment of the site was carried out. There was no observed difference between or within treatments but the drilled area was subjected to much heavier grazing than the remainder of the paddock as the distribution of dung pats revealed.

The presence of the sown species was still limited to the drill rows and the plants were small. Although there were Trifolium and Lotus plants present in large numbers they were very small with leaflet lengths of 2 - 5 mm.

The drilled rows did not appear to have been selectively grazed.

RESULTS

The dry matter production per treatment estimates are presented in Table 1. There is a response to fertiliser, an application of 375 kg ha^{-1} giving a significantly higher DM yield than the other treatments. All the treatment plots were significantly different from the control. The introduction of the seeds alone at the 0 fertiliser level resulted in a much heavier DM yield than control though it is likely that some fertiliser was accidently applied to this treatment (see discussion).

DISCUSSION

Observations

The slow germination of the sown seeds could be attributed to the cold damp conditions which prevailed for six weeks after sowing. The observed competition from the existing sward could cause severe problems where potentially productive pasture is drilled. It may prove necessary to check the existing vegetation in some way prior to drilling to ensure successful establishment of sown species. This is of importance in considering the establishment of a legume where the light-sensitive seedlings may not compete successfully with the adjacent native sward which will be responding to the drilled fertiliser.

Suggested pre-drilling treatments could be 1. severe defoliation by heavy grazing 2. a partial check to growth by light spraying with herbicides 3. careful burning.

If the botanical composition of the existing sward consists of species of high potential and quality it may be of more advantage not to attempt to introduce new species as broadcast distribution of fertiliser may achieve a better result than direct drilling.

Production data

The high yeild observed when no fertiliser was applied could be explained by the observation that even with the cambox setting on the drill at zero a small trickle of fertiliser appeared to be coming through the rollers and into the slits. Hence the treatment listed at zero cannot be regarded as a true no-fertilizer control and the apparent wide difference between the overall control (2823 kg ha^{-1}) and the no-fertiliser control (4115 kg ha^{-1}) is not real.

The period of time elapsed between seeding and cutting was 100 days. Hence, with an application of 125 kg ha^{-1} of 20:15:10 fertiliser an average daily production of 43.5 kg DM ha^{-1} was realised. This represented an increased over control (ie due to the fertiliser and seeds alone) of 15.2 kg DM ha^{-1} day^{-1}.

The economic benefit accruing from this increased herbage production (in terms of milk, meat or wool produced) will depend on the subsequent utilisation and management of the sward.

FUTURE MANAGEMENT

It is suggested that attempts be made to assess the establishment success of the sown species at a later date and to estimate their contribution to the sward.

SUMMARY

The Bettinson drill was used successfully to renovate an old pasture by drilling seed and fertiliser.

Competition between the sown species and the existing sward was severe and to the detriment of the former.

There was a significant response to an application of 125 kg ha^{-1} fertiliser and seed over no fertiliser or seed - a mean daily increase of 43.5 DM ha^{-1} being realised. Higher application of fertiliser did not produce a significant increase in dry matter production.

TABLE 1

Dry matter production (kg ha^{-1}) from a range of fertiliser treatments.

Treatments (kg ha^{-1}) fertiliser)	DM production (kg ha^{-1}) over period 11/11/76 - 21/2/77 (mean of 4 quadrats).
0 + no seeds	2823
0 + seeds	4116
125 + seeds	4345
250 + seeds	4587
375 + seeds	6061
LSD (5%)	1196

ANALYSIS

F value = 5.023 i.e. significant differences between treatment means (P = 0.05).

ACKNOWLEDGEMENTS

I would like to thank the Falkland Islands Government for the use of their tractor and Mr C Spall, who had tenure of the paddock, for considerable help and co-operation.

2. An assessment of the operation and effect of direct drilling native *Cortaderia pilosa* pasture using a range of seed and fertiliser treatments.

SITE

Location

Orqueta park, Goose Green, East Falkland (see Fig 1) 51°52'S 59°07'W. Area approx. 550 ha.

Geology

Lower permian, Lafonian sandstone (Greenway, 1972).

Topography

Gently undulating, bordering a salt water inlet.

Vegetation

Cortaderia dominant with uniform cover tending to form low tussocks interspersed with *Baccharis magellanica* and *Blechnum penna-marina*.

Present use

Set stocked with approximately 300 rams which are only removed during mating time.

MATERIALS

Machinery

The Bettinson 3D direct drill towed by a 'County' 87 hp four wheel drive tractor was used and seed bottles were fitted in the drill hopper.

Fertiliser

A compound grassland fertiliser analysis 20N:15P:10K was used.

Seed

Holcus lanatus (Yorkshire fog) New Zealand origin dressed seed. This was the only type of seed obtainable in the Islands for a trial of this size.

METHODS

The trial consisted of a series of adjacent strips drilled using five different fertiliser levels at two seed rates. The cambox was calibrated according to the manufacturer's instructions and these data are presented in Table 2.

In the previous trial difficulty was experienced in shutting off the fertiliser hopper completely. Hence, in this trial the control (zero) fertiliser treatment was achieved by drilling with the fertiliser hopper empty.

The % possible take actually achieved was measured in February 1978 by placing a metre stick across the rows at a number of random positions in each plot and recording the presence or absence of Holcus plants at each intersection of the drill channel and the stick. (See Fig 2 for details). A total of 510 records of presence or absence of Holcus plants (in the drills) per plot was obtained. The % possible take actually achieved was expressed as the % of successes in the total recorded.

$$\% \text{ possible take actually achieved} = \frac{\text{No of recorded presents} \times 100\%}{510}$$

A quantitative assessment of grazing selectivity on the drilled and non-drilled area was carried out in February 1978. A 30 cm square quadrat was randomly positioned 42 times inside and outside the drilled area. An estimate of Cortaderia cover (estimated on a 0 - 5 scale as a vertical projection of leaf area on the horizontal ground surface) inside the quadrat was made and the longest leaf was measured.

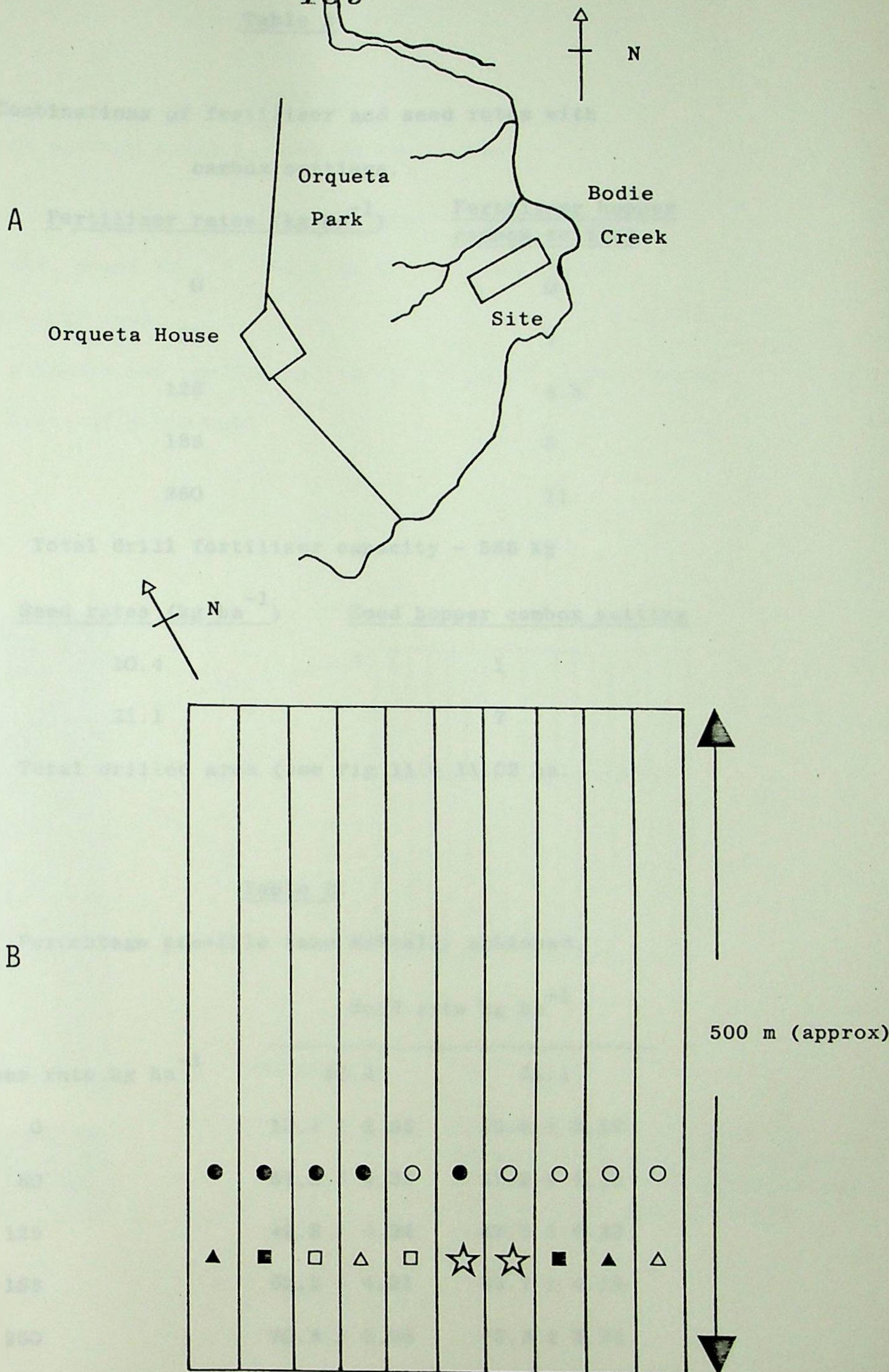

Fig. 1 Site plan (A) and layout (B) of direct drilling trial. Treatments:- Seeding rates S_1 (10.4 kg ha^{-1}) (●), S_2 (21.1 kg ha^{-1}) (○); Fertiliser rates 0 (☆); 80 (△); 125 (▲); 188 (□); 250 (■)kg ha^{-1}.

Table 2.

Combinations of fertiliser and seed rates with cambox settings.

Code	Fertiliser rates (kg ha^{-1})	Fertiliser hopper cambox setting
F0	0	0
F1	80	1
F2	125	4.5
F3	188	8
F4	250	11

Total drill fertiliser capacity - 588 kg

	Seed rates (kg ha^{-1})	Seed hopper cambox setting
S1	10.4	1
S2	21.1	7

Total drilled area (see Fig 1) = 11.02 ha.

Table 3.

Percentage possible take actually achieved.

	Seed rate kg ha^{-1}	
Fertiliser rate kg ha^{-1}	10.4	21.1
0	13.1 ± 2.93	15.9 ± 3.17
80	51.2 ± 4.33	47.2 ± 4.33
125	49.2 ± 4.34	52.5 ± 4.33
188	62.2 ± 4.21	65.7 ± 4.12
250	70.4 ± 3.96	75.3 ± 3.74

95% Confidence limits attached. Calculated as ± 1.96 x S.E. of possible take percent.

Table 4.

Mean maximum plant ht. per 30 cm quadrat

	Drilled Area	Undrilled Area
Mean max. plant ht. per quadrat (mm)	101 ± 21.6	260 ± 24.0

With attached 95% confidence limits d = 10.07 corresponding to a level of p = 0.0001

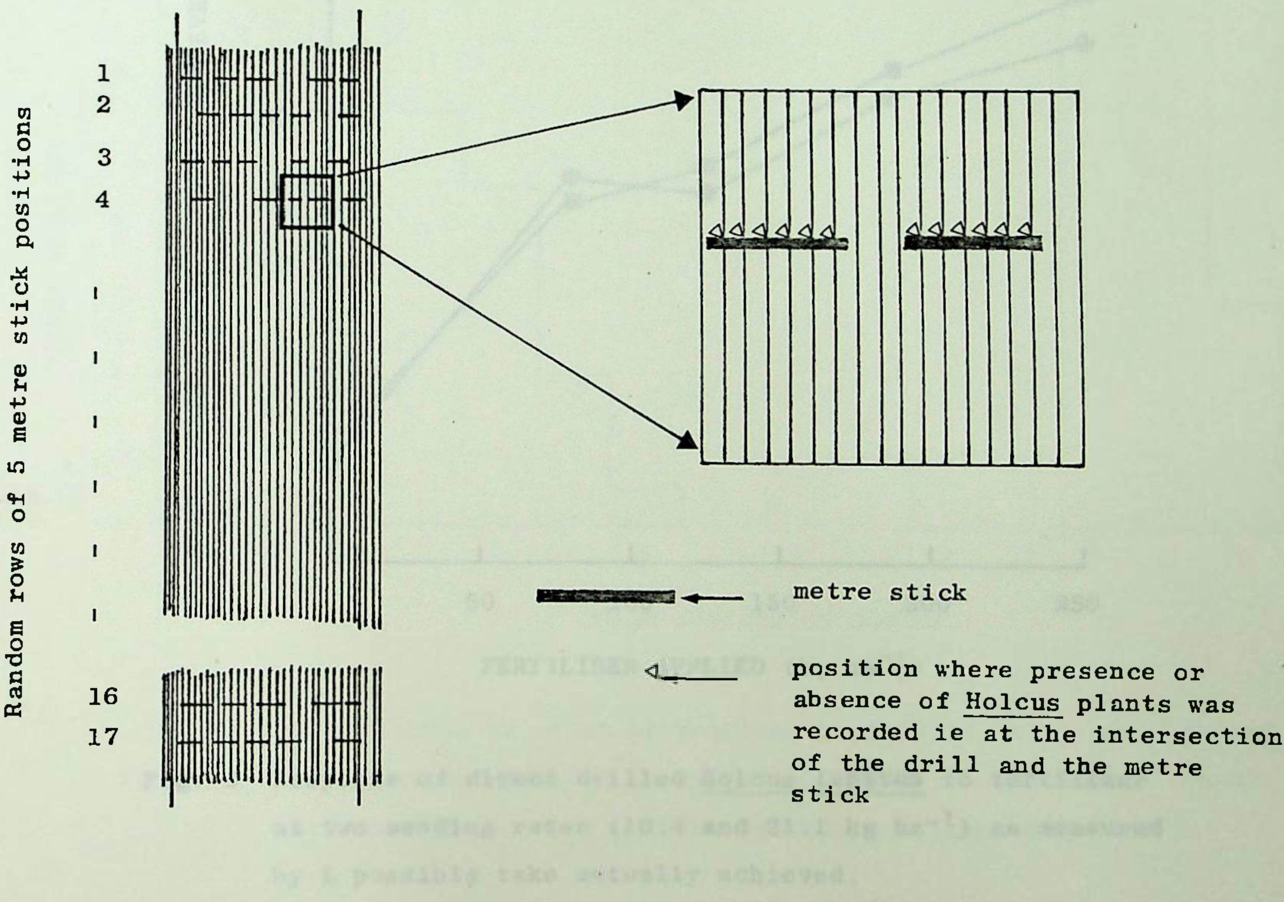

Fig 2 Plot sampling method

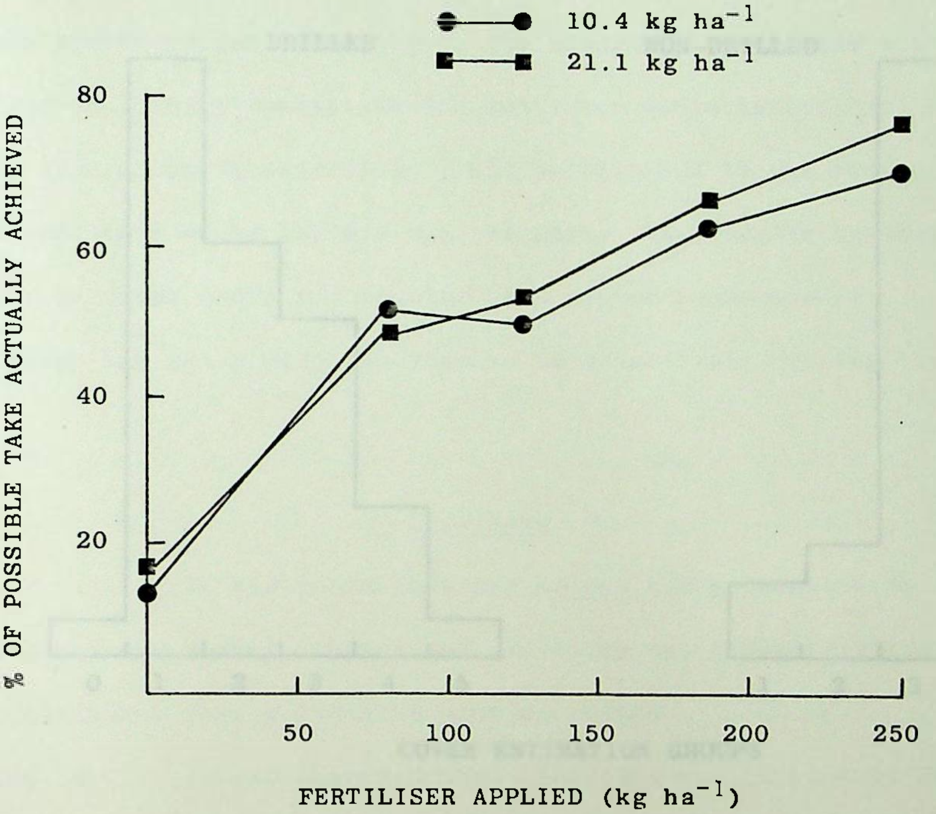

Fig. 3 Response of direct drilled Holcus lanatus to fertilizer at two seeding rates (10.4 and 21.1 kg ha^{-1}) as measured by % possible take actually achieved.

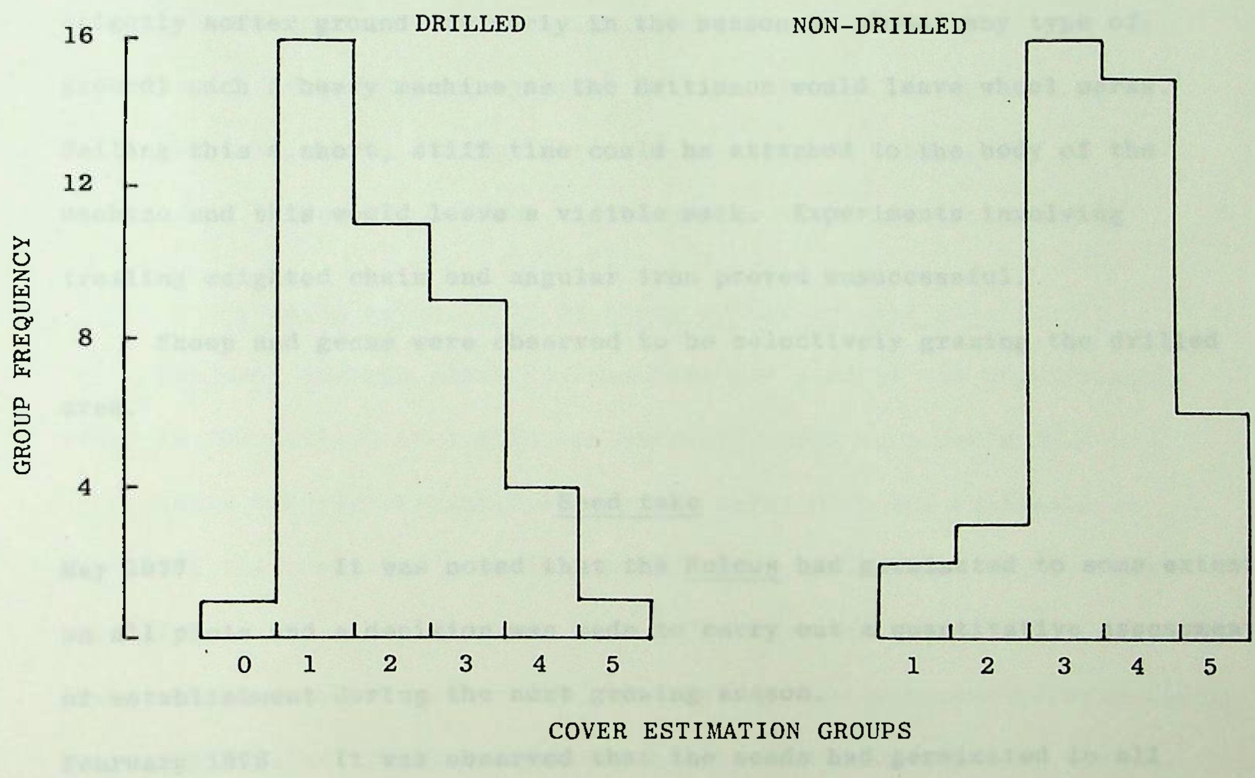

Fig. 4 Distribution of cover estimations in drilled (mean cover = 2.05 ± 0.36) and non-drilled (mean cover = 3.48 ± 0.15) areas. Cover estimated on a scale 0 (bare ground) - 5 (complete cover).

RESULTS

Operation speed

1. In the trial area - uniform Cortaderia cover: 2.1 - 2.6 ha hr^{-1}
2. In an area of dense tussock-forming Cortaderia: 1.3 ha hr^{-1}

Observations

A problem encountered was that the operator could not see where he had been and therefore could not match up with previous work. On slightly softer ground (or early in the season on almost any type of ground) such a heavy machine as the Bettinson would leave wheel marks. Failing this a short, stiff tine could be attached to the body of the machine and this would leave a visible mark. Experiments involving trailing weighted chain and angular iron proved unsuccessful.

Sheep and geese were observed to be selectively grazing the drilled area.

Seed take

May 1977. It was noted that the Holcus had germinated to some extent on all plots and a decision was made to carry out a quantitative assessment of establishment during the next growing season.

February 1978. It was observed that the seeds had germinated in all plots and plants were still confined to the original drills with the density of plants in the drill rows with treatment. As outlined in the methods section the % possible take actually achieved was calculated (see Table 3 Fig 2)

There was no significant increase in % possible take with increasing seed rate from 10.4 to 21.1 kg ha^{-1} at all fertiliser treatments.

Application of fertiliser produced a significant increase in % take, the response per unit application being greater in the range 0 to 80 kg ha^{-1} (Slope = 0.434 correlation coefficient = 0.99) than the range 80 to 250 kg ha^{-1} (Slope = 0.176 correlation coefficient = 0.97). The response at 80 kg ha^{-1} is highly significantly greater than that at zero: ($P = 0.001$) whereas the response at 250 kg ha^{-1} is only slightly significantly greater ($P = 0.05$) than that at 188 kg ha^{-1} as is the resopnse at 188 kg ha^{-1} over 125 kg/ha^{-1}. There was no significant difference between the responses at 80 and 125 kg ha^{-1}.

<u>Grazing selectivity of sheep on the drilled area</u>

The mean mazimum plant ht. recorded per quadrat was significantly lower in the drilled area than the undrilled area (see Table 4).

There was significantly less plant cover over the drilled area than over the undrilled area ($d = 6.174$ corr. to level of $P = 0.0001$) see fig 4.

These results support the observation that the sheep tended to selectively graze the drilled area in preference to the undrilled area.

DISCUSSION

The trial demonstrated that the Bettinson drill could be used satisfactorily in gently undulating <u>Cortaderia</u> grassland. The area of ground sown per unit time would have been considerably higher than where conventional ground preparation treatments had been used.

It is estimated that in a 7 hr working day, allowing 25% of time for filling machine and transport, 11.2 - 13.6 hectares could be drilled by one man. Hence, the sowing time for 100 ha would be 7.4 - 8.9 days. Using conventional methods the preparation and sowing of a similar area would take considerably longer depending on the range of cultivations used.

From the data presented on seed rate it is clear that there is no advantage in direct drilling <u>Holcus lanatus</u> at a seed rate greater than 10 kg ha^{-1}.

The rapid increase in the % if possible take with relatively low (up to 80 kg ha^{-1}) levels of fertiliser and the decrease in response to higher rates of fertiliser would indicate that some fertiliser should be applied at seeding. From the results of this trial it is recommended that not less than 100 kg ha^{-1} fertiliser be applied at seeding.

It is of interest to consider the broadcast application of a small dose of fertiliser after establishment to encourage the plants to spread into the inter-drill spaces. The use of grass species with a more spreading or rhizomatous habit would merit further study, however it could not be reasonably extrapolated that the response from the same rates of seeding and fertiliser would apply to species other than <u>Holcus</u>. It is known that <u>Holcus</u> will respond to low levels of fertilizer in a low fertility situation (Fleming 1965). Further work should be carried out on species of superior nutritional quality and growth characteristics than <u>Holcus lanatus</u>.

It has been clearly demonstrated that the drilled areas are more heavily grazed by sheep and geese than the undrilled areas. This is an important consideration in the planning of management system where increased utilisation of the indigenous herbage is sought.

In the direct drilled situation the sheep are effectively defoliating the senescent portion of the *Cortaderia* plants and encouraging green regrowth. This leads to increased utilization of these pastures and the intake of higher quality herbage, both of *Cortaderia* and the sown species. This defoliation would increase the rate of establishment of the sown species by reducing competition from the native vegetation.

It has been demonstrated (Floate 1971) that as a result of increased pasture utilization or greater return of organic materials as excreta there is more potentially available N and P released and this enhances plant uptake and yield of N and P. This increased utilization has been shown to lead to an improvement in upland soils and vegetation.

In view of the argument presented in section 1Bb of this report where it is postulated that herbage of sufficiently high quantity and quality may not be available at essential periods in the energy demand cycle of the ewe, the use of the direct drill may be of value in creating areas of improved pasture and increasing the utilization of indigenous vegetation. When grazing control is exercised this improved pasture can be utilized in conjunction with a large area of pasture of poorer quality and the whole system integrated into the cycle of energy demand of the breeding sheep.

SUMMARY

The Bettinson 3D drill can be used to direct drill seeds and fertilizer into native *Cortaderia* grassland.

The use of the direct drill enables large time savings over conventional seed bed preparations to be made.

A relatively low rate of seeding can be used, not more than 10 kg ha^{-1} being recommended for *Holcus lanatus*.

There is marked response to fertilizer in terms of the % possible take achieved, the response being greater in the 0 - 100 kg ha^{-1} range than in the 100 - 250 kg ha^{-1} range.

It is recommended that 100 kg ha^{-1} of 20:15:10 fertilizer be applied on drilling with a suggested further broadcast application on establishment to encourage spreading. This recommendation may vary with the species sown.

The drilled area was selectively grazed and this led to an increase in utilization of the Cortaderia.

The implication of the integration of this improved pasture in relation to a source of increased nutrition for the ewe at critical periods in the production cycle is discussed.

ACKNOWLEDGEMENTS

The Falkland Islands Company Ltd kindly allowed this trial to be carried out on their land and further assisted by providing a tractor and driver.

2.B.

b. THE RENOVATION OF REVERTING Holcus lanatus RESEEDS BY A COMBINATION OF FERTILISING AND OVERSOWING TREATMENTS

INTRODUCTION

Over the past 25 years most farms have made efforts of some sort or other to improve grassland. The practices of burning and mowing have been reviewed in other sections of this report. In addition, various methods of reseeding have been attempted. These have been reviewed in Davies et al (1971). Both sod-seeding and conventional cultivations have been carried out, the latter method proving the more successful and the one which has been most used.

However, the problems of pasture establishment and the selection of appropriate species remain unsolved for many sets of conditions and sites.

Many of these reseeds are characterised by very low dry matter production of poor quality herbage and a low plant population leaving a considerable percentage of bare ground. Reseeds in this condition are generally referred to as reverting, and suffer from a noticeable ingress of native vegetation.

Many of the problems of low production and reversion now encountered centre around the initial extensive use of Holcus lanatus. There can be no doubt that the initial reasoning behind the selection of this species for the Falklands was sound and the enthusiasm and expertise expended in its establishment in many situations (eg. on a large scale at Roy Cove, West Falkland) was very commendable.

The relatively inexpensive labour, high fertilizer costs and dry conditions would lead one to initially consider the selection of species such as Holcus lanatus. It is unfortunate that the quantity and quality of the seed used in the early work was suspect - had the improved strains of Holcus now developed (mainly in New Zealand) been available 25 years ago the present status of Holcus lanatus in the Islands might have been different.

However, it was felt that the tendency of Holcus lanatus to put much of its energy into seed production early in the season and its seeming inability to spread and form a dense sward in most situations was an undesirable characteristic in view of the modified grazing management programme being proposed by the Unit.

The problem under consideration is whether to attempt to improve the reverting reseeds or, if considering reseeding, to commence in a fresh situation. The first of these alternatives, renovation of reverting reseeds will be considered in this section (2Bb) the other being considered in the next (2Bc).

1. Fitzroy experiment

METHODS AND RESULTS

A simple experiment to measure the effect of Lime, phosphate and a compound (NPK) fertilizer was laid down in January 1977 on a reseeded area of Holcus at Cow Point, Fitzroy. This area had been reseeded in 1973 and ground cover in early 1977 was poor.

Levels of applied nutrients were as follows:-

NPK - 0 and 250 kg ha^{-1} representing 0 and 50 kg N;33 kg P: 42 kg K

Phosphorus - Po(0), P1 (125 kg ha^{-1}) P2 (250 kg ha^{-1}) triple super phosphate representing 0, 25 and 50 kg P ha^{-1}

Lime - 1.26 and 2.52 tonnes $hectare^{-1}$.

Table 1 Effects of seeds, lime and fertilizer on dry matter production of an established *Holcus* reseed (Fitzroy). DM production in kg ha^{-1}.

Compound fertiliser	Phosphate & lime treatments	May 1977	Jan 1978
	P_1 L_1	2443	3580
	P_1 L_2	3652	3911
	P_2 L_1	2062	3542
	P_2 L_2	3193	3736
NPK	P_0 L_0	2141	2597
	P_1 L_1	1197	1288
	P_1 L_2	644	911
	P_2 L_1	1018	1423
	P_2 L_2	1167	970
No NPK	P_0 L_0	998	1120

Table 2 Soil pH at (A) surface (B) 2.5 cm below surface, 5 months after lime application at levels L_0(0), L_1(1.26 tonnes ha^{-1}), L_2 (2.5 tonnes ha^{-1}).

	L_0*	L_1**	L_2**
A	4.66	5.42	5.47
s.e.	0.07	0.20	0.09
B	4.44	4.63	4.48
s.e.	0.03	0.10	0.03

(* = mean of 8 values, ** = means of 6 values)

Half the plots were oversown with a seeds mixture containing equal seed numbers of Poa pratensis (Dutch origin), Festuca rubra (Novorubra) F. arundinacea (S170), Lolium perenne (S23), Dactylis glomerata (S143) and Trifolium repens (wild white) at 22.4 kg ha^{-1}.

The experimental layout was of a split-plot design with most of the treatment plots being replicated. Plot size was 2 m x 2 m. The area had been heavily grazed previous to the setting up of the experiment and it could be assumed that the standing crop of vegetation was zero.

Quadrats (150 cm x 25 cm) were cut from the centres of the plots in June 1977 and January 1978 (5 months and 1 year after setting up the experiment) and soil cores for pH determinations were removed in June 1977. Soil pH was measured at the surface and a depth of 2.5 cm below the surface.

On examination of the cut samples it was seen that none of the sown species were present in June 1977 and the vegetation cut consisted wholly of Holcus lanatus. By January 1978 some Dactylis, Poa and Trifolium plants were seen, but Holcus represented a high proportion of the DM. The samples were oven dried (90°C for 48 hours) and weighed.

The effect of treatments on herbage yield (Table 1) and soil pH (Table 2) are presented.

L1 and L2 gave significant increases in pH over Lo, but L2 was not significantly different from L1 from pH measured at the surface. At 2.5 cm depth there was no significant difference between the means of treatments Lo, L1 and L2.

DISCUSSION

Overall it is apparent that Holcus lanatus responds to applied fertilizer as yields obtained were considerably higher than those obtained from grazing exclusion cages erected on an adjacent area (360 - 480 kg ha^{-1} $annum^{-1}$). The control plots in this experiment did, however, give a mean production value of 1000 kg ha^{-1}. This was considerably higher than the value obtained by the grazing exclusion cages and may be explained by fertiliser drift at sowing or leaching of nutrients from adjacent plots. Herbage production can be doubled or trebled by the application of seeds, NPK and Lime at 2.5 tonnes ha^{-1}. There was no apparent effect of phosphate on yield. The sown species were not contributing to yield after 5 months, however their contribution was significant ($P = 0.01$) after 12 months although this was not obviously apparent from sward observation.

The lack of response to Lime of soil pH at 2.5 cm depth is to be expected in view of the short time which had elapsed between application and sampling.

From the herbage production data for the oversown plots and the effect on soil pH it is possible to detect a direct response to lime although from the complete data presented this is not clear.

The presence of small Trifolium plants was encouraging and future observations on the status of these plants in the plots would be of value.

2. Darwin experiment

METHODS AND RESULTS

An experiment was designed which could be laid down on a number of sites by relatively inexperienced personnel. The experiment was laid down at Darwin, Chartres, Teal Inlet, Roy Cove and Port Stephens.

Layout:- Split plot design (one half oversown with seeds mixtures? with 2 replicates per treatment. Plots 2 m x 2 m.

Table 3 Effects of seeds, lime and fertilizers on DM production of an established Holcus reseed (Darwin). DM production kg ha^{-1}.

Treatment		oversown (s)	not oversown (ns)	all plots
	L0	3875	2950	3258
P0	L1	3298	4132	3715
	L2	3307	4011	3659
	L0	2658	3978	3318
P1	L1	4258	3834	4046
	L2	3803	3289	3546
	L0	3251	6692	4003
P2	L1	3739	4047	3893
	L2	3077	2153	2615

No fertilizer control = 2950 kg ha^{-1}.

Fertilizers: All treatments received 187 kg ha^{-1} of 20:10:10 (NPK) fertilizer with 10 kg ha^{-1} of a proprietry trace element mixture for plants.

Phorphorus: 3 levels (0; 25; 50 kg P ha^{-1}) applied as granular triple superphosphate.

Lime: 3 levels (0, 627 and 1254 kg ha^{-1}) applied as ground chalk.

Seed mixture: Equal proportions of seed by numbers of Poa pratensis (Dutch origin), Festuca rubra (Novorubra), F. arundinacea (S170), Lolium perenne (S23), Trifolium repens (Wild White), Lotus corniculatus.

The experiment was laid down near Fish Creek, Darwin in February 1977 and plots were cut in February 1978. Samples were dried and weighed. Results were only available from the experiment at Darwin and these are presented in Table 3. The experiment was not laid down at the other sites until the following season. The presence of introduced species was not detected in the plots, the sward being composed of a dense stand of Holcus lanatus. Results for sown and non-sown (S & NS) plots were amalgamated for each treatment (Table 3).

From Table 3 it was apparent that the effect of Phosphate was more pronounced (though probably not significantly) than lime. Lime does not appear to be affecting yield one year after application.

DISCUSSION

Holcus lanatus responds significantly to applied fertilizer in a situation where soil nutrient levels are probably low. It was thought that the vigorous response of Holcus was inhibiting the growth of the seedlings of sown species, the competition in the base of the sward being severe. A different result may have been obtained if the plots were grazed.

There were some observed differences between results from Darwin and Fitzroy. These can be explained by the nature of the sites - the Fitzroy reseed being on poorer drained soil of lower pH than the site at Darwin which was generally more productive. Hence the response to lime noted at Fitzroy and not at Darwin.

3. Response of reseeded hay fields to fertilizer

Fields sown with a range of species were used for hay production for the farm dairy at Darwin. Fertilizer is applied to these fields regularly and during the 1977 season the Dairyman agreed to leave some areas unfertilized and cut plots for DM yield data immediately prior to removing the hay crop. The results obtained from these are presented in Table 4.

DISCUSSION

It can be seen that there was a significant response to nitrogen by the *Holcus*. The yields on all the *Holcus* areas (even those where fertilizer was applied) were lower than those found in *Dactylis* and Festuca dominant swards. It must be borne in mind that these plots were cut at the end of December, approximately half way through the growing season. The yields of *Dactylis* (Cocksfoot) dominant swards at low levels of fertilizer application indicate that this species has

Table 4 Response of hayfields to nitrogen fertilizer. Treatment applied 28 - 30/10/77. Plots cut 29 - 30/12/77.

Species & sward composition			Fertilizer treatment (kg N ha^{-1})	Number of replicates	Mean DM (kg ha^{-1})	s.e.
Holcus lanatus (100%)			0	24	1238	127
			45	20	2890	256
			90	4	3946	381
Dactylis glomerata(%)	Holcus lanatus(%)					
75	25		0	4	4752	411
75	25		90	4	6253	387
85	15		0	4	4296	299
90	10		45	4	5906	512
95	5		45	4	6042	310
Festuca rubra(%)	Dactylis glomerata(%)	Holcus lanatus(%)				
60	35	5	45	4	4042	357
45	55	0	0	4	5034	416

considerable potential for high production under these conditions. The limitations of Holcus lanatus (Yorkshire fog) as a high yielding pasture species are indicated.

SUMMARY AND CONCLUSIONS (1-3)

Holcus lanatus will respond to applied fertilizer and lime (in certain situations). Oversowing of reverting Holcus reseeds is not successful and other techniques, such as direct drilling must be investigated if improved species are to be introduced. Improved species (such as Dactylis and Festuca) are capable of much higher production than Holcus under fertilized and unfertilized conditions. The indicated potential of Dactylis is encouraging especially when considered against the relatively low production of Holcus under similar conditions.

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2B

C THE EFFECTS OF APPLIED LIME AND PHOSPHATE ON SOILS AND RESEEDS

INTRODUCTION

In the Falklands the present system of year-round set stocking of pastures imposes limitations on production. Basically these limitations are poor nutrition and low pasture utilization, herbage intake being low in relation to production with a large proportion of standing dead matter diluting the quality of feed available. Improvement in sheep production depends on increasing pasture production and improving the efficiency of its utilization (Eadie, 1970). Fundamentally this improvement is realized by differentiating areas of 'good' and 'poor' pasture and integrating the grazing on these to ensure that the energy demands of the sheep are met at critical periods in the annual cycle.

In practice the distribution of natural vegetation in the Falkland Islands may not permit a high enough proportion of the better classes of pasture to be included in the areas delimited to provide the necessary nutritional boost. In this case land improvement involving inputs to the system must be considered. This investigation considered the response of a range of vegetation types to some of these inputs.

The low pH of peaty soils leading to low concentrations of available nutrients, poor decomposition, poor mineralisation and limited plant nutrient cycling (Floate, 1970) are the primary factors limiting herbage growth. There are few reported soil analyses from the Falkland Islands. From Davies (1939), King, Lang & Rains (1969) and Davies et al. (1971) pH values range from 3.9 to 4.7 and total-P levels on unimproved ground are low (0.9 - 7.0 μg/g) and K and Mg adequate (73 - 480 μg/g and 125 - 712 μg/g respectively).

Most marked improvement on natural hill pastures and peaty soils in the UK have been obtained by using lime and fertilizers with inorganic P being the most significant fertilizer input (Ogg & Robertson, 1934; Collins, 1961; McConaghy & McAllister, 1973). Davies, Edwards & Rowlands (1968) on Welsh upland pasture demonstrated changes in chemical composition but not botanical composition following lime and phosphate application. Significant responses in terms of increased yield to small quantities of lime and phosphate on indigenous pasture (Robertson & Nicholson, 1961) and on reseeded and established pasture (Reith & Robertson, 1971) have been demonstrated.

With the severe limitations imposed by the absence of a road system and the high cost of imported fertilizers it was thought that investigation into low levels of input would be most applicable to the Falklands.

The quality of the indigenous herbage is relatively low (Davies et al. 1971) due to the high proportion of standing dead matter in the sward at any time. It was thought that the response of the indigenous species to applied nutrients could not be reasonably justified in terms of the quality and quantity of herbage produced, hence lime and fertilizer application should be accompanied by the introduction of improved pasture species. Some reseeding work has been done by local farmers with Miller's (1966) work on Holcus lanatus demonstrating both the application and limitations of that species. Young (1968) tried many species, the most successful of these being Festuca ovina, F. rubra, F. arundinacea and Dactylis glomerata.

The role of white clover (Trifolium repens) has been shown to be of importance in improvement situations where levels of available N is low (Newbould, 1973; Munro & Davies, 1974). Attempts have been made to introduce the species into the Falklands (Davies, 1939; Gibbs, 1946; Young, 1968) but these have met with little success. Davies et al. (1971) attempted unsuccessfully to find the minimum dressing of lime and phosphate which would establish white clover. It was felt that this aspect of development was sufficiently important to merit further work and white clover was included in the species under investigation.

In the present study a range of sites was chosen and the response of the soil types to lime and phosphate measured as chemical changes in the soil and yields of sown species. A mixture of species was sown and detailed herbage analysis enabled an assessment of the suitability of each to be made under a range of input conditions on different soil types.

MATERIALS AND METHODS

Sites

Four sites were chosen on the south-facing slope of Mount Usbourne, East Falkland, representing an altitudinal transect. The site characteristics are detailed in Table 1.

These sites were typical of those found over large areas of the Falkland Islands, 1 and 2 being typical of the fertile valleys and flat lowlands and 3 and 4 typical of upland areas. The sites were within a large enclosure (2100 ha) extensively grazed by sheep (Arroyos camp).

Site preparation

The surface vegetation and uppermost 3 cm of soil were removed by shallow rotary cultivation and the trash was raked off by hand, leaving the site as a uniform bare soil surface.

Treatments

Four levels of lime (0, 0.63, 1.25 and 2.51 t/ha) applied as ground chalk and three levels of phosphate(0; 50.5 and 101.1 kg P ha^{-1}) applied as granular triple superphosphate. All plots received a basic dressing of 125 kg/ha of a compound fertilizer containing 25% N and 16% K and a proprietary trace element mixture for plants (10 kg/ha) to correct any trace element deficiencies which may exist in the peaty soils. A further dose of 25 kg N/ha was applied at the commencement of the second growing season.

Seeds mixture

The mixture contained the following species in equal seed numbers per unit weight: Poa pratensis (Danish origin); Dactylis glomerata (S.143); Festuca rubra (novorubra); Lolium perenne (S.23); Phleum pratense (S.48); Festuca arundinaceae (S.170) and Trifolium repens (S.100) sown at a rate of 30 kg/ha.

Layout

The experiments were laid out as randomized blocks with one replicate per block and three blocks per site. Each plot measured 2 m x 2 m and all plots were separated by a 1 m boundary and fenced.

Timing

The sites were rotary cultivated to a depth of 5 - 10 cm in June 1976 (mid-winter), the trash cleared off in July 1976 and the lime treatments applied immediately afterwards. The seeds and fertilizers were broadcast and lightly raked in mid-October 1976.

Herbage sampling and analysis

One quadrat (150 cm x 25 cm) was harvested to ground level from each plot in May 1977 (i.e. after the cessation of that season's growth). The remaining herbage was trimmed off each plot and in February 1978 a second sample was taken from each plot. A subsample of each herbage sample taken was separated into nine fractions comprising the seven species sown, the indigenous vegetation which had either regrown or germinated from seeds blown onto the plots and the trash which had not been cleared from the site and had been included with the sample.

These fractions and the remainder of the original sample were oven dried for 48 h at 90 ^{o}C and weighed.

In view of the importance placed on the establishment of a legume in the Falklands, at the completion of the experiment (February 1978) a detailed assessment was made of the legume status in each plot. The presence or absence of white clover was noted and, if present, a random selection of 20 leaf lengths were measured and the presence or absence of nodulation was also recorded. A subjective assessment of cover of the white clover plants per plot and of leaf greeness was also made.

Results were subjected to conventional analyses of variance (n = 3) with a total of 35 d.f. (22 for the estimation of error variation).

Soil Analysis

A soil core was removed from the centre of the cut area in each plot and a pH analysis (Anon, 1973) was carried out on soil just below the surface and at a depth of 2.5 cm. Soil samples for pH analyses were taken at the same time as herbage samples (i.e. May 1977 and February 1978). An analysis of extractable PO_4^{3-} using the molybdenum blue method

(Allen et al. 1974) was carried out on soils from some of the plots sampled in February 1978. Due to limited facilities for soil analysis only samples from sites 1 and 2 (3 samples per treatment) were analysed.

RESULTS

Herbage data

Effect of lime and phosphate on herbage yield (Table 2)

There were considerable differences among sites in both seasons, sites 1 and 2 showing a higher level of production than sites 3 and 4. There was however little difference in production between site 1 and site 2, and site 3 and 4 in both seasons. From 1977 to 1978 the mean production per site increased by an approximate factor of three on sites 1 and 2 and by thirteen on sites 3 and 4. A considerable decrease in the variation in yield within sites was observed in the second growing season, the very high figure obtained in the first season being accounted for by the very slow, uneven germination and low yields. The herbage production on sites 3 and 4 was low compared with those found on reseeded wet peat in upland Britain (e.g. Reith & Robertson, 1971). Approximately 3 t/ha was produced by sites 1 and 2 during part of the second season of growth. Data from other experiments in the programme indicated that by early February, on this type of site approximately 80% of the total annual DM production would have accumulated. On this basis it can be assumed that the mean total production on sites 1 and 2 in the second season of growth would be about 3.75 t/ha. This is less than the value reported for marginal land in Northern Ireland (McConaghy & McAllister, 1973) though in many cases the inputs were higher.

Over the duration of the experiment no herbage production response to lime was detected on any of the sites. A significant ($P<0.001$) response to phosphate was found on site 2 in both seasons and on site 3

($P<0.01$) in 1978.

Effect of site, lime and phosphate on the success of establishment of sown species

The response of the herbage to treatments in terms of the individual sward component species response is illustrated for each site and season in Figs 1 and 2. An analysis of variance of the treatment means and treatment interactions on the botanical composition of the plots in 1977 and 1978 was carried out (Table 7) and no significant effect of treatment on individual sward component species was detected. This was in agreement with the results of Davies et al (1968).

The overall contribution of sown species in the sward (Table 3) was higher for all sites in 1978 (85%) than in 1977 (54%). The species contributing most to the total DM of the sown component of the sward were *Dactylis glomerta*, *Festuca rubra*, *Poa pratensis* and *Phleum pratense*. The relative frequencies of these species changed slightly from 1977 to 1978, the increased contribution of *F. rubra* and *P. pratense* being most noticeable.

White clover status

The occurrence of clover plants was significantly related to applied lime ($P<0.01$) and phosphate ($P<0.05$) and appeared to bear no relation to soil type. Sixty one per cent of plots on site 1, 75% on site 2, 64% on site 3 and 36% on site 4 had any visible clover plants in February 1978. Of those plots with plants 45% on site 1, 11% on site 2, 30% on site 3 and 31% on site 4 had pink root nodules on any of the plants examined. The presence of nodulated plants was significantly related to applied lime ($P<0.01$) and phosphate ($P<0.05$).

There were no significant differences between white clover cover, leaf greeness and mean leaf length per treatment or site.

The presence of plants in the plots was independent of the level of applied lime where lime treatments were applied (Table 4). Nodulation was dependent on lime being applied although at all levels of application less than half the plots with white clover contained nodulated plants.

Soil analyses

pH (Table 6)

One year after application a significant ($P<0.001$) response to lime was detected on all sites at ground level and no response at a depth of 2.5 cm. In the second year after application pH values at surface layers were lower than after season 1 for all levels of applied lime on sites 1-3. On these sites a significant response to lime and lime x P interaction was measured at ground level. The effect of lime significantly ($P<0.01$) affected the pH at 2.5 cm on site 1 but not on site 2 though the values at 2.5 cm on site 1 were still almost 1 pH unit below those at ground level. The increase in pH per unit of applied lime in this trial in the Falkland Islands on deep peat (sites 3 and 4) was similar to that recorded by Robertson & Nicholson (1961) and Reith & Robertson (1971) in Scotland on similar soils and higher on the better sites (1 and 2) than that recorded by Robertson & Nicholson (1961).

Phosphorus (Table 6)

Lime application produced no significant increase in extractable soil P whereas applied phosphate, as would be expected, produced an increase. On site 1, application of 50 and 100 kg P/ha led to a higher extractable soil phosphate than the nil plots, 100 kg P/ha not giving a higher response than 50 kg/ha as was the case on site 2.

The extractable soil P was lower than that obtained by Reith & Robertson (1971) who found 11.6 mg P/100 g after applying 98 kg/ha. Equivalent amounts of applied P in this experiment led to 2.5 mg P/100 g soil after approximately the same time interval.

DISCUSSION

The yields of herbage obtained on the deeper peat sites (3 and 4) were so low as to indicate that attempts to improve such areas by re-seeding could not be economically justified. Establishment of pasture species on these sites was slow, hence the large increase in production in the second season of growth. The physical nature of the soil also severely limits cultivation operations.

On sites 1 and 2 where some mineralisation and breakdown of the peat has occurred and there is less impeded drainage the threefold increase in yield from seasons 1 and 2 may indicate that even on these soils establishment is retarded and the maximum level of production may not have been obtained. Even at the projected yields for the second season, production is thought to be acceptable for the relatively low inputs.

The highly significant response to applied phosphate in terms of herbage yield and extractable soil P would indicate that soils of this type would be amenable to improvement by reseeding and applying relatively small amounts of phosphate. Projected herbage yields on the basis of 50-100 kg applied P/ha are 4.3-4.7 t/ha per year.

It has been calculated (Section 1B.b.) that the mean annual DM production of native vegetation on this type of site is 3t/ha with organic matter digestibilities ranging from 37% (Jan) to 33% (May). The low OMD of this native pasture is largely due to a high proportion of standing dead matter and non-graminaceous herbs. Organic matter digestibilities were carried out on a limited number of the samples from the second cut (February 1978) and these ranged from 67% (site 2) to 57% (site 4). Hence, although there was an increase in production over the native vegetation in the order of 50% the sown species also represented a considerable improvement in herbage quality.

It has been demonstrated (sections 1B.d. & e.) that the growth rate of the native pastures is very slow in the first part of the growing season (October - December), not increasing rapidly until mid-January. Possibly the early season growth is being limited by a combination of climatic, edaphic and nutritional factors. Growth on the sown plots in this experiment was observed to commence earlier than on the adjoining native vegetation and to follow a growth pattern similar to that observed in the British Isles. If this were a constant, significant feature then one of the most serious limitations to sheep production would be largely eliminated provided grazing of the improved pasture was integrated with a larger area of unimproved pasture enabling the improved area to be periodically rested.

The overall suitability of the individual sown species does not appear to be dependent on treatment or site. The data for February 1978 are of more value, the sown species by that time contributing a high proportion of the overall sward composition. These results generally agree with those of Young (1968) who had success with *Festuca rubra* and *Dactylis glomerata* but do not confirm his recommendation of *Festuca arundinacea*. On the basis of this experiment the grass species performing best under all conditions were *Dactylis glomerata*, *Festuca rubra*, *Phleum pratense*, and, to a lesser extent *Poa pratensis*. The plant population density and ground cover was high in all plots (on sites 1 and 2) due to the presence of erect (*Dactylis* and *Phleum*) and more prostrate species (*Festuca* and *Poa*) in the sward. The percentage of indigenous species decreased with time hence it appears that sown species can compete successfully with the indigenous vegetation and provided the soil nutrient status was maintained reversion of the reseed would not be a problem.

The results relating to clover establishment are encouraging in that where clover had germinated the plants were vigorous and some had large pink root nodules. Seedling germination and nodulation did not appear to be a junction of the water-logged state of a size as results from sites 1-3 were similar.

The application of 0.63 t lime/ha on sites 1 and 2 resulted in a soil pH of 5.0 and this value is within the pH tolerance range widely quoted for satisfactory white clover growth.

In view of the problems associated with obtaining and transporting lime in the Falklands the whole question of lime application must be given serious consideration. From the data presented lime does not appear to be essential for grass establishment, but is necessary if effective nodulation of white clover plants is to occur. The response in terms of white clover establishment and nodulation where a small quantity of lime (0.63 t/ha) was applied is encouraging. If a response was obtained using lime coated seed or with even smaller applications of lime the feasibility of applying lime to establish white clover would be greatly enhanced.

The low levels of available soil Pfollowing applications of inorganic phosphate may be either a function of the soil itself or of the analytical method adopted. In peaty soils only a small fraction of the total P is in the extractable form (Floate, 1971) and anomalous results have been found for the determination of available P in peaty soils following P application (Floate & Pimplaskar, 1976). The low 10 cm soil temperatures found in the Falklands (mean annual range 2.0-9.5 ^{o}C) may be contributing to the limited availability of P. As a consequence, legume introduction may prove to be more successful if delayed until an improvement in nutrient cycling within a pasture system has been established. This improved nutrient cycling can be best achieved by the creation of a grass sward with a high density of plant cover and the results presented show that this is possible on favourable soil types with moderately low levels of fertiliser input.

SUMMARY

Experiments to determine the effects of a range of applied lime and phosphate treatments on the establishment of species and the subsequent herbage production in the first and second seasons following sowing on four sites in the Falkland Islands are described and the results discussed.

Festuca rubra, Dactylis glomerata, Phleum pratense and Poa pratensis established successfuly yielding up to 4.5 t D.M./ha per year with inputs of 55 kg N/ha, 50 kg P/ha and 20 kg K/ha. Applied P increased the yield of herbage and produced a small, though significant increase in P status of the soil.

The lowest level of applied lime (0.63 t/ha) increased the soil pH to 5.0 and although this did not affect the yield or botanical composition of the grass component of the sward it did affect the presence and nodulation of white clover.

The problems of establishimg white clover are presented in view of the severe limitations on the use of lime and fertilizer in the Islands. The implications of grazing this improved pasture are discussed in relation to increased pasture production and improved soil fertility.

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Site no.	Position and aspect	Soil	Vegetation	Elevation (m)
1	Fertile valley slope	Some organic matter with a high proportion of mineralization and unimpeded drainage	Large tussocks of Cortaderia pilosa (D'Urv.) Hack interspersed with Blechnum penna-marina (Poir.) Kuhn, Festuca (L.) spp. and Aira praecox L.	30
2	Undulating	Peaty with some mineralization and partially impeded drainage	Low tussocks of C. pilosa with Baccharis magellanica (Lam.) Pers and Gunnera magellanica Lam.	46
3	Low lying, damp	Peat with little evidence of mineralization and severely impeded drainage	Uniform cover of lax C. pilosa with Baccharis magellanica and Oreobolus obtusangulus Gaudich.	102
4	Elevated peat bank	Deep undifferentiated peat with no mineralization and severely impeded drainage	Very sparse cover of C. pilosa with O. obtusangulus, Astelia pumila (Forst. f.) Banks & Sol. ex R. Br., and Rostkovia magellancia (Lam.) Hook. f.	138

Table 1. Description of experimental sites

		1977							1978					
Site		* L_0	L_1	L_2	L_3	S.E.	Site mean	Site	L_0	L_1	L_2	L_3	S.E.	Site mean
	** P_0	0.96	0.55	1.23	0.68				2.19	1.95	2.89	3.07		
1	P_1	0.91	0.65	0.53	0.87	0.486	0.91	1	2.70	3.34	3.11	2.59	0.883	2.81
	P_2	1.12	0.93	1.25	1.17				2.62	2.66	3.65	3.01		
	P_0	0.33	0.27	0.15	0.22				2.13	1.50	2.58	1.95		
2	P_1	1.43	0.99	1.03	0.69	0.200	0.84	2	3.23	2.71	4.34	3.37	0.543	3.07
	P_2	1.24	1.24	1.20	1.27				3.46	4.05	1.96	4.26		
	P_0	0.16	0.02	0.08	0.01				0.69	0.53	0.52	0.56		
3	P_1	0.05	0.15	0.09	0.12	0.049	0.09	3	0.56	0.76	1.75	1.19	0.272	0.97
	P_2	0.04	0.19	0.17	0.06				1.24	1.01	1.53	1.35		
	P_0	0.02	0.03	0.04	0.09				0.15	1.21	1.60	1.72		
4	P_1	0.13	0.03	0.07	0.11	0.040	0.08	4	0.65	1.18	1.46	1.78	0.302	1.30
	P_2	0.20	0.07	0.05	0.17				1.11	1.23	1.64	1.87		

* L_0, L_1, L_2 and L_3 represent 0, 0.63, 1.25 and 2.51 t/ha applied lime.

** P_0, P_1 and P_2 represent 0, 50.5 and 101 kg/ha applied phosphorus

Table 2. Mean dry matter yields (t/ha) for treatments and sites per season

	Site	Dactylis glomerata (%)	Festuca rubra (%)	Phleum pratense (%)	Poa pratensis (%)	Lolium perenne (%)	Festuca arundinacea (%)	Trifolium repens (%)	Indigenous species (%)
1977	1	38.3	14.1	10.5	11.6	1.0	0.2	0.2	25.2
	2	19.7	9.2	13.1	16.1	0.7	0.4	0.4	41.2
	3	10.0	3.9	13.7	5.9	0	0	4.2	49.2
	4	12.4	12.6	3.5	13.2	0	0	0	55.5
	Mean	20.1	10.0	10.2	11.7	0.4	0.2	1.2	42.8
1978	1	27.1	31.1	16.1	7.0	3.9	0.2	1.3	14.1
	2	23.8	20.5	21.9	9.3	3.5	0.6	1.3	20.1
	3	10.6	29.0	29.0	6.9	4.7	0.2	7.8	18.7
	4	14.2	57.1	7.6	3.8	3.5	0.9	1.2	12.8
	Mean	18.9	34.4	18.6	6.7	3.9	0.5	2.9	16.4

Table 3. Botanical composition of plots (based on % by dry weight) in May 1977 and February 1978 (means of all treatments per site)

Table 4. Effect of applied lime on (a) number of plots with white clover plants (all sites) (b) number of plots where plants had successfully nodulated

	Lime applied (t/ha)			
	0	0.63	1.25	2.51
a	11	24	26	27
b	0	5	9	10

Site		1977 $* L_0$	L_1	L_2	L_3	S.E.	Site Mean	Site	1978 L_0	L_1	L_2	L_3	S.E.	Site Mean
1	GL	4.69	5.22	5.62	6.23	0.180	5.44	1	4.46	4.91	5.71	5.87	0.148	5.24
	2.5	4.53	4.52	4.72	4.74	0.069	4.63		4.41	4.52	4.86	4.63	0.147	4.60
2	GL	4.92	5.38	5.58	6.56	0.171	5.61	2	4.56	5.18	5.34	6.44	0.161	5.38
	2.5	4.91	4.76	4.88	4.81	0.132	4.83		4.48	4.52	4.69	4.74	0.159	4.61
3	GL	3.90	4.21	5.11	5.22	0.228	4.61	3	3.96	4.13	4.40	4.67	0.078	4.29
	2.5	3.97	4.12	4.08	4.34	0.142	4.13							
4	GL	3.94	4.49	4.43	5.47	0.175	4.58		4.41	4.52	4.78	4.69	0.11	4.05
	2.5	3.92	4.23	4.28	4.19	0.136	4.15							

* L_0, L_1, L_2 and L_3 represent 0, 0.63, 1.25 and 2.51 t/ha applied lime

Table 5. The effect of treatment on soil pH at ground level (GL) and a depth of 2.5 cm (2.5) one season (1977) and two seasons (1978) after lime and phosphate application

Table 6. The effect of treatment on soil phosphorus levels (mg/100 g) at sites 1 and 2, two seasons after initial phosphate application

Site	**	* L_0	L_1	L_2	L_3	Mean P	S.E. (for P means)	S.E. (all means)	Overall site mean
	P_0	0.54	0.56	0.61	0.60	0.58			
1	P_1	1.27	1.70	1.32	0.64	1.23	0.122	0.244	1.00
	P_2	0.36	0.96	1.05	2.36	1.18			
	P_0	0.50	0.55	0.55	0.55	0.54			
2	P_1	1.31	1.06	0.70	0.65	0.94	0.146	0.293	1.25
	P_2	2.04	2.25	2.15	2.65	2.27			

* L_0, L_1, L_2 and L_3 represent 0, 0.63, 1.25 and 2.51 t/ha applied lime

** P_0, P_1 and P_2 represent 0, 50.5 and 101 kg/ha applied phosphorus

Table 7 Analysis of effect of treatment and treatment interactions on botanical composition of plots (based on % by dry wt) (see figs 1.&.2)

Species	Year	Site	Lime	Phosphate	Lime x Phosphate	s.e.d. (d.f. 22).
			Treatment and treatment interactions			
Dactylis glomerata	1977	1	*	NS	NS	12.23
		2	NS	NS	NS	12.08
		3	NS	NS	NS	14.70
		4	NS	NS	*	11.90
	1978	1	NS	NS	NS	6.61
		2	NS	NS	NS	7.28
		3	NS	NS	NS	5.91
		4	NS	NS	NS	6.75
Festuca rubra	1977	1	NS	NS	NS	6.09
		2	NS	NS	NS	5.79
		3	Insufficient samples			
		4	NS	NS	NS	10.71
	1978	1	NS	NS	NS	7.43
		2	NS	*	NS	6.95
		3	***	NS	*	8.89
		4	NS	NS	NS	15.77
Phleum pratense	1977	1	NS	NS	NS	4.75
		2	**	**	NS	5.41
		3	NS	NS	NS	14.49
		4	*	NS	NS	5.16
	1978	1	NS	NS	NS	5.30
		2	NS	NS	NS	8.46
		3	NS	NS	*	11.02
		4	**	NS	NS	5.04

Table 7 (contd)

Species	Year	Site	Lime	Phosphate	Lime x Phosphate	s.e.d. (d.f. 22).
			Treatment and treatment interactions			
Poa pratensis	1977	1	NS	NS	NS	7.20
		2	NS	NS	NS	8.90
		3	NS	NS	NS	7.62
		4	*	NS	NS	10.43
	1978	1	NS	NS	NS	3.12
		2	NS	NS	NS	4.38
		3	NS	NS	NS	4.23
		4	NS	NS	NS	1.44
Lolium perenne	1978	1	NS	NS	NS	2.90
		2	NS	NS	NS	2.56
		3	NS	NS	NS	4.13
		4	***	NS	NS	2.21
Indigenous species	1977	1	NS	NS	NS	16.77
		2	*	NS	*	18.93
		3	NS	NS	NS	33.02
		4	NS	NS	NS	24.76
	1978	1	NS	NS	NS	8.81
		2	NS	NS	NS	10.06
		3	NS	NS	NS	15.20
		4	**	*	*	14.93

(* P<0.05; ** P<0.01; *** P<0.001; NS = Not Significant)

Legends to Figures

Fig. 1. Response of sown species to treatments on sites 1 and 2 for 1977 and 1978. Histograms show % by weight of species components. The columns in each histogram represent four levels of applied lime (▨-0, □-0.63, ■-1.25, and ▧-2.51 t/ha) for each level of applied phosphate (P_0-0, P_1-50.5 and P_2-101 kg P/ha).

Fig. 2. Response of sown species to treatments on sites 3 and 4 for 1977 and 1978. Histograms show % by weight of species components. The columns in each histogram represent four levels of applied lime (▨-0, □-0.63, ■-1.25 and ▧-2.51 t/ha) for each level of applied phosphate (P_0-0, P_1-50.5 and P_2-101 kg P/ha).

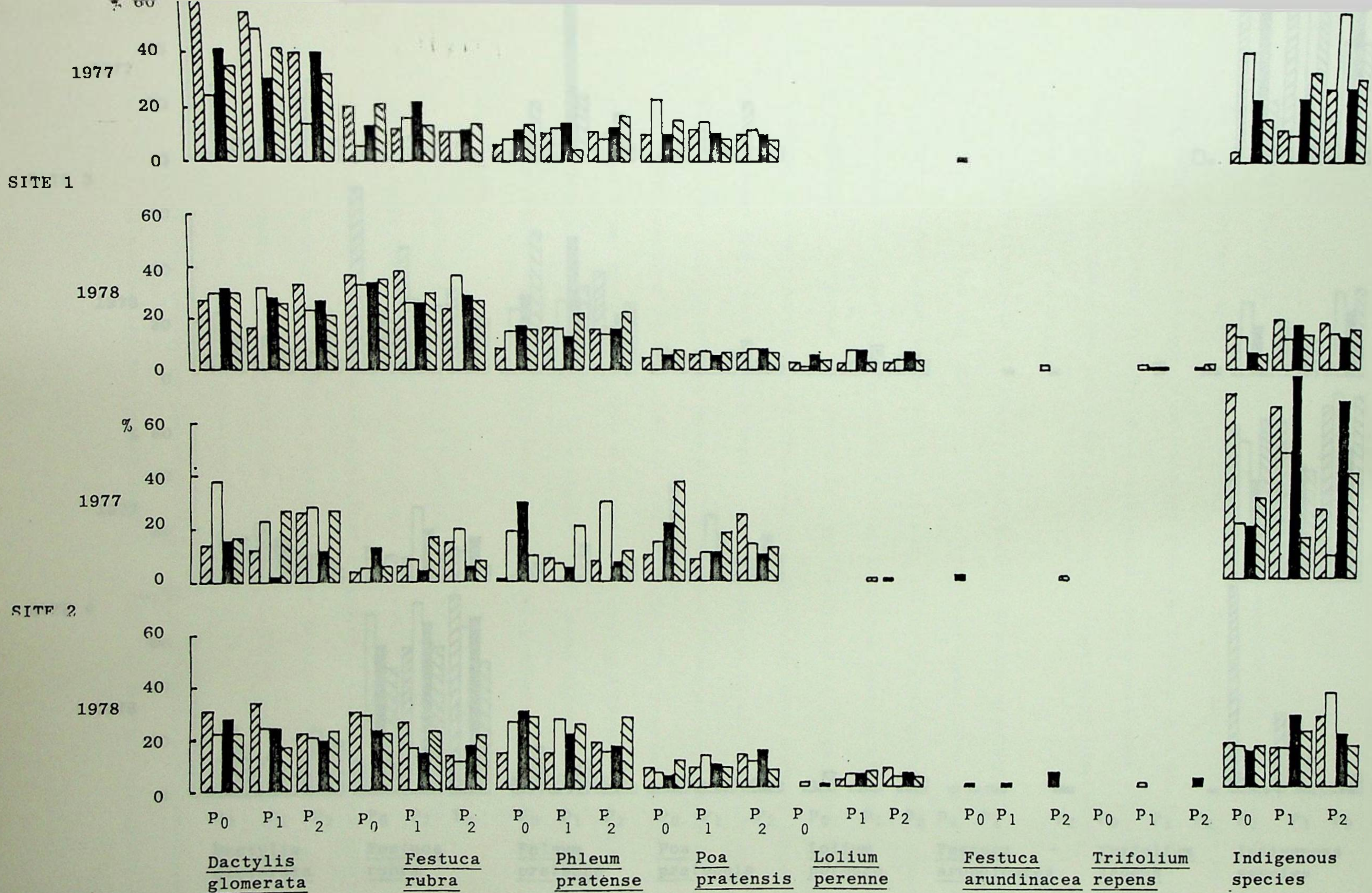
SITE 1
1977
1978
SITE 2
1977
1978
%
0
20
40
60
P0 P1 P2
Dactylis glomerata
Festuca rubra
Phleum pratense
Poa pratensis
Lolium perenne
Festuca arundinacea
Trifolium repens
Indigenous species

FIG 1

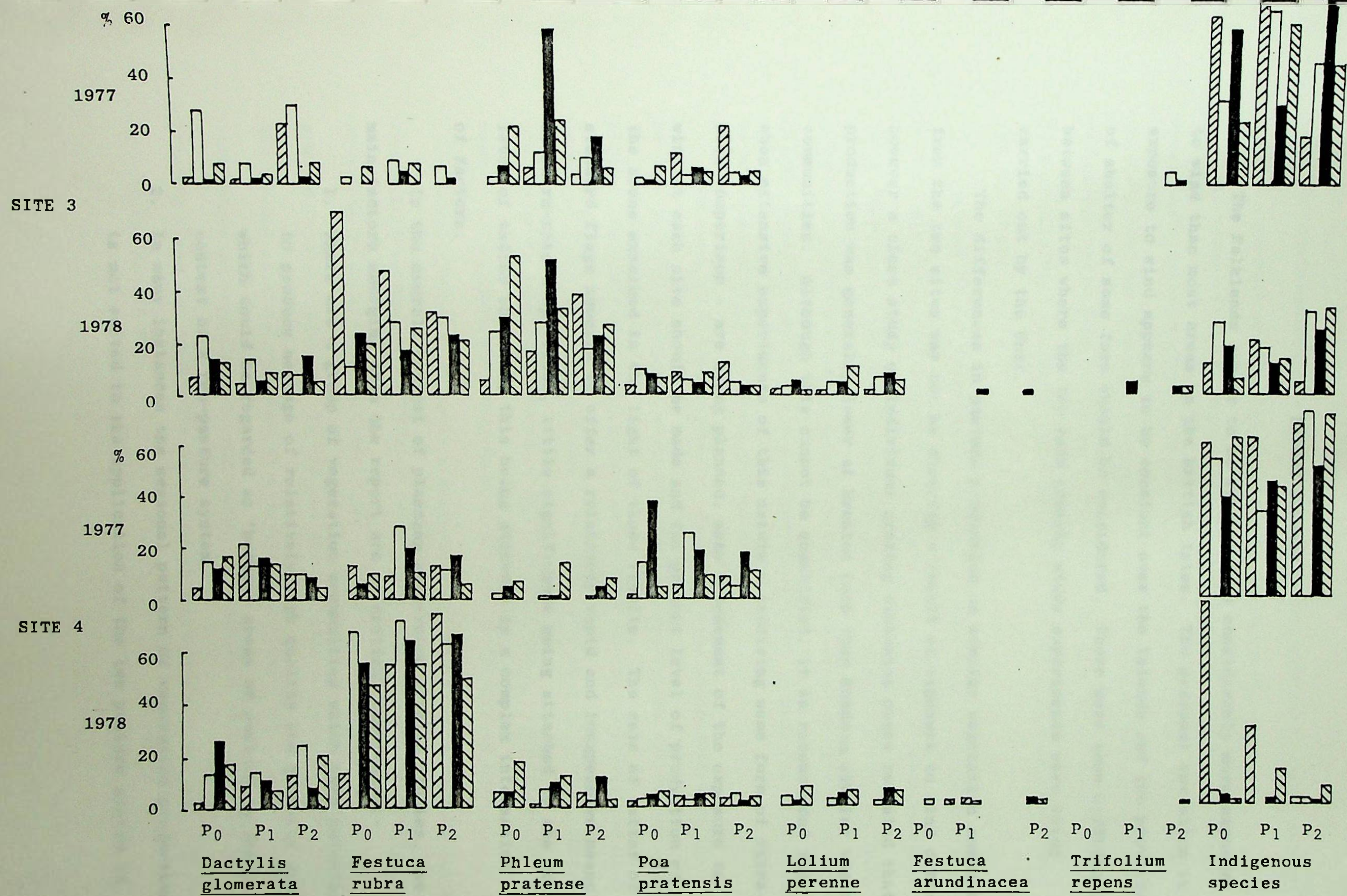
% 60
40
1977
20
0
SITE 3
60
40
1978
20
0
% 60
40
1977
20
0
SITE 4
60
40
1978
20
0
P_0 P_1 P_2
Dactylis glomerata
Festuca rubra
Phleum pratense
Poa pratensis
Lolium perenne
Festuca arundinacea
Trifolium repens
Indigenous species

FIG 2

REPORT SUMMARY

The Falklands appear to be subjected to considerably more exposure to wind than most areas in the British Isles. The seasonal variation in exposure to wind appears to be constant over the Islands and the provision of shelter of some form should be considered. There were some differences between sites where the two main grazing study experiments were being carried out by the Unit.

The differences in pasture production on similar vegetation communities from the two sites may not be directly a result of exposure to wind differences, however a close study of individual grazing exclusion cages revealed that production was generally lower at Brenton Loch than Ronda on similar vegetation communities. Although this cannot be quantified, it is recommended that when extensive experiments of this nature - involving some form of intra-site comparison - are being planned, some assessment of the exposure to wind at each site should be made and the present level of production of the areas examined in the light of these results. The rate of tatter of standard flags appears to offer a relatively rapid and inexpensive means of intra-site comparisons, little significance being attached to the actual level of tatter obtained, this being affected by a complex interaction of factors.

In the overall context of planning year-round grazing studies, two main factors emerging from the report are of critical importance:-

1. There are a group of vegetation communities which have potential to produce herbage of relatively high quality and quantity and which could be regarded as 'better' areas of pasture in the context of a two-pasture system.
2. In many instances the seasonal pattern of vegetation production is not suited to the application of the two pasture system in

its fundamental conception, the marked absence of early season production imposing severe limitations on the system.

In terms of application of the 2 pasture system, there are certain areas where the distribution of high quality pasture is such that there is no doubt that the system can be applied in its simplest form ie. by fencing off better areas from poorer and controlling the grazing on these areas in a pattern best suited to satisfying the nutrient requirements of the grazing stock.

On most of the farms on the smaller islands vegetation of sufficient quality and quantity is probably available to stock and on some mainland camps there is a high proportion of coastline or greenvalleys. In these situations the provision of fences or the readjustment of present management practices may be sufficient - provided the grazing is properly controlled - to produce increases in animal production.

However, on a large number of camps there is an insufficient quantity of high quality vegetation available for the application of the two pasture system. This situation is further exacerbated by the inhibition of high levels of early season production. In situations such as these - where the aim is to improve performance of breeding sheep - in the first instance some form of vegetation improvement will have to be carried out.

Small increases in pasture production can be achieved by relatively inexpensive means such as burning and flail mowing, but if increased productivity of breeding flocks is the aim, these techniques will not produce dramatic results. In the context of large hogget camps however, the removal of the large fund of standing dead vegetation and the increased utilisation of <u>Cortaderia</u> is important. If increases in productivity of breeding sheep are to be made some form of reseeding with cultivation will have to be carried out.

The direct Drill may be of value in certain situations, namely the introduction of more productive species of grass into defoliated Cortaderia with the aim of maintaining the plant leaves in a relatively juvenile, and hence more palatable state and preventing the build up of dead matter, these aims being achieved by increased grazing pressure of stock attracted to the drilled areas.

The renovation of reseeds on the introduction of improved species into already established improved pasture may be a further application of the direct drill. In areas where erosion is likely to be a severe problem reseeding may only be safely carried out using minimal cultivation techniques.

In most situations the improvement of pasture by reseeding will be most successful if some form of cultivation is carried out. The use of a seeds mixture containing Cocksfoot (Dactylis glomerata), Red Fescue (Festuca rubra) and smooth-stalked meadow grass (Poa pratensis) and the provision of low levels of N and P at sowing should be sufficient to establish an adequate plant cover. The introduction of a legume to the system deserves further research as there is encouraging evidence from better sites that white clover (Trifolium repens) can grow successfully. This legume introduction may be seen as the second stage in a two-stage operation, the first essential of which is to establish a grass sward of relatively high plant population density. The economic constraints at present existing prohibit the use of lime on a large scale and at high application rates and it is reasonable to assume that future work to be done on reseeding should be within the constraint of low pH. Results from establishment of grass species demonstrated that the low pH was not severely limiting grass growth on sites where some soil mineralisation had occurred.

Further work must be done on the maintenance of these established pastures.

In summary, the importance of climate in the Falklands on plant growth and animal production is emphasised. The ecological investigations carried out revealed that the pattern of production of the native vegetation was not suited to the application of the two-pasture system in many situations. There were however areas of high herbage production potential and where these could not be integrated into an improved grazing system they could be successfully reseeded with relatively low levels of input and animal production subsequently increased.

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Where appropriate,the assistance given by various individuals is acknowledged at the end of each experiment reported. However, in the context of the overall study special thanks must be rendered to certain individuals and bodies.

Much of the work reported here could not have been carried out were it not for the interest, enthusiasm and practical co-operation given by the managers and staff on many farms in the Islands.

The Falkland Islands Sheep Owner's Association were most helpful at all times and it is a pleasure to record the assistance given by that forward-thinking body in all aspects of the work.

I would especially like to thank the Managers and their wives for their unfailing hospitality on many, often inconvenient and unforeseenly prolonged occasions. The kindness of many of the people of Stanley in this respect combined to make my own and my family's stay in the Islands an enjoyable one.

I should like to thank my colleagues in the Grassland Trials Unit for their practical help, guidance and advice and Mr T H Davies and Mr J Eadie for helpful criticism and direction during their respective visits to the Islands.

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APPENDIX

List of species quoted throughout the text with authorities for latin names and common names where appropriate. (See Moore 1968).

Code		
	Agrostis canina L.	Velvet or brown bent
Am	Agrostis magellanica Lam.	Native bent
	Agrostis stolonifera L.	Creeping bent
	Agrostis tenuis Sibth.	Common bent
Ap	Aira praecox L.	Goose grass
Aa	Ammophila arenaria (L) Link	Marram grass
	Apium graveolens auct., non L.	Wild celery
Ap	Astelia pumila (Forst.f.) Banks & Sol. ex R. Br.	
Bm	Baccharis magellanica (Lam.) Pers.	Christmas bush
Bm	Blechnum magellanicum (Desv.) Mett.	Tall Fern
Bg	Bolax gummifera (Lam.) Spreng.	Balsam bog
	Calluna vulgaris (L.) Hull	Heather
	Colobanthus quitensis (Kunth) Bartl.	
Cp	Cortaderia pilosa (D'Urv) Hack	Whitegrass
Dg	Dactylis glomerata L.	Cocksfoot
	Deschampsia flexuosa (L) Trim	Wavy hair grass
Ea	Elymus arenarius L.	Sand grass
Er	Empetrum rubrum Vahl ex Willd.	Diddle-dee
	Euphrasia antarctica Benth	Antarctic eyebright
	Festuca arundinacea Schreb.	Tall Fescue
Fe	Festuca erecta D'Urv.	Land tussac

Fm	Festuca magellanica Lam.	Native fescue
	Festuca rubra L.	Red fescue
Gm	Gunnera magellanica Lam.	Pig-vine
Hl	Holcus lanatus L.	Yorkshire fog
Js	Juncus scheuzerioides	Small rush
Lp	Lolium perenne L.	Perennial ryegrass
	Lotus uliginosus	Marsh trefoil
	Luzula alopecurus Desv.	Native woodrush
	Lycopodium confertum Willd.	Clubmoss
Mn	Myrteola nummularia (Poir.) Berg	Tea berry
Oo	Oreobolus obtusangulus Gaudich.	Oreob
Per.p.	Pernettya pumila (L.F.) Hook	Mountain berry
	Phleum pratense L.	Timothy
Pa	Poa annua L.	Annual meadow grass
Pf	Poa flabellata (Lam) Hook f.	Tussock grass
Pp	Poa pratensis L.	Smooth-stalked meadow grass
Rm	Rostkovia magellanica (Lam.) Hook. f.	Short brown rush
	Rumex acetosella L.	Sorrel
Sc	Senecio candicans (Vahl) DC.	Sea cabbage
Tr	Trifolium repens L.	White clover
	Viola maculata Cav.	Violet