R/AGR/GRA/2#9

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Agricultural Research Project 1983/4

The study and research of agriculture in the Falkland Islands is an objective of the Falkland Islands Trust.

Knowing the need for improvement in the grass yield for sheep grazing in the Islands, the Trust contacted the Institute of International Husbandry (IIBH) in the summer of 1983 to determine whether a trial in organic husbandry to improve the soil could be purposeful.

Following a meeting attended by Mr David Stickland, Chairman of IIBH, and after discussion with the Civil Commissioner, Sir Rex Hunt, it was decided to commission IIBH to undertake an initial phase of a project to test the possibilities of using this form of husbandry.

Accordingly, IIBH got the agreement to The Department of Agriculture in Northern Ireland to make Mr J. H. McAdam BSc, BAgr, MAgr - a former member of the Grass Trials Unit in the Islands - available for the month of December, 1983 to visit selected settlements in the Islands for this purpose. His subsequent report is attached. Once the result of the trials can be evaluated, the Trust will decide whether a Phase II will be undertaken.

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SOIL FERTILITY IN THE FALKLAND ISLANDS

- Biological activity and soil chemistry

A preliminary report for the United Kingdom Falkland Islands Trust

by

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SUMMARY AND PERSONAL COMMENTS

Following an intiative by the UK Falkland Islands Trust (in conjunction with the International Institute of Biological Husbandry) a short visit was paid to the Falkland Islands to investigate means of improving soil fertility. The main purpose of the visit was to collect samples to enable assessments of biological activity in the soils to be made. In addition small trials were carried out on the potential use of seaweed extract and introduced bacteria. Opinions and views on the improvement of soil fertility and on the project were sought.

The farmers were receptive to considering almost any means of pasture improvement although for most of the relatively new 'small' farmers in the islands there were many other investment priorities before land improvement.

The FIARDC are building up a valuable fund of information on the many aspects of the science and practice of pasture improvement. Much of this work, which has concentrated on the establishment of an adequate plant cover and the responses of pasture to fertiliser, is now at a stage where the introduction of a legume into the system to increase levels of mineral nitrogen cycling may be considered.

The problem of stimulating nitrogen cycling and mineralisation of N from the organic soils is not an easy one to resolve and the environmental constraints are great although experimentation with combinations of inorganic N applications, suitable bacterial inoculations and the use of legumes may yield some positive results.

It would be wrong to be over optimistic at this stage about the impact which the use of organic fertilizers or introduced bacteria could have on agriculture in the Falklands. The climatic limitations are great and there is a clear need for relatively high doses of added N to stimulate cycling and have a significant effect on pasture production. If the efficiency of the soil microflora (and hence nitrification) cannot be substantially improved it is difficult to see how the application of anything but huge amounts of seaweed will have any effect in this context.

However such practices have not been tried before and if the analyses and conclusions resulting from this work do nothing but persuade those engaged in agricultural research in the Islands to at least consider investigating the use of improved strains of bacteria (in conjunction with organic or inorganic nitrogen applications) then I feel that something worthwhile will have been achieved.

It is my considered opinion however that in such a relatively small community and country as the Falkland Islands the fragmentation of agricultural research and development is wholly undesirable. Especially in view of the sudden impetus placed on development in the islands and the relatively sensitive nature of the development programme all agricultural development and research should be carried out by the FIARDC.

It is accepted that the FIARDC may not have the back-up facilities and expertise to carry out work of this nature in the Islands but consideration should be given to 'sub-contracting' some of the background development work to microbiological laboratories in the UK and then testing the results in the Falklands. Much of this work is already in progress for cold acid soils in NW Europe and should be readily applicable to the Falklands.

ACKNOWLEDGEMENTS

That the relatively large amount of work reported here was able to be carried out in such a short time is due in large part to the kindness, co-operation and help of many individuals both in UK and the Falklands.

I wish to firstly record my thanks to the farmers on whose land samples were taken and trials laid down. Ron Reeves, Marshall Barnes, Sam Miller, Tony Heathman and Brook Hardcastle and their respective families gave me every possible assistance and I am extremely grateful for their interest, enthusiasm and hospitality.

In Stanley the FI Government Air Service and other government departments were most helpful. I am especially grateful to John Ferguson, Tom Davies and their staff at the FIARDC for their hospitality, for discussing their work and providing me with every assistance within their stretched resources.

The satisfactory completion of all the objectives of this project would not have been possible without the help of Malcolm and Glennis Ashworth and most especially Mrs Ada Watts whose home was my base in Stanley and whose kindness and hospitality were unlimited.

In UK I am extremely grateful to my colleagues Dr Martin Wood, Dr Jim Stevens, Dr Peter Christie and Dr Leslie Dickson, of the Department of

Agriculture who have kindly consented to analyse some of the soil samples.

Dr Alwyn Davies of the AWRE at Aldemaston has agreed to carry out some of the trace element analyses. Mr David Stickland of Organic Farmers and Growers Ltd has been most helpful in the planning and organisation of the project.

I would especially like to thank the UK Falkland Islands Trust for giving me the opportunity to visit the Islands again and carry out the project. The Trust's director, Nigel Gribbon, has been most helpful, efficient and generous in organising the whole exercise.

Finally I should like to express my gratitude to the Department of Agriculture for N Ireland for permission to take leave of absence to undertake the project.

BACKGROUND

Nitrogen is the most important major element for plant growth and most trials carried out by the Grasslands Trials Unit and the Falkland Islands Agricultural Research and Development Centre (FIARDC) have demonstrated a significant response to applied N in terms of herbage production. Such a consistent response has not been found for any other form of applied fertilizer. Much of this very important research and development work may now be at a stage where the introduction of a legume into the system should be given some consideration.

Although the peaty soils in the Falklands are high in total N content (2-2.2%) it is apparent that, as a result of the low soil temperatures which favour the formation of acid peats, only a small proportion of the N is in a form available to plants. The breakdown of this organic N is dependent on environmental conditions and the level of microbiological activity (particularly nitrifying and nitrogen fixing bacteria) in the soil. There has been no quantitative measure of the level of biological activity or of the nitrifying potential of Falkland Island soils although it would be expected that such levels are low.

This being the case, it would be of obvious advantage to investigate means of increasing nitrification either by adding nitrogen substate in some form or introducing appropriate strains of bacteria. The resultant improvement in soil fertility would be of benefit to all aspects of farming and horticulture within the Islands.

PURPOSE OF VISIT

In view of the above background, the Falkland Islands were visited during November 1983:-

1) to collect soil and herbage samples for analysis in the UK (detailed below),
2) to initiate a study of the effects of organic and inorganic sources of N on soil chemical properties and biological activity,
3) to test strains of acid tolerant and cold tolerant nitrogen fixing bacteria along with their legume hosts,
4) to assess, as far as possible, the views of the farming public on the use of naturally occurring fertilizer (specifically seaweed) and to estimate the reserves of harvestable seaweed available locally.

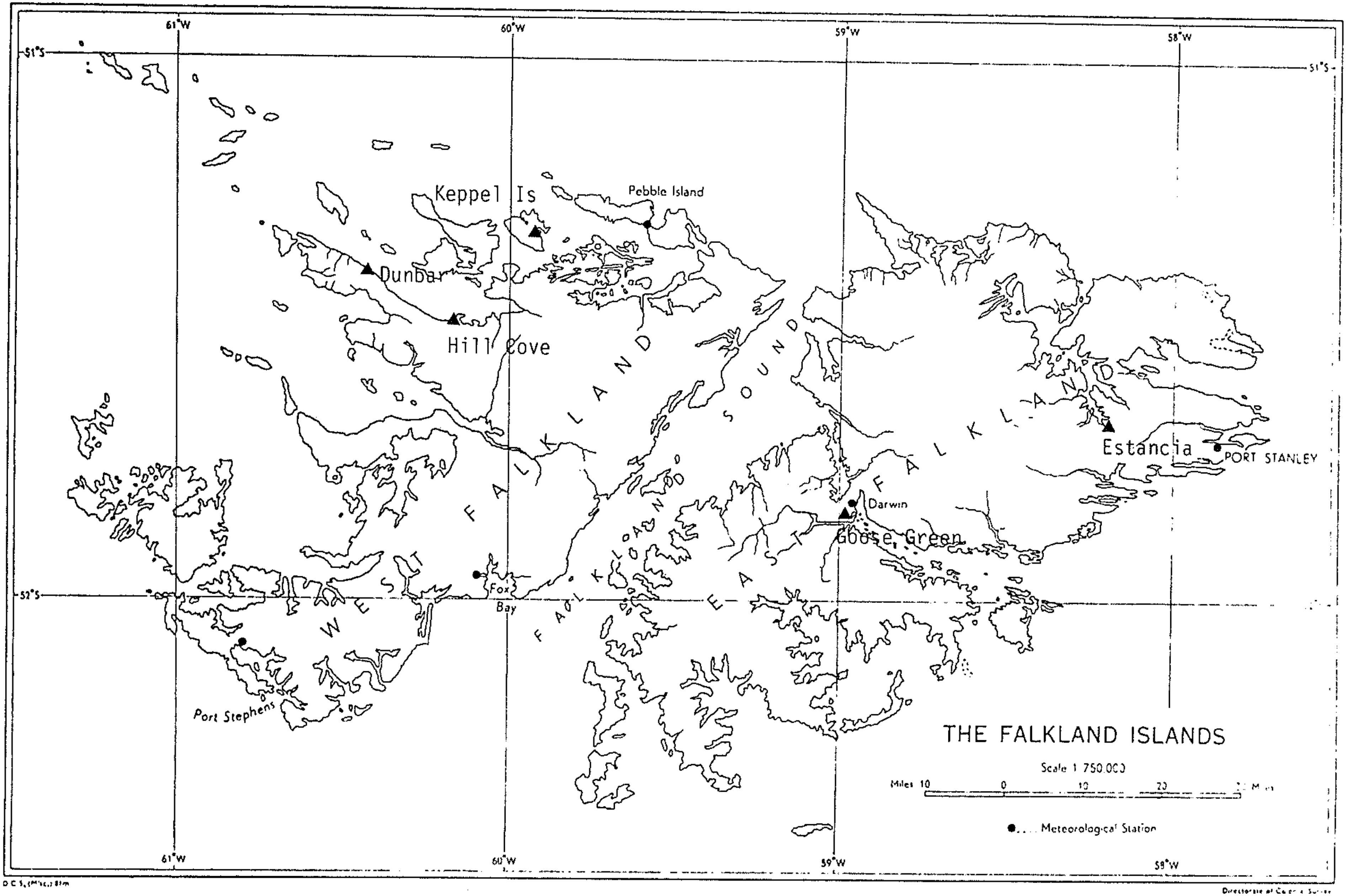


Fig. 1. The Falkland Islands, illustrating the location of the sites referred to in the text and detailed in Appendix 2

It is clear that a realisation of the overall objectives of the project will only be possible when the results of the various soil analyses are available and some details of the regular climate and soil monitoring exercise initiated in the Islands are known.

This preliminary report is, therefore, a summary of the visit, an outline of the nature and quantity of the samples taken, details of the analyses to be carried out, and the opinions expressed by some of the farmers talked to.

TRIALS CARRIED OUT

A SOIL SAMPLING PROGRAMME

(i) Objectives

In previous consultation with the International Institute of Biological Husbandry it was decided to sample soils from at least four sites on three farms. Two of these sites would be on relatively 'good' land which either had a history of cultivation, high stock density or was land likely to be suitable for improvement. The other two would be on unimproved land with a low stock density. The sites would be distributed between East and West Falkland. At these sites soils were to be sampled, mapped and tested and organic and inorganic N sources applied to small plots. Meteorological data were to be collected from as near to each site as possible.

In addition, if possible, a coastal transect (running inland) was to be sampled, seaweed samples taken, samples taken of compost and garden soils and other small trials carried out where applicable.

(ii) Samples taken

(a) Location (Fig 1) (Details - see Appendix 2)

On West Falkland (WF) the 'good' (G) site was at Hill Cove on a previously cultivated area which had received nitrogen fertilizer in previous years. The 'poor' (P) site chosen was an area of natural vegetation on dry shallow soil at Dunbar farm which had no previous history of cultivation or intensive stocking. On East Falkland (EF) both 'good' (G) and 'poor' (P) sites were sited on Estancia farm.

The coastal transect (CT) was taken in Stevelly Bay, Dunbar farm and pasture established by 'conventional' means was sampled at Goose Green - GG (East Falkland). Miscellaneous samples were taken from various localities.

(b) Sampling procedures

Trial sites (see Fig 2). At each site (EFG, EFP, WFG and WFP) an area, 25 m x 25 m, was pegged out and a transect across the area selected. At 5 m intervals along the transect a soil profile pit was dug. From each profile pit samples ('T' samples) and measurements were taken from each definable horizon down to the basal clay. Details of the subsequent treatment and analyses of soil samples are presented in the 'ANALYSES' section.

Small plots (5 in all), 5 m x 2 m, were pegged out within the 25 m x 25 m area and to these the treatments detailed in A (iii) were applied. In two instances (EFG and EFP), where additional cultivation of the plot area was carried out, it was possible to fence the plots from grazing stock. A representative area of vegetation, 30 cm x 30 cm, was clipped from several localities within the plots and topsoil samples (5-15 cm depth) were taken from each plot ('P' samples).

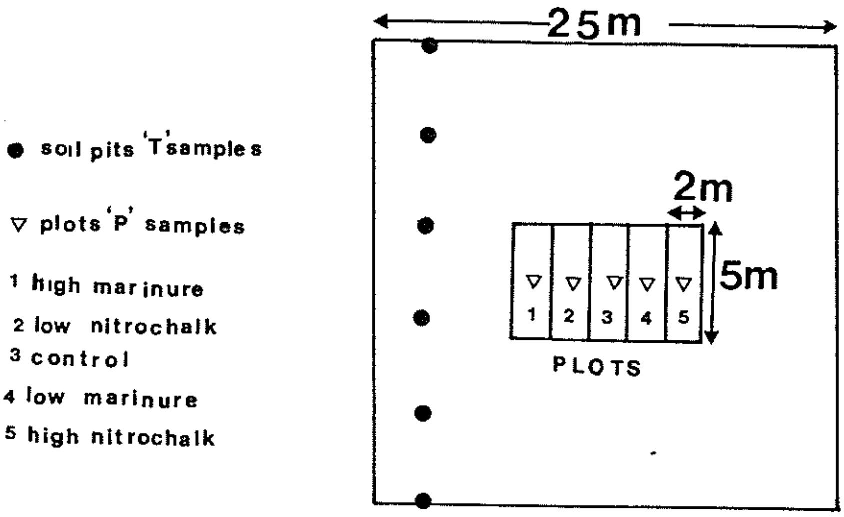


Fig 2. Details of trial sites

Samples to be taken back to UK were stored in domestic refrigerators.

<u>Beach transect</u> (Fig 3). A transect was taken from just above sea level (on a coastal green) extending inland at Stevelly Bay, Dunbar farm (see Appendix 2 for site details). The transect was terminated adjacent to a penguin rookery (Gentoo) approximately 80 m inland and was selected to traverse an area which had been a penguin nesting area in previous years, the birds having moved their nesting ground annually. The lush green turf (mainly *Poa annua*) was evidence of much enhanced fertility as a result of the manurial effect of penguin droppings.

Soil profile pits were dug at 20 m intervals along the transect. To avoid disturbing the birds, the topmost profile pit was dug 25 m from the rookery at a similar height above sea level and only a small surface sample was removed from the rookery area itself.

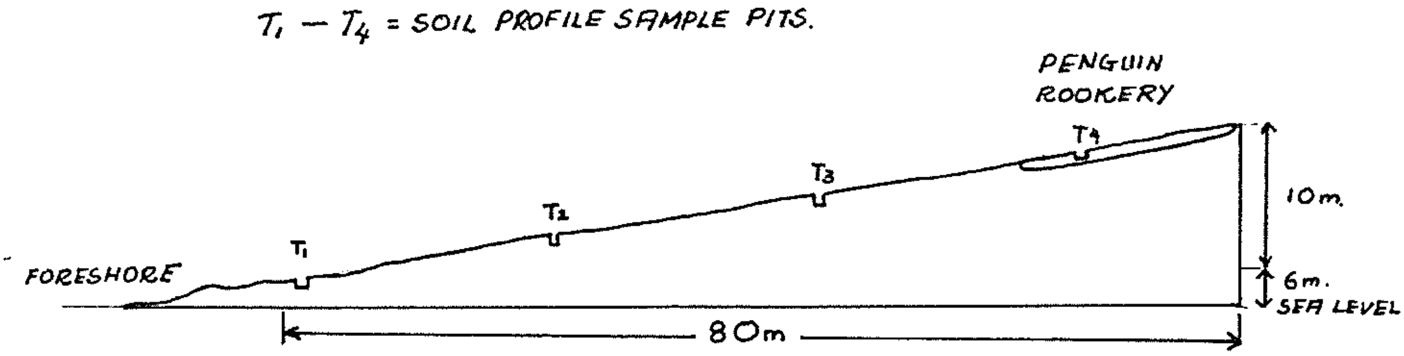


Fig 3. Beach transect profile

Other sample sites (see Fig 1)

At Gocse Green a large (400 ha) section of the Gimmer Ground (Tranquilidad) had been fenced off and within the fenced area approximately 80 ha had been reseeded each year since 1980 following rotavation and burning (see Appendix 2). Each area received approximately 25 kg N ha^{-1} in the second year after seeding with a cocksfoot/red fescue/smooth-stalked meadow grass mixture.

Hence this site presented an opportunity to observe the effect of a relatively low application of N fertilizer on soil N status over a series of years.

Ten-centimetre diameter soil cores (approx 20 cm deep) were taken at random from the four reseed stages viz untreated native vegetation (GG0); after rotavation and burning (GG1); reseed sown out in February

1983 (GG2); reseed sown out in summer 1982 (GG3); reseed sown out in summer 1981 (GG4).

Samples were taken from gardens at Hill Cove, Keppel Is, Boundary Farm (Roy Cove) and Estancia Farm. On at least one farm visited (Hill Cove) correctly prepared compost was widely used and samples of this compost and garden soil (to which it had been applied in previous years) were taken.

(iii) Treatments applied

On the small plots delimited on the trial sites two levels of an organic N source and an inorganic N source were applied to observe the subsequent effect of both sources of N on soil chemical and biological activity.

The source of organic N substrate was a commercially manufactured liquid extract of brown seaweed (see Appendix 3 for chemical analysis). This was applied in diluted form using a watering can with dribble-bar attachment to give two application rates equivalent to 10 litres hectare^{-1} (recommended application rate) and 30 litres hectare^{-1}. At 1.4% N these treatments represent extremely low nitrogen application rates - 0.14 and 0.42 kg N ha^{-1} equivalent.

The source of inorganic N used was Nitrochalk fertilizer (26% N). This was applied at the rate conventionally used in the Falklands (25 kg N ha^{-1}) and, as for the organic N, at three times the conventional rate (75 kg N ha^{-1}).

A control plot (no treatment) was incorporated into the design. Hence, on each trial site, 5 treatments (high and low levels of seaweed extract; high and low levels of Nitrochalk and control) were used with one plot of each treatment.

(iv) Meteorological recording

The recordings being made at each site are tabulated below. Monthly record sheets are to be returned at 4-monthly intervals.

	RECORD			
SITE	MAX TEMP	MIN TEMP	10 CM SOIL TEMP	RAINFALL
Dunbar	x	x	x	x
Hill Cove			x	x
Estancia	x	x	x	x

B NITROGEN FIXING BACTERIA TRIALS

(i) Methods

Small cultures of several strains of acid tolerant and cold tolerant Rhizobium lotii (for trefoils) NZP 2037 and NZP 424 and a similar strain of Rhizobium trifolii (for clovers) HP3 were taken to the Falklands as small agar slopes.

The cultivar of trefoil used was Lotus pedunculatus cv. Grasslands Maku and the white clovers used were Trifolium repens cvs S184, Grasslands Huia (NZ) and Kent wild white.

The Rhizobia were rinsed out of the agar slopes, diluted with water and applied using a watering can with dribble-bar attachment.

(ii) Sites

The above listed of Rhizobia strains were applied to small plots (2 m x 2 m) of the clovers and trefoil listed, in an old garden site at Hill Cove (see Appendix 2).

The cultivar S184 was sown at Estancia on both trial plot sites and the Rhizobium strain HP3 was used.

The owner of Keppel Island (Mr S Miller) has agreed to reseed a small paddock near the settlement early in 1984. He has been given sufficient grass seed, clover seed (cultivars New Zealand Grasslands Huia and S184) and Rhizobia for the purpose.

(iii) Sampling

Soils from areas where white and red clovers were growing were sampled and a Research Fellow in the Department of Agricultural Bacteriology at Queen's University, Belfast has agreed to study the numbers and effectiveness of Rhizobia present. Other soils will be similarly studied.

C SEAWEED EXTRACT TRIALS

In addition to the principal trial areas, liquid extract of seaweed was tried in several other situations.

(i) At Hill Cove, in addition to the clover cultivars referred to above, small plots of cocksfoot cv, Prairial, smooth-stalked meadow grass cv, Newport, and creeping red fescue cv, Rubina, were sown with and without extract applied at the recommended rate of 10 litres ha^{-1}.

(ii) Willow trial. On the same old garden site referred to above, small rows of 3 willow cuttings (possibly *Salix viminalis*) were planted with and without extract applied to the soil at the recommended rate of 15 litres ha^{-1} (as per recommendation for fruit trees) and with the cuttings dipped in dilute extract solution.

(iii) Tussac grass trial. In a small establishing tussac grass (*Poa flabellata*) plantation adjacent to the hen run at Estancia, extract was applied around the base of twelve 'bogs' (see Appendix 2 for site details).

(iv) Conifer trial. Seaweed extract (liberal dressing) was applied to nine young *Pinus contorta* (lodgepole pine) trees (2nd year of planting out) in the corner of a small plantation at Estancia. The trees sprayed were those situated nearest the small pen containing the meteorological instruments.

(v) Oats trial. The extract was applied at 15 litres ha^{-1} to a 10 m x 5 m plot in a small paddock of oats sown at Estancia. The oats were at the 2-3 leaf stage when sprayed.

(vi) Reseed trial. Mr S Miller has been left a sufficient quantity of seaweed extract to apply to the small paddock he has agreed to reseed on Keppel Island. The paddock (0.25 ha), which has been relatively intensively grazed with horses in the past, will be rotavated and seeded with a mixture of cocksfoot cv Prairial, smooth-stalked meadow grass cv Newport and white clover cvs NZ Grasslands Huia and S184.

(vii) Vegetable trial. Mr M Barnes has applied extract to half of the emerging carrots and other vegetables sown in his garden at Dunbar.

In all the above listed trials, the persons responsible for the areas concerned have agreed to report on the relative progress of each trial.

D SEAWEED MEAL TRIAL

(i) Livestock feed

Samples (5 kg) of dried ground seaweed meal (for analysis see Appendix 3) were left at two farms.

(a) On Keppel Island Mr S Miller agreed to feed the meal to weaned lambs.

(b) At Estancia, Mr T Heathman agreed to feed the meal to his two milking cows and their calves.

Both farmers have agreed to comment on the results wherever practicable or noticable.

(ii) Sampling

Samples of both 'leafy' kelp and 'tree' kelp were collected from the lower shore on Keppel Island and in Stanley harbour (see Appendix 4).

ANALYSES

Presented below is a complete list of the analytical procedures carried out. Clearly not all analyses will have been carried out on all the samples collected. The criteria analysed for will depend on the nature of each individual trial.

A ANALYSES CARRIED OUT AND MEASUREMENTS TAKEN IN THE FALKLANDS

A1 The BOTANICAL COMPOSITION of the vegetation on each of the trial sites was described.

A2 The STANDING CROP of herbage was found for each site by clipping 30 cm x 30 cm quadrats. The fresh and dry weights of herbage were found and botanical separations carried out on a subsample of the fresh herbage.

A3 SOIL PROFILE. The depths of the various horizons were noted from the pits dug on the trial areas. Samples were generally taken from each horizon and placed in clean minigrip bags.

A4 The ACIDITY of soil samples was measured using a portable pH meter (Fisons PT1-2). Samples were mixed with an equal volume of distilled water and the pH measured.

A5 The soil CONDUCTIVITY was measured using a portable conductivity meter (Fisons PT1-7D). The results are expressed as microsiemens/cm ($\mu S\ cm^{-1}$).

A6 SOIL MOISTURE CONTENT was measured by drying samples in a domestic oven in the Falklands and checking the results against those for samples sealed and returned to the UK.

B ANALYSES TO BE CARRIED OUT IN UK

A7 BACTERIAL ANALYSES (to be carried out by Tate and Lyle Ltd).

A8 TOTAL NITROGEN CONTENT - measured by Kjeldahl micro-digestion technique.

A9 MINERAL NITROGEN CONTENT ie AVAILABLE NITROGEN.

A10 TOTAL PHOSPHORUS CONTENT.

A11 TOTAL CALCIUM CONTENT.

A12 SOIL ORGANIC MATTER CONTENT.

A13 SOIL NITRIFICATION POTENTIAL - using low temperature (8 and 10°C) incubations.

A14 RHIZOBIA (bacteria) count in soils.

A15 MYCORRHIZAL FUNGI present in soils.

A16 Multielement TRACE ELEMENT analysis.

A17 CLAY PARTICLE SIZE analysis.

A18 Prediction of SUPPLY OF AVAILABLE SOIL N (see Whitehead DC. J. Sci. Food Agric. 1981 32 359-365).

C FURTHER ANALYSES PROPOSED

Samples from the small plots in the trial areas are to be taken at 2-monthly intervals during the next year. At each site, the farmers concerned will measure the pH and conductivity of the soil using the instruments previously referred to (A4 and A5).

Small samples (100 g) from each plot are to be sent to the UK at 4-monthly intervals and some of the NITROGEN analyses (A8, A9, A13 and A18) and the bacterial analyses carried out on these samples.

The value of some of the above will depend on the condition of the samples on arrival in the UK.

RESULTS

In this section the results of analyses carried out in the Falklands are presented.

A BOTANICAL ANALYSES

(i) Botanical composition of trial sites

The botanical composition has been estimated on a percentage cover basis using a scale + (one or two plants only) ..... 10 (representing 100% cover).

(a) 'Good' sites

West Falkland		East Falkland	
<u>Holcus lanatus</u>	7	<u>Holcus lanatus</u>	4
<u>Luzula</u> sp	1	<u>Agrostis magellanica</u>	3
<u>Festuca rubra</u>	+	<u>Gunnera magellanica</u>	2
Bare ground	2	<u>Poa</u> spp	1
	10		10

(b) 'Poor' sites

West Falkland		East Falkland	
<u>Empetrum rubrum</u>	6	<u>Cortaderia pilosa</u>	9
<u>Baccharis magellanica</u>	2	<u>Gunnera magellanica</u>	1
<u>Gunnera magellanica</u>	1	<u>Myrteola nummularia</u>	+
<u>Festuca erecta</u>	+	<u>Luzula</u> sp	+
	10		10

(ii) <u>Herbage standing crop</u>

Estimated from randomly sited quadrats 30 cm x 30 cm cut to ground level.

	'Good'		'Poor'	
	West Falkland	East Falkland	West Falkland	East Falkland
Fresh wt (g m^{-2})	923	526	2286	1444
Dry wt (g m^{-2})	277	252	1166	968
Dry matter content (%)	30	48	51	67
% Green in dry matter	53	68	34	26

B SOIL PROFILES AND ANALYSES

(i) Trial Areas

(a) East Falkland 'Poor'

		Transect position					
		1	2	3	4	5	Means
SOIL PROFILE (cms)	1. Horizon 1 (brown fibrous peat)	30	30	39	31	34	32.8
	2. Horizon 2 (sticky black peat)	9	11	8	9	15	10.4
	3. Blue clay	WITHOUT SMALL STONES/WITH SMALL STONES					
MOISTURE CONTENT (% FRESH WT)	Horizon 1	85	86	87	85	87	86
	Horizon 2	69	71	68	73	73	70.8
pH	Horizon 1	4.1	4.1	4.2	4.2	4.2	4.16
	Horizon 2	4.4	4.4	4.4	4.4	4.4	4.4
CONDUCTIVITY ($\mu S\ cm^{-1}$)	Horizon 1	160	150	150	170	170	160
	Horizon 2	150	150	120	140	120	136
PLOTS	pH	4.2	4.2	4.1	4.1	4.1	4.14
	CONDUCTIVITY	180	150	160	150	200	168

(b) West Falkland 'Poor'

		Transect position					
		1	2	3	4	5	Means
SOIL PROFILE (cms)	1. Horizon 1 (well humified peat)	23	26	24	22	20	23
	2. red brown clay			all			
MOISTURE CONTENT	Horizon 1	39	43	37	36	39	38.8
pH	Horizon 1	4.2	4.5	4.2	4.2	4.2	4.26
CONDUCTIVITY	Horizon 1	1550	1620	1480	1480	1520	1530
SMALL PLOTS	pH	4.5	4.4	4.3	4.3	4.4	4.38
	CONDUCTIVITY	1250	1150	1580	1480	1540	1400

(c) East Falkland 'Good'

		1	2	3	4	5	Means
SOIL PROFILE (cms)	1. Horizon 1 (dark soil with many roots)	21	21	24	24	22	22.5
	2. Clay	brown	brown/ blue	brown/ blue	blue	blue/ grey	
MOISTURE CONTENT	Horizon 1	46	43	44	49	50	46.4
pH	Horizon 1	4.5	4.1	4.4	4.3	4.4	4.34
CONDUCTIVITY	Horizon 1	180	190	180	180	180	182
SMALL PLOTS	pH	4.6	4.6	4.6	4.6	4.5	4.58
	CONDUCTIVITY	180	200	250	180	200	202

(d) West Falkland 'Good'

		Transect position					
		1	2	3	4	5	Means
SOIL PROFILE (cms)	1. Horizon 1 (very dark soil - good crumb structure)	31	30	18	14	30	24.6
	2. Clay			Blue clay			
MOISTURE CONTENT	Horizon 1	59	58	51	55	56	55.8
pH	Horizon 1	4.0	4.1	4.1	4.2	4.0	4.08
CONDUCTIVITY	Horizon 1	200	210	250	230	210	220
SMALL PLOTS	pH	4.0	4.1	4.2	4.1	4.1	4.1
	CONDUCTIVITY	230	220	240	230	250	234

(ii) Coastal transect

		FORESHORE (6 m.a.s.l.) - - - 80 metres - - - - INLAND (16 m.a.s.l.)			
		T1	T2	T3	T4
SOIL PROFILE (cms)	1. Horizon 1 (sand/soil/peat)	25	13	22	24
	2. Horizon 2 (black amorphous peat)	40	33	36 (some sand)	21 (some sand)
SOIL PROFILE (cms)	3. Horizon 3 (gravelly blue clay)	15	13	10	0
	4. Horizon 4 (sticky blue clay - no gravel)				

		T1	T2	T3	T4
MOISTURE CONTENT (%)	Horizon 1	14	12	12	22
	Horizon 2	68	32	46	38
pH	Horizon 1	3.9	4.5	4.25	5.5
	Horizon 2	4.0	4.2	3.9	4.2
	Horizon 3	4.5	4.5	4.6	-
CONDUCTIVITY ($\mu S\ cm^{-1}$)	Horizon 1	1610	1510	1380	15500
	Horizon 2	1350	1310	1350	2240
	Horizon 3	1400	1350	1280	1310

(iii) <u>Other sites</u>

(a) Gardens and improved sites

	pH	Conductivity
Fertile garden (Hill Cove)	4.5	560
Compost (" ")	6.2	3750
Garden soil with compost added 1 yr previously (Hill Cove)	5.0	2400
Soil from oat field (Estancia)	3.8	480
Soil from site of clover (*Rhizobia* and seaweed extract trial)	4.1	350

(b) Native vegetation sites

		pH	Conductivity	Moisture Content
Native vegetation - low grazing density				
(Hill Cove)	Horizon 1 (0-7 cm)	3.8	300	66
	Horizon 2 (7-25 cm)	3.9	240	62
- high grazing density				
(Hill Cove)	Horizon 1 (0-7 cm)	4.9	280	46
	Horizon 2 (7-25 cm)	4.8	250	35
Pond green (Dunbar) (*Agrostis*/*Poa*/*Gunnera*)	Horizon 1 (0-10 cm black soil)	4.5	1010	67
	Horizon 2 (10-33 cm brown fibrous peat)	5.0	1840	49
	Horizon 3 (33-40 cm sand)			
	Horizon 4 (dark blue clay)			

DISCUSSION OF RESULTS

The sites chosen represent a wide range of vegetation and soil types found in the Falklands. All sites were acid (4.08-4.58) with most having low levels of soluble salts (conductivity 160-200 $\mu S\ cm^{-1}$). The dry soil from the poor site on West Falkland was the exception with an unusually high conductivity level (1500 $\mu S\ cm^{-1}$).

The 'poor' site on East Falkland was typical of the large areas of whitegrass which are widespread throughout the Islands whereas the drier, shallower soil from the 'poor' site on West Falkland was very typical of large areas of hard camp found on West Falkland. The difference in moisture content of the two soils (86% and 39% respectively) was very marked.

From the results presented there is little to distinguish between the 'good' and 'poor' sites with pH, conductivity and moisture contents comparable. The results of the chemical analyses (especially available N) should illustrate some of the fundamental differences between soil types.

The complex horizons found in the coastal transect were possibly a function of the cumulative effect of seabirds (mainly penguins) and blown sand. The shallow top horizon was much drier (moisture content 15%), more fibrous and sandy than the deeper, wetter second horizon (mc 46%) and there were distinct clay horizons.

The high conductivity levels of soils at this site are to be expected with the exceptionally high value (15500 $\mu S\ cm^{-1}$) found at the penguin rookery reflecting the high concentration of soluble salts in the birds' droppings. Such soils should be high in available N.

The garden soils were surprisingly acid although their conductivity levels were higher than those for surrounding soils. Even with the limited results available the enhanced pH and level of soluble salts in properly made compost illustrate its value as a soil improver. This statement is borne out by the results of the analysis of a garden soil with compost added one year previously. Although the pH was lower than that of the pure compost, the conductivity level was still approximately 4 times that of an adjacent, untreated soil.

There can be considerable variation between results from apparently similar sites. The vegetation found on a 'pond green' at Dunbar was very similar to that found in the 'high grazing density' sheep paddock at Hill Cove yet there was a 5-6 fold difference in their conductivity levels of their respective soils.

In conclusion, although the soils represent a wide range of soil and vegetation types found on the islands, the few simple analyses performed in situ do little to portray the inherent differences in the soil types. The soils are uniformly acid with most variation occurring in moisture and conductivity levels. The results of the chemical and microbiological analyses will be of much more interest.

OPINIONS AND CONCLUSIONS

Three of the farms on which trials were conducted are relatively small owner-occupied holdings. The incentive of ownership seems to have instilled an enthusiasm amongst each of these people to improve the quality of their own holdings. Each individual expressed a willingness to co-operate with and assist in any venture which might bring about grassland improvement on their farm though for two of the people, Tony Heathman at Estancia and Marshall Barnes at Dunbar, investment in grassland improvement must still be of a low priority. These farmers are still 'finding their feet' and the prohibitive cost of fencing materials, machinery for cultivation and fertilizers provide some inducement to consider and explore alternative forms of land improvement. Although their farms are small and they will be under considerable pressure to remain viable, their attitude is a positive one and augurs well for the future of agricultural development within the Islands.

On Keppel Island, the other 'small' farm, Sam Miller has had time to become established and with potentially good land resources available is almost in a position to consider pasture improvement. He did, therefore, express great interest in any means of improving soil fertility, either conventional or relatively unconventional. He is particularly interested in the possibility of using liquid seaweed extract as a fertilizer living, as he does, on a small island. He plans to use an old sheep dipping tank to liquify some seaweed collected locally.

At Hill Cove the gardener, Ron Reeves, is an enthusiastic and dedicated organic gardener and the initial results from his compost and compost-treated soils are encouraging. There is a tradition of good gardening in the Falklands and the islanders are well acquainted with the practice of composting although seaweed is not widely used. Sheep manure (collected from sheds) is dug into the gardens and it could be said that most of the garden produce from the Islands is grown 'organically'.

Goose Green farm, the largest company-owned farm in the Islands has a relatively ambitious reseeding policy. The effects of the low levels of applied N on soil fertility will be interesting to note though it is felt that the older reseeds will soon exhibit nitrogen deficiency. It is somewhat surprising that even 2 years after a relatively low N application, the sown species are performing reasonably well. Perhaps once nitrogen cycling has been stimulated on this relatively good soil type, soil N reserves are mobilised and cycling is maintained for some considerable time. Hence the importance of stimulation of nitrogen cycling by whatever means possible. Brook Hardcastle has also experimented with the introduction of clovers into an established reseed. This is an encouraging development and now seems an appropriate time to consider the introduction of acid-tolerant, cold-tolerant strains of Rhizobia bacteria to enhance the clover growth and to contribute to the overall pool of nitrogen cycling in the system. It still remains to be demonstrated that widespread use of legumes in the Falklands will be a feasible proposition but it seems as if some progress and development might be made along the lines of introducing suitable inoculant bacteria.

Hence, most people talked to were receptive to the idea of improving the biological activity of the soil although one must continually emphasise the considerable constraints on the soil system, namely the acidity, the low soil temperatures and periods of often considerable water deficit (see Appendix 5). It is not widely realised that drought poses a problem in summer time in the Falklands and rapid surface-drying of the shallow peat by strong, cool spring winds imposes severe restrictions on plant growth. It may be that such constraints may impose a very low ceiling on the level of improvement possible.

The cost of importing fertilizers to the Islands is prohibitive and there is interest in any means which might alleviate the need to use large quantities of nitrogenous fertilizers. It may be that low levels of application of inorganic N (such as are being investigated thoroughly by the FIARDC at present) to stimulate N cycling, followed by introduction of more effective soil nitrifying bacteria may prove to be a successful treatment. The importance of nitrogen is clear - the problem of mineralisation and release of N is of the most fundamental importance to the islands and this is well realised. There is also widespread support for the idea of using local seaweed as a source of fertilizer. Realistically it is difficult to see how such low levels of applied N can have a significant effect on pasture growth and soil microflora though in this context the results of the various analyses will be of great interest. It is a salutory thought that to add an equivalent of 25 kg N ha^{-1} (probably the absolute minimum required to have a significant effect, as was seen on Brook Hardcastle's reseed at Goose Green) would require the application of approximately 2 tonnes of dry seaweed (almost 7 tonnes of wet weed) per hectare.

In a study for the Overseas Development Administration entitled "Land systems analysis of the Falkland Islands, with notes on the soils and grasslands" by R B King, D M Lang and A Blair Rains (1969, reprinted 1982) it was concluded that "In the Falkland Islands the mineral soils appear adequately supplied with potassium and the application of seaweed to grassland is unlikely to bring about any improvement either in their nutrient status or in their physical condition".

The interest expressed in the use of legumes is to be encouraged and further work on effective low temperature strains of Rhizobia would appear to be worthwhile.

Summary of conclusions

The farmers were receptive to considering almost any means of pasture improvement although for most of the relatively new 'small' farmers in the islands there were many other investment priorities before land improvement. Some of the better established 'small' farms and the larger farms are in a position where some form of pasture upgrading is essential if their enterprises are to expand. The soils are almost uniformly peaty and acid with soil moisture deficits proving a problem in many places where improvement is to be carried out. The problem of stimulating nitrogen cycling and mineralisation of N from such organic soils is not an easy one to resolve. Although the environmental constraints are great and although conclusive evidence is lacking, experimentation with combinations of inorganic N applications, suitable bacterial inoculations and the use of legumes may yield some positive results.

APPENDIX 1 - ITINERARY OF VISIT

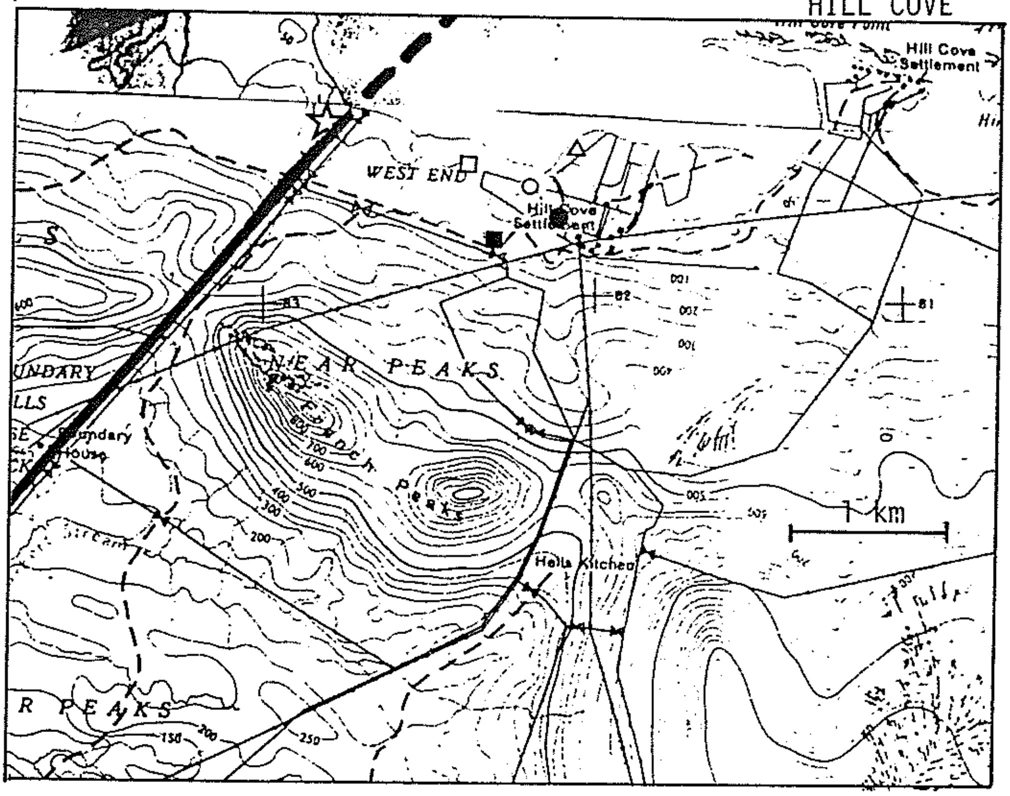
MON 31st OCT	Fly Belfast - London and overnight at RAF Brize Norton.
TUES 1st NOV	Fly RAF Brize Norton - Ascension Is (via Dakar).
WED 2nd	Fly RAF Hercules ("Air Bridge") Ascension - Stanley (unable to land) - Montevideo, Uruguay.
THURS 3rd	Fly RAF Hercules Montevideo - Stanley.
FRI 4th	Book return flight to UK, local flights to W Falkland, speak to W Falkland and E Falkland farms by radio telephone. Discuss current experimental work with FIARDC.
SAT 5th -	Discussions with FIARDC staff and visit experimental plots near Stanley.
MON 7th	By air to Hill Cove to carry out trials (WF - 'Good' site) and sample sites.
THURS 10th	Overland Hill Cove - Dunbar farm to carry out trial (WF - 'Poor' site) and carry out coastal transect.
SUN 13th	Overland to Hill Cove to complete trials.
MON 14th	By air to Keppel Island to sample soils, arrange seaweed extract trial and seaweed meal feeding trials.
WED 16th	By air from Keppel Is - Stanley (stop over at North Arm for 5 hours).
THURS 17th	Overland Stanley to Estancia to carry out trials on 'good' and 'poor' sites (EF) and various seaweed extract and seaweed meal trials.
SUN 18th	Return to Stanley from Estancia (overland).

MON 19th	Fly to Goose Green to sample reseeds of varying ages.
TUES 20th	Stanley to settle accounts, sample peat core, carry out analyses and pack samples. Meetings with Sir Rex Hunt, FIARDC personnel, Mr Fred Gooch (seaweed survey) and some farmers.
FRI 25th	Depart for UK.

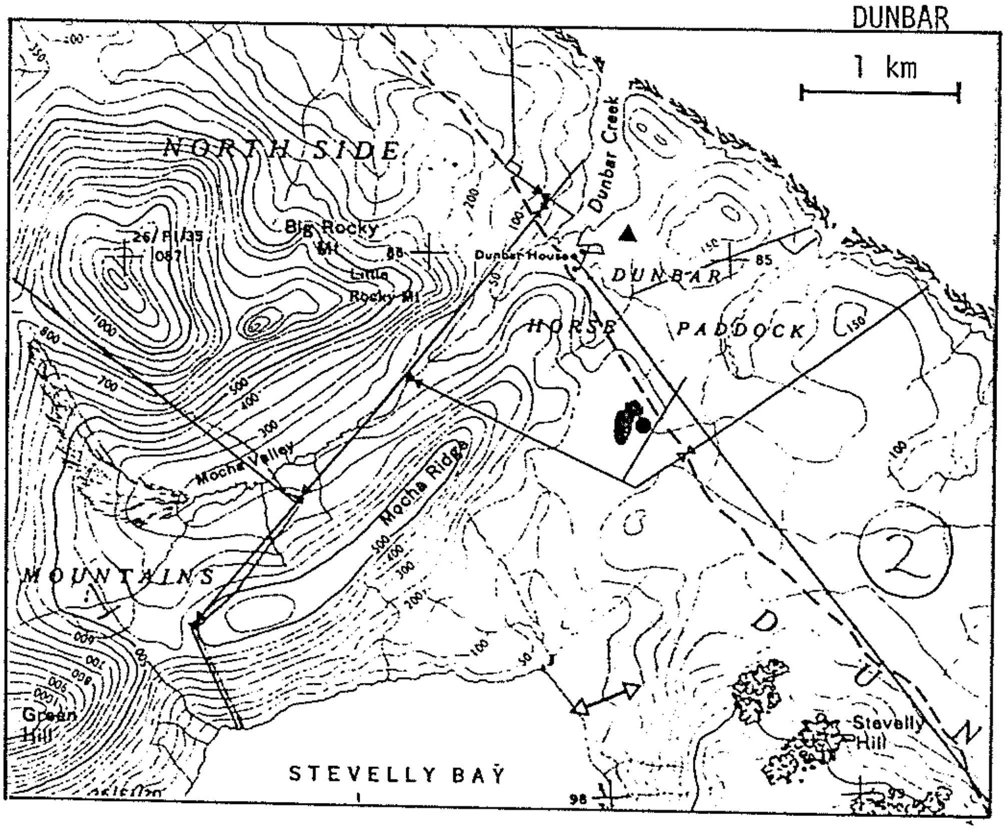
APPENDIX 2 - SITE DETAILS

1 WEST FALKLAND

a. Good (Δ) site; Rhizobia bacteria trial, seaweed extract trials, legume trials (●); Compost sampling and garden sites (○); High (■) and Low (□) intensity grazing sample sites. Boundary farm oat paddock (☆).

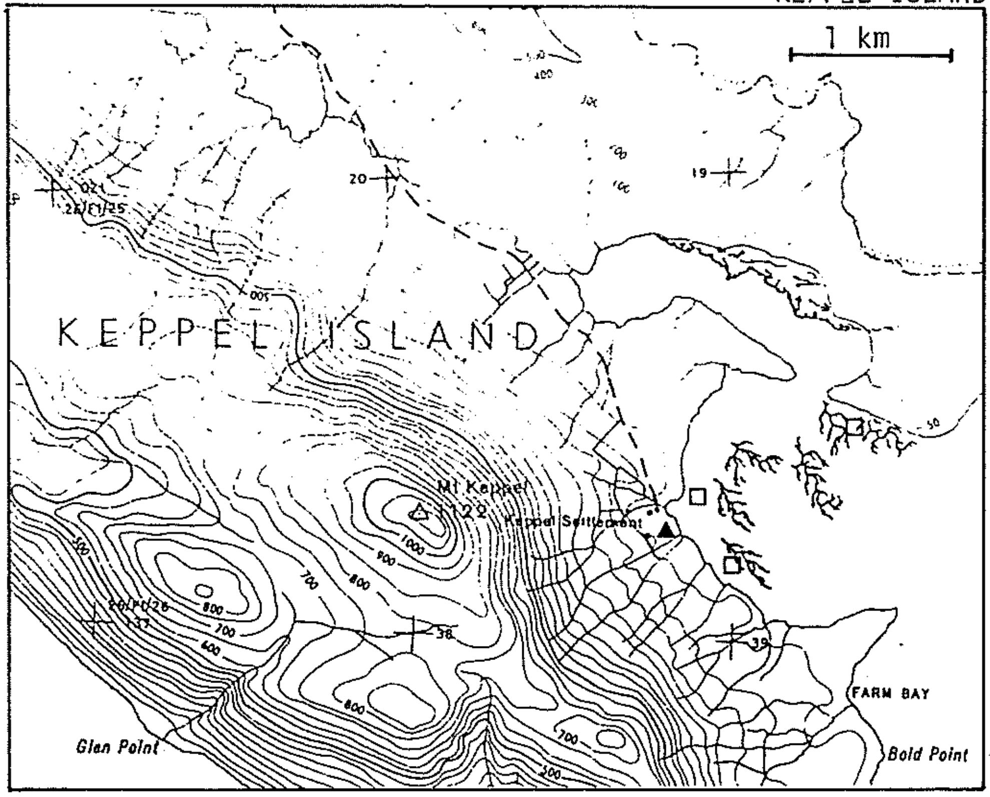


b. Dunbar Farm. 'Poor' site (▲); Coastal transect (◁—▷): Pond green sample site (●).



c. Keppel Island. Seaweed sampling (□); Reseeding using seaweed extract (▲).

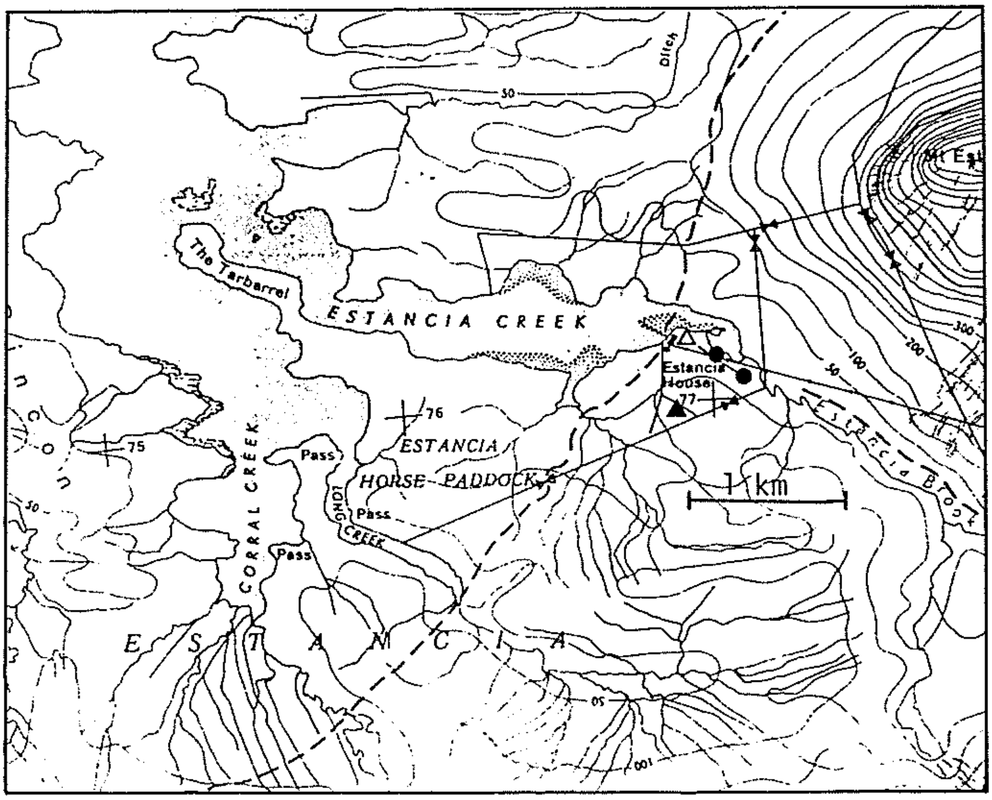
KEPPEL ISLAND



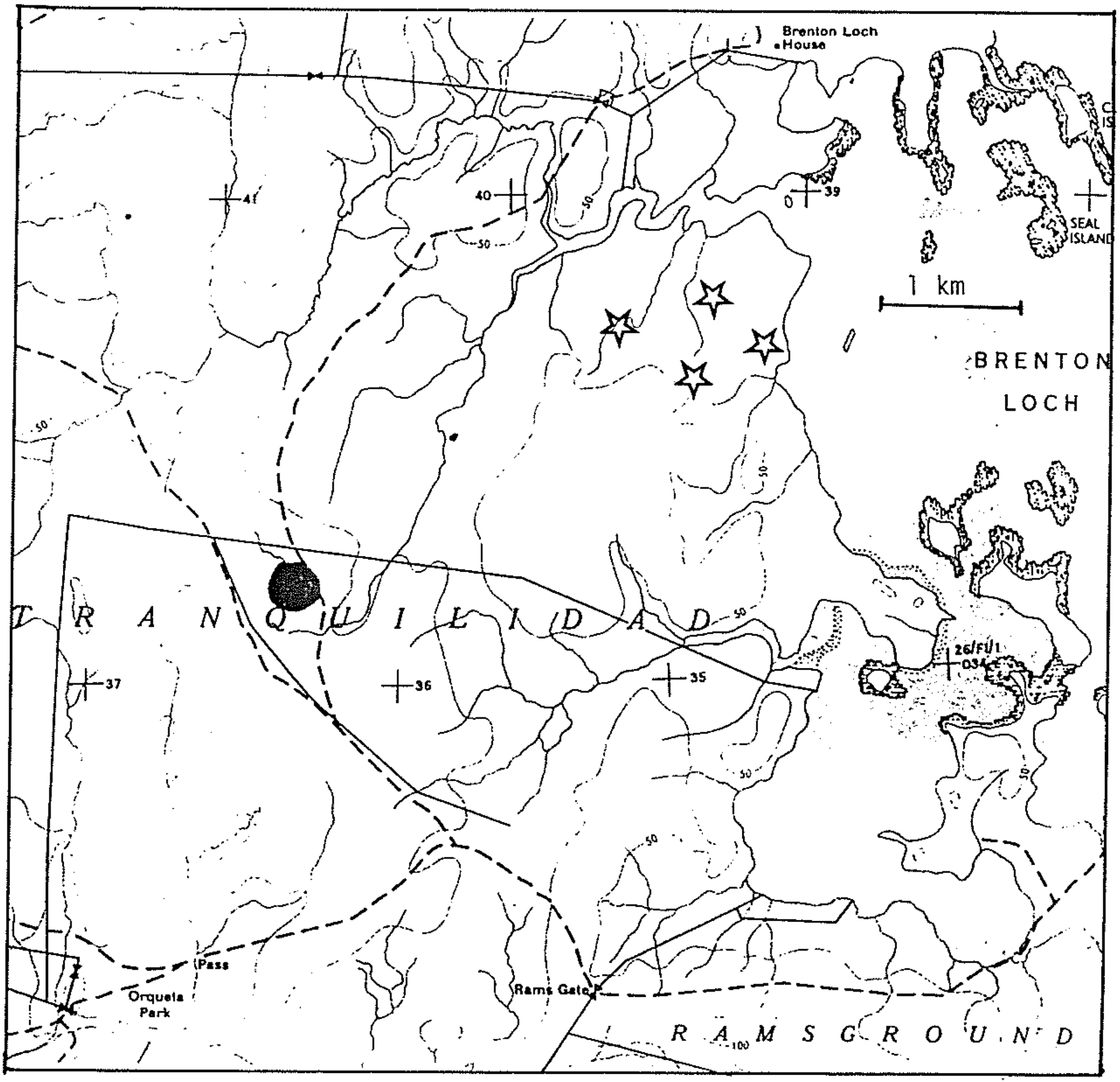
2. EAST FALKLAND

a. 'Good (△) and 'Poor' (▲) sites; various seaweed extract trials (●).

ESTANCIA



C. Goose Green Farm. Approximate sites of sequential reseed sampling (☆)



APPENDIX 3 - SEAWEED MEAL AND LIQUID EXTRACT ANALYSES

Analyses of "MARINURE" liquid extract of seaweed and "ALGIT" seaweed meal as provided by the UK agents, Organic Farmers and Growers Ltd of Ipswich.

(i) Liquid extract of seaweed

Average Analysis of MARINURE in dry powder form

		%			parts per million
Dry matter		92/95	Al	Aluminium	5,0
Moisture		5/8	B	Boron	82,0
Organic matter		50/55	Co	Cobalt	1,6
Inorganic matter		40/45	Cu	Copper	5,0
			Fe	Iron	3000,0
N	Nitrogen	1,4	I	Iodine	1800,0
P	Phosphorous	0,05	Mn	Manganese	12,0
K	Potassium	2,5	Ni	Nickel	5,0
Ca	Calcium	1,2	V	Vanadium	0,7
Mg	Magnesium	0,8	Zn	Zinc	100,0
S	Sulphur	3,7			
Cl	Chlorine	4,0	Cytokinins and other growth promoting hormones		130-260,0

(ii) Seaweed meal

Average Analysis of ALGIT		Some elements		mg/kg
Crude Protein	5-8%	Ag	Silver	0,5
Crude Fat	2-4%	Al	Aluminium	400,0
Nitrogen free extract		B	Boron	70,0
(Carbohydrates)	55-60%	Ba	Barium	35,0
Fibre - less than	8%	Br	Bromine	1,0

Ash	20-27%
Sand - less than	0.5%
	mg/kg
Provit A (beta carotene)	40-65
Vit B_1	6-8
Vit B_2	5-10
Vit B_{12}	0,004
Vit C	200-400
Vit D	4
Vit E	100-200
Ascorbic Acid	500-1000
Folic Acid	0,2
Folinic Acid	0,2
Niacin	10-30
Pantothenic Acid	3

Aminoacids, analysis to date shows 20 different aminoacids present:

Alganine	Lysine
Arginine	Methionine
Aspartic Acid	Ornithine
Citrulline	Phenylalanine
Cystine	Proline
Glycine	Serine
Glutamic Acid	Treonine
Histidine	Thyrosine
Isoleucine	Valine
Leucine	Tryptophane

Ca	Calcium	12,500,0
Cl	Chlorine	25,000,0
Co	Cobalt	4,0
Cr	Chromium	1,0
Cu	Copper	4,0
Fe	Iron	500,0
Ge	Germanium	0,5
I	Iodine	800,0
K	Potassium	25,000,0
Mg	Magnesium	7,000,0
Mn	Manganese	35,0
Mo	Molybdenum	0,5
N	Nitrogen	10,000,0
Na	Sodium	35,000,0
Ni	Nickel	4,0
P	Phosphorous	1,200,0
Pb	Lead	1,0
S	Sulphur	3,000,0
Se	Selenium	0,7
Sr	Strontium	1,0
V	Vanadium	3,0
Zn	Zinc	100,0

APPENDIX 4 - SEAWEED RESOURCES IN THE FALKLAND ISLANDS

1. Terminology

In the Falklands seaweed is referred to locally as "kelp". The term "kelp" is an inclusive one referring to several species of brown seaweed found growing in different zones just below the water line. The main species of interest in the Falklands and also the most abundant is Macrocystis pyrifera which tends to be found in the deeper waters of the sub-littoral zone, and which forms vast beds commonly extending to many hectares. Other species found, and also included under the name "kelp" are species of Lessoniae (mainly L. flavicans but also L. nigrescens and L. frutescens).

In the context of this report the word "kelp" will be assumed to refer to Macrocystis pyrifera.

2. Chemical analysis of kelp

There are few reliable chemical analyses of the kelp found around the Falkland Islands. There have been detailed analyses made of the chemical composition of various brown seaweeds found in other localities and their composition is probably fairly similar to that of kelp.

Kelp samples were, however, collected during this visit and these are being analysed for major and trace elements.

3. Abundance and annual sustainable yield

All the information available on this subject is published in The Shackleton Report (1976 Vol 1 pp 150-152) and in the report of a survey made by the Kelco Company of San Diego in 1973 when a commercial evaluation was made of the Falkland Islands Macrocystis resource. I am grateful to Mr Fred Gooch of Stanley for allowing me access to the Kelco report and for permission to quote from it.

Lord Shackleton has estimated that the total sustainable yield of the Falklands resource is 1 million tonnes of wet weed per annum - yielding 80,000 tons of dried milled weed.

The Kelco estimate, based on a detailed coastal survey by sea and air, covered the entire south coast of East Falkland from Cape Pembroke round to Choiseul Sound and then down the East coast of Lafonia to Bull Point. A small length of coast to the north of Stanley was also included by the survey. This whole length of coastline, representing the area that could be worked from Stanley (and approximately 1/6 of the total coastline) had a standing crop in excess of 120,000 tonnes. It was anticipated that three harvests per year could be sustained giving approximately 360,000 tonnes of wet weed or 28,000 tonnes of dried weed.

It has been estimated that this represents one of the largest areas of sustainable kelp resource in the world at present.

4. Utilization

It is clear that the Falklands do have a huge and potentially valuable seaweed resource. Commercial companies have shown some interest in this in the past. Alginate Industries Ltd had a pilot plant operating until the early 1970s but ceased production due to a worldwide slump in the alginate trade.

Just prior to the Argentine invasion in 1982 an American company (Ocean Labs Ltd) expressed great interest in establishing a seaweed drying and milling plant with a view to export.

Hence there is clearly a well recognised potential. In the past the possible utilization of kelp in the Islands in agriculture and horticulture has been seen to be along 2 main lines:-

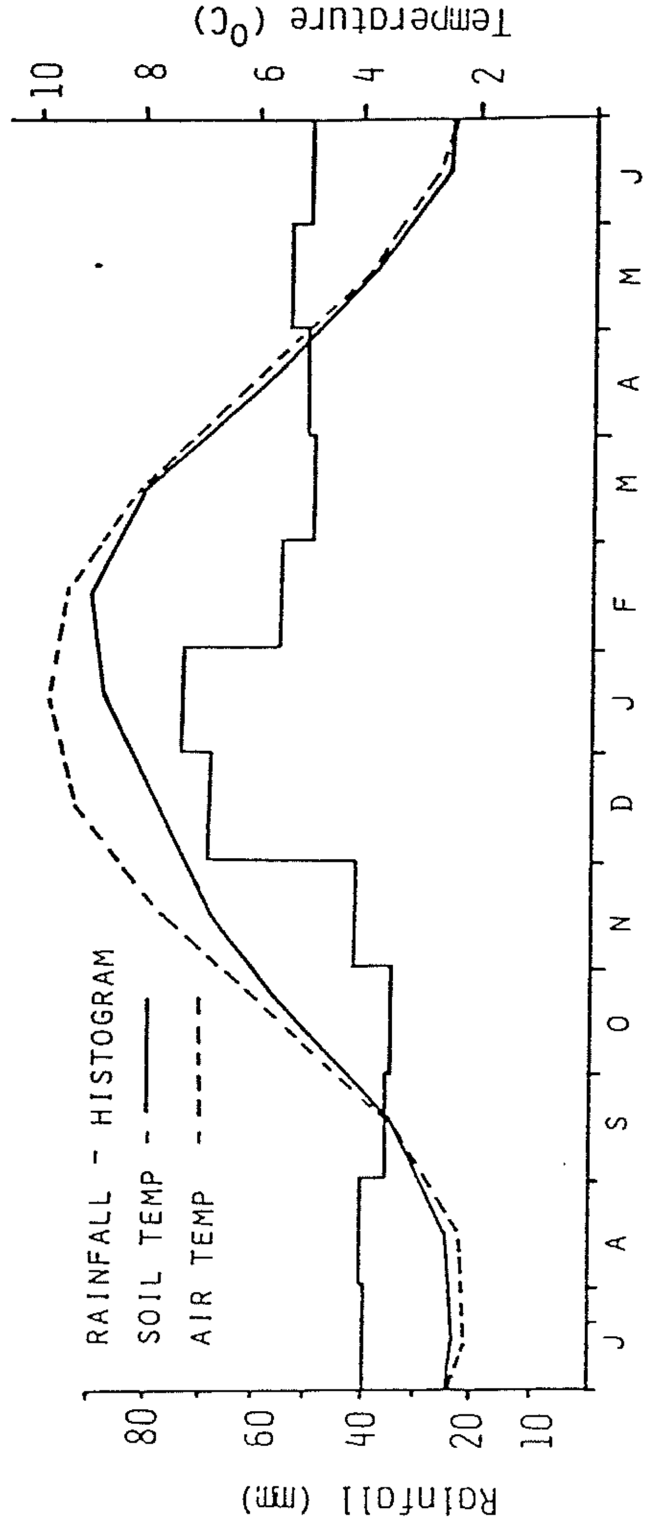
(a) dried, ground and fed as meal to breeding sheep or used to check trace element deficiencies.

(b) in making the cost effectiveness of a commercial horticulture scheme more attractive in its usage as an adequate natural substitute for artificial fertilizer.

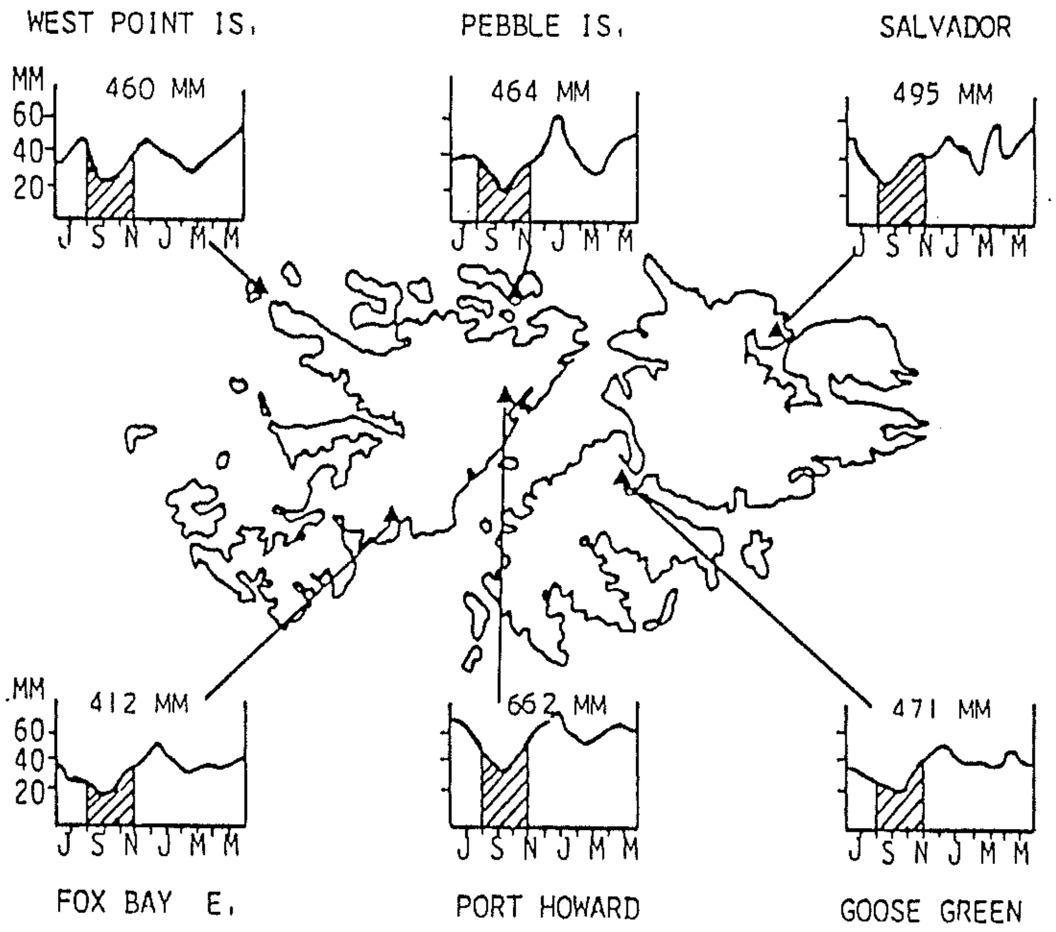
The results from the present exercise may indicate the viability of these proposed uses or may shed more light on other possible uses of kelp in the Falklands.

APPENDIX 5 METEOROLOGICAL DATA FROM THE FALKLAND ISLANDS

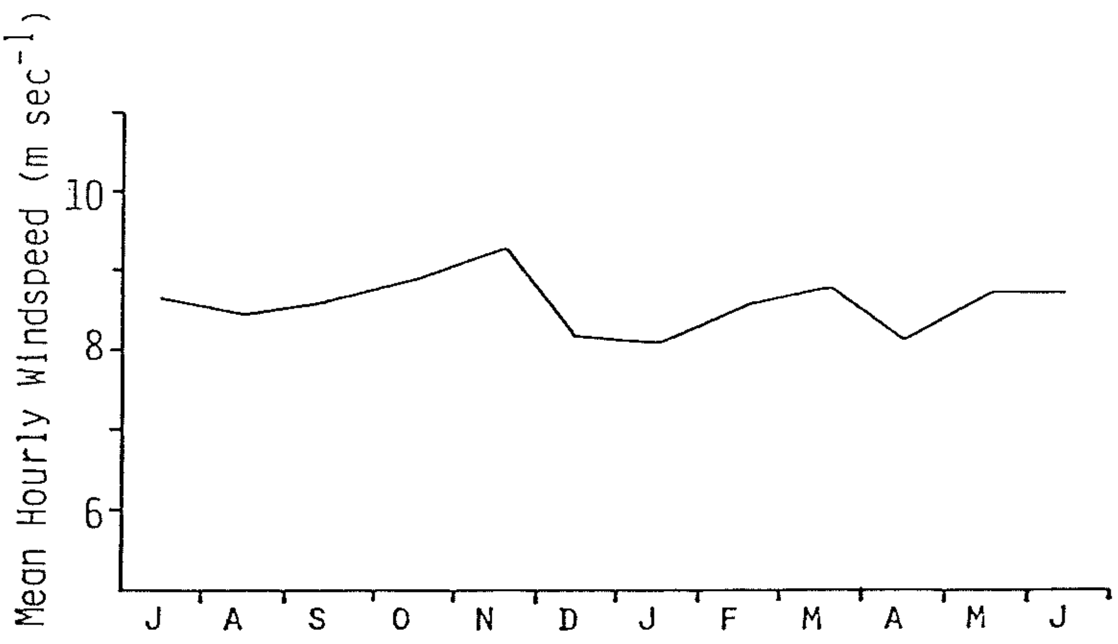
A. Rainfall, air and soil temp. B. Rainfall distribution
C & D. Windspeeds E. Wind direction



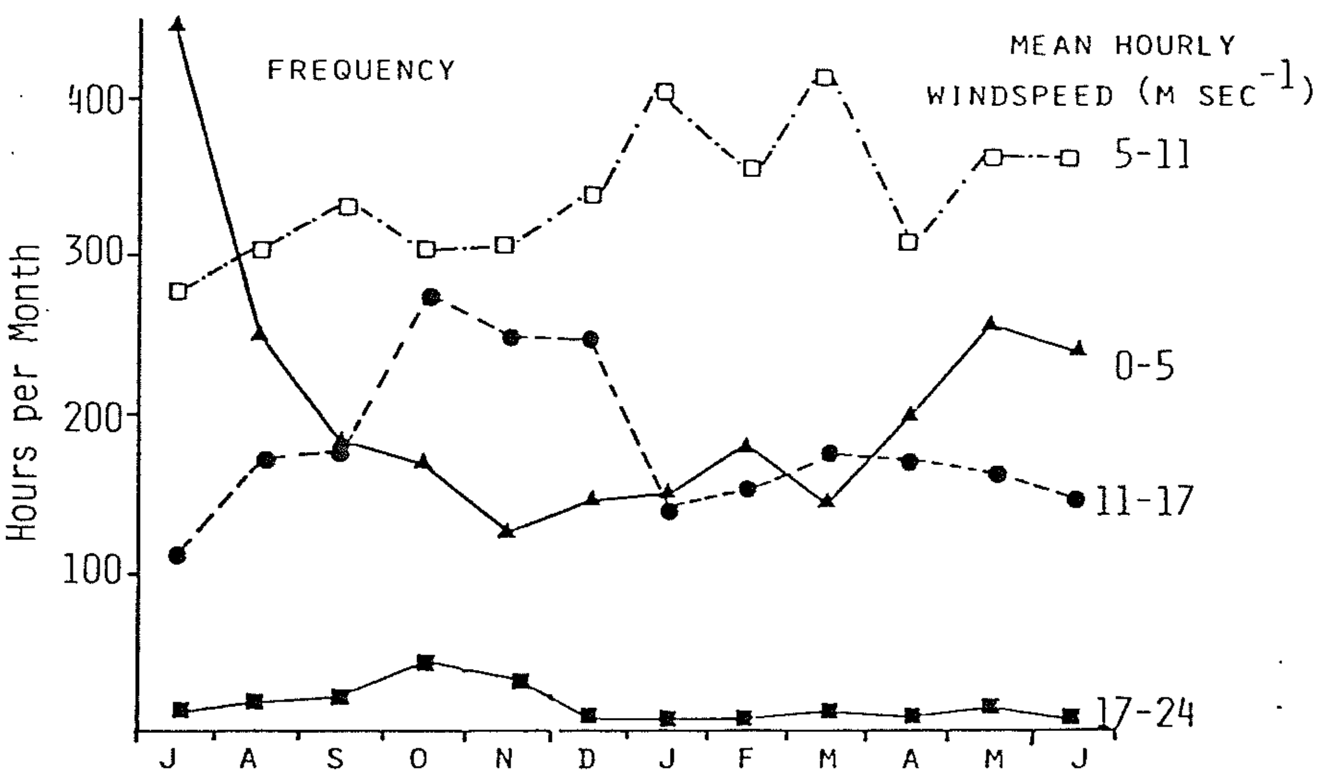
A. The mean monthly rainfall, 10 cm soil temperature and air temperature at Stanley (30 year mean).



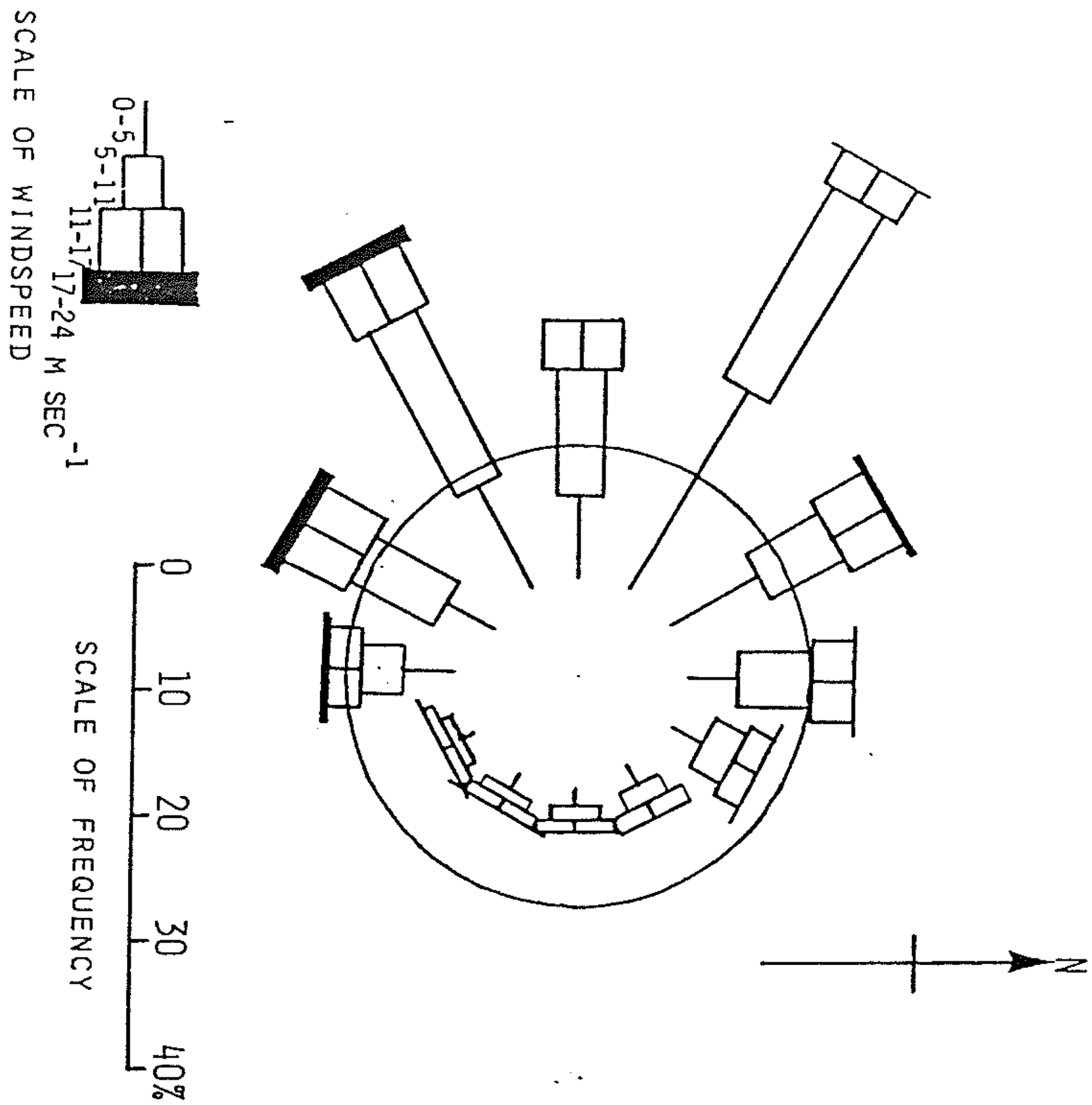
B. The seasonal distribution of rainfall from 6 stations (▲) in the Falkland Islands.



C. Mean hourly windspeed at Stanley, East Falkland (1976-79).



D. The number of hours per month when the mean hourly windspeed was 0-5 (▲-▲), 5-11 (□- - □), 11-17 (●--●) and 17-24 (■-■) m sec^{-1}.



E. The mean frequency, speed and direction of the wind at Stanley for the whole year (means 1944-1950)