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THE CONTROL OF HELMINTHS IN SCOTTISH HILL SHEEP BY THE USE OF TETRAMISOLE

THIS THESIS CONSISTS OF A STUDY ON THE CONTROL OF HELMINTH PARASITES AS ONE METHOD OF IMPROVEMENT IN THE SCOTTISH HILL SHEEP INDUSTRY. REFERENCE IS MADE TO THE STRUCTURE AND GENERAL ECONOMIC BACKGROUND OF THE INDUSTRY AND CURRENT TRENDS AND INFLUENCES.

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FOREWORD

This thesis examines, in the context of the Scottish hill sheep industry, the effectiveness of worm control measures within the different husbandry systems using the anthelmintic tetramisole. This involves both a biological and an economic evaluation of the effects of the anthelmintic. The large volume of earlier work on anthelmintics has concentrated on biological evaluation almost to the complete neglect of economic considerations. The author believes that the failure to undertake such integrated studies leaves a serious gap in the evaluation of anthelmintics.

The method of investigation is to conduct a large number of field trials under different husbandry systems on commercial hill sheep farms in Scotland. The choice of field trials is dictated by the objective of carrying out an economic evaluation with tetramisole. It is recognised that field trials lack the precise control available in laboratories and on experimental farms. However, a reduction in the degree of control is unavoidable if an economic appraisal is to be conducted since farmers do not operate under laboratory conditions.

The field trials are designed to measure the physical parameters, i.e. production factors, liveweight gain and fleece weights to which realistic economic values can be given. They are sited on a large number of farms throughout Scotland to take into account area differences in topography, climate, management and nutritional status.

In particular, the study relates the use of the anthelmintic to the scope and need for husbandry improvements in hill farming. Many hill farmers are attempting (or are envisaging) methods of intensification in order to raise flock performances and increase farm outputs, despite the inherent problems due to the position of their farms. The control of helminthiasis is of significance in any improvement scheme.

Accepted routine times of drenching in hill farming practice have been examined to confirm (or otherwise) previous field studies conducted many years ago with earlier anthelmintics. The opportunity is also taken to examine optimal times of drenching and to gauge the response where new management practices have been introduced, e.g. in-wintering of ewe hoggs.

In view of these considerations, the approach taken in this thesis is to relate the practical aspects of husbandry to the economic and helminthological considerations so as to form one cohesive study. Hence an extensive review of the industry, husbandry systems and helminthology is made to draw all the parts of the related disciplines together to give perspective to the field work. The project design is described in Chapter I. In Chapter II the results of the field trials are set out in tables according to the different drenching protocols for ewes and hoggs; the latter according to the particular system of husbandry employed. Summary tables are also shown for both ewes and hoggs. In Chapter III the results are discussed in two clearly differentiated parts, technical and economic.

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GLOSSARY OF TERMS

Hill sheep farming in Scotland, as in other sectors of the industry, has its own special technical vocabulary. For the sake of clarity some of these terms are defined.

RAM OR TUP	An entire male sheep used for breeding.
HOGG	Sheep from six months to gimmer stage: usually considered a gimmer after milk clipping in July. (Thus: ewe hogg or wether (or wedder) hogg, i.e. castrate).
GIMMER	Female sheep from about $1\frac{1}{2}$ to $2\frac{1}{2}$ years. Most hill ewes are mated for the first time as gimmers.
KEBBED EWE	A ewe that having conceived, loses the foetus before the end of pregnancy (cf. "yeld").
YELD (OR EILD) EWE	Ewe which has not conceived that season.
CAST EWE (OR DRAFT)	A breeding ewe which is drafted out of the flock for some physical defect (e.g. teeth; age; bad udder). In normal practice it is usual to cast ewes from the flock at five to six years of age.
MARKING LAMBS	The removal of part of the tail, also castration of males not to be kept for breeding.
SPEANING LAMBS	The practice of permanently removing lambs from the ewes (i.e. weaning).

SHOTTS Poor lambs unlikely to develop sufficiently well to make satisfactory breeding ewes.

BREEKING EWE HOGGS (hence: DE-BREEKING) The practice is confined to ewe hoggs being wintered on hill pastures where it is necessary to prevent service by rams at the breeding season. Basically it is a crude contraceptive method - consisting of sewing a small square of canvas under the tail on three sides, leaving the lower portion free. Thus, various expressions refer to the operation, e.g. "breeks on" or "breeks off".

HIRSEL A large part of a hill farm - perhaps a whole hill-side. An area capable of carrying about 500 to 700 breeding ewes.

HEFT A hirsel is usually split into several hefts: these are areas roughly of equal size, usually divided from each other by a natural barrier such as a mountain stream, ridge or a ravine. A heft will sustain sbout 70 to 150 ewes and with very few exceptions they will go to their own heft without being driven all the way there, such sheep are then described as "hefted". There will, of course, be differences between hefts depending on the quality of the keep, the elevation and the aspect.

RAKING The movement of a heft of ewes or of the flock to graze the lower pastures during the day, returning to the higher ground in the late afternoon or evening.

Raking is a partly instinctive grazing behaviour of sheep but in the Borders, it is assisted by shepherds in their daily routine.

IN-BYE A portion of land near to the farm buildings either under permanent grass or even partly cultivated.

YELD-CLIPPING The practice of shearing ewe hoggs and yeld ewes at the same time. Invariably it is done during June.

MILK-CLIPPING The practice of shearing the main breeding flock. Invariably it occurs during July or early August.

UDDER LOCKING Removal of wool around the udder to allow the lamb freedom to suck. The gathering for this purpose gives shepherds the chance to identify barren ewes.

LIST OF PARASITES

A list, naming in full the internal parasites mentioned in this thesis is as follows.

Phylum NEMATHELMINTHES

Class NEMATODA

Order Strongyloidea

Bunostomum trigonocephalum

Chabertia ovina

Cooperia curticei

Dictyocaulus filaria

Haemonchus contortus

Muellarius capillaris

Nematodirus battus

Nematodirus filicollis

Oesophagostomum columbianum

Oesophagostomum venulosum

Ostertagia circumcincta

Ostertagia trifurcata

Ostertagia ostertagi

Trichostrongylus axei

Trichostrongylus colubriformis

Trichostrongylus vitrinus

<u>Order</u> <u>Ascaroidea</u>

Strongyloides papillosus

<u>Order</u> <u>Trichuroidea</u>

Trichuris ovis

<u>Phylum</u> PLATYHELMINTHES

<u>Class</u> TREMATODA

<u>Order</u> <u>Digenea</u>

Fasciola hepatica

DEFINITION OF A HILL FARM

The wide range of conditions found in Scotland, as in other hill farming areas of the U.K., makes any exact definition difficult as so much depends on the geographical position of the farm and the husbandry methods employed.

One acceptable definition is where at least 90% of the land area is in rough grazing and 35% of its labour requirements are for sheep.

In the majority of cases and where the terrain permits, there is also a limited enclosed area of better land known as "in-bye" which is either partly cultivated or kept entirely under permanent grass.

The extent of in-bye can range from a few acres or a "strip", so characteristic of crofts, to over 100 acres on hill farms. In some respects the extent of in-bye is an indication of what is possible in terms of wintering hoggs, fattening lambs or keeping cattle during the winter. It is also a measure (though not invariably) of the level of livelihood which can be derived from the farm. It can also be one measure of the scope for improvements.

The type of farm classified geographically as "upland" is often included in the term of "hill farm" and it would be difficult to distinguish it from a true hill farm in some areas of Scotland. But, compared to other hill farming areas of Britain, the characteristic difference lies in the relationship between the amount of rough grazing and of improved land. Generally, upland farms have a larger area of improved land devoted to arable cropping and to beef cattle. This gives it economic advantages in terms of potential for improvement, compared to the true hill farm.

However, in both types of farm, irrespective of structural differences, flocks of Blackface and of Cheviot breeds are predominant.

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INTRODUCTION

PART I

The Scottish hill sheep industry

Aspects of flock management

Dependence on the market

Trends towards improvement

THE SCOTTISH HILL SHEEP INDUSTRY

In the economy of the sheep production process of this country, the two Scottish hill breeds - Blackface and Cheviot - constitute an integral part. Well suited to their rigorous environment of rough hill and mountain grazings, both breeds provide a valuable source of breeding stock for other parts of the country and other management systems.

Permanent hill flocks provide surplus ewe hoggs and draft ewes for farms further down the chain of production, to be crossed with lowland breeds such as the Border Leicester. The progeny, whether it is the "Greyface", produced from the draft Blackface ewe, or the "Scotch Halfbred" from the Cheviot, inherit hybrid vigour. These female first-cross progeny may then be crossed with rams of quick maturing breeds, such as the Suffolk, to produce fast-growing fattening lambs.

The stratified nature of the industry, therefore, implies the movement of sheep from land of low to higher fertility. The implications of this, infer a greater fecundity arising from hybrid vigour, increased production costs but, nevertheless, a greater level of profitability.

Within these broad confines there are variations in practice, e.g. wether lambs are sold as "stores" or fat from pure or cross-bred flocks. Basically, hill farms in Scotland, as in other hill farming areas of the country, are dependent on sheep (and on cattle possibly to a lesser degree).

(a) Area

Forty per cent of the agricultural area of Scotland ($12\frac{1}{2}$ million acres) consists of rough grazing land representing two-thirds of the total acreage of rough grazing in Britain, most of which is devoted to hill farming.

(b) Population

Table 1 gives official data for the total population of 29 million sheep in the United Kingdom (1970).

Table 1 — 1970

	Total U.K.	Scotland	On hill and upland	On hill only
Breeding ewes	13m	7m	3m	$2\frac{1}{2}$m
Blackface	25%	-	-	77%
Cheviot	5%	-	-	15%

Other hill breeds and first crosses make up the remaining 8%.
Sources: D.O.A.S. Subsidy returns (1969) HMSO Agric. Statistics (1969)

The total population of sheep in the United Kingdom has declined in recent years for economic reasons by 10% or approximately three million ewes.

The significant fact remains, that this downward trend has been accompanied by an increase in the average flock size with twice as many units (500 ewes and over) found in Scotland compared to other parts of the country. Of even more significance, this trend is more marked in the hill farming sector, possibly encouraged by increased subsidy rates (page 50) and the economic necessity to raise outputs, and to make improvements.

(c) Size and composition of farms

Since 1968, Scottish farms have been classified in terms of labour requirements (designated as "standard man-days" - S.M.D.) and farms with over 250 standard man-days have been placed in eight main types.

Table 2 shows that hill and upland farms together constitute about 26% of the total of Scottish farms and, although they are below average in terms of size of business and labour requirements, compared to lowland grass and arable farms (700 - 900 S.M.D.), the hill and upland sector, nevertheless, carries extensive acreages of rough grazing. Therefore, hill sheep farms with an average of 4,000 acres carry nearly 40% of the Scottish ewe flock and the upland area carries a further 26%. It is significant in economic terms that over 80% of each group raise beef cows and this number is increasing in recent years with increased Government support in the form of subsidies.

Table 2 - Distribution of holdings by type of farming (a) 1963, 1965 and 1968

Type of Farming	Holdings ('000)			Percentage		
	1963	1965	1968(b)	1963	1965	1968(b)
Hill Sheep	1.4	1.3	1.5	5	5	6
Upland	3.8	3.2	4.5	14	13	20
Rearing with Arable	5.7	5.1	3.5	20	20	16
Rearing with Intensive Livestock	1.7	1.3	0.6	6	5	3
Arable Rearing and Feeding	2.3	2.2	1.4	8	9	6
Cropping	3.9	3.6	4.0	14	14	18
Dairy	7.4	7.2	5.7	26	29	25
Intensive	1.9	1.3	1.4	7	5	6
Total	28.1	25.2	22.6	100	100	100

(a) Holdings with 250 smds or more.

(b) Smd factors were revised in 1965 and 1968 and holdings reclassified in 1968.

Source: H.M.S.O. The changing structure of agriculture (1970)

(d) <u>Regional distribution - farms and flock sizes</u>

Table 3 - Hill sheep farms - number and distribution*

	Scotland	North East	East	South East	South West	High Lands
No. of farms	2,025	77	305	233	614	796
Proportion of all hill sheep farms %	100	4	15	12	30	39
Proportion of all full-time farms %	6	1	6	8	7	22

Table 3 indicates the distribution of hill farms within Scotland and shows the Highland region to have 39% of the hill sheep farms and the South West has some 30% although within this latter area, "true" hill farming cannot be described as predominant. At the other extreme, the North East of Scotland with more fertile land has, as might be expected, the smallest concentration with only 4% of the farms.

In the distribution of flocks by size, the largest are to be found in Argyllshire, Perthshire, Roxburghshire and Dumfriesshire whilst at the other end of the range, the smallest flocks are in what is described as the "crofting" counties of Sutherland-shire, Ross-shire and Inverness-shire (including the Islands). This is shown in Table 4 which has been self-compiled from data extracted from subsidy returns and then allocated into appropriate geographical regions. This compares the Borders and the Highlands and illustrates the two extremes of flock size.

*Source: H.M.S.O. Types of farming in Scotland (1952)

Table 4 - Number of flocks

Flock Size	Highlands	North East	East C.	South East	South West	Total
1 - 24	3,662	212	8	10	20	3,912
25 - 49	2,841	183	13	2	29	3,068
50 - 99	1,794	179	40	8	116	2,137
100 - 199	757	165	116	41	256	1,335
200 - 299	275	87	92	54	212	720
300 - 499	280	73	120	116	292	881
500 - 699	145	23	94	70	196	528
700 - 999	107	9	47	46	124	333
1,000 - 1,999	128	6	68	81	116	399
2,000+	43	-	16	8	18	85
	10,032	937	614	436	1,379	13,398

THE SIGNIFICANCE OF THE HILL AND UPLAND SECTORS

Table 5 - Comparisons of value of hill and upland production with that of Great Britain, 1967

Item	Value of output from hills and uplands	Value of total G.B. output	Hills and uplands output as a % of total G.B. output
	£m	£m*	
Crops	6	368	2
Cattle	36	242	15
Sheep and Wool	32	100	32
Pigs; Eggs and Poultry; Milk and Milk products and Other Cattle	5	822	1
Total Livestock	73	1,166	6
All agriculture	81	1,760	5

* Source: Annual Abstract of Statistics

Table 5 shows the value of hill and upland production compared with the total agricultural output of Great Britain in 1967 indicating that the total value produced from hill and upland farming is £81 million equivalent to 5% of the total gross output of the whole industry.

(a) Scottish contribution

It is extremely difficult in the absence of data and because of various complications, to place a realistic value on the contribution made by the hill and upland sectors of Scottish sheep farming. Basically, this is due to an annual movement from hill to lowland sectors both in Scotland and in England. Also, store animals off hill farms may be slaughtered immediately, or may spend a fattening period on upland or lowland areas before slaughter.

However, it can be calculated very roughly, that possibly over two million lambs and hoggs are sold annually from the Scottish hill and upland sector (the contribution by each sector is indivisible) and possibly over one million are sold as stores - of which, possibly 25% are sold into England in any one year. Thus, it could be roughly estimated that sales of all classes of sheep could be valued at over £20 million.

In terms of wool production, the value of the turnover in the United Kingdom (British Wool Board returns) is estimated to be £13.03 million, Scotland's total contribution to this being estimated as £3.65 million.*

(b) Government support

Hill farming is a heavily subsidised sector of the Agricultural Industry. Currently (1971) the rate of subsidy is £1.425 per hill ewe and £0.90 per upland ewe. Other provisions are available in the

*Data calculated from Brit. Wool Board returns 1970-71.

series of Government Acts, enabling hill farmers to get further assistance - especially for those who wish to try out new techniques and methods to increase production.

ASPECTS OF FLOCK MANAGEMENT

A diagrammatic representation of the management cycle indicating the general sequence of events is shown in Figure 1. This can only be general, since it is acknowledged that there will be a difference of a few weeks in the timing of seasonal operations and variations in management practice as between one area and another throughout Scotland.

Methods of selection and management

(a) Lambs

The lambing period usually extends from mid April to the beginning of May (if not later) although in some districts, it can commence earlier. Whilst lambing on the hill normally occurs ewes may be lambed on in-bye or on fenced lower hill pastures on some farms. The marking of lambs takes place by mid June and speaning is done during August or even September depending on the area. Following this, store lambs and surplus ewe lambs are disposed of at the annual autumn sales.

Ewes with twins are invariably kept on in-bye or on rented grazings throughout summer but the lambs are dealt with in a similar fashion as single lambs kept on the hill pastures.

(b) Ewe hoggs

The hill sheep system being a self-replenishing one, a number of ewe lambs (usually 30 - 35 per 100 ewes) are retained from each year's ewe lamb crop. The quality of the animals selected is basically determined by the total number weaned successfully to August or September, and also on the owner's subjective judgement as to what constitutes "quality" aided by his knowledge of the animal's performance as a lamb, and the dam's earlier productive performance. However, there is some risk attached in making a "once-for-all" selection on mere subjective opinion as pointed out by Cooper's (1958) statement: "There is an almost complete absence of measurement of performance in sheep, and selection based largely on eye appraisal has not been very effective in improving economic traits".

A more unsatisfactory position is reached if, due to low lambing rates and poor performance during the summer months, only a small number of lambs are in fact available for selection. (Pages 32, 69).

Where surplus ewe lambs are available for selection, it is a more satisfactory practice to retain all the ewe lambs except "shotts" at speaning, and at a later stage, i.e. in the spring of the following year, to make subsequent re-selections as hoggs and even later as gimmers before the breeding season. This practice is followed by a few farmers, and may lead to long term improvement in flock performance. (Page 39, 69).

(c) Ewe hogg wintering systems

The choice of system as between keeping hoggs at home or sending them away to be wintered on a lowland farm is largely dictated by availability and quality of pasture and local conditions of climate.

i) Hill wintering

In milder districts where it is feasible (or where it is an economic necessity), hoggs are wintered alongside the ewes on the hill pastures and "breeked" before the tups are released. Some breeders assert that, although the animals' body condition is reduced by the spartan conditions during winter, they develop greater hardiness, heft better and develop resistance to tick borne diseases (Robinson, 1953). Whatever the arguments to support "acclimatisation value", there is little doubt that bodyweight, if it is a reflection of "condition", is considerably reduced during the winter. (Page 106, 212).

ii) In-bye wintering

The success of this system is dependent on the availability of suitable terrain and on the extent and quality of the grazing, supplemented by root crops or other feeding, and therefore, is more feasible on upland farms rather than on the true hill farms. The potential success of the system can be reduced if the pastures are grazed earlier by ewes with twins, or by draft ewes together with cross-bred lambs during the summer and early autumn.
This reduces not only the quality of the grass in the autumn "flush" but even if it is a way of raising flock output, it is also a source of general infection as a result of heavy over-crowding with older sheep. (Pages 54, 66, 183).

iii) Away-wintering

The reasons for away-wintering ewe hoggs are invariably due to the inadequacy of the in-bye and hill pastures and the recognition by many hill farmers that the conditions during winter would severely reduce the condition of these young animals. It also relieves the "pressure" on the main ewe flock for "grazing room" besides reducing the spread of infection from parasites. (Pages 70, 185).

If the home pasture has an inherent mineral "deficiency", away-wintering may have a "tonic" effect and for this reason many wintering sites enjoy a high reputation.

The period of away-wintering extends from about October 1st to April 1st. In different areas various districts for wintering ewe hoggs are favoured by farmers such as the South West, along Speyside in the North East, along the shores of the Moray Firth and in the Black Isle in Ross-shire. In central Scotland, flocks can be found in the Carse of Stirling. In the Borders, some hill farmers send their hoggs away for shorter periods during winter to the West and South West.

In recent years, a general scarcity of suitable "winterings" and the rising cost of transport and labour, have forced some to adopt alternative systems such as in-shed wintering.

iv) In-shed wintering

This method, as an improvement tactic, has become slowly established in recent years, although the system is by no means an innovation. There are various historical references to the practice (Mackintosh 1729; Hogg 1888; Brydon cited by Wallace 1923; Haldane 1952; Symon 1959). Indeed in the Highlands and Islands (such as in Sutherland-shire and Lewis) over a period of 40 years or more, it has not been at all unusual to in-winter small numbers of poorer hoggs on the crofts. Various reasons have encouraged some hill farmers to adopt in-wintering in recent years. The basic reason is not necessarily humanitarian to protect sheep from the rigours of winter weather, but more an exercise either in the preservation of pasture and soil structure on in-bye when it is very wet for long periods (prevention of "poaching"); saving the in-bye for other purposes; or simply as an alternative system due to the shortage of away-wintering ground and to make some saving in agistment charges.

In modern practice there are variations in the system depending on farm situation:-

i) the animals are completely confined for whole or part of the winter season.

ii) a modification, by allowing the animals access to a pasture area during the daylight hours.

Sometimes, where the animals are housed in early winter they may be put inside on being gathered off the hill pastures or, housing may be delayed and they are kept on in-bye for a number of weeks before housing.

Many hill farmers have adapted existing buildings but those who have put up new buildings require at least some capital and notwithstanding the cost of feeding, this outlay must be recouped by benefits including a reduction in labour costs.

On balance, the suitable adaptation of existing buildings or the erection of specially low cost buildings made from salvaged materials have proved to be essential to produce a viable proposition on the short or medium term. However, no matter what sort of building has been adopted, adequate ventilation, floor space and proper feeding facilities are essential.

(d) Ewe management

In traditional practice the ewe flock is only gathered from the hill pastures for the usual seasonal operations (e.g. sorting, dipping, etc.). The flock can be held in-bye, or on fenced lower pastures to facilitate close shepherding at tupping, lambing or for feeding at strategic periods in the year.

In Scotland there are many variations in the methods of management but basically there is a similarity between the Borders and the rougher areas of the Highlands. However a distinctive feature of the management in the Southern Uplands, unlike the Northern areas, is the hefting system where each hirsel is split into hefts usually composed of 75 - 150 animals and each heft is self-replenishing. A further distinctive feature is that from late winter until early summer the sheep are "raked", that is they are driven downwards in the morning and upwards in the afternoon. In the areas north of the Forth there is virtually no daily raking although on some farms there is a daily inspection routine (if not, every two or three days). In the absence of regular "raking" and in the winter the sheep grazing in "families" tend to congregate on the lower slopes which are inclined to become fouled with faeces; in summer they tend to keep out on the higher ground which may be cleaner.

There are very few hill farmers who, as yet, have adopted the strategy of in-wintering gimmers and ewes despite what appears to be a sound enough policy if stocking rates are to be increased, twinning encouraged and early lamb mortality reduced alongside other improvements. The main reluctance of farmers to in-winter ewes appears to be based on the economics of the practice and in consideration of the extra costs involved principally by extra feed and housing. Salmon (1970) writes, "It is clear, therefore, that the simple substitution of in-wintering, without intensification, is unlikely to increase the profitability of a sheep flock substantially".

Major constraints on production and profitability

(a) Physical constraints

Modifications in the traditional systems on hill farms of the United Kingdom must be related to the quality of the land, the topography and the climatic conditions - no control over the last two factors being possible.

This can be judged from the wide variety of conditions found on Scottish hill farms as between the rugged mountainous exposed terrain of the North West and the milder gentler grassy hills of the Borders. In some districts rainfall can be up to 100 inches. Winter snows can be heavy in some areas. It follows, therefore, that these different conditions influence what can be expected or what is potentially possible in terms of flock performance both in output and profitability. Thus the economic prosperity of the owners and the scope for improvement can differ widely. (Pages 50, 51-56).

In particular, pasture production sets limitations which are largely dictated by low soil fertility which in turn generally declines with increasing altitude. This is the primary reason for stocking rates being set according to the limited resources of winter grazing and limited supplies of winter keep.

In full realisation of such limitations, the Hill Farming Research Organisation has turned its attention to the problem. Eadie (1967) in pointing out the unbalanced situation between the patterns of pasture growth existing through the seasons, describes the situation as a vicious cycle reflected in flock performance (pages 32-34) whilst Hunter (1962), in appreciation of the seasonal patterns and grazing intensities in a free range set-stocked system, stresses the effect of long term climatic conditions and the trend towards pasture and soil deterioration over the years. It seems that the problems are largely inherited due to the depression and readjustment at the early part of the century and before, leading to gradual but progressive deterioration. This is summarised by the "Report of the Committee on Hill Sheep Farming in Scotland" (1944) which states:-

> "The first prosperous phase of hill sheep farming, particularly in the Highlands, was undoubtedly a period of "extractive" farming. The fertility of the land to which the industry had fallen heir was gradually exploited and much of the profit made was really capital extracted from the land; little was put back", and further, "This failure on the part of the industry to preserve fertility and carry out improvements in good times has continued up to the present day".

This was said about thirty years ago and it may still be an indictment of some farmers even today, although there are nowadays more significant restrictions. For instance, the changing economic position is perhaps more critical. Nevertheless, the problems in relation to raising the productivity of all hill land may be truly insuperable due to obvious practical and economic impossibilities; it is in the recognition of this that compromises have to be made by seeking ways to make other improvements in one way or another. (Pages 51-56). The extent and quality of the in-bye land imposes limitations: too many farms are restricted in acreage even if the land can be improved. This imposes serious difficulties in providing winter keep and maintaining facilities at different times of the year such as for wintering hoggs at home, extra feeding for lean gimmers and ewes or for the production of fat lambs by cross-breeding from older ewes.

Further constraints are imposed by the lack of suitable buildings on many farms for wintering stock which, in turn, limits the number of cattle which can also be carried.

(b) Flock performance

Compared to lowland areas, there is a wide divergence in flock performance on the hills. This is apparent from the rate of stocking normally found; it can vary from 1.5 to 9 acres per ewe (table 6) and in extreme conditions 15 acres per ewe is not unusual. This is, indeed in sharp contrast to some areas in the South of England where seven ewes per acre can be achieved.

Table 6 - Stocking rates

	Number of flocks	Range of acres per ewe	Average acres per ewe
South of England	16	1.5 to 4.3	2.7
Angus	8	2.1 to 4.8	3.7
Perth	10	2.5 to 9.7	5.3
Argyll North	4	2.9 to 5.3	4.6
Argyll South	6	2.5 to 5.5	3.7

Source: Survey of Blackface Sheep with special reference to their hardiness.
A Report to the Scottish Hill Farm Research Committee HMSO 1953

Losses on some farms can be high, depending on the severity of the winter, the quality of the pasture and the degree of management skills employed. From 2% to 15% of ewes can be barren (kebbed or yeld) whilst lamb percentages attained at marking time can range from 52% to 89% although on better placed farms they can be higher (Robinson 1953).

The net result of early mortality and/or poor development is of long term significance. The most important is the lack of freedom in the selection of ewe lambs for future flock replacement conditioned by the reduced numbers available from which to make a choice. Under such conditions it is inevitable that even the most experienced will be tempted to retain stock of sub-optimal conformation and quality. Of lesser significance, but only marginally less, is the reduced opportunity for culling of unsatisfactory breeding ewes and the physical lack of numbers of store lambs and draft ewes for sale. Undoubtedly lamb losses can be high due to drowning and other accidents as pointed out by Robinson (1953) and Gunn and Robinson (1963). However, few hill farmers would disagree that there are other causes for loss and it is postulated that poor ewe quality and milk yield may be more significant than generally realised in the farm economy. These deserve closer attention particularly in cases where stocking rates have increased.

(c) <u>Nutrition and bodyweight</u>

Under hill pasture conditions, hill sheep are subject to variable conditions of nutrition all year round. Eadie (1967) and later Russell and Eadie (1968) pointed out that the seasonal pasture growth cycle (although recognised in other environments in which sheep production takes place) operates at such a low level on the hill as to be reflected in the low range of body condition. Further, if body condition bears a relationship to bodyweight, the loss in sheep of all ages, especially on the hill, is illustrated by the marked drop in bodyweight from autumn to spring coinciding with poor pasture growth and aggravated by weather exposure. This has been shown in studies by Robinson et al (1961) particularly in pregnant ewes.

Therefore the winter season marks a key period in the economy of hill farms.

i) Ewes

It is generally accepted that by the onset of the breeding season, i.e. late October, early November, the bodily condition of breeding ewes is already declining. Better standards of feeding at this time have been shown to give a better response in performance (Gunn 1967; Gunn et al 1969). This view is reinforced by Eadie and Black (1968) in their statement, "improvements in summer, and particularly late summer and autumn nutrition, can be expected to lead to improvements in early winter body reserves, so that the winter nutrition problem (except for the immediate pre-partum period) may well be more concerned with improving winter pasture carrying capacity than with improving individual animal nutrition".

It must be remembered however, that very few farmers give extra feed at tupping time (for fear of inducing twins) or during the height of the winter in January and February. Some farmers have increased numbers on the hill to cope with the economic situation but it is doubtful if equal consideration has been given to increase the nutritional levels. Peart (1967) has demonstrated the value of supplementary feed before lambing. A higher growth rate of lambs has been produced over the first few weeks - and even more significantly, after six or seven weeks of age as lambs become more dependent on solid food (i.e. on the grazing). While growth rate declines to weaning, the early performance is reflected at speaning condition and may still be in evidence at the hogg stage. It might be conjectured that lack of pre-lambing feeding (or poor quality and quantity) is the "seat" of chronic low productive performances found in some flocks on some farms. In hill flocks, the age factor plays a part in bodyweight loss during the winter - a consideration which cannot be divorced from nutritional demands and a reason itself for the normal practice of drafting ewes from the hill at five years old. Studies have been made by Robinson et al (1961) and Russel et al (1968) in respect of maternal tissues and the losses suffered by pregnant ewes, between mating in November and parturition in April. In this, the further effect of age and also the wide range of weight at tupping in Blackface ewes is shown in a report issued in November 1970 by the Meat and Livestock Commission. ("Sheep Improvement Services No. 3")

Table 7

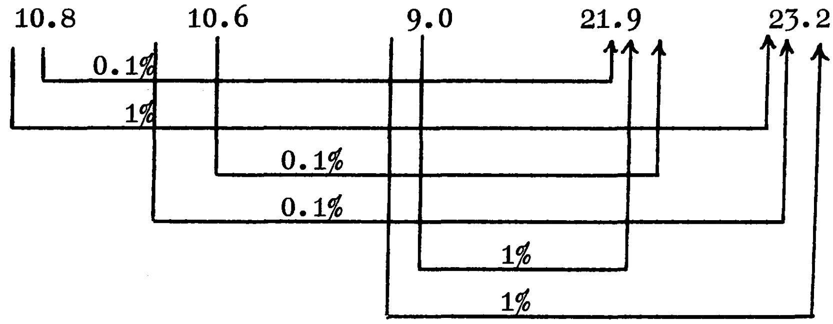
Age (at lambing)	Range of individual ewes lb
2	74 - 160
3	97 - 162
4	91 - 167

It seems paradoxical that he who spends so much time selecting store lambs for sale and choosing the right type and uniformity of ewe lambs for flock replacement, apparently ignores any disparities in the condition of ewes as manifested by the "spread" of weights in any one age group for the breeding season, and not least the possible reflection of this variation in their subsequent performance. Further evidence of this variation in bodyweights of ewes was observed by the writer during the winter of 1964 - 65 on two farms situated at different heights above sea level which emphasises the effect of winter exposure and different nutritional levels.

Table 8
Argyllshire grazings rising to 2000 feet above sea level

	Group I	Group II	Group III	Group IV	Group V
Age by lambing	2	3	4	5	6
No. of animals	40	54	44	34	9
Mean wt. (lb)					
at pretupping (Nov)	86.9	72.3	93.0	99.6	100.1
January	80.2	84.8	84.4	84.2	80.2
at prelambing (April)	76.1	82.7	84.0	77.6	76.9
Mean wt. loss (lb)	10.8	10.6	9.0	21.9	23.2

Significance



At the initial weighing, gimmers (Group I) were significantly lighter than the older sheep (Group III, IV and V) whilst the middle-aged groups were lighter than the five year olds (Group IV). By prelambing it is apparent that the lighter sheep (Groups I, II and III) had lost less weight than the older sheep which confirms the necessity to draft out older sheep due to their inability to withstand winter conditions without an extreme loss of bodyweight. A further significant factor is that on this farm, feeding was restricted to a small amount of hay fed during the worst of the weather.

Table 9

Perthshire grazings rising to 750 feet above sea level

	Group I	Group II	Group III	Group IV	Group V
Age by lambing	2	3	4	5	6
No. of animals	12	39	55	45	2
Mean wt. (lb)					
at pretupping (Nov)	109.4	109.9	109.9	109.5	Void for analysis
at post-lambing (May)	104.2	106.5	105.4	100.0	
Mean loss wt. (lb)	5.2	3.4	4.5	9.5	
Significance		1% (II vs IV)	5% (III vs IV)		

This farm is in direct contrast to the previous farm, in that the ewes at the breeding season were kept on a better standard of nutrition which was maintained for the rest of the winter. The ewes were fed with concentrates ($\frac{1}{2}$ lb. per head/day) and hay ad lib starting six weeks before lambing and continuing during lactation throughout May. The effects of this treatment and the less rigorous weather are reflected in the body weight losses sustained during winter, although it is conceded that hand-feeding in the spring with the improvement of weather and grass hastened the restoration of normal maintenance weight. The middle-aged ewes (Groups II and III) lost less weight than the five year olds whilst the gimmers (Group I) did likewise - but nevertheless lost a little more weight than the middle-aged groups.

In general summary of the two tables, it appears (despite the limitations of only two sample tests) that the younger the animal the less loss of weight occurs during winter despite the lighter starting weights.

ii) Hoggs

Responses in the performance in hoggs on varying planes of nutrition ascribed to the different methods of wintering have been evaluated by many investigations with divergent results, depending no doubt on the variety of conditions in which the work was carried out. Fraser (1937) working in Argyllshire verified, not unexpectedly, that away-wintering on lower ground was superior to hill wintering of hoggs despite some of these being fed, and stated, "When ewe hoggs are wintered on their native hill, there is a grave risk of excessive loss from disease, storm, accident and starvation. There is a further risk of permanent stunting or the development of undesirable conformation in the ewe hoggs that survive, which, if repeated over a series of years, would lead to the general deterioration of the stock".

How much these latter points regarding deterioration in some flocks is applicable today or whether the position has changed radically enough even today despite improvements in winter treatment and/or a change of attitude by owners are matters for debate beyond the scope of this paper. Smith (1953-54) on the other hand, found no difference between home-wintered hoggs and those away-wintered in terms of subsequent performance and survival. Gunn (1964 a.b., 1965, 1967 a.b.) in relating the different levels of feeding to subsequent breeding performance found little evidence to suggest that highly fed animals were in any way superior to those fed at lower planes of nutrition (although the results were not statistically significant - not surprising over a period of years presumably due to the number of sheep involved and the varied conditions). In Blackface hogg studies and during their subsequent performance as breeding ewes, those reared on the higher plane of nutrition as hoggs, appeared to maintain a better performance than animals reared on a lower plane of diet (although Gunn (1968) warns that too much emphasis cannot be attributed). However, in agreement with Jackson (1963) Gunn (1968) observed an improvement in the performance of gimmers in their first breeding year. Gunn (1968) suggested that there may be an optimum level of nutrition during rearing which is related to the "environmental threshold" or the level of most efficient productive performance later on the hill. However, in appreciation of the variety of conditions found on hill farms, it was stated "obviously there are many situations where the level of nutrition during rearing is below the optimum and where an increase will create productive response".

Thus, to summarise, nutrition is a major limiting factor throughout the year, known and regarded as such under hill farm conditions by many but unfortunately not by all hill farmers. Possibly more realistic economic proof as to these losses is needed to try and evoke a greater awareness and appeal in those resigned to the acceptance of their present position and who, for various reasons, are unable to make other improvements, either of an intensive or extensive nature.

Where undue losses from death or reduced productivity in gimmers occur, it may be economically advantageous to ensure higher productivity on the farm as a whole, by feeding or wintering hoggs well. This view is in line with the statement by Coop and Clark (1966) "it is the author's strong opinion that priority of effort should go to the rearing of young sheep". A direct advantage arising from hogg improvement and from breeding from a selected few (although without subsidy) is that ewes could then be culled at a younger age to be used for twinning or for bringing on big single wethers destined for fattening either on lowland grazings or on the home farm if sufficient in-bye pastures suitably fenced and fertilised, are available. It also allows the owner or shepherd/manager to note the hoggs of inferior quality which have not responded to better conditions and to ensure that these are culled before entering the main breeding flock and eventually lowering its general standard (pages 25,66,183) It is recognised that liveweight itself as postulated by Gunn (1967a) may or may not be the sole criterion of productive performance as opposed to body "condition" (pages 32, 106) but it is generally recognised that at the early hogg stage it is meaningful enough to allow some practical assessment, although a flock recording system worthy of practical interpretation would offer greater scope. Therefore, in consideration of bodyweight changes during winter in hoggs, any estimated target must constitute a reasonable cost/benefit. However, any generalisation can be misleading particularly in view of the difference to be found under farm conditions not only from one year to the next, but also between one farm and another. For instance, a starting weight range even in the late autumn from 50 to 60 lb on one farm may be considered normal and accepted as such by the owner whereas on another farm it may be considered as very poor. Therefore the weight gain or loss during the ensuing months has to be related to this. Other factors, such as the overall quality of the flock, quality and type of the tups used, the quality and extent of the pastures and the system of wintering, all need careful consideration.

Jackson (1963) indicated from studies on hoggs the following bodyweight ranges according to different systems.

i) Hill wintering

A bodyweight <u>loss</u> of 5 - 10 lbs can be expected though a loss of 10 lbs could be considered serious. Obviously much depends on the severity of the weather and pasture conditions when this weight is lost, i.e. whether the greatest loss is sustained in the early part of the winter.

ii) In-bye wintering

The bodyweight can depend on the quality and the amount of keep until January. After January no growth can be expected. It may be that too much is expected from in-bye on many farms particularly where no attempt has been made to improve the quality of the land. Its potential use may be restricted in the early part of the winter until such time as hand feeding commences and be reflected in the bodyweight of the hoggs.

iii) Away-wintering

A range of weight <u>gain</u> can be expected of 5 - 20 lb although a gain of 10 lb is acceptable. Wintering is invariably taken on the same farm year after year. But it can suddenly become an economically risky arrangement even when the cost/benefit has been considered satisfactory in previous years. In case the wintering-away facilities have changed, it is essential to make an annual re-appraisal of the management and grazing policy as was evidenced in a recent trial carried out by the author (page 186).

iv) In-shed wintering

It would be reasonable to expect a comparable weight gain to that of hoggs away-wintered but from some evidence (pages 154-158, 190) it would appear that the weight gain expected depends on the overall weight of the hoggs on entry to the shed. Those who have given careful study to the problems of in-wintering now appreciate that the preparation of hoggs for going inside must be different from the long established methods used when getting ready for the hill. For instance, where the weight on entry is high (i.e. in excess of 70 - 80 lb) then this weight may not be sustained or increased during the housing period due to inadequate food being given to sustain an "over-ripe" condition more suited to the rigours of the hill. (Page 190)

(d) Compensatory weight changes during summer

Where bodyweight is lost during the winter, it is to be expected that some compensatory weight increase will occur during the early summer with improvement in weather and nutritional conditions (pages 181,185)

Jackson (1963) found that the summer gains were inversely proportional to the wintering gains. For instance, away-wintered hoggs proportionately increased less during summer (i.e. in 1952 by 18 lb) whilst hoggs in the other systems put on 40 - 45 lb. It is also significant that the away-wintered group reached first mating weight by mid-June and thereafter improved in condition. It was this condition of the gimmers at tupping which had the greatest effect on subsequent performance.

DEPENDENCE ON THE MARKET

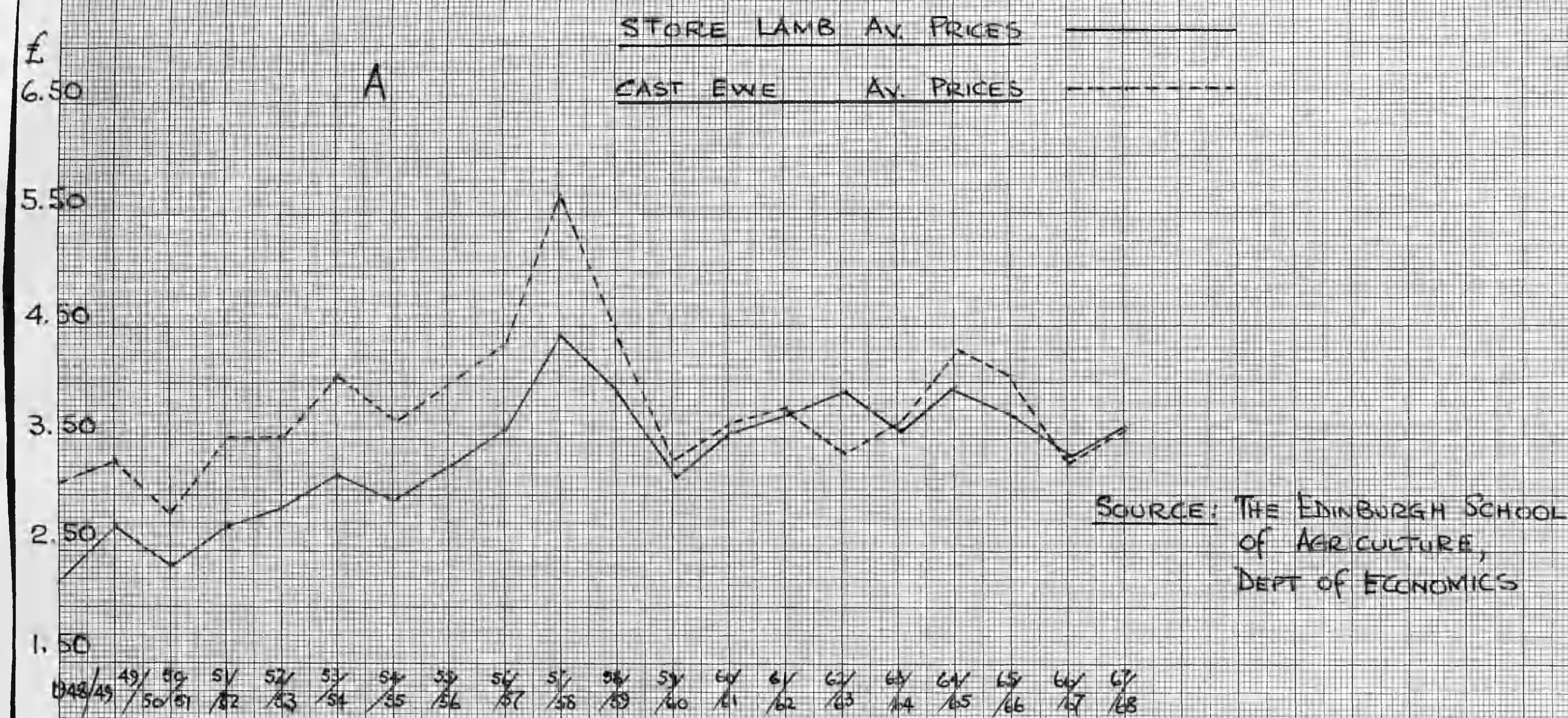
(a) Supply and demand

The physical constraints on increased production and the continuance of low outputs create economic problems in maintaining satisfactory levels of income against a background of rising costs and in generating profits to be re-invested in improvements. This situation has been appreciated and well discussed in recent years.

For instance, it is well recognised that due to its position in the industry, the distance from main market outlets to large urban populations and its dependence on lowland demand for store and breeding animals, the hill farming sector is particularly vulnerable to annual changes in demand. This is apparent in graphs A B and C which indicate how this variable demand has resulted in fluctuations in the level of store prices, and net profit per 100 ewes. The fixed breeding season and therefore the glut of lambs reaching marketable condition by the early autumn are other factors.

Graph C shows how the net income per farm has barely exceeded the level of Government support in some years. Generally, for many, the buoyancy of prices at the area market, particularly for breeding stock, is dependent on the number of lowland farmers who attend the sales, particularly in the North of Scotland. However, an awareness of the situation and its resolution is seen in the activities of co-operative groups (e.g. Caithness Livestock Breeders) who actively seek and create their own market outlet for sales of breeding stock in the lowland market.

Another important factor causing fluctuating demand has been the


A
STORE LAMB AV. PRICES
CAST EWE AV. PRICES
£
6.50
5.50
4.50
3.50
2.50
1.50
1948/49
49/50
50/51
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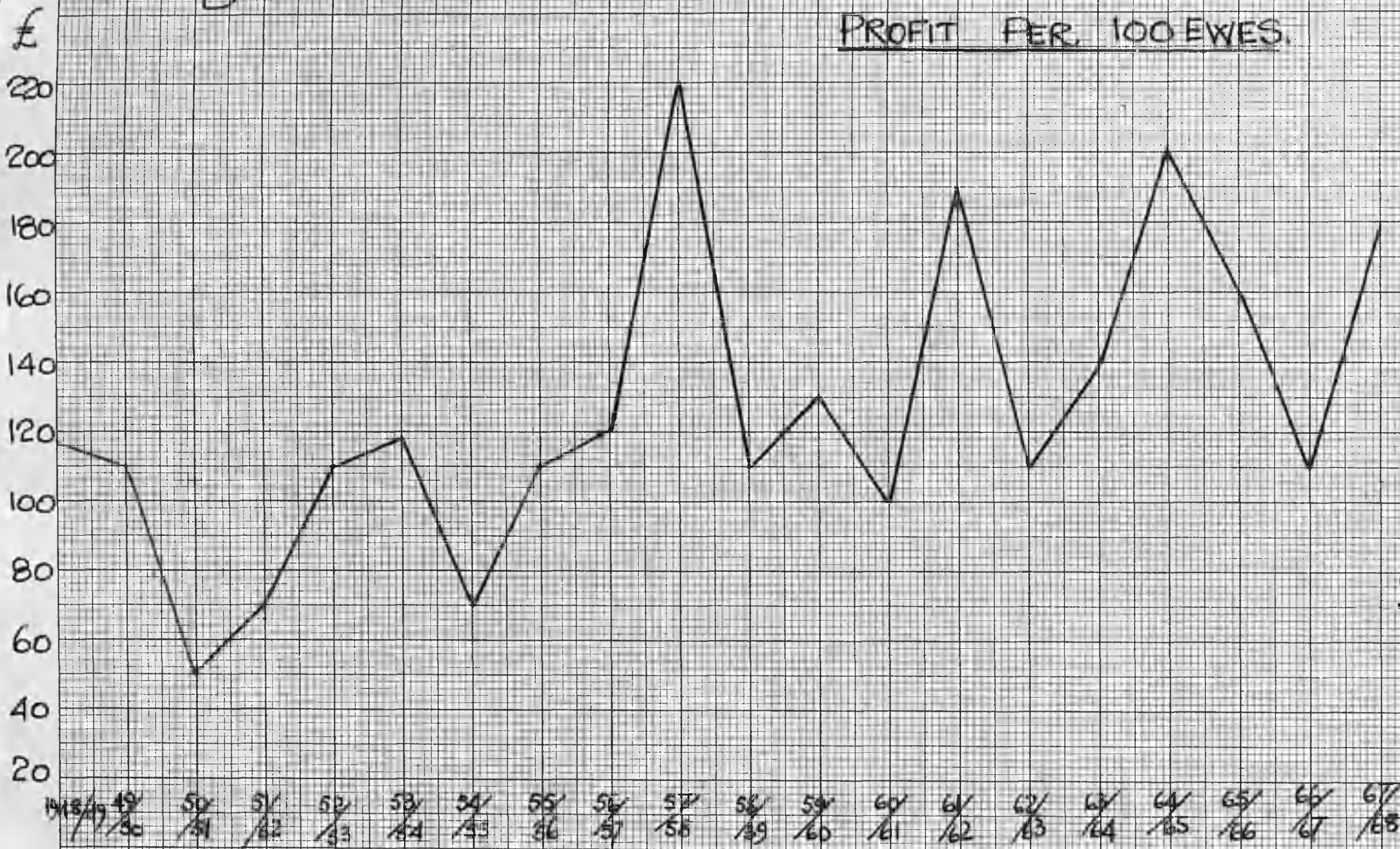
SOURCE: THE EDINBURGH SCHOOL
OF AGRICULTURE,
DEPT OF ECONOMICS

B

HILL FARMS

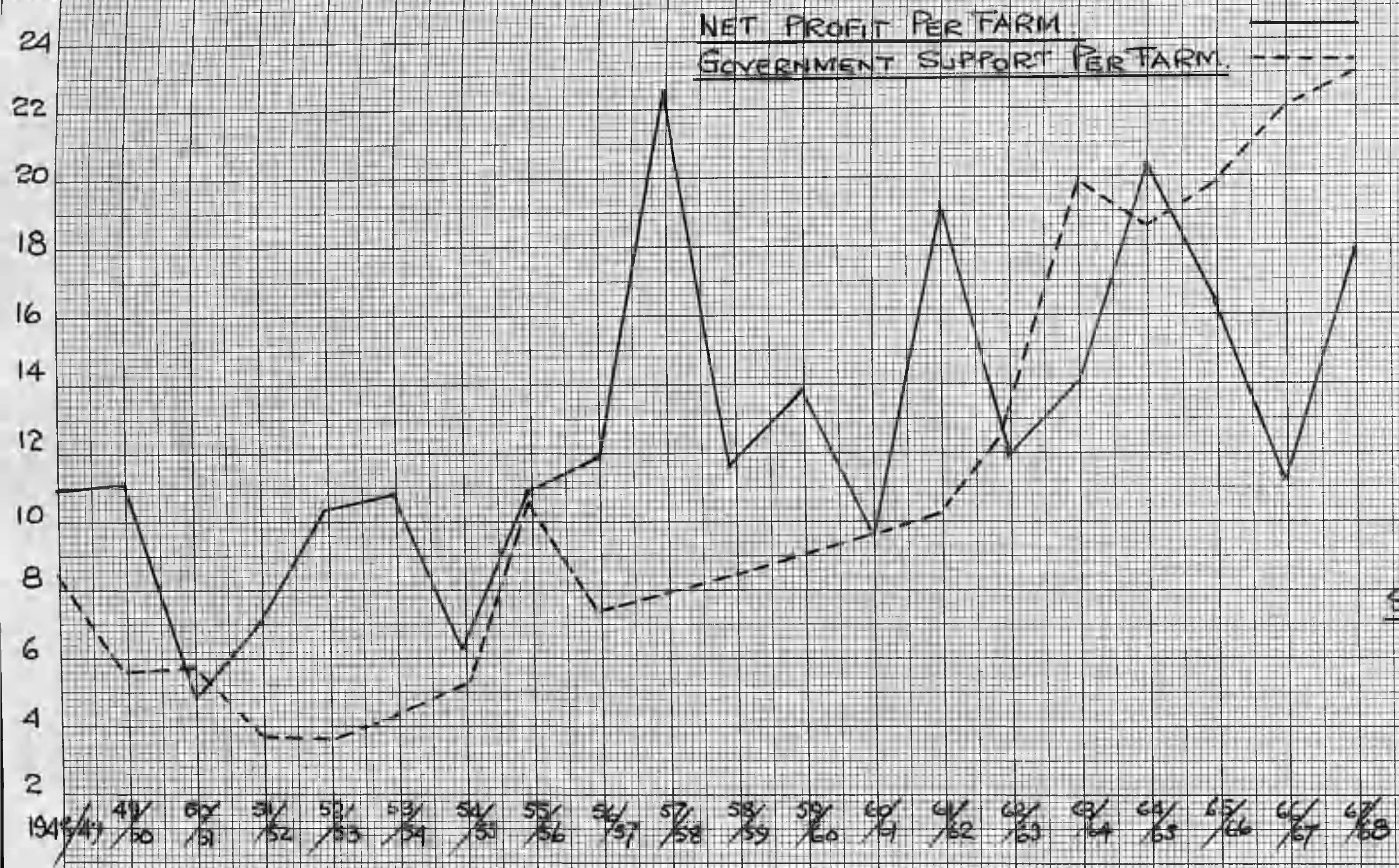
PROFIT PER 100 EWES.



SOURCE THE EDINBURGH SCHOOL of AGRICULTURE, DEPT of ECONOMICS.

C

HILL FARMS



SOURCE: THE EDINBURGH SCHOOL of AGRICULTURE, DEPT. of ECONOMICS.

reduction in the lowland flock populations (pages 50,51) caused partly by lowered profit margins in fat lamb production and partly by the development and expansion of more profitable enterprises such as cereal growing or expansion in or into beef and dairy herds. In reflection of this, Whitby (1970) states: "It is still not clear how far this will go, although in Scotland, where the pressure of cereals expansion on the grass area is less than in many parts of England, there are recent signs that low grass farms may again be regarding sheep production more favourably".

The situation created in the lowland sector is also reflective of the consumers' changing preference for other meats. Mutton and lamb consumption has remained fairly static over the years at about 25 lb per head per annum whilst poultry and pork consumption has shown an upward trend.* However, in the light of current E.E.C. negotiations it is worth noting that British consumption of sheep products is far in advance of continental consumption at slightly under 5 lb per head. This is a reflection of consumer antipathy, poor husbandry standards and lack of Government encouragement to sheep farming. At home, the increasing trend in poultry and pork consumption may not be truly reflective of consumer preference but more the result of greater marketing skill in getting the product distributed at the right time, at the right price and in an attractive presentation. Poultry has been more convenient to buy, particularly when it is ready cooked, whilst pork has always been comparatively cheaper and "rides on the back" of the extensive bacon publicity programme.

A major problem, therefore, is to find ways to stimulate fat lamb production at home and against competition and from overseas sectors

*Household Consumption of Foods (1970) H.M.S.O.

of the meat industry including New Zealand. Obviously a "quality", uniform and suitable product well promoted is imperative and will command a premium. The position may be improved with entry into the Common Market and/or by any re-routing of New Zealand production to South East Asia. The position will also depend to some extent on the future of the poultry and pig meat production at home, although there are difficulties in even making generalisations at this stage.

Despite this, for those hill farmers totally dependent on the store market, there is, unfortunately, no price advantage under the present marketing system for the "quality" product and producers must still rely on the particular and often fluctuating trends in their local market - not only from week to week at the late summer or early autumn sales - but even from hour to hour on the day of the sale. Whilst some farmers are fully aware of this and are critical of the situation, others, seemingly, accept it.

This lack of incentive to improve the quality of lambs, inhibits attempts to make other improvements, and merely encourages increased numbers of ewes without due consideration being given to the quality of the flock or the risks of overstocking.

(b) Rising costs

Rising production costs are of serious concern in any industry and especially so where a record of unstable price returns exists for a limited number of products such as in hill farming. However, during the sixties, the Scottish beef cow population increased by 35% and it is currently estimated to be one-third of the U.K. population. The contribution to this expansion of suckler herds has been significant on hill farms.

It is also apparent that increased costs have by and large been offset by the increased output from these suckler herds particularly on the larger farms. Nevertheless an examination of regional economic data reveals the considerable variation which occurs in output and fixed and variable costs according to the scope and structure of the farms within the province. Generally it can be considered that on a 20 ewe basis, (and allowing for the difficulties of abstracting data when a proportion of the farms in an economic survey are given over to cattle and cropping) fixed costs can range up to £4 per ewe and variable costs up to £2. From this, it is estimated that the average profit per ewe lies between one and two pounds although on the better farms in the better years, profit margins may well exceed two pounds. A significant feature of farm costs lies in the increased costs of labour as wages continue to rise, although other costs such as rent, rates and costs of away-wintering have in very few cases remained static. It is considered that costs per ewe for labour has risen over a few years from approximately £1.25 to over £2. For instance from a survey in the Southern uplands the labour costs per 20 ewes was considered to be £35 in 1959 (including the farmer's labour at £4 per 20 ewes) compared to £41 per 20 ewes in 1969 (including the farmer's labour at £6 per 20 ewes).

The relative increase of some other costs (not allowing for the changing value of the £ over the years) is shown by an actual farm record based on a 600 ewe flock. (Next page : personal communication).

Table 10

	*Labour costs per 20 ewes	Rent	Wintering away per 180 ewe hoggs : per head	
	£	£	£	
1952	13	200	180	1
1962	22	400	360	2
1971	42	600	450	2.50

*includes farmer's labour

Although greater outputs per man from improved labour rationalisation by increased cattle numbers, an increase in the size of flock numbers looked after by one man and other changes in the system such as in-wintering, have no doubt been achieved, nevertheless it is ventured that even small changes could still be made to allow better use of the labour. For instance, much remains to be done to improve flock handling facilities on many hill farms. In many cases antiquated sheep penning arrangements and inadequate facilities are wasteful both in time and labour. Paradoxically, the use of modern drugs and vaccines and means of administration are hampered by poor handling conditions. Considering that during winter, the daylight hours are short and time to carry out the various operations is at a premium, the situation is worthy of Time and Motion studies especially where the owner is actively seeking ways to economise and to increase the labour output. On many farms the problem is to find ways of making more use of skilled labour at strategic periods such as lambing in an effort to minimise lamb losses which in turn increases the potential income per ewe.

The cost of use of modern dips and anthelmintics has remained remarkably static during the last ten years or so. Whilst a dose of modern worm remedy may cost three or four times as much as say phenothiazine, the spectrum of activity is very much wider and the cost of use is still in about the same relationship to the value of the animal to be treated, as it was in the immediate post-war years.

(c) Capital availability and deployment

In the traditional system, capital is mainly tied up in stock. Low profits over the last decade have allowed little capital reserves (despite the support of subsidies and grants) to re-invest in improvements in an attempt to raise productivity. At the same time however, the "affluent society" mentality of the last ten or fifteen years, being apparently more concerned with outward appearances, must bear some of the responsibility for the mis-direction of capital or the failure to consolidate and retain profits to re-invest in the business.

In other areas there must be those hill farmers, even with capital resources, who are unwilling to effect improvements due to the risk and uncertainty involved in getting adequate returns from their investment, particularly in the present economic climate.

Within the wide range of possibilities such as cross-fencing, reclamation, building improvement and increased flock numbers, any wise potential "improver" is faced with the need to appraise and evaluate possible techniques within the scope and resources of the farm, the costs involved and the returns to be expected from the investment. Obviously, even if the improvement is only slight or a mere tactical innovation, costs have to be considered and related to the benefits in so doing.

(d) Government policy

This policy can be best defined as a desire to develop the industry and to encourage hill farmers to actively participate in this development. Confirmation of this was indicated and summarised by the 1970 Annual Review White Paper, "The Government have sought through their decisions at Annual Reviews to encourage greater productivity and growth in the hills and uplands to offset the decline in lowland flock numbers but this will take time. Moreover, sheep are important to husbandry in many lowland areas. If production is to be maintained over the longer term, it is necessary to check and offset the decline in the breeding flock. To offset higher costs and to give the further resources needed for investment in additional breeding stock, the Guaranteed Price for fat sheep will go up 3d to 3/10¾d (15.448p) per pound. This should improve returns from producers in all parts of the country and in all sectors of the industry".

In the 1971 Government White Paper this policy has been continued with an increase in Guaranteed Price for sheep and lamb (and cattle) plus a rise in production subsidies for the hill farming sector.

TRENDS TOWARDS IMPROVEMENT

The "Report of the Committee on Hill Sheep Farming" (1944) stated:- "The introduction of improved methods into the hill farmers' daily practice is perhaps the weakest link in the chain. In no other type of farming is there a stronger belief in traditional methods . . . . "

Although it must be apparent that "improved methods" in daily practice form only part of the answer to the problem, there is no particular reason to suppose that the majority of hill farmers have changed their attitude or practices in the last quarter of a century. However, the seriousness of the current economic situation may be summarised by Whitby's (1970) statement:- "In very broad terms the task facing the hill sheep sector is the same as that which faces sheep farming as a whole; it is to strengthen its competitive position by technical change and a higher rate of productivity; and secondly to get more lamb consumed". For those well aware of the situation, they might be further encouraged and challenged by Whitby's concluding statement:- "None of these inter-related tasks is easy but there are many indications that both are being tackled". The position might be further summarised by citing one farmer's viewpoint, "We can no longer afford the luxury of semi-productive acres or semi-productive cows or semi-productive ewes or semi-productive producers". Findlay (1966).

There are undoubtedly apparently insurmountable problems in parts of Scotland where farms or crofts are either too small or by their structural limitations prevented from ever becoming viable businesses - even with considerable capital infusion. The Crofters Commission Report (1968) states:- "Apart from the social, legal, financial and physical factors which make the creation of full-time units impossible in these areas, the position of the man who can combine outside employment with a spare-time croft is very much more secure than that of the man who is committed to earn his whole livelihood from agriculture in a remote area where costs are high and soil and climate unfavourable".

Unfortunately there are too many die-hard traditionalists who have avoided making any kind of meaningful change in an attempt to meet current economic difficulties. For instance, for some years supplementary feeding before lambing has been advocated as a means of increasing performance, yet it is questionable at the present time if many have yet adopted the practice. Many, doubtless, believe with some conviction, but little critical evidence that a minimum quantity of hay - often of questionable quality - is all that is required over a very short period only during the worst of weather. (Pages 84,85)

This attitude is based on the belief that feeding will interfere with the hardiness of the sheep and their progeny and their instinct for self-preservation and that in any case, "condition" will be restored during the summer months.

The fear of feeding before tupping, in case the result of this flushing will result in too many twins for the in-bye to support or that the ewe will not breed from becoming too fat, exists in the mind of some owners. Yet, the other all too common extreme is starvation and some degree of neglect, i.e. what is aptly described as "poverty" in ewes - a condition certainly not conducive to the much sought "hardiness". The fact that lambs are so very dependent on strong milky ewes for a number of crucial weeks and that their progress during summer, if not their very survival depends on this, seems to be completely ignored by many, as are the longer term implications in being able to exploit the full potential of well grown healthy hoggs.

There are those who accept, and are resigned to the fact, that a number of yeld or kebbed ewes in greater or lesser numbers every year is virtually inevitable, without attempting in any way to reduce these numbers or to seek specialist veterinary advice on the possible reasons. There are undoubtedly many possible causes; the analyst might be forgiven for thinking that one of the main responsible factors may be ram infertility. Defenders of the status quo point out that one defective ram does little damage where a number of rams are used! Many have not even adopted the primitive, simple but effective practice of raddling rams even when tupping takes place on enclosed pastures as a means of more efficient control at lambing time; others have not adopted the use of "teaser" rams (although in actual practice the use of "teasers" is not reliable if left running, as oestrus can occur during pregnancy and "teasers" can mark ewes after conception). Undoubtedly, the question of barrenness in ewes merits fuller investigation, particularly on those farms where the potential for radical improvements are limited. But there are those who give "no second chance" to any ewes which are barren in any one year and these are sold rather than kept on for a further year. There are those, where sufficient low ground is available, who are wintering on either selected or older draft ewes to eventually produce cross-lambs and doing so with a high degree of success; others have been less successful in some years due to the inadequacy of the flushing on the in-bye prior to tupping or as a result of underestimating the cumulative effects of faulty nutrition on the condition of the animals prior to the breeding season.

On the other hand, others quick to realise the potential advantages, have not only improved in-bye and fenced lower pastures but select ewes and rams which themselves were twins in an effort to encourage a twinning factor. Others have introduced new hybrid breeding flocks in an effort to raise outputs. Whatever the ways found, undoubtedly, they call for greater skills in management to balance the use of lower or in-bye land with the increased rate of stocking at strategic periods both in the spring and autumn.

In the autumn, the position can be aggravated when it is necessary to relieve pastures to allow hoggs to be brought down for in-bye wintering for whole or part of the winter. It is possible, therefore, that the strategic worming programmes will have to be reviewed where such practices cause enforced congestion on already limited low ground. (Pages 25,66,183). In philosophical retrospection it would also seem that some hill farmers who are introducing such improvements have, even at the earlier stage of transition or in the adoption of modified improvements, to adapt lowland tenets both in attitude and in all managerial aspects and even to discard some traditional methods.

A further resolution of the problem is advocated by a system of paddocks which may include drainage and regular renovation. This means, in essence, an adaptation of rotational grazing similar to that practiced on low ground farms, but with consideration of the demands on different grasses by the stock at such periods as spring. Another approach is by means of off-wintering ewes to allow the better utilisation to be made from summer pastures by increased stocking rates besides resting the grazings during winter. Various arguments can be levelled for or against the practice of in-wintering at the present time, chiefly on economic grounds, but it may be advocated that at least it provides a way of giving weaker or older ewes or gimmers some preferential treatment during winter to exploit the potential of a bigger crop of better lambs than otherwise would be obtained. Whatever the potential possibilities for improvement on the better farms to raise stocking rates, undoubtedly any synthesis cannot be complete without making improvements in other ways. For instance, it raises practical problems of pasture renovation to carry more sheep and to tide them over critical periods of the year. It also raises problems particular to many farms on the questions of drainage, liming and bracken eradication* of some portions of hill ground - a problem not overlooked nearly thirty years ago in the "Report of the Committee of Hill Sheep Farming in Scotland" (1944). Undoubtedly, in exposing and considering these problems it is easy to generalise, but the answers can be difficult to achieve.

For some, cattle raising (with Government assistance) has been a way

*Figures taken from the Report of the Committee on Hill Farming in Scotland (1954) based on a 73% return suggest that about 450,000 acres of land is under bracken - land classed as "stock producing"!

of increasing outputs (page 19) but, by virtue of their numbers especially during the winter period, some congestion in grazing priorities as between sheep on the lower slopes, and cattle will be caused by their different grazing habits.

Some shepherds believe that cattle remove too much roughage from the lower ground which limits sheep during winter. On the other hand, on some farms, far too many older ewes (if not younger sheep) are allowed to stay on the unfenced lower ground during the whole of the winter even if that winter is mild. Nevertheless, there seems to be much to recommend the use of cattle on sheer economic grounds, if not for practical reasons, to eat off summer accumulated roughage on lower ground, and to keep down roughage if kept out on the hill during summer. A further advantage is that ewes with twins or big single lambs could be turned on to lower ground which has been well "renovated" by cattle.

The fattening of lambs has been a way of increasing output by folding on autumn aftermath and later on root breaks and selling off the lambs from early January onwards. This method has its critics who maintain that the price obtained does not cover the costs involved and who prefer early speaning so that single lambs can be sold off before the end of the year and command the higher price for the Christmas trade.

For some, an improvement in some respects, is to adopt the tactic of in-wintering hoggs partly to engender a better standard of nutrition and management and not least to attempt to reduce costs of away-wintering. Yet, in terms of improvement of production performance whatever the benefits of one method or another and whether or not radical departures from the traditional systems have been suggested, the cost/benefit must always remain critical at any stage of the production process.

Other constraints on production

One important factor involves the incidence of disease and in particular parasitic worm infestation. Helminthiasis is of special significance because infestation has been shown to exert a potent "braking effect" on production generally.

The economic losses from disease in sheep, measured in terms of mortality alone, are lower nowadays, the situation having vastly improved over many years. But losses from internal parasitism even at sub-clinical levels, still remain and may be considered to be paramount in terms of interference with appetite and reduction in growth potential of young animals, of wool and milk production. (Pages 82-88).

It is to be expected therefore, that with increasing intensification, the prevention of infestation even at a low level has become the sine qua non of sound husbandry.

(a) Losses in production

The true extent of losses on hill farms due to parasitism is often obscured by the effects of severe weather and malnutrition and it is difficult to assess to what extent each is responsible. Nevertheless it is appreciated that most hill farmers are well aware that there is an inter-dependence between the factors of weather and malnutrition which limits the exploitation of the full performance from their flocks. The situation has been reached (in particular where improvements have been carried out or are envisaged) where a degree of imbalance may be caused solely by parasitism and it may become a more serious matter for concern. Unfortunately there is no recent published evidence, so figures may be somewhat speculative.

As long ago as 1937, the British Veterinary Association conducted a survey on the annual mortality caused by the ten major diseases of sheep in Great Britain. The total loss was estimated to be over £1 million (at a time when a hill ewe was valued at £2 only). Losses from parasitic gastro-enteritis were estimated to be just over one-third of the whole, i.e. £348,000. In the wetter Western areas, liver fluke infestation remains a very serious problem despite the advent of safer, more efficient, flukicides, probably because there is still a lack of appreciation of the fact that a dosing programme throughout the season, rather than random dosing, is required.

Whilst this thesis refers in detail to the problem of helminthiasis, it is of course acknowledged that there are many other disease problems in hill sheep. Metabolic problems such as hypomagnesaemia and hypocalcaemia occur. "Pregnancy toxaemia" is common in hard winters when there is a shortage of "energy"; the significance of increased numbers of cattle on hill pastures by removing roughage and fibrous grasses so essential to the ewe, must not be overlooked. The problem of tick infestation and the diseases associated with it on the rougher parts of the hill is still of great importance despite the use of modern insecticides. Removal of the Statutory Dipping regulations appears indirectly to have resulted in an increase in lice infestation in late autumn and winter.

These are all problems which further constrain optimum production, whatever the size of the farm.

In 1949, W.W. Wilson cited by Parnell (1952) estimated financial losses from parasitic nematodes to be over £300,000 and later in 1952, a conservative estimate was given as over £500,000 based on field studies by Morgan and his co-workers. Further, it was estimated that parasitic nematodes contributed 15% to the estimated annual average death rate of 100,000 gimmers and ewes. The losses in wool and meat were considered to be still greater. In total, it was estimated that some 480,000 gimmers and ewes and a further 170,000 hoggs suffered damage to some degree from sub-clinical helminthiasis.

In today's financial terms the original figure of £500,000 for hill sheep could be revalued at nearer £1 million and therefore, part of the original statement by Morgan et al (1952) still holds true: "Some of these losses could be avoided given a wider knowledge of control measures and of the appropriate times of dosing and also better anthelmintics".

Today, there are better anthelmintics available (page 96) and technical knowledge is widely disseminated, but it is greatly to be doubted whether real progress commensurate with the passage of almost thirty years has been achieved. The basic reasons for this postulation are matters for debate, particularly when related to the extremely vigorous (and highly successful) attack on the problem of the clostridial diseases of sheep.
(A more detailed discussion on the pathogenesis of helminth infestation appears later).

(b) The present position

On lowland farms, unlike hill farms, the commonly accepted methods of worm control include various systems including rotational grazing (where sheep can be grazed continuously over fairly clean ground) and the strategic use of anthelmintics. With the limitations on hill farms, this is virtually impossible to achieve unless a total improvement in part or whole of the potential grazing area takes place. Even where structural improvements are possible and have been made to some extent (such as fencing, drainage and grassland improvement of lower slopes), they invariably lead to situations at some periods of the year (e.g. autumn) where pasture congestion from overcrowding is simply unavoidable. This occurs, too, by virtue, of attempting to increase productivity by "twinning" either part of the flock or just older ewes, and holding them on lower "green" slopes or on the traditional in-bye throughout the entire summer and part of the autumn. This, in turn, eventually leads to a lack of strategic reserve of clean ground which has been free of sheep for any lengthy period. Therefore, under any system of improvement, it has to be accepted that there will be a greater use of, and reliance on, anthelmintics.

It has become customary for many hill farmers to drench their flocks for roundworms, once, twice or more times in the year at well-defined intervals. Invariably, these times are confined for what are considered to be either economic or practical reasons to the gathering times for carrying out the normal seasonal husbandry operations. On the other hand, there are hill farmers who resist drenching or feeding of their sheep and make no attempt to improve stocking rates in an attempt - however mistaken - to reduce costs.

It is doubtful if many readily appreciate that the optimal times for anthelmintic treatment in some cases do not necessarily coincide with the normal gatherings for other purposes. Where a problem exists or is suspected, it is this unwillingness to make a special gathering (for what the shepherd believes to be sound reasons) purely for strategic worm control that may perpetuate the problem.

Until very recently little has been done to evaluate the cost/benefit of drenching programmes, but with the advent of wide spectrum anthelmintics and a greater knowledge of epidemiology the opportunities have greatly improved.

(c) The potential advantages

For hill farmers, intent on making adjustments or improvements in otherwise traditional systems, the costs and the advantages have to be given a great deal of consideration. However, any change in the drenching programme will be relatively cheap when compared to the cost involved in making other changes to improve flock performance. The capital outlay will be insignificant in comparison to say improving even a few acres of hill, land or even patching up and restoring a dilapidated building to "store" a few more cattle. Where stock numbers are increased or the flock kept under more intensive conditions, it does not necessarily involve extra labour or even extra time in dosing more sheep, provided the handling arrangements on many farms are improved.

What is needed, however, is a greater willingness to accept the results of worm infestation for what they are - unsuspected depreciation in flock performance in all its aspects, e.g. bodyweight, milk and wool production, resistance to disease, "survival" of the newborn and speed of maturity.

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INTRODUCTION

PART II

The Bursate nematodes

The significant aspects of seasonal occurrence

Pathogenesis of nematode infestation

The significance of grazing behaviour

The use of anthelmintics

THE BURSATE NEMATODES

With a few exceptions, the more important parasitic nematodes pathogenic to sheep have similar life histories differing only in certain characteristics.

Gordon (1948) divided the "standard" life cycle into the free living and parasitic periods.

(a) Life cycle

i) Free living period

This takes place outside the animal and comprises the egg, and the first, second and third larval forms. In the first stage, the larva does not leave the egg for about 24 hours or longer when conditions of warmth and moisture are optimum.

Feeding for one or two days or even longer, the first stage larvae moult into the second stage, which feeds before undergoing a further moult into the third stage. The third stage retains the sheath or "skin" of the second stage as an extra protection. The larvae of this third stage are infective to sheep. Active in moist warm weather, they swim up damp grass to a height where they can be eaten by sheep. The second stage protecting sheath is then lost.

ii) Parasitic period

Where the life cycle is direct, the infective third stage larvae on being swallowed by the host, make their way to the preferred part of the body, complete the third "moult" into the fourth and finally to the fifth stage to become adult. In some species, the final moult takes place in the body tissue of the host (e.g. Ostertagia in the mucosa of the abomasum and small intestine) referred to as the "histotropic stage" (pages 76-80). The prepatent period varies for the various species from three weeks for those in the abomasum and the small intestine to four to seven weeks for those in the caecum, large intestine and lungs.

iii) Species in Scottish hill sheep

Cameron (1923) first observed the various species by examining hill sheep slaughtered for human consumption at an Edinburgh abattoir. Although limited by the method of collection the various species recovered from the alimentary tract included:-

Haemonchus contortus
Trichostrongylus vitrinus
Ostertagia circumcincta
Ostertagia trifurcata
Cooperia curticei
Nematodirus filicollis
Bunostomum trigonocephalum
Trichuris ovis
Oesophagostomum venulosum
Chabertia ovina
Strongyloides papillosus

Later Robertson (1937, 1939, 1942) in a further survey examined hill ewes and lambs and added various species including *Ostertagia ostertagi*, *Dictyocaulus filaria* and *Muellerius capillaris*.

The importance of *Ostertagia* spp. in sheep particularly their pathogenic and economic significance, was first stressed by Robertson (1933)(1937). The prophetic truth of Robertson's findings based on work started no less than forty years ago rings true today ". . . . it (*Ostertagia*) is the most important helminth in sheep in Scotland". The significance of the species is currently only too well realised in cattle also.

An extensive survey commenced by Morgan and his collaborators in 1946 and reported by Parnell *et al* (1954) was based on worm egg counts from 720 hill sheep which had died for various reasons on 80 hill farms distributed throughout Scotland, and it was on these findings that further work by Morgan and his collaborators was based.

iv) Implications of the life cycle in practice

As a result of research over the years, ideas on what constitutes the "standard" life cycle have had to be altered. This is particularly significant under the variable conditions found on hill farms from one season to another. The simple concept of a few days from egg to infective larvae and a few weeks of prepatency may only have theoretical implications and may bear little significance to the evolvement of a practical anthelmintic programme (page 76, 182).

Again, as improvements are made on hill farms in the future, the situation may be created where some revision of accepted anthelmintic programmes will have to be made; the implications being that the anthelmintic programme suitable at some periods of the year whilst sheep are kept on hill grazings, may be different from the programme suitable at other times of the year if more seasonal use of in-bye or improved grazings develops. With increasing knowledge in the epidemiology of the parasites, it is likely that a clearer definition of what constitutes strategic or tactical methods of treatment will emerge alongside altered systems in husbandry. In reflection of this, where it is the current and basically sound practice of some hill farmers to drench ewe hoggs or older sheep immediately they are put in-bye which has only been recently vacated by ewes and lambs, the hypothetical argument might be presented that dosing should be delayed until later to allow hoggs to pick up the residual larval population. In this way, the cost/benefit from using a modern anthelmintic might be widened resulting from more worms being destroyed. However, it raises the possibility of more larvae of some species becoming inhibited in the process (page 173). On further reflection, the possible development of paddock grazing on the better hill land raises implications in the development of a suitable anthelmintic programme suited to this particular system and in relation to the degree of intensification which has been developed. In recognition of some of these implications, a discussion follows on some of the significant aspects in the seasonal occurrence of bursate nematodes.

SIGNIFICANT ASPECTS IN SEASONAL OCCURRENCE

Graphs D-J* indicate the seasonal occurrence and levels of a few of the different species which were found in all ages of Scottish hill sheep by Morgan et al (1951, 1952); Wilson et al (1953); Parnell et al (1954).

It was on the basis of these findings, including detailed data on seasonal variations in worm-egg production by Morgan and Sloan (1947) and Morgan et al (1950) that anthelmintic trials mainly using phenothiazine (pages 71,77) were conducted by Parnell and his collaborators (1955 a.b., 1960, 1961).

Although some repetition of the points made in this section and others may occur, it is considered as unavoidable in an attempt to produce further clarification.

(a) Autumn and winter, spring and summer

The opinion is advanced that autumn and winter mark key periods in the year, not only in the incidence of bursate nematodes but in their significance in relation to other periods both in the free-living and parasitic phases.

i) Autumn

In Scottish hill sheep the increase in worm-egg production was found to occur later in the autumn compared to that found by Crofton (1954) from observations in sheep in Western England. Several species are shown to be involved, the increase being mainly composed of eggs of the more important species - *Ostertagia*; *Trichostrongylus vitrinus*; *Trichostrongylus colubriformis*; and *Bunostomum trigonocephalum* - although the latter species does not show marked seasonal fluctuations. This increase in worm

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egg laying at this autumn season causes pasture contamination and increased numbers of infective larvae to be found on the pastures.

Graphs 1-3* indicate the numbers of immature worms which were found free in the alimentary tract. Unfortunately these graphs do not indicate the true numbers of larvae, since Morgan and his co-workers were unable to record (from inadequacy of the method used) the numbers of larvae found in the histotropic stage in the mucosa of the abomasum and small intestine. (Page 76). Graph 4* indicates the worm egg counts of hill sheep throughout their flock life.
On Northumbrian hill pastures the peak numbers of larvae were found during August and slowly declined to the end of October (Crofton 1949) - a factor significant in itself to indicate the need for a strategic drenching of the flock in the late autumn or early winter before the onset of the breeding season.

This occurrence of large numbers of larvae led investigators, including Cushnie and White (1948) and Morgan and his collaborators, to associate the autumn "rise" with the occurrence of infestations in the spring (pages 76,77); the appearance of increased pasture contamination and in the numbers of infective larvae implying a potential source of further infection to the flock in later weeks and months. For instance, the spread of infection can be encouraged on both in-bye and on improved but restricted grazings where ewes with twin lambs have been densely stocked through summer and part of the autumn and where some precedence is given to fattening lambs after speaning. It is further encouraged where hoggs are wintered in-bye for the whole winter

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period or kept until housing in December or January (pages 172-3). Some risk is incurred to the ewe hoggs from infection when brought down in-bye as they are invariably put on the same pastures some two or three weeks after they have been vacated by the twinning ewes on being returned to the hill. Where controlled tupping is practiced, the further spread of infection can be encouraged. Several investigators share the view that the acquisition of larvae in the autumn confers a degree of immunity while the sheep are still in good condition. (Page 70,78)

A factor apparently inescapable on many hill farms, is the variable condition of the younger animals (i.e. replacement hoggs) by the end of the autumn season. The quality and condition of some individuals in the flock may still be inferior (as a continuing reflection of their condition at speaning) and the inevitability of their enforced selection as flock replacements due to a variety of reasons (page 24,32,34).

On the other hand, some mitigation of this extreme situation can be achieved where it is possible and practicable year after year to retain <u>all</u> the available ewe lambs at speaning over and above what is actually required, as potential candidates for flock replacement. In addition to a programme of strategic drenching suitably timed, some improvement can be afforded by further culling of poorer animals at the end of the winter and even later at the gimmer stage (page 24).

This suggested scheme of improvement may possibly result in better fitter animals more resistant to helminths and may close the gap in the widely differing degrees of response to infection (Gibson 1954) and the differences in inherent resistance as suggested by Paver et al (1955).

Further, in acknowledging that some animals may be more prone to infection than others, the suggestion made by Robertson (1942) of giving the poorer hoggs preferential feeding by folding on turnips rather than encouraging infection by leaving them to graze with the better class of animals has considerable merit. On some farms the position may be alleviated by preferential treatment under cover in sheds : any animals which obviously do not respond are then culled and disposed of before their condition further declines.

In further recognition of the need to reduce the degree of pasture contamination and the subsequent survival and development of larvae (pages 89,90) away-wintering offers advantages by relieving the pressure on the home pastures and also "perhaps indirectly help the older sheep on the hill" as stated by Paver et al (1955).

Obviously the question of increasing resistance of younger animals as Paver et al (1955) suggests requires more study - and more so in view of the trend towards flock improvements.

ii) Winter

By the end of December and early January, worm egg production in hill sheep has reached a low level. Why this should occur is apparently conjectural. It may simply be due to the acquisition of larvae earlier, which results in a high immunity in the host (Crofton 1954) (Soulsby 1957, 1962) or as further suggested by Crofton (1954) a delay in the prepatency period of these larvae even without a histotropic stage (page 77).

Nevertheless, under the enforced deprivations of the hill flock from weather and poor feeding (pages 32-39) and the period of waning immunity, it was recognised that anthelmintic treatment was necessary. Removal of infections in the late autumn or early winter was imperative and prompted anthelmintic trials using mainly phenothiazine in Scottish hill sheep (Parnell <u>et al</u> (1955 a&b); Parnell and Dunn (1960); Parnell <u>et al</u> (1961).

iii) Spring

Morgan <u>et al</u> (1950) confirmed the findings of Morgan and Sloan (1947) (and later Cushnie and White (1948)) who first recorded that faecal worm-egg counts declining during winter, increased rapidly by early spring, commencing as early as end of January and the beginning of February and reaching a peak by the end of May or early June; in this, Parnell <u>et al</u> (1961) noted, "The late winter or early spring rise in worm-egg production is caused by an increase in the numbers of adult <u>Ostertagia</u> spp; <u>Trichostrongylus</u> spp., <u>Chabertia</u> <u>ovina</u> and <u>Oesophogostomum</u> <u>venulosum</u> . . . .".

The phenomenon has been generally well recorded (pages 75-79) by several observations in sheep kept under a variety of conditions and the descriptive phrase "spring rise" is now in everyday use. Under hill conditions, increased worm-egg production is seen in relation to reduced resistance in hoggs and ewes arising from poor nutrition during winter and early spring; the extra strain of pregnancy in ewes, and severe climatic conditions (Paver <u>et al</u> 1955). Additional stresses in ewes are parturition and lactation (pages 72-78; 85-87).

The origin lies in the contamination of the pastures and especially in this, Paver et al (1955) stress the role of hoggs and gimmers. The ultimate significance is that the peak of worm-egg production occurs when lambs are nearly six to eight weeks old and nibbling grass. Therefore, it is important to forestall contamination of the pastures with eggs and the development of larvae by strategic drenching of both hoggs and ewes.

The situation in the spring for the hill farmer may be summed up by Spedding's (1965) rather broad ecological viewpoint, "Little knowledge is available on the interaction of ewes, lambs, pasture, plants, parasites and weather, yet the farmer lives with the problem of putting them together for a profit". The problem is obviously of significance in the current hill farming situation; it also raises the question of when to drench ewes and in this, practical and hypothetical considerations arise.

There is a case for drenching ewes before lambing both under lowland and hill conditions, on the basis that not only does it reduce pasture contamination, but also by removing sources of internal damage and thus restraints on productivity, helps ewes over the critical period of lambing and encourages milk yield (page 86).

To encourage yield, many hill farmers customarily give supplementary feeding over four to six weeks before the onset of lambing in an effort to raise production in terms of better nourished lambs, increasing their chances of survival and growth progress at least up to marking. Despite the obvious logic of this, it might be argued that the level of supplementary feeding may in some cases be inadequate insofar that it is merely lifting the flock above a level of relative starvation which has lasted for a considerable period during winter. It might be argued therefore that it does little to offset the depredations and further risks of parasitism (page 83). Moreover, the quality of the food given is worthy of further consideration (page 84).

Therefore the feasability of removing the burden of worms at udder locking should it occur some four to six weeks before lambing and at a time when supplementation commences on many farms, has strategic and tactical merit; dosing then, should check the accumulation of *Ostertagia* spp., *Trichostrongylus* spp., and *Chabertia ovina*. On the other hand, the gathering for udder locking can be delayed to the beginning of April - for a variety of reasons. Either from traditional habit, to avoid an extra handling when hoggs return from wintering, to give a timely dipping for tick infestation, or in following the recommendations for vaccination programmes.

By virtue of these practical situations - whatever their own merit, or for what are believed to be economic considerations, drenching may be missed out or delayed until early April. Such a delay is frequently not in the best interests of the flock from a parasitic control point of view. It is becoming ever more evident that a degree of rapprochement is needed between the often stubborn traditionalism and the need to do what is best for the flock at the optimal time in terms of parasite control.

Whatever the practical situations met with, a further argument in favour of drenching before the onset of lambing lies in the anomalous situation caused by the spring weather on many hill farms. Lambing can often be nearly completed and the ewe's milk yield reaching or even passing its peak before appreciable pasture growth and the peak rise in worm-egg production occurs. Drenching may help to bridge the critical gap of three or four weeks between lambing and the establishment of pasture growth.

In appreciation of this nutritional situation, especially with regard to increased numbers of breeding ewes with more twins as a result of improvement schemes, Dickson (1969) poses the question if the "traditional date" of April 15th is indeed the best date on which lambing should commence and suggests it should be delayed for fourteen days.
It can be postulated that not only would milk production both in yield and quality be improved but it would allow greater chances of lamb survival and a steady, more uniform liveweight increase possibly accruing from an easier transition by the lambs from a milk to a grass diet. This, in turn, may allow the lambs a more gradual exposure to any infection persisting on the pastures - despite pre-lambing drenching - and the development of acquired resistance.

There is the view that a post-lambing treatment for worms should be of value in reducing the spring rise in egg production under lowland conditions (Gibson 1965) (Nunns et al 1965) but on the hill this would only be practicable where lambing is restricted to in-bye and fenced portions of the improved lower grazings.

Nevertheless, a post-lambing drenching of ewes with young lambs at foot poses practical difficulties in handling. Besides, the critical period for gimmers and ewes before and during lambing is over, so that on balance it is postulated that a pre-lambing rather than a post-lambing drenching is to be preferred.

Where housing of gimmers or older cast ewes is practiced - and this currently seems to be limited to only a few hill farms - a different problem arises as to the most beneficial time to drench

iv) Summer

Morgan and his collaborators (Parnell _et al_ 1955a) on farms in Southern Scotland noted the occurrence of increased worm-egg counts in hill lambs by late June and early July, the principal contributor being _Ostertagia spp_. Following a slight fall in worm-egg output for a few weeks from mid July, increased numbers of _Trichostrongylus_ spp., and _B. trigonocephalum_ occurred. Significantly the pattern varied on farms near the West coast; increases in the worm burdens did not occur until August which suggested that the dosing of lambs would need to be later than indicated elsewhere.

(b) The origin of "the spring rise"

Considerable attention has been given to the origin of the "spring rise" in view of its considerable practical importance.

Taylor (1935) in his first observation on the theory of increased seasonal fecundity of the various worm species was supported by Hawkins and de Freitas (1947); Cushnie and White (1948) and Naerland (1949).

Morgan et al (1951) associated the occurrence in Scottish hill sheep with an increase in the worm burden from the acquisition of infective larvae by the host during the winter : these larvae laid as eggs in the previous autumn having developed and survived the winter on the pastures to become established in the host.

In analysis of the work, Paver et al (1955) stated: "Under hill conditions therefore, the resistance of the host appears to be of greater importance than the availability of larvae; even under severe winter conditions, the intake of larvae appears sufficient to allow the development of heavy infestations".

In Norway, Naerland (1949) although supporting the theory of worm fecundity concluded fresh thoughts on in-wintered hoggs which were kept at different nutritional levels by stating: "probably to a certain extent, due to new females having developed to maturity from larvae which, since the foregoing pasture season, have been latently in the intestinal mucosa".

Since then, from the evidence of studies by several investigators, it is generally accepted that the spring rise is related to the maturation of previously dormant or retarded larvae of certain species in the mucosa of the abomasum and small intestine, these larvae having remained latent in the histotropic stage for several weeks or months after being ingested possibly in the autumn and completing their third "moult" in the host.

It has been found that the principal species to display latency in sheep are Ostertagia which can do so for a period of three months (Sommerville 1954), Trichostrongylus spp. (Ford et al 1960) and H. contortus (Gibbs 1964).

Significantly, Morgan and his collaborators found Ostertagia spp. to be a predominant contributor to the spring rise, although other species were also present, and the species also appeared in lambs (pages 71,75). The earlier hypothesis by Morgan et al (1951) of acquired larvae from the hill pastures during the winter and early spring has never been entirely refuted by other investigators principally Crofton (1954; 1958; 1963); Brunsdon (1963); and Nunns et al (1965). The fact that some species can survive cold conditions and resist dessication lends support to the contention. Recent unpublished evidence clearly indicates that development and survival of larvae can take place under Scottish hill conditions. (Page 90).

In recognition of the possibility that the initiation of the spring rise in Scottish hill sheep can be derived from two sources (i.e. the maturation of latent larvae acquired from the pastures during autumn and early winter and the intake of larvae which survived winter conditions on the pasture) Parnell et al (1961) stated: "If this is so, and if treatment can reduce the numbers of these stages in the late autumn the pattern of the spring treatment might have to be revised", and further, in recognition that phenothiazine had limited activity (pages 80,94) it was stated: "It is possible therefore, especially if treatment in winter had removed any immature stages that treatment of gimmers and ewes in early winter might also be beneficial".

Nowadays, it would seem possible with the greater efficiency of a modern anthelmintic (pages 96,99) to remove not only the adult but also the immature larvae (i.e. before they reach the histotropic stage) not only in early winter before tupping - but also in mid winter when hill sheep are in a poor state (pages 71,102). This latter point is also significant as worm-egg counts appear to increase by early February (page 71 & see appendix, Graph 4).

i) Retarded larvae

It is generally accepted from the evidence that the sudden maturation of retarded or quiescent larvae is related to the immunological status of the host; Crofton (1954), Soulsby (1957, 1962) believe that the high immunity status from the larvae acquired in the previous months, was followed during winter by a progressive breakdown in the resistance of the host due to reduced numbers of larvae being ingested. From investigations, it is apparent that decreased or fluctuating levels of resistance can be induced by various stress factors; factors well recognised as significant in hill sheep especially during the winter (pages 171-178) and in relation to the height of the spring rise. (Paver et al 1955).

Crofton (1954, 1958) in relating the stress of lambing and lactation to the post parturient fluctuating rises in spring and autumn lambed ewes, also observed a similar, but less marked rise in wether hoggs during spring and in barren ewes in spring and autumn.

In recognition of the occurrence in un-bred sheep, Crofton (1958) and later in review (Crofton 1963) stated: "the fact that the rise in egg count has been observed in non-reproductive sheep excludes the possibility that the loss of resistance is due to the stress of parturition, and, although various stress factors may enhance the effect, the fundamental basis of the spring or post parturient rise seems to be the relationship between the reproductive cycle and the immune status of the host". Later Crofton (1963) pointed out the "spring rise" was merely descriptive of a phenomenon which may arise in different ways.

The fact that several investigators including Spedding and Brown (1956); Field _et al_ (1960); Parnell (1963); Brunsdon (1966); Gibbs (1967); James and Johnstone (1967) found that on transferring sheep from pastures to pens (and thus removed from exposure to reinfestation) the development of otherwise inhibited larvae continued, is significant in relation to forms of stress. This is of particular interest where hill hoggs and ewes have been housed as an improvement tactic. It is also important particularly since no known observations on anthelmintic trials have so far been carried out in Scottish hill sheep in shed, and especially in view of the importance of resistance. Not all investigators found a significant rise in worm-egg counts in unbred housed hoggs. In this, Ford _et al_ (1960) working with ewe and wether hoggs stated in their conclusion: ". . . .small rises occurred in nulliparous ewe hoggs and wether hoggs".

Nevertheless, James and Johnstone (1967) found from observations on _O. circumcincta_ that wether hoggs, previously exposed to infection showed an increase in faecal egg counts within two months and in explanation stated: ". . . .presumably as a result of the renewed development of inhibited larvae, associated with a stress factor or the change of environment". In addition to this environmental effect, they agreed with Soulsby (1957) that the level of larval intake and host resistance was a controlling factor in the inhibition of ingested larvae; this latter point is in general agreement with observations by other investigators including Ford _et al_ (1960) in Scotland and Parnell (1963) in Australia. Therefore it is to be expected that the level of larval uptake and the acquired resistance in ewe hoggs will vary on hill farms according to the time when the ewe hoggs are put into the sheds.

Among other suggestions postulated as interfering with the resistance of hoggs, has been the effects of nutrition at different levels even after anthelmintic treatment (Naerland (1949); Spedding and Brown (1956)) (presumably the worm-egg counts rose later due to the failure of the anthelmintic to kill the immature stages). Further, Parnell (1962, 1963) in Australia noted that worm-egg counts rose in wether hoggs transferred to and kept in concrete pens and fed on a chaff diet, and persisted for six to seven months despite anthelmintic treatment. However in discussion of the phenomenon it was stated by Parnell (1962): "part of the increase in the number of eggs per gramme was probably caused by decreased faecal output, but, it is unlikely that it accounted for such a marked and prolonged increase". The point of a decreased faecal output possibly occuring with a change of diet is not only significant in respect of housed hoggs, but quite apart from this, it is well recognised that other factors ought to be taken into consideration as to the value of worm-egg counts as an aid to diagnosis.

ii) Diagnostic value of worm-egg counts

It has been established that eggs are not uniformly distributed throughout the faeces and there are not only seasonal variations but also hourly variations in egg output; the fecundity of worm species also varies (Stoll (1929); Spedding (1952) (1953); Kingsbury (1965)). Originally devised as a research tool involving the sampling of all members of a small experimental group on three days in one week, the technique has been progressively debased to a situation where faeces samples from 5% or less of a flock or herd are examined once only. A 5 gramme sample from a ewe passing about 5 lb of dung per day from which a two gramme sample is prepared for examination by mixing with salt solution from which less than one millilitre is withdrawn, is not conducive to an acceptable degree of accuracy. Dependence on the results of <u>one</u> such test can be misleading but is commonplace.

iii) Biochemical aspects

Several investigators including Armour *et al* (1966), Horak and Clark (1964, 1966), Horak *et al* (1965, 1967) have made detailed studies on the pathophysiological changes which take place following heavy infections of *O. circumcincta*, *colubriformis* and *Oesophagostomum columbianum*.

In this brief synoptic review, it is noted that increases in the pH and plasma pepsinogen occurred which were associated and correlated to interference with the various components of digestion in the experimental sheep due to mechanical damage from the infections. The fact that the increase in plasma pepsinogen reached a peak by day 16 and correlated with the emergence of the larvae from the mucosa may have practical implications in the strategic timing of in-wintered hill sheep (page 105). Further significance is attached to the findings that a marked reduction in food intake occurred, besides the appearance of other symptoms within a month after infestation.

PATHOGENESIS OF NEMATODE INFESTATION

The general signs of clinical infestations are variously described as anaemia, loss of weight, anorexia, lassitude and diarrhoea.

However, it is only in recent times that the full effect involving loss of productivity, has been appreciated or measured in economic terms. It is proposed, therefore, to deal more with the general effects detrimental to economic husbandry than to consider the localised pathological effects in the body itself. The extent of the loss is obscured by a multiplicity of factors including age, fluctuating levels of infection, the amount and quality of food eaten and the duration of each infection. To measure the extent of damage on productivity generally, several investigators have removed sheep from their natural environment comparing artificially infected animals with worm-free groups. However, considering the fundamental principles of epidemiology that every sheep is infested to some degree with more than one worm species, that the process of reinfection from one sheep to another is continuous, and the effects of the various species on the host are additive - renders it difficult to determine and to evaluate the total amount of damage inflicted.

In Scottish hill sheep in an attempt to appraise the potential damage caused by the various species, Parnell et al (1954) suggested a "morbidity table" as follows:-

1 Hookworm (Bunostomum trigonocephalum) = 2 larger mouthed bowel worms (Chabertia ovina) = 4 Oesophagostomum venulosum = 10 barber's pole worms (Haemonchus contortus) = 60 brown stomach worms (Ostertagia spp.) = 80 black scour worms (Trichostrongylus spp.) or 80 small intestine hair worms (Cooperia curticei) or 80 long-necked bowel worms (Nematodirus spp.) or 80 Strongyloides papillosus or 80 larvae free in the alimentary tract.

In this estimate, however, no account was taken of the potential life span of the various species.

Much of the more recent data on consequential losses are derived from work done in lowland sheep. However, there is no reason to suppose that hill sheep suffer to a lesser degree and thus the general considerations are valid.

(a) Significance of nutritional status

With faulty nutrition in hill sheep for at least six months of the year if not longer (pages 33-34) it is to be expected that there must exist a close relationship between resistance to parasites and the nutritional status of the flock. Paver et al (1955). The balance in this relationship must be critical. Fraser's (1945) observation, although obviously a truism, i.e. "It is easier to increase the sheep's resistance than to decrease the number of worms", cannot be entirely applicable in hill farming under the strictures of present economic and environmental restraints.

Nevertheless, various studies have indicated the significance of feeding. For instance White and Cushnie (1952) observed that worm-egg counts were reduced in hoggs during the spring season by giving a simple concentrate rich in protein. Similar studies under controlled conditions were observed in lambs by Fraser and Robertson (1933) and in wether hoggs by Naerland (1949).

(b) Loss of appetite and reduced digestive efficiency

A significant feature of infestation is the depression of appetite which it appears to produce. Gibson (1955) noted that lambs infected with T. axei did not thrive when fed with hay and concentrates. A reduction in appetite of 8% in lambs was observed by Spedding (1954) whilst Gordon (1958) under Australian conditions and in lambs infected with T. colubriformis reported a 50% reduction. Conversely, the removal of mixed infections under practical field conditions stimulates appetite and increases food conversion as shown by Thomas and Bainbridge (1967). There is also a suggestion that the digestive efficiency of the food given may be impaired; Spedding (1954) estimated a lowering of 10% besides reducing appetite by 8%.

The type and quality of food fed to sheep is important and this is particularly applicable to hill sheep. Following infections of B. trigonocephalum, hay consumption was reduced six weeks later (Lucker and Neumayer 1947); whilst Laurence et al (1951) demonstrated that lambs fed at maintenance level did not respond compared to those fed at production levels when exposed to infections of H. contortus and O. venulosum. The inference may therefore be drawn that where hill sheep are fed limited amounts of supplementary food or only hay at particular periods, this besides being insufficient to provide energy (more so, if it is of doubtful digestibility and palatability) will hardly raise the resistance to a level to restrict parasites and increase the cost/benefit ratio.

Also, if too much reliance is placed on the value of in-bye or fenced pastures in the late autumn or early winter, especially if heavily stocked under a system of improving productivity, the end result may be poor resistance to parasites and damage to the flock even before the onset of the worst winter conditions.

This cumulative effect, at worst may be reflected by unsuccessful conception by some ewes despite recourse to supplementary or improved feeding management prior to tupping or again, in poor condition of hoggs before the full onset of winter conditions.

Although observations suggest that good standards of feeding depress the effect of worms, nevertheless under systems of improvement it would seem that more study is needed on the relationship of the food requirements of parasites and those of sheep. In this connection, Hunter (1963) postulated, "The nutritional requirements of the parasite and the relation of this need to the host are not well known, in spite of the fact that many definitions of the term "parasite" imply a knowledge of how the parasite obtains its food".

(c) Anaemia

The anaemia resulting from the blood sucking activities of the worm H. contortus in the lamb, was studied by Fourrie (1931) and later by Andrews (1942). The amount of blood lost - estimated from the blood content of the faeces - over a ten-day period - amounted to no less than $1\frac{3}{4}$ to $2\frac{1}{2}$ times the original quantity of the blood in the lambs, as calculated from bodyweight. These figures were in fact checked by deliberate jugular bleeding. The subsequent strain placed on other organs arising directly from the anaemia is evidenced by degenerative changes in heart muscle, liver, kidney and spleen. Damage to this degree particularly when occurring in vulnerable young stock, must have a profound effect on their future progress throughout life.

(d) Effect on milk production

Any interference by sub-clinical infections - whatever the extent of the spring rise in worm-egg production - on the milking capacity of hill ewes is critical in its effect on their nursing lambs, particularly over the first six or eight weeks. Gordon (1950) reported under Australian conditions that infections of Haemonchus contortus larvae reduced milk yield from 50 fl.oz. daily to 11 fl.oz. within three weeks. Following treatment with an anthelmintic (i.e. phenothiazine) yield was restored to only 29 fl.oz. three weeks later.

With the introduction of even better anthelmintics, it seems that when used strategically, the loss of milk yield could be prevented. If used at a later stage, a higher level of milk flow may be restored more quickly, thus avoiding a serious check on the lambs.

The importance of inadequate milk supply in relation to worm infestation has more involved implications. Milk being a major part of the lambs' diet in the first few weeks, it follows that any restriction will force lambs to graze at a much earlier age than they otherwise would and thus expose themselves to a greater intake of infective larvae. Depending on the challenge met with from the existing level of infection, then the acquisition of early resistance may be impaired. The effect on growth rate even for a short period may ultimately restrict survival rate and full potential growth being achieved by weaning. Under hill pasture conditions, lamb growth can already be restricted from marking to weaning due to the poor utilisation of the pastures by the flock and declining digestibility of the herbage (Eadie 1967), therefore any interference by parasites particularly over the early part of the lamb's life may further inhibit growth potential.

The value of a good milk supply was illustrated by Spedding et al

(1963) who showed that lambs reared as singles have fewer worms at slaughter than lambs reared as twins even when grazed on the same pasture. Therefore with limited acreage to support ewes with twins, it is important to ensure adequate milk supply and prevent any restriction in growth in the lambs.

(e) Effect on wool

The precise influence of worm infestation on wool growth and quality, is undoubtedly difficult to measure as various factors are concerned.

These include the age of the animal, the extent of the infestation and the time of the year (Spedding et al 1957) and further confounded by the different stress factors of pregnancy and lactation. Doney (1964); Doney and Smith (1961) a. b. (1964).

The effect of a "break" or tenderness in the wool fibre can be associated with "lowered condition" of sheep - any improvement being followed by part of the fleece being "shed" (page 107). Gordon (1958) stated: "In addition to producing less wool the effects of malnutrition in causing tenderness and "break" in the fibre may be aggravated in infested sheep".

Kauzal (1936) found that reduced wool production could be caused by infestations of C. ovina during the prepatent period substantiated by Gordon (1958) whilst Carter et al (1946) showed a reduction of 40.2% in wether lambs from infestations of T. colubriformis compared to the control animals. Brunsdon (1966) found the wool response related to liveweight gain and a 3% extra yield in greasy wool was obtained from drenched animals. However, in hill sheep the response from anthelmintic treatment is difficult to judge when nutrition and weather conditions obscure any real response to a winter anthelmintic programme (page 32,57). However there is some indication that the dosing of in-shed ewe hoggs gives a response in fleece weight (Pages 161,162).

(f) Other aspects

Studies have been made on genetic differences between breeds in their susceptibility to worm infestation. For instance, Ross (1970) compared cross and pure bred Blackface with Dorset Horn lambs in their susceptibility to *T. axei* larvae. It was found that the latter displayed a greater resistance when expressed in terms of mortality, survival and weight gain at two months old and a greater competence to develop an acquired immunity at six months old. Parnell (1939) observed (although on a very small scale) that Southdowns were less resistant than Cheviots to Haemonchosis.

THE SIGNIFICANCE OF GRAZING BEHAVIOUR

Compared to low ground or unimproved in-bye, where heavier infestations of parasites can be a risk due to overcrowding at certain periods of the year, the low stocking rates normally found on hill pastures would suggest that little risk is incurred from one season to another.

But, with the virtual absence of close shepherding or daily "raking" and low feeding values of many pastures especially during winter (page 30), sheep tend to congregate in groups or "families" - even more so than is their gregarious habit - on "patches" of the more nutritious herbage best suited to their immediate needs.

In this, Hunter (1962) noted this selective grazing pattern resulted in the overgrazing of certain grasses resulting in uneven pasture utilisation.

Earlier Crofton (1949) estimated that less than 50% of the total area was utilised on poorer farms whilst on better farms it was estimated that about 20% was under-utilised.

Even a casual observation on hill pastures shows that numbers of hill sheep can be found competing for grazing on favoured green areas, around deserted crofts and shielings, along burnsides and in the lee of rocks, and along hill tracks. These sites become heavily soiled and a potential source of infection from concentrations of larvae. During winter when deep snow lies for long periods and prevents sheep from ranging out on the lower slopes more especially just above the fences of renovated or better grazing ground the result is heavy fouling - even where raking is practiced to some degree. It is also recognised that "night camping" on lower or sheltered areas often by older ewes (and thus encouraging younger animals to follow suit) encourages the fouling of these favoured places.

All these considerations emphasise the degree of potential risk of infection, and in its way disputes the belief held by some that by virtue of the terrain and the stocking rates, hill sheep need not be wormed.

(a) Survival of larvae

Studies have revealed the importance of seasonal climatic changes on the rates of development, survival, migration, and mortality of eggs and larvae at different times of the year.

It has been shown that larvae are relatively long lived and capable of lying dormant in sheep for considerable periods during the winter and to have the capacity to resume development later. (Griffiths (1937); Hawkins *et al* (1944); Harbour *et al* (1946); Crofton (1949, 1954, 1958); Morgan *et al* (1951); and Gibson and Everett (1967)).

These findings have several implications in the development of the possible optimum time during winter to strategically drench hill sheep when subjected to lowered resistance due to "poverty" (i.e. effects of weather and malnutrition).

On the hill, the concept of an "average" life cycle is misleading, because of the slower development and different survival rate of larvae from eggs laid in the autumn or early winter completing their third "moult" and reaching full patency, compared with low ground farms on which most of the earlier observations were made.

A dose in January or early February if it should prove beneficial may be important on hill farms where improvements are envisaged or have already been carried out. In this, Crofton (1949) made the point that the improvement of pastures with accompanying increased stocking rates, distributes larvae over the whole area and tends to reduce local concentrations of infection. Although Crofton emphasised in his hill sheep studies in Northumberland that the removal of sheep from the pastures for a few weeks reduced the number of larvae, the opportunities for this are scant on limited in-bye and on the lower pastures where hoggs are home-wintered in-bye or eventually transferred indoors in January.

(b) Evidence of survival

Further evidence on the survival of larvae on the pasture may be drawn from Paver <u>et al</u> (1955): ". . . .there is a close association between a long period of low temperatures and a surface of frozen snow" and Gibson and Everett (1967) who observed a regular pattern of survival under snow. This showed that the micro-climate under the snow was sufficient for larvae survival and conditions of alternating freezing and thawing were more lethal than sustained periods of freezing conditions. Under practical conditions, the height of the snow line may be of significance. The tops of hills or mountains may become free of snow, but if a "freeze" follows the thaw, a collar of snow or ice may block-off the higher reaches. The result of this is a greater concentration of sheep in a smaller area and thus an increased chance of infestation.

Rayski (1969 - personal communication) made observations on Scottish hill pastures commencing in 1967, to establish the survival rate of Trichostrongylus and strongyle larvae on experimental grass plots where sheep were known to congregate during winter at height ranges from 900 to 1200 feet in the Pentland, Moorfoot and Lammermuir hills. The plots were one square foot in area, "seeded" with faeces containing the parasite eggs. Samples of grass picked close to the "mat" of the old pasture were taken at intervals, (this presumably in recognition of Crofton's (1948) findings that from November to March "nearly all the larvae occurred in the "mat").

Tables 11, 12 give an indication of the results. It suggests that the infective larvae of Ostertagia and Trichostrongylus spp., are capable of developing from the egg stage and surviving the winter and spring on the pastures. Adult Bunostomum trigonocephalum does not show the same marked fluctuations as other species and the levels of the infestations are in tens rather than hundreds. Although it is a prolific egg layer, it would appear necessary for experimental plots to be "seeded" with the free-living stages of the species, before sufficient data could be obtained on the survival rate.

No data were obtained on the survival of free-living stages of Cooperia spp. although Rose (1963) found that larvae may survive two years.

Although Nematodirus spp. are very seldom in sufficient numbers to harm hill lambs, it is seen that infective larvae appear in May. However under heavy stocking of in-bye with ewes and twins, the potential problem cannot be discounted.

Table 12 suggests that the infective stage of C. ovina increase in numbers on hill pastures in the spring.

No infective larvae of H. contortus were found in any sample of herbage but this is more commonly a lowland parasite.

Table 11

Date	Ostertagia spp.	Trichostrongylus spp.	Nematodirus spp.	Muellarius capillaris
18/12/67	-	-	-	-
8/1/68	-	-	-	-
29/1/68	2	-	-	2
12/2/68	2	-	-	3*
28/2/68	4	1	-	2*
11/3/68	5	3	-	1
29/3/68	4	1	-	1
6/4/68	3	-	-	0
29/4/68	3	-	-	-
13/5/68	0	-	-	-
29/5/68	2	-	5	-
18/12/67	-	-	-	-
8/1/68	-	-	-	-
29/1/68	-	-	-	-
12/2/68	-	-	-	-
28/2/68	-	-	-	-
11/3/68	2	-	-	-
29/3/68	2	1	-	-
6/4/68	1	-	-	-
29/4/68	2	2	-	-
13/5/68	2	-	-	-
29/5/68	1	-	-	-

*Under snow

Table 12

	25th March 1968	5th May 1968	15th July 1968
Ostertagia spp.	7	7	1
Trichostrongylus spp.	3	-	-
Nematodirus	-	11	-
Chabertia ovina	-	3	-
O. venulosum	1	-	-

THE USE OF ANTHELMINTICS

It is quite apparent that in hill sheep no less than on low ground, the use of anthelmintics is not the complete answer to the problem of helminth infestation. As with the use of flukicides, they should be used judiciously alongside good standards of flock and pasture management to obtain the best results.

Poor standards of nutrition obscure the results and effectiveness of any anthelmintic treatment. It is also acknowledged that the results achieved can be variable whether they are judged "by the eye", measured in terms of liveweight gain or by calculation of the economic productive efficiency.

The results are also influenced by the immunological status of the host animal - the relative timings of the infection which is influenced by weather and other factors; the severity of these infections; the accuracy of dosing, and many other considerations. Nevertheless, an effective anthelmintic used at the optimum time, both strategically and tactically, gives a freedom to intensify methods of grazing and to permit a better chance of increased production at a lower cost.

A number of these anthelmintics are now briefly reviewed.

(a) Earlier treatments

(i) Phenothiazine

In 1939 the introduction as an anthelmintic of phenothiazine (thiodiphenylamine) previously used as a dyestuff marked a decided improvement over previous treatments such as copper sulphate alone or in combination with nicotine sulphate; a review was carried out by Vierling (1970).

The properties of phenothiazine have been well recorded. With the advantages of a very high therapeutic index and high safety margin, it was also remarkably stable even when mixed with foodstuffs, minerals and other agents.

Innumerable field studies have been carried out over the years in different parts of the world by various investigators. In earlier work on Scottish hill sheep, phenothiazine was used. However it was realised that the shortcomings of phenothiazine were in its lack of acceptable levels of efficiency against some mature species and nearly all the immature stages : this led to improvement in purity and particle size in an effort to enhance anthelmintic activity. Nevertheless the failings were perpetuated. Again relatively large doses were needed if high efficiency was to be achieved; there was also a risk of photosensitisation in both lambs and calves and staining of the wool in sheep during dosing. These disadvantages were later exacerbated by its poor activity against outbreaks of nematodiriasis particularly during the 1950's.

The discovery of Bephenium compounds, first the embonate and later the hydroxynaphthoate derived from quaternary ammonium complexes was found to be effective against trichostrongyloid parasites in ruminants and more especially against Nematodirus spp. (Rawes and Scarnell (1959)). Whilst solving the immediate problem of nematodirus in lowland sheep, unfortunately the chemical displayed lower anthelmintic activity than phenothiazine against other worm species, more especially against Ostertagia and Trichostrongylus spp.

Since then, the development of more widely efficient anthelmintics has continued, with special attention being paid to activity against the immature stages.

(ii) Methyridine

This compound (2(beta methoxyethyl pyridine), was derived from coal-tar fractions and was found to be completely miscible with water. The chemical, whether given orally, subcutaneously or intraperitoneally, was found to be effective against a wide range of gastro-intestinal nematodes of sheep and cattle. In describing its effectiveness Walley (1961) and later in review (Walley 1966) emphasised its activity against adult lungworm with a slightly lesser effect against the immature forms especially from the tenth day after ingestion by animals. Trials by Broome (1961); Gracey and Kerr (1961); Gibson (1962); Groves (1961); Harrow (1961, 1962); Macrae (1961); Walley (1962, 1963) confirmed its effectiveness and its striking clinical improvement of animals treated. The drug was found to be rapidly absorbed after administration and a high proportion excreted or re-excreted into the intestines during which the anthelmintic action took place. The drug acts by causing muscular paralysis due to neuromuscular block.

Despite the high activity however, methyridine exhibited undesirable properties. It had a low therapeutic index so that some risk could be attached to over-dosage on the farm. Again in injectable form some local reactions could occur at the injection site. Since then the discovery of new compounds highly active against a wide range of nematodes with wide safety margins have been introduced on the market.

(b) Modern treatments

(i) Thiabendazole : Pyrantel Tartrate

Thiabendazole (2-(4-thiazolyl) benzimidazole) was discovered in 1961 and was reported by Brown et al (1961) and reviewed by Dunlop (1967). Since then, the chemical has been used in various studies by several investigators including Connan (1967); Leaning et al (1970) and Murray et al (1971). It has virtually no toxicity and a high degree of activity against intestinal nematodes. However it has limited action against lungworm in sheep and cattle. More recently it has been combined with another chemical, Rafoxanide, to extend the commercial use to control liver fluke. Another compound, Pyrantel tartrate (trans-1-methyl-2 (a-thienylvinyl, 1, 4, 5, 6 Tetrahydro pyrimidine tartrate) reported on by Austin et al (1966) and Cornwell et al (1966) was found to exhibit activity against most of the intestinal nematodes.

(ii) Tetramisole as an anthelmintic

Thienpont et al (1966) first described tetramisole as a white, colourless, stable and water soluble crystalline hydrochloride of 2, 3, 5, 6 - tetrahydro - 6 - phenyl - imidazo (2, 1 - b).

Preliminary observations showed the compound to be active at low dose levels against adult and immature gastro-intestinal and pulmonary nematodes. Detailed evidence on the field use of tetramisole was reported by Walley (1966) who established outstanding results following oral or parenteral dosing at different therapeutic levels.

Even at the low dose level of 2.5 mg/kg anthelmintic activity was demonstrable; the activity against the parasites increased with the dose level until at 10 mg/kg a very high activity was reached. A review of published papers confirms that at a level of 15 mg/kg the majority of adult and immature larvae were removed of the genera Haemonchus, Ostertagia, Trichostrongylus (abomasal and intestinal species), Nematodirus, Cooperia, Bunostomum, Chabertia, Oesophagostomum and Dictyocaulus. The activity of the chemical is shown against the various species in the following table.

Table 13 - Percentage efficiency of dl-tetramisole at 10 and 15 mg/kg in sheep

	10 mg/kg				15 mg/kg			
	Adults	Immatures (age in days)			Adults	Immatures (age in days)		
		0-6	7-12	12		0-6	7-12	12
Haemonchus contortus	99	91	88	98	99	93	98	100
Ostertagia spp.	92	54	48	77	96	86	75	92
Trichostrongylus (abomasum)	97	73	82	97	99	92	93	99
Trichostrongylus (intestine)	98	93	98	99	99	97	98	99
Nematodirus spp.	98	69	96	99	99	100	95	99
Cooperia	98	28	88	96	99	83	98	98
Bunostomum spp.	91	-	88	42	96	-	100	100
Chabertia ovina	99	100	58	83	99	97	96	99
Oesophagostomum spp.	98	58	82	66	99	58	84	84
Dictyocaulus filaria	97	41	84	96	98	58	90	91

Source: The anthelmintic activity of dl-tetramisole against nematode parasites of sheep, cattle and pigs. I.C.I. publication (restricted).

In its mode of action, tetramisole does not directly kill the nematodes but paralyses the control nervous system by inhibiting succinate dehydrogenase. Further properties of the drug are the rapid elimination from all the body tissues and excretion in the urine and faeces of the treated animals. It may be mixed with the compound oxyclozanide, thus permitting the treatment of both roundworm and liver fluke in one dose, a factor not overlooked in the conduct of the field trials. (Page 111).

Tetramisole has a four to six fold margin of safety. Some 102 authors in 33 countries have published 146 papers on the chemistry, biochemistry and activity of this drug in 36 species of animals, including cattle and pigs. A further development is that this drug can now be administered as a subcutaneous injection, due to its property of being a racemate with optically active "dextro" and "laevo" isomers in almost equal proportions. However in common with other modern anthelmintics, tetramisole has a very low activity against inhibited (histotropic) forms of nematodes. Armour (1967) has suggested that these forms may be unable to absorb the drugs due to their low level of metabolism.

In production trials Forsyth (1966) in Australia reported that sheep infected with moderate worm burdens reached a fixed weight (60 or 75 lb) more quickly than untreated animals, i.e. the weight was attained in 32 weeks by 50% of the animals as compared to 10% of those left untreated. Further, all treated sheep gained from ½ to 1 lb of wool per head compared to the untreated. Estapanian (1970) reported on the value of dosing sheep with tetramisole in North Western Iran and concluded: "The economic assessment showed that the dose cost/response ratio was at its greatest at the standard dose of 15 mg/kg. There is thus no justification for reducing the dose to obtain a "phenothiazine-like" effect at a lower cost per dose".

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CHAPTER ONE

Methods and project design

Field trials using tetramisole

Project design

CHAPTER I

FIELD TRIALS USING TETRAMISOLE

The basic aim of the trials was to show the benefits of the greater activity of tetramisole and whether drenching at the different times or repeat dosing was sounder practice. Moreover, in view of more recent developments in hill farming practice such as wintering ewe hoggs in-shed and the spring dosing of ewes, an opportunity was presented to test the optimal time for drenching and to gauge the response on the animals. It is believed that the in-shed studies on ewe hoggs were the first ever to be conducted in any country; further, a measurement of the strategic worth of drenching in winter has not previously been made in ewe hoggs and ewes.

In the current field trials, the seasons are for the sake of clarity, defined as "early winter" (or "late autumn") taken from late September to November; "winter" as ranging from December to February and the "spring" season as from March to April.

(a) The scope of the trials

There are so many systems and variations in the pattern of management and differences in climate and topography from one area to another, that it proved difficult to select systems into which to fit the studies of the benefits to be achieved from dosing and optimal dosing strategy. It was finally decided to investigate five systems. In recognition of the area differences in topography, climate, management and nutritional status the trial sites were spread over Scotland as much as possible from Kirkcudbrightshire in the South, Berwickshire and Aberdeenshire in the East, Argyllshire in the West and Ross-shire in the North. Maps, suitably marked to indicate the approximate location of the trial sites of each system are shown. (Appendix)

(b) Hill ewes

In a somewhat paradoxical situation, breeding ewes, even during a normal winter are expected to seek out and exist on the available herbage and yet to cope with the strain of advancing pregnancy. This endurance test is increased every winter by the added factor of increasing age and associated bodily wear and tear until drafted. Drenching to remove any worm infection could be a way to combat this and widen the flock cost/benefit.

Owners and shepherds well recognise that many ewes "will strip it off their own backs", inferring the mobilisation of bodily reserves. The loss has been estimated as 86% of the fat in the subcutaneous reserves of five year old ewes in the first four months of pregnancy by Russel, Gunn and Doney (1968). It is also recognised that extra feeding is not in practice given until near lambing. Therefore the aim of the drenching trials was not only to measure the effect on the stamina of the animals by productive factors, but also to judge the effects on the lambs at a later stage. The strategic times of drenching were prescribed at pre-tupping or in early winter; in winter (i.e. in January or early February to suitably coinciding with the gathering to remove the tups and debreek hill wintered ewe hoggs) and at pre-lambing. In order to test the merit of a January drenching either a single or second dose was given at this time.

(c) The case for ewe hoggs

(i) Hill wintered

Loss in bodyweight is to be expected in sheep of all ages kept on the hill during winter (page 32) and in this, the stress on the in-lamb ewe is the greatest. However, the extent of the loss in ewe hoggs is relatively more important because they are still at a stage of growth and development and a serious "check" during the winter could have serious repercussions later, particularly in the early stages of breeding life (page 37). Indeed, many shepherds take the view that a serious check in condition and bodyweight at this stage is seldom regained.

Therefore the basic aim of the trials was to determine if the loss of bodyweight could be reduced by one or two well timed strategic drenchings with tetramisole.

Thus, these drenchings were carried out in the early winter (or late autumn) before the commencement of the breeding season either at the "breeking" of the hoggs where it was practised, or when they were gathered before being returned to winter on their own part of the hill. Further, in order to test the effectiveness of a winter drenching (i.e. mainly in January) either a single dose or a second dose was given at this time (i.e. when the ewe hoggs were "de-breeked" during winter to coincide with the gathering of the breeding ewe flock for the removal of the tups).

(ii) In-bye wintered

Whilst those kept in-bye do not have to face the rigours of the winter to the same degree as those on the open hill, nevertheless as young sheep, they need to continue to develop and to grow to fit them for their breeding life.

In-bye land varies greatly from farm to farm. The area in proportion to the size of the flock, the extent to which the area is used and the uses to which it is put, are obvious variable factors. Ideally, the soil and pasture management should closely follow that employed for any piece of lowland. However, the nature of the terrain may prevent normal cultivation or it may be felt that the expense of anything beyond the minimum "care and maintenance" is not justifiable.

The limitations of in-bye acreage and its poor quality may often be over-looked and too much may be expected of it. Being enclosed and handy to the house and buildings, it can easily become "over-used" by a wide variety of stock for a host of different reasons throughout the year. Such land, unless very carefully managed, can quickly become a potent source of infection and infestation, and thus a danger to all animals that use it.

Again the basic aim was to compare the value of drenching at the early winter stage with a strategic drenching in the winter, to coincide with the seasonal "rise" in infestation at that time.

(iii) Away-wintered

As the stock hoggs in this system are removed to, and spend the winter under different conditions of weather and feeding without direct supervision by the owner, it was decided to examine the value of the normal practice of drenching the ewe hoggs on being sent to the winterings and a further or single treatment in January.

(iv) In-shed wintered

The practice of housing stock hoggs for the whole or part of the winter is increasing (page 26). When the practice of housing under uncharacteristically intensive conditions was first mooted, it was inevitable that comparisons would be made with the health difficulties experienced with pigs and poultry under similar circumstances. In the event, very few of these have materialised, possibly with the exception of pneumonia outbreaks due to inadequately ventilated buildings. But the desire to house "clean" animals is very strong in some quarters and it is accepted practice by many owners to dose their hoggs on entry to the buildings to prevent the spread of worm infestation.

Therefore the primary aim of the trials was to test the response from this treatment on the day of entry and the benefits of so doing over the housing period. However, bearing in mind the stressful nature of housing on otherwise free-ranging animals, delay in dosing was also arranged. It was to be expected that a delayed dose would permit more larvae to develop to the adult stage when they are more easily attacked by anthelmintics. In addition, however, it was postulated that a period to allow the effects of stress to take effect, might, by inducing the liberation of histotropic forms, produce a better response to treatment.

PROJECT DESIGN

There are many criteria which can be used in attempting to determine the economic value of worming livestock. Liveweight, growth and "condition" are the most obvious, although fecundity and productivity in female animals can also be measured in longer term work and where the time of treatment is related to the breeding cycle.

"Condition" is in part, a subjective measurement and suffers in respect of this. Measurement of growth as evidenced by records of girth, body length, leg length, etc. (Gunn 1964 a & b) and others, are by their very nature more suited to studies on lowland sheep under intensive conditions or small groups under close control.

Under the conditions of the work reported in this thesis, liveweight measurements provided the most convenient "yardstick", although it is appreciated that liveweight per se by not taking cognisance of body size or "condition", has its limitations. However, since the trials were done within one breeding year on the same farm in one group and class of stock, the complicating factors of variations in age, nutrition, and inter-seasonal weather conditions were avoided. Weight recording was confined to the work on hoggs and on the progeny of ewes that had been dosed pre-lambing. Referring to hoggs specifically, it is well appreciated that female stock intended for subsequent breeding do not have a slaughter value. Nevertheless for the sake of comparison the benefit of dosing can be shown by attributing a nominal market value and deducting the cost of treatment.

Pregnant ewes were not weighed because of the complications resulting from the presence of the foetus, foetal membranes and fluids. Post-partum weighings are also of little value because of the varying effects of the strain of lactation depending on the number and the size of the lambs and the quality of the grazing.

There are several criteria which can be used in determining whether there is any advantage in drenching ewes. Some of these depend on the time of dosing in relation to the breeding cycle but may include:-

1. A study of the numbers of "tup yeld" and "kebbed" (together recorded as "empty"). In consideration of the numbers of "yeld", it is only valid where the dosing programme includes a pre-tupping treatment. Further, under practical conditions, it is not always possible by January or by udder locking in March or early April, to distinguish ewes which were "yeld" or "kebbed".

2. Any increase in the number giving birth to twin lambs.

3. The number of ewes giving birth to dead lambs and also those with no milk or with insufficient milk to keep lambs alive until they can fend for themselves.

4. Any increase in the bodyweight of lambs at marking and/or at speaning as the result of treatment of the ewes at a strategic time before lambing.

5. Any increase in fleece weights. The differences are likely to be slight due to the number and complexity of the other factors which influence wool growth. These include nutrition, weather and size of individual animals. Furthermore the weight of the fleece may be

no criterion of quality. A further even more pertinent factor, is when drenching is given (or for that matter when conditions improve) animals previously subjected to poor conditions and visibly checked in their condition, can then start to thrive. The result is that some individuals peel their fleeces so that at clipping only parts of the fleece will be available for weighing. Differences arising from variations in clipping methods (i.e. hand shears or electric shearing); closeness of clipping between one operator and another; and humidity of atmosphere, are recognised.

6. Any reduction in the number of ewe deaths in the various trial groups; it is recognised that in practice this rarely occurs, nevertheless any differences were recorded.

(a) <u>Selection of farms</u>

Whilst it is freely accepted that the selection of trial sites should be entirely at random, the practical nature of the field work involved had a restraining influence. It is emphasised that a high degree of selectivity was not practiced, but much perforce depended on willing co-operation over long periods from owners and shepherds alike. It should be appreciated that farm trial work involves considerable extra expenditure in time and labour and interference with normal husbandry practices and indeed actual loss to owners in having to keep undosed controls.

Nevertheless, the farms used were completely typical of the average hill or upland farm and may be taken as a "mini"-cross-section of the hill sheep industry in Scotland. Two types of enterprise only, were not involved - the very large specialist, financially strong enterprise or at the other end of the scale, the subsidised Highland croft.

The deficiencies in terms of lack of complete standardisation of the animals involved or their nutritional status at all times, in comparison with laboratory-controlled research work are freely admitted. On the other hand, artificiality of any kind was not involved and thus the results achieved are directly comparable and applicable to the industry as it exists in every day practice.

(b) Selection of animals

On many trial sites, depending on the size of the farm, the entire population of hill sheep was taken; on other sites it was possible to take a sufficiently large genuinely random sample of animals all kept under similar conditions of pasture and climatic conditions. The aim throughout was to ensure uniformity in all groups regarding the sex, breed and type of the animals involved.

In the formation of trial groups the animals were allocated so as to ensure homogeniety in respect of weight spread as between the lightest and heaviest in each group.

For instance, the weight "scatter" was limited to 7 lb in respect of hoggs. An even weight spread was attained by running the flock through the pen "race" and by using the "shedding gate" allocating alternative animals to respective groups. Where it was necessary, a further selection was made by the same method to ensure even greater inter-group uniformity, supplemented by discarding animals of obvious extreme weight from each group. Obviously the success of this method in its essence depended on a large population at the disposal of a trial so that a high degree of inter-group uniformity could be attained.

An alternative method, where practical conditions at the start of the trial permitted, was to weigh each animal in the sample and to set out the weights as follows:-

lb. wt.	Number	lb. wt.	Number
64	/	75	///
65	/	76	//
66		77	////
67		78	/
68	//	79	//
69		80	
70	/	81	
71	/	82	/
72	/	83	/
73	//	84	//
74	//	85	/

Thus, setting down the weights in lines left to right, right to left alternately:-

	A	B	C	D
	64	65	68	68
	73	72	71	70
	73	74	74	75
	76	76	75	75
	77	77	77	77
	82	79	79	78
	83	84	84	85
Total	528	527	528	528
Av.	75.4	75.3	75.4	75.4
Range	64-83	65-84	68-84	68-85
No. per group	20	20	17	18

This method involved a double handling of each animal but it was necessary to ensure an even weight spread where at first sight the available animals were obviously ill-balanced in weight.

Ewes and gimmers were also divided by shedding paying particular attention to ensure an even distribution of ages.

(c) Group identification

The general method employed to identify the trial groups was by the use of coloured, series-numbered ear tags inserted in the ear. In case ear tags should become lost during the course of the trial period, the precaution was taken of painting one or other of the horns or applying a "buist" mark (i.e. a colour mark with marking fluid).

A further precaution was the inclusion of a number of extra animals in each group to allow for accidents, deaths and other mishaps.

(d) Method of weighing

Generally a pig weighing machine, suitably placed in the pens to allow easy working, was used to weigh the animals - due care being taken to ensure the weight recording dial was accurate at each weighing, and the "platform" kept reasonably clean during the course of weighing.

(e) Control of liver fluke

On those trial sites where liver fluke was present or where the owner's custom was to dose against fluke, care was taken to ensure that treatment was given. This was done by giving all groups liver fluke treatments, i.e. by giving a combination of tetramisole and oxyclozanide to the "treatment" groups and giving oxyclozanide, the fasciolicide, to the "non treatment" groups according to the trial protocol.

CHAPTER II

Results

Hill ewes and gimmers

Ewe hoggs

Note: In results tables, the "top" pair of figures reading across, refers to the treated group, the "bottom" pair to the control group.

HILL EWES AND GIMMERS

The treatments given may conveniently be divided into (a) 1st phase improvement and (b) 2nd phase improvement.

The former refers to attempts to cut down the number of barren ewes and gimmers by means of strategic dosing, and also to measure the number still nursing a lamb or lambs at marking time.*

'Second phase improvement' refers to measurements of lamb weights from dosed and undosed ewes at marking as a measure of the quality of the nursing.

The results on '1st phase improvement' are considered to be of special significance not only by revealing the true extent of losses on some farms, but also the benefit, albeit indirect, arising from dosing at strategic points in the breeding season.

The statistical evaluation in this section of the results is by the chi-squared test.

*Note: In calculating the number "barren", any which may have died have first been removed.
In the "nursing" tables (Suffix a) this is shown as a percentage of those originally put to the tup. This method of calculation is considered in detail in Chapter III (Discussion - Economic Considerations).

Table 14

HILL EWES AND GIMMERS

SUMMARY OF BARREN AT UDDER LOCKING

(Tables 16,17,18,19,20,21)

Treatment	Number of trials	Number of farms	Mean advantage over control	Statistical significance p value
i	ii	iii	% iv	v
Early winter	4	3	7.9	< 0.10
Winter	8	6	10.8	< 0.01
Early winter and winter	8	5	5.4	< 0.02
Early winter and spring	5	4	2.3	> 0.10
Winter and spring	4	3	6.7	> 0.10
Spring	5	4	2.4	> 0.10

Table 15

HILL EWES AND GIMMERS

SUMMARY OF NURSING TO MARKING

(Tables 16a,17a,18a,19a)

Treatment	Number of trials	Number of farms	Mean advantage over control	Statistical significance p value
i	ii	iii	% iv	v
Early winter	3	2	9.5	> 0.10
Winter	5	4	15.0	< 0.02
Early winter and winter	5	3	14.9	< 0.01
Early winter and spring	5	4	4.9	> 0.10
Spring	5	4	12.6	< 0.02

Early winter v no treatment (Tables 16 and 16a)

Table 16 shows that the number of barren ewes in the four trials recorded was reduced in the treated groups by 7.9% to give a statistical significance at the 10% level. Only one trial (No. 72) was clearly significant at the 2% level.

Table 16a indicates the number of ewes nursing lambs at marking in June when taken as the percentage of those put to the tup in early winter. In the three trials recorded, the difference in favour of the treated groups was 9.5% but this was statistically insignificant at the 10% level.

Table 16

HILL EWES AND GIMMERS : NUMBER RECORDED AS BARREN

Comparison : Early winter v no treatment

Trial No.	Location	Number of animals	Deaths	Barren (at udder locking)			
				Number	%	Difference from control %	Statistical significance p value
52	XXXVI	70* 140	10 10	23 56	38.3 43.0	+ 4.7	> 0.10
64	XVII	16* 18	0 0	2 4	12.5 22.2	+ 9.7	> 0.10
65	XVII	16* 18	0 0	3 5	18.8 27.8	+ 9.0	> 0.10
72	XXI	83 83	0 0	0 7	0.0 8.4	+ 8.4	< 0.02
				Overall mean		+ 7.9	< 0.10

*gimmers

Table 16a

HILL EWES AND GIMMERS : NUMBER RECORDED AS NURSING

Comparison : Early winter v no treatment

Trial No.	Location	Ewes put to tup	No. nursing	Percentage nursing	Difference from control %	Statistical significance p value
52	XXXVI	70* 140	37 74	52.9 52.9	0.0	> 0.10
64	XVII	16* 18	12 11	75.0 61.1	+13.9	> 0.10
65	XVII	16* 18	13 12	81.3 66.7	+14.6	> 0.10
				Overall mean	+ 9.5	> 0.10

*gimmers

Winter v no treatment (Tables 17 and 17a)

Seven of the eight trials recorded in table 17 showed an improvement from treatment relative to the control with three individual trials (numbers 59, 72, 73) statistically significant. The overall mean difference of 10.8% in favour of the treated groups was significant at the 1% level.

In table 17a the nursing numbers were increased as a result of treatment in four of the five trials recorded. The overall mean difference of 15% in favour of treatment was significant at the 2% level although three individual trials (numbers 58, 60, 77) were insignificant.

HILL EWES AND GIMMERS : NUMBER RECORDED AS BARREN

Table 17

Comparison : Winter v no treatment

Trial No.	Location	Number of animals	Deaths	Barren (at udder locking)			
				Number	%	Difference from control %	Statistical significance p value
58	XLI	122 122	11 8	7 6	6.3 5.3	- 1.0	> 0.10
59	XI	19 31	0 0	1 8	5.3 25.8	+20.5	< 0.10
60	XI	20 30	0 0	0 4	0.0 13.3	+13.3	> 0.10
63	XVII	30 27	0 0	2 4	6.7 14.8	+ 8.1	> 0.10
72	XLIV	83 83	0 0	0 7	0.0 8.4	+ 8.4	< 0.02
73	XLV	50 50	0 0	3 13	6.0 26.0	+20.0	< 0.02
74	XLV	50 50	0 0	3 6	6.0 12.0	+ 6.0	> 0.10
77	XV	46 19	1 0	2 3	4.4 15.8	+11.4	> 0.10
				Overall mean		+10.8	< 0.01

Table 17a

HILL EWES AND GIMMERS : NUMBER RECORDED AS NURSING

Comparison : Winter v no treatment

Trial No.	Location	Ewes put to tup	No. nursing	Percentage nursing	Difference from control %	Statistical significance p value
58	XLI	122 122	71* 76*	58.2 62.3	- 4.1	> 0.10
59	XI	19 31	18 19	94.7 61.3	+33.4	< 0.02
60	XI	20 30	16 20	80.0 66.7	+13.3	> 0.10
63	XVII	30 27	27 18	90.0 66.7	+23.3	< 0.10
77	XV	46 19	43 16	93.5 84.2	+ 9.3	> 0.10
				Overall mean	+15.0	< 0.02

* 8 in treated group and 5 in control group died between udder locking and lambing

<u>Early winter and winter v no treatment</u> (Tables 18 and 18a)

Table 18 indicates the number of barren ewes was reduced by treatment in five of the eight trials recorded giving a pooled response of 5.4% which is significant at the 2% level.

In trial number 51, high numbers of barren ewes occurred in both treated and untreated groups. The flock history revealed that high numbers of barren animals was a normal occurrence; reasons for this are obscure. Nevertheless, treatment reduced the incidence by 16% which is statistically significant at the 2% level.

Trial number 53 was conducted on the same farm but in this case the flock spent a part of the winter on a different portion of the grazings than the animals involved in trial number 51.

The results of five trials in table 18a based on the number of nursing ewes recorded at lamb marking in June gave a response of 14.9% in favour of treatment which is statistically significant at the 1% level.

Table 18

HILL EWES AND GIMMERS : NUMBER RECORDED AS BARREN

Comparison : Early winter and winter v no treatment

Trial No.	Location	Number of animals	Deaths	Barren (at udder locking)			
				Number	%	Difference from control %	Statistical significance p value
51	XXXVI	125* 125*	4 10	52 68	43.0 59.1	+16.1	< 0.02
53	XXXVI	100* 100*	0 0	1 0	1.0 0.0	- 1.0	> 0.10
55	XXXVIII	220 110	0 0	28 7	12.7 6.4	- 6.3	> 0.10
56	XIL	39 40	0 0	10 12	25.6 30.0	+ 4.4	> 0.10
64	XVII	16* 18*	0 0	2 5	12.5 28.0	+15.5	> 0.10
65	XVII	16* 18*	0 0	0 4	0.0 22.0	+22.0	> 0.10
73	XLV	182 182	0 0	19 39	10.4 21.4	+11.0	< 0.01
74	XLV	228 228	0 0	67 66	29.3 28.9	- 0.4	>0.10
				Overall mean		+ 5.4	< 0.02

* Gimmers

Table 18a

HILL EWES AND GIMMERS : NUMBER RECORDED AS NURSING

Comparison : Early winter and winter v no treatment

Trial No.	Location	Ewes put to tup	No. nursing	Percentage nursing	Difference from control %	Statistical significance p value
51	XXXVI	125* 125*	69 47	55.2 37.6	+17.6	< 0.01
53	XXXVI	100* 100*	93 94	93.0 94.0	- 1.0	> 0.10
56	XIL	39 40	29 28	74.4 70.0	+ 4.4	> 0.10
64	XVII	16* 18*	13 11	81.3 61.1	+20.2	> 0.10
65	XVII	16* 18*	16 12	100.0 66.7	+33.3	< 0.02
				Overall mean	+14.9	< 0.01

* Gimmers

Early winter and spring v no treatment (Tables 19 and 19a)

Table 19 shows that treatment in three out of the five trials recorded gave a reduction in the number of barren ewes and that despite an overall mean response of 2.3%, the results were insignificant.

In table 19a, the results were also insignificant despite the mean difference of 4.9% being attained in favour of treatment. The variability in the results (which also occurs in the other ewe results) is considered in more detail in Chapter III (Economic Considerations, Page 197).

Table 19

HILL EWES AND GIMMERS : NUMBER RECORDED AS BARREN

Comparison : Early winter and spring v no treatment

Trial No.	Location	Number of animals	Deaths	Barren (at udder locking)			
				Number	%	Difference from control %	Statistical significance p value
49	XXXIV	36 37	0 0	2 6	5.6 16.2	+10.6	> 0.10
50	XXXV	43 43	0 0	6 7	14.0 16.3	+ 2.3	> 0.10
54	XXXVII	80* 80*	0 0	21 25	26.3 31.3	+ 5.0	> 0.10
64	XVII	15* 18*	0 0	4 4	26.7 22.2	- 4.5	> 0.10
65	XVII	12* 18*	0 2	4 5	33.3 31.3	- 2.0	> 0.10
				Overall mean		+ 2.3	> 0.10

* Gimmers

Table 19a

HILL EWES AND GIMMERS : NUMBER RECORDED AS NURSING

Comparison : Early winter and spring v no treatment

Trial No.	Location	Ewes put to tup	No. nursing	Percentage nursing	Difference from control %	Statistical significance p value
50	XXXV	43 43	37 36	86.1 83.7	+ 2.4	> 0.10
54	XXXVII	80* 80*	52 52	65.0 65.0	+ 0.0	> 0.10
56	XIL	40 40	32 28	80.0 70.0	+10.0	> 0.10
64	XVII	15* 18*	11 12	73.3 66.7	+ 6.6	> 0.10
65	XVII	12* 18*	8 11	66.7 61.1	+ 5.6	> 0.10
			Overall mean		+ 4.9	> 0.10

* Gimmers

Winter and spring v no treatment (Table 20)

It is considered that this drenching procedure would not be the normal practice on many hill farms. Nevertheless, the four trials conducted showed an overall advantage from treatment of 6.7% but the result was statistically insignificant.

It was not possible to record the numbers of nursing ewes at the lamb marking in June.

HILL EWES AND GIMMERS : BARREN NUMBERS ONLY

Table 20

Comparison : Winter and spring v no treatment

Trial No.	Location	Number of animals	Deaths	Barren (at udder locking)				Nursing (at marking)			
				Number	%	Difference from control %	Statistical significance p value	Number	%	Difference from control %	Statistical significance p value
49	XXXIV	36 37	1 0	4 6	11.4 16.2	+ 4.8	> 0.10	not recorded		-	-
58	XLI	122 122	8 8	6 6	5.3 5.3	0.0	> 0.10	not recorded		-	-
71	XLIV	50 50	0 0	6 13	12.0 26.0	+14.0	> 0.10	not recorded		-	-
72	XLIV	50 50	0 0	2 6	4.0 12.0	+ 8.0	> 0.10	not recorded		-	-
				Overall mean		+ 6.7	> 0.10				

Spring v no treatment (Tables 21 and 21a)

The results in table 21 were statistically insignificant. This is consistent with the fact that treatment given in spring would have no real effect on reducing the numbers of barren ewes earlier in the season.

In table 21a, the percentage of nursing ewes was increased by 12.6% from treatment which is significant at the 2% level.

HILL EWES AND GIMMERS : NUMBER RECORDED AS BARREN

Table 21 Comparison : Spring v no treatment

Trial No.	Location	Number of animals	Deaths	Barren (at udder locking)			
				Number	%	Difference from control %	Statistical significance p value
50	XXXV	43 43	0 0	3 7	7.0 16.3	+ 9.3	> 0.10
58	XLI	122 122	16 8	7 6	6.6 5.3	- 1.3	> 0.10
59	XI	91 25	0 0	7 6	7.7 24.0	+16.3	< 0.10
60	XI	49 25	0 0	9 2	18.4 8.0	-10.4	> 0.10
63	XVII	30 27	0 0	5 4	16.7 14.8	- 1.9	> 0.10
				Overall mean		+ 2.4	> 0.10

Table 21a

HILL EWES AND GIMMERS : NUMBER RECORDED AS NURSING

Comparison : Spring v no treatment

Trial No.	Location	Ewes put to tup	No. nursing	Percentage nursing	Difference from control %	Statistical significance p value
50	XXXV	43 43	40 36	93.0 83.7	+ 9.3	> 0.10
58	XLI	122 122	74 76	60.7 62.3	- 1.6	> 0.10
59	XI	91 25	81 16	89.0 64.0	+25.0	< 0.02
60	XI	49 25	40 17	81.6 68.0	+13.6	> 0.10
63	XVII	30 27	25 18	83.3 66.7	+16.6	> 0.10
				Overall mean	+12.6	< 0.02

Pre-lambing dosing v no treatment (Table 22)

'Second phase improvement'

In the nine trials recorded, three trials (numbers 56, 71, 75) were clearly significant at the 0.1% level whilst six of the total nine trials recorded were insignificant at the 10% level. Nevertheless the overall mean advantage of the lambs from the treated ewes was 2.8 lb at the statistically significant 5% level.

Table 22

PRE-LAMBING DOSING V NO TREATMENT

Effect on bodyweight of lambs at marking

Trial Number	Location	Mean wt. at marking(lb) a. Lambs off treated ewes b. Lambs off untreated ewes	Difference from control	Standard Error	Stat. signif. "p" value
i	ii	iii	iv	v	vi
56	XIL	a. 37.5 b. 32.3	+ 5.2	1.5	< 0.001
57	XL	a. 42.8 b. 41.6	+ 1.2	3.1	> 0.10
66	XVII	a. 31.2 b. 29.2	+ 2.0	2.1	> 0.10
67	XIX	a. 30.0 b. 28.2	+ 1.8	1.4	> 0.10
68	XLIII	a. 34.0 b. 32.4	+ 1.6	1.6	> 0.10
69	XIV	a. 39.8 b. 37.7	+ 2.1	1.4	> 0.10
71	XLIV	a. 38.0 b. 30.4	+ 7.6	1.3	< 0.001
75	XLVI	a. 37.8 b. 31.4	+ 6.4	1.8	< 0.001
76	XXXII	a. 35.0 b. 38.1	- 3.1	2.2	> 0.10
		Overall mean	+ 2.8	1.1	< 0.05

Table 23

EWE HOGGS : SUMMARY TABLE

	Treatment	Recorded (Spring (A) / Summer (B))	No. of trials	No of farms	No. of animals		Mean advantage over untreated + Gain − Loss (lb)	S.E.	Stat. signif. "p" value	Net value less cost of treatment (p)
					Treated	Control				
	i	ii	iii	iv	v	vi	vii	viii	ix	x
HILL WINTERED	Early winter	A	12	6	134	137	+ 3.0	0.58	<0.001	22
	Early winter	B	11	5	105	112	+ 3.7	1.19	<0.02	29
	Winter	A	10	5	116	110	+ 4.2	0.82	<0.001	34
	Winter	B	9	4	99	90	+ 4.9	1.74	<0.02	41
	Early winter & winter	A	8	4	87	91	+ 5.6	1.19	<0.01	40
	Early winter & winter	B	8	4	87	91	+ 4.7	1.94	<0.05	31
IN-BYE WINTERED	Early winter	A	7	6	202	147	+ 3.4	1.20	<0.05	28
	Early winter	B	5	3	113	82	+ 3.7	2.33	>0.10	30
	Winter	A	7	6	140	115	+ 3.8	1.06	<0.02	31
	Winter	B	4	3	62	66	+ 4.3	1.78	>0.10	36
	Early winter & winter	A	8	7	186	150	+ 5.0	1.15	<0.02	35
	Early winter & winter	B	6	4	128	90	+ 6.6	2.15	<0.05	52
AWAY WINTERED	Late autumn	A	8	6	226	159	+ 1.6	0.97	>0.10	9
	Late autumn	B	4	3	92	62	− 0.4	3.30	>0.10	−11
	Late autumn & winter	A	7	6	148	147	+ 1.5	0.80	<0.10	− 1
	Late autumn & winter	B	5	4	100	92	+ 0.7	1.54	>0.10	− 7
	Late autumn & spring	B	5	4	87	85	− 0.75	1.51	>0.10	− 7.4
IN-WINTERED	Day of entry	A	14	10	333	293	+ 4.1	0.46	<0.001	34
	Day of entry	B	6	5	144	123	+ 2.9	0.80	<0.02	23
	Short term delay	A	15	11	395	345	+ 5.9	0.70	<0.001	53
	Short term delay	B	5	5	117	114	+ 7.4	2.33	<0.05	66
	Long term delay	A	6	5	252	251	+ 2.7	0.90	<0.05	20
	Long term delay	B	2	2	65	65	+ 2.6	0.13	<0.05	17.5

Note: The statistical evaluation in this section of the results is by the t-test

Results (contd.)

(a) <u>Hill wintered ewe hoggs</u>

The "early winter" dose was given between mid October and mid November. The "winter" dose where given was towards the end of January.

As with the in-wintered work, duration of effect was studied in some cases beyond spring to summer.

Early winter v no treatment (Table 24)

In the twelve trials recorded, treatment in early winter resulted in a high level of significance ($p < 0.001$) with a mean advantage of 3 lb. In only one trial (No. 6(b)) was there a slight weight loss in the treated group.

A feature of the trials was the wide variation in liveweight at the start (a range of 60 - 85 lb approx.) which indicates the varying condition of animals found on farms. On three farms (numbers 2, 3, 6) the hoggs were split and treated according to the different hefts to allow for any variations during the winter.

Ten trials were recorded to summer and it was noted the statistical significance was reduced to the 2% level although there was a slight improvement in the mean weight advantage from the earlier dosing. Again trial number 6(b) showed that the control group gained over the treated animals, although in the other nine trials, the treated groups gained within a range from 3 - 5.9 lb.

Table 24

Hill wintered hoggs

Comparison : Early winter v no treatment to spring

Trial No.	Location	Mean Wts. (lb) Initial	Mean Wts. (lb) Final	Diff (lb) over control	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
i	ii	iii	iv	v	vi	vii	viii
1	I	64.0 62.6	62.3 57.9	+ 3.0	1.34	< 0.05	23
2(a)	II	84.4 83.3	62.3 57.9	+ 3.3	1.86	< 0.10	24
2(b)	II	81.0 80.9	58.7 57.6	+ 1.0	1.94	> 0.10	1
3(a)	III	71.8 79.8	62.8 63.7	+ 7.1	1.61	< 0.001	64
3(b)	III	82.2 81.6	65.5 64.5	+ 0.4	3.18	> 0.10	- 5
3(c)	III	82.2 78.8	68.9 62.8	+ 2.7	2.50	> 0.10	20
4	IV	60.6 60.6	59.6 54.3	+ 5.3	1.98	< 0.02	46
5	IV	67.2 68.0	64.4 62.3	+ 2.9	2.07	> 0.10	22
6(a)	V	71.6 70.7	54.2 50.2	+ 3.1	2.34	> 0.10	24
6(b)	V	69.7 68.8	50.5 49.7	- 0.1	1.38	> 0.10	-17
7	VI	75.6 74.0	60.6 55.5	+ 3.5	3.45	> 0.10	26
8	VI	72.8 77.4	60.0 60.7	+ 3.9	4.08	> 0.10	30
	Overall Mean			3.0	0.58	< 0.001	22

Comparison : Early winter v no treatment to summer

Trial No.	Location	Mean Wts. (lb) Initial	Mean Wts. (lb) Final	Diff (lb) over control	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
i	ii	iii	iv	v	vi	vii	viii
1	I	64.0 62.6	76.4 71.1	+ 3.9	1.79	< 0.05	32
2(a)	II	84.4 83.3	86.5 81.9	+ 3.5	1.99	< 0.10	26
2(b)	II	81.0 80.9	87.4 81.6	+ 5.7	2.21	< 0.02	48
3(a)	III	71.8 79.8	84.8 85.4	+ 7.4	2.43	< 0.01	67
3(b)	III	82.2 81.6	95.5 89.6	+ 5.3	3.98	> 0.10	44
3(c)	III	82.2 78.9	97.0 88.4	+ 5.3	3.08	> 0.10	44
6(a)	V	71.6 70.7	78.6 74.6	+ 3.1	3.03	> 0.10	24
6(b)	V	69.8 68.8	75.1 80.5	- 6.4	3.36	> 0.10	-71
7	VI	75.6 74.0	77.4 69.9	+ 5.9	3.39	< 0.10	52
8	VI	72.8 77.5	78.4 80.1	+ 3.0	6.36	> 0.10	21
	Overall Mean			+ 3.7	1.19	< 0.02	29

Winter v no treatment (Table 25)

The effect of a treatment in winter (i.e. towards the end of January coinciding with the "debreeking") showed a significant response at the 0.1% level in the ten trials recorded to spring with the overall mean weight advantage of 4.2 lb. However four of the ten trials recorded (numbers 3(b), 6(a), 7, 8) were individually statistically insignificant.

Comparing the treatments to summer, seven of the nine trials recorded to spring increased in weight as a result of treatment by summer. Overall the mean weight advantage of the total nine trials recorded to summer was 5.0 lb which is statistically significant at the 2% level. It is also noted that there was a greater variability in weight gains within trials to summer.

Table 25 Hill wintered hoggs

Comparison : Winter v no treatment to spring

Trial No.	Location	Mean wts.(lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
2(a)	II	82.5 80.9	64.7 57.6	+ 5.5	1.81	< 0.01	46
2(b)	II	81.4 83.3	61.8 57.9	+ 5.8	1.63	< 0.01	49
3(a)	III	71.3 79.8	63.4 63.7	+ 8.2	1.87	< 0.001	75
3(b)	III	82.6 81.6	67.0 64.5	+ 1.5	2.73	> 0.10	6
3(c)	III	80.6 78.9	69.5 62.8	+ 5.0	2.50	< 0.10	41
4	IV	58.1 60.6	58.3 54.3	+ 6.5	2.04	< 0.01	58
6(a)	V	71.2 70.7	52.5 50.2	+ 1.8	1.79	> 0.10	11
6(b)	V	69.1 68.8	55.7 49.7	+ 5.7	1.51	< 0.01	50
7	VI	77.9 76.3	58.5 55.7	+ 1.2	3.66	> 0.10	3
8	VI	73.8 77.4	58.0 60.7	+ 0.9	4.08	> 0.10	2
		Overall Mean		+ 4.2	0.82	< 0.001	34

Comparison : Winter v no treatment to summer

Trial No.	Location	Mean wts.(lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
2(a)	II	82.5 80.9	91.0 81.6	+ 7.8	2.17	< 0.01	69
2(b)	II	81.4 83.3	88.0 81.9	+ 8.0	2.06	< 0.001	71
3(a)	III	71.3 79.8	85.8 85.4	+ 8.9	2.31	< 0.01	80
3(b)	III	82.6 81.6	93.9 89.6	+ 3.3	3.4	> 0.10	24
3(c)	III	80.6 78.9	100.4 88.4	+10.3	2.6	< 0.01	94
6(a)	V	71.2 70.7	79.8 74.6	+ 4.7	2.3	< 0.05	40
6(b)	V	69.1 68.8	83.3 80.5	+ 2.5	3.0	> 0.10	18
7	VI	77.6 74.0	80.0 69.9	+ 6.5	3.44	< 0.10	56
8	VI	73.8 77.5	69.4 80.1	- 7.0	6.35	> 0.10	-77
		Overall Mean		+ 5.0	1.74	< 0.02	42

Early winter and winter v no treatment (Table 26)

To the spring, the overall mean response in the eight trials recorded was 5.6 lb from treatment which is statistically significant at the 1% level. Measured to the summer, the overall statistical significance was reduced to the 5% level but the mean weight increase of the treated groups remained constant.

Once again attention is drawn to the variability of the results between trials and indeed two trials (6(b), 8) showed a negative response to treatment by summer though in both cases there was a positive response up to the spring.

Table 26

Hill wintered hoggs

Comparison : Early winter and winter v no treatment to spring

Trial No.	Location	Mean Wts. (lb)		Diff (lb) over control	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
1	I	63.9 62.6	61.0 57.9	+ 1.8	1.41	> 0.10	4
3(a)	III	75.7 79.8	69.9 63.7	+10.3	1.95	< 0.001	84
3(b)	III	79.5 81.6	69.7 64.5	+ 7.3	3.18	< 0.05	55
3(c)	III	80.3 78.9	72.7 62.8	+ 8.5	2.11	< 0.01	67
6(a)	V	71.0 70.7	55.0 50.2	+ 4.5	1.82	< 0.05	31
6(b)	V	69.0 68.8	53.1 49.7	+ 3.2	1.46	< 0.05	18
7	VI	72.8 76.3	60.3 55.7	+ 8.1	3.44	< 0.05	67
8	VI	77.4 77.5	62.0 60.7	+ 1.4	4.08	> 0.10	- 4
		Overall Mean		+ 5.6	1.19	< 0.01	40

Comparison : Early winter and winter v no treatment to summer

Trial No.	Location	Mean Wts. (lb)		Diff (lb) over control	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
1	I	63.9 62.6	75.1 71.1	+ 2.7	1.55	< 0.10	13
3(a)	III	75.7 79.8	93.0 85.4	+11.7	2.45	< 0.001	99
3(b)	III	79.5 81.6	96.3 89.6	+ 8.8	3.98	< 0.05	70
3(c)	III	80.3 78.9	97.4 88.4	+ 7.6	3.06	< 0.05	58
6(a)	V	71.0 70.7	79.4 74.6	+ 4.5	2.80	> 0.10	31
6(b)	V	69.0 68.8	76.3 80.5	- 4.4	2.98	> 0.10	-57
7	VI	72.8 76.3	76.6 69.9	+10.2	3.39	< 0.05	65
8	VI	77.4 77.5	78.4 80.1	- 1.6	6.3	> 0.10	-34
		Overall Mean		+ 5.7	1.94	< 0.05	31

(b) <u>In-bye ewe hoggs</u>

Due to the "peculiar" nature of the in-bye, as determined by its relatively small area and over-usage by all classes of stock, it is not surprising that some of the body weight losses were greater than would be expected on the hill.

The results show that under these circumstances a strategic dosing programme is essential.

<u>Early winter v no treatment</u> (Table 27)

The overall advantage from treatment in the seven trials recorded to the spring was found to be at the 5% level of significance. Whilst two of the trials (numbers 12, 18) gave highly significant results from treatment ($p < 0.001$), two trials (numbers 16, 21) were insignificant. The response to treatment ranged from -0.2 to +9.2 lb in the seven trials recorded.

The lower limit of -0.2 lb occurred on a farm in Argyllshire (number 16) where the hoggs were kept on a marginal pasture of poor quality, whilst the upper limit of +9.2 lb was achieved on a Perthshire farm (number 12) where the hoggs were introduced on in-bye in autumn which had been heavily stocked with sheep earlier.

In every case the hoggs kept on in-bye received some degree of hand-feeding by January and held in-bye until late March or early April. In the five trials recorded to summer, two trials (numbers 11, 12) were significant at the 2% and 0.1% levels respectively whilst three trials (numbers 18, 19, 22) showed insignificant differences. Trial number 19 showed a negative mean weight response to treatment.

Overall, the mean response to summer was 4 lb but this was insignificant at the 10% level.

Table 27

In-bye hoggs

Comparison : Early winter v no treatment to spring

Trial No.	Location	Mean wts. (lb) Initial	Final	Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra l/wt gain less cost of dose(s) pence
i	ii	iii	iv	v	vi	vii	viii
9	VII	72.8 75.2	82.8 81.5	+ 3.7	1.10	< 0.01	30
10	VIII	79.8 79.8	87.8 84.5	+ 3.3	1.40	< 0.05	24
11	IX	56.0 56.2	51.6 48.6	+ 3.2	1.18	< 0.02	25
12	IX	65.3 67.6	59.3 52.4	+ 9.2	1.58	< 0.001	85
16	XII	61.7 59.6	57.0 55.1	- 0.2	1.36	> 0.10	- 9
18	XIII	72.8 73.3	72.2 67.9	+ 4.8	1.25	< 0.001	41
21	XV	63.1 62.0	61.9 60.8	0.0	2.80	> 0.10	- 7
		Overall mean		3.4	1.20	< 0.05	28

Comparison : Early winter v no treatment to summer

Trial No.	Location	Mean wts. (lb) Initial	Final	Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra l/wt gain less cost of dose(s) pence
i	ii	iii	iv	v	vi	vii	viii
11	IX	56.0 56.2	71.5 67.3	+ 4.4	1.63	< 0.02	37
12	IX	65.3 67.6	78.6 70.1	+10.8	2.30	< 0.001	101
18	XIII	71.6 73.3	86.7 84.2	+ 4.2	2.02	< 0.10	35
19	XIV	62.5 59.1	70.1 70.2	- 3.5	3.17	> 0.10	-42
22	XV	55.5 56.7	88.6 85.5	+ 4.3	2.79	> 0.10	36
		Overall mean		4.0	2.27	> 0.10	33

<u>Winter v no treatment</u> (Table 28)

Measured to the spring, the overall mean increase in liveweight of the seven trials recorded was 3.8 lb in favour of treatment giving a statistical significance at the 2% level. Overall the four trials recorded to summer gave a significant response (4.3 lb) from treatment at the 5% level although, as expected, the control groups also improved in weight with the better seasonal conditions of pasture growth on the hill from spring onwards.

Table 28

In-bye hoggs

Comparison : Winter v no treatment to spring

Trial No.	Location	Mean wts. (lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
9	VII	74.1 75.2	81.6 81.5	+ 1.2	1.21	> 0.10	5
11	IX	56.3 56.2	52.8 48.6	+ 4.1	1.37	< 0.01	34
12	IX	65.2 67.6	57.0 52.4	+ 7.0	1.69	< 0.001	63
13	X	59.6 59.4	63.7 60.4	+ 3.1	1.23	< 0.02	24
14	XI	55.1 63.9	49.2 51.1	+ 6.9	3.14	< 0.05	62
17	XII	63.1 66.9	70.5 69.2	+ 5.1	1.90	< 0.01	44
21	XV	60.9 62.0	59.2 60.8	- 0.5	2.80	> 0.10	-12
		Overall mean		3.8	1.06	< 0.02	31

Comparison : Winter v no treatment to summer

Trial No.	Location	Mean wts. (lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
11	IX	56.3 56.2	71.4 67.3	+ 4.0	2.03	< 0.10	33
12	IX	65.2 67.6	75.7 70.2	+ 7.9	2.15	< 0.001	72
14	XI	55.1 63.9	64.3 70.5	+ 2.6	3.41	> 0.10	19
22	XV	56.8 56.7	88.4 85.5	+ 2.8	2.90	> 0.10	21
		Overall mean		4.3	1.25	< 0.05	36

Early winter and winter v no treatment (Table 29)

The treated groups gave an overall greater mean response in liveweight of 5.0 lb in the eight trials recorded which is statistically significant at the 2% level. Two of the trials (numbers 16, 21) were statistically insignificant at the 10% level. Measured to summer, the six trials recorded gave a significant response from the treated groups at the 5% level. One of the trials (number 19) failed to show a response from treatment.

Table 29 In-bye hoggs

Comparison : Early winter and winter v no treatment to spring

Trial No.	Location	Mean wts.(lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
9	VII	74.8 75.2	85.3 81.5	+ 4.2	1.23	< 0.01	28
10	VIII	79.3 79.8	90.6 84.5	+ 6.6	1.40	< 0.001	50
11	IX	56.2 56.2	54.6 48.6	+ 6.0	1.24	< 0.001	46
12	IX	65.2 67.6	61.1 52.4	+11.1	1.67	< 0.001	97
13	X	59.3 59.4	64.0 60.4	+ 3.7	1.49	< 0.02	23
16	XII	65.1 59.6	59.8 55.1	- 0.8	1.99	> 0.10	-22
18	XIII	73.4 73.3	74.5 67.9	+ 6.5	1.45	< 0.001	51
21	XV	56.3 62.0	56.8 60.8	+ 1.7	2.94	> 0.10	3
		Overall mean		5.0	1.15	< 0.02	35

Comparison : Early winter and winter v no treatment to summer

Trial No.	Location	Mean wts.(lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
11	IX	56.2 56.2	73.8 67.3	+ 6.5	1.82	< 0.001	51
12	IX	65.2 67.6	82.4 70.2	+14.6	2.65	< 0.001	132
15	XI	59.2 60.8	71.0 64.5	+ 8.1	3.46	< 0.05	67
18	XIII	73.4 73.3	90.7 84.2	+ 6.4	2.23	< 0.01	50
19	XIV	61.0 59.1	71.8 70.2	- 0.3	3.00	> 0.10	-17
20	XIV	67.0 68.8	76.8 76.6	+ 2.0	1.35	> 0.10	6
		Overall Mean		6.2	2.15	< 0.05	48

(c) <u>Away-wintered ewe hoggs</u>

The results were very variable not only between farms but also between types of treatment.

In the Discussion, special attention is drawn to the highly variable nature of the away-wintering pastures in terms of their nutritional status and of their usage before the hoggs arrive for the winter. One outstanding example of this is described in detail.

<u>Late autumn v no treatment</u> (Table 30)

In seven of the eight trials recorded to spring there was a positive response in liveweight to treatment. The wide variation in the conditions of away-wintering on low ground farms is discussed in Chapter III, Page 185, and may be responsible for the variability of the results.

The overall mean response from treatment (1.6 lb) is insignificant at the 10% level.

To summer, only two of the four trials recorded showed a positive response to treatment. The overall mean gain was marginally negative and insignificant at the 10% level.

Table 30

Away wintered ewe hoggs

Comparison : Late autumn v no treatment to spring

Trial No.	Location	Mean wts. (lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
23	XVI	73.0 73.2	102.0 100.0	+ 2.2	1.71	> 0.10	+15
24	XVII	54.7 53.6	68.7 71.4	- 3.8	1.41	< 0.02 against	-45
25	XVII	53.0 54.3	56.6 57.7	+ 0.2	0.94	> 0.10	- 5
26	XVIII	61.5 60.1	64.8 62.8	+ 0.6	1.26	>0.10	- 1
27	XIX	77.6 76.2	93.4 90.1	+ 1.9	2.83	> 0.10	+12
28	XX	66.9 67.5	80.2 75.6	+ 5.2	1.49	< 0.01	+45
29	XXI	65.6 68.6	74.6 73.6	+ 4.0	1.84	< 0.05	+33
30	XXI	71.6 70.7	81.2 77.8	+ 2.5	2.35	> 0.10	+18
		Overall mean		+ 1.6	0.97	> 0.10	9

Comparison : Late autumn v no treatment to summer

Trial No.	Location	Mean wts. (lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
24	XVII	53.9 53.6	82.5 88.5	- 6.3	2.11	< 0.01 against	-70
25	XVII	52.5 54.3	67.8 73.7	- 4.1	1.97	< 0.05 against	-48
27	XIX	78.1 76.2	121.2 112.9	+ 6.4	1.97	< 0.01	+55
28	XX	66.4 67.5	105.4 103.9	+ 2.6	1.60	> 0.10	+19
		Overall mean		- 0.4	3.30	>0.10	-11

Late autumn and winter v no treatment (Table 31)

Six of the seven trials recorded to the spring responded in mean weight from treatment though only one trial (number 28) was the gain statistically significant. The overall result was marginal (1.6 lb) which is insignificant at the 10% level. Again to summer, the overall gain in the five trials recorded was marginal which is insignificant at the 10% level.

Table 31

Away wintered ewe hoggs

Comparison : Late autumn and winter v no treatment to spring

Trial No.	Location	Mean wts.(lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
23	XVI	74.0 73.2	102.7 100.0	+ 1.9	1.74	> 0.10	1.0
24	XVII	53.8 53.6	70.0 71.4	- 1.6	1.66	> 0.10	-30
25	XVII	52.0 54.3	56.0 57.7	+ 0.6	1.12	> 0.10	- 8
26	XVIII	61.8 60.1	64.6 62.8	+ 0.1	1.22	> 0.10	-13
27	XIX	75.4 76.2	92.5 90.1	+ 3.2	2.72	> 0.10	+14
28	XX	66.9 67.5	80.1 75.6	+ 5.1	1.73	< 0.01	+37
30	XXI	72.2 70.7	81.2 77.8	+ 1.9	2.38	> 0.10	+ 5
		Overall mean		+ 1.6	0.80	< 0.10	+ 2

Comparison : Late autumn and winter v no treatment to summer

Trial No.	Location	Mean wts.(lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
24	XVII	53.8 53.6	84.7 88.5	- 4.0	1.78	< 0.05 against	-54
25	XVII	52.0 54.3	69.4 73.7	- 1.9	2.17	< 0.01 against	-33
26	XVIII	61.9 60.1	83.2 79.2	+ 2.2	1.48	> 0.10	+ 8
27	XIX	75.4 76.2	115.6 112.9	+ 3.5	2.41	> 0.10	+21
28	XX	66.9 67.5	107.0 103.9	+ 3.7	2.20	< 0.10	+23
		Overall mean		+ 0.7	1.54	> 0.10	- 7

<u>Late autumn and spring v no treatment</u> (Table 32)

Five trials were recorded of which two trials (numbers 26, 28) gave a positive response in mean liveweight. The overall result was negative (-0.75) and this is statistically insignificant at the 10% level.

Table 32

Away wintered ewe hoggs

Comparison : Late autumn and spring v no treatment to summer

Trial No.	Location	Mean wts. (lb)		Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
		Initial	Final				
i	ii	iii	iv	v	vi	vii	viii
24	XVII	55.3 53.6	84.0 88.5	- 6.2	2.71	< 0.05 against	-45
25	XVII	53.5 54.3	72.2 73.7	- 0.7	1.95	> 0.10	- 8
26	XVIII	61.8 60.1	83.5 79.3	+ 2.5	1.60	> 0.10	+16
27	XIX	77.2 76.2	112.8 112.9	- 1.1	3.03	> 0.10	- 3
28	XX	67.5 67.5	105.4 103.8	+ 1.6	2.01	> 0.10	+ 2
		Overall mean		- 0.75	1.51	> 0.10	- 7.4

(d) <u>In-wintered ewe hoggs</u>

Particular importance is attached to these results since no practical field studies are known to have been reported on drenching in-wintered ewe hoggs.

Since the best time for, and the optimum duration of, housing have not yet been firmly established and probably will vary with the location, the sites for this work were spread over a wide area from Ross-shire in the North to Kirkcudbright in the South.

Whilst the results during the housing period only, to spring, were very encouraging, it was decided to try to determine if these were solely characteristic of the housing period. Consequently, in some trials, weight observations were continued after release to the hill, for a period of two to three months. These studies on duration of effect are shown in table 36.
The results indicate that the effect endures with similar differentials between day of entry, short and long term delay. The performance of the "short-term delay" group in fact improved disproportionately to the others.

Day of entry v no treatment to spring (Table 33)

In the total of fourteen trials recorded to spring, an overall mean difference in liveweight was obtained in favour of treatment (4.1 lb) at the significant level of $p < 0.001$. The liveweight gain of individual trials ranged from 1.1 - 7.6 lb with a housing period of 10 - 19 weeks approximately. An interesting point is raised with the loss of liveweight in both treated and control groups of hoggs in trial numbers 35 and 44; this is discussed on pages 188 - 191.

Table 33

In-wintered hoggs

Comparison : Day of entry v no treatment to spring

Trial No.	Location	Days In	Mean Wts. (lb)		Diff. over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra l/wt gain less cost of dose(s) pence
			Initial	Final				
i	ii	iii	iv	v	vi	vii	viii	ix
31	XXIII	97	56.0 54.6	69.8 63.7	+ 4.7	1.50	<0.005	40
32	XXIII	97	49.1 48.6	59.8 55.2	+ 4.1	2.39	>0.10	36
33	XXIV	73	55.9 56.5	63.3 60.0	+ 3.9	1.01	< 0.001	32
35	XXV	77	83.6 83.1	79.0 74.2	+ 4.3	1.25	<0.001	33
36	XXVI	101	79.6 80.1	79.4 75.8	+ 4.1	1.84	<0.05	31
37	XXVII	106	51.4 53.8	67.5 68.5	+ 1.4	1.67	>0.10	7
39	XXVIII	129	68.3 70.6	75.1 72.8	+ 4.6	3.65	> 0.10	39
40	XXVIII	136	75.1 74.4	82.8 76.2	+ 5.9	2.56	< 0.05	52
41	XXVIII	115	68.9 69.9	73.9 68.4	+ 6.5	2.23	<0.01	58
42	XXIX	124	59.0 60.8	61.5 59.5	+ 3.80	0.84	<0.001	31
44	XXX	122	64.8 64.3	59.3 55.9	+ 2.9	1.72	>0.10	22
46	XXXII	117	57.6 58.8	60.9 61.0	+ 1.1	1.35	>0.10	4
47	XXXII	118	66.0 70.0	71.1 72.1	+ 3.0	1.30	< 0.05	23
48	XXXIII	111	70.7 69.1	85.2 76.0	+ 7.6	2.02	<0.001	69
			Overall mean diff.		+ 4.1	0.46	<0.001	34

Short term delay v no treatment to spring (Table 34)

The overall advantage in favour of the treated groups was highly significant ($p < 0.001$) in a total of fifteen trials. The weight gain ranged from 3.1 - 11.0 lb in the treated over the control groups with the overall mean advantage of 5.9 lb. Only one trial (number 34) failed to show any response from treatment after a short delay on housing.

Table 34

In-wintered hoggs

Comparison : Short term delay v no treatment to spring

Trial No.	Location	Days In	Mean Wts. (lb) Initial	Mean Wts. (lb) Final	Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
i	ii	iii	iv	v	vi	vii	viii	ix
31	XXIII	97	57.5 54.6	73.4 63.7	+ 6.8	1.40	< 0.001	61
33	XXIV	73	56.1 56.5	63.8 60.0	+ 4.2	1.07	< 0.001	35
34	XXIV	72	57.4 55.9	63.3 62.5	- 0.7	1.02	> 0.10	- 0.2
35	XXV	77	87.6 83.1	83.5 74.2	+ 4.8	1.31	< 0.001	38
36	XXVI	101	79.9 80.1	83.5 75.8	+ 7.9	1.72	< 0.001	69
37	XXVII	106	52.4 53.8	72.4 68.5	+ 5.2	1.76	< 0.01	47
40	XXVIII	136	70.8 74.4	80.3 76.2	+ 7.7	2.76	< 0.01	70
41	XXVIII	115	71.4 69.9	73.0 68.4	+ 3.1	2.23	> 0.10	24
42	XXIX	124	59.5 60.8	62.6 59.5	+ 4.4	0.69	< 0.001	37
43	XXIX	100	54.8 55.6	58.7 50.8	+ 8.7	1.27	< 0.001	80
44	XXX	122	63.8 64.3	61.6 55.9	+ 6.2	1.38	< 0.001	55
45	XXXI	104	58.8 58.6	62.7 55.3	+ 7.2	2.00	< 0.001	65
46	XXXII	117	58.5 58.8	67.2 61.0	+ 6.5	1.30	< 0.001	58
47	XXXII	118	63.2 70.0	71.4 72.1	+ 6.1	1.23	< 0.001	54
48	XXXIII	111	68.1 69.1	86.0 76.0	+11.0	2.03	< 0.001	103
			Overall mean		+ 5.9	0.70	< 0.001	53

Long term delay v no treatment to spring (Table 35)

Six trials were recorded; five of these showed a liveweight gain from treatment. Overall the mean weight advantage from treatment of 2.7 lb was significant at the 5% level though only four of the trials individually showed a significant response.

Again trial number 35 showed a weight loss in both the treated and control groups over the housing period of 77 days; this is discussed on pages 188 - 191.

Table 35

In-wintered hoggs

Comparison : Long term delay v no treatment to spring

Trial No.	Location	Days In	Mean Wts. (lb) Initial	Mean Wts. (lb) Final	Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
i	ii	iii	iv	v	vi	vii	viii	ix
31	XXIII	97	57.7 54.6	70.6 63.7	+ 3.8	1.39	<0.01	31
34	XXIV	72	57.6 55.9	62.7 62.5	- 1.5	1.55	>0.10	-22
35	XXV	77	85.4 83.1	79.3 74.2	+ 2.8	1.24	<0.05	18
38	XXVII	85	51.6 50.8	64.1 60.4	+ 2.9	2.25	>0.10	24
46	XXXII	117	58.8 58.8	64.0 61.0	+ 3.0	1.54	<0.10	23
47	XXXII	118	63.1 70.0	70.2 72.1	+ 5.0	1.44	<0.002	43
			Overall mean		+ 2.7	0.90	<0.05	20

Treatments v no treatment to summer (Table 36)

Day of entry v no treatment

Five of the six trials recorded to summer responded to treatment on the day of entry. Trial number 35 showed no response from treatment. Only one trial (number 31) showed the highly significant response of $p < 0.001$; three trials (numbers 32, 36, 44) were only significant at the 10% level; and the other two trials (numbers 35, 37) insignificant at the 10% level. Overall the mean weight gain was 2.8 lb which is significant at the 2% level.

Short term delay v no treatment

In the five trials recorded, the overall mean advantage in favour of treatment after a "short term delay" was 7.4 lb giving a degree of significance at the 5% level. The range of weight gain from treatment in the five trials recorded was 0.6 - 14.4 lb; three trials (numbers 31, 35, 36) were significant at the 0.1% level whilst trial number 37 showed an insignificant gain at the 10% level.

Long term delay v no treatment

Only two trials were recorded to summer. In both these trials, the groups treated after a long delay on housing responded in liveweight to give an overall mean of 2.6 lb which was significant at the 5% level.

Table 36

In-wintered hoggs

Comparison : Day of entry v no treatment to summer

Trial No.	Location	Days In	Mean Wts. (lb) Initial	Mean Wts. (lb) Final	Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
i	ii	iii	iv	v	vi	vii	viii	ix
31	XXIII	97	56.0 54.6	78.5 72.2	+ 4.9	1.24	< 0.001	42
32	XXIII	97	49.1 48.6	73.9 68.6	+ 4.8	2.67	< 0.10	43
35	XXV	77	83.6 83.1	91.0 90.5	Nil	1.56	> 0.10	-
36	XXVI	101	79.6 80.1	85.7 83.0	+ 3.2	1.83	< 0.10	22
37	XXVII	106	51.4 53.8	76.0 77.3	+ 1.1	1.15	> 0.10	4
44	XXX	122	64.8 64.3	74.2 70.7	+ 3.0	1.75	< 0.10	23
			Overall mean		+ 2.8	0.80	< 0.02	22

Comparison : Short term delay v no treatment to summer

Trial No.	Location	Days In	Mean Wts. (lb) Initial	Mean Wts. (lb) Final	Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
31	XXII	97	57.5 54.6	83.2 72.2	+ 8.1	1.39	< 0.001	74
35	XXV	77	87.6 83.1	104.3 90.5	+ 9.3	1.50	< 0.001	83
36	XXVI	101	79.9 80.1	97.2 83.0	+14.4	2.28	< 0.001	134
37	XXVII	106	52.4 53.8	76.6 77.4	+ 0.6	1.75	> 0.10	1
44	XXX	122	64.6 64.3	75.5 70.7	+ 4.5	1.99	< 0.05	38
			Overall mean		+ 7.4	2.33	< 0.05	66

Comparison : Long term delay v no treatment to summer

Trial No.	Location	Days In	Mean Wts. (lb) Initial	Mean Wts. (lb) Final	Diff over control (lb)	Standard Error	Degree of signif. "p" value	Value of extra 1/wt gain less cost of dose(s) pence
35	XXVI	77	85.4 83.1	95.5 90.5	+ 2.7	1.90	> 0.10	17
31	XXIII	97	57.7 54.6	77.8 72.2	+ 2.5	1.18	< 0.05	18
			Overall mean		+ 2.6	0.13	< 0.05	17.5

Wool weights (in-wintered hoggs) (Table 37)

The response from treatment whether the treatment was given on the "day of entry" or after a "short term delay" varied considerably in the few trials recorded.

Comparing treatment protocols in trial number 31, the response in mean wool weight per animal from giving a "short term delay" treatment was 0.65 lb at the statistically significant 0.1% level; treatment on the "day of entry" gave a response of 0.76 lb, again statistically significant but at the 1% level while the response to "long term delay" treatment of 0.12 lb was insignificant.

On the other hand in trial number 43, although there was a weight gain response to both "day of entry" and "short term delay" treatments neither were statistically significant.

Table 37 Wool weights - in-wintered hoggs

Trial No.	Location T1 T2	Day of entry			Short term delay			Long term delay		
		Untreated			Untreated			Untreated		
		T1-T2 lb	S.E.	p value	T1-T2 lb	S.E.	p value	T1-T2 lb	S.E.	p value
31	XXIII	0.76	0.21	< 0.01	0.65	0.17	< 0.001	0.12	0.17	> 0.10
39	XXVIII	0.33	0.27	> 0.10	-	-	-	-	-	-
42	XXIX	N/A			0.47	0.23	< 0.05	-	-	-
43	XXIX	0.13	0.28	> 0.10	0.27	0.27	> 0.10			
44	XXX	0.57	0.24	< 0.05	0.41	0.24	> 0.10	-	-	-

(e) Inter-group comparisons

Ewe hoggs - inter-group comparisons (Table 38)

As the results of the trials on away-wintered ewe hoggs were generally insignificant at the 10% level, these have been omitted in the inter-group comparison. In the other three systems examined, the appropriate treatment comparisons are recorded to spring and summer by the capital letters A and B respectively as shown in column (ii). The mean weight difference between treatments (column (i)) are shown in column (vii). The trials considered are those where two or more treatment protocols were used as well as the basic untreated control group.

Hill wintered

To spring, the response from giving two treatments, early winter and winter compared to a single treatment in early winter was 2.4 lb and this was statistically significant at the 5% level.

To summer, the response was only marginal (1.2 lb) and this was insignificant at the 10% level.

Comparing the two treatments, early winter and winter with a single treatment in winter, the gain from the two treatments was 2.7 lb which was significant at the 10% level to the spring; to the summer the response in mean weight was negligible and insignificant at the 10% level.

In-bye wintered

Again the two treatments compared to a single treatment in early winter measured to the spring gave an advantage of 1.6 lb; this being statistically significant at the 2% level. To the summer, the advantage in favour of two treatments, early winter and winter was 3.4 lb. The statistical evaluation was considered invalid as four or less trials was unacceptable. (See footnote below table).

To spring, measuring the effect of two treatments compared to a single treatment in winter, the response in mean weight (3.1 lb) was significant at the 2% level. Again, though the response was 4.6 lb for the two treatments measured to the summer, there were too few trials to allow statistical appraisal.

In-wintered

The advantage of treatment to spring after a "short term delay" on housing was 2.1 lb which was statistically significant at the 1% level compared to the animals dosed on the day of entry. To summer, the mean liveweight advantage of the total animals dosed after a "short term delay" was increased to 5 lb but the degree of significance was reduced to the 10% level.

Compared to a "long term delay" treatment the advantage from a "short term delay" was 2 lb to give a statistical significance at the 5% level when assessed to the spring. Measured to the summer, though the response was 6.1 lb, the few trials precluded a statistical appraisal.

Table 38

EWE HOGGS - INTER-GROUP COMPARISONS

Treatment	Recorded to Spring (A) Summer (B)	Number of trials	Number of farms	Number of animals		Mean Difference lb	S.E.	Stat. signif. "p" value	Net value less cost of treatment p
				Treated	Control				
i	ii	iii	iv	v	vi	vii	viii	ix	x
HILL WINTERED									
Early winter & winter v early winter	A	8	4	87	99	+ 2.4	1.1	< 0.05	16
	B	8	4	87	99	+ 1.2	1.0	> 0.10	3
Early winter & winter v winter	A	7	3	67	66	+ 2.7	1.2	< 0.10	18
	B	7	3	67	66	+ 0.8	1.7	> 0.10	- 0.4
IN-BYE WINTERED									
Early winter & winter v early winter	A	7	6	179	202	+ 1.6	0.5	< 0.02	9
	B	4	3	84	90	+ 3.4	-	- *	26
Early winter & winter v winter	A	5	4	128	109	+ 3.1	0.6	< 0.02	24
	B	2	1	39	32	+ 4.6	-	- *	49
IN-WINTERED									
Short term delay v day of entry	A	12	10	316	303	+ 2.1	0.66	< 0.01	13
	B	5	5	117	134	+ 5.0	2.24	< 0.10	43
Short term delay v long term delay	A	5	4	164	152	+ 2.0	0.52	< 0.05	13
	B	2	2	62	65	+ 6.1	-	- *	53

* Where four or less trials were available no statistical evaluation was made.

CHAPTER III

Discussion

Discussion

General considerations

Parasite control

Economic considerations

(a) short term benefits

(b) long term benefits

(c) summary

DISCUSSION

GENERAL CONSIDERATIONS

Reference has been made in the Introduction part I, in particular "Major Constraints on Production and Profitability" (page 29) and when considering "Dependence on the Market (page 42) to show that the hill sheep industry in Scotland faces many basic difficulties.

There are other pressures which have not yet been mentioned. The Forestry Commission in outlining its expansion programme for the post-war period, claimed that there would be no conflict of interests with the sheep farmer. Yet, there are signs that the problem of integrating and rationalising forestry and farming interests has not been resolved. Forestry Commission interests are indeed a formidable competitor with its planting target of 50,000 acres annually up to 1976 and supported by an annual subsidy of £40 million. In recent years there have been a few in hill farming who have found the disposal of land to forestry developers too attractive to resist. On the other hand, there are those who claim that it is already known that by the time the timber is ready for use the return will be much less than the outlay and that in any case, the whole production is much less than 5% of the country's requirements.

Attempts have also recently been made to run deer on a commercial scale mainly for carcase export to Germany. The practical and economic viability is debatable on the grounds that it is an unnecessarily difficult enterprise for what can only be a connoisseur's food of limited potential.

Hill farming is also subsidised, and is equally open to criticism on the basis of its relative contribution to the National Economy. This merits deep discussion but within the broad aims of the present supportive policy there resides a challenge to increase production and efficiency but this also involves a radical change of attitude to the long-held precepts of traditionalism.

Improvement by intensification across the whole system is undoubtedly needed and in the last resort, this lies with owners and tenants. For instance, Whitby (1970) states: "To ensure that such intensification of output is profitable, will require a high level of management particularly in maintaining the health of the flock under modified systems of hill husbandry". Research findings applied and tested under farm conditions coupled with studies on economic feasibility are essential under modern agricultural conditions. However, linked advancement along the whole length of what is a very broad front is needed. Absolute co-ordination between those concerned with improved breeding, feeding and husbandry practices on the one hand, and those deeply involved in the control of animal disease generally and internal parasitism in particular on the other, has not been particularly or continuously evident.

The particular aim of this Thesis was to make a broad study of the economic features of the hill sheep industry in Scotland and it can be concluded by dividing the discussion into two parts.

(a) the control of internal parasites as an aid to husbandry and
(b) the economic consequences of such control.

Before dealing with parasitism however, there is one important factor not previously listed as a major constraint. Much attention is now being given to "stress" and its implications throughout all branches of animal husbandry - in spite of the somewhat summary nature of its dismissal by the Swann Committee in its Report on the Use of Antibiotics in Animal Husbandry.

"Stress" is a simple word in current widespread use in the field of human medicine, which has been given a special meaning to describe the basic cause of a heterogeneous group of illnesses of psychosomatic origin. Man, no doubt pre-occupied with his own stresses, often fails to recognise that they also occur in lesser members of the animal kingdom. Animal behaviourists have provided many examples, i.e. the naturally timid and sometimes hornless cow in a horned herd which is bullied into a situation where it is in a perpetual state of giving way to others even to the extent of malnutrition; the pecking-order established in a poultry flock eventually affects the productive life of the unfortunates at the lower levels; those concerned with the environment in terms of the "population explosion" have observed that the "lower-orders" in an overcrowded rat colony will become so emotionally disturbed that starvation and death follow.

Very recently the use of time-lapsed photography amongst ewes lambing indoors in large groups, has shown the obvious unrest and anxiety created in some ewes by their inability to find a quiet corner in which to bring forth their young.

Of all the domesticated animals, the sheep is most used to the wide open spaces. Until ten years or so ago (except in Orkney and the Hebrides where weather conditions were considered to be too unfavourable) it was not common practice to keep sheep indoors for any length of time.

An observation by Black, N.M. (1967) is of interest as a behavioural study of some significance. In Cheshire a mixed flock of St. Kilda and Soay sheep were being kept for experimental purposes. Because of the danger from foxes at lambing time, these very small but exceedingly sturdy sheep, capable of withstanding wild North Atlantic weather, were put into a large barn from about 4 p.m. of one day till 8.30 a.m. the next morning. Although having access to hay and straw and sometimes cereals from broken bags and despite more than ample space, this hardy breed showed every sign of anxiety from the moment of housing until they re-gained their freedom. They would not move away from a position just inside the door; they would not lie down; they would not eat. The unusual environment - although protected from natural enemies and from the elements was stressful to them.

"Stress" is indeed essentially psychosomatic and not to be confused (as is sometimes done) with "predisposing factors" which are more easily identifiable and usually of a physical nature.

It is the author's belief that "stress" is a potent factor in hill sheep husbandry - particularly in housed sheep - and appropriate references will be made in the discussion which follows.

PARASITE CONTROL

To really quantify the results, it is necessary to recognise that the responses obtained from the trials in all age groups of sheep, have to be viewed against a background of varying nutritional levels throughout the year, which of themselves, restrict flock performance. It is evident that the incidence of parasitism is sufficient to augment this poor performance by further depressing the condition of hill sheep. In this context, emphasis is given to the need for an accurately timed strategic drenching programme particularly for the six months winter period synonymous with more severe conditions of stress.

A characteristic feature throughout this work has been the absence of egg counts at the levels generally associated with clinical manifestations of helminthiasis. (In fact, frank clinical disease was evident in only one trial (Number 14)). Reference has already been made (page 80) to the general unreliability of worm egg counts as a diagnostic aid and for this reason, they were seldom carried out in the work described in this Thesis.

Worm egg counts where done, could be classified as denoting a "sub-clinical" condition. Considering the large number of sheep involved in various different locations, this is surprising. However, judging by the many body weight increases in treated sheep, it must be concluded that even sub-clinical infestations are damaging. Of course, throughout the whole field of animal disease, it has been observed that sub-optimal production spread over large numbers of animals is a greater source of loss than frank disease amongst a few. There seems little doubt, that removal of low-grade infestation, by means of a strategically planned dose, prevents an escalation of damage over the winter months to spring.

There is some evidence to suggest the effects of damage from sub-clinical infestations can extend beyond spring to the summer months though lesser evidence to suggest the duration of the effect is seen by early winter. (Graph P Appendix). This contention may be revealing to many hill farmers in that the magnitude of the loss from worms alone, more than offsets the full recovery normally expected by summer with the restoration of pasture growth. (Graphs M, O & P).It follows, that on farms where the drenching programme is ill-defined or simply inadequate then the damage could well be cumulative over a number of years with consequent regression in flock performance.

These observations on sub-clinical infestations are supported by the views of various other investigators including Robertson (1942) and Spedding (1954) and in respect of hoggs to amplify Spedding's (1956) view: "This means that normal sheep do not achieve their potential rate of growth at a given nutritional level". Again the results tend to indicate that losses occur.

In gimmers and in ewes also, the results show that damage restricts their full potential performance especially in regard to the numbers which are able to continue nursing lambs to marking in June (page 116-128). This assumes greater importance where in recent years flock numbers have been increased in order to raise farm output, and especially where pasture improvements have not been made or at best limited solely to providing feeding for production. With the distinct tendency to make fuller use of in-bye during the summer months, crowding on ewes with lamb, and also heavy stocking by early autumn, it could be expected to increase parasitism considerably. A situation can thus be foreseen where control measures involving a high degree of dependence on anthelmintics similar to that on lowland farms can evolve. It is obvious that in the future more field research will be needed into the inter relationships between pasture improvements, nutritional requirements, stocking rates and parasitism, since it is evident that no single factor can be considered in strict isolation.

The responses to drenching in early winter, in winter or at both these times, are seen in relation to the degree of pasture contamination and larval uptake during autumn and early winter, and in particular, to the capacity of these larvae to over-winter by inhibition in the host and survival on the pastures, providing a source and reservoir of infection to the following spring (page 76,89). To what extent this source of infection is mainly due to the maturation of retarded immature stages and to what real extent this is encouraged by increased grazing pressure during the late summer, autumn and early winter, is not clear. It may be that overstocking the in-bye or improved grazings, from spring throughout summer and autumn has particular significance. The evidence to suggest that inhibition of larvae occurs to a considerable extent, is judged from the remarkable degree of consistency obtained in the responses from delayed treatment in hoggs wintered in-shed (page 188). This is also borne out from the fact that in many of the trials the hoggs were previously kept in-bye for at least four to eight weeks prior to housing and in some cases were known to have been treated immediately on being shifted from their hill grazings.

On the other hand, the source of re-infection from infective larvae surviving on hill pastures during the winter as shown by Rayski (1969) (page 91) cannot be excluded, but the evidence from the numbers recorded from plucked pasture samples may not be sufficient to indicate that it is such a significant contributor to the spring "rise" in hill sheep as originally suggested by Paver et al (1955), and further clarification is needed. At the moment, an imponderable is the influence of weather on the numbers of infective larvae which are able to climb up the blades of grass and be ingested by the grazing animals during winter and the influence of grazing pressure on restricted improved grazings.

In the course of these trials, it was recognised that fairly wide differences in performance from farm to farm (and even from heft to heft) could occur. These differences can be attributed to particular farm conditions, and to some extent to variations in strains of animals within the same breed (e.g. Lanark or Galloway Blackface). Table 24 shows, for example, a bodyweight scatter of 24 lb from lightest to heaviest in hill wintered hoggs, which must be assumed to be a reflection of varying environmental conditions. Not unexpectedly, the greatest reduction in weight over the winter period occurred in the heaviest animals with a tendency for these to respond better to two drenchings (early winter and winter) which suggests that resistance to infection was more impaired. However, the statistically evaluated results are remarkably consistent which suggests that variations in inter-group quality on the same farm (which the method of selection (page 109) tended to reconcile) do not outweigh ecological considerations. In the ewe trials, to ensure a higher degree of validity and credibility, any heft to heft comparisons were purposely omitted from the results as these introduced difficulties freely admitted by the investigators in previous trials on earlier anthelmintics (Parnell et al 1955 b, 1961).

In these trials, due to practical difficulties, or insufficient numbers to be assessed statistically, it was not always possible to measure all the productivity factors in the various categories within the broad system. However the results do provide a measure of the response which can be achieved by drenching under everyday conditions of farm practice.

(a) Hill ewes and gimmers

Ewes

Few would deny that the hill ewe in her winter environment can be regarded as the most under-privileged of farm animals. Climatic and nutritional conditions are such that it is little wonder that fecundity is affected and even survival is threatened. Over-dependence by some farmers on the hill ewe's inherent capacity to fend for herself even under rugged conditions, is not consistent with attempts to increase her potential as demanded by current economic conditions.

The worm control trials reported in this Thesis are intended to show that they can provide motivation in two aspects of improving flock performance. Fundamentally, and referred to as "1st phase improvement", the intention was to improve productive capacity by removing worm burdens during the period October to April. By stimulating the appetite, "condition" was kept up and this in turn increased resistance to adverse climatic conditions and may in fact have helped to maintain the pregnant state. It is freely acknowledged, however, that in practice it is very difficult to differentiate "yeld" and "kebbed" and resort has been made to adding these figures and recording as "barren". Another benefit arose from the effects of stress (see "general discussion", above) induced by rapid climatic changes, being "harnessed" to a strategic dose so as to destroy histotropic larvae which have emerged as a result of that stress. Again it must be admitted that a clear-cut picture could not be obtained due to "black loss", i.e. loss due to accident, or "unexplained" deaths - but this is in the nature of practical hill farming and it must be recalled that all the trials were done on farms using "farm groups" rather than on carefully delineated plots with "experimental" groups.

Body weight as a measure of "condition" has been mentioned elsewhere, but in in-lamb ewes, it was realised that the age, size and number of foetuses plus variations in the size of the membranes and the volume of fluids would render weight records meaningless and so they were not reported.

Many studies have been made to determine the value of dosing in relation to the "spring rise" whether this be done during pregnancy or after lambing and the most recent are those of Lewis and Stauber (1969), Leaning et al (1970) and Murray et al (1971) in New Zealand. In the trials reported here, treatment was done in January. This is a direct departure from the accepted principle of spring dosing and the reasons in favour of January are as follows :-

1. In practice, it is a convenient time as it coincides with the gathering to remove the tups, to "de-breek" ewe hoggs and to treat for fluke if that is necessary.

2. In Scotland, the worst of the winter in terms of weather stress comes during the second half of January, February and in some years well into March. A dose in January will assist lean gimmers and ewes over the bad period to come.

3. A dose at this time will reduce the level of pasture contamination up to the pre-lambing period.

4. Where flock numbers have been increased as part of a general improvement or where controlled methods of grazing come into use, the benefits may be offset unless a January dose is given.

It is interesting to note the changing pattern of statistical significance in relation to time of dosing when related either to the "barren" or the "nursing" state of the ewes and gimmers concerned. Dosing in "early winter", i.e. in November pre-tupping, or in "winter", i.e. January, or both, has a significant influence on the number "barren" when examined at udder locking. As might be expected, the effect of dosing is to assist in increasing the numbers holding to service (reduction of "tup yeld") and decreasing the numbers which may have held to service but subsequently abort (reduction of "kebbed"). The period of pregnancy is a difficult and stressful time for female sheep and the elimination of one source of stress, i.e. worm infestation, must be helpful to them. If dosing is left until "winter" and "spring" (six weeks before lambing), it is understandable that the reduction in numbers "barren" is minimal.

The influence on "numbers nursing" of dosing so early on in pregnancy was, not unexpectedly, not significant. However, a pre-lambing dose in spring (table 21a) does show that improved appetite by influencing milk yield and duration of lactation, is a significant influence in increasing the number of ewes still with a lamb or lambs at foot, at marking time.

The value in terms of lamb weight at marking of treating ewes at udder-locking (five to six weeks before lambing) was also investigated and may be described as "2nd phase improvement". Its worth is seen in the lambs at marking and is reflected by increased weight. This is a direct result of the stimulation of appetite sufficiently long before lambing to influence the quantity and the duration of the milk yield. Lambs from treated ewes receiving an ample milk supply are thus not thrown on to a grass diet before the rumen is fully developed and digestive upset is thus avoided. Another benefit common to both ewes and lambs is the reduction of pasture contamination at a time when ewes are under stress and lambs are particularly susceptible.

From a management point of view, dosing at about six weeks before lambing is less dangerous than at any time closer to lambing. There is much less chance of causing traumatic abortion, or precipitating pregnancy toxaemia in a hard winter when food is short or difficult to obtain due to frost or snow covering.

Gimmers

Mention has been made of gimmers and there is specific evidence that a January dose is of particular advantage to them, probably because their resistance to infestation can be more unstable than in older sheep. It has been recognised that the poor performance of gimmers can be the result of their earlier condition as hoggs. Gunn (1967); Coop (1962) and Coop and Clark (1966). The opportunity was taken to continue the studies of hoggs away-wintered on a "good" farm compared with those on a "poor" farm (see page 186). A re-statement of their performance during the away-wintered period, their weight in the following November when tupped as gimmers and their subsequent breeding history is shown in the tables 39 and 40. When brought back to the home farm in April, the two batches were run together right through the summer and autumn. Some weight compensation took place during this time, but as will be seen, those from the "good" farm were still heavier than the others at tupping.

Table 39 - Hoggs to tupping

	Weight performance when wintered away Sept - April (lb)		Weight at tupping in November (lb)	
	Batch A (good farm)	Batch B (poor farm)	Batch A	Batch B
Untreated	+ 17.8	+ 3.4	96.9	91.0
Treated late autumn	+ 12.8	+ 3.4	94.3	91.7
Treated late autumn & winter	+ 16.2	+ 4.0	101.3	88.2

Table 40

Performance as gimmers

BATCH A

TREATMENT	GIMMERS				LAMBS		GIMMERS		
	Number tupped	Yeld and kebbed	Died	Number lambed	Born	Died	Still Nursing at speaning	Nursing as % of those tupped	
Pre-tupping only	16	2	0	14	16 (2 x twins)	0	14	87.5	All treated 87%
Pre-tupping + January	16	0	0	16	16	0	16	100	
Pre-tupping + pre-lambing	15	4	0	11	13 (2 x twins)	0	11	73	
Nil	18	4	0	14	14	2	12	66.6	

BATCH B

TREATMENT	GIMMERS				LAMBS		GIMMERS		
	Number tupped	Yeld and kebbed	Died	Number lambed	Born	Died	Still Nursing at speaning	Nursing as % of those tupped	
Pre-tupping only	16	3	0	13	13	1	12	75	All treated 75%
Pre-tupping + January	16	2	0	14	16 (2 x twins)	1	13	81	
Pre-tupping + pre-lambing	12	4	0	8	8	0	8	66.6	
Nil	18	5	2	11	11	0	11	61	

This evidence confirms the findings of others that body weight at tupping is important, but additionally it may indicate that a pre-tupping dose may also be a factor in the reduction of the number of those "yeld". "Flushing" is normally taken to mean raising the nutritional status before service as a means of improving fertility. However, it may be that the stimulation of appetite and improved digestive efficiency which follows dosing, may at this time improve fertility not only by assisting "flushing", but even take the place of it where the cost of doing so is unacceptable or where suitable in-bye ground is unavailable. Improved "condition" by helping gimmers and ewes to cope with the worst of the winter at a more advanced state of pregnancy may reduce the numbers of "kebbed". This view is reinforced by a study of the table where the number of ewes satisfactorily nursing lambs was compared on the basis of a January dose as against a pre-lambing dose.

Working with <u>in-bye wintered</u> hoggs summered on the hill, an opportunity became available on one farm to study tupping weights as gimmers and while their subsequent breeding history was not followed in detail, the tupping weights are of interest.

<u>Table 41</u>

	Weight performance during in-bye period October-March lb		Weight performance during summer on hill grazings lb		Weight at tupping November lb	
Weight range in October	51-60 lb	61-70 lb	51-60 lb	61-70 lb	51-60 lb	61-70 lb
Untreated	- 7.5	-15.6	+11.3	+ 1.7	82.5	87.2
Treated early winter (Nov)	- 4.9	- 6.0	+14.9	+13.4	89.6	92.1
Treated winter (Jan)	- 3.7	- 8.9	+15.6	+10.3	86.9	91.8
Treated early winter & winter	- 1.8	- 4.1	+17.4	+17.2	87.6	92.5

(b) Ewe hoggs

(i) Hill wintered ewe hoggs

With the background of sub-optimal performance in all groups becoming evident as early as January (Graphs K & L) it is apparent that parasitism will continue to reduce this further by the spring.

It is also significant that, despite inverse proportionate weight gains to summer with renewed pasture growth, the treated groups, where recorded, emerged significantly heavier, which suggests that more adequate use of available food was being made both in winter and summer. (Graph M)

A particular feature of the trials was that those in the weight range at the start, greater than 70 lb, lost over 30%, a fact surprising to owners who had never weighed sheep and thus not aware of the possible extent of the loss in previous years. This information was all the more startling as the winter on this occasion had been extremely mild. In these cases, it simply emphasised that the improvement of the breed with expensive sires does not necessarily guarantee better performance. After all, expensive rams can spend a considerable part of their life on low ground! Again, it seems difficult to reconcile the view that breed "hardiness" and better pastoral conditions before winter necessarily means that bodily reserves are sufficient to allow better wintering on the hill. It could invite consideration of whether it is not false economy to make breed improvements yet continue with the traditional cheapest, but nutritionally inadequate, method of wintering.

Lighter hoggs, less than 70 lb, fared better. This is illustrated in trial no. 1,Table 26 during 1970/71 where, in sharp contrast, weather conditions were more severe compared to other trials. It could be that flock performance at all seasons though not optimal was more in balance with environmental conditions. It would appear that factors of maturity, type, quality and inherent growth propensities are reflected in wintering qualities and in turn, on the results of field studies.

Although nutrition and the effect of parasitic infections have been studied by several investigators, one of the earliest being Fraser and Robertson (1933), hill farming has received scant attention in this respect, where any improvement policy could well alter preconceived drenching programmes. (Page 66). At present, it appears that two treatments judiciously timed to avoid an extra gathering, are beneficial on the basis that it is wise to remove the infections before the onset of winter and also again at a strategic period round about mid-January to early February when the stress of wintering is making itself felt. As a result, these doses limit the extent of contamination and the height of the so called "spring rise" later.

The variable responses from drenching in early winter alone, could be explained in that drenching at that stage is not able to remove any larvae which had become inhibited, yet to drench earlier would not prevent reinfection by that time. This could be a reasonable contention with the tendency of the hoggs, with deteriorating seasonal growth, to follow the ewes by crowding on more attractive parts of sheltered grassy areas.

By January, increasing environmental stresses with possibly reduced resistance could be such as to allow numbers of embedded larvae to emerge to provide the springboard for later infections. This situation needs more detailed study.

These hypotheses could be strengthened by reference to field observations (trials numbers 2(a) and (b) and 3(a) (b) and (c) - Tables 25 and 26) where the hoggs and ewes were forced to seek lower ground in early January because the upper reaches were under deep snowdrifts for a few weeks. This enforced confinement on restricted pasture could well have precipitated dietary and psychological stresses. Insufficient observations were made to determine whether the second dose could be left over until early spring (or a third dose given then) but from the evidence obtained and with costs in mind, it seems evident that with modern highly effective anthelmintics an additional dose in January would be sound strategy.

(ii) <u>In-bye wintered ewe hoggs</u>

The acceptance by many hill farmers as fundamental, that young stock by virtue of being kept in-bye are protected and therefore grow and develop better, could be challenged. The relative success or failure of the system may not readily be seen to be a significant component of flock productivity. Factors within the system, initiated by the quality of the soil and pasture and including the pressure of grazing at all seasons, must surely be reflected in the capability of such land by late autumn and during winter. Not least in this reflection, are factors of environmental stress in all its implications to younger stock - factors which are so imperfectly understood, let alone their true relation to economic improvement of such land if over-used by sheep and cattle at the different seasons. The limitations of the area and its poor quality may often be overlooked and too much expected from it by October even if this only means putting on a selected number of hoggs from each hirsel (in view of a heavy stocking rate with ewes and twins to early September). Unless carefully managed in a manner more allied to the normal practices on lowland farms, such land can become a potent source of disease infection and worm infestation.

This contention is further exemplified in a study of the bodyweight progress of untreated animals; in trial numbers 11, 12, 16, 21 the loss was greater than would be expected on some hill pastures. The fact that the treated animals did not lose anything like so much weight is a direct indication of the value of treatment. In some cases it even emphasises the need to introduce supplementary feed earlier and not to depend on the animals' bodily resources entirely.

In subscribing to the basic relationship of quantity and quality of "winter keep" and the degree of infestation, it is to be expected that in this system it will be more erratic from farm to farm. For instance, the relatively low response from drenching in trial number 16 could be ascribed to the hoggs being drenched earlier whilst still on the hill and later put on clean permanent grass in-bye. On the other hand, in trial number 17 hoggs on the same farm, all treated in autumn responded to treatments in late January after being transferred from two year rye grass to previously stocked permanent grass. Again in a previously unreported trial, hoggs responded to drenching later in October ($p = 0.01$) than drenching earlier in September when retained on in-bye after speaning.

By taking the winter period as extending from late October to March the best policy is to drench the hoggs soon after they come on in-bye, and try to keep them on relatively clean pastures throughout winter if that is possible. Where there is a history of previous stocking by others on in-bye, a second treatment could be justified by January or early February to remove any newly acquired infection especially in a mild season, and any emerged larvae which previously had become inhibited. This would be of ultimate benefit in reducing the degree of spring infestations especially in gimmers or lean ewes brought down later for feeding and lambing in-bye. The justification for a

January or early February drenching is reflected in a study of liveweight progress in January compared to the other times of weighing (illustrated in graphs N and N_1). Again, as in hill wintered hoggs, the significance of drenching extends beyond spring when the hoggs return to hill pastures (graphs O and O_1). The few trials on re-drenching before the hoggs return to the hill in March were inconclusive.

(iii) Away wintered ewe hoggs

As far as is known, no field trials to determine the value and the optimum timing of drenching as it normally occurs in practice, have previously been reported.

Where hoggs go away about the first week of October, the timing of dosing has to be seen in relation to the sequence of management events. Even if they were drenched earlier in the year at weaning, they have ample opportunity to become re-infected. General conditions on the wintering farm also vary widely. Facilities for handling and dosing may be inadequate or non-existent. The nutritional value of the pastures will obviously depend on their manurial treatment and on the extent to which they have been grazed during the preceding six months, and whether this was by sheep or by cattle.

These considerations suggest the wisdom of a strategic drenching before the hoggs leave the home farm, to reduce the chance of contaminating the wintering pastures. The results from the trials were variable, but nevertheless more positive results were obtained where the only drenching was before the hoggs left for wintering. Repeat drenching in January may not be economically justifiable but much of course would depend on whether there was a history of heavy stocking in the previous autumn and summer (if known) and thus the grazing potential of the pasture on the wintering farm.

In practice, many hill farmers drench their hoggs immediately on return from wintering, but from the few observations made, it seems to be contra-indicated on economic grounds, on the basis that possibly the hoggs returned with little infection. However, since on many farms, it would be difficult to gather again before the yeld clipping in June then drenching may be justified if there is any doubt. But the value of drenching in June remains to be established on helminthological grounds or if resistance is affected by comparatively infection-free animals grazing contaminated parts of the hill.

Taken as a measure of success, the weight gains made whilst at wintering (range 2 - 18 lb) indicates, as might be expected, that the cost/benefit ratio is extremely variable. Added to this, where it is an economic necessity for the lowland farmer to heavily stock the same pastures with cattle, then it is hardly conducive to the nutritional well-being of the wintering hoggs, though the practice reduces the risks of parasitism.

In case the wintering-away facilities have changed, it is essential to make an annual re-appraisal of the management and grazing policy, as was evidenced in a recent observation carried out by the writer. A large batch of hoggs was split and away-wintered on two neighbouring farms under one owner and not apparently differing from each other in elevation, aspect, etc. Each batch was split into four groups (three treated, one control) and the results are recorded as Trials 24 and 25.

However, it was quite evident early on in these observations that there was considerable difference in the performance of the two batches whether untreated or treated and whatever the treatment given. Investigations showed that one batch (B) was on an area which had previously been heavily stocked with sheep and cattle and from a nutritional point of view was much inferior to the area on which the other batch (A) was being grazed.

Inter-batch weight comparisons during the away-wintered period were as follows.

Table 42

	Batch A	Batch B
	lb	lb
Untreated		
Sept.	53.6	54.3
April	71.4	57.7
	+17.8	+ 3.4
Treated late autumn		
Sept.	53.9	52.5
April	66.7	55.9
	+12.8	+ 3.4
Treated late autumn and winter		
Sept.	53.8	52.0
April	70.0	56.0
	+16.2	+ 4.0

Ironically, the agistment charge for both groups was the same, i.e. £2.50 - no doubt the lessor (without knowing the weight figures!) considered this fair and proper. This would further emphasise the "hit and miss" nature of present day away-wintering where economic pressures force lowland farmers to either put more land under the plough or increase stocking rates. This, including rising transport and agistment charges and the inevitable lack of personal supervision by the hill farmer could further encourage a decline in away-wintering systems. However, this also introduces the problems of wintering young stock at home and these have to be reconciled either with a return to traditional methods or by considering the comparative cost/benefits of alternative methods such as in-wintering.

(For further studies on these ewe hoggs as gimmers see page 178).

(iv) In-wintered ewe hoggs

A study of the results shows first of all that dosing - whenever it is done - produces better results in terms of bodyweight at the end of the housing period than leaving animals untreated. This situation also remains true in those cases where observations were prolonged for a further two to three months till early summer.

A feature of the greatest practical significance is the demonstration that "short-delay" after housing (i.e. 14 - 21 days) before the dose is given, produces a superior response. A delay of thirty or more days after housing ("long-delay") whilst also proving favourable, did not, without exception produce as favourable a response as short-delay.

Examination of the basic causes of this phenomenon (which has since been demonstrated in one trial in housed cattle) leads one first of all to a simple explanation. Anthelmintics in general, are less efficient against larvae than against adults. A delay in dosing will therefore allow more larvae to mature to the adult stage when they can be more easily dealt with by the anthelmintic.

That this is not the whole explanation is a matter for debate - particularly since long term benefits have been demonstrated following the use of one dose only.

An embedded or histotropic stage in the life cycle of some of the nematodes has been observed. The knowledge that one day, sooner or later but unpredictable in time, these embedded forms will leave their tissue habitat and re-enter the alimentary canal to become adult is well appreciated. The "mechanism" whereby this is brought about, is not.

Armour et al (1966) in sheep, and Jennings et al (1967) and Armour (1967) in cattle, have described the phenomenon in Ostertagia infections. Earlier theories based on reduced resistance have been questioned by studies on immuno-suppressants (Soulsby 1965; Brunsdon 1966; and Gibbs 1967); other influences such as "photoperiod" described by James and Johnstone (1967) cannot be disregarded.

It is the author's opinion that "stress" is also a factor. The subject of "stress" has been dealt with at length in the first part of the Discussion and the housing of sheep is but one example. It is believed that stress builds up over some days and then gradually subsides as the majority (but not necessarily all) of the flock adjust to the new environment. Stress may very well be an important factor in "communicating" to the embedded larvae a threat to the continued survival of the host - and therefore their urgent need to reach maturity to perpetuate the species.

If the stress thesis is acceptable, it could provide a credible explanation for the undoubted value of the "short-term" delay of about 14 days from the day of housing, before the dose is given. Embedded forms are not destroyed by any anthelmintic, but by allowing stress to reach a high plane, more otherwise histotropic larvae will be present in the lumen of the gut where they can be effectively acted upon by the anthelmintic. By contrast, too long a delay, i.e. "long-term" delay (30 or more days following housing) merely permits larvae in the lumen to become adult, to commence egg laying and to damage the gut wall and interfere with digestion. Subsequent dosing while removing very large number of adults, does so after damage has been done and when the adult worm population has increased considerably.

The prolongation of beneficial effect to early summer in the few cases where observations were made, is interesting. In some cases, the differential between treated and untreated was even widened during the extra period. Obviously, this is beneficial in terms of getting the hoggs thoroughly "fit", avoiding any check on being re-introduced to hill pastures, and able to take full advantage of renewed pasture growth.

During nutritional studies, Gunn (1964a)observed a check in body weight in highly fed hoggs when kept inside, which he attributed to both changes in diet <u>and in habitat</u>. Apparently however, the possibility of parasitism as a factor was not considered. The wisdom from an economic point of view, of having hoggs in too good a condition at housing is questioned. It appears that since the act of housing for long periods on the scale now practiced is "new", so should the preparation for it. Trial number 35 showed that all groups at first lost weight on housing. Whilst this did not affect the favourable response of the treated groups, it is presumed that their over-heavy condition could not be maintained due to the relative inadequacy of the indoor feeding system.

These observations on the strategy to be employed in dosing housed sheep are of considerable practical value. Many otherwise skilled husbandmen can easily convince themselves that housed animals, away from pasture contamination, are therefore unlikely to need dosing at all. Even if the idea occurs that it would be better to house "clean" sheep, it is highly probable that dosing would be done just before, or on the day of housing. Thus, the discovery of the advantages of "short-delay" is of prime importance.

When sheep first started to be in-wintered on a large scale, doubts were expressed about the growth of wool in the "altered" environment. It was decided to check the fleece weights in five in-wintered trials and the results are shown in Table 37.

The value of the extra wool per hogg (based on a price of 20 pence per pound) is as follows.

Table 43

Trial Number	Day of entry	Short term delay	Long term delay
31	15.2 p	13.0 p	2.4 p
39	6.6 p	-	
42	N/A	9.4 p	
43	2.6 p	5.4 p	
44	11.4 p	8.2 p	
Mean	8.95 p	9.0 p	

Within the limitations of few trials, it is clear that anthelmintic treatment favours wool growth and this is in line with the many reports implicating T. colubriformis, Oesophagostomum spp. and C. ovina in lowered wool production. (Page 87)

Economic Considerations

The general approach adopted in this thesis is that there is both scope and need for husbandry improvements in Scottish hill sheep farming.

The scope arises from improved management practices using all the available methods such as better drainage of pastures, fencing and supplementary feeding of sheep at strategic periods, and also by introducing new techniques as they become available (e.g. the use of modern anthelmintics). The need arises from the precarious financial viability of hill sheep farms even considering their reliance on Government support schemes.

Two diametrically opposed attitudes, may be taken when considering the economic need for adopting improvements.

An improvement may be considered in isolation, with all other variables held constant, so that the effect of one change is separately analysed; alternatively, the improvement may be fitted into a management plan in which several changes are to be carried out either simultaneously or in a planned sequence so that the entire programme is evaluated as a whole. The view is subscribed that the second method - a planned sequence of events or a "step by step" approach - is more desirable, since only by making several complementary changes will the full benefit of any one of them be realised (e.g. use of in-bye requires special attention to disease prevention due to the density of stocking).

However, it has been equally recognised that the utopian approach of identifying the best possible methods of improvement may be self defeating within any given situation. Hill sheep farmers are, in general, short of capital and are often traditional in outlook; the latter attitude possibly being encouraged by the element of uncertainty which is involved in making changes. Consequently, the spending of large sums on improvements is often regarded as being out of the question, and even where the necessary capital could be raised, the uncertainty imposed by market conditions makes a bold approach seem ill advised. Viewed realistically, the result is that a piecemeal approach to improvement may be the most that can be expected and under these circumstances, the rationale for an improved dosing programme may be evident.

The adoption of an anthelmintic drenching programme has special attractions as it can be easily fitted into the existing husbandry pattern (pages 101-105). It involves only small outlays, and some of the benefits may be realised quickly (general flock improvement, though a potentially important part, may only be realised in the long term). In this, tetramisole, as a modern, technically efficient, anthelmintic is considered as a single component towards making improvements, since the field work was based on existing husbandry systems. The economic evaluation is made firstly by identifying any improvements in flock productivity associated with the drenching programme and secondly by measuring the additional output or input savings. But, as the identification of improvements in productivity has formed a major portion of this thesis, a summary is all that is now required. Nevertheless, the evaluation of the benefits derived, poses some problems and these remain to be considered.

One consideration is that the evaluation depends on those considered to be recipients of the benefits from any improvements. If the farmer alone is considered, the benefit from increased output is then :-

*Net present value of drenching programme =

$$(P\Delta Q - \Delta C)_t \quad + \frac{(P\Delta Q - \Delta C)}{(1 + i)}_{t+1} \quad \cdots\cdots \quad + \frac{(P\Delta Q - \Delta C)}{(1 + i)^n} \quad - I_t$$

where Q = quantity, Δ = change, P = current price,

C = cost, years shown as t, t+1, ... t+n

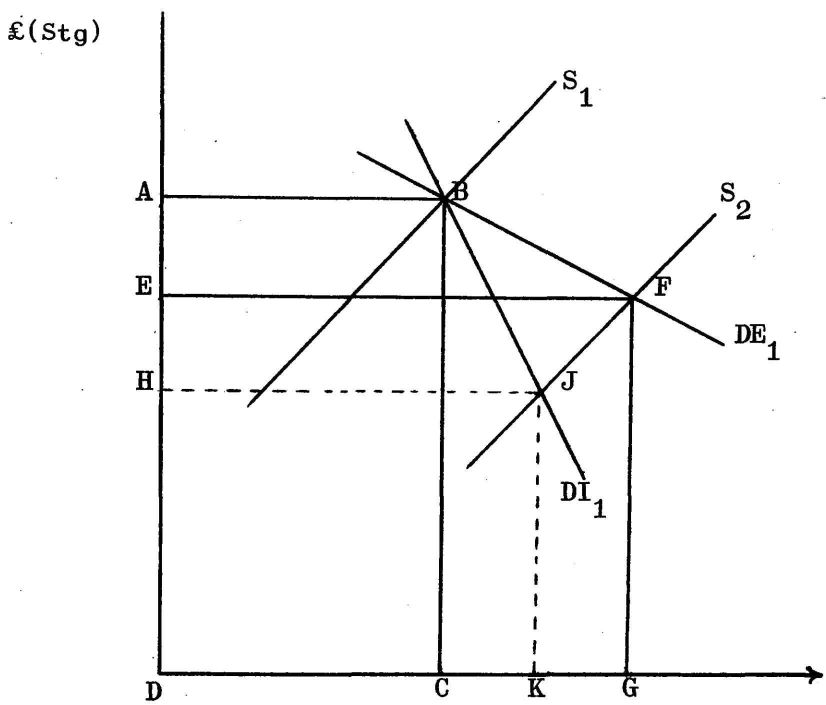
I = initial investment

However, if the increased output results in lower prices then the consumer may benefit and this must also be considered. A further view is that whether or not the price falls, the effect of a higher income for the farmer may lead to a reduction in Government support and hence some benefit indirectly to the public in terms of reduced taxation. The problem of evaluating the total net benefit to farmers consumers and taxpayers alike, is omitted in the calculations provided, but the relevance of such an evaluation for a Government considering its support policy (e.g. subsidising improvements) cannot be denied. In the succeeding analysis, the evaluation is confined to deriving the net benefit to a farmer.

A further problem concerns the effect of increased productivity on output and hence prices. If the supply of lambs produced, at any given

*This is a generalised statement of the benefit and is considered in the final summary. For the present it is sufficient to note that both hoggs and ewes hardly involve any investment expenditure since it is expected that the benefits in the first year outweighs the cost of dosing (even if a delay of three to six months in the benefits is allowed for).

price, is increased, then, unless there is a corresponding shift in the demand curve, prices will tend to fall in a free market.* Without such a shift in the demand curve, the effect on total revenue depends on the elasticity of demand; with a demand elasticity $\left(\frac{\triangle Q}{\triangle P} \Big/ \frac{Q}{P}\right)$ of less than unity total revenue falls; with a demand elasticity greater than unity total revenue increases.



S_1 = supply curve prior to improved productivity

S_2 = supply curve after improvement in productivity

DE_1 = elastic demand curve

DI_1 = inelastic demand curve

Total revenue prior to improved productivity = ABCD

Total revenue after improvement in productivity on assumption of elastic demand curve = EFGD

Total revenue after improvement in productivity on assumption of inelastic demand curve = HJKD

EFGD > ABCD > HJKD

*At present only the fat lamb market is controlled. Hence sales of lambs to lowland farmers will be directly subject to price deterioration in a free market.

In the absence of a shift in the demand curve, market demand elasticity must be greater than unity for gross revenue to be increased by any advance in the quantity offered to the market and for the programme to be worthwhile for hill farmers generally. Alternatively, farmers might avoid the problem of reduced prices by decreasing the size of their flocks and by increasing numbers of beef cattle, although once again any benefit will depend on the price elasticity of demand for beef cattle. An increase in output by an individual farmer producing an insignificant part of lamb and beef output will have virtually no effect on the market supply and hence price. It is the aggregation of small increases in output that causes price to decline.

The final problem concerns the behaviour of supply, demand and prices over the next few years. As already indicated (page 50), the supply situation depends on the Government support policy for sheep and hill farming in general. Similarly, the demand situation will depend on the success of the British sheep industry in promoting its product and perhaps on the level of exports to other countries of the European Economic Community. This will also be affected by the Government and E.E.C. policy towards imports from New Zealand since their market share will limit the market available to British products. These crucial problems affecting the position of the supply and demand curves are subject to Government decisions as well as consumer preferences. The likely outcome is uncertain.

Given both the uncertainty surrounding, and the importance of, supply and demand (shape and position) it would be quite wrong to choose a particular price to evaluate the productivity gains and consequently the approach followed is to assess these gains at a variety of prices. (Pages 43, 201-206).

The remainder of this chapter is divided into an analysis of the potential short term and long term benefits for the individual farmer from a drenching programme for ewes and hoggs, followed by a final summary.

(a) Short Term Benefits

(1) Hill ewes and gimmers

(i) Increased nursing percentages

Any increase in the nursing percentages is seen as an important factor in the prospects for improved economic performance in a hill flock. However, to avoid misunderstanding the definition of the term "nursing percentage"* has to be clearly enunciated. Nursing percentage is taken as the number of ewes which have successfully reared lambs to marking in June as a percentage of the number originally put to the tup. This definition is the one most often recognised in standard hill farm practice. The shortcomings are that it takes no cognisance of losses through barrenness, death of ewes** or lack of milk resulting in inability to rear lambs. The extent of these losses has been shown in the results tables. But this should not necessarily detract from the final evaluation according to the accepted definition.

In tables 44-50, the economic evaluation is shown on an individual trial basis and according to the different treatment protocols. This is done to indicate the general tenor of the results as well as the inter trial variability within each treatment regime. The latter possibly reflects the effect of variables which could not be controlled in extensive field studies of the type undertaken in this study.

TABLE 44

TREATMENT : POTENTIAL EFFECT ON EWE FLOCK REPLACEMENT PER 100 EWE FLOCK

Treatment	Trial No.	Potential No. of viable lambs	Difference from Control	Possible No. of Ewe Lambs	Difference in the No. of Ewe Lambs
(i)	(ii)	(iii)	(iv)	(v)	(vi)
Early Winter	52	53 53	0	26 26	0
	64	75 61	14	37 30	7
	65	81 67	14	40 33	7
Winter	58	58 62	-4	29 31	-2
	59	95 61	34	47 30	17
	60	80 67	13	40 33	7
	63	90 67	23	45 33	12
	77	94 84	10	47 42	5
Early Winter and Winter	51	55 38	17	27 19	8
	53	93 94	-1	46 47	-1
	56	74 70	4	37 35	2
	64	81 61	20	40 30	10
	65	100 67	33	50 33	17
Early Winter and Spring	50	86 84	2	43 42	1
	54	65 65	0	32 32	0
	56	80 70	10	40 35	5
	64	73 67	6	36 33	3
	65	67 61	6	33 30	3
Spring	50	93 84	9	46 42	4
	58	61 62	-1	30 31	-1
	59	89 64	25	44 32	12
	60	82 68	14	41 34	7
	63	83 67	16	41 33	8

Notes 1. All trial results have been converted into their 100 ewe flock equivalent. Hence column (iii) figures may also be interpreted as nursing percentages.

2. The top figure for each trial is the treated group and the lower figure is the control group.

As may be seen from table 44, any increase in the nursing percentages indicates the potential number of viable lambs available from both treated and control groups for each trial by the lamb marking in June. In calculating the possible number of potential ewe lambs (column v) the following assumptions are made: approximately 50% of the total lambs available in column (iii) are ewe lambs; lambs are singles***; and no male lambs are retained for breeding.

* "Lambing percentage by literal definition must mean the number of lambs per 100 ewes put to the tup; unless defined carefully in texts, a casual definition is the number of <u>viable</u> lambs per 100 ewes at birth, or even in some circumstances, at a later stage in life.

** Obviously such losses affect eventual profitability and are also reflected in reduced freedom to select suitable replacement stock ewe hoggs.

*** Twins on hill farms are the exception rather than the rule.

(ii) Lambs available for sale and prices

Table 45, derived from Table 44, column (vi), shows the possible number of ewe lambs for sale by taking a few trials according to the different treatments and compares this within a range of replacement rates of stock hoggs per 100 ewes normally acceptable on hill farms. The surplus ewe lambs are calculated after the lambs are extracted for ewe flock replacement.

Table 45 Extra ewe lambs in relation to different requirements for flock replacement

Treatment	Trial No.	Extra ewe hoggs available per 100 ewe flock					
		30	31	32	33	34	35
Early Winter	64 65	7 7	6 6	5 5	4 4	3 3	2 2
Winter	59 60	17 7	16 6	15 5	14 4	13 3	12 2
Early Winter and Winter	56 64	2 10	2 9	2 8	2 7	2 6	2 5
Early Winter and Spring	64 65	3 3	3 2	3 1	3 0	2 0	1 0
Spring	50 60	4 7	4 7	4 7	4 7	4 7	4 6

From consideration of Tables 44 and 45, two primary benefits may be seen to accrue from the various trials within the drenching protocols. Since the number of lambs available for both flock replacement and for sale is increased (apart from trial numbers 52, 58, 53, 54 shown in Table 44), then firstly the opportunity for a better selection of stock hoggs is increased and, additionally more store lambs are available for immediate sale. The benefit from greater selectivity in stock hoggs is a long term consideration and further discussion on this is postponed to that section. The benefits arising in the short term under the different treatments employed have to be considered with emphasis on the increased potential sales from surplus ewe and wether lambs available. In cases where the number of ewe lambs available for flock replacement is inadequate, then any improvement in the number due to drenching provides a short term benefit in reduced purchases of replacement ewe lambs on the open market.

To aid the discussion for the reader, tables are compiled for the appropriate treatment regimes. The following explanatory notes are also given.

1. The number of surplus ewe lambs available is calculated at the "30" and "35" ewe hogg replacement levels per 100 ewe flock. The "35" replacement rate is shown in parenthesis.
2. The increased sale of surplus lambs is taken at prices ranging from £3 to £6 per head which are based on sales records (1966-71) of Livestock Marts Limited, Stirling, for Blackface ewe and wether lambs during autumn marketing (i.e. August and September: see also graph A on page 43).
3. The benefit is calculated as "price x number of lambs sold less cost of treatment per 100 ewe flock". The cost of a single treatment is taken as £9.60 per 100 ewes.
4. The buying and selling price for stock ewe lambs is assumed to be the same. It is also assumed that the price differential between ewe and wether lambs would be negligible as usually "mid" ewe lambs for disposal are generally classed with "top" store lambs in the higher range of prices obtained. "Top" ewe lambs are invariably retained on the farm as stock hoggs.

The different treatments within the context of their respective tables are now discussed. The evaluation shows the differences between the treated and control groups.

TABLE 46

Economic Benefit from Early Winter Treatment

Trial No.	Surplus ewe lambs for sale	Savings in 'buying-in' No. of lambs	No. of wether lambs for sale	Gain(+) or Loss(-) less cost of treatment			
				£3	£4	£5	£6
52	0 (0)	0 (0)	0	£ -9.60	£ -9.60	£ -9.60	£ -9.60
64	7 (2)	0 (5)	7	£+32.40	£+46.40	£+60.40	£+74.40
65	7 (5)	0 (2)	7	£+32.40	£+46.40	£+60.40	£+74.40

Treatment in early Winter in two of the three trials was beneficial. In trial number 52 (see Table 44 page 198) since the nursing percentages of the treated and control groups were identical, the treatment cost the farmer £9.60 without providing any extra benefit from the sale of lambs. In the other two trials, the net benefits ranged from £32.40 to £74.40 depending on the price obtained in the market. A further, unquantified benefit may also arise if the farmers in trials 64 and 65 wished to raise their flock replacement level from 30 to 35 ewe hoggs. Although the savings in the market place are unaltered (e.g. in trial 64 two extra ewe lambs are available for sale and five ewe lambs need not be purchased due to treatment, as opposed to seven extra lambs for sale and zero purchase savings) the risks of losses associated with non-acclimatisation** are avoided since no 'buying-in' is required for the treatment group.

** 'acclimatisation' is a characteristic of sheep adapted to particular grazings being able to find the best pasture, avoiding natural hazards and being more resistant to tick-borne and other diseases.

Although it appears that an early Winter treatment is beneficial, it should be noted that this result is derived from only three trials, and that for the group as a whole the difference in nursing percentage between treated and untreated groups was insignificant at the 10 per cent level. (See Table 16a page 117).

TABLE 47

Economic Benefit from Winter Treatment

Trial No.	Surplus ewe lambs for sale	Saving in 'buying-in' no. of lambs	No. of wether lambs for sale	Gain(+) or Loss(-) less cost of treatment			
				£3	£4	£5	£6
58	-1 (0)	-1 (0)	-2	£-21.60	£-25.60	£-29.60	£-33.60
59	17(12)	0 (5)	17	£+92.40	£+126.40	£+160.40	£+194.40
60	7 (5)	0 (2)	6	£+29.40	£+42.40	£+55.40	£+68.40
63	12(10)	0 (2)	11	£+59.40	£+82.40	£+105.40	£+128.40
77	5 (5)	0 (0)	5	£+20.40	£+30.40	£+40.40	£+50.40

The single treatment in Winter provided an economic advantage in four out of five trials. Once again the results show considerable variation - ranging from a deficit of between £21.60 and £33.60 in the case of trial number 58 where the untreated 'control' group had a higher nursing percentage, to a net benefit of between £92.40 and £194.40 in the case of trial 59. It should be noted that, although in only two of the five trials the differences in nursing percentages were significant at the 10 per cent level, for the group as a whole, the difference in favour of the treatment regime was significant at the 2 per cent level. (See Table 17a p.119). This seems to indicate that a Winter treatment is generally beneficial but that there is risk in individual cases that a loss may be incurred.

TABLE 48

Economic Benefit from Early Winter and Winter Treatment

Trial No.	Surplus ewe lambs for sale	Saving in 'buying-in' no. of lambs	No. of wether lambs for sale	Gain(+) or Loss (-) less cost of treatments**			
				£3	£4	£5	£6
51	0 (0)	8 (8)	9	£+31.80	£+48.80	£+65.80	£+82.80
53	-1(-1)	0 (0)	0	£-22.20	£-23.20	£-24.20	£-25.20
56	2 (2)	0 (0)	2	£ -7.20	£ -3.20	£ +0.80	£ +4.80
64	10 (5)	0 (5)	10	£+40.80	£+60.80	£+80.80	£+100.80
65	17(15)	0 (2)	16	£+79.80	£+112.80	£+145.80	£+178.80

** The cost of two treatments is deducted

Treatment in early Winter and Winter was beneficial at all lamb prices in three out of the five trials. In one other, trial 56, the breakeven point was obtained when the market price of lambs reached £5. In the remaining trial (number 53) where the untreated group had a marginally higher nursing percentage, the treatment was obviously not worthwhile.

The net 'benefit' from treatment varied between -£22.20 to -£25.20 in trial number 53, to +£79.80 to +£178.80 in trial 65.

Taking the five trials together the difference in nursing percentage in favour of the treated group was significant at the 1 per cent level. Hence it appears that a treatment in early Winter and Winter is economically worthwhile, though once again the variability of results show that in individual cases the farmer may not benefit.

TABLE 49

Economic Benefit from Early Winter and Spring Treatment

Trial No.	Surplus ewe lambs for sale	Saving in 'buying-in' no. of lambs	No. of wether lambs for sale	Gain(+) or Loss(-) Less cost of treatments**			
				£3	£4	£5	£6
50	1 (1)	0 (0)	1	£-13.20	£-11.20	£ -9.20	£ -7.20
54	0 (0)	0 (0)	0	£-19.20	£-19.20	£-19.20	£-19.20
56	5 (5)	0 (0)	5	£+10.80	£+20.80	£+30.80	£+40.80
64	3 (1)	0 (2)	3	£ -1.20	£ +4.80	£+10.80	£+16.80
65	3 (0)	0 (3)	3	£ -1.20	£ +4.80	£+10.80	£+16.80

** The cost of two treatments is deducted

Although four out of five trials showed a higher nursing percentage for the treated group, (see Table 19a p.123), when the cost of two treatments was deducted, only one trial (number 56) showed a short term economic benefit from the sale of lambs at all market prices. Trials 64 and 65 showed a marginal net benefit when the market price of lambs was £4; trials 50 and 54 resulted in a net loss.

Taking the five trials together it appears that this treatment is of doubtful advantage and bearing in mind the relatively more favourable response from other treatment regimes the early Winter and Spring protocol cannot be recommended as a result of this study.*

*Although the conclusion may be criticised since it is based on only five trials, there were 190 treated and 119 untreated ewes involved and the group difference in nursing percentage was insignificant at the 10%

level, there are also biological reasons to support the above conclusion (see pages 71-87; 175-180).

TABLE 50

Economic Benefit from Spring Treatment

Trial No.	Surplus ewe lambs for sale	Savings in 'buying-in' no. of lambs	No. of wether lambs for sale	Gain(+) or Loss (-) less cost of treatment			
				£3	£4	£5	£6
50	4 (4)	0 (0)	5	£+17.40	£+26.40	£+35.40	£+44.40
58	-1 (0)	0(-1)	0	£-12.60	£-13.60	£-14.60	£-15.60
59	12 (9)	0 (3)	13	£+65.40	£+90.40	£+115.40	£+140.40
60	7 (6)	0 (1)	7	£+32.40	£+46.40	£+60.40	£+74.40
63	8 (6)	0 (2)	8	£+38.40	£+54.40	£+70.40	£+86.40

A single treatment in Spring yielded a net economic benefit in the short term in four out of the five trials. The benefits range from -£12.60 and -£15.60 in the case of trial 58 to +£65.40 and +£140.40 in the case of trial 59.

Although the net benefits show considerable variation, the overall favourable difference in nursing percentages between the treated and control groups for the five trials was significant at the 2 per cent level and hence it appears that a Spring treatment is economically worthwhile.

(iii) Ewe mortality

It would appear, at least from the sample available, that treatment has no effect on mortality and this is not unexpected. Indeed, for all treatments 24 out of the 29 trials revealed no apparent difference. Only one trial suggested some improvement and the remaining four suggested a deterioration. Although in many of the trials the number of deaths was either non-existent or low, it seems possible that for larger samples, the multiplicity of reasons for deaths or losses on a hill farm due to "black loss"* would obscure the value or otherwise of anthelmintic treatment <u>per se</u>.

*A loss due to accident or unexplained deaths.

(iv) Wool clip

No measurements were taken of the wool clip for ewes and gimmers because of the labour problems and work pressure on the farm at this season.

<u>Summary of the short term benefits : treatment of ewes and gimmers</u>

A comparison of the various treatment regimes suggests that in general, an anthelmintic treatment is economically justifiable. However, the variability of the results, as well as the recognised deficiencies in experimental control in field trials makes the conclusion somewhat tentative.

An examination of the relative economic benefits from the different treatment protocols suggests the following recommendations :-

1. Single treatment in early Winter	: The economic benefit appears doubtful*
2. Single treatment in Winter	: Seems to be economically justified
3. Single treatment in Spring	: Seems to be economically justified
4. Two treatments in early Winter and Winter	: Seems to be economically justified
5. Two treatments in early Winter and Spring	: The treatment is not justified

*The few trials concluded, combined with the variability of the results precludes a more optimistic economic evaluation within the type of field studies undertaken.

(2) Ewe hoggs

Since ewe hoggs are normally retained as part of the breeding flock it is difficult to illustrate the benefit purely in terms of body weight, but as discussed earlier, weight may very well be an indication of "condition" and stamina. The only exception concerns those owners who retain all their ewe hoggs except "shotts" through the winter and practice delayed selection (page 24) and hence have hoggs available for sale.

(i) Wool clip

Wool clip was measured in a small number of trials for ewe hoggs. The difficulties of measuring in situ were less for hoggs than for ewes - due to the fact that the hogg clipping is done separately from the milk clipping of the breeding flock in July and subject to less pressure. Unfortunately only a few trials were completed because farmers determine the day of clipping at short notice depending on the weather, labour and other commitments. Despite the small number of trials the results are based on 172 treated and 102 untreated animals.

The increase in fleece weight attributed to dosing in-wintered hoggs is shown (pages 161 and 191). The sample of five trials indicates that the monetary benefit is in favour of dosing after a short term delay (9.0 pence) per hogg compared to the untreated animals; the gain is only slightly greater than dosing on the day of entry. The net short term benefit from drenching 30 ewe hoggs is £2.70.

(ii) Sales of hoggs

The price obtained from a hogg is partly determined by its quality and it is probable that a heavier "fitter" hogg would attain a higher price. However, with the small numbers of hoggs sold in the spring the price obtained may merely cover the wintering costs and be unlikely to make a substantial difference to the income.

(b) Long term benefits

The long term benefits from a continuous worming programme could result in higher lambing and nursing percentages; lower flock mortality; heavier and better quality lambs for sale and an improved wool clip. In order to estimate the extent, if any, of such benefits it would inevitably need a lengthy study as the productive life of a flock is usually five years. Thus, any flock improvement programme must be evaluated over at least two generations. Inevitably such a study would involve a very large sample of animals kept under well controlled conditions and even then it would be difficult to evaluate the results due to the influence of individual variables from the many factors which affect hill flocks. Again, any changes in productivity that did occur would have to be given an economic value and, as has already been discussed earlier in the introduction to this section, this, in itself, would raise problems. Because it was not feasible either to undertake such a long term study nor, under hill farming conditions, would it be possible to keep close control,* a number of shorter term field trials were carried out which could give some indication of the longer term benefits. A further criterion in the choice of field tests was to use the same measurement as other investigators (i.e. liveweight). A discussion of the measures is given as appropriate in the evaluation below.

(1) Hill ewes and gimmers

(i) Lambing and nursing percentages

The short term benefits showed that farmers may expect more lambs by the lamb marking in June as a result of tetramisole treatment.

*The main purpose of the study was to investigate the effect of anthelmintic treatment as carried out in everyday practice as opposed to that of research farms.

(Table 44 page 198). From this the immediate benefit was the extra cash value from the sale of store and surplus stock hoggs. The long term benefit arises from being able to choose replacement stock hoggs from a larger number available every year. Consequently it is hoped that the cumulative benefit from flock improvement, subject to the physical constraints inherent in the system, may be to raise the lambing percentages and wool clip in subsequent years.

A hypothetical example may further serve to illustrate the possible benefits from increasing the nursing percentages. The <u>first</u> treatment of ewes, after the short term benefit (10 extra lambs for sale) is assumed to raise the nursing potential after two years* (i.e. in the third year) by two more lambs, which will marginally increase the number of ewe lambs for eventual flock replacement or provide two extra lambs for sale. The <u>second</u> and <u>subsequent</u> treatments, again allowing for the immediate short term benefit, are assumed to maintain the higher nursing potential. This in turn, from allowing greater selectivity, is assumed to increase nursing potential from <u>the fifth year</u> onwards by a further one per cent. Although this example is plausible, it is appreciated that there are environmental constraints which serve to confine flock performance on the hill grazings, irrespective of any treatments given.

A similar "progression potential" for improved wool clip would be possible but as the reasoning would be identical to that of nursing percentages and the results simply hypothetical, no further discussion is needed.

(2) <u>Ewe hoggs</u>

Many farmers, as well as observers of the sheep industry, have argued that uninterrupted growth of young animals is desirable, since

*It takes two years from birth to the first lambing as gimmers.

any retardation is felt likely to reduce their productive performance in later years. Given this belief, it is not surprising that helminthologists and nutritionalists as well as farmers, have taken liveweight as a convenient measure of both growth and general condition of the animal, though recognising that it is only one possible measure and not necessarily the ideal.* Unfortunately little experimental evidence is available to support the strongly held beliefs concerning liveweight, both as a measure of condition and as a factor affecting subsequent productive performance. The main evidence available only relates hogg weight and growth to performance at the gimmer stage and ignores the later years. Jackson (1963) and Gunn (1968) showed that heavier hoggs produced more lambs at the gimmer stage, depending on their weight at the time (pages 37,38). Again, Jackson (1963) and Coop (1962) showed that there was a relationship between liveweight at the hogg stage and wool production in later years. On the other hand, Gunn (1968) in nutritional studies on hill sheep, has suggested that the better performance at the gimmer stage is not maintained and that, over the full productive life, the heavier hoggs (high plane of feeding) did not perform any differently to others of lesser weight. However the group sizes studied were small; it concerns a nutritional study and hence is not strictly comparable with the evidence from an anthelmintic study; and finally there is no justification for well fed hoggs if the nutrition in later life will not sustain the earlier heavier weight.

Thus, there are at least three plausible assumptions that can be made about the relationship of liveweight at the hogg stage to later performance.

(i) The heavier the hoggs, the better their subsequent performance subject to diminishing returns and the environmental constraints.

*A measure of "condition" would ideally include records of girth, body length, leg length, etc. (page 106).

(ii) Heavier hoggs perform better in their first productive year (and are inclined to produce twins) and may or may not perform better in subsequent years.

(iii) Heavier hoggs perform better in their first productive year but this performance is not sustained and that over the full productive life there is no significant increase in flock productivity.

The first and second assumptions can be shown to provide a long term justification for a drenching programme for hoggs by taking a simple example based on the second, more pessimistic, assumption. The calculation ignores the short term benefit from an increased wool slip. The low price of £3 per lamb is taken. The cost of drenching 30 ewe hoggs is approximately 210 pence and labour is almost certainly a fixed cost,* whereas the price of a lamb would seem unlikely to fall anywhere near that level. Even with a 15% discount rate, the net present value of dosing 30 ewe hoggs once, to obtain one extra lamb for sale two years later** (price £3 minimum) from the gimmers is still positive.

On the final and pessimistic assumption, the only long term gain is a redistribution of the flock performance. This may be still worthwhile if the flock life on the hill grazings could be reduced so that the same output is obtained from the flock over a shorter period. A method of achieving this would be to bring the older ewes on to in-bye in an effort to increase the twinning factor. (Page 54).

*Drenching would be arranged to ensure that there was a minimal effect on other farm work so that the opportunity cost of the labour would be trivial.

**Single cost of dosing 30 ewe hoggs in early winter £2.10. Revenue earned from sale of lamb two years after drenching - £3.

$$\text{Net present value} = \frac{R}{(1+i)^2} - I = \frac{3}{(1+0.15)^2} - 2.10 = +\text{£}0.17$$

where R = revenue
i = cost of dosing

(c) Summary

(1) Hill ewes and gimmers

A drenching programme for ewes appears to be justified in the first year of dosing and may also provide a long term benefit from increased nursing percentages due to flock improvement. The only investment outlay to attain such an improvement for a 100 ewe flock is indicated below for the best three treatment protocols:-

Winter	:	£9.60 Five months in advance of the benefit
Spring	:	£9.60 Three months in advance of the benefit
Early winter and winter	:	£9.60 Eleven months in advance of the benefit, and
		£9.60 Seven months in advance of the benefit

A reservation should be made that these results do not preclude the possibility that in individual cases the benefit may be less than the cost, since the productivity gain was either negative or marginal in a few trials.

(2) Ewe hoggs

A drenching programme for ewe hoggs is more difficult to evaluate. There are clear advantages from dosing in terms of liveweight as well as some evidence of advantages to be made in fleece weight. Liveweight gain may be insufficient in some cases to justify a drenching programme. On the other hand, the short term liveweight gain may result in some long term benefit from some improvement in lambing percentages. Since the cost of drenching 30 ewe hoggs is only £2.10 a single extra lamb after two years would be sufficient to justify a single dosing.

The exception to this seems to be in hoggs away-wintered, where the variability of wintering conditions may outweigh the need for a drenching programme. (Page 185). For the other wintering systems, the best times of dosing in respect of liveweight gain would be:-

Hill-wintered	:	Early winter and winter
In-bye	:	Early winter and winter
In-shed	:	A short delay after housing

However since the cash value of weight gain in terms of later productivity is uncertain, no economic evaluation may be given to these technical findings.

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CHAPTER IV

General summary

General Summary

This Thesis deals with the Scottish hill sheep industry.

It commences with a study of the size and importance of the industry and examines current methods of husbandry. The constraints imposed by husbandry and economic difficulties are discussed and compared with the trends towards improvement which are becoming evident.

The part played by nematode parasites specifically, is closely examined with particular reference to seasonal occurrence, the pathology of infestation and the use of anthelmintics.

A study in depth, is made of the value of tetramisole as an example of the more recent established anthelmintics, when used on farms by farmers with the minimum of technical supervision. Since under these circumstances there were many practical difficulties, the field studies were confined to ewe hoggs, gimmers and ewes. However, all the main husbandry systems were involved and included the relatively new method of housing ewe hoggs during the winter months.

A great deal of fresh information was gathered on the productivity performance of both treated and untreated groups on the same farm. Some traditional beliefs were confirmed; others were not. New knowledge was gained on the true extent of winter losses whether in terms of survival, body weight or of lamb production. In the course of the "in-wintered" work, an unexpected response to delay in dosing, whether "short term" or "long term" was discovered. This finding is discussed at length and the opinion expressed that "stress" (illness of psychosomatic origin) is probably involved. In hill ewes and in hogg wintering on the hill and in-bye the value of a mid winter treatment was shown.

The economic consequences of strategic dosing are analysed to show which of the many programmes produced economically viable results. The work shows that a well conceived programme of strategic dosing with a modern anthelmintic appears to be worthwhile for hill ewes and gimmers and for three of the four systems of hogg wintering.

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Types of Farming in Scotland (1952) H.M.S.O.

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FARM INDEX

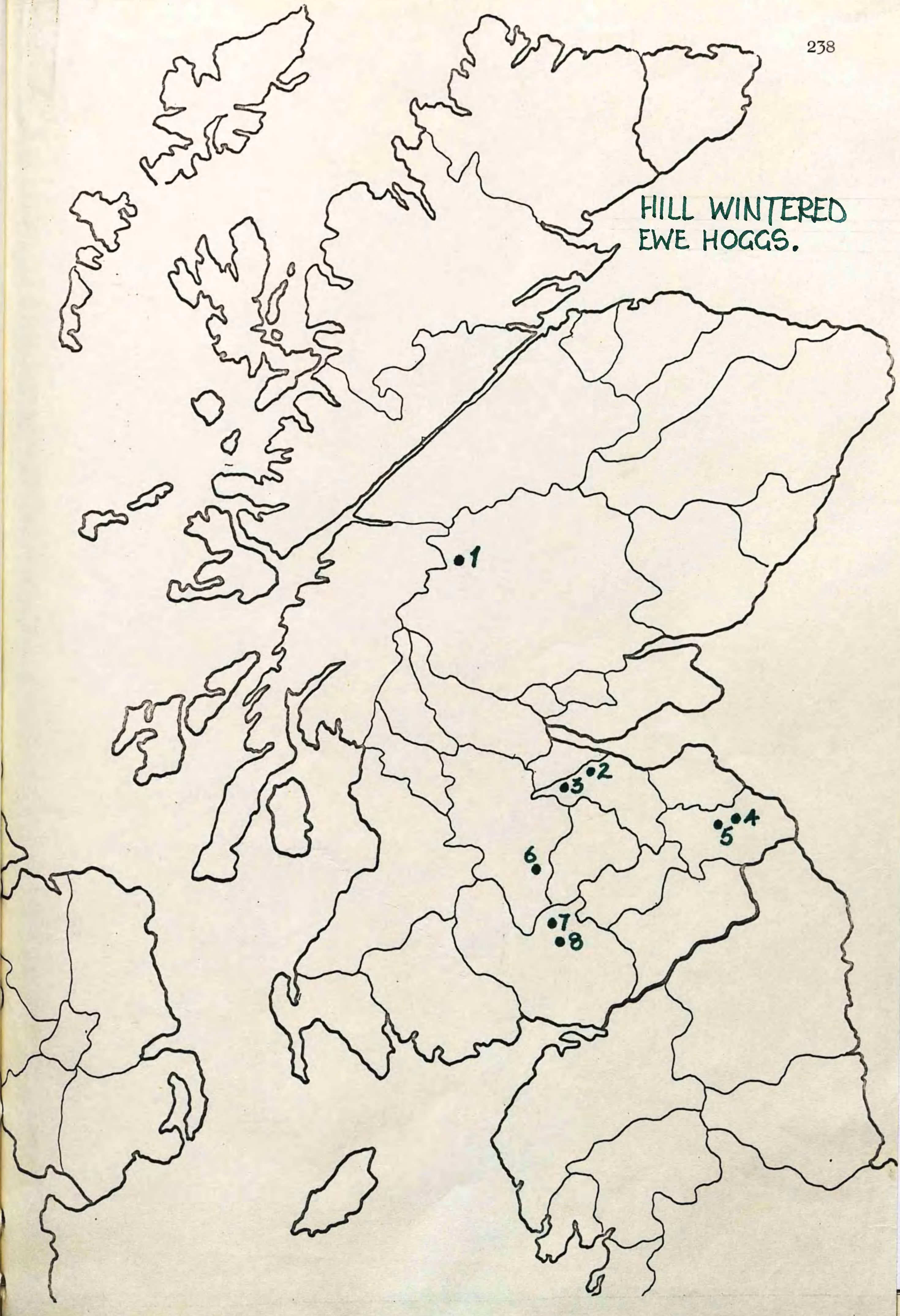
Hoggs 1966 - 1971

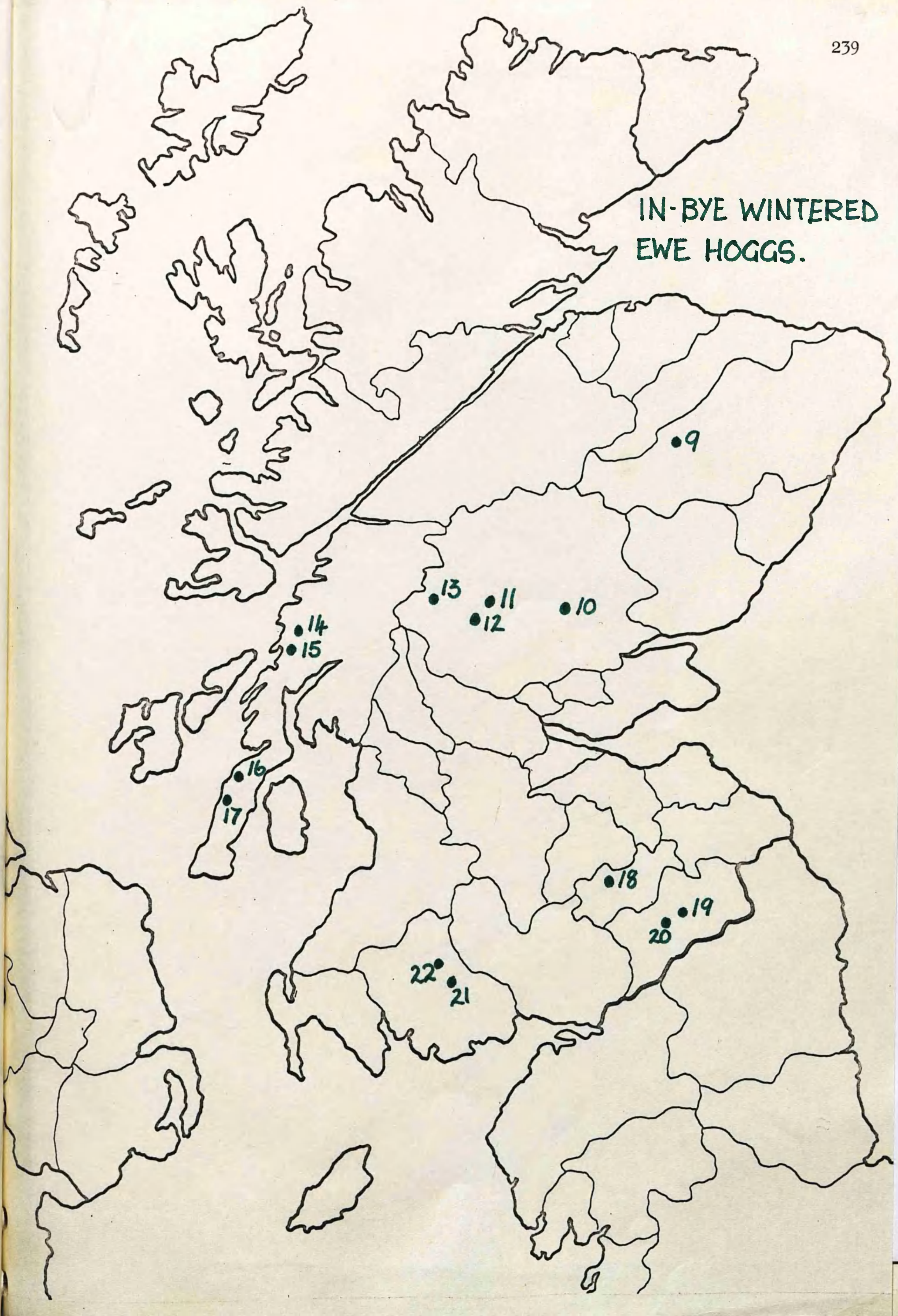
	Trial Number	Location	County	Breed
Hill-Wintered	1	I	W. Perthshire	B.F.
	2(a)	II	Midlothian	B.F.
	2(b)	II	Midlothian	B.F.
	3(a)	III	Midlothian	B.F.
	3(b)	III	Midlothian	B.F.
	3(c)	III	Midlothian	B.F.
	4	IV	Berwickshire	B.F.
	5	IV	Berwickshire	B.F.
	6(a)	V	S. Lanarkshire	B.F.
	6(b)	V	S. Lanarkshire	B.F.
	7	VI	Dumfriesshire	B.F.
	8	VI	Dumfriesshire	B.F.
In-bye	9	VII	W. Aberdeenshire	B.F.
	10	VIII	C. Perthshire	B.F.
	11	IX	W. Perthshire	B.F.
	12	IX	W. Perthshire	B.F.
	13	X	W. Perthshire	B.F.
	14	XI	W. Argyllshire	B.F.
	15	XI	W. Argyllshire	B.F.
	16	XII	W. Argyllshire	B.F.
	17	XII	W. Argyllshire	B.F.
	18	XIII	Selkirk	B.F.
	19	XIV	Roxburghshire	s/c Chev.
	20	XIV	Roxburghshire	s/c Chev.
	21	XV	Kirkcudbrightshire	B.F.
	22	XV	Kirkcudbrightshire	B.F.
Away-Wintered	23	XVI	W. Aberdeenshire	B.F.
	24	XVII	Dunbartonshire	B.F.
	25	XVII	Dunbartonshire	B.F.
	26	XVIII	Dunbartonshire	B.F.
	27	XIX	W. Stirlingshire	B.F
	28	XX	Clackmannan	B.F.
	29	XXI	Midlothian	B.F.
	30	XXII	Lanarkshire	B.F.

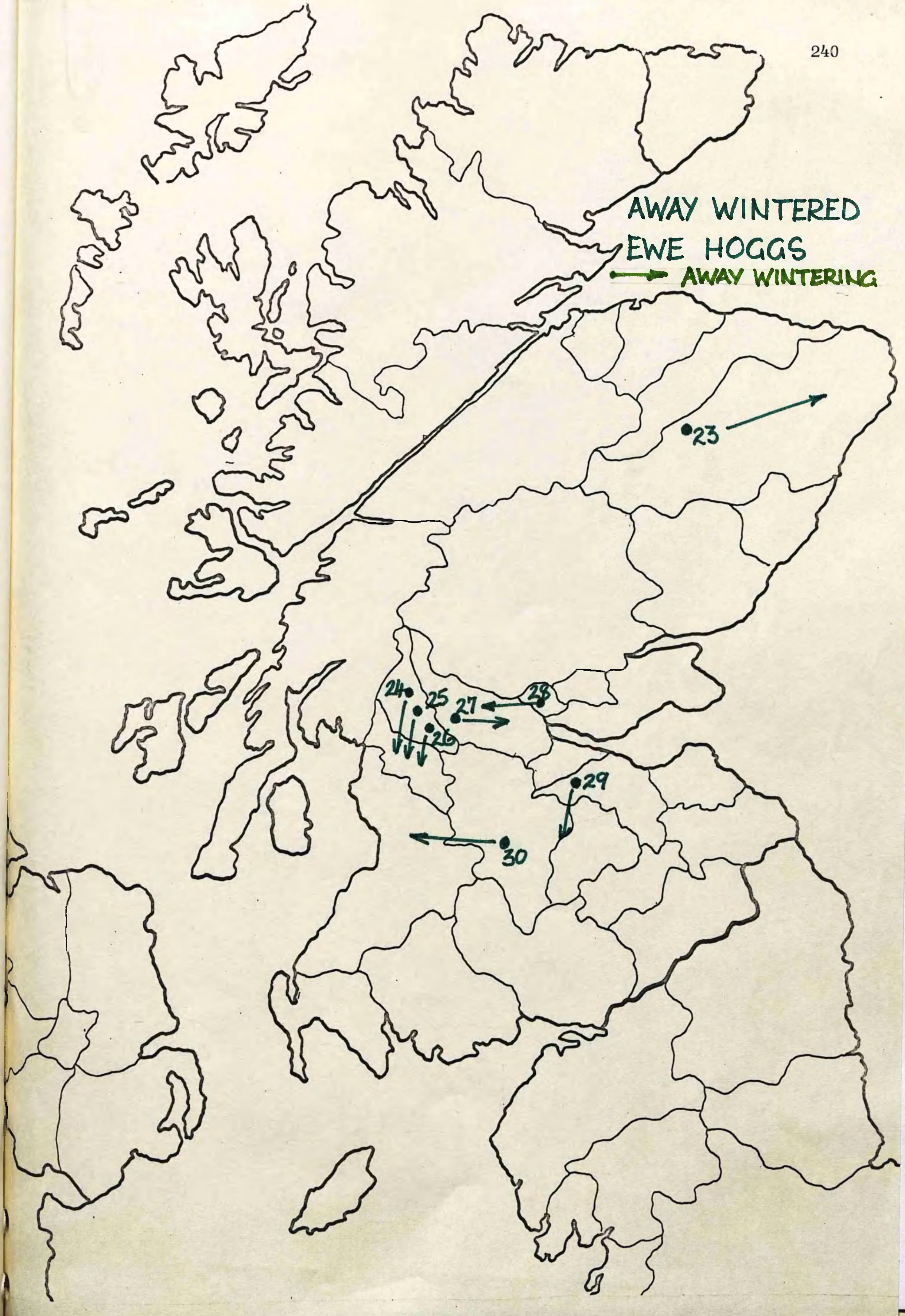
	Trial Number	Location	County	Breed
	31	XXIII	Ross-shire	B.F.
	32	XXIII	Ross-shire	B.F.
	33	XXIV	C. Perthshire	B.F.
	34	XXIV	C. Perthshire	B.F.
	35	XXV	S. Perthshire	B.F.
	36	XXVI	W. Perthshire	B.F.
	37	XXVII	W. Argyllshire	B.F.
	38	XXVII	W. Argyllshire	B.F.
In-	39	XXVIII	Midlothian	B.F.
Wintered	40	XXVIII	Midlothian	B.F.
	41	XXVIII	Midlothian	B.F.
	42	XXIX	Berwickshire	B.F.
	43	XXIX	Berwickshire	B.F.
	44	XXX	Selkirk	s/c Chev.
	45	XXXI	Roxburghshire	s/c Chev.
	46	XXXII	Dumfriesshire	s/c Chev.
	47	XXXII	Dumfriesshire	s/c Chev.
	48	XXXIII	Kirkcudbrightshire	B.F.

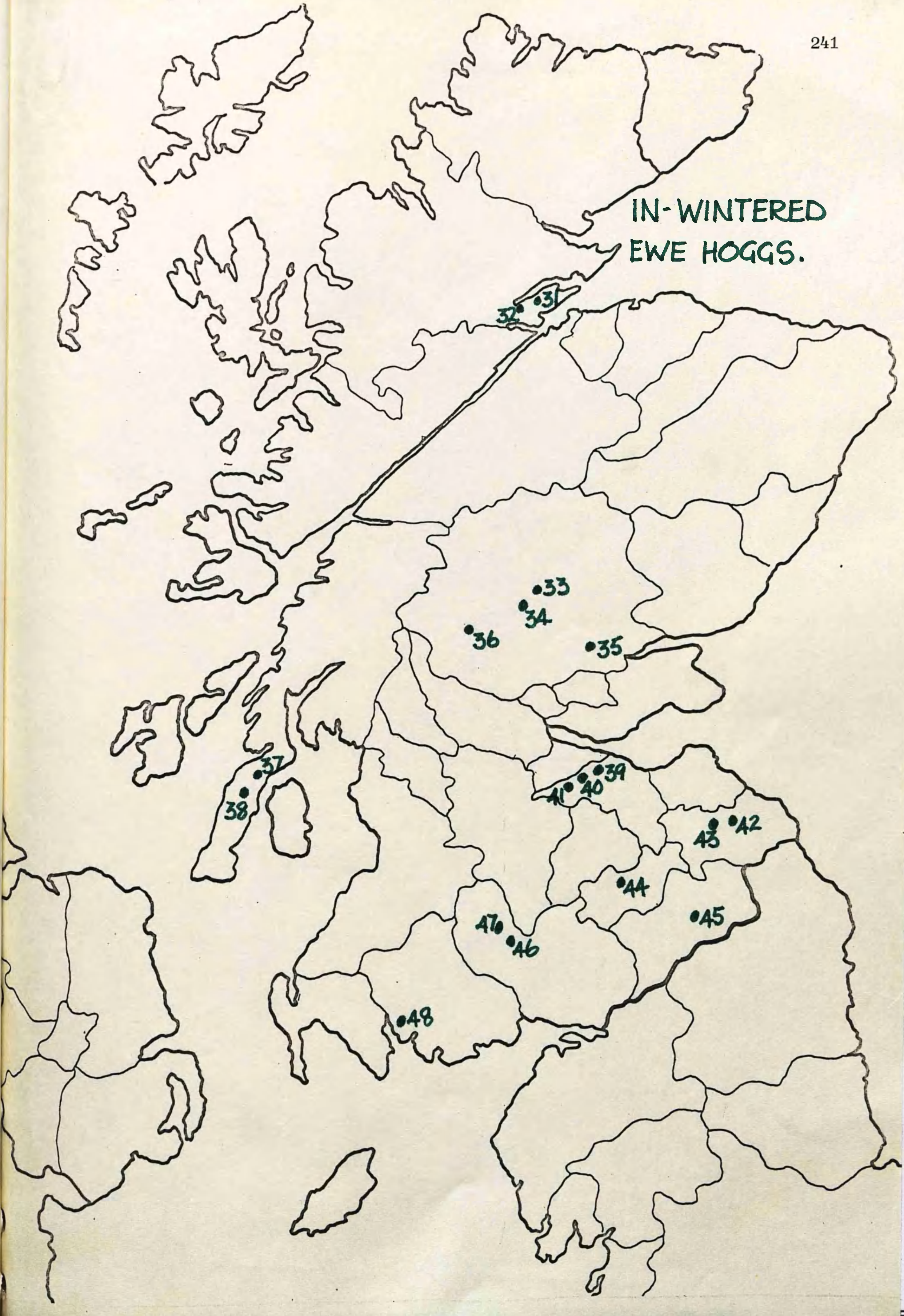
Hill Ewes and Gimmers 1966 - 1971

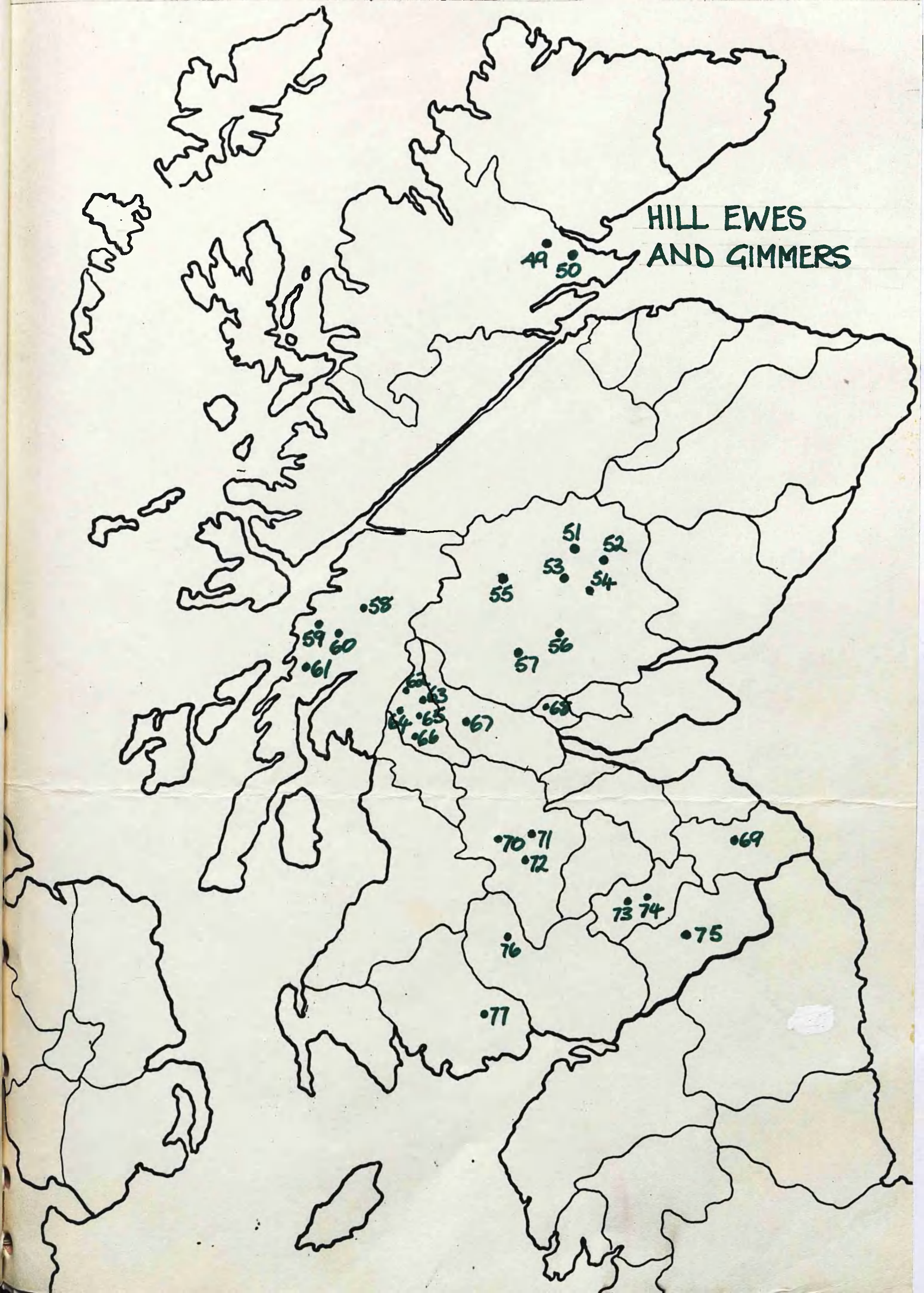
Trial Number	Location	County	Breed
49	XXXIV	Ross-shire	B.F.
50	XXXV	Ross-shire	B.F.
51	XXXVI	C. Perthshire	B.F.
52	XXXVI	C. Perthshire	B.F.
53	XXXVI	C. Perthshire	B.F.
54	XXXVII	C. Perthshire	B.F.
55	XXXVIII	C. Perthshire	B.F.
56	XIL	C. Perthshire	B.F.
57	XL	C. Perthshire	B.F.
58	XLI	W. Argyllshire	B.F.
59	XI	W. Argyllshire	B.F.
60	XI	W. Argyllshire	B.F.
61	XLII	W. Argyllshire	B.F.
62	XVII	Dunbartonshire	B.F.
63	XVII	Dunbartonshire	B.F.
64	XVII	Dunbartonshire	B.F.
65	XVII	Dunbartonshire	B.F.
66	XVIII	Dunbartonshire	B.F.
67	XIX	W. Stirlingshire	B.F.
68	XLIII	Clackmannanshire	B.F.
69	IV	Berwickshire	B.F.
70	XXI	C. Lanarkshire	B.F.
71	XLIV	C. Lanarkshire	B.F.
72	XLIV	C. Lanarkshire	B.F.
73	XLV	Selkirk	s/c Chev.
74	XLV	Selkirk	s/c Chev.
75	XLVI	Roxburghshire	s/c Chev.
76	XXXII	Dumfriesshire	s/c Chev.
77	XV	Kirkcudbrightshire	B.F.


HILL WINTERED
EWE HOGGS.
1
2
3
4
5
6
7
8


IN-BYE WINTERED
EWE HOGGS.
9
13
11
12
10
14
15
16
17
18
19
20
22
21


AWAY WINTERED
EWE HOGGS
AWAY WINTERING
23
24
25
26
27
28
29
30


IN-WINTERED
EWE HOGGS.
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48


HILL EWES
AND GIMMERS
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
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73
74
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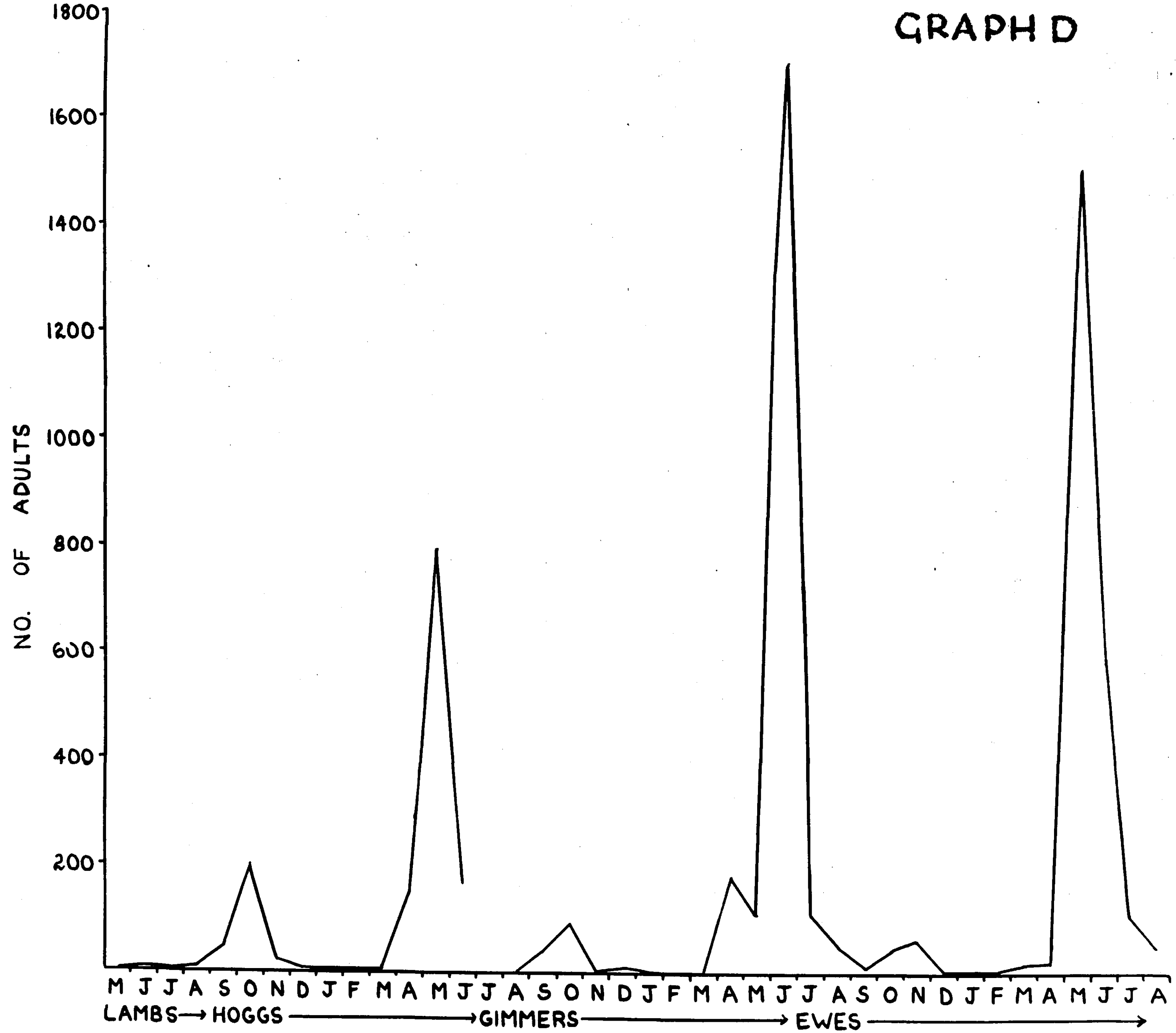
77

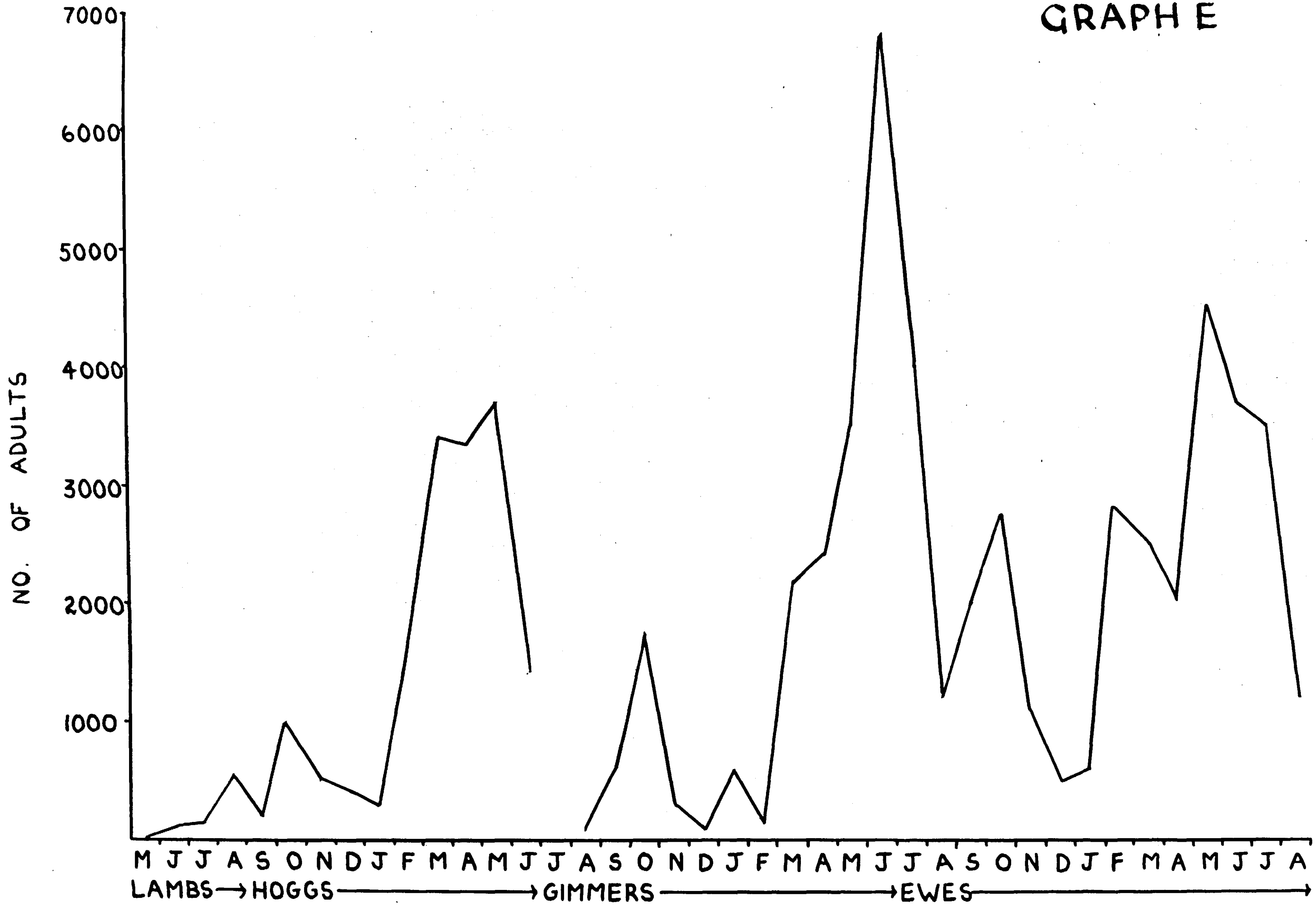
THE "AVERAGE" HAEMONCHUS CONTORTUS INFECTIONS IN SCOTTISH HILL SHEEP

GRAPH D



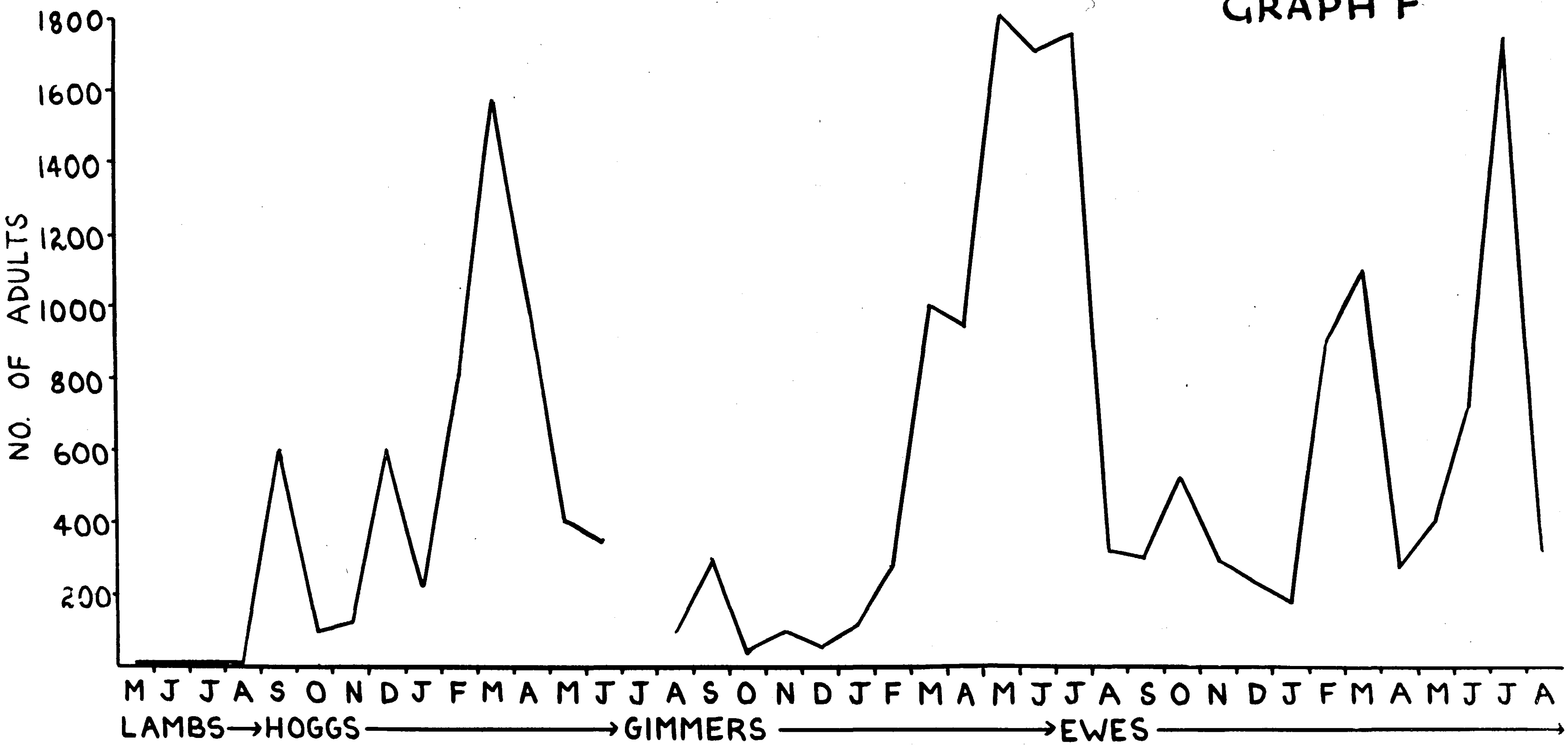
THE "AVERAGE" *OSTERTAGIA* SPP. INFECTIONS IN SCOTTISH HILL SHEEP

GRAPH E



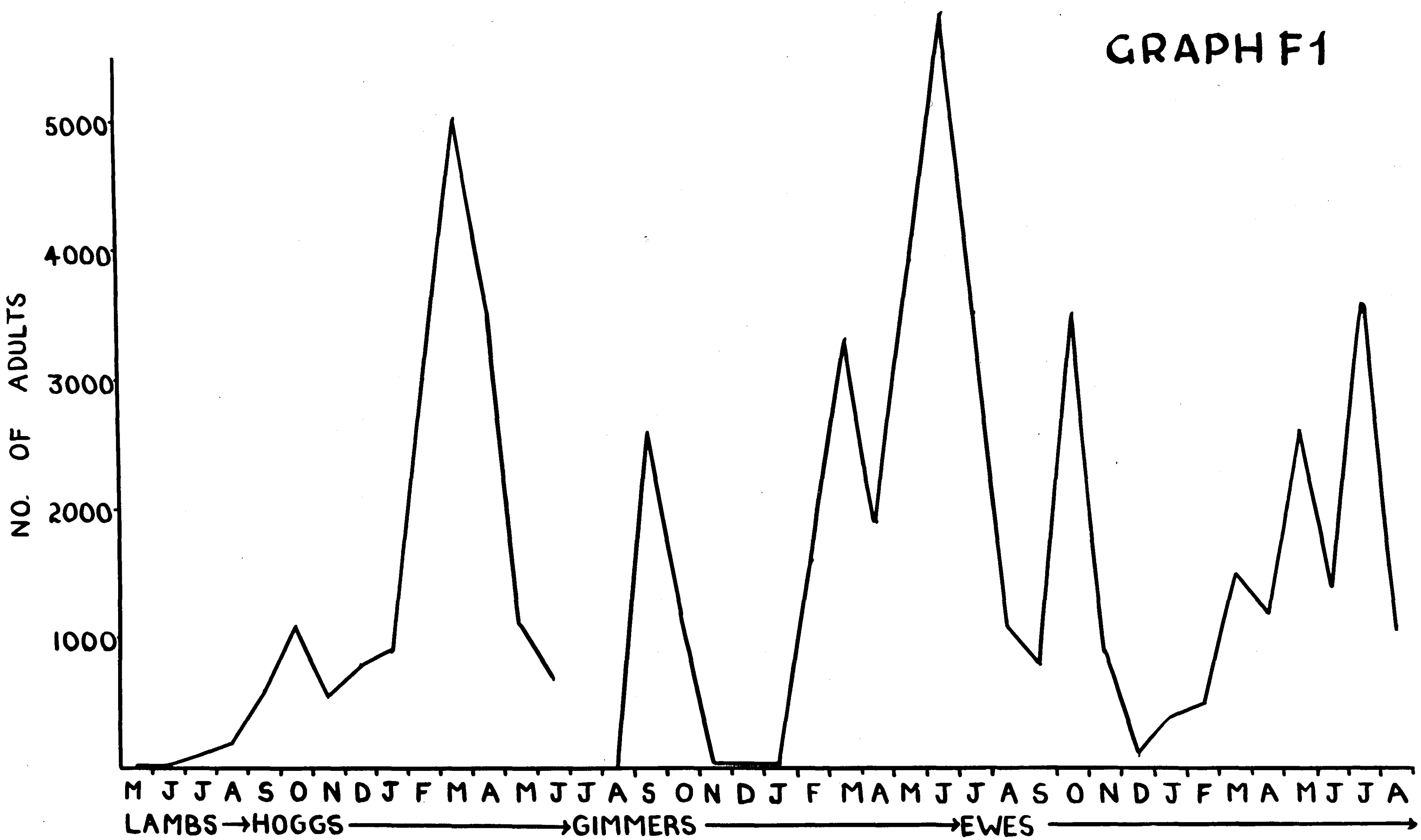
THE AVERAGE TRICHOSTRONGYLUS AXEI INFECTIONS IN SCOTTISH HILL SHEEP

GRAPH F



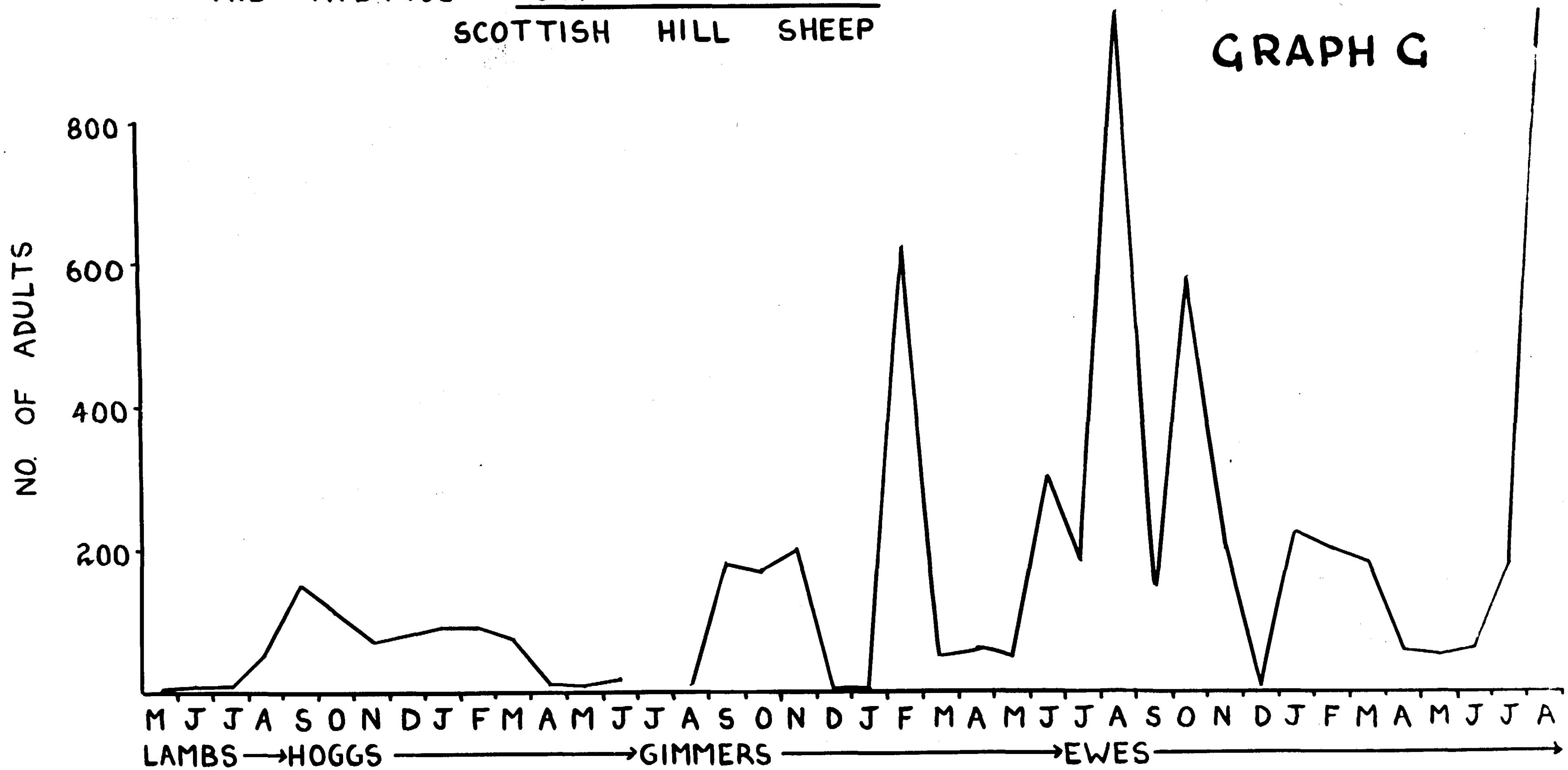
THE AVERAGE INFECTIONS OF _TRICHOSTRONGYLUS VITRINUS_ WITH _T. COLUBRIFORMIS_ IN SCOTTISH HILL SHEEP

GRAPH F1



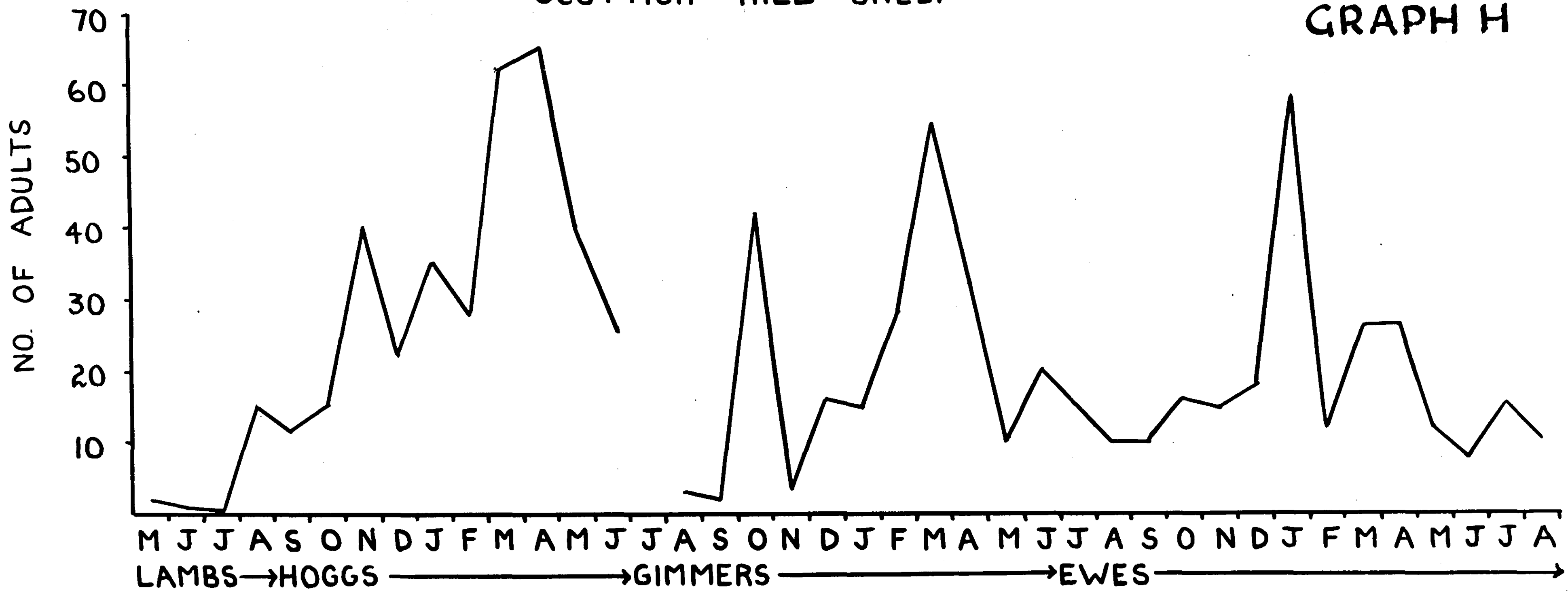
THE AVERAGE *COOPERIA CURTICEI* INFECTIONS IN SCOTTISH HILL SHEEP

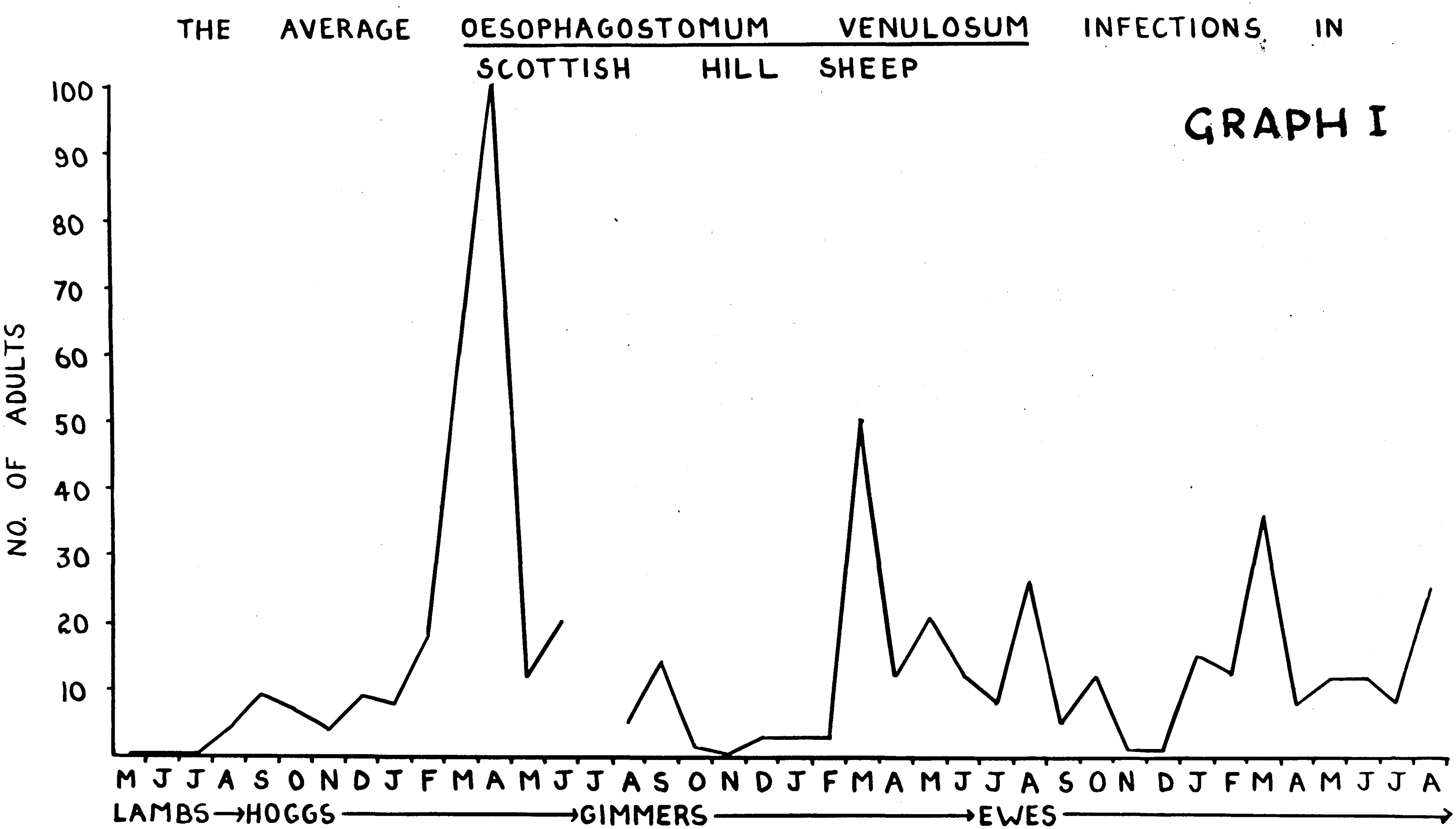
GRAPH G



THE AVERAGE *BUNOSTOMUM TRIGONOCEPHALUM* INFECTIONS IN SCOTTISH HILL SHEEP

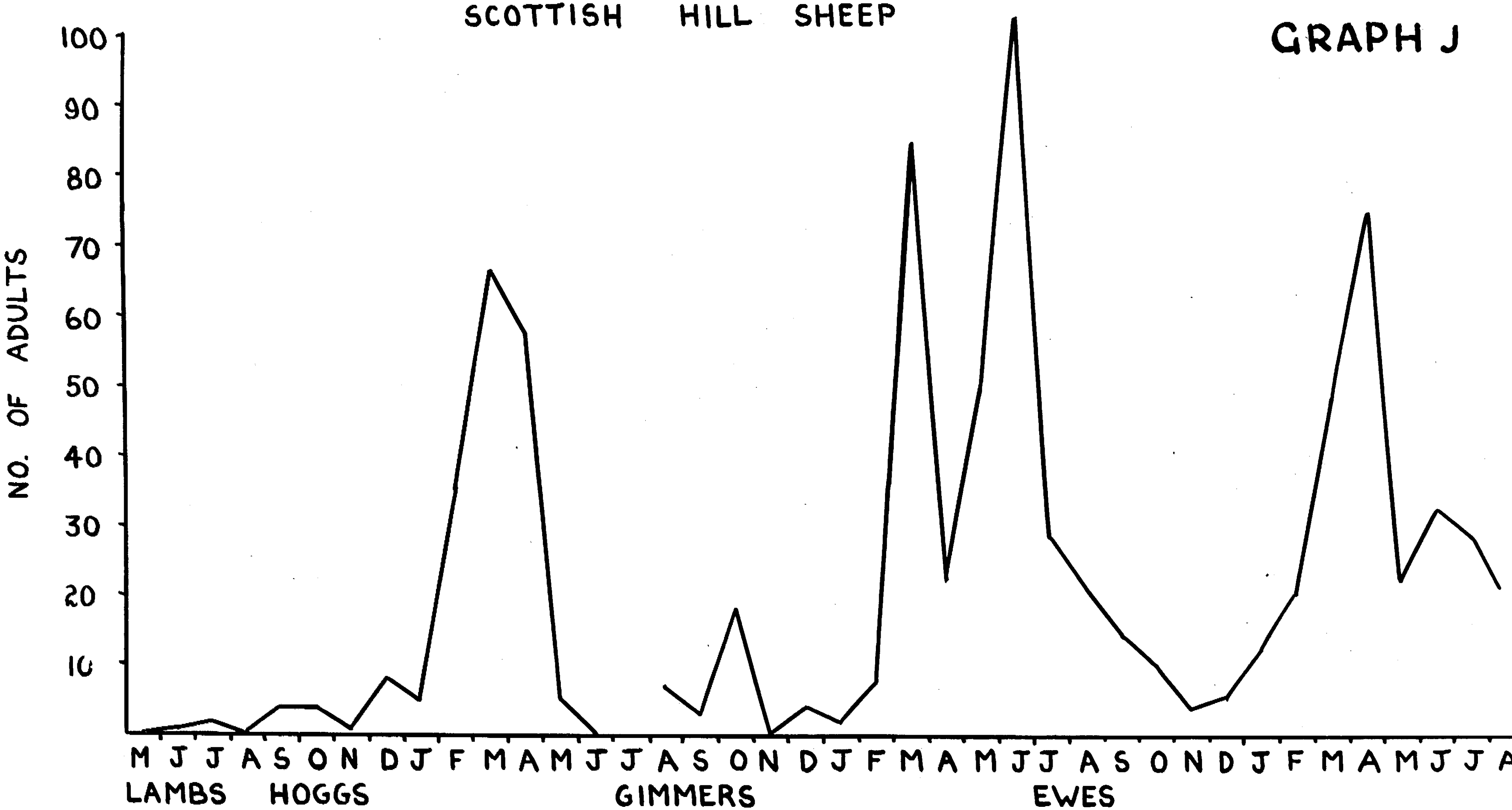
GRAPH H




THE AVERAGE OESOPHAGOSTOMUM VENULOSUM INFECTIONS IN
SCOTTISH HILL SHEEP
GRAPH I
NO. OF ADULTS
100
90
80
70
60
50
40
30
20
10
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
LAMBS→HOGGS→GIMMERS→EWES→

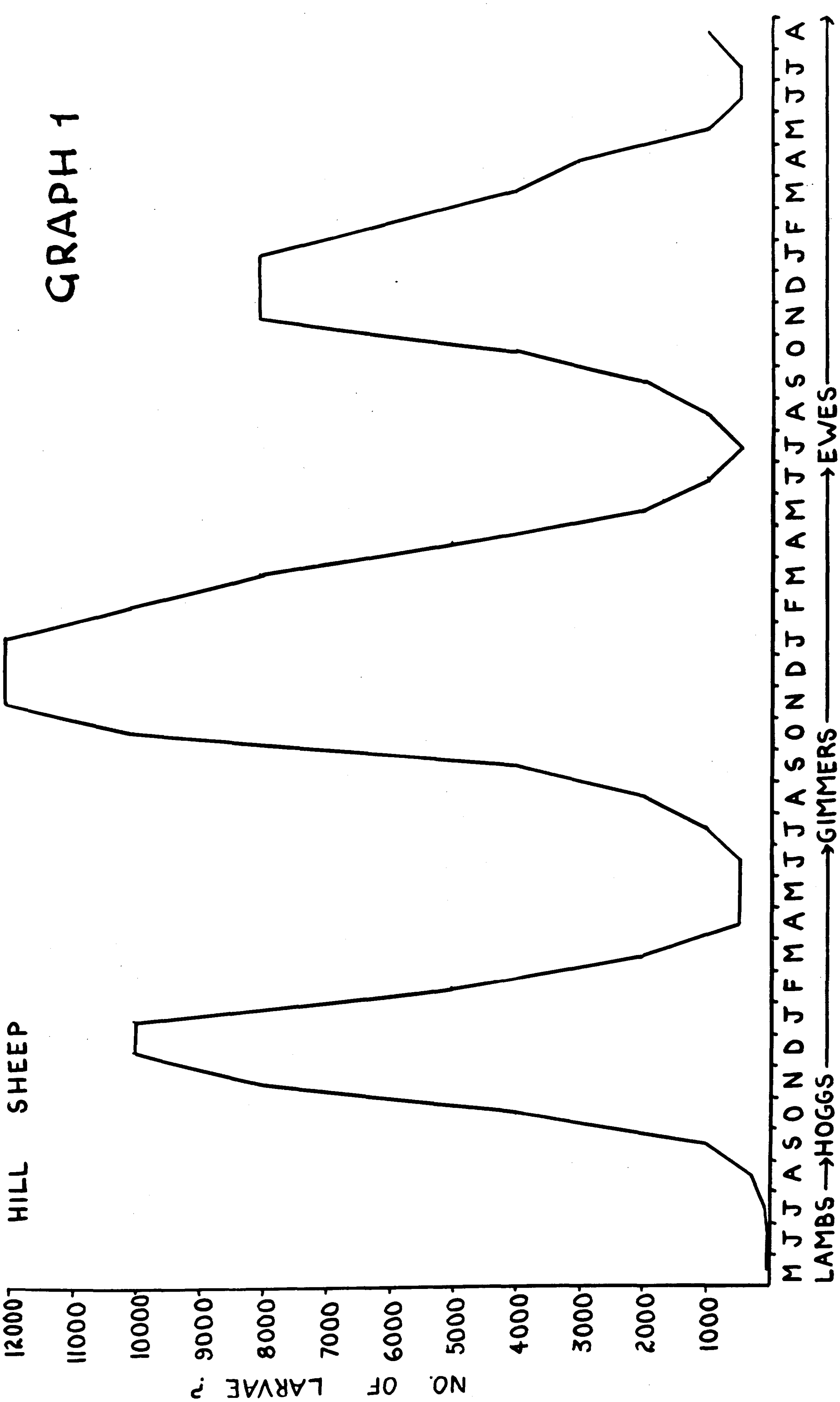
THE AVERAGE *CHABERTIA OVINA* INFECTIONS IN SCOTTISH HILL SHEEP

GRAPH J



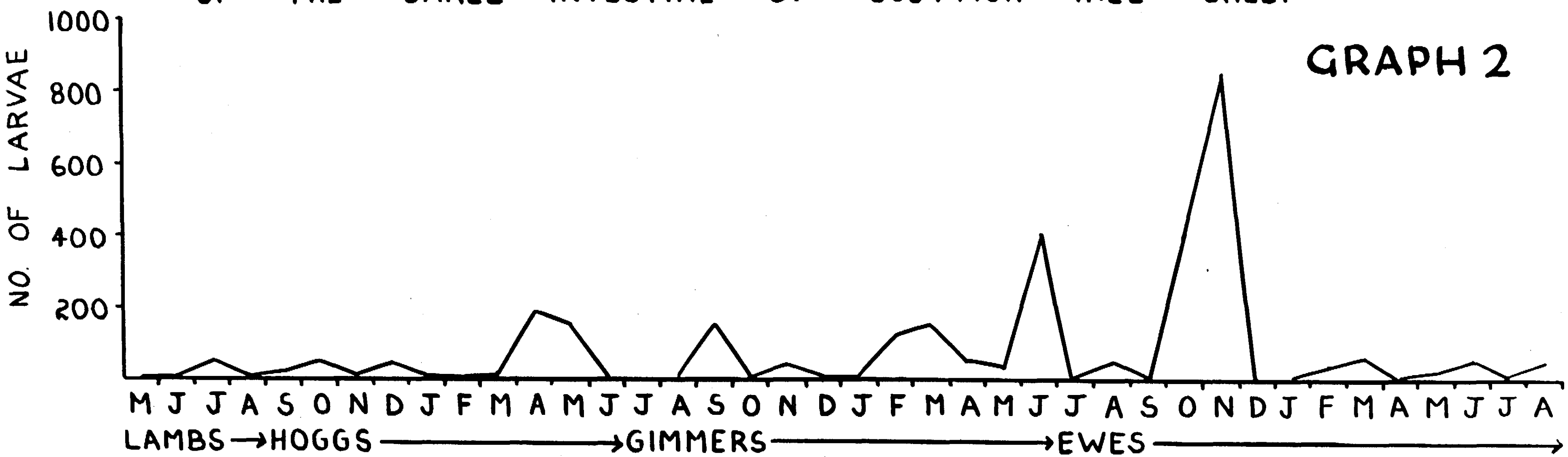
THE CONJECTURED AVERAGE NUMBERS OF LARVAL NEMATODES IN THE MUCOSA OF THE ALIMENTARY TRACT OF SCOTTISH HILL SHEEP

GRAPH 1

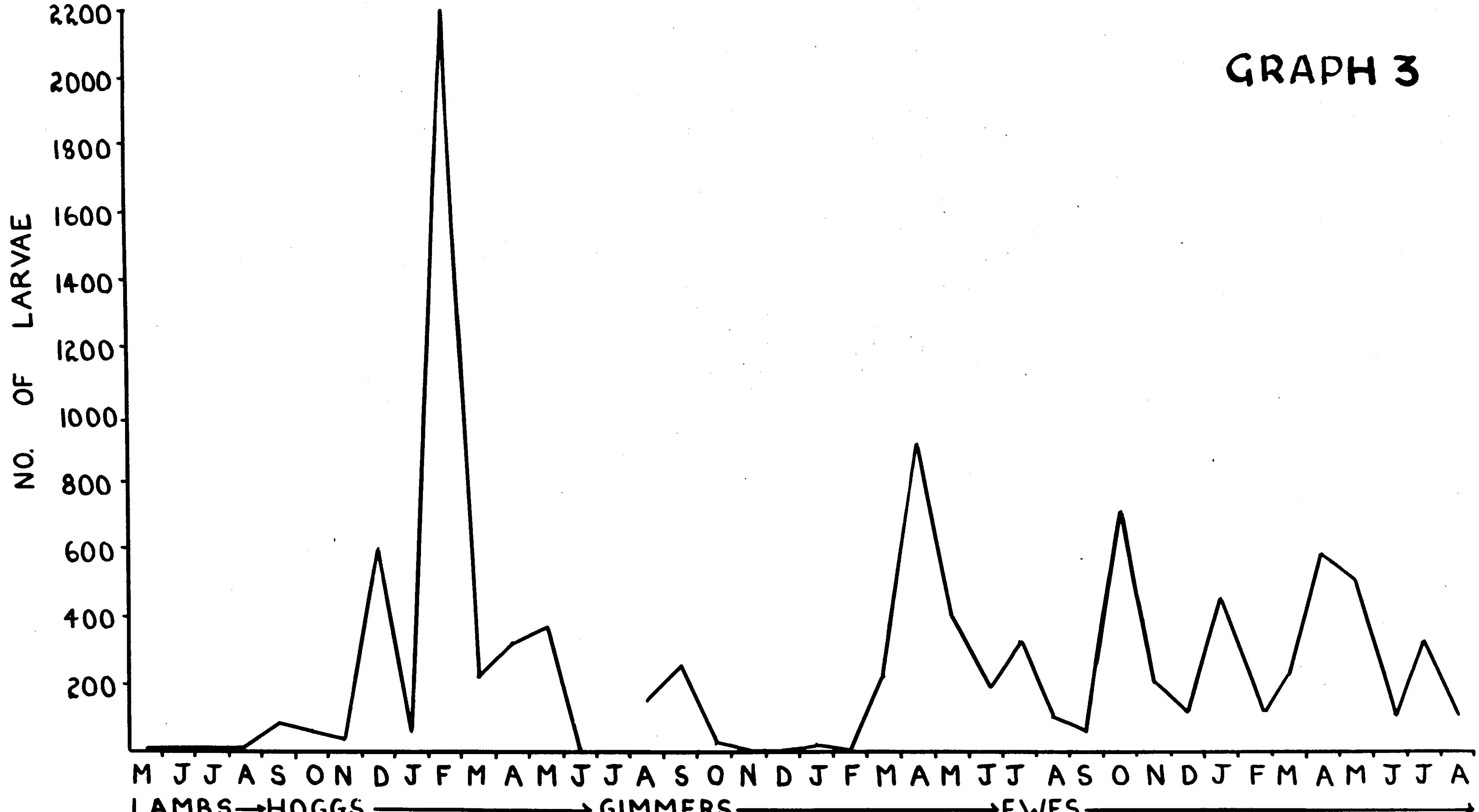


THE AVERAGE NUMBER OF LARVAL NEMATODES IN THE LUMEN OF THE SMALL INTESTINE OF SCOTTISH HILL SHEEP

GRAPH 2

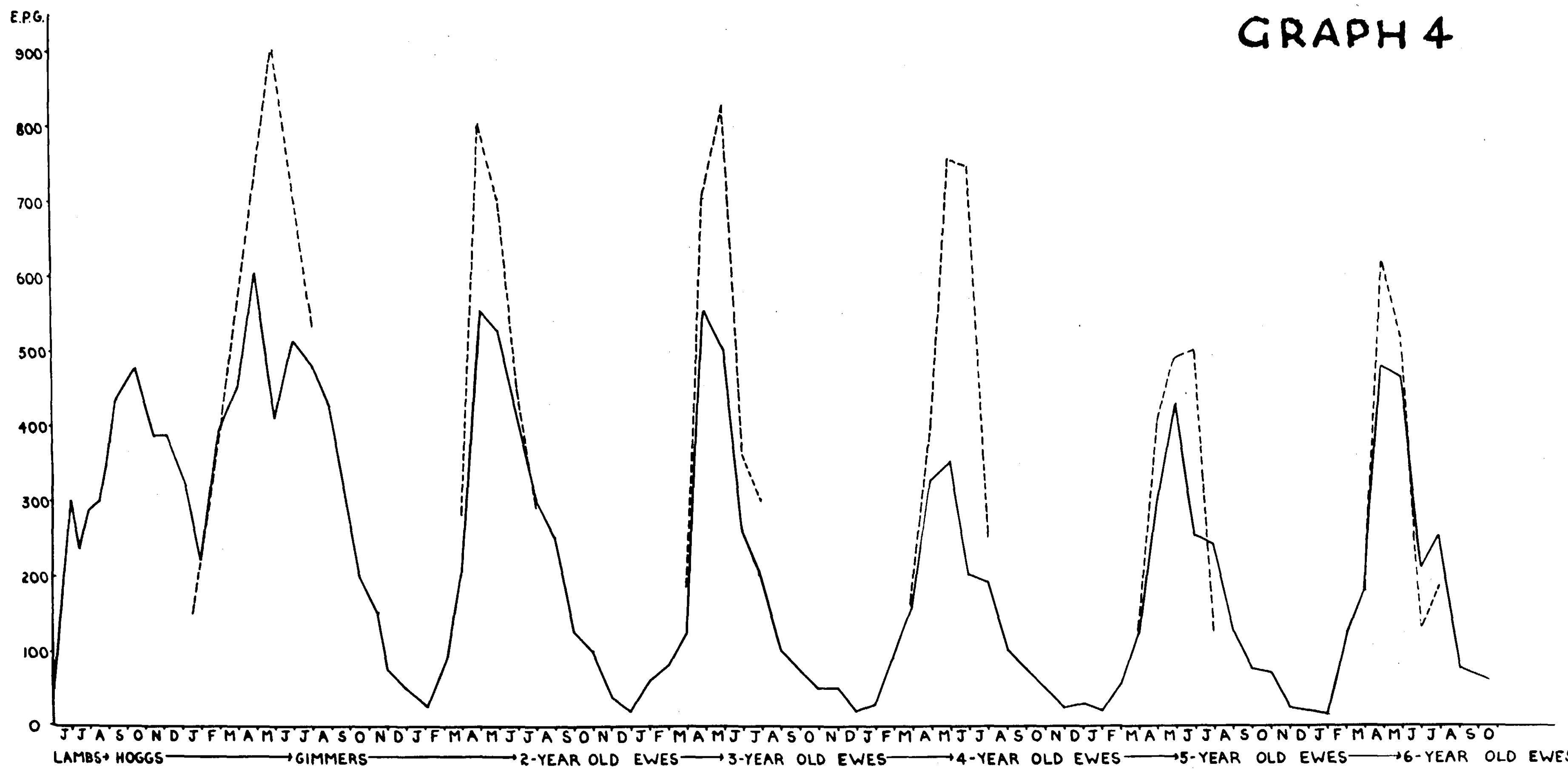


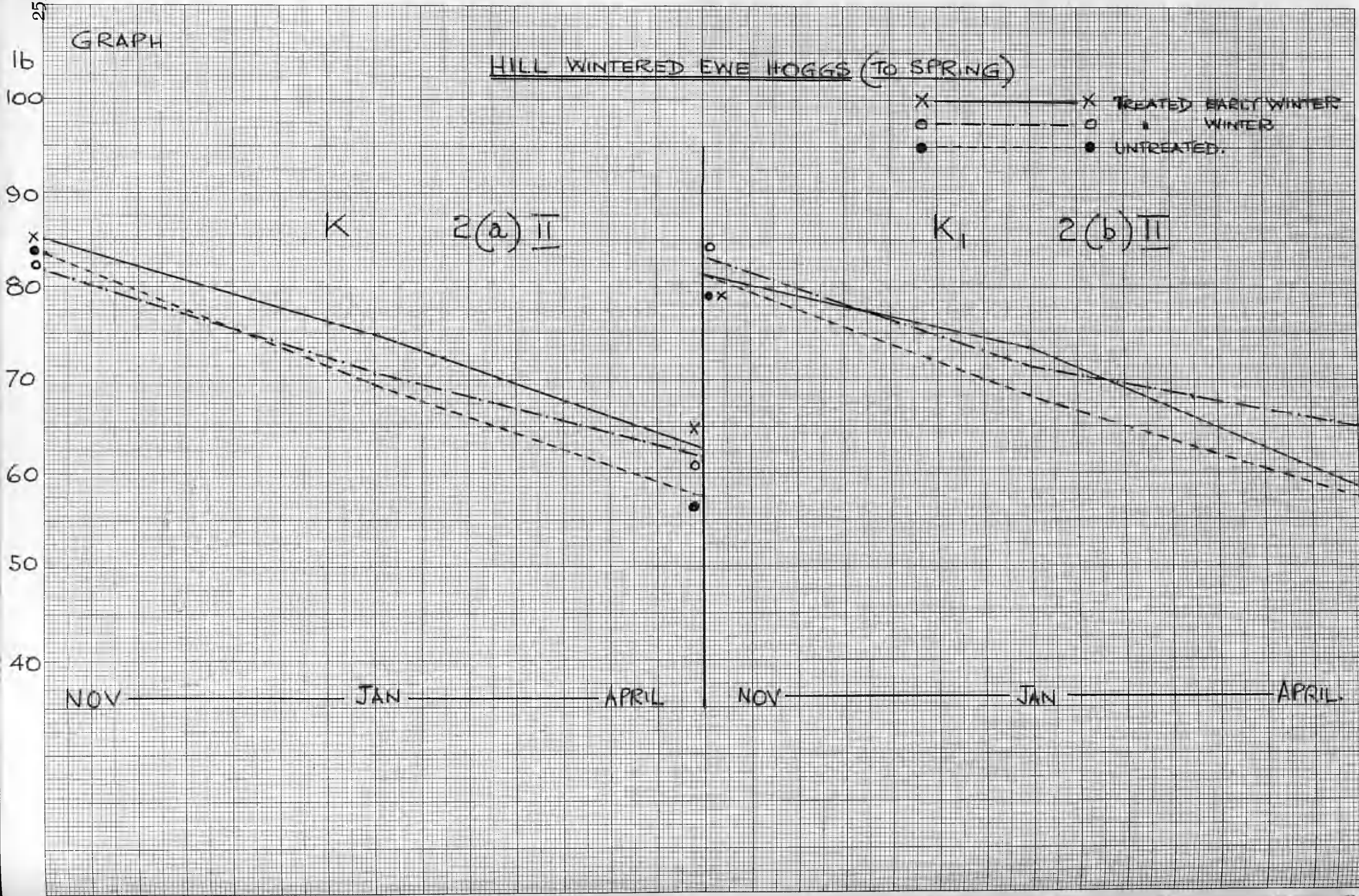
THE AVERAGE NUMBERS OF LARVAL NEMATODES IN THE LUMEN OF THE ABOMASUM OF SCOTTISH HILL SHEEP

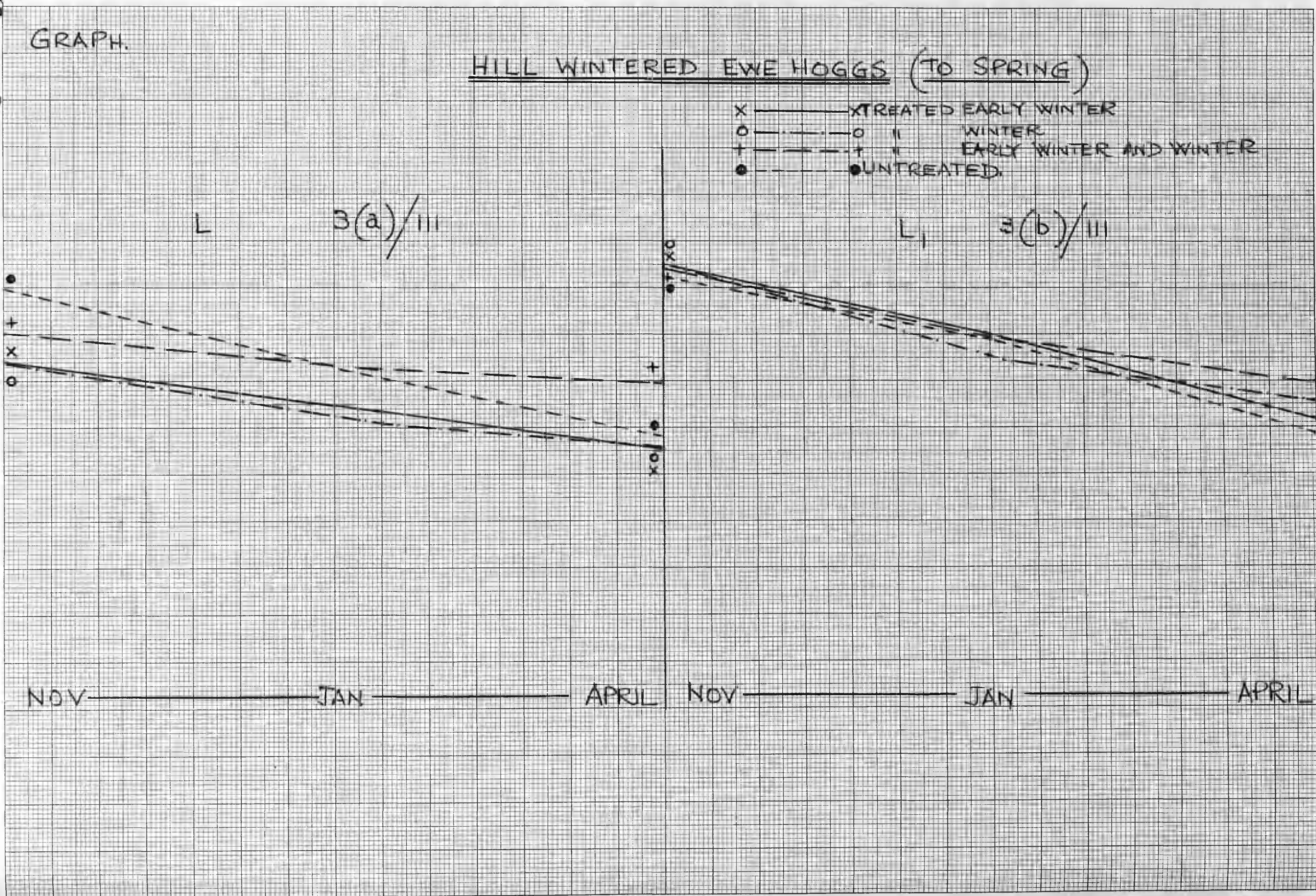


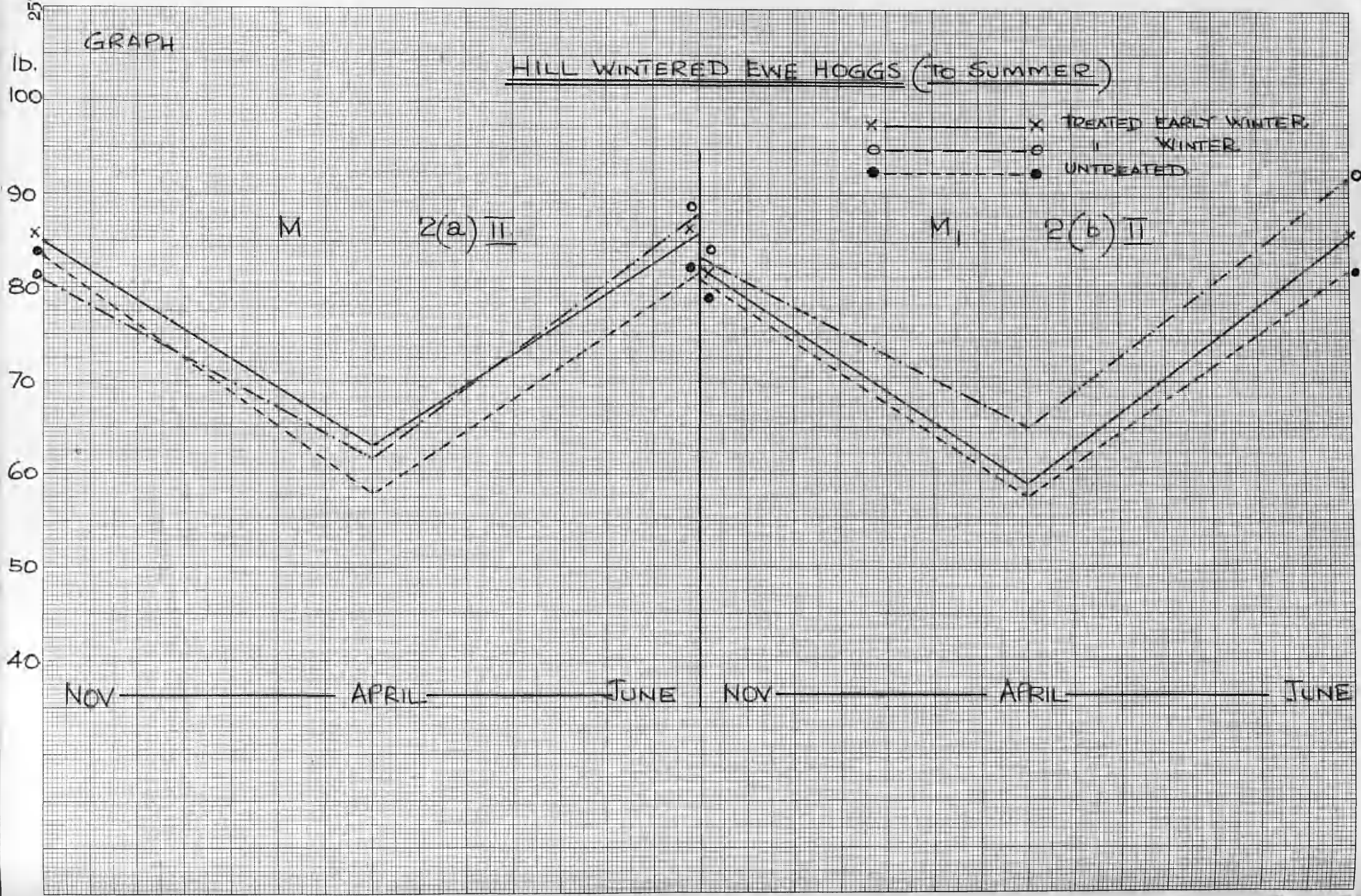
GRAPH 4

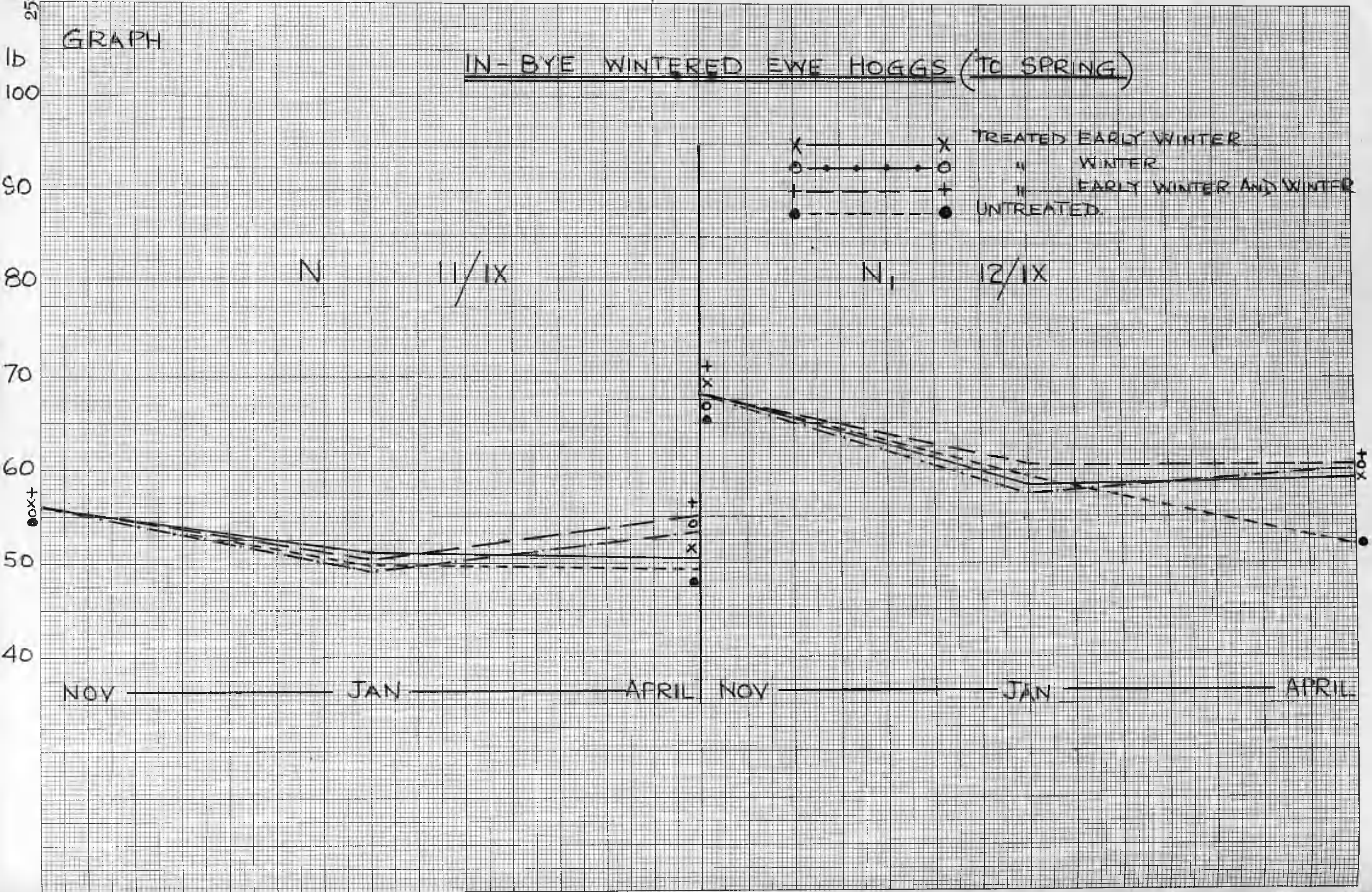
THE AVERAGE "OTHER STRONGYLE" EGG COUNT PER GRAM OF FAECES OF SCOTTISH HILL SHEEP (BLACKFACES AND SOUTH COUNTRY CHEVIOTS) THROUGHOUT THEIR LIVES.
[THE BROKEN LINE (----) SHOWS THE HIGHER AVERAGES ON TWO HEFTS AFTER TWO EXCEPTIONALLY SEVERE WINTERS (1947 + 1951), IN NORMAL YEARS THE COUNTS ON THESE HEFTS CONFORMED TO THE AVERAGE]

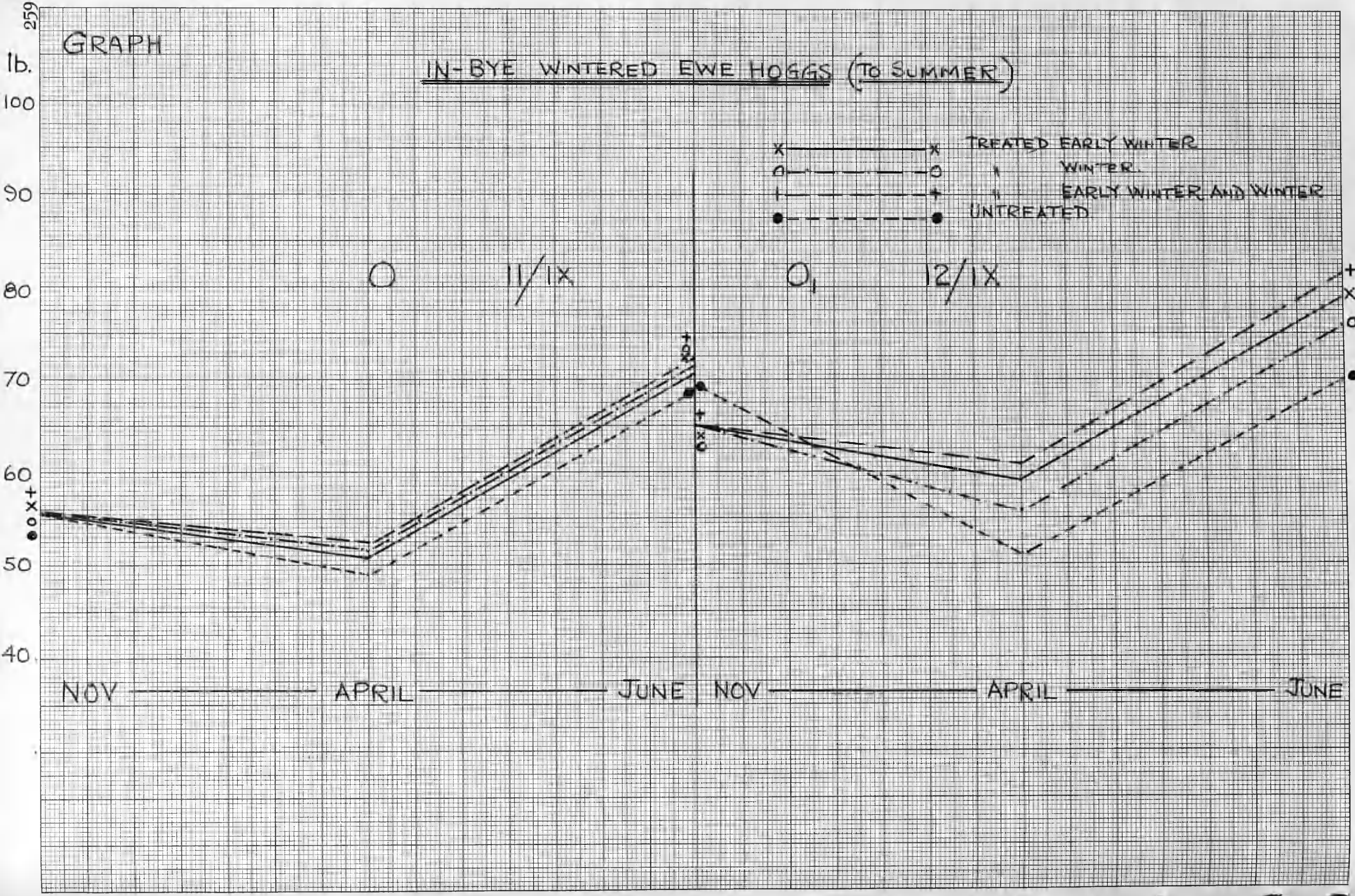


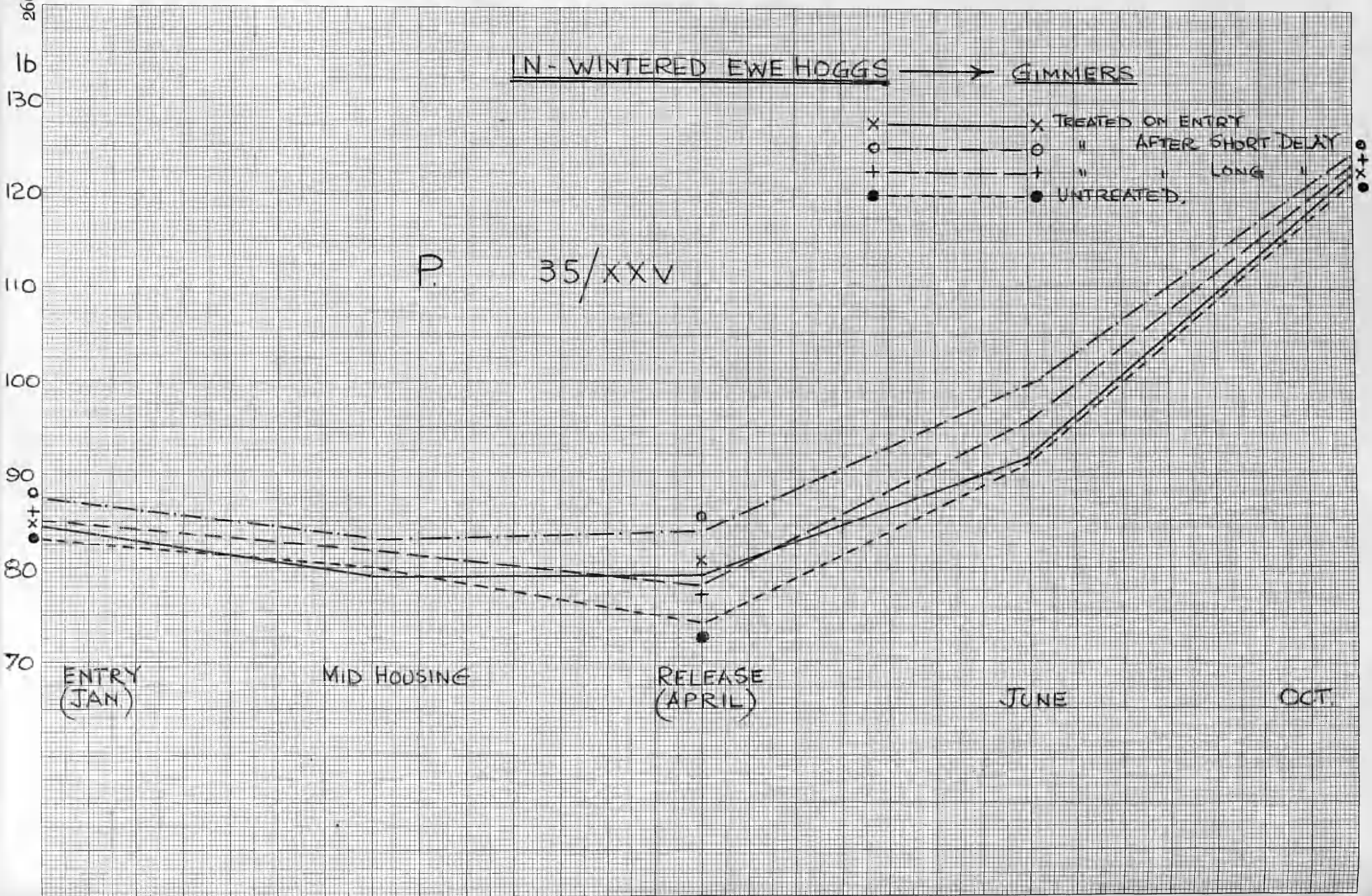

GRAPH
HILL WINTERED EWE HOGGS (TO SPRING)
lb
100
90
80
70
60
50
40
K
2(a) II
K1
2(b) II
TREATED EARLY WINTER
" WINTER
UNTREATED.
NOV
JAN
APRIL
NOV
JAN
APRIL.


GRAPH.
HILL WINTERED EWE HOGGS (TO SPRING)
x ——— x TREATED EARLY WINTER
o —·—·— o " WINTER
+ — — — + " EARLY WINTER AND WINTER
● - - - - ● UNTREATED.
lb
100
90
80
70
60
50
40
L
3(a)/III
L1
3(b)/III
NOV
JAN
APRIL
NOV
JAN
APRIL


GRAPH
HILL WINTERED EWE HOGGS (TO SUMMER)
lb.
100
90
80
70
60
50
40
TREATED EARLY WINTER
" WINTER
UNTREATED
M
2(a) II
M1
2(b) II
NOV
APRIL
JUNE
NOV
APRIL
JUNE

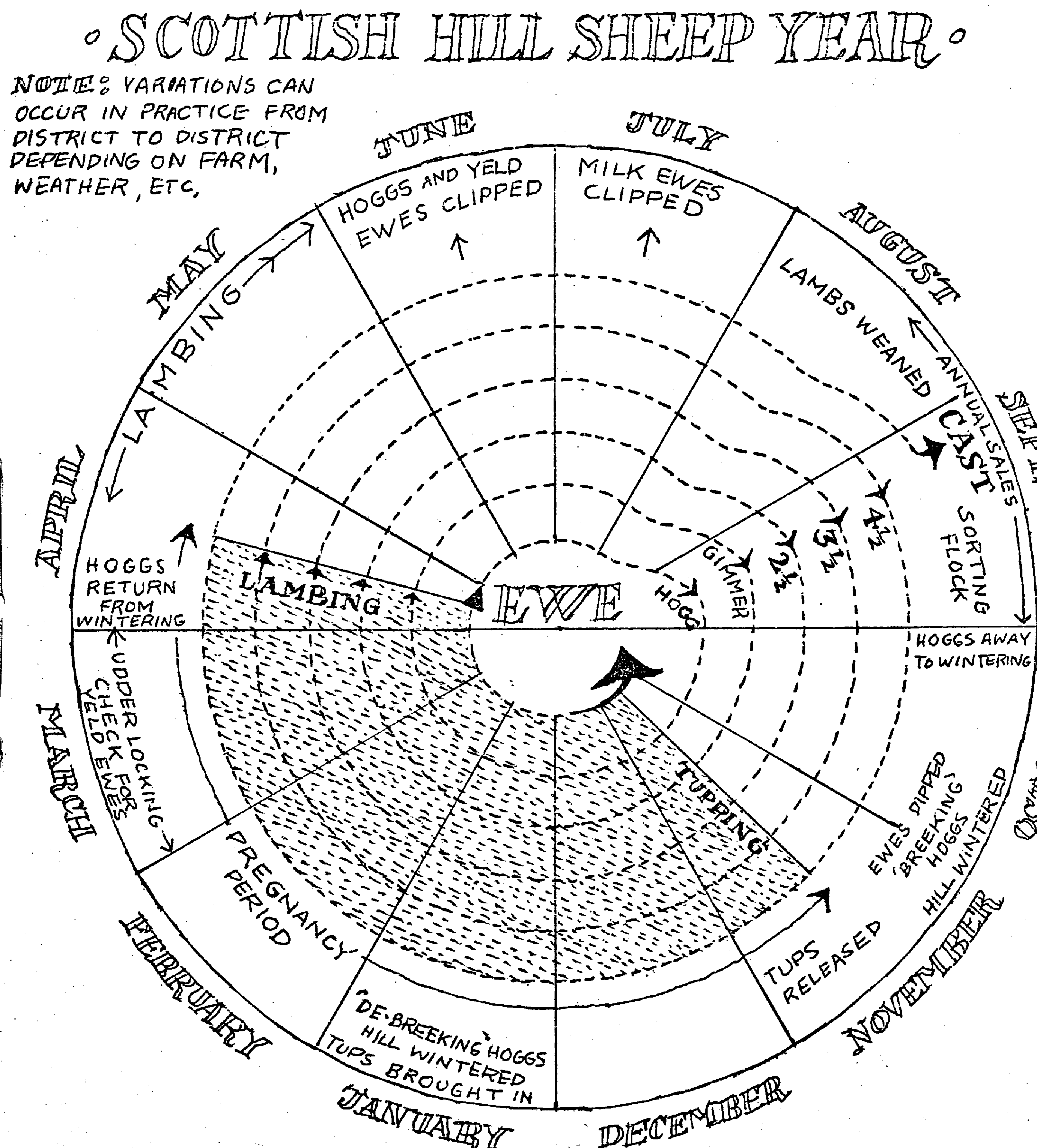

GRAPH
IN-BYE WINTERED EWE HOGGS (TO SPRING)
lb
100
90
80
70
60
50
40
TREATED EARLY WINTER
" WINTER
" EARLY WINTER AND WINTER
UNTREATED
N
11/IX
N1
12/IX
NOV
JAN
APRIL
NOV
JAN
APRIL


GRAPH
IN-BYE WINTERED EWE HOGGS (TO SUMMER)
lb.
100
90
80
70
60
50
40
TREATED EARLY WINTER
" WINTER
" EARLY WINTER AND WINTER
UNTREATED
O 11/IX
O1 12/IX
NOV
APRIL
JUNE
NOV
APRIL
JUNE



IN-WINTERED EWE HOGGS → GIMMERS
lb
130
120
110
100
90
80
70
TREATED ON ENTRY
" AFTER SHORT DELAY
" " LONG "
UNTREATED.
P. 35/XXV
ENTRY (JAN)
MID HOUSING
RELEASE (APRIL)
JUNE
OCT.

Figure I


SCOTTISH HILL SHEEP YEAR
NOTE: VARIATIONS CAN OCCUR IN PRACTICE FROM DISTRICT TO DISTRICT DEPENDING ON FARM, WEATHER, ETC.
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
HOGGS AND YELD EWES CLIPPED
MILK EWES CLIPPED
LAMBS WEANED
ANNUAL SALES
CAST
SORTING FLOCK
HOGGS AWAY TO WINTERING
EWES DIPPED 'BREEKING' HOGGS HILL WINTERED
TUPS RELEASED
TUPPING
'DE-BREEKING' HOGGS HILL WINTERED TUPS BROUGHT IN
PREGNANCY PERIOD
UDDER LOCKING CHECK FOR YELD EWES
HOGGS RETURN FROM WINTERING
LAMBING
LAMBING
EWE
HOGG
GIMMER
$2\frac{1}{2}$
$3\frac{1}{2}$
$4\frac{1}{2}$

E.R.

ACKNOWLEDGEMENTS

The author is deeply indebted to the Directors of the Pharmaceuticals Division of Imperial Chemical Industries and especially to Dr. Alfred Spinks, one-time Director of Research, for their permission to undertake this study and for their generous support.

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I am also indebted to other colleagues. To G. Froyd, F.R.C.V.S., for his generous interest; to S.H. Ellis, M.Sc., for his valuable advice on statistical analyses and to F. Rook for graphical work.

In addition to those mentioned, I also wish to express my sincere thanks to I.W. Parnell, B.A., Ph.D., F.R.S.E., late of the University of Edinburgh, for the benefit of his wide experience; to C. Rayski, Ph.D., M.R.C.V.S., of the University of Edinburgh for permitting me access to his reference files; to J.M.M. Cunningham, B.Sc., Ph.D., Director of the Scottish Hill Farming Research Organisation for use of the library facilities and to the librarians of the University of Stirling who were always most helpful.

Many others have been generous. In particular I am grateful to Professor E.J.L. Soulsby of the University of Pennsylvania, Philadelphia, U.S.A. for his constructive comments and references and to I. Cullens of Dollar, President of the Blackface Sheep Breeders Association, for his valuable comments on practical aspects.

By no means least, are the many flockmasters and shepherds - too numerous to mention individually - but nevertheless without whose co-operation, generosity and invaluable help on their farms, this study would not have been possible. I owe them all a very special debt of sincere gratitude.

Above all, a very large measure of profound gratitude is due to Norman M. Black, M.R.C.V.S., my close friend and colleague of many years standing, not only for his unfailing interest and understanding, but his sustained encouragement and wise guidance, enlarged by constructive criticism, both in the conduct of the field work and in the compilation of this thesis.

Finally, notwithstanding the debt owed to many, I must express my thanks to my wife and family for their interest and encouragement - and at times their fortitude - throughout the entire project.

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