MONKS WOOD EXPERIMENTAL STATION

SYMPOSIUM No. 2

April 6th—7th, 1965

Grazing Experiments and the Use of Grazing as a Conservation Tool

THE
NATURE
CONSERVANCY
(1966)

GRAZING EXPERIMENTS AND THE USE OF GRAZING AS A CONSERVATION TOOL

A Symposium held at Monks Wood Experimental Station
April 6th-7th 1965.

Organised by the Conservation Research Section.

Proceedings edited by
T.C.E. WELLS

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PROGRAMME AND SUMMARY

At the Annual Meeting of the Conservation Group in December, 1964, Mr. Skellam circulated a paper suggesting that a seminar might be convened to formulate and discuss such aspects of grazing experiments as "definition, design, measurement, recording, documentation, liaison, responsibility and finance". This suggestion was followed up by the Conservation Research Section who organised the Symposium at Monks Wood Experimental Station.

The objects of the Symposium were:

(i) To discuss the importance of grazing as a management technique on land of conservation interest.

(ii) To discuss problems of experimental design and layout, with special reference to the type of research results the Conservancy should be trying to obtain and how these results could be applied to conservation problems.

(iii) To bring together the scientific staff of the Conservancy who were interested in the use of the grazing animal as a management tool.

The meeting which was planned primarily for Conservancy staff was attended by 26 members from research stations, specialist branches and regional offices, and two representatives of Naturalists' Trusts. The programme was as follows:-

<u>Tuesday, April 6th</u>

Introduction by Dr. K. Mellanby.

Opening Address by Mr. J. Skellam.

Types of vegetation grazed in England and their representation on Nature Reserves. Mr. T.C.E. Wells.

Grazing in Scotland and Upland England. Dr. D. Ratcliffe.

Theoretical basis of a grazing policy. Dr. P.A. Gay.

Documentation, communication and semantics with special reference to field experiments. Mr. J. Skellam.

Theories and Models for Grazing. Mr. P.H. Cryer.

The Power of tests, and inferences from small scale experiments. Mr. P. Holgate.

The need for collaboration between experimenter and statistician. Mr. M.D. Mountford.

Wednesday, April 7th	Practical difficulties encountered by the Regional Staff in using sheep as a management tool. Mr. J. Hemsley and Mr. M.J. Woodman.
	Grazing rights and the Agricultural Holdings Act, 1948. Mr. D.H. Wood.
	Grazing experiments in Snowdonia. Mr. J. Dalé.
	Grazing studies at Moor House Field Station. Mr. M. Rawes.
	Thriplow Grazing Experiment. Mrs. G. Crompton.
	Grazing and Mowing Experiments on Chalk Grassland. Mr. T.C.E. Wells.
	Research in progress on the Reserves on the chalk in South-East Region. Dr. P.A. Gay.
	Summing-up and General Discussion.

The meeting began its work by posing certain fundamental questions concerned with the need and desirability of using grazing on Nature Reserves. Was there justification on conservation grounds for maintaining large areas of unstable grassland where a grazing regime seemed necessary for management? If so, was it necessary to carry out experiments in order to find the most satisfactory method of grazing to maintain the conservation interest? How important was the grazing as a conservation tool and could other methods not involving the use of animals be substituted? On how many N.N.Rs had grazing been the form of land use which in the past had maintained or created richness in flora and fauna?

The discussions which followed the papers presented at the Symposium centred around the questions posed above and the following is an attempt to summarise the many, often conflicting, views expressed during these discussions. Two quite different aspects of the grazing problem became apparent when grazing activities on Reserves in different geographical regions were considered. In Wales, Scotland and Upland England, overgrazing by sheep has been responsible for changes in the vegetation which many ecologists consider to be deleterious. Heavy grazing prevents the regeneration of trees and shrubs, while species which are sensitive to grazing such as Heather (Calluna vulgaris), Cowberry (Vaccinium vitis-idaea) and other rarer shrubs, as well as many rare dicotyledon herbs such as Dryas octopetala are eradicated. These communities are converted to grassland. Loss of productivity, especially on the poorer soils is associated with a policy of continued heavy grazing with the result that soil erosion and scree formation is commonplace in Highland regions. The position on N.N.Rs in lowland England is quite the reverse; the absence of grazing leading to invasion of scrub and increase in competition from coarse grasses, with the end-result a loss of floristic richness. A survey of N.N.Rs and L.N.Rs in England showed that of the 62 declared Reserves, 33 contained some vegetation formation which had been grazed in the past or was being grazed at the present time. It was estimated that 21,000 acres of land on N.N.Rs in England were suitable for grazing, 16,500 acres occurring on 2 upland Reserves which were grazed by commoners, the remainder being divided unequally between 6 lowland vegetation types of which chalk grassland was the most important. (See Appendix). Maritime dune systems and lowland heaths on N.N.Rs in England contain 2,255 acres of vegetation which would probably benefit from grazing, but it was considered that the problem was not so urgent there as on chalk and limestone grasslands.

In lowland England, attempts have been made to graze Reserves with livestock owned by local farmers, the farmer usually being granted licence, but in most cases, this arrangement has been unsatisfactory even with goodwill on both sides, and it is suggested that in order to be able to control the time of year and intensity of grazing, ownership of livestock by the Conservancy for the purposes of conservation management should be given serious consideration. Many Reserves are too small to warrant a permanent flock of sheep on the Reserve and it was suggested that consideration be given to the use of a "mobile" flock of sheep for management purposes in different areas.

Experimental work using the grazing animal is concentrated on three main vegetation types:- mountain grasslands of Wales, moorlands of Upland England and Scotland, and chalk grasslands of southern England. In most of these investigations, sheep have been used as the grazing herbivore and with the exception of the Aston Rowant experiment, the animals have not been under the direct control of the experimenters. This arrangement has been adopted for many productivity studies and for investigations involving the relationships between soils, climate, vegetation and voluntary sheep densities on open hill grazings. However, in the case of detailed studies on the relationship between grazing intensities and the behaviour of species of plants and animals of conservation interest, this arrangement is not satisfactory. It is suggested that careful consideration must now be given to the purchase of animals specifically for experimental use. Allied to the problem is the desirability or otherwise of using N.N.Rs for experimental purposes. Many N.N.Rs, especially in southern England are unsuitable as experimental areas for reasons of size, excessive use by the public and difficulties associated with the control of the experiment in an area with many conflicting uses. It was suggested that the Conservancy should consider obtaining control over experimental areas outside Reserves with facilities for housing and feeding experimental animals.

Concern was expressed during the Symposium by the Biometrics Section at the lack of adequate documentation, recording and continuity in large long-term experiments involving many people, and it was suggested that before an experiment was begun, a proforma should be completed giving a full account of the objects, methods, location, documentation of the experiment with a clear statement of the responsibilities shared by the persons involved. It was pointed out that the distinction between proper experiments involving the use of randomisation, replication and providing estimates of error, and management of Reserves using animals in which observations were made on the effects of grazing, had become blurred, and it would be preferable to use the term 'experiment' only in the accepted statistical sense and refer to other work as trials. The zoologists referred to the relationship between the structure and floristic composition of the vegetation and the associated fauna. The elimination of certain plants by the grazing animal can cause profound changes in the fauna both vertebrate and invertebrate, and the need for more information on this particular conservation problem was emphasised.

Experimental work being done by Conservancy staff using the grazing animal falls under three main categories. (1) productivity studies; (2) exclosures, in which competition between species is being studied; (3) effects of various treatments, especially cutting as a substitute for grazing, on the floristic composition of the grassland. Although many different approaches are being used to investigate the complex relationship between the sward, the soil, climate and the grazing animal, there was general agreement that in all of these different approaches a knowledge of the biology of individual species was of great importance and attention should be given to this often neglected aspect of the work.

LIST OF PARTICIPANTS

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THOMPSON, Mr. J.A., The Nature Conservancy, Midland Region, Shrewsbury.

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WELLS, Mr. T.C.E., The Conservation Research Section, Monks Wood Experimental Station.

WOOD, Mr. D.H., Deputy Land Agent, H.Q., London.

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- OPENING ADDRESS -

J. G. Skellam

The members gathered here at this Symposium do not all belong to the Conservation Branch and some may possibly wonder how it is that this meeting has come about. It is true that I cannot claim any personal credit for the Symposium but must nevertheless accept some responsibility for having precipitated it at this time.

I will begin therefore by reading my note of November 1964 which was circulated to the Conservation Group for the Annual Meeting in December 1964. The note reads:-

"It is generally recognised that the nature and composition of vegetation (and by implication the associated fauna) may be profoundly affected by grazing. Indeed one of the major problems confronting officers concerned with the conservation and management of many areas consists in making wise decisions on the kind of grazing regime to impose.

In order to reach a decision about a particular site, the conservation scientist is guided by a considerable body of knowledge which already exists on the subject but which has normally been acquired from studies on other areas. He is also guided by such ecological surveys as have been made on the site and in the light of such tentative inferences as he may have been able to reach by ordinary observational examination. But quite understandably he is cautious in extrapolating results from one place to another or in applying any measures, the lasting effects of which he cannot with reasonable certainty foresee.

It is not surprising therefore that conservation scientists are beginning to adopt an experimental approach. Very often this amounts to little more than the extension of observation resulting from deliberate interference, and as such is a valuable adjunct to passive observation. But it would be misleading to think that all such activities constitute proper experimentation in the sense normally employed in research. The conclusions from simple trials rarely stand up to scientific criticism and the results of many such investigations are often a poor return for the amount of scientific effort employed.

During the first decade of the Conservancy it was not normally possible for us to keep experimental herds of domesticated animals, but it now appears that this limitation will not be so severe in future. We can certainly expect an increase in the number of grazing trials for which we shall be responsible.

The Biometrics Section is only aware of those grazing studies which are brought to its notice when advice is sought. We would welcome the opportunity to learn something about the present scale of grazing trials and the intentions which regional officers may have to extend them in the near future. It might be pointed out here that such liaison machinery as we have at present to keep regional staff, the Conservation Research Section and the Biometrics Section mutually informed is already defective and inadequate to meet future developments.

The Conservation Group is asked to consider convening a seminar so that those primarily concerned can attempt to formulate common lines of policy in the general interest to cover such aspects as definition, design, measurements, recording, documentation, liaison, responsibility, finance."

Even before the Group actually met, I received a most encouraging response from Dr. Duffey who suggested that the general approach should be broadened somewhat. He offered to seek Dr. Mellanby's approval to hold the meeting at Monks Wood and to ask Mr. Wells to undertake the local organisation. These ideas were readily endorsed by the Conservation Group and after much consultative activity and tricky diplomacy by Mr. Wells, the programme which we now have before us was drawn up.

One of the great pleasures about giving an opening address is that the speaker is usually permitted to infiltrate into his talk, occasional elements of his own personal philosophy, matters which normally might not be tolerated in a formal scientific contribution. I will therefore take advantage of this opportunity straight away.

It is my personal belief and many others share it too, that any human activity, be it scientific research, conservation work or everyday life, is shapeless, incoherent and without meaning unless it is firmly rooted in a comprehensive philosophy and is guided by a clearly defined policy. Quite understandably, I do not expect any philosophy or policy to be rigid and final, but merely require that it should be in keeping with current experience and prevailing realities.

Perhaps by the end of the Symposium, after a free and frank exchange of viewpoints, we shall be in a better position to develop a collected approach to the complex of ideas engendered by putting such terms as "Conservation", "Experimentation", "The Grazing Tool", in juxtaposition and we may be able to translate the principles which emerge into a workable policy which will not only guide our actions in the immediate future, but will, I hope, also commend itself to those who will judge us in the years to come for our wisdom or our stupidity.

One way of clarifying our ideas of evoking new thoughts and perhaps provoking discussion is to ask questions. This device, as is well known, dates back to classical antiquity and was developed with such great skill and genius by Socrates, Plato and others that the modern game of 20 questions appears moronic by comparison.

It is best of course to ask the right questions in the right order.

The particular questions I am going to put to you today are not as highly refined as they would have to be in a strict scientific investigation, but I note from the programme that I am favoured by being given a further opportunity this afternoon to make up for any lack of rigour that I may display this morning. Whether or not my questions are relevant is a matter of opinion, but I believe them to be so. My list is certainly not comprehensive, and I trust that any serious omission at this stage will soon be put right.

Despite our apparently hierarchical constitution in which policy is presumed to emerge by inspiration at the top and henceforth to diffuse downwards, in reality the democratic aspects of the machinery can be equally effective in determining the policy which is actually practised and even in creating new policy, provided that we are prepared to use the machinery properly and that our ideas are sufficiently well thought out to merit being put up.

It will already have been observed that the official title of the Symposium embraces two distinct subjects which are presumed to be related. They are:-

1. Grazing Experiments;

2. Grazing as a Conservation Tool.

The first set of questions I have to ask about these subjects concerns their importance.

We could ask:-

Q.1a. Are these subjects of sufficient importance to the Conservancy or any of its branches to merit special attention?

Please believe me when I say that I am not trying to be facetious. The question is meant seriously because so many things hinge on the answer.

It will be noticed that the real significance and full implications of the question however is not entirely apparent because of the unsatisfactory way it is framed. It would be better to ask:-

Q.1b. How important are these subjects relatively to other matters with which the Conservancy is concerned?

The last question can be refined much further. For example, we may ask:-

Q.1c. How important is it that our knowledge of the grazing tool should be adequate (i) as soon as possible; (ii) in the more distant future?

Q.1d. Is it envisaged that the research problems connected with the use and assessment of the efficacy of the grazing tool are (i) of transient importance - to be solved in major respects once and for all as far as practical purposes are concerned, or (ii) of enduring importance - involving a long-term or permanent interest or even an indefinite commitment?

Some of these questions may appear premature and difficult to answer. But I must emphasise that unless we have a very sober appraisal of the relative importance of grazing studies we shall be unable to deploy our limited resources wisely.

The consideration of resources in money and man-power prompts numerous further questions about desirability and feasibility.

Q.2a. Is there much justification on conservation grounds for maintaining large areas of unstable vegetation in a highly artificial condition?

Q.2b. Is there an upper limit to the area of grassland of the kind which requires grazing to maintain it in the desired state, without overstretching the economy of the Conservancy unduly?

Q.2c. If so, has the limit yet been approached, reached or surpassed by the acquisitions made so far?

The answers to these questions about importance in relation to other projects and the resources available together with the answers to the many supplementary questions on feasibility which automatically spring to mind, largely determine our whole attitude to the subject matter of this Symposium, and may prompt us to give thought to the measures and positive steps which appear desirable not only for keeping this complex field under constant review, but also for dealing with the practical problems existing on the ground.

My third set of questions concern the relationship between the two main subjects included in the title of the Symposium.

Q.3a. Is it necessary to carry out experiments in order to employ grazing satisfactorily as a conservation tool?

I rather suspect that the answer is "sometimes". It may be that in certain circumstances, we already have all the knowledge that we need in practice, or that enough knowledge is available if only we could get hold of it or if we were to make the effort to do so. I hope that subsequent speakers will have something to say on this point.

It may be that in certain circumstances, we may consider that our knowledge of the grazing tool appears to be more or less adequate for practical purposes, but consider it desirable that management operations should be carried out experimentally so as to provide a monitoring system to measure success, to note special effects and guard against serious mistakes.

These considerations may be condensed in:-

Q.3b. Do we advocate, as a general guide, that the grazing tool be used in an experimental manner where feasible, or failing this, to set up experimental plots within or alongside, the treated area?

It will be noted that whereas Q.2a. contains the word "necessary", Q.2b. uses the word "desirable". In fundamental science, we do often have to ask whether condition A is necessary for phenomenon B but those who try to criticize other people's actions or delight in stifling activity by asking "Is it really necessary?" rarely have the right to do so. What matters to the practical man is whether an action is desirable and whether it is sufficient to achieve the purpose which he has set. I hope in this connection that Conservation and Management Research as they develop in the Conservancy will avoid becoming bogged down in the bottomless search for necessary truths and will concentrate on discovering ways and means which are sufficient to achieve desirable results.

My fourth set of questions refer to co-operation.

Q.4a. Do grazing investigations normally require the co-operation of several people with specialist knowledge or special responsibilities?

If we exclude simple trials with very limited objectives or straightforward operations without experimental content, it seems to me almost apparent that many specialists are required - field and estate workers such as shepherds to ensure that the grazing treatment is applied as prescribed, biologists to measure and record such features as floristic composition, biometricians to advise on the statistical aspects of the experimental design and the analysis of the data. Field operations usually cost money for such things as fencing and student labour, so that the land agent and the administration (finance and estabs.) might be involved. Co-operative effort always requires co-ordination and this is usually considered to be one of the functions of the regional staff. Last but not least is the Conservation Research Section which has a special responsibility for this field of work.

We now come to:-

Q.4b. Where co-operation is called for, are the specialist staff who are available both willing and able to work together to the extent which is necessary to achieve success?

After all, the degree to which any officer is prepared to co-operate in a collective project depends on the priority which is attached to that project, and the extent to which he is able to co-operate depends on his existing burden of commitments.

The problems raised by these considerations are great indeed. It seems that we shall be obliged to be highly selective in the choice of desirable projects, and there is a serious danger that much time and effort could be wasted on grandiose plans which might not materialise or on projects which might have to be abandoned before completion.

My last set of questions refer to communication.

Q.5a. Even if the staff are willing to co-operate and are not prevented by other commitments from doing so, are they nevertheless unable to co-operate effectively because of their inability to communicate their ideas clearly to one another?

Q.5b. Even if specialists are able to communicate effectively, will they in fact always do so and are they prepared to document their thoughts so unambiguously that satisfactory communication will be maintained over the whole duration of each project?

I have singled out some of the problems of communication for my talk this afternoon, and therefore bring this opening address to a hasty and rather abrupt close.

J.G. Skellam.

TYPES OF VEGETATION GRAZED IN ENGLAND AND THEIR REPRESENTATION ON NATIONAL NATURE RESERVES.

T.C.E. Wells

Introduction

When nature conservation first began in this country, preservation was foremost in the minds of those concerned, and although some thought was given to the need for managing areas of land acquired as Reserves, priority was given to acquisition. As the concept of conservation evolved, it soon became apparent that any change away from the old form of land use brought about rapid changes in the habitat which were usually detrimental to the biological interest of the Reserve, and it was realised that some form of management would be required to maintain, and in some cases, to re-create, the conservation interest.

The grazing animal, whether cattle, sheep, horses, goats or rabbits has had a major effect on most types of vegetation in the British Isles in the past, and all of our lowland grassland and much of our hill pastures owe their existence to the grazing animal. It is not surprising then, that the idea of using sheep or cattle on Reserves as a form of management was considered by the Conservancy in its early years, although the urgency for some form of positive management on lowland Reserves only became apparent when myxomatosis in 1954 destroyed most of the rabbits on Reserves, and significant changes in the vegetation were noticeable after only two years. However, for various reasons, some practical and some administrative, sheep and cattle have seldom been used for managing Reserves in England, although interest in this subject has been revived in the past three years, chiefly in connection with work being done on chalk grassland.

Most of the research in which Conservancy staff have used grazing animals has been done on upland areas in Wales, Scotland and northern England, and little work has been done on lowland grasslands in England. More information is needed about the effects of various management techniques on natural vegetation, and although a start has been made with Aston Rowant grazing experiment, more experiments are required if we are to be successful in maintaining the diversity of habitats which we believe to be desirable on Nature Reserves.

However, before we can decide on the kind of information that is needed from experiments, we require certain basic information relating to the areas of land on Reserves covered by different plant associations, and the purpose of this paper is to outline the distribution and extent of those plant associations which are dependent for their existence on some form of grazing and which change both in structure and species composition when the grazing animal is removed.

Classification

Vegetation may be classified in many different ways, but for the purposes of this review, a simple classification based on easily recognisable ecological units has been used. Some of these units, such as chalk and limestone grassland may be similar in structure and contain many species common to both, although some species are restricted to one or the other. On the other hand, the vegetation may be dissimilar in both structure and floristic composition: nevertheless the common factor uniting these units is found throughout - that is their dependence on grazing for their continued existence.

7 vegetation types are recognised and these are:-

Chalk Grassland
Limestone Grassland (including oolite, magnesian, carboniferous)
Maritime Dune Systems
Dry Heaths
Moorlands
Fens
Saltmarsh and shingle.

All of these habitats have been grazed by rabbits, sheep or cattle in the past and in the absence of grazing, seral changes occur which alter the structure and floristic composition of the sward in a way which is mostly deleterious to the flora and fauna although in a few cases, the absence of grazing may be beneficial to the fauna. In general, there are 2 main effects of withdrawing grazing which directly effect the species present:-

(i) The more vigorous species in the grassland increase in size in the absence of defoliation and compete for light with the lower growing species. The response to this change in conditions varies with different species. Some, such as Poterium sanguisorba, Cirsium acaulon and Pimpinella saxifraga show remarkable phenotypic plasticity and are able to compete and survive successfully in competition with the longer growing grasses, mainly by increasing leaf area and changing the angle of leaves. This characteristic is well demonstrated by Cirsium acaulon which grows as an appressed rosette under heavy grazing and as an erect herb in grassland 6"-8" high. Other species with less inherent plasticity are unable to change in size or form, and rapidly disappear. This is demonstrated by Asperula cynanchica, Hippocrepis comosa and Coeloglossum viride. Annuals such as Linum catharticum and Gentianella amarella are also eliminated quickly in undergrazed grassland.

(ii) Scrub, especially Hawthorn invades the grassland and quickly becomes established in the absence of the grazing animal.

These generalisations, hold for the majority of habitats under consideration, although there are instances where small parts of the major habitat remain relatively stable even in the absence of grazing because of edaphic factors. Good examples of this can be seen on roadside verges on the chalk and oolite in Lincolnshire where species rich communities have developed in areas where the soil has been dist bed by man. Similar effects can be seen at Aston Rowant on terraces formed by turf removal.

Analysis of N.N.Rs, N.R.As, and L.N.Rs in England

Of the 62 N.N.rs and L.N.Rs declared in England, 33 contain some form of vegetation which has been grazed in the past or is being grazed at the present time. On nearly all of the remaining 29 reserves, the main interest is either woodland, meres or mosses where grazing is not wanted or is physically impossible. However, it is worth noting that even on the thirty-three Reserves where some form of grazing is required, the major interest on the Reserve may not be grassland and management may be directed towards maintaining some other feature of the Reserve such as scrub or woodland which is in direct opposition to the maintenance of open grassland.

Applying the classification outlined previously, I have tried to estimate the approximate acreage of each vegetation type on Reserves in England, together with information on the recent land use history of the area and other relevant information. This is set out in Table 1. Using this approach, I hope to show where our commitments are heaviest and where efforts to obtain information of use in managing these areas, based on sound experimental work, should be concentrated. Every effort has been made to obtain exact figures for acreages by measurement, but in some cases, this has proved impossible because of the absence of vegetation maps, while on sand-dune systems, the figure for "area suitable for grazing" is only a rough estimate. However, making allowances for these sources of error, the picture that emerges is one of great differences in the area of land occupied by vegetation types on Reserves in England.

Moorlands

By far the largest acreage in this table is found under the moorland heading, which is made up of 2 Reserves, Moor House and Upper Teesdale, which together, occupy 16,500 acres of land. The problem here is essentially different from most of the other areas, and is more akin to the situation in Wales and Scotland where overgrazing, chiefly by sheep is widespread and protection of areas from grazing may be the required management technique. The system of land tenure in these upland areas and the right of common pasturage over the moors makes control of grazing difficult, and the absence of any detailed knowledge of grazing pressures under which the special flora of Teesdale has developed, further stresses the need for experimentation and examination of old agricultural records relating to past land-use. We know in general terms that grazing has increased greatly in recent years in conjunction with the increased use of the area for recreation by the public, but little work has been done to find out the effect of these changes on the flora of Teesdale.

Dune-systems

The second largest vegetation type found on N.N.Rs. in England is sand-dune systems which occupy 4,888 acres. The best examples of sand-dune systems are found along the western shores of Britain and many of these at Newborough Warren, Whiteford Dunes, Morfa Dyffryn and Morfa Harlech occur in Wales and are outside the scope of this paper, although the problems and principles which apply to the English dune systems are similar to those met with in Wales.

Well-developed dune systems are found in East Anglia between Hunstanton and Cromer, Scolt Head, 1,821 acres in extent being the best example with a wide range of plant associations, salt-marsh, shingle, sand-dunes and stabilised grassland all occurring within close proximity of each other. Winterton Dunes, a much smaller Reserve (259 acres) lies further east than Scolt Head, and contains well-developed dune systems which provide nesting sites for numerous sea-birds. Much of the North East coast of England from Tynemouth to Northumberland consists of extensive maritime dune systems. Lindisfarne, is the only N.N.R. on this coast but Ainsdale and Ravenglass on the N.W. coast bring the total acreage to more than 3,000. Braunton Burrows in Devon is the only dune-system in south West England scheduled as a N.N.R.

It is difficult to assess the area of land on dune systems which might benefit from grazing because of the absence of detailed vegetation maps, but a conservative estimate of grazable land is 1,000 acres. Common sense dictates that grazing the foredunes or yellow dunes is undesirable as "blow-outs" and erosion result from the impact of man or the grazing animal, and it is doubtful if sheep would eat the course, tough Marram Grass which is usually the dominant in these zones. Similar considerations apply to the grey dune systems which are also vulnerable to disturbance. Once the mat of mosses and lichens is broken, erosion occurs and stabilised areas become mobile again. The areas grazed by sheep and cattle in the past were the dune meadows and grassland developed on the landward side of the succession. We know that on all sand-dune systems rabbits were abundant before myxomatosis and it is possible that domestic grazing animals have never been a feature of many dune areas in this country. On the other hand, we have good historical evidence that Scolt Head and Braunton Burrows have been used as sheep and cattle pasture until recently, while at Lindisfarne, spasmodic grazing is still carried out. In the absence of grazing by rabbits, many of the more stabilised areas are being invaded by scrub - this is especially noticeable at Ainsdale where thickets of Sea Buckthorn are frequent and there is no reason why this species may not spread into many of the more interesting dune-slacks. The general lowering of the water-table is occurring on this P.N.R. and this would tend to accelerate the process. Similar scrub invasion is occurring on other Reserves and some substitute for rabbit grazing will have to be found. It seems likely that the pattern of grazing on dune systems in the past may have been unusual, with grazing limited to those months of the year when the vegetation was green and growing, or to those occasions in the year when keep was in short supply on the nearby salt-marshes.

Salt-marsh and Shingle

Salt-marsh occurs on 5 Reserves but the total area of this type of vegetation on N.N.Rs. in England is only about 750 - 1,000 acres. The largest area, about 500 acres occurs as a fringe around Bridgewater Bay and over most of Fenning Island and the remainder is distributed in small fragments at Hartland Moor, Orfordness, Scolt Head and to some extent, on Reserves where the main interest is the sand-dune systems.

Salt-marsh vegetation varies considerably. The lowest zone of the marsh, which may be submerged for considerably long periods of the day, is generally colonised by scattered plants of Salicornia. As mud and silt are trapped by the vegetation, the height of the marsh is gradually raised and the mature salt marsh consists of a grassland in which Puccinellia maritima and Festuca rubra are generally the dominants, accompanied by numerous halophytes such as Armeria maritima, Aster tripolium and Limonium vulgare. Spartina townsendii generally occurs in an intermediate zone between the open Saliconietum and the closed Festucetum, and other local societies, too numerous to mention occur interspersed among the dominants. Some of these communities are grazed only at low tide and for short periods of the day, but the upper zones of the marsh which are only inundated at exceptional high tides are the traditional pastures, and it is under a regime of sheep grazing that the characteristic short turf has developed.

At Bridgewater Bay, the traditional system of grazing Cord Grass and Puccinellia/Festuca swards on the upper levels of the marsh is continuing and it is generally agreed that this form of traditional management is best for the flora. At Orfordness, where much of the Reserve is shingle, there is little need for grazing, but it should not be thought that grazing shingle beaches has not occurred in the past.

Tansley on page 871 shows a photograph of sheep feeding on Silene maritima near Burton Bradstock, Wiltshire, in 1911!

Changes that occur when grazing ceases on salt-marshes are not well documented, but one would think that on the upper reaches, Juncus maritimus might become dominant and exclude species of the grazed marshland.

Lowland Heath

Lowland heath is a well defined vegetation type found scattered across southern England, never covering large areas because the rocks which bear the podsols and peats on which the flora depends, are not extensive. The Heaths occupy distinct geographic regions and although each type is recognisable as a distinct entity, there are many common features shared by this type of vegetation which make it reasonable to consider them as a whole.

The Cornish Heaths, the Dorset Heaths and the Breckland form the most easily distinguishable units, but it should not be overlooked that extensive tracts of heathland occur on the Bagshott Sands in the Reading-Aldershot area, and lesser amounts are found on lower Greensand around Hindhead and in Bedfordshire. Heaths also occur on the Wealden Sands, in the Ashdown Forest region and in the Cannock Chase area of Staffordshire.

The Conservancy have declared N.N.Rs on only 2 of these areas, in the Breckland and in Dorset, although many other heaths are S.S.S.Is.

In the Breck, Thetford Heath, Westleton Heath, Weeting Heath and Cavenham Heath form a close-knit group of Reserves covering 1,035 acres with a similar history of land use and with similar problems for the future. This group of Reserves, together with other important remnants of the Breck which are not Nature Reserves such as Lakenheath Warren, Stanford Battle Training area and Wangford Warren, exhibit a whole range of grassland types, which A.S. Watt has labelled A to G which are of great value to the scientist for studying the relationship between the flora and such factors as ph, soil depth, organic matter and podsolisation. Variation in soil characteristics is the primary factor responsible for the characteristic vegetation of the Breck, but agricultural practices, in which sheep, rabbits and spasmodic arable farming by man have all played a part, make this region of East Anglia unique.

The old agricultural method of walking large numbers of sheep across the Heaths can only be used in the context of an agricultural system and is a method characteristic of large estates. This is obviously outside the scope and capabilities of the Conservancy, and experiments are needed to investigate the feasibility of using other techniques such as mowing and rotovating as a means of creating favourable conditions for the maintenance of typical Breck habitats. The past land use history of the Dorset Heaths, together with their conservation interests and problems have been discussed at length by Moore in J.Ecol. (50). The heaths owe their existence to a combination of fire and grazing, but Moore points out that since 1955, grazing has become less because of smaller rabbit populations and fewer sheep, while burning has increased. The result of this trend is that the larger Heaths which in general are not used for grazing are dominated by ericaceous shrubs while the smaller heaths tend to change to grass heaths when grazing is high or are invaded by subspontaneous pine if left ungrazed. The exact grazing pressure required to maintain the high biological interest on the Conservancy Reserves in this region, at Hartland Moor, Morden Bog, Arne and Studland, remains to be found, and it could be argued that grazing is not needed and that burning alone will maintain the interest. Grazing and burning experiments are being done at Furzebrook and it would be interesting to hear of their results.

Further complications arise because of the fragmentary nature of the remaining pieces of heathland and the increased isolation of Reserves, and it seems appropriate at this stage to mention that experimental work is needed to determine the smallest size of Reserve which can be considered a viable biological unit.

Chalk Grassland

The Conservancy own or lease 7 Reserves on the chalk covering 1,448 acres. This figure includes the woodland areas at Kingley Vale, Old Winchester Hill and Aston Rowant, and after subtracting these areas from the total acreage, there remains 1,124 acres of grassland, or grassland and incipient scrub.

Chalk grassland varies greatly from region to region, and often within one area, communities with different dominants occur side by side. The large number of plants found in the grassland and the differences in structure that are caused by different growth habits and degrees of vigour of the dominant species are responsible for the high biological interest of this type of vegetation. Because of the range of communities found on the chalk, different approaches to management are needed, although as a general rule, we know that some form of grazing is beneficial. For example, although grazing at Old Winchester Hill has been restricted to less than one month in any one year, this small amount of grazing on the shallow soils of the south-facing slope has been beneficial and the effect is noticeable when compared with the fenced paddocks. A similar grazing programme on another area, where the soil is deeper, would probably have been ineffectual. Experiments are needed to investigate the effect of different grazing intensities and time of year of grazing on the flora of the many varieties of chalk grassland - a start has been made with the Barton Hills work and the Aston Rowant grazing experiment, but this approach needs extending elsewhere.

Alternative forms of management such as mowing need to be considered; although it is unlikely that this technique can be applied widely, because most of the remaining areas of chalk grassland are restricted to the steep, scarp slopes which precludes the use of the mowing machine, unless some revolutionary technique of mowing is developed.

Fyfield Down in Wiltshire, 612 acres in extent, accounts for more than half the Conservancy acreage of chalk grassland. As recently as 1961, the traditional downland method of sheep farming could be seen on Fyfield Down with a large flock of Downland sheep controlled by a dog and shepherd. Fortunately, the Reserve is still being grazed by sheep and it would be valuable to know if changes in the structure and floristic composition of the flora are occurring, because of changes in the method of managing the sheep. It would be equally informative to compare mowing with grazing on this Reserve, because the topography of this Reserve is such that mowing would be possible.

The remaining 512 acres of chalk grassland is divided between 6 reserves, which range in size from 22 acres at Knocking Hoe to 155 acres at Lullington Heath. Lullington supports a variety of habitats ranging from chalk grassland and ericaceous heath to thickets of Forse and ex-arable grassland. Old Winchester Hill with about 100 acres of grassland exhibits more typical chalk grassland, mainly Festuca-dominated and with a rich selection of herbs, the south-facing slopes being especially good. Public pressure is high at holiday times on this Reserve and trampling by visitors of the coarse grassland on the hill-tops may be beneficial and eventually change the turf to a richer, shorter form. This kind of effect can be seen at Box Hill, Surrey, where public pressure is high.

The 74 acres of grassland at Wye and Crundale are very different from other Reserves, but they are characteristic of many sites in Kent. Brachypodium pinnatum is the dominant grass over much of the Reserve, although small areas of Festuca turf are common in places. Management of this area is particularly difficult because of the abundance of Tor Grass, and the steep slopes over much of the Reserve preclude any form of management other than grazing. Cattle and sheep are being used for management at the present time, and mowing treatments are being investigated by Dr. Gay.

Managing chalk grassland within an agricultural system is not difficult and we know that it is by this process that characteristic chalk grassland has developed. However, the Conservancy are having to face the problem of managing small areas of grassland outside an agricultural system and without the flexibility which normal farming practices allow. I believe that the time is ripe for us to decide either to find alternative ways of managing grassland without animals or to develop a system of using animals outside the context of agriculture and primarily for purposes of conservation management. Serious consideration should also be given to more destructive ways of managing small areas, such as turf-cutting and rotovation if there is evidence that indicates such conditions are necessary for the survival of certain plants or as starting points in seral changes. Observations on ploughed and disturbed ground in the Chilterns indicate that such practices are beneficial and add to the variety of habitats in an area.

Fens

The 6th type of vegetation listed is Fen. For our purposes, this is defined as vegetation growing on peat in which there is an adequate supply of bases and includes vegetation such as sedge, mixed fen, and fen carr. We know from the historical record that regular cutting of sedge and reed for thatching and summer grazing by sheep and cattle were factors responsible for the creation and maintenance of mixed herbaceous fen, rich in plant species and associated insects. Of the 5 places listed as Fen N.N.Rs, one, Holme Fen, has reached the stage of woodland and little herbaceous fen exists, while North Fen in Lancs., a small four-acre reserve leased from the National Trust is too wet for grazing to be considered as a management tool. There remains 3 Fen N.N.Rs, Woodwalton, Chippenham and Wicken which do support herbaceous fen, although much of these Reserves have reached the stage of fen carr and an estimate of herbaceous fen on these 3 Reserves would not exceed 150 acres. There is in addition, about 80 acres of land at the southern end of Woodwalton Fen which is not strictly fen, which supports communities characteristic of acid heath and in places where the clay reaches the surface, grasslands dominated by Calamagrostis and Arrhenatherum have developed. Grazing is being used at Woodwalton to manage parts of the Fen with good results, and we are hoping that the effect of trampling by cattle will be to create areas of bare peat on which Erica tetralix and Calluna will germinate freely.

The Bure Marshes are ecologically fens and not marshland and are best considered, along with Hickling Broad, under the heading of Fens. We know from past records that reed and sedge-cutting were important industries in the wetter areas until the end of the nineteenth century and that the grassland areas nearer the uplands were important pastures for grazing. Less than 100 acres of grazed fen meadow are to be found in the Bure Marshes now, and at Hickling Broad, only 55 acres are grazed by bullocks and 60 acres cut for reed and sedge. If these traditional practices continue, there will be little need for change and the biological interest of the areas should continue, but if the market for reed and sedge diminishes, or labour for cutting becomes unavailable alternative ways of managing these areas will have to be found.

Other types of vegetation traditionally grazed but not represented on Nature Reserves.

Other than temporary leys, which are of no interest to the conservationist, the most outstanding omission from the list of Reserves is any N.N.R. where lowland marsh is represented. The best examples of lowland marshes are to be seen along the banks of slowly flowing rivers which flood in the winter and deposit fresh silt each year. Most are used for hay-making in early summer, the aftermath being grazed by cattle. Under this traditional system of management, a characteristic flora has developed, which contains species such as the Lodden Lily (*Leucojum aestivum*) and Snake's Head (*Fritillaria meleagris*) not found in other associations. Tamm (1956) has reported on the floras of meadows which have been cut or grazed for at least 100 years, and he shows that considerable floristic differences result from these treatments.

Conclusions

1. The purpose of this paper was to define the Conservancy's commitments on Nature Reserves in England where grazing might be used as a form of management. Although the use of grazing as a management tool has been discussed for many years and experimental work on grazing started many years ago, the different approaches adopted have not been related to any national policy and it is believed that progress can only be made by a co-ordinated plan of survey and study by conservation and research staff.
   A start has been made in that direction by the Aston Rowant experiment which is a joint regional and research staff project and a second project for grazing Woodwalton Fen and Castor Hanglands is being considered by the Conservation Research Section and East Anglia Branch.

   Using the area occupied by each vegetation type as a criterion for suggesting where experimentation into management problems is most needed, the following priorities are noted:-

   (a) Moorlands

   (b) Chalk grasslands, heaths and sand-dune systems.

   (c) Salt-marsh and shingle.

   (d) Fens

   (e) Limestone grasslands

   The problems are dissimilar on different types of vegetation. Moorlands are generally overgrazed and control of the grazing animal is the main problem. Conversely, chalk grasslands are undergrazed, and finding a method of grazing which can be operated successfully outside an agricultural system is the main concern.

On sand-dune systems and heaths, experimentation is needed to find the level of grazing and time of year of grazing which is most beneficial to the conservation interest.

The effects of undergrazing are less noticeable on saltmarshes and shingle banks than on most other habitats, and the traditional pattern of management should be encouraged, until more information is obtained concerning the effects of no grazing.

6. Fens are probably the rarest vegetation type in England and because of this, are of immense value to the scientist. Careful experimentation is needed to separate the effects of traditional practices such as mowing from the effects of summer grazing by cattle.

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APPENDIX I

TYPES OF VEGETATION ON NATIONAL NATURE RESERVES IN ENGLAND WHERE GRAZING COULD BE USED AS A MANAGEMENT PLAN

Vegetation Type	Reserve	Total Acreage	Area suitable for grazing	Recent land use history	Present Management	Management Experiments
Chalk Grassland.	Aston Rowant, Oxon.	166	51	Rabbits, sheep, cultivated.	Rabbits, grazing experiment.	Grazing experiment
	Fyfield Down, Wilts.	612	612	Rabbits, sheep.	Sheep run.	
	Kingley Vale, Sussex.	230	110	Rabbits, sheep.		-
	Knocking Hoe, Beds.	22	22	Rabbits, sheep, cattle.	Sheep and cattle	Cutting, exclosure, selection by sheep.
	Lullington Heath, Sussex.	155	155	Rabbits.	Mowing, gorse clearance.	Mowing.
	Old Winchester Hill, Hants.	140	100	Rabbits, sheep, cattle.	Light sheep grazing in parts.	Effects of sheep grazing.
	Wye and Crundale, Kent.	123	74	Rabbits, cattle.	Cattle grazed.	Mowing, selection by sheep.
	TOTAL	1,448	1,124			
Limestone Grassland*	Caster Hanglands, Northants.	221	60	Rabbits, cattle, sheep.	Cattle and scrub clearance.	Belt transects on two autoscythed plots.
	Rodney Stoke, Somerset.	86	28	Cultivated strawberry fields.	-	-
	TOTAL	307	88			
Maritime Dune System	Braunton Burrows, Devon.	560	(150)	Rabbits, sheep.		
	Lindisfarne, Northumberland.	1,665	(400)	Rabbits, sheep, cattle.	Ross-links, sheep and cattle.	

2. Vegetation Type.	Reserve	Total Acreage	Area suitable for grazing.	Recent land use history	Present Management	Management Experiments.
	Scolt Head	1,821	(200)	Rabbits.		
	Winterton Dunes.	259	(150)	Rabbits.		
	TOTAL	4,305	900			
Dry Heaths	Cavenham Heath, Suffolk.	337	337	Sheep and rabbits.		Competition between grass-heath and heath in absence of grazing
	Hartland Moor, Dorset.	214	(150)	Sheep, rabbits, fire.		Effect of burning and grazing.
	Morden Bog, Dorset.	367	(70)	Grazing, turf cutting, rabbits.		Effect of burning and grazing.
	Studland Heath, Dorset	429	(100)	Grazing		-
	Thetford Heath, Suffolk.	243	243	Sheep, rabbits and fire.		
	Westleton Heath, Suffolk.	117	117	Sheep, rabbits and fire.		Autoscything of plots.
	Weeting Heath, Norfolk	338	338	Sheep, rabbits and fire.		
	TOTAL	2,045	1,355			
Moorlands	Moor House, Westmoreland.	10,000	10,000	Sheep and grouse.	Sheep and grouse.	Effects of cutting and grazing.
	Upper Teesdale.	6,500	6,500	Sheep and grouse.	Sheep and grouse.	Numerous ecological studies by Northern Universities.
	TOTAL	16,500	16,500			
Fens	Chippenham Fen, Cambs.	193	(20)	Sedge & reed cutting, summer grazing.	Cattle	
	Holme Fen, Hunts.	640		Peat cutting.		

19. Vegetation Type	Reserve	Total Acreage	Area suitable for grazing.	Recent land use history	Present Management	Management Experiments.
Fens (cont.)	North Fen, Lancs.	4	-		-	
	Woodwalton Fen, Hunts.	514	(100)	Sedge & reed cutting. Peat extraction, summer grazing.	Cattle.	Heath regeneration.
	Bure Marshes, Norfolk.	1,019	(100)	Sedge cutting, sheep and cattle.	Occasionally "swiped".	
	Hickling Broad, Norfolk.	1,204	(60)	Sedge cutting, sheep and cattle pasture.	-	
	Cothill, Berks.	4		Cutting for peat, sedge, etc.		
	TOTAL	3,256	280			
Salt-Marsh and Shingle.	Bridgewater Bay, Somerset.	6,076	(500)	Sheep pasture, rabbits.	Sheep grazed.	Grazing.
	Hartland Moor (in part).	214	(24)	Sheep, fire, peat cutting, rabbits.		
	Orfordness - Havergate	514	(50)	Rabbits, cattle and sheep.		Four exclosures.
	Scolt Head, Norfolk.	1,821	(100)	Rabbits.		
	Arne, Dorset.	9	(1)	Rabbits		
	TOTAL	8,634	675			

* Does not include Teesdale, which is classified under moorlands.

() Estimated acreage, based on vegetation maps, personal knowledge and communications from Regional Officers.

GRAZING IN SCOTLAND AND UPLAND ENGLAND

D.A. Ratcliffe

Although goats and cattle were important prior to about 1800 A.D., in recent and present times, the important grazing animals of the uplands in Scotland are sheep and Red Deer, and in England, sheep with deer only very locally. The Red Grouse, in a sense, is a grazing animal, but is less important as an agent of change. Management of hill-land for these animals involves repeated burning of the ground, and the effects of this activity are often difficult to separate from those of grazing.

In these upland areas, the effects of grazing by sheep and deer are in general, deleterious from the viewpoint of wildlife conservation in that they cause more or less irreversible changes in original vegetation and habitat. These changes may be grouped as follows:-

1. Eradication of woodland

In many areas, forests have been destroyed to create pasture-land and the large herbivores may hasten the end of existing woodland, or more especially scrub, by 'barking the stems'. The much more common effect however, is to prevent regeneration by grazing down all the seedlings which appear. Over much of our uplands, heavy grazing is very effective in preventing tree regeneration. In sheep and deer country the woods to which these animals have access (and this means practically all the upland woods) are potentially moribund, and their life-span is that of the existing trees.

2. The eradication of other species sensitive to grazing

(a) On acidic, base-poor soils, ericaceous and other shrubby species (e.g. Juniper) usually predominate, either within woodland, when woodland disappears, or above the tree limit and below that of the mid-Alpine zone. Heavy grazing with burning, causes the replacement of these woody species by grazing and fire-resistant grasses to form a grassland "biotic climax".

This process may be observed in many parts of the British uplands, but especially where grouse moor is abandoned in favour of sheep - increasing in stocking density converts the heathery grouse-moor into grassy sheep-walk. A very large part of the Lake District and Southern upland hills have suffered this change. Not only common ericoids such as heather disappear, but rarer species such as bearberry, crowberry, cowberry and dwarf Juniper and with them other organisms, both plant and animal which depend on these dwarf shrubs for food or shelter.

(b) On base-rich soils, Dicotyledon herbs (forbs) usually predominate in place of ericoids though in some areas, calcicolour dwarf shrubs, small willows and *Dryas* may once have been abundant. These species are often eagerly sought by the large herbivores and are very sensitive to grazing. Their communities are again usually converted to grassland, though some of the original species may long persist as grazed-down remnants. Originally associated organisms are affected and may disappear. This kind of vegetation becomes confined to ungrazed situations, notably as fragments on inaccessible cliff ledges, or within fenced and ungrazed woods, or upland hay meadows.

3. Loss of Productivity

More marginal to our field of interest are the effects which result in a loss to the crop - the herbivores themselves. These are believed to result from a gradual running-down of soil fertility under an extractive policy of management, especially on the poorer soils, and perhaps exaggerated by the effects of repeated burning. On many steep and rocky hillsides, heavy grazing (with burning) has clearly been responsible for soil erosion and scree formation. And within the grassland complex of many sheep-walks, the highly selective nature of the grazing has favoured a spread of coarse, unpalatable grasses at the expense of nutritious species.
N.B. A good deal of work still needs to be done to establish the detailed nature and direction of these various downgrade changes.

On the credit side of the picture, some plants of interest have been favoured by these changes. Alchemilla alpina has probably spread a good deal locally in close-cropped grassland, and Parsley Fern has certainly done so on extending screes. Some species have proved adaptable e.g. a dwarf ecotype of Myosotis alpestris capable of flourishing in short turf, seems to have been selected by grazing on the high Pennine limestone. Part of the interest of the Upper Teesdale area is due to the grazing regime though this has involved cattle and a relatively low stocking density of sheep, and is a special case.

On the whole however, existing management of uplands for sheep (and, to a lesser extent, deer), is detrimental to wildlife conservation and the Conservancy must pay regard to this. On Reserves, unless grazing rights are inviolable, it is usually desirable to restrict or exclude grazing by sheep, and to prevent burning e.g. on Rhum and Beinn Eighe. Where woodland regeneration is desired, this exclusion of large herbivores is essential, and often has to be accomplished by extensive fencing. I know of no case in which sheep have been used to maintain the interest of a Reserve; most experiments in this field have been concerned with observation of changes in vegetation on fenced areas from which sheep are excluded. Recovery of vegetation to something approaching the original state can sometimes be achieved in this way, but often the deterioration is too advanced, and must be regarded as virtually irreversible in terms of the human life-span. In time however, a good deal may be accomplished in restoration of vegetational composition on some Reserves.

The more serious problem concerns events on the very much larger area of upland which is not N.N.R. and over which we have little or no control.

Here, as long as grouse, or even Red Deer remain the chief interest, other wildlife (except predators) will probably be less seriously threatened; but with ever-increasing pressure for full economic exploitation, more and more upland is likely to be turned into sheep-walk (or coniferous forest) with consequent spread or acceleration of degradation from the broader wildlife aspect. We cannot rest content that Reserves will be protected - they are such a fragment of the whole - and the fate of our uplands with their wildlife, under a grazing regime, will be a major problem of the future.

SUMMARY OF THE DISCUSSION FOLLOWING PAPERS GIVEN BY WELLS AND RATCLIFFE -

Mr. Duckett enquired about the possibility of using grazing as a means of controlling the spread of Spartina in the upper zones of salt-marshes. In reply, Mr. Hemsley stated that experiments done at Furzebrook by Dr. Ranwell had shown that Spartina was readily accepted by cattle and sheep. However, heavy grazing of Spartina marshes brought about radical changes in the floristic composition of the marsh which were not always desired by the conservationist.

Dr. Ratcliffe had stated in his paper that grazing could produce irreversible changes in vegetation and this statement was commented upon by several people. Mr. Charles suggested that excessive grazing produced an "ecological run-down", especially of nutrients, which prevented the re-establishment of the old community. He suggested that there were two ways of looking at the problem - (1) from the conservation point of view in which the animal was considered as a kind of selective lawn-mower to be used for management, and (2) from the agriculturists point of view, in which vegetation was a source of food for the animal, and for whom maximum productivity was the main consideration. In Scotland, they were working on the idea that grazing could be used to manipulate plant communities to support the present stocking densities, without necessarily leading to a "run down" of the ecosystem.

Mr. Rawes thought that Dr. Ratcliffe's statement only applied to a few very localised species such as Dryas, which disappeared under heavy grazing and were unable to re-colonise because of an absence of a source of seed. Sorbus acuparia was quoted as an example of a species in N. Wales which was reappearing in areas fenced against sheep, although this species was absent from near-by sheep walks, and was restricted to mountain ledges inaccessible to sheep. It was thought that birds had carried the seed into the fenced areas.

The effect of treading by sheep and other herbivores was considered important. In N. Wales, erosion occurred on steep slopes used by sheep. Experiments using Creeping Red Fescue (Festuca rubra) to control erosion had begun. On chalk slopes, especially where the angle at rest was more than 20°, movement of chalk rubble down the slope may be considerable. This often produced habitat conditions favourable for some species, and it was considered by the meeting that treading was generally beneficial. Continual treading produces compaction, and it had been observed that old Neolithic pathways and other earthworks usually had a more interesting flora than surrounding untrodden vegetation.

Mr. Skellam suggested that perhaps we were too preoccupied with going back to past conditions, and that we should be trying other forms of management, such as rotovation or ploughing. This idea was warmly supported by many of those present, with certain reservations. Dr. Perring commented that most areas of chalk grassland had been ploughed within the last 150 years, yet the turf which had been established on these areas was botanically almost as good as areas of very old chalk grassland. Even areas that had been ploughed less than 10 years ago, although they had not reached the floristic composition of older areas, had their own special interests.

Some Reserves had been acquired for the conservation of specific plant communities, and it was essential that the form of land management which had produced these communities should be continued.

THEORETICAL BASIS OF GRAZING POLICY

P.A. Gay

This note does not attempt to lay down a grazing policy but to explore some of the underlying theoretical considerations and possible approaches to the grasslands which need to be taken into account in arriving at a grazing policy. Although grasslands and grazing are of major importance in agriculture, the agriculturalist differs from the approach the Conservancy is most likely to adopt because he usually deals with relatively simple mixtures of species and the success of his policy is judged not by the grassland itself, but by the stock which the grassland supports. In relatively few cases is the latter approach paralleled in the Conservancy.

All grasslands do not call for identical grazing treatments but each case must be considered according to the desired objective. There are several ways of defining the objective of a grassland and each calls for a different approach in studying the problems although each approach can be complementary to the others. Considerations of energy flow and production are not explored here. Four main lines of approach are being explored in grassland work in progress in the South East Region.

(1) Argument from history

Historical studies are necessary to define what states of grassland it is desirable should be conserved. Grasslands have been subjected to various management treatments according to economic considerations of the day so that it should be possible to define the desired purpose of a grassland by reference to some date in history. Many of the basic ideas of ecology were conceived in the early years of this century when agriculture was relatively depressed and much farm land was under a lax management or not managed at all. Most ecologists' conception of a good chalk grassland sward propably refers to the state during the early years of the agricultural decline, but as the scientific interest is probably the result of a much longer history of human use it may be desirable to define the desired objective in terms of earlier or later dates in history.

By using an historical date by which to define the desired objective it automatically follows that the method of achieving that objective is to employ the management system current at the time, e.g. prior to the introduction of root crops in about the 17th Century the regime on the Downs was essentially one of summer grazing.

Besides providing an aid in defining objectives, this approach gives a useful guide to the range of tolerance of any grassland when information of a more fundamental nature is lacking, and can also provide pointers to what fundamental research should be carried out.

(2) Problems of the plant community

The objective can also be defined by reference to the desired composition of the sward. Under different treatments the balance of species in the sward changes according to the response of each individual to that treatment. A change in treatment not only affects the sward through its direct effects upon the individual species but also modifies the nature and extent of competition between members of the sward. The species in a sward usually complement each other to some degree in their periods of maximum production and it is through the timing of grazing in relation to maximum production rate that the selective mechanism of grazing probably acts in producing its effect on sward composition. Experiments are desirable on such matters as the effect of the date of grazing and its intensity upon sward composition. Work is also necessary on the rates of deterioration of swards when grazing is withdrawn and whether such deterioration is reversible.

(3) The individual plant species

This approach is closely allied to, and provides information necessary for a proper understanding of studies upon the community. If prescriptions made for grasslands are to be truly scientific and are to produce predictable results this can only be achieved by an understanding of the way in which the biology of each constituent species in the sward relates to the prescription, although the inter-relation of species in mixtures will undoubtedly confuse any predictions made on the basis of species alone. More information is needed on such matters as seed production rates, germination requirements, perennation, growth times and rates and plasticity. Such an approach is most urgent with the major constituents of the sward and the rariefes. Before complex experiments are begun it is essential to know the base level of populations as sometimes wide fluctuations in numbers of individuals take place irrespective of the management treatment. Without a prior knowledge of the pattern of fluctuation management experiments could easily be open to erroneous interpretation.

(4) The plant/grazing animal relationship

The grazing animal can also be used as the end product in defining a grazing regime, e.g. maximum production of deer or animal protein.

Because of problems of palatability of species, selection by stock, the patterns of stock movement and their choice of site, the introduction of animals into experiments greatly confuses their interpretation. In prescribing grazing it is necessary to determine not only the grazing species, breed and age, but also the form the grazing is to take - e.g. close folding, creep grazing, continuous grazing, - and whether supplementary feed is to be allowed. If clipping or mowing experiments are to be substituted it must be determined whether cutting is to be at regular intervals or according to production rate. Clipping and mowing experiments cannot satisfactorily act as a substitute for grazing experiments because of lack of treading, selectivity and faecal material although some agricultural experiments show that some of the deficiencies can at least be partly overcome.

Conclusion

Because choice by the grazing animal can so complicate grazing experiments it is desirable in the first instance to narrow the field of enquiry by using mowing and clipping trials. Fundamental ecological information on the constituent species of a grassland and the change in balance in communities in response to certain simple treatments can provide material for more closely prescribing a grazing treatment to achieve any objective which can be usefully defined by reference to an historical date.

It is desirable to carry out observations and design experiments in a way that will provide information that is of practical value in determining a grazing treatment for any area.

DISCUSSION FOLLOWING DR. GAY'S PAPER

Dr. Mellanby stressed the need for knowing what sort of experiments were being done elsewhere before beginning grazing experiments in the Conservancy. In this way, duplication of work would be avoided, but it was pointed out by several people that the aims of much of the work being done outside the Conservancy were mainly agricultural, and little attention was given to "natural grasslands".

Many different approaches to grazing and plant communities were known, and it was suggested that co-ordinated research was needed to find a technique which could be applied to conservation problems.

Mr. Mountford thought that the ultimate aims of management were still obscure and made a plea for a clear definition of objectives in all Management Plans. Dr. Gay had suggested that a point in time should be selected as an example of the type of vegetation which was wanted on a particular Reserve. It was agreed that this was generally desirable but in many cases impossible as detailed lists of species from different vegetation types had only been made in the last 50 years. Nevertheless, it was felt that provided the potential was present in the grassland, a carefully defined type of grassland could be recreated by applying the right sort of management.

The need for observations on the biology of individual species was reiterated by many speakers, and it was suggested that this type of study could be encouraged by the Conservancy giving grants to students for this specific purpose. Autecological studies on key species in grassland ecosystems were considered essential as a means of understanding plant/animal relationships.

DOCUMENTATION, COMMUNICATION AND SEMANTICS WITH SPECIAL REFERENCE TO FIELD EXPERIMENTS

J.G. Skellam

I will begin by explaining that every few years I write a formal minute complaining about the Control of Long-term Experiments. I did so in August 1958, again in March 1960, still again in August 1962, and here I am once more taking up the same points in April 1965.

The last note I wrote was prompted by an unbelievable muddle which arose in 1962 in connection with the Gisburn Experiment. In this investigation, by arrangement with a local smallholder, certain plots at that time were being grazed on a rotational basis by two sheep. A legal dispute over the ownership of the sheep led the Police to remove them in July, and though an offer was made about a week later by the smallholder to replace the sheep, the administration, for reasons of propriety, declined the offer. As a result, the continuity of the grazing treatment was seriously threatened. There was clearly a conflict between the requirements of scientific discipline and the niceties of official behaviour. The record in London is silent on whether the grazing treatment was ever restored. It was certainly not done before 24th August.

For all I know, the incident may not have been very serious in its effects on the experiment, but it does raise matters of principle which cannot be ignored.

My note dealt with wide or general issues and was addressed to Mr. Nicholson, Dr Worthington, Mr. Cooper, Mr. Boote and a copy sent to Dr. Ovington. It said:-

"For some years I have felt unhappy about our major experiments because of the absence of:

(i) a clear policy outlook
(ii) guiding principles defining responsibility
(iii) machinery for supervision and control.

Some of these problems were raised in my minute of 28.8.58 but no action has been taken. The broad issues were raised again in my minute of 13.3.60, but again no action has been taken.

The need for proper control is made apparent by recent developments affecting the grazing by sheep of certain plots in the experiment in Gisburn Forest /File N. 127/."

It is evident that appropriate drills and machinery are required simply to look after the pieces of paper which relate to field experiments.

This need is clearly apparent if we refer once again to File No. 127 on Gisburn. In March 1960, I found it necessary to add the following short note:

"I saw Dr. Ovington today. He has the experiment well documented. Carbon copies etc. of aims, history, data sheets are in his possession in foolscap envelopes kept in a box-file. The original papers are presumably at Merlewood."

I need say no more about the physical handling of sheets of paper, and pass on to the general problem of communication.

The basis of communication is language, either spoken or written or physically recorded. The amount of information which is conveyed from one mind to another depends primarily on two things: the length of the message and the meaning which the symbols have in common to the sender and receiver. I repeat the meaning that the symbols have in common to the sender and receiver". When a symbol has different shades of meaning for different people, a state of confusion arises which becomes more marked as the number of people involved increases. Personally, I don't mind much what words are used provided that I am clearly given the precise sense in which each word is employed.

Let us take the word "grazing" for example. In the narrow sense, the word means the biting off of herbage, but in the broad sense, implied in the title of this symposium, the word "grazing" is almost synonymous with "stocking" because we are normally concerned with the combined effects of the grazing animals on the vegetation - the effects of their urine and faeces, the trampling that occurs, and so on. Personally, I would prefer the word "stocking" in connection with the kind of experiments we envisage but I have no real objection to "grazing" provided that the word is defined by its users in such a way that it really corresponds to the treatment which is applied.

Another word appearing in the title is "conservation". I will waste little time on it, but merely express my contempt for those who, when asked to define it, produce some such statement as - "Conservation is not the same thing as preservation. What we stand for is 'conservation by wise land use'." This may be a good slogan but it is certainly not science.

Ordinary language, developed to meet the needs and convenience of everyday life, has numerous defects. It is saturated with linguistic conventions that reflect primitive scientific hypotheses about the world in which we live, assumptions which are no longer tenable. It is not good science for example to say that the sun rose, or that the sun does not shine at night.

Ordinary language has four main uses of which only one, the informative use, concerns us as scientists. It has four modes of which we employ only two, the designative mode in natural science and the formative mode in logical and mathematical studies.

The language of ecology has inherited many of the inadequacies and weakness of ordinary language because its subject matter has so much in common with everyday experience and attitudes. The Conservancy has inherited even more of them because its activities are not wholly scientific. Indeed, of the sixteen categories into which Charles Morris classified discourse, only two are relevant to us as scientists whilst at least six are employed by us as conservationists.

The age in which we live is one of hypocrisy and propoganda. It is not therefore surprising that scientists working in the field of wildlife conservation have to be on their guard and find it difficult to bring the quality of their written work up to the level which is ideally required in scientific studies. In this respect, the mathematician and the theoretical physicist are much more fortunate.

Ordinary language does not distinguish between the symbol and its meaning. This is evident for example, if we compare the two statements:-

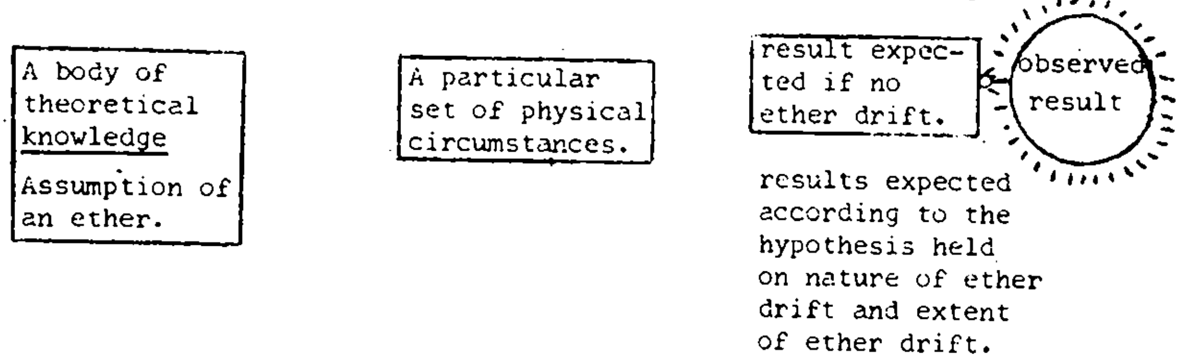
1. There is no apostrophe in Monks Wood.
2. There is no dinosaur in Monks Wood.

We are only too often inclined to forget this and feel that we have written up our work when we have inscribed numerous hieroglyphics on paper. But our task is not finished if there still remains the reasonable possibility that the sense of our words might be misunderstood.

The terms used by ecologists seem to have such very different meanings for different people. Take for example, the word "experiment" which also occurs in the title of our symposium. Some years ago, the President of the British Ecological Society gave an interesting presidential address[1] entitled "Ecology as an Experimental Science". It is noteworthy that he used the word "Experiment" in the most general sense conceivable to mean little more than an extension of experience resulting from the intervention of man, whether intentionally or accidentally, on the course of Nature. The statistician however, unless contaminated by his ecological colleagues, always uses the word in the classical sense to mean the proof of testing of hypotheses. The range of meanings is so great in our field of work that there is something to be said for attempting a classification. We might for example, recognise three categories A, B,C, or if you like, ortho, quasi and pseudo experiments. Category C includes those investigations in which we do something and see, and then hope for the best. Many people who are prone to do this however, are often intellecturally dishonest - though they may not know it. When the experiment comes to be written up, we may find that the logical order of operations is reversed. The hypotheses created afterwards are presented as if they were in the experimenter's mind from the beginning. Statistical tests are then carried out to show how right he was. It would be surprising if the tests showed him wrong!

Categories A and B are genuine experiments in the sense that everything is well defined and selected hypotheses formulated beforehand are subjected to test. The difference between categories A and B is more technical. The design of A is such that it provides its own estimate of error, whereas in B, the estimate of error is made on the basis of other knowledge - or auxiliary experiments.

A good example of an experiment of type B is the celebrated Michelson-Morley Experiment of 1881. This experiment yielded a null result and by so doing, precipitated the collapse of the theory of the ether, and thereby cleared the way for the theory of special relativity which emerged twenty-four years later. Though the technical details may be familiar in varying degrees to many people present, the field of application does not concern us. The point about it which merits our attention is its logical structure.



All experiments which are worthy of the name have in essence this kind of logical structure. The written account therefore should do justice to all components.

But how often in ecological work is this the case? Very rarely I fear.

Let us start with the aims or objects of the experiment. We don't pick them out of a hat. They arise out of a wide range of background circumstances. At first, the aims are rather general and usually are too broad or comprehensive to be practicable within the confines of a single experiment. We are obliged to be selective and to narrow the objects down to the achievement of a few highly specific details.

The written account should therefore deal at some length with the background and why the investigator has selected certain specific points for special study rather than others.

Having dealt with the general objectives, he should then set out the specific objectives with the greatest care and ensure that all his terms are fully defined. This is of course, more easily said than done, but unless the theoretical argument is recorded, the working hypotheses well defined, the treatments fully prescribed and the measurement of the results taken care of in all relevant detail, all subsequent effort spent carrying out the work is wasted. After all, what is the cost of a few weeks of diligent thoughtfulness, compared with all the labour involved in an experiment which may extend over several years.

To me it is somewhat alarming that in a research council in this scientific day and age, it should be taken for granted that a graduate biologist who has subsequently worked on say, the insect fauna of puff-balls, is thereby qualified to engage in costly experimental work. This is a type of investigation for which few ecologists get any real training That of course, is not their fault. Experimentation is a highly skilled activity and normally requires long experience as well as insight. The responsibility rests with the organisation to make up for possible inadequacies in the training of its staff in this particular scientific discipline. If I did not know so many of the scientific staff personally and had to base my judgement of the quality of their scientific thinking only on the evidence to be found in the files dealing with experiments, I must in all frankness, say that I should certainly be gravely concerned for the future.

It would be invidious of me to quote specific examples from the files as I had originally intended to. But believe me when I say that we have documents which are undated, booklets which are anonymous, figures than mean nothing. We have graphs for which the scales are not properly shown and quantities which are given without units. Certain techniques are indicated by title only and are presumably passed on to successive workers like many a mediaeval craft. Objects are stated which are not objects and treatments which are not treatments. Statements on the files contradict statements on committee papers and even these may be at variance with the statements in the appendices. But all these issues are dwarfed by one consideration - what precisely are the experiments about anyway?

As I have said already, it is of course very easy to criticise. But because of that very fact, the field biologist must guard against criticism. The best way of doing this is to be highly critical of one's own work.

THEORIES AND MODELS FOR GRAZING

P.H. Cryer

Summary

Persistent use of scientific method, both in research and in management problems, is essential if any substantial value is to be obtained from statistical methods in designing and analysing experiments and surveys. It is suggested that application of scientific method in such problems requires the adoption of an attitude of mind - the Inductive Outlook. Elements of this habit of thought are considered under three headings:

(i) Introspection, (ii) Observation and (iii) Experiment and the systematic development of scientific theories is discussed with special emphasis on the cyclical nature of inductive thought processes.

The characteristics of a scientific theory, including its ability to explain, predict and relate different fields of study are illustrated by the work of Olsen and of Piggott and Taylor on the ecology of the nettle. Some practical suggestions for fostering regular application of scientific method and for facilitating theoretical speculation include (a) the use of models and (b) writing down aims and objects before carrying out the experiments or collecting data from surveys.

Introduction

There are two important aspects of the design and execution of experiments. One of these concerns the layout and arrangements for comparing different experimental treatments. Another, and I believe of fundamental importance, is the adoption of Scientific Method to deal with the problems in which the research originated. Unless experiments are founded in an adequate and effective use of Scientific Method the refined and subtle methods of design and analysis which are available to the statistician can contribute little to advances in knowledge and power. In this paper I want to describe some features of Scientific Method and to suggest ways of fostering its use rather than to discuss technical aspects of any particular statistical method. Some of my contribution may seem simple and obvious but I believe an understanding of Scientific Method to be so essential to fruitful research and effective management that it is worth giving time to its consideration.

It is a commonplace to say that a well developed theory is a key element in determining Policy and for the appropriate Management and Research activities (Fig. 1). Furthermore, these three functions interact and evolve in the light of a growing theoretical framework. The whole complex of administrative decisions and actions required of the Management function in the Nature Conservancy - especially in respect of Nature Reserve management - must be based on scientific theory. Without this theoretical basis it will inevitably deteriorate into a series of arbitrary, ad hoc decisions not necessarily related to reality. It is therefore just as important to apply Scientific Method to management problems as to research, and to ensure that management experience is incorporated into the theory, either directly or via new research. I believe there are two important ways of securing such a development:-

First: By the conscious adoption of a frame of mind and method which I call the "Inductive Outlook".

Second: By the preparation of a written record of all stages in a research project. In particular, by writing down the aims and objects of each experiment and formulating all hypotheses explicitly before any experimental work is attempted.

My ideas are illustrated by examples taken from the literature [C. Olsen (1921); C.D. Piggott and K. Taylor (1964)]. These were chosen mainly to illustrate particular points of methodology, rather than because of any special relevance to this symposium. If I have not always given these the correct biological interpretation I hope nevertheless they will be useful illustrations.

2. Scientific Method and Development of Theories

2. (i) The Inductive Outlook

I regard the use of Scientific Method as being dependent, essentially, on an attitude of mind which involves a tendency to organise knowledge in a logical system combined with the habit of testing ideas and tempering theory by experience. This attitude of mind (which I call the Inductive Outlook) comprises three elements:-

(1) Introspection - Theorising
(2) Observation - Recognition of significant phenomena.
(3) Experiment - Testing ideas by experiment.

Introspection: This is the organisation of experience and observation into a theoretical framework. In its most highly developed forms such a framework comprises a hierarchy of statements involving abstract concepts in the highest levels of the system. Statements in different levels in the system may be deduced from the statements in higher levels of the system; at some stage there are rules of correspondence connecting abstract non-instantial concepts with observable entities. Newtonian mechanics is one example of such a system and Mendelian genetics is another. However, much simpler theoretical systems are possible and can be just as useful in stimulating and making possible the second element of the Inductive Outlook.

Observation: This has been described by Professor G.A. Barnard in a slightly different context (F.J. Anscombe 1963) as ".. recognising significant phenomena ...". It depends very much on the ideas and concepts present in the mind of the observer, as is shown by the following examples:

(i) Fleming's work on the antibiotic substances produced by the Penicillium mould was started by his observation of the inhibition of bacterial growth on an agar plate, following its accidental contamination by the mould. (A. Fleming, 1929). This had been seen by other observers previously (Tyndall, Pasteur and Joubert for example) but it was left to Fleming to interpret the phenomena and to realise their theoretical significance. It seems that the failure of all efforts to consolidate these earlier observations must have been due to a lack of microbiological and chemical knowledge with the accompanying imperfections in experimental techniques. (D. Papp - 1954).

(ii) In the course of researches on the distribution of the nettle, C. Olsen (1921) studied the influence of mineral salts in the soil on this distribution. Soil samples from sites where nettles grew and from adjacent positions with no nettles were assayed for nitrate, water and pH. Other mineral elements were also determined for a limited selection of these samples and among these subsidiary observations Olsen noted some which pointed to the importance of phosphate for the growth of the nettle. However, although he remarked that

"..... where the quantity of phosphoric acid is smaller than 2.6 mg. no nettle is found ...."

he failed to recognise the primary importance of this factor in limiting the distribution of the nettle. This was due, at least in part, to pre-occupation with the importance of nitrate as a factor. These examples show how the framework of ideas and concepts present to the observer influence his ability to recognise the significance of phenomena.

The third element of the Inductive Outlook is Experiment - testing ideas and hypotheses derived from the interaction of Introspection and Observation. The essence of such experiments is that they should be critical in the sense that they can lead to rejection of some hypothesis. In order to obtain critical experiments, the logical consequences of the alternative possibilities implied in the hypothesis - together with the accepted theory - must be carefully deduced. The hypothesis must be such that only a limited number of quite definite possible results could arise from the experiment, given the truth of the hypothesis. If none of these possible results actually occur when the experiment is carried out, the hypothesis must be rejected.

With a quantitative theory, such as Mendel's theory of genetics, numerical predictions may be made for the results of an experiment (e.g. in a back-cross of varieties with two dominant characteristics a definite ratio of types should be obtained.) This leads to a relatively more severe test of the theory than when qualitative outcomes are involved.

A simple example of a critical experiment is seen in Piggott and Taylor's work on the distribution of the nettle (loc.cit.). Olsen postulated that nettles require an adequate supply of nitrate for growth and suggested that they are limited in their distribution by this factor. He showed that nettles grown in sand with a solution of mineral salts showed a clear response to increments of nitrate. However, these experiments do not show that nitrate is a limiting factor. Piggott and Taylor suggested growth experiments in soil which does not normally support the nettle. They obtained soil which did not support nettles, from sites in a number of woodlands although the plants were growing on adjacent sites. Seedlings of nettles failed to grow in these soils in laboratory conditions even with the addition of nitrate to the soil. The hypothesis that the nettle is limited in distribution by availability of nitrate is thus rejected. This experiment is critical in the sense intended above, since on Olson's hypothesis, addition of nitrate to these "deficient" soils should lead to growth of the nettle.

2. (ii) Development of Scientific Theories

The Inductive Outlook is an attitude of mind rather than a systematic procedure, involving as it does a tendency to speculate and organise observations into a theoretical system - even though this may be of a simple rudimentary kind. There are two reasons for analysing and studying the process of induction. One of these is to justify the use of the process and to relate it to other modes of reasoning. The other is to improve one's practise of scientific method by obtaining some insight into the reasoning and processes involved. The following account is intended to serve the second purpose - it is admittedly highly simplified and abbreviated.

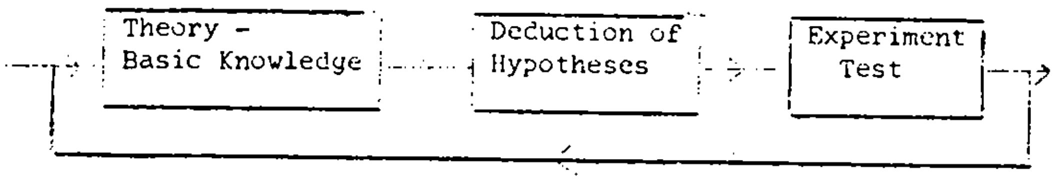
Two approaches may be seen in the methods used in scientific research, although it may be argued that the first of these is merely a varient of the second. On the one hand there is a process of generalisation from experience - a "one way only" process.

Collection of data → Search for Patterns → Generalisation.

This procedure suffers from a number of limitations and although in some situations its use cannot be avoided it is important to appreciate these limitations. The most serious of these is, I believe, that the method cannot lead to abstract, theoretical concepts. Thus Olsen's work on the nettle involved a survey of this sort, covering a variety of sites some of which supported nettles and some did not. Measurements of nitrate, water-content and pH were obtained and light intensities were recorded at each site. It is true that Olsen had some theoretical ideas relating nitrate concentration to the structure, moisture content and pH of the soil but his main reason for choosing to investigate nitrate was the existence of statements in previous literature that Urtica dioica is a nitrate-plant. This survey was supplemented by studies of other elements and salts in a limited number of sites only. His conclusions were thus limited

(i) by the data recorded at each site and
(ii) to the particular sites which were included in the survey.

This limitation of the scope of generalisations from the data and sample is typical of the "one way only" process. In order to introduce theoretical concepts into a system and to provide a basis for more general applications it is necessary to use a cyclical process - "Cycles of Induction". This is a more accurate reflection of the way in which we learn from experience and incorporates theoretical ideas from the outset.



This diagram should be understood to represent a single step in the process of developing a theory. Theory from previous work, together with new concepts are used in deducing one or more hypotheses. These are constructed so that they may be subjected to a critical experimental test. If one or more of these hypotheses in rejected some modification must be introduced into the theory; if all are accepted the theory (as modified for this experiment) is provisionally accepted and must be tested in other ways. Thus after each experiment a return is made to the theoretical framework and at any stage in the process this may be falsified by rejection of one hypothesis. It is not difficult to see how such a process involving cycles of induction is related to the hierarchical structure of theories mentioned in p. 2 (i). The process can be traced in the work of Piggott and Taylor.

Three phases can be distinguished in this work, each involving a number of individual tests of the hypotheses (see Fig 2) some of which are outlined below. For a more detailed account, reference should be made to Piggott and Taylor's original paper.

(i) The first of these was based on ideas and conclusions derived from Olsen's work and involved studies of the part played by nitrates in the growth of nettles, with some observations on the importance of phosphate. Measurements were made of the storage of nitrogen and phosphorus in the aerial shoots of nettles and associated species throughout a growth season. These showed that much larger quantities of these elements were utilised by nettles than by Mercurialis perennis or by Deschampsia caespitosa. Then the total organic nitrogen, and production of ammonia and nitrate was studied in samples of soil taken from adjacent sites dominated respectively by nettles, D. caespitosa and M. perennis. There was little difference between these soils in these respects and such differences as were noted were thought unlikely to prevent establishment of the nettle. The third series of experiments in this phase were designed to test the hypothesis that distribution of the nettle depended on available nitrogen. This was carried out, as mentioned above, by attempting to grow nettles in a variety of soil samples taken from sites in Derbyshire and in Cambridgeshire, which did not normally support the nettle. Addition of nitrate to these soils did not lead to growth of the nettle and in some cases resulted in a reduction in growth. In contrast, addition of phosphate, with or without addition of nitrogen, resulted in vigorous growth on all soils. The main result of this first phase was rejection of Olsen's original idea and indicated the importance of phosphate to the growth of the nettle.

(ii) In the second part of this work the idea that growth depends on the availability of nitrogen and phosphorus as mineral salts was tested. A variety of woodland species including nettles, M. perennis, Brachypodium silvaticum and D. caespitosa, were grown in glasshouse conditions in soil collected from under M. perennis. These culture experiments showed that other species in addition to U-dioica were sensitive to deficiency of phosphate, all of which showed hardly any response to addition of nitrogen alone. In some cases there was an apparent positive interaction between nitrogen and phosphorus (most marked with Galium aparine). Field experiments formed part of this second phase of the investigation and these were set up to examine the response of nettles to additional phosphate on soils which normally supported M. perennis. These were sited in woodlands in Cambridgeshire and in Derbyshire and some variation was provided in the amount of shade (i.e. light intensity) at each location. These experiments confirmed previous observations of the importance of phosphate for growth of the nettle and in addition showed the importance of light intensity as a factor of growth.

It was concluded, after these two stages of the investigation that "except in deep shade the failure of Urtica dioica and at least some of its common associates to become established in sites dominated by Mercurialis perennis or Deschampsia caespitosa must be attributed to the low supply of available phosphate in the surface soil ...". In a third stage of the research this theory was further tested by a hypothesis deduced from the theory. It was known that in spite of the deficiency of phosphate in protorendzina or mull soils under Mercurialis, the total phosphorus content of the soil was generally about 30 - 80 mg. per 100g. dry soil. Much of this phosphorus was considered to be bound in organic matter so that if the soil was ignited or scorched, phosphate would be formed. Such soil should then support the growth of nettles and it was found that the ignited soil itself, or when added to deficient soil, did have this property. This final experiment thus provides additional support for the theory since the hypothesis deduced from the theory was not rejected. If, on the other hand, the ignited soil had not allowed growth of the nettles, the phosphate theory would have required some modification.

Each phase in this work was based on the theoretical idea that growth of the nettle and associated plants is dependent on availability of minimal supplies of certain minerals in the soils in which the seeds were planted. The observation that growth of the nettle is also influenced by intensity of light (first recorded by Olsen and noted also by Piggott and Taylor in some of their later field experiments) shows that this "minimal mineral availability" theory does not account for all the facts.

2. (iii) Characteristics of a Good theory

What features should be present in a theory which has developed from a succession of cycles of induction? Such a theory should

- Explain all the observations;
- Predict relationships;
- Relate the particular study to other fields of interest.

Thus in Piggott and Taylor's work on the nettle the theory finally adopted besides providing an explanation for the failure of nettles to grow at certain sites is also able to explain the characteristic distribution of the plant. Piggott and Taylor point out that the conditions at typical sites which support nettles - burnt ground; ground contaminated with animal faeces; sites of woodland fires; sites with decaying brushwood and shallow feeding roots of trees - are all sources of phosphorous.

Then again Piggott and Taylor's theory would predict that if soil containing phosphorus bound in organic compounds is ignited so that phosphate is formed in the soil, the ignited soil should allow the growth of nettles. As described above this prediction was borne out by an experiment with ignited soil from under M. perennis.

A satisfactory theory should relate studies in one field of work to another. In this respect the work described in Piggott and Taylor's paper is not satisfactory, and questions arise about the mode of action of phosphate. The answers to these questions might show how their work could be related to the biochemistry and physiology of plant growth. One might speculate, for instance, that plants vary in the amount of nutrient material stored in their seeds, and thus have different requirements, both for inorganic ions from the soil and for intensity of radiation. It seems possible that any given plant has to achieve a certain minimum initial rate of growth in order to become established - to overcome, as it were, an energy barrier in order to grow on. These and similar speculations suggest further lines for research to widen the theoretical basis of the explanation for the distribution of nettles to a theory including other species in its scope. This might be expected to show why differing supplies of inorganic ions are required for different species and to explain the importance of radiation intensity in quantitative terms.

The great importance of theoretical, abstract concepts in a theory can now be seen: not only do these provide a starting point for a particular cycle of induction within a given field of study but they also provide the link between different studies. When one sequence of experiments (cycles of induction) leads to a development in the underlying theory, this development must be applied and tested in other related fields, with new sequences of deduction and experiment. In this way a theoretical idea is continually subject to modification or rejection in the light of a succession of critical experiments. A theory which survives many such cycles of experiments, perhaps with modifications, acquires great predictive power and enhanced plausibility.

3. Models and Hypotheses

Two practical suggestions can be made to encourage the adoption of the Inductive Outlook and to promote fruitful experimentation on the lines discussed above. The first of these is about the use of "models" in order to make theoretical arguments easier to carry out. The second concerns the importance of writing down aims and formulating hypotheses before carrying out experiments.

In the terminology of biometrics a "model" is any set of concepts, having the same logical structure as the associated theory which is easier to use in making deductions. Models may often be represented in pictures and diagrams and frequently provide the most convenient way of thinking about the structure of a theory. As an illustration of a good model one may consider the representation for organic chemistry of carbon atoms as having valencies orientated in 3-dimensional space like the lines joining the centre of gravity of a regular tetrahedron to its vertices. Again, genes may be represented according to Mendelian theory, as particles located in definite positions on a linear chromosome. The purpose of these models is to concentrate attention on those features of a situation which are the essence of its logical structure, avoiding and ignoring all irrelevant factors.

It is often possible to give a model a quantitative interpretation: in this case deductions about the system may be given mathematical form. Not only does this lead to more precision in reasoning but quantitative predictions are made possible. This is not an essential characteristic and models of a quite simple kind may be useful and stimulate ideas about the theory. It is always necessary to remember, however, that a model is not identical with its theory - thinking about a theory in terms of a model is always "as if" thinking. One model may not, therefore, be sufficient for all aspects of a field of study. For example, while the rectilinear ray model for light is useful for problems of reflection and refraction, a wave model becomes necessary for problems arising in connection with diffraction.

A simple model of the general grazing situation is shown in Fig. 3. This is based on suggestions of J. Olson and represents the theory that grazing and the growth of herbage depends on a circulation of energy and matter within the terrestrial environment. Boxes in the diagram represent positions in the system where matter may accumulate and be built-up into living tissue or be degraded to more elementary particles of matter. Transfer occurs between parts of the system according to the arrows between pairs of boxes. Attempts have been made to formulate mathematical models of processes similar to these: with many "boxes" where accumulation is possible such models may be difficult to manipulate (see J. Olson 1964). One of the most useful functions of a quantitative model is the guidance it gives in deciding how to represent a complex system by the values of a few variables. Quantitative models also help in the design and analysis of experimental results. In all the above discussion of models, whether quantitative or not, it is implied that some theoretical structure is embodied in the model. When as may be found sometimes, a particular model is chosen arbitrarily, this is only of use for interpolation and is not suitable for prediction.

There are two main reasons for recommending experimenters to write down the objects of an experiment and to specify explicitly any hypotheses before doing experimental work. First, this is a valuable spur to thought and calculations based on the theory. It helps in devising critical experiments and in deciding on the observations which should be collected. Second, by this means one can avoid the trap of "data-snooping", i.e. using the same data to suggest a hypothesis and then to test it. Besides these considerations, it is necessary to define objects and express hypotheses explicitly when deciding how to arrange experimental treatments within given plots and in connection with any sampling which might be required.

4. Conclusions

Although the Inductive Outlook has been considered mainly in terms of experimental work it is clearly just as desirable in connection with management problems. An adequate framework of theory is essential for this function and the use of models and pictures just as helpful with its particular problems.

The ideas presented in paras. 2 and 3 may be summarised under four headings:

(1) Policy making, Management and Research should be integrated by an adequate Scientific Theory. The adoption of the Inductive Outlook in each of these functions will stimulate and promote this integration.

(2) The Inductive Outlook comprises

Introspection	-	theorising; speculation.
Observation	-	recognising significant phenomena
Experiment	-	testing and tempering theories.

(3) Models are indispensable aids to the use of theory in management and in research.

(4) The aims and objects of an experiment should be written down and hypotheses formulated explicitly <u>before</u> any experimental work is commenced.

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FIGURE 1

THEORY IN RESEARCH AND MANAGEMENT

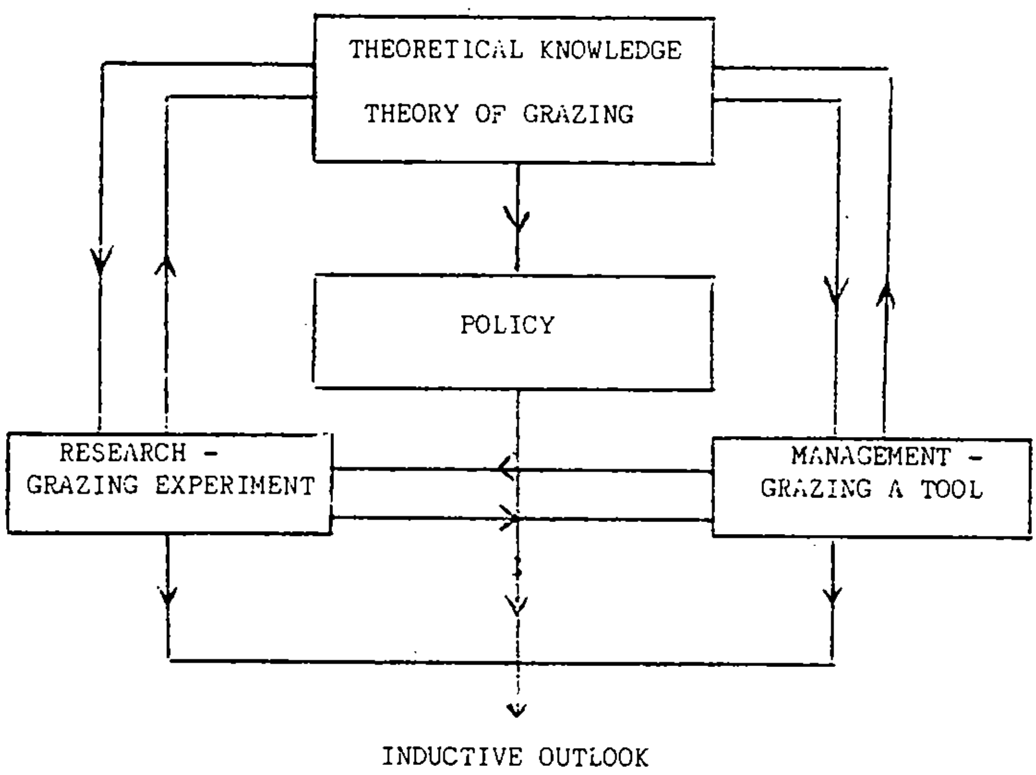
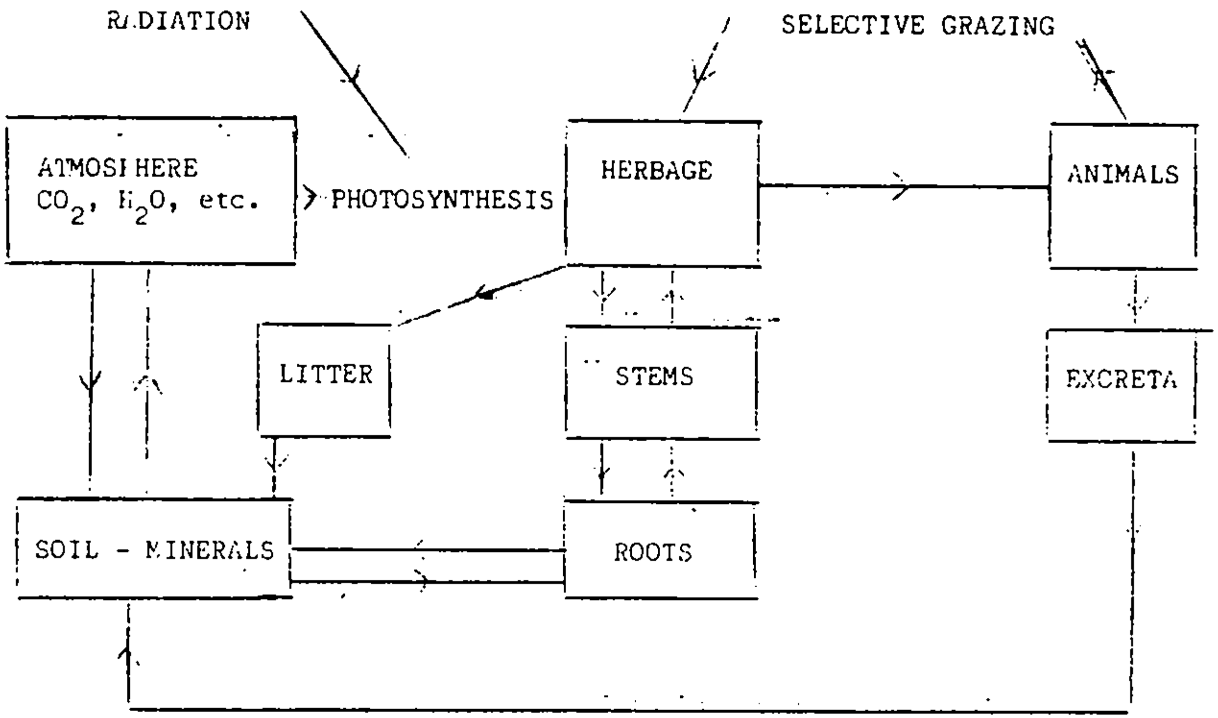


FIGURE 2

CYCLES OF INDUCTION

	1ST PHASE	2ND PHASE	3RD PHASE
THEORY	Olsen's work - Dependence of woodland plant distribution on available minerals in soil	Nettles store more N, P than M. perennis etc. but not limited by N available as NO_3.	Nettles limited by available phosphate and light. Phosphorus in "deficient" soils bound in organic compounds.
HYPOTHESIS	Nettles limited in their distribution by free nitrate in soil	Growth of woodland plants limited by available N and P	Phosphorus in "deficient" soils converted to phosphate by ignition of soil and thus made available.
EXPERIMENTS	1. Use and storage of N and P by U. dioica etc. 2. Availability of nitrogen from different soils. 3. Addition of NO_3 to "deficient" soils.	1. Growth of nettles in soils from woodland sites with added phosphate. 2. Growth of woodland species with addition of N and P. 3. Growth of nettles in "deficient" woodland sites.	1. Growth of nettles in deficient soil with addition of ignited soil. 2. Growth of nettles in ignited soil

FIGURE 3



MODEL FOR GRAZING

THE POWER OF TESTS, AND INFERENCE FROM SMALL SCALE EXPERIMENTS

P. Holgate

By small scale experiment, in this context, I do not mean those which take only a small amount of effort, but those in which the amount of replication of the treatments is small. In fact, one of the points I bring out is that much work can be expended on work which is incapable, because of the small scale on which replication takes place, without leading to any useful results. In cases like these, waste of effort could be avoided by the use of the theory of the power of statistical tests.

The use of the term "statistics" to describe the application of mathematics to biological experimentation is unfortunate, and I much prefer the term "applied probability". It is commonplace to complain of the high variability of the material with which ecologists have to work, and it is generally accepted that this makes it necessary to call on the related branches of applied probability theory known as "experimental design" and "statistical inference" in the planning and interpretation of experiments.

While these should be familiar to any ecologist contemplating an experiment, the theory of power may be less well known. I describe the elements of it here, concentrating on experiments laid out in simple randomised blocks, and illustrate its importance by reference to the results of an experiment recently carried out in the Nature Conservancy.

Before discussing the theory, I present part of the results of the experiment, which was to investigate the effects of different treatments intended to control the growth of bracken on Cannock Chase. It comprised three blocks, in each of which were three plots to which the three treatments were assigned at random. Table 1 gives the number of bracken fronds counted in each plot. I should point out that the data refers to an early stage in the experiment when a treatment cannot have been expected to have produced a result.

Table 1.

Treatment Block	X	Y	Z	Block means
A	1523	1517	1502	1514
B	3821	3625	4103	$3849\frac{2}{3}$
C	972	1298	1188	$1152\frac{2}{3}$
Treatment means	$2105\frac{1}{3}$	$2146\frac{2}{3}$	$2264\frac{1}{3}$	General mean 2172 1/9

The model assumed in an experiment of this type is that the number of fronds is the sum of four terms: (i) a general effect independent of block or treatment, (ii) a block effect, (iii) a treatment effect, and (iv) a residual random component which is normally distributed about its zero mean, and for which the realised value is independent in each plot, and which is taken to account for all variable factors which could conceivably affect the growth of bracken, which are not accounted for by block and treatment effects.

From the above results it is possible to estimate the effects involved. Clearly the estimate of the overall effect is the general mean 2172 1/9. The estimate of the effect of being in Block A, say is the difference between the mean for that block, 1514 and the general mean of 2172 1/9, i.e. it is -658 1/9. Similarly the effects of each block and treatment can be estimated, and the results are given in Table 2.

Table 2

	Block effects		Treatment effects
A	-658 1/9	X	-66 7/9
B	+ 1677 5/9	Y	-25 4/9
C	- 1094 4/9	Z	+92 2/9

From these results it is possible to reconstruct estimates of what the reading would be in each plot, if it were not subject to the random "error" component. For instance for the plot in block A, receiving treatment X, the estimate is the sum of the general mean, the effect of block A, and the effect of treatment X. The values obtained are given in Table 3.

Table 3

Treatment Block	X	Y	Z
A	1447 2/9	1488 5/9	1606 2/9
B	3782 8/9	3824 2/9	3941 8/9
C	1085 8/9	1127 2/9	1244 8/9

If the values of Table 3 are subtracted from the observations in Table 1, we are left with the residuals, the parts of the observations which cannot be explained by the factors that have been taken into account. These are given in Table 4.

Table 4

Treatment Block	X	Y	Z
A	+75 7/9	+28 4/9	-104 2/9
B	+38 1/9	-199 2/9	+161 1/9
C	-113 8/9	+170 7/9	-56 8/9

I have analysed this data at length to try to convey the point that "high variability in the material" is not just a vague term or excuse, but something which can be studied numerically. In the present case we see that after allowing for treatment and block effects, even after being as favourable to the data as possible by estimating these effects from the observations themselves, the number of fronds may be say 100 out in either direction, from what would be expected in view of the block and treatment effects. This estimation means that when the standard deviation of the random component is estimated, the sum of squares of quantities in Table 4 has to be divided by 4 rather than 9 before taking the square root, since 5 degrees of freedom have been lost. The answer is just over 180.

The Neyman-Pearson theory of statistical tests provides a way in which the responses to treatments applied during an experiment can be compared with the internal variability of the material so as to give the experimenter an idea as to whether these differences might have arisen as a result of chance fluctuations, or whether they are sufficiently large that he can assert that since there was say only 5% probability of getting such a decisive result in the absence of real differences, he accepts, "at the 5% level", that there are real differences.

The theory of power functions, introduced by Neyman and Pearson in a series of papers during the thirties, (1) - (3), and described well by Kendall and Stuart (4), is concerned with the following problem. Suppose an experimenter is working at a 5% significance level, and that there are certain real differences between his treatments. What is the probability that in a given experiment the observed results will be sufficiently decisive for him to detect these real differences?

The mathematical problems involved are generally very difficult, and have to be worked out for each test. However, for several types of experiment leading to an analysis of variance, the power can be read off from a series of charts provided in a paper by Pearson and Hartley, (5). Randomised blocks are dealt with in their section (4.2). To compute the power it is necessary to know the standard deviation of the residual component which will be denoted by , and the actual treatment means which will be denoted by Ti. Suppose there are h treatments and k blocks. All that is required is to compute the sum of squared deviations of the Ti about their mean $\bar{T}$

$$S = Ti^2 - h\bar{T}^2$$

and then calculate

$$\emptyset \quad \underline{1} \quad \frac{k}{h} S$$

Let v_1 be the number of degrees of freedom in the numerator of the variance ratio (one less than the number of treatments), and v_2 the number of degrees of freedom on which the residual mean square is based. Pearson and Hartley provide separate charts for each value of V_1 from 1 to 8. The correct curve for the value of V_2 is then selected, and where it meets the vertical line for the calculated value of ϕ, the power can be read off on the left hand scale.

Of course, the standard error may not be known, and the treatment effects are unknown or the experiment would not be being conducted. However, an idea of σ can often be gained from other studies. It is certainly often worth while conducting a preliminary experiment simply to estimate this factor. For the Ti, the experimenter should put into the calculation a whole series of values representing both pessimistic and optimistic forecasts of what real treatment differences there are likely to be. For each case he will be able to answer the question, what is the chance that the experiment will reveal these differences?

The use of the charts is illustrated by the bracken experiment. Assume that $\sigma = 180$. We have $h = k = 3$. One treatment was a control, and I suppose that each of the others had reduced the number of bracken fronds per ten square yards by A and B respectively, as an overall average. Table 5 gives the chance that, in the presence of so much randomness, the superiorities of A and B would have been detected.

Table 5

A / B	300	400	500	600	700	800
100	.26	.45	.65	.81	.91	.96
200	.26	.42	.60	.77	.89	.95
300	.33	.45	.60	.76	.86	.94
400		.54	.65	.76	.86	.94
500			.73	.77	.89	.94
600				.86	.91	.95
700					.94	.96
800						.98

This table illustrates the dangers of small scale experimentation. Suppose the overall effects of treatments A and B are to reduce the numbers of fronds by 300 per plot. There is only one chance in three of detecting what is clearly an important effect. Even if they both caused an overall reduction of 400 fronds per plot the chance of detection of only just greater than a half.

The lay out of the bracken control experiment illustrates the interaction between mathematical ideas and biology. After considering the planned experiment and with a rough idea of the variability, a certain size experiment was recommended. This was halved on "practical" grounds at the outset, and halved again in the process of being carried out, leaving three blocks of three. Although I have described the data on bracken fronds, measurements were also made on several other variables. Not surprisingly, most of these failed to give significant results, probably because of the smallness of the experiment, and the outcome of three years of substantial work has been to prove that if you cut down all the bracken in a ten yard square and seed it with heather, you definitely get less bracken the following year.

In thinking about grazing experiments with the above ideas in mind, and being conscious of the expense of these experiments even when carried out on a hopelessly inadequate scale, I am forced to the conclusion that formal experiments are not likely to be a fruitful source of knowledge at the present stage, and I recommend some other line of approach such as large scale surveys of grazing practice.

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THE NEED FOR COLLABORATION BETWEEN EXPERIMENTER AND STATISTICIAN

M.D. Mountford

The severity of the biometrical requirements for successful grazing experimentation imposes on the experimenter the necessity of a keen awareness of statistical considerations. The experimenter should consult the Biometrics Section at the outset, at the early planning stage of the experiment. The collaboration between the experimenter and the statistician should be close and two-way: the statistician can produce worthwhile advice only if he understands the biological aspects of the experiment; the experimenter will rarely make the most of his resources without the application of statistical methods and principles. The success of the experimenter in answering the questions he sets himself, within a fixed budget of time and money, depends largely on the right choice of statistical methods. The decisions on the size of the experiments, the number and the nature of the treatments the amount of replication, are too often decided solely by the experimenter; he calls for statistical advice only on the finer details of the planning and on the analysis of the results. Often the experimenter has only a rudimentary knowledge of the power of the statistical methods and yet is unaware of serious consequences of his deficiency; he does not realise that his experiment can be considerably imporved by a little statistical ingenuity with no extra cost in time and labour. For example many experiments are planned without the experimenter appreciating the usefulness of a factorial design in improving efficiency.

When setting up an experiment the experimenter first must, as closely as possible, define the problem which led up to the experiment. He must then define the objectives of the experiment. Though it is not always possible to define precisely the aims of the experiment, if the experimenter asks vague questions, he must expect vague answers from the experiment.

The experimenter, in collaboration with the statistician, must then give an exact documentation of the different treatments to be included in the experiment. The important criterion in the selection of treatments in their relevance to the field to which the results will be applied; in grazing trials, questions of whether comparisons made between small paddocks are relevant to ordinary grazing conditions need to be carefully considered.

But to have treatments and size of plots relevant to the problem under consideration, sometimes means that the proposed experiment is too costly. Whether or not an experiment is worth setting up depends on the precision of the estimation and on the money and effort allocated to the experiment. Some idea of the precision of the experiment may be obtained either from a preliminary trial or from the data of previous experiments in the same field of study.

The cost of the experiment needs a close consideration. The measurement of the cost of such different items as time, labour, materials on a single scale is difficult and approximate. However even a rough approximation can be enormously helpful in maximising the return on expense. When the total cost of the available resources is determined it can be used to determine the best allocation of treatments to plots. In the simple example of an experiment in which the cost is determined by the treatment, the maximum precision is obtained by replicating the jth treatment by a number proportional to

$$1/\sqrt{C_j}$$

where C_j is the cost per plot of the jth treatment. After deciding on the amount of treatment replication, the experimenter must allot the treatments to the plots by a random procedure. The results can be given a valid interpretation only when some form of randomization has been included in the design. If there is no randomization the analysis will depend for its validity upon personal judgement rather than statistical theory.

In his initial documentation of the experiment, the experimenter must specify the measurements and the records to be made on each plot. The choice of measurement should be based on its relevance to the aims of experiment: for example it is of little value in an experiment relating the weight of vegetation to grazing regime to sample the vegetation by pointquadrat readings.

DISCUSSION FOLLOWING MESSRS. SKELLAM, CRYER, HOLGATE AND MOUNTFORD'S PAPERS

Dr. Mellanby opened the discussion by agreeing that in all well conducted scientific experiments the thought processes and cycles of induction which Mr. Skellam and Mr. Cryer had expounded as being the basis of the scientific method were essential and often overlooked. In all long term ecological research, in which teams of people often worked together, it was essential that the objectives of the experiment, methods of evaluation and ways of analysing the results were clearly thought out and written down before beginning the experiment. Dr. Duffey noted that most of the remarks made by the speakers had been orientated towards the research worker, but he thought that the same principles should be applied to the planning of research programmes. Other research organisations had a planned research policy based on the needs and functions of the organisation and it was thought that with the body of experience which the Conservancy now had, a planned programme of research which embraced the many facets of conservation was required and essential.

A shortage of funds and manpower was suggested by some people as the reason for the few management experiments that had been done, while others thought that the limiting factor may have been that ideas had not been developed to the full. Further controversy was evoked by the statement that many of the research staff worked under a handicap of academic tradition, choosing a line of fundamental research when many of the Conservancy's commitments required a more simple approach related to practical management. This statement met with severe opposition from some members at the meeting, who felt that precisely the opposite was true.

Experience had shown that the distinction between simple management treatments and true scientific experiments had become blurred, and it was suggested that it would be better to use the term "trial" for work which did not allow the use of normal statistical methods.

CONTROL OF VEGETATION BY GRAZING PROJECT - ASTON ROWANT N.N.R. A CONSIDERATION OF SOME OF THE PROBLEMS ARISING FROM THE USE OF SHEEP AS A GRAZING 'TOOL'.

M.J. Woodman

Introduction

This paper is an outline of some of the problems which faced the Southern Regional staff in operating their part of the Control of Vegetation by Grazing Project on the Aston Rowant National Nature Reserve.

First we would wish to say that we formed part of a team drawn both from the Research and Conservation Branches, and that much of the success of the project so far is due to the co-operation of all concerned, although individual views have occasionally conflicted. We are also deeply indebted for the help given by the Advisory Committee under the distinguished chairmanship of Dr. F. Fraser Darling.

The chalk grasslands of Britain have provided some of the most interesting floral and faunal associations in the country. Under traditional farming systems, a short sward with an abundance of species was produced by sheep specially chosen for chalkland conditoins and by the grazing of rabbits. However with changes in agricultural practice and periodic outbreaks of myxomatosis since 1954, the grazing on many chalk grasslands has been reduced. Consequently the growth of coarse grasses and scrub species has proceeded unchecked, resulting in a much less interesting flora and fauna.

The grazing project, which is the first of its kind, initiated by the Conservancy, was set up to examine certain aspects of these problems by comparing the effects of different sheep grazing intensities on the composition of the sward.

1. Policy

(i) Resources

The proper management of a Reserve depends on (i) the presence of a full-time Warden who is a member of the Conservancy staff and (ii) on the guidance and direction the Reserve receives from the Regional Officer, who has the necessary administrative structure to carry out this function. These requirements have only begun to be met in the past few years, and much remains to be done.

Again it is only recently that the necessary finance needed for management has been made available. Many discussions, both formal and informal have sought a scientific basis for conservation management and research, but these theoretical considerations can only go so far. Ultimately hypotheses must be tested in the field by trial and experiment. All these problems were recognized by the Regional staff, who have contributed where possible to their solution. Thus the initiation of the Control of Vegetation by Grazing Project (CVGP) represents an important stage in the development of conservation management.

(ii) Other experience

There was little or no experience either within the Conservancy or outside, which could assist in the formulation of this particular project. Organisations like the Grassland Research Institute, Hurley, have carried out similar projects but as their aims are usually directed towards grassland improvement and productivity their experience was not really relevant. However, Mr. Alder, Head of Dept. Animal Agronomy at the Institute is member of the Advisory Committee (See below). Several Naturalists Trusts have similar problems, but their experience and resources were less than that of the Conservancy. The Society for the Promotion of Nature Reserves had been conducting similar grazing and mowing trials on their own Reserve at Dancer's End, near Tring, which are now supported by a contract with the Conservancy (awarded 1st April, 1964). Close liaison was maintained by the Warden/Naturalist Oxfordshire who attended the S.P.N.R. management committee meetings.

(iii) Management Plan

The Reserve Management Plan (J.H. Hemsley and M.J. Woodman, February 1960) stipulates as its conservation objectives, the conservation of the chalk grassland - scrub - woodland sere, and also the retention of a representative sample of open chalk grassland. In the Management Plan, under the section headed "research objectives" it was suggested that the setting up of a series of grazed/ungrazed plots for future recording of grazing effects upon the grassland should be set up. While it was possible to remain within the remit of the Plan with respect to examining the effects of grazing, it was clear that the project would take up most of the existing chalk grassland within the declared Reserve. This experimental use could conflict with the retention of sample grassland.

This difficulty stimulated further efforts to acquire more grassland in the P.N.N.R. along the south eastern edge of the declared Reserve, which have resulted in the negotiations for the acquisition of a further 35 acres now nearing completion.

(iv) Aim of Project

This was finally set down as a comparison of the effects of two intensities of grazing (at 1 and 3 sheep to the acre respectively) on the floristic composition of the sward on three aspects of the grassland at the foot of Beacon Hill. The plots were paired, one for each grazing intensity, on north east, north, and north west facing slopes, together with control plots. The grazing season was to extend from 1st September to 31st May, and the duration of the project was for five years. The vegetation was to be photographed and recorded before and after each grazing season. The warden was also to be instructed to make field notes regularly on the condition of the vegetation during grazing.

2. Public Relations

As the project was the first of its kind its smooth running was one of the vital elements required for success, especially in the first year.

The project was expected to arouse national interest because of the implications of using sheep as a grazing tool, under controlled conditions on chalk grassland. Other National Nature Reserves might benefit from the results, whether we were managing our own sheep or providing precise details of our needs to grazing licensees.

On several occasions distinguished visitors from overseas were shown over the Reserve, so that the project took on an international significance.

In the initial stages of the project it was most important to obtain the good will of local interests.

A great deal of the Regional staff's time was taken up informing our neighbours of our intentions, and ensuring that we were seen to be responsible and humane in the conduct of the grazing project.

The local Hunt was restricted in its use of the Reserve, and the need for visitors to keep their dogs under control emphasized. One of the Honorary Wardens was a local councillor, and this facilitated the support of local government.

University Scientists from Reading and Oxford and the Buckinghamshire, Berkshire and Oxfordshire Naturalists' Trust (B.B.O.N.T.) were kept informed, and representatives invited to serve on the Advisory Committee.

A Voluntary Warden Service was set up to assist the Warden and Warden/Naturalist in watching over the project and in guiding public interest.

Finally an article by the Warden/Naturalist in the leading county newspaper the 'Oxford Times", set out our aims and methods simply and clearly for the public to understand.

3. Organisation

(i) Finance

This was met from Nature Conservancy funds.

(ii) Staffing

It was essential that the Conservancy Staff responsible for the day to day running of the project were both trained scientists and agriculturists. In this we were fortunate that the Warden/Naturalist was a trained agriculturist and that the Warden had practical experience and training in agriculture.

especially with sheep. Trained sheep dogs were necessary and again we were fortunate in the Warden possessing two of these animals.

One of our Honorary Wardens is a local farmer, and has on several occasions looked after the stock in the unavoidable absence of the Warden.

Section (iv) and (v) below show the wealth of practical advice and experience which were readily available in the Advisory Committee and Scientific Staff Panel.

(iii) Logistics - Phasing of Operations and Assembly of Materials

In working to a definite date when the sheep were to be introduced to the grazing plots, it was necessary to plan the various operations so that all would be ready in time. The Land Agents' Section were deeply involved at this stage with the Regional Staff. Scrub had to be cleared to make way for new fence lines, after surveying. Farm equipment was purchased mostly at sales, and included troughs, hurdles and weighing machine. During this period botanical surveys were made by the Conservation Research Section. Fencing was carried out under contract, and sheep purchased. The latter were held nearby until the grazing plots were ready. Arrangements were also made to provide a holding area for the sheep when they were taken off the plots during the grazing period because of bad weather.

(iv) Specialist Advice

This was thought necessary in view of possible difficulties that might arise from the unique nature of the project. Therefore an Advisory Committee was established under the chairmanship of Dr. Fraser-Darling, member of the Scientific Policy Committee. Committee members included Mr. F.C. Alder from the Grassland Research Institute, Hurley; Professor A.H. Bunting, Department of Agricultural Botany, University of Reading; Dr. R.H. Clarke, representing the Naturalists' Trust (B.B.O.N.T.); Mr. F.T. Holmes, farmer and Honorary Warden; Dr. F.H. Perring, Monks Wood Experimental Station; The Hon. Miriam Rothschild, S.P.N.R.; Mr. R.K. Sharratt, veterinary surgeon; Dr. F.C. Warburg, Department of Botany University of Oxford. This Committee keeps in touch with the Staff Panel by regular meetings on the Reserve, attended by Dr. J.F.D. Frazer, Conservation Officer, (England), and the Regional Staff. This ensures that their advice is available at the right time and place and accordingly their help has been invaluable. Mr. Sharratt has actively participated in the project by studying the level of parasites in the dung.

(v) Staff Panel: Scientific Control of Project

The Staff Panel is constituted as follows, and emphasizes the team work required to mount such a project. Not the least of the problems were the difficulties in co-ordinating the functions from the various sections, often separated by large distances.

A list of these sections and their duties illustrate the difficulty.

(a) Conservation Branch - Regional Staff, Wareham, Dorset; Thame and Aston Rowant, Oxon.

Day-to-day management of stock, continual observations on stock and vegetation and public relations, including wardening, general administration as required.

(b) Conservation Research Section - Monks Wood Experimental Station

Botanical Recording and analysis of data.

(c) Land Agents Section - London H.Q.

Arrangement of contracts, licences agreements, supervision of estate work, advice on stock and equipment.

(d) Biometrics Section - London H.Q.

Project design and evaluation.

(e) Technical Services - London H.Q.

Photography in connection with recording.

(f) Veterinary Surgeon - Thame

Welfare of stock.

4. Animal Husbandry

The welfare of the stock used in the project was of paramount importance. Although our primary aim was to examine the effects of grazing on the sward, its use as a management technique would be very limited if too much were demanded of the stock. In the event, the stock chosen stood up well to winter grazing conditions although they had to be taken off the experimental plots in February - March owing to insufficient feed. All of the stock came through the winter well and remained healthy, the only damage being a bruised knee-cap on one animal!

(i) Stock

Twenty-two 7-8 month Scotch Half-bred ewe Lambs were used as the best breed, age, sex of sheep for the project. This choice was eminently successful.

(ii) Fencing

Fencing in the experimental plots was erected by the Economic Forestry Group, and by the Warden in the holding area just off the Reserve.

(iii) Feed

The vegetation in the experimental plots provided most of the feed, but when the stock were removed to the holding area, the stock were fed on hay and concentrates purchased locally.

(iv) Water

This was brought in churns in a Land Rover to the troughs in the experimental plots.

(v) Disturbance of Stock

No problems were experienced here and it seems reasonable to assume that the efforts of the Regional Staff and the Voluntary Warden Service played a large part in achieving this result, especially on a Reserve where public pressure could be a problem.

(iv) 'Natural' Hazards

(a) Medical

The sheep were dosed with "Loxon" (against parasites), vaccinated with mixed enteroxaemia vaccine.

(b) Foxes, dogs, etc.

No disturbance or harm from these animals was apparent.

(c) Poisonous Plants

All the experimental plots and the holding area were examined for living and dead yew plants and none were found.

5. The Future

In looking back over the first grazing season, it is obvious that there were many problems but most of these were solved. Many difficulties arose during the initiation of the project and should not recer. The remainder should be capable of solution by the Regional Staff in their routine management of the project, especially in the light of their newly gained experience.

It was agreed at the Advisory Committee meeting (June 1965) that a detailed Soil Survey and the establishment of a small climatological station would enhance the scientific value of the project. These measures with other minor modifications e.g. periodicity of weighing stock, should ensure the successful continuation of the project over the next four years.

GRAZING RIGHTS AND THE AGRICULTURAL HOLDINGS ACT, 1948

D.H. Wood.

In this paper I propose to deal with letting grazing rights and the Agricultural Holdings Act, 1948, in England and Wales.

The art of not creating a tenancy when letting rights for stock owned by one person to graze the land of another began to develop after the passing of the 1923 Agricultural Holdings Act under which licences for less than a year were excluded from the Act and the custom of granting successive 364 day licences came into vogue as a neat means of sidestepping the law whilst enabling the grazier to enjoy his rights over long periods of time.

This simple evasive tactic was finally stopped by the Agriculture Act 1947, which was re-enacted in the 1948 Act and as far as we can tell is unlikely to be available again.

The 1928 Act section 2 with certain exceptions now brings any letting of agricultural land for less than a year to year within the scope of its terms. In letting grazing rights we have to stay with the exceptions otherwise an agricultural tenancy is created under which the tenant will enjoy a security of tenure a wide freedom of use of the land, and rights to compensation when he finally vacates.

The Act does not of itself regulate grazing it merely indicates at which points a tenancy may be created, and as it does not do this very clearly it is inclined to make lawyers and land agents over-cautious lest their sins of omission or commission shall have far greater results than ever were intended.

Section 2 of the Act applies to the grant of a licence to occupy so that the nice distinctions between a letting and a licence become pointless. There is case law to show that a person who has purchased or hired grass keep gets the legal right to use and occupy the land. As grazing is expressly included within the definition of "agriculture", anyone letting grazing rights thus risks creating a tenancy.

As a matter of interest I have never had the experience of receiving a claim for a full agricultural tenancy and in those cases where a grazier could have claimed, for example at Old Winchester Hill where the agreement, in writing, continues from year to year, the person concerned has not done so.

I have dealt with the first effect of the Act, to cause fear, the second effect is to limit freedom of action and the third it to take grazing out of the direct control of the Regional Officer and make it indirect through the Land Agents section, which whilst being a normal situation on a landed estate is not entirely satisfactory when applied to Nature Reserves.

Grazing as a problem frequently met with in our section is almost entirely concerned with the control of vegetation on Reserves resulting from reduction in rabbits, shortage of staff and machinery and, from an agricultural point of view, the uneconomic size or location of the Reserve. The particular requirements of each Reserve as to period, type, and intensity of grazing required often makes reliance on the farmer as a source of stock appear irrational.

When considering a request to let grazing rights we have to bear in mind the following features:-

Firstly the Agricultural Holdings Act. In order to avoid a tenancy only a single period may be offered. The period must not exceed one year, no promises as to further periods may be made, and although successive licences may be granted no action may be indulged that might suggest that further licences will be forthcoming, such as the erection of permanent fences or laying on water supplies by the grazier. Temporary shelter and temporary hurdles are acceptable. Stock and any other property of the grazier must be removed at the end of the period and rights for the Conservancy and its staff to use the land must be reserved.

Secondly the scientific requirement. The most common requirements that we are asked to secure provide that artificial fertilizer and chemical sprays should not be applied, lime is not to be spread and hay should not be brought on to the land although purchased feed in the form of cake or nuts is often acceptable. There is usually a specified time of the year when grazing may or may not be required, and longer grazing seasons seem to be acceptable. The improvement of the land in an agricuttural sense has never in my experience been a requirement. I have listed these so as to contrast with the third feature:- the farmers requirements. The normal and quite natural approach is that the farmer would like the grazing for as long as possible, for successive years and that given security of tenure he would be delighted to invest money to improve the land. He has of course to be disappointed.

Fourthly general practicability, as to adequate water supply and fences, access and the type of stock to be used, our tenure of the land and any covenants or other rights which may affect the proposal.

To succeed therefore the Conservancy must be prepared for some capital investment on water supplies and fencing, and possibly shelters, the farmer must be able to see some financial advantage in using the land, the scientific interest must be safeguarded, the licence must remain outside the terms of the Act, and the land must either be Freehold or the Conservancy must hold it on a lease the terms of which permit the letting of rights.

Other cases arise from time to time where we are put in considerable difficulty. For example where common land is involved, as at Castor

Hanglands, and we are prevented by the Law of Property Act from fencing, or where the purchase of land is made subject to an existing grazing tenant as is the case at Wye and Crundale Reserve.

The rents obtained from letting periodic grazing are quite disproportionate to the work in which Regional and Land Section staff are involved and this work is no less for a small area than for a large.

At the present time some 1,600 acres on twelve Reserves are let on periodic licences in England and Wales and others are under consideration, but this forms only a small part of the total land holding.

Where the scientific requirement is more exacting than those I have alraady mentioned the letting of grazing rights becomes unsatisfactory and it is only where there is grazing of reasonable nutritive value (e.g. Bridgwater Bay Reserve) that the stocking intensity can be raised sufficiently to give the standard of control usually required. On poorer grassland our task is increasingly difficult and any restrictions at all will tend to deter graziers.

From time to time there have been discussions on increased mechanisation and the purchase of stock for use on Nature Reserves both of which in the face of shortages of local labour have their part to play. But they both have severe limitations for controlling the small and scattered areas such as the Conservancy own.

It is outside the scope of this paper to venture into the future of Reserves or the given scientific aspects of each case, but (to generalise) if it is seriously wished to continue grazing regimes with stock that are not owned by the Conservancy then it follows that more consideration will have to be given to pasture improvement either as an inducement to graziers or as a resultant of grazing.

The Conservancy's grazing land has as it were been frozen at a point in time that the average farmer left many years ago, and as agricultural advances are made the demand for rough grazing where improvements to the pasture are not allowed will disappear.

The Agricultural Holdings Act is no friend of Nature Conservation, security of tenure subsidies for draining and improving land amongst many other features are so often incompatible with your requirements that I can see no advantage in granting an agricultural tenancy, apart from the other considerations that this would raise.

Where the letting of rights appears to be the only practical solution I would ask you to consider an acceptance of some agricultural practices. This acceptance may be limited in time, it may be limited to zones on a particular Reserve but it will almost certainly involve fertilisers, its result would I hope be just sufficient to make graziers keener to put their stock on the land in succeeding years.

As I have said the essential point in keeping a grazing licence outside the Act is that it shall be for a single period, of less than one year in extent and that no promise should be made as to the grant of future periods.

There is no bar to the number of successive periods that may be granted and in the case of Scene Estate Ltd. v. Amos there were no less than 21 successive agreements each for a period of 3 months, each complete in itself and making no reference to any possibility of a future extension of the period of letting.

A specified period does not need to be any special season and may stretch over parts of two calendar years.

However once the details of the licence have been settled and the farmer has paid his money he cannot be made to graze the land, since the positive convenants necessary to achieve this would be impractical. He can be made to cut thistles or other named plants but if the period of the licence is short he may well consider that it would not be worth his while and is unlikely to accept such a licence.

On the other hand he may decide that it suits his purpose to stock very heavily and where this is likely we can state in the licence that he is permitted to graze not more than a specified number.

In practice therefore once the grazing is let there is very little control over stock numbers on the land at any one time and extending or shortening the grazing period is not then possible. The period itself will have to suit the farmer.

The type of stock used will depend entirely on those available in the district, sheep and cattle are most common but occasionally graziers wish to put on horses as well. There has been no demand for grazing for anything more exotic.

This lack of flexibility is one of the unsatisfactory aspects of using someone else's stock. The advantages are that it is cheap possibly profitable, we have little if any responsibility for the health and safety of the animals and we use very little capital.

Another aspect of grazing involves the personality of the grazier and if we fall out with him over some matter which is not covered in the licence a difficult situation can develop. An example of this is omitting any reference to a bull in the licence and the grazier promptly puts one on the land.

In my plea that you should consider accepting some agricultural practices my main object is to get competition for the grazing, since if a demand can be created control is more easily imposed. I also have in mind that if you accept grazing in principle then you also accept some improvement in the sward from manuring and tillering, and the logical extension to this is to apply fertilisers or lime where by so doing the particular scientific interest will not be harmed.

To the Land Agents Section grazing is one of many management problems, a visit should always be made to see the land and a meeting held with the prospective grazier and I have always found that personal contact is worth a great deal. This all takes time and I doubt if we devote as much attention to it as we ought to, or would like to. If I can persuade you to look at this problem from the farmers' point of view as well as from that of floristic composition on the Reserve I have hopes that letting grazing rights will continue to prove a useful tool.

Occasionally we meet grazing problems in reverse - In acquiring land the owner may be willing to grant a lease provided that he can retain the grazing and the right to apply fertilisers and lime, or use chemicals to control weeds. Such matters are promptly referred to Regional Staff for advice but the stakes can be high - to secure or lose a Reserve - and not only are there practical issues but the integrity of the future Reserve may be at risk.

I hope that I have been able to indicate some aspects of grazing that may not have been entirely obvious and why in the future its use as a tool of management may be dependent upon the Conservancy's willingness to provide a better diet for stock.

POINTS RAISED IN THE DISCUSSION FOLLOWING MR. WOOD'S PAPER

(i) Whilst the Act has a general application to licences, licences do not have general application to Reserves and have to be tailor made for each case.

(ii) Where grazing rights are let some compromise is usually necessary between scientific interest and the grazier's requirement, bearing in mind the future of the Reserve is no action is taken.

(iii) Rent - generally an economic rent induces graziers to stock fully - this is advantageous as maximum stock numbers can then be controlled.

(iv) In the case of some Reserves it may be possible to acquire additional land in order that stock can be carried, or which can be treated on agricultural lines, making a base from which a Reserve can be grazed.

GRAZING EXPERIMENTS IN SNOWDONIA

J. Dale

1. Introduction

The research programme being conducted at Bangor is concerned with investigations to determine the influence of local variations in rainfall and geology on the soils, vegetation and biological productivity of areas in Snowdonia. To this end work is being carried out at sites located along a rainfall gradient, which runs in an approximately north - south line across North Wales and shows a variation in rainfall ranging from less than forty inches at the drier coastal end up to almost two-hundred inches at the wettest end, centred over the Snowdon massif. Within these experimental areas, are soils derived from both basic and acid igneous rocks, as well as soils derived from glacial deposits and the plant communities associated with these soils include many of those common to upland Britain.

In an area, such as Snowdonia, a factor which is of paramount importance is the grazing animal (in this instance sheep). The agricultural activities of the human race and in this particular area, grazing by sheep, have a profound influence on the ecosystem as a whole. The human influence has been present since prehistoric times but of course its effects have become more pronounced and intense with the passage of time.

The pattern of land settlement and utilisation has been largely determined by environmental factors and there has been conscious selection of areas of high productivity. This selection is perpetuated up to the present day, in that certain areas are more intensely grazed than others, because of the reputation of these areas for producing heavier animals or being capable of carrying larger flocks of animals.

The part played by the combined effect of rainfall, soil type, and vegetation in determining the numbers of grazing animals carried by a particular area is complex and in turn the effect of the grazing animal on the soils and vegetation is equally intricate.

II. A few years ago Dr. Hughes established the broad relationships between the environment of Snowdonian sheepwalks and the population densities of sheep which they carried. In this work Dr. Hughes analysed stock data for nine ecologically distinct groups, based on fifty-five sheepwalks in Snowdonia and the Conway Valley. Seven of these sheepwalks are located within the low or medium rainfall range of the gradient and two within the high rainfall range. This work demonstrated a north-south line of sheep numbers per unit area and it would seem that climate is responsible for this, but soils and vegetation are of importance in areas where the mean annual rainfall is less than a hundred inches. Areas which are substantially Agrostis/Festuca grassland on brown earth soils, derived from basic rocks, were shown to carry the highest number of sheep (viz. 2-2.84 ewe units/acre), whilst areas on podsolic, gley podsolic or peaty podsolic soils, derived from acidic rocks, the population density is substantially smaller, (only 1.3 - 1.7 ewe units/acre). At low rainfall these latter areas are dominated by Calluna vulgaris and at high rainfall, Molinia caerulea and Nardus stricta.

Thus it was considered that the hundred inch isohyet is an important ecological boundary as Dr. Hughes showed a clear difference in sheep numbers above and below this level of rainfall.

III. An extension of this earlier work is the sheep census work which is being carried on at present. This sheep census was initiated in 1956 on a weekly basis. The units of study for the earlier work were whole sheepwalks, but the present sheep census is of the numbers of sheep grazing on particular areas within a sheepwalk. These census units were selected as being uniform, as far as possible, with regard to vegetation and soil type, and these are located along the rainfall gradient mentioned earlier.

The results of this sheep census are being prepared for publication elsewhere, but some generalisations may be made.

1. Differences in soil, vegetation, rainfall and altitude all play some part in determining the stock number per unit area.

2. On the whole the summer sheep population density shows an inverse relationship to altitude, rainfall and the trend towards podsolisation.

3. The census work confirms the earlier observation that sheep preferentially graze those areas where the soils are derived from basic igneous rocks, rather than adjacent areas where the soils are derived from acid igneous rocks.

An investigation into the differential effect of differing levels of grazing has been in train for a number of years. This is being carried on at four sites, which are also sheep census sites. The experiment consists of a randomised block of enclosures covering the following treatments replicated four times:-

(a) open to grazing all year round.
(b) grazing permitted April to October only.
(c) closed to grazing all year round.

At three sites, Cwm Idwal, Pen-y-Pass and Llyn Llydaw, one block of replicates are located on contrasting soil types, a brown earth and podsolic type.

Each year the plots are sampled during the month of August by a point quadrat technique. The accumulated data hitherto, have not been examined in great detail, but at present, consideration is being given to the application of the statistics of information theory to these data. No results of this are available.

A casual observation by eye of these plots after six years, shows that certain plants have become prominent where enclosure has been complete. These changes are dramatic and easily catch the eye, but other more subtle changes have been taking place less noticeably.

In general the observed trends on, say an acid site at Cwm Idwal are the same as those to be observed on an acid site elsewhere. Different locations however, do show differences in particular features notably in the scale of the changes. The same is also true of the trends to be seen in the various basic plots.

The histograms illustrate some of these changes and show examples of acid and basic sites at Llyn Llydaw and Cwm Idwal under open grazing and closed grazing treatments.

The most noticeable feature of the enclosed subplots on the acid sites is the prominence of the ericoid shrubs. In considering these Erica tetralix, E. cinerea, Vaccinium myrtillus and Calluna vulgaris have been lumped together since the scale of response of individual species to enclosure was so small. These species are present only on the acid plots and show only a very small increase after enclosure. The numbers of plants would seem not to have increased, except perhaps in the case of Vaccinium myrtillus. On basic sites, two plants which become noticeably prominent after enclosure, are Deschampsia caespitosa and Achillea millefolium both of which, show strong positive response to enclosure (rather more marked in Cwm Idwal example than Llyn Llydaw).

Species which have increased in prominence in the enclosed subplots, have not necessarily undergone any increase in actual numbers but have only increased in height and spread.

Nardus stricta

Acid site

On subplots which are open to grazing this species maintains the same general level, with only slight variation, which is probably due to season. On the subplots which are closed to grazing the quantity of Nardus is seen to decrease steadily.

Basic site

The responses on the basic sites are substantially the same as those already described but obviously on a much reduced scale, as Nardus stricta is not present in any quantity on these sites. It is interesting to note that enclosure gives an initial boost to the Nardus. In years 5 and 6 there is total absence f Nardus in the enclosed subplots.

Acid site

Festuca ovina

On the open subplots there is a pronounced seasonal fluctuation, but on the whole, a fairly high level is maintained. Initially enclosure produced a reduction in the amount of this species present. This phase is followed by an increase in subsequent years.

Agrostis spp.

There is considerable seasonal fluctuations in the cases of both A. tenuis and A. canina. On the whole both Agrostis species seem to increase under enclosed conditions and at Cwm Idwal there seems to be a tendency for A. canina to be gaining ascendancy over A. tenuis, at Llyn Llydaw this is not the case.

Basic site

On the basic site the enclosed subplots show an increase in the amount of Festuca ovina, but the scale of the increase is different at Cwm Idwal and Llyn Llydaw. At Cwm Idwal the difference between open and closed plots is quite small, but there is a maintained increase in the amount of F. ovina in the enclosed subplots.

At Llyn Llydaw on the freely grazing subplots the figure for A. tenuis is consistently high and steady. Under enclosed conditions, for the first three years A. tenuis shows a steady decline but subsequently an upward trend in the percentages for this species is shown. At Cwm Idwal there is a different picture, here free grazing produces a lower figure than for the enclosed subplots. Agrostis canina at Cwm Idwal follows the same pattern but at Llyn Llydaw the quantities of this latter species are too small to be comparable.

Molinia/Holcus

Molinia caerulea shows a marked response to enclosure in locations where it is present. For example at Cwm Idwal it has increased very rapidly in the subplots. Year four, corresponded with a very late Spring after a very hard winter and this may account for the rather low figures for this year. At Llyn Llydaw on the equivalent site Molinia is not present in any quantity, so unfortunately no comparison is possible.

On basic sites Holcus lanatus seems to take over the role of Molinia and it shows a similar pattern of response to enclosure. This is very well demonstrated at the Llyn Llydaw site and at Cwm Idwal it is seen on a smaller scale.

Two plants present on one of the basic sites viz., Llyn Llydaw are worthy of mention, these are Trifolium repens and Plantago lanceolata. One of these species, Plantago lanceolata shows a positive response to enclosure and there is a steady upward trend in the amount present. The other species, Trifolium repens, shows a negative response and enclosure has produced almost total eradication of the species. These two plants are an interesting example of how morphology of a species determines its fate under changed circumstances. Plantago lanceolata being a rosette, suffers badly, particularly in spring from grazing and under conditions of free grazing the plants are dwarf and stunted, whereas Trifolium repens being a creeping plant, it does not suffer so much grazing damage. When the removal of grazing allows the vegetation to grow up however, the position is reversed, now the Plantago is able to compete successfully against neighbouring species because of its rosette form. But Trifolium shaded from all sides by the surrounding vegetation, cannot get sufficient light to maintain its growth and therefore gradually diminishes in quantity.

Partial exclusion of grazing, that is enclosure during the winter months from the end of October to April, does not appear to produce any changes in the composition of the vegetation. Although at the start of a season, in spring, the subplots which have been enclosed for the winter, do show a flush of growth and appear rather greener than areas outside, especially if there is an early spring. However, once sheep graze these subplots after the removal of the barriers the different appearance is soon lost.

At Crib Goch where this work has been proceeding for a shorter period, (1965 will be the fourth season), it is rather too early for trends to be well established, especially as the rate of growth at this higher altitude is much slower.

The above comments show a very incomplete picture of what happens when the grazing pressure is suddenly altered. Many questions remain to be answered, but the examples quoted, illustrate the extreme complexity of the situation.

The interactions between competing species are very complicated and the process of building up the complete picture will take quite a number of years yet. What will be the effect of the reappearance of trees, as must surely happen, already two seedlings of Sorbus aucuparia have been recorded as present on one of the sites.

IV. During the past four years, an attempt has been made to find out if the voluntary densities, as indicated by the sheep census, reflect a real difference in the increment of animal material per unit area. Two sites, dissimilar both ecologically and in sheep population densities they bear, were enclosed. One site is on a peaty podsol derived from acid igneous rocks and acid drift and the vegetation is dominated by

Nardus stricta. Here the sheep population density varies from 1.5 to 2.5 ewe units per acre during the growing season. The plot size is 6.5 acres and the enclosed experimental population density would be approximately 2.75 ewe units per acre.

The other site is on a brown earth derived from basic igneous rocks, the normal voluntary sheep population density during the growing season varying between 2.25 to a maximum of 4.1 ewe units per acre. The plot size is 2.4 acres and bore an experimetnal population density of 7 ewe units per acre. The vegetation is Agrostis/Festuca grassland.

Since the voluntary sheep population densities differed, the plots were constructed so that the experimental densities were proportional to the densities observed under free grazing conditions.

The management of the experimental plots depended on the co-operation of the tenant farmer concerned, but for the last four years it has been as follows:-

January until experimental grazing began - closed to stock. After experimental grazing was complete, the plots were left open until the following January.

The animals are weighed at the beginning of the experimental period, at an intermediate stage at the end. The results being expressed in the form of a net gain or loss of animal material in lbs/acre.

The start of the experiment coincides as near as possible with the time when local farmers are returning their flocks to the mountains from lowland wintering and lambing quarters.

This time varies slightly from year to year depending on weather, the condition of the sward at the stage of growth of the lambs. Sometimes as in the case of 1963 after a severe winter this return may be delayed until quite late. In other years after a mild winter the sheep return to the hills earlier.

The duration of the experiment is also subject to variation depending on the condition of the experimental animals, the state of the sward, and the utilisation of the available herbage by the animals. Thus the duration of the experiment has varied between 28 and 40 days.

The stocking rates for the experiment ware calculated in ewe units per acre, the animal units consisting of ewe/lamb pairs, each lamb being considered as representing half a full ewe unit.

Measurements were also made of the herbage dry matter yields in lbs/acre, both at the beginning and end of the experimental period. Climatic data are also available for the experimental sites. (Monthly rainfall, mean air temperature and mean earth temperature).

Results

From the results obtained for the four years it has been shown that the net production of animal per acre differs on the two plots. Performance on the Nardus plot seems to be relatively the same each year, and only ranges from a net gain of animal material of 8.15 lbs/acre in 1963 to 14.52 lbs/acre in 1964. On the heavier stocked Agrostis/Festuca plot, results show a range from a net loss of 12 lbs/acre in 1963 to a net gain of 46.00 lbs/acre in 1964.

The large variation in the results of the Agrostis/Festuca may be due to the variation in the losses in weight incurred by the ewes. For all years, except 1964, the ewes on the Agrostis/Festuca show larger weight losses in lbs/acre than those on the Nardus, results from the Nardus plot show either very small losses or small gains. In the case of the lambs however, total gain of lambs in lbs/acre on the Agrostis/Festuca is always double the gain produced on the Nardus.

Environmental climatic factors have some effect on the liveweight gain results, because the highest net gains are produced in seasons following mild winters and mild springs, e.g. 1962 and 1963. The springs preceding these two seasons showed low mean air and soil temperatures for the early part of the year whilst the 1961 and 1964 seasons were preceded by relatively warmer milder springs. Cold, very wet springs will give adverse growing conditions and will affect sward production which is reflected in correspondingly low herbage dry matter yield results, for 1962 and 1963. The Nardus sward appears to be less affected by these cold spring conditions.

The low value for the net gain animal material per acre on the Agrostis/Festuca in 1962 and also the loss in 1963, may be attributed to an insufficiency of herbage being available to the ewes on the Agrostis/Festuca. It is likely that in order to maintain their body heat etc. and produce milk for the lambs the ewes were utilising their body source for supply of energy, so producing a loss in body weight, which was not offset by the gain in weight achieved by the lambs. A very small loss in weight of ewes occurred on the Nardus in 1963, but not nearly as large as that which occurred amongst the ewes on the Agrostis/Festuca. A possible explanation is that the Nardus plot carried only half the stocking density compared with the Agrostis/Festuca, so that there was more herbage available per ewe, to satisfy the body requirements.

In 1964 the stocking rate on the Agrostis/Festuca was slightly reduced from 10 to 8 ewe units and the results indicate that there may have been overstocking of the Agrostis/Festuca in the years 1961, 62 and 63, because in 1964 after a mild spring and under good growth conditions, the ewes on both plots produced gains in weight on a lbs/acre basis. The increase on the Agrostis/Festuca over previous years being more marked than that produced on the Nardus.

Generally, the results tend to show that in years when the spring seasons are warm, have adequate rainfall, and good growing conditions, net production of animal material/acre on the Agrostis/Festuca, even at the higher stocking rate, is about two to three times greater than the Nardus. Whilst in years which have had a wet spring with low temperatures the net production on the Agrostis/Festuca is very much lowered and may be less than the net production of the Nardus.

V. In the foregoing, an account has been given of some of the work which is going on in Snowdonia to investigate various aspects of the effects of the grazing animal on the mountain grassland ecosystem. The picture is as yet incomplete and only time will rectify this.

DISCUSSION FOLLOWING MR. DALE'S PAPER

Mr. Moss stated that on some Scottish heather moors productivity was about the same from both acidic and basic sites. However, in those situations, excess food was always available and differences in productivity might become more obvious if sheep densities were increased. Seasonal differences in weather greatly influenced the productivity of mountain grasslands and it was necessary to obtain results from several years before definite trends could be established.

Species which changed their habit of growth in response to enclosure and increased competition for light were commented upon by Mr. Wells, who compared changes which occurred within an enclosure on the chalk with those described by Mr. Dale in N. Wales. In both cases, normal rosette plants such as Plantago lanceolata greatly increased in leaf area and became erect in habit as a result of enclosure. The importance of this change in relation to defoliation by cutting or grazing was discussed.

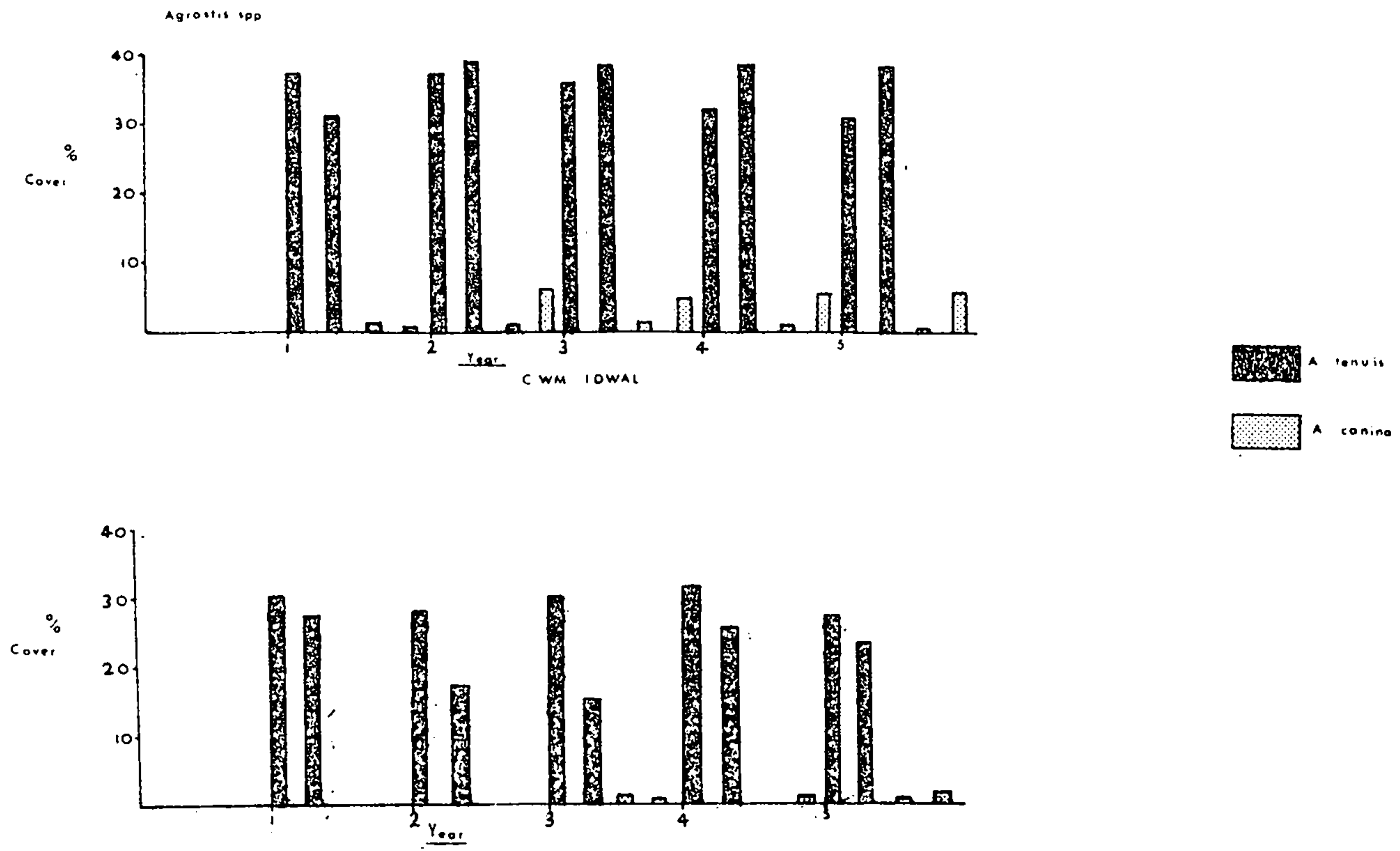
INTERPRETATION OF HISTOGRAMS

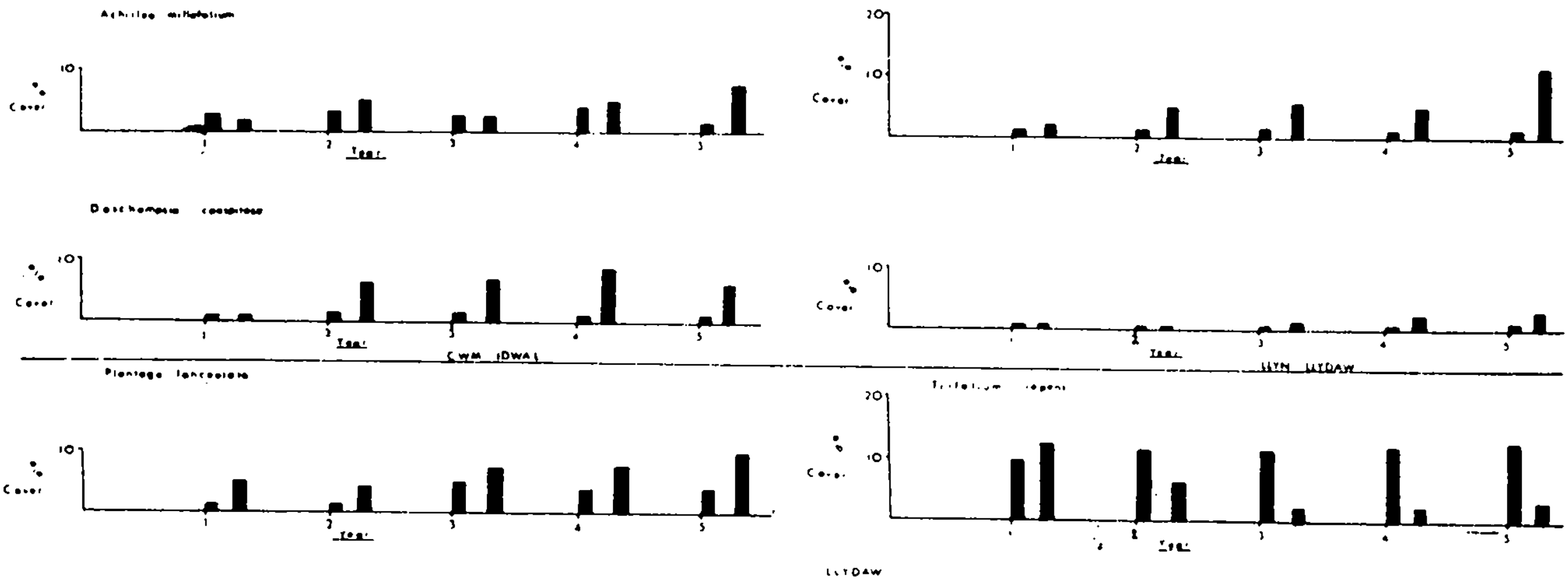
Please Note:

1. The right-hand column of each pair, represents the percentage cover valuo of a species under conditions of total enclosure, i.e. no grazing.

2. Left-hand column of each pair, represents the percentage cover value of a species under open conditions, i.e. normal grazing at all times of the year.

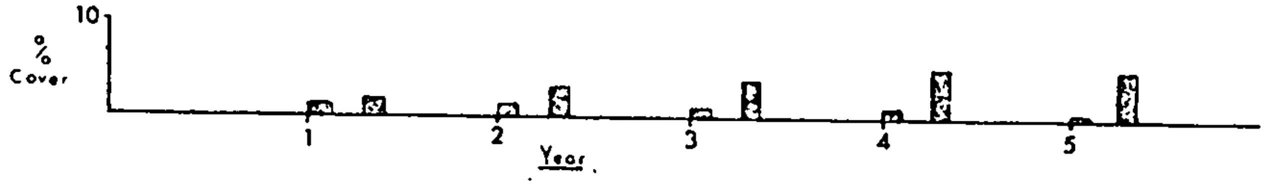
BASIC SITES


Agrostis spp
%
Cover
40
30
20
10
1
2
3
4
5
Year
C WM IDWAL
A tenuis
A canina
%
Cover
40
30
20
10
1
2
3
4
5
Year



Achillea millefolium
Deschampsia caespitosa
Plantago lanceolata
Trifolium repens
% Cover
Year
CWM IDWAL
LLYN LLYDAW

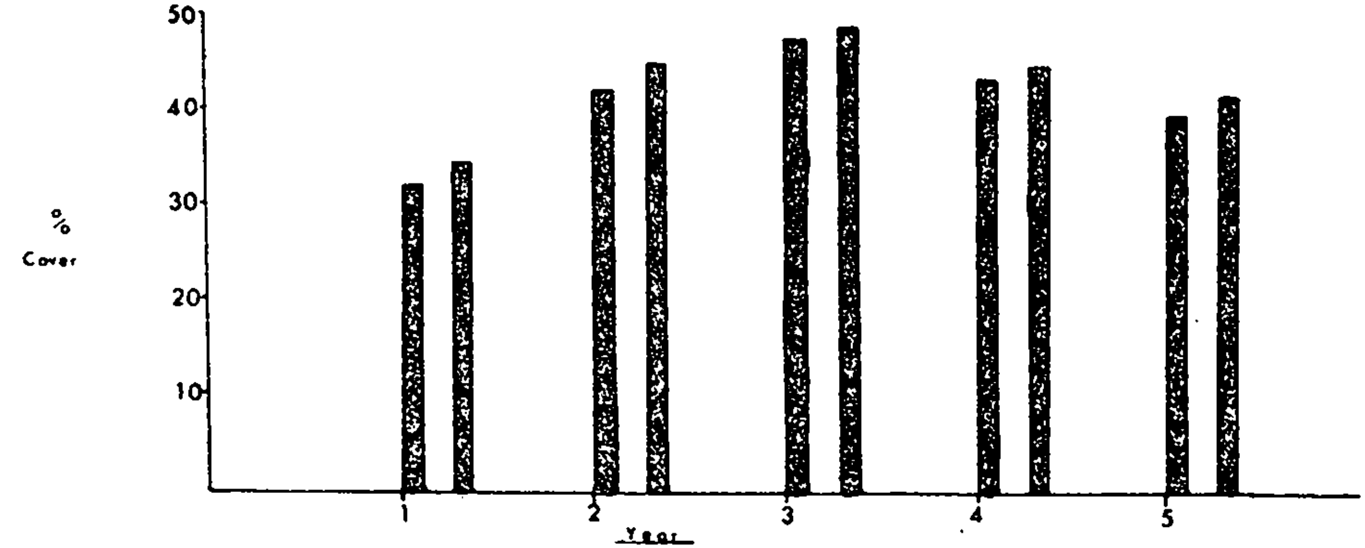
Holcus lanatus



CWM IDWAL

LLYN LLYDAW

Festuca ovina



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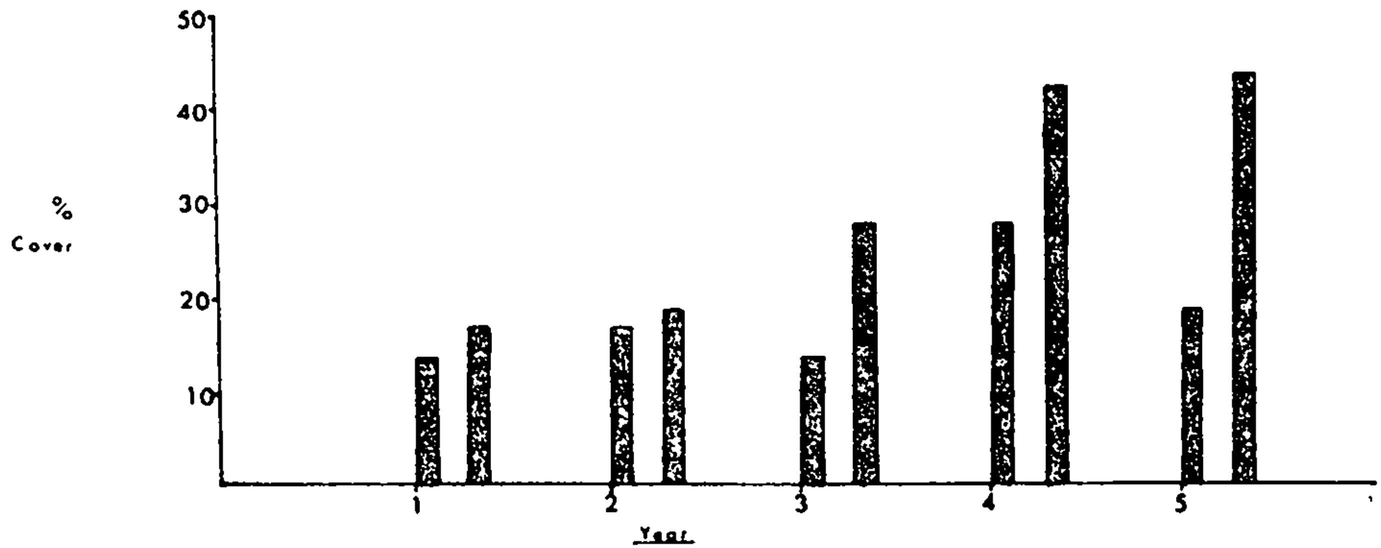
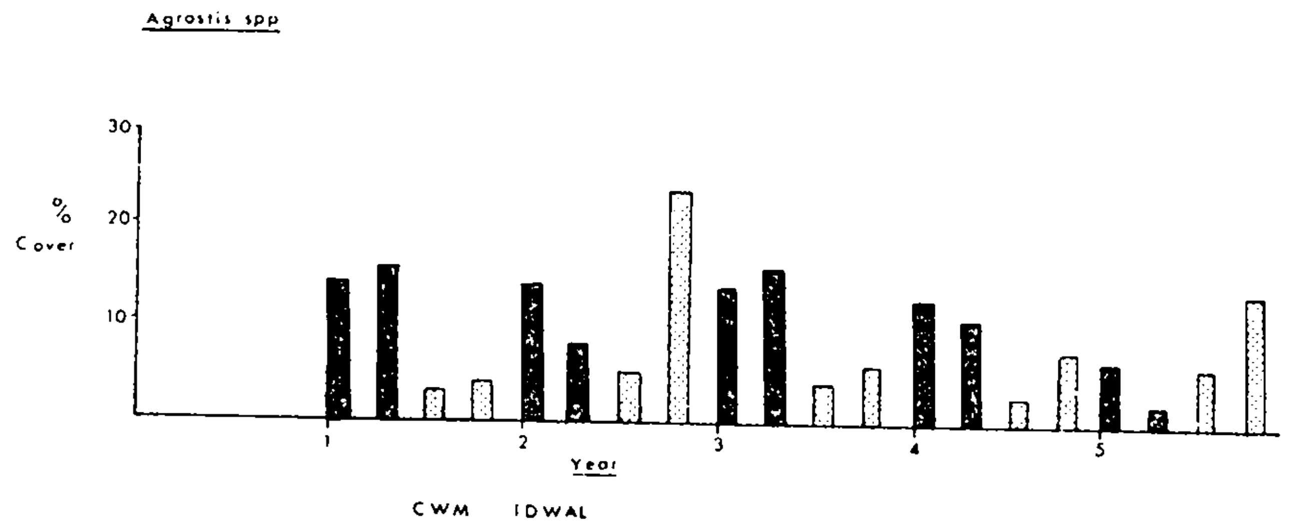
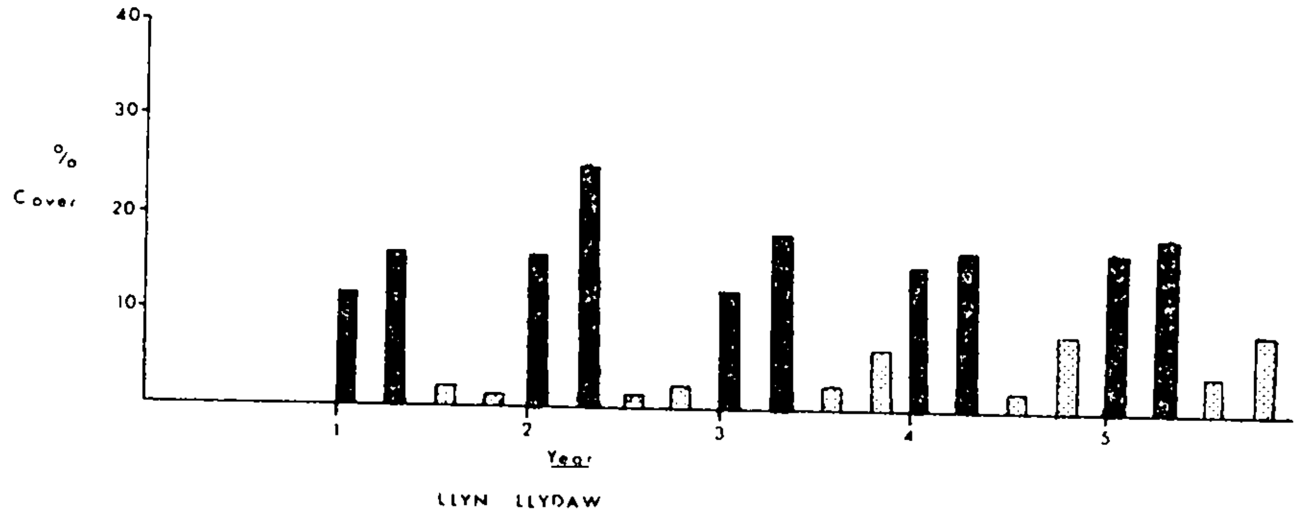
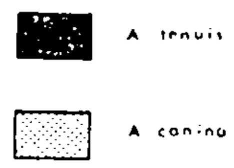


LLYN LLYDAW

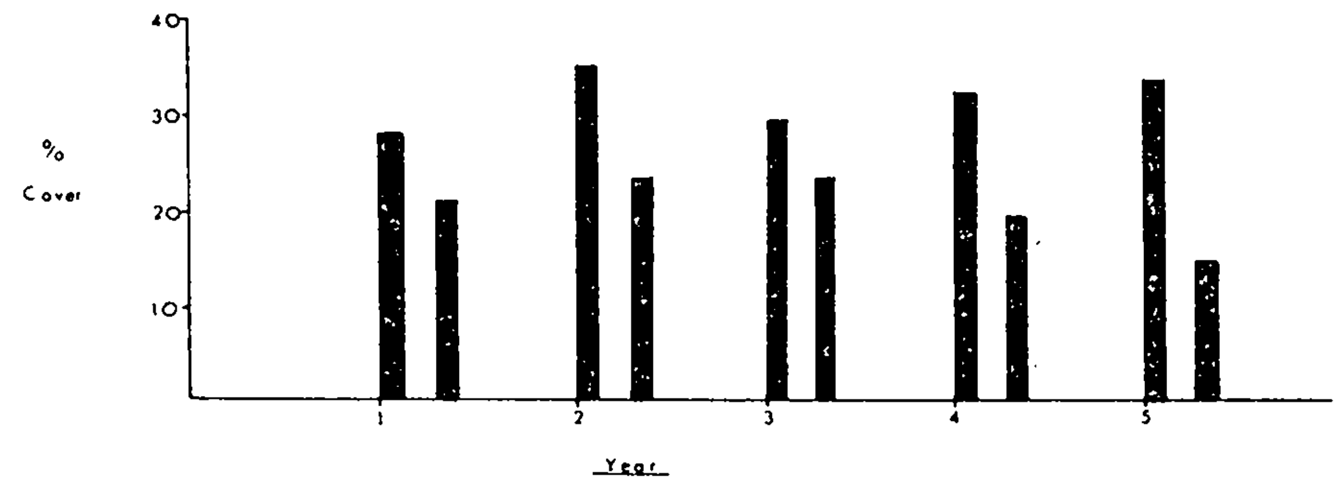
ACIDIC SITES







Nardus stricta



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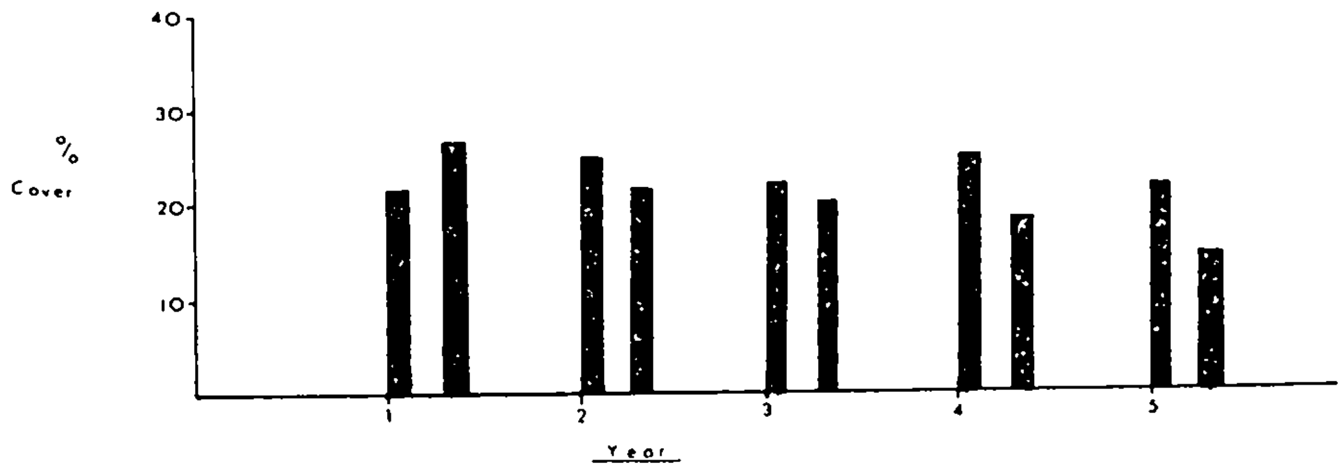
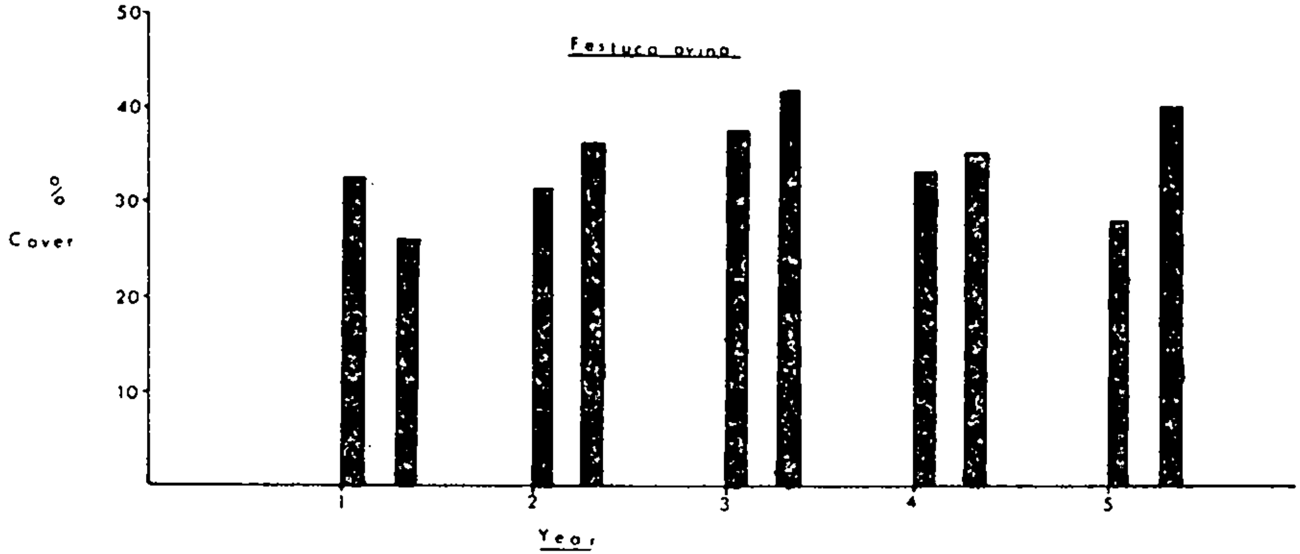


LLYN LLYDAW

Festuca ovina



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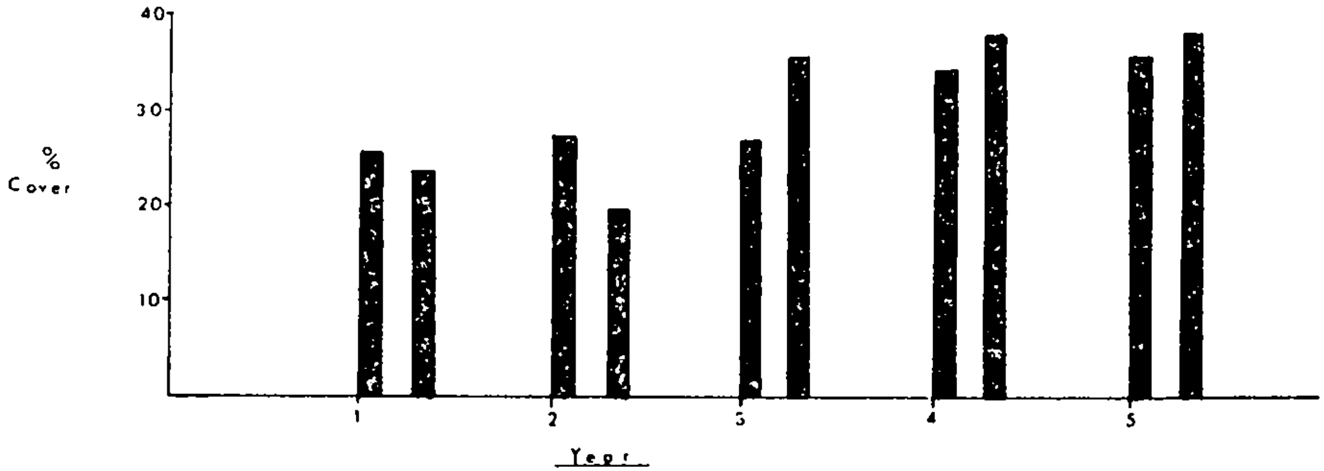
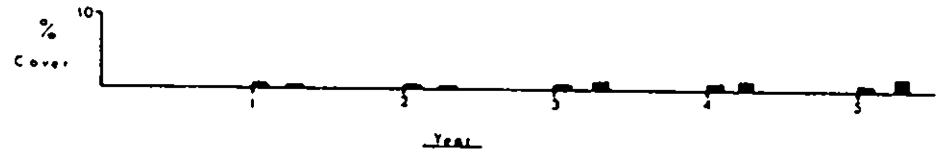


LLYN LLYDAW

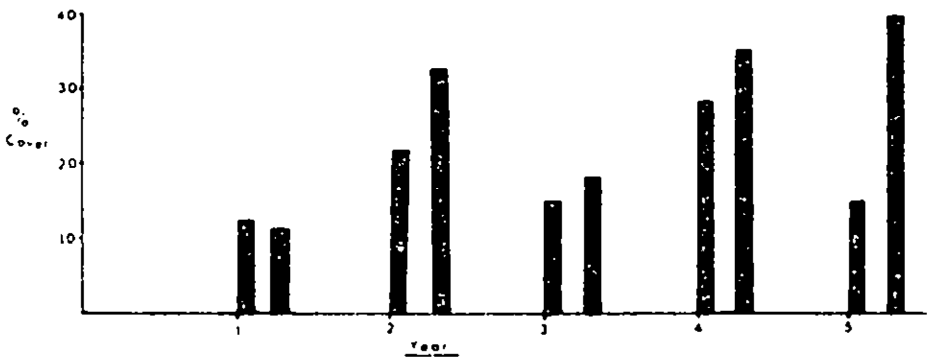
Ericoid shrubs

CWM IDWAL



LLYN LLYDAW

Molinia caerulea



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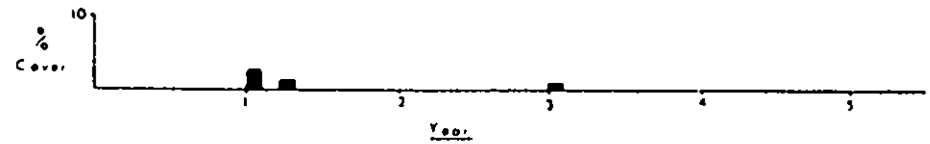

LYN LLYDAW

GRAZING STUDIES AT MOOR HOUSE FIELD STATION

M. Rawes

My investigations are concerned with the effect of sheep grazing on the vegetation and soils of Moor House, which although owned by the Nature Conservancy, is common land. In this, it is typical of much of the open fell of the northern Pennines where sheep farming and grouse shooting are the normal land-use. The greater part of the Reserve lies just below 2,000 ft. but the summits rise to 2,800 ft. Well over half the 10,000 acres is blanket bog moorland. The grasslands tend to be small and those on mineral soil cover less than 5% of the area, but they are of major importance to the sheep. Pearsall once remarked to me at Moor House that we were fortunate in having a place whose ecological state was so low that whatever we, or I, did to it, it would be next to impossible to make it worse!

Be this as it may, my object is to present evidence of fertility, generally exemplified by the vegetational cover, in relation to a known sheep grazing regime, and, by altering this management experimentally, to effect changes thought to be in some cases desirable and in others undesirable. You are all probably familiar with the often repeated saying that sheep grazing is responsible for much of the continuing impoverishment of our hills. It is this statement that has led me to make my investigations and my hypothesis is that although this is true in some instances, it is a generalisation, and some upland grasslands are dependent for their variety on the continuation of grazing. I hope eventually to give factual evidence on this aspect of land-use as it affects Moor House. To do this it is necessary for me to obtain information not only on the present position but on the past; I need to know what occurs in both the absence of grazing and when the grazing regime is altered. I propose now to tell you briefly how far I have gone to meet these requirements.

The first necessity has been to study past history. In this, as in all our research, we must draw on the work of others: Johnson and Dunham on soils and pollen analyses, the work of geographers and numerous historians, on estate, manorial and county and parish records, and more recently on Agricultural returns. From this we can deduce that sheep grazing of the fells is long-continued, probably since the Norse introduced the mountain sheep. We know that a grazing pattern, similar to the present, has been in operation for many years, certainly over the last 200 years. We also know that contrary to popular belief, sheep numbers have been steadily increasing over the past 200 years in the hilly counties of Cumberland and Westmorland. Agricultural returns of four parishes, one of which contains land mostly above 1,000 ft. and the others largely hill land, show a doubling of the sheep population in the last 100 years. On common land the grazing pressure has always been thought to be too high. As far back as 1794 a report to the Board of Agriculture complained that the Commons of Westmorland were almost always overgrazed.

The second part of my research concerns the present position. We have information of plant cover and sheep numbers. In the case of the sheep we know their management, we know the live weight increment of two flocks and an estimate of their mineral composition. We can calculate from these data the annual sheep production for the Reserve as a whole. Unfortunately in so far as the mineral analyses of the animals are concerned we have to rely on data produced 100 years ago by Lawes; surely a strange commentary on progress in this field!

In more specific work I have attempted to find out the weight of herbage removed by a recorded number of sheep grazing certain swards. This has involved detailed work. Measurement of sheep pressure has been by counting numbers and collecting dung. Measurement of herbage consumption has been by a cage difference method and hand sorting has permitted estimates of grouped plant intake to be made. In some cases it has been possible to relate the herbage removed to the sward's primary above-ground production.

The swards we have dealt with in this manner, have so far been the better class grasslands, the Festuca-Agrostis swards, and the poor grasslands of the summits, dominated by Festuca and Deschampsia flexuoso. Last year we investigated the productivity of a Juncus squarrosus dominated sward and in the present season we have returned to Nardus, which I first looked at, at Moor House, in 1957 with rather negative results.

With a completed vegetation map and widespread observations of sheep pressure, it has been possible to relate these small experiments to the Reserve as a whole. In some cases it has been possible to measure the sheep utilisation of the vegetation immediately surrounding the grassland investigated. By this means we can demonstrate the poverty of the blanket bog in so far as its use for sheep is concerned. However, work by others, such as Hunter on hill sheep behaviour and on the comparative grazing intensities of different hill swards, has proved invaluable. I believe that much of the grazing pattern and its effect on vegetation is strongly related to animal behaviour, the development of social groups that determine sheep density. For example, work on one of our more productive grasslands showed that the standing crop of the grazed sward was approximately 900 lb/acre (dry weight) in September. This does not suggest that the sward was grazed to capacity. The population utilising the sward averaged 5 sheep/acre, and remained comparatively constant throughout the season, although increasing slightly after July when family groups merge into larger units. Hunter and Milner have shown that sheep groups habitually take possession of part of the hill, and do not normally graze outside it. Swards on mull soils are preferred and it is on these grasslands that competition between animals leads to aggressive behaviour. It is probable, therefore, that social barriers prevented an increase above a certain level in the Moor House Festuca/Agrostis grasslands. A fairly constant population will use them although in the first place this will be dependent on their productivity. Changes in the over-all population will, however, lead to alterations in the grazing pressure on the poorer swards and this change must affect their botanical composition. I am not, however, convinced that improvement of the swards will not destroy existing social barriers. This remains to be seen.

Finally we can present a rough nutrient balance sheet of a moorland ecosystem as it exists today. Measurements of nutrient input by way of rainwater and losses in run-off (estimated by Crisp) show that the part played by sheep is indeed small. On a 200 acre catchment Crisp calculated that the loss to the catchment by way of sheep products, wool and sales, was no more than 1 lb of K, $1\frac{1}{2}$ lb of P, 2 lb of Ca and 7 lb of N.

The annual loss of minerals by way of the sheep could be met for the whole Reserve by applying each year a couple of tons of ground limestone and superphosphate, a few bags of muriate of Potash and 10 tons of Sulphate of Ammonia.

However, as the input of rain-borne nutrients is greatly in excess of this it can be argued that the amount removed by sheep is too small to consider. This is not, however, to say that other biological effects of sheep upon the distribution of nutrients over the fell as a whole is negligible.

The third part of my investigation is to show what happens in the absence of grazing. In view of the long-continued history of grazing, removal of sheep is certain to produce relatively quick changes on the less exposed grasslands. The more adverse the climatic conditions the less spectacular will these changes be. Enclosure of ericaceous swards, where the sheep pressure is low, can not be expected to produce much measurable change initially. Some 10 years ago a variety of exclosures, each normally not less than 160 m^2, were set up on selected sites at Moor House. In time these exclosures will provide our ungrazed control swards. A paper on the first seven years of sheep exclosure from three high-level grasslands was recently published. In this, our conclusions were of an increase in the amount of fine-leaved grass, especially Deschampsia flexuosa, and a general decrease in the number of species. Most important probably was the sharp fall in Juncus squarrosus, a rush whose widespread occurrence in the northern Pennines is largely related to sheep grazing. However, in our view, the present build-up of undecaying vegetation in these exclosures is of much greater interest than the passing floristic changes. Under conditions of sheep grazing there may be no accumulation of plant material on mineral soils even with rainfall above 70 inches a year. The fraction of dead material in the herbage of grazed vegetation has not been found to alter drastically during the summer. At the end of May, 46% of the vegetation above 1 cm. of ground level may be senescent and in September, 36%. When grazing is removed the dead tissue accumulates and the animals and agencies involved in plant decomposition are unable to deal with this additional material. In time we shall see if this continues and leads to the development of a more acidic and uninteresting sward. This may well occur on the previously close grazed limestone grasslands which are our most diverse habitats.

Lastly we need to investigate the effect of different grazing regimes. Moor House is common land and any interference with the commoners rights of grazing has its difficulties. However, I have been able to compare different grazing systems by using adjoining fells. For example, last year on blanket bog we compared all-year round grazing of two intensities, with the Moor House summer grazing regime. We were able to show big differences in vegetation and existing grazing pressures. In this case, the heavier continuous grazing far from leading to botanical impoverishment, resulted in greater variety, though less Calluna, without affecting the bog surface. The practical methods of creating a sward that can be utilised to the extent of 1 sheep/2 acres over the year as against 1 sheep/100 acres on a Moor House Bog is important enough to attempt experimentally.

I would like to conclude by saying that in my view hill sheep farming need not be incompatible with conservation. So often the first reaction of a conservationist is to enclose the rarity, fencing apparently giving the necessary mystic protection. We have had several instances of this in our area. An example is the rare saxifrage, Saxifraga hirculus, which admittedly has its flowers grazed. An enclosure was set up and within a matter of a few years the ungrazed flush vegetation quickly suppressed it; it is now extinguished. Then there are alpine plants that grow in unstable habitats where plant competition is low. Sheep by treading often maintain these open conditions on slopes and their removal could endanger the plant. One species I have in mind in this context is Myosotis alpestris. For the conservation of a wide range of species it is desirable to have areas grazed and ungrazed. Usually these conditions exist in hill country. I believe careful trials with plants under controlled conditions should precede any attempt to preserve the plant it its own habitat.

To sum up, I am in the first place attempting to provide basic information of past and present utilisation and productivity of this upland area. We intend to measure the effect that changes in management may have, and it is in this context that I believe it is just as important to have experiments aimed at creating conditions that we consider to be bad as to have trials of so-called improvement.

Finally, I would emphasise that changes in soil fertility are usually slow and therefore difficult to measure. The recognition of decline should be by way of vegetation change for although loss of animal productivity is more obvious, it denotes an advanced state of soil deterioration.

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DISCUSSION FOLLOWING MR. RAWES' PAPER

The effect on the ecosystem of burning heather and moorland grasslands was commented upon by several speakers. In the west of Scotland excessive burning of heather and excessive grazing by sheep led to severe erosion. At Moor House, experiments had been laid down to measure the effect of different regimes of burning on the soil and vegetation of selected areas.

Burning, sheep and grouse were the important biotic factors on moorlands which greatly influenced the vegetation as a whole. At a lower level, changes in intensity of any one of these factors could be responsible for the eradication or success of individual species of special conservation interest. Mr. Rawes did not agree with the comment that there were no examples where grazing had been used to maintain the conservation interest. Grazing was important in preventing tree regeneration in the Highlands but there were good examples available at Moor House where grazing had maintained the interest in particular areas. *Myosotis alpestris* was an example of a species which benefited from heavy grazing and treading, while *Saxifraga hirculus* had disappeared when enclosed.

THRIPLOW GRAZING EXPERIMENT

G. Crompton

For a full account of this experiment the reader is referred to the 1962 Handbook of the Cambridgeshire Naturalist Trust. In this account I will concentrate on some of the difficulties we have encountered, and on selected observations made over the past four years.

This experiment was planned by Dr. Walters with the limited aim of learning something about the variation in the numbers of flowering Dactylorchis under different forms of management; it is concerned with aesthetics as well as with changes in the numbers of flowers of this species of orchid. It is not concerned with the survival of the species.

The Nature Conservancy gave a grant towards the setting up of the experiment and I would like to take this opportunity of thanking Dr. Duffey, Dr. George and Mr. Ducker for all their help and interest.

Although the aims of the experiment are simple, the complications of being dependent on other people's livestock and machinery are not only very time consuming, but have the added disadvantage of not being controllable.

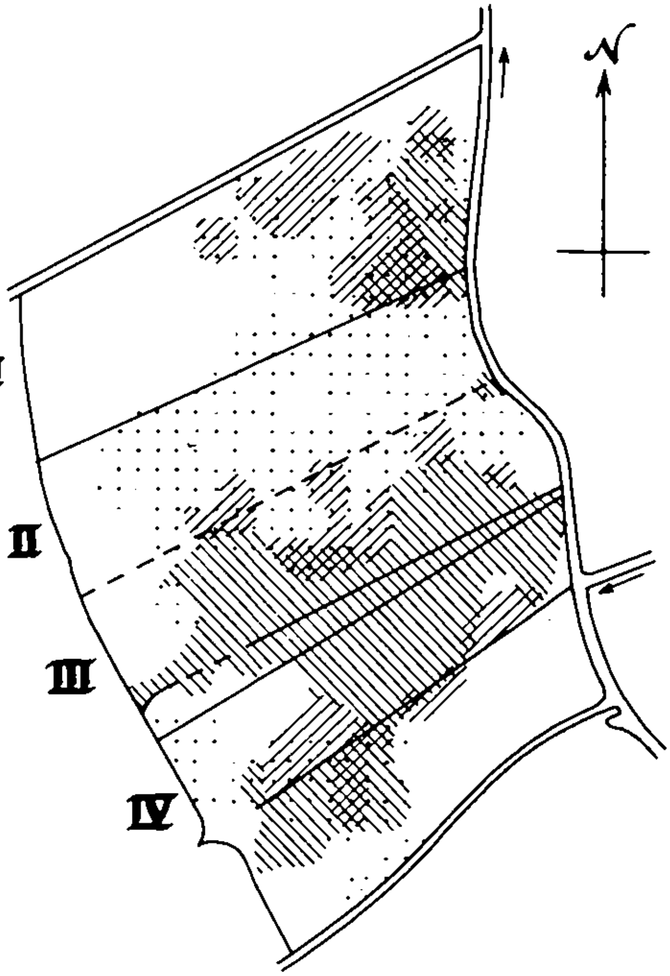
Under the general heading of difficulties I would first like to discuss the uneveness of the plots or strips for purposes of comparison. As you will see from the diagram (Strip 1, 48%, Strip 2, 86%, Strip 3, 37%, Strip 4, 28%), the percentage of area in which the Dactylorchis are found in each strip and the area over which Carex acutiformis is dominant, is very uneven. The arrangement of the strips was necessitated by the access arrangements for grazing.

Secondly quadrats should not adjoin fences. Despite all the extra wiring around quadrats the animals lean over a good 50 cms. and graze the control or cut strip making it necessary to discard a third of each quadrat. Furthermore, a quadrat should not be by a gate. The ponies in strip 1 are fed twice a day by the owner and they stand by the gate waiting for this. Heavy trampling has occurred in a quadrat placed there, and during the winter of 1964 vegetation in the quadrat was almost eradicated.

Thirdly, because each strip is over an acre, the margin of error in the annual count must be very great (usually counted ca 1 July). The method of counting adopted is to assemble as many volunteers as possible in a straight line at one end of a strip and to slowly walk across, counting all the orchids between oneself and the next person of the left. Every 5 yards or so the line comes to a halt and each counter given their total to a teller who is standing facing them. Dr. Duffey has made the helpful suggestion that each person counting should hold on to a knot in a long rope which is knotted at regular intervals.

It is too early to come to any conclusions about the results obtained so far. No analysis has been made of the recordings in the quadrats and

Experimental field at Thriplow 1961.



KEY

- Grassland
- Orchis praetermissa and O. strictifolia
- Carex acutiformis
- Juncus subnodulosus
- Streams and ditches

TREATMENT

Strip	I	grazed by horses
	II	cut yearly
	III	control
	IV	grazed by cows

0 20 40 60 80 100

Scale in yards

the orchid counts have not been related to the fluctuations in the water table, climate or the grazing times. However, useful subjective observations have been made, and are recorded below.

Grazing preferences: the cows when put in at the end of the year will eat everything that is not prickly, except Juncus inflexus. They will eat Carex acutiformis. I have never seen the mares or yearlings, who were thoroughbred Arabs, touch Carex acutiformis but on the other hand one of the ponies (retired from the circus), will eat Carex acutiformis even when there appears to be much better things on offer. Differences within a species of animal must be taken into account, as well as between different species.

One of the factors we are interested in is the palatability of the orchids. I have never seen any animal eat a Dactylorchis. It was suggested that I try offering a bunch of Dactylorchis to the cows and horses but I did not do this. It was also suggested that a trough be set up with compartments filled with different species growing in the meadow and observing which species were selected by the animals. This has not been done because of the danger of poisoning animals which were not owned by the Trust. We would be interested to hear if anyone has tried this method.

I have already mentioned the trampling effect on one of the quadrats by the ponies during last winter. This is an important factor which speakers have already referred to. I have rarely seen a trampled Dactylorchis, but trampling has an important effect on the taller herbs and furthermore the cows do flatten Carex acutiformis by lying on it (a damp and cool area in summer?).

I would like to mention only two of the measured results. Firstly, the totals of the orchid counts.

Strip	1961	1962	1963	1964	% decrease 1963-64
1	1047	1516	2049	1222	40%
2	486	409	658	500	25%
3	693	-	498	309	40%
4	250 (est.)	716	1231	908	27%

There is a steady rise for three years (at least in the grazed strips) and then a tremendous drop. I would not like to draw any conclusions after only four years recording, as we know nothing about seasonal fluctuations or the effect of the low water table of the past 3 years.

Secondly one of the measured effects in the control has been the advance of 3½m. by Carex acutiformis into the permanent Blysmus quadrat set up in 1958. In 1958 quadrat 1 contained 1 plant of C. acutiformis and 150 other plants of 12 different species. In 1964, the same quadrat contains 52 plants of Carex, and 2 plants of Equisetum palustre, and 1 plant of C. otrubae.

The results obtained up to the present time indicate that the orchids flower best in the grazed strips. It is suggested that this may be because grazing effectively reduces the shading from tall herbs. A second factor of some importance is the unpalatability of the orchid to grazing animals.

Dactylorchis used to flower abundantly when the rides in the osiers were open but as they closed over the orchids became paler and fewer and now that the canopy has closed orchids are scarce. This suggests that shading may be important in regulating the number of flowering specimens of Dactylorchis.

But the shading effect may not affect the survival of the species; for example, my lawn adjoins these meadows and has been regularly mowed since it was created thirty years ago. However, two years ago it was not cut at a critical time and about thirty flowering heads of Dactylorchis were counted, which I suspect had been present all the time. Although there has not been a comparable rate of increase in the numbers counted in the strip cut annually, it may be that cutting in August reduces their vigour but this does not necessarily mean their absence.

This pilot trial has a life of 5 yaars. With only one more year to go we are therefore beginning to think about the design of a future experiment in the area. One suggestion is to contain the management experiment in much smaller units, all to be placed in Strip 2, firstly for ease of management and secondly, for counting accuracy and most important for uniformity of comparison.

We have recently begun two other small trials connected with the flowering of Dactylorchis.

(1) Following a suggestion made by Mr. A.E. Smith we have cut twice a year a plot 10 X 30 yards in an area dominated by Carex acutiformis to see if biannual cutting will reduce or even eliminate Carex. In the first year there was some sign of diminished vigour and the bare earth between the Carex plants was found to be more or less completely colonised by grasses and eight species of dicotyledons. It will be interesting to see whether these colonisers can compete effectively with the cut Carex, and whether there will be any orchids.

(II) The human factor has also not been investigated and I have therefore started a small trial in which the flowering Dactylorchis are pulled by hand.

Palatability tests as outlined will have to be undertaken and there are many long term effects still to be investigated.

The effect of a fluctuating water table and the manuring effect of livestock are two aspects which we hope to study, in our investigations of the factors influencing the flowering of Dactylorchis.

DISCUSSION FOLLOWING MRS. CROMPTON'S PAPER

Mr. Skellam thought that the fluctuations in the number of orchids with time was probably related to the water table. From the little evidence available, it appeared that the number of orchids and the water table were fluctuating in phase and it was suggested that this line of investigation would be worthwhile following up.

Comment was made on the fact that sheep, cattle, horses, rabbits and hares did not eat plants of *Dactylorchis*, although other species of orchid are readily acceptable to the grazing animal. The reasons for this need elucidating.

GRAZING AND MOWING EXPERIMENTS ON CHALK GRASSLAND

T.C.E. Wells

1. Introduction

Chalk grassland is one of seven vegetation types discussed in an earlier paper which is dependent for its continued existence on the grazing animal. Changes which occur in chalk grassland when the grazing animal is removed have been documented by Tansley (1939) who describes the effect of excluding rabbits and sheep from an area of downland in Hampshire, and more recently Thomas (1960, 1963) has described the dramatic effect which the absence of rabbits has had on the flora of the chalk. In general, invasion by scrub occurs in the absence of the grazing animal and there is an upsurge in the growth of all species with the result that competition for light becomes intense and the lower growing species disappear and are replaced by more vigorous species, such as Upright Brome Grass, Tor Grass, False Oat Grass and Cocksfoot. The overall result of these changes to the conservationist is a lowering of the biological interest, although it has been observed that the rate of change in the vegetation in the absence of grazing varies from site to site, and is dependent on many factors of which soil depth, aspect and the presence of parent plants for invading species are most important.

The Conservancy have 7 Reserves on the chalk containing more than 1,000 acres of grassland, while Naturalists' Trusts own or lease other areas of chalk grassland. To manage these areas successfully information is required assessing the effects of different management techniques on the floristic composition of these areas, and the purpose of this paper is to describe experiments that are being done, and to suggest lines of research which would provide the kind of information that is required. It might be thought that the agricultural literature could provide many of the answers, but unfortunately, most of the work in this country, in which grazing and mowing experiments are reported, is related to sown leys, and there are few references to work on downland pasture. Exceptions to this statement are papers by Warne (1934) Norman (1957) and Kydd (1964) in which the effects of various cutting and grazing treatments on the botanical composition of permanent downland pasture are reported, although it should be noted that Norman and Kydd's work was done on grassland which was grown on deep drift deposits overlying the chalk and that their "permanent downland" had been arable 30 years previously. It is not surprising then that the floristic composition of the grassland on which they worked contained many species not characteristic of chalk grassland, and their results are only of limited value to the problem of chalk grassland management.

2. Information required for managing chalk grassland

(a) Grazing

(i) A comparison of the effect of sheep and cattle grazing on the structure and floristic composition of chalk grassland;

(ii) The effect of differnet intensities of sheep and cattle grazing on the floristic composition of the grassland;

(iii) A comparison of the effect of time of grazing on the floristic and faunistic interest of chalk grassland.

(iv) The effect of different breeds of sheep on the botanical composition of grassland.

(b) Mowing

(i) Effect of frequency of cutting on floristic composition.

(ii) Effect of time of year of cutting on floristic composition.

(iii) Effect of height of cutting on floristic composition.

(c) Burning

(i) Effect of frequency of burning on the vegetation, with particular reference to the spread of invading species such as Tor Grass.

(d) Individual Species

(i) The effect of the above management treatments on individual species, particularly those of special conservation interest e.g. *Anemone pulsatilla*, *Seseli libanotes*, many orchid species.

(ii) A study of the biology of individual species.

(e) The rate of reversion of sown pastures and abandoned arable to chalk grassland.

In an idealised situation, the management of chalk grassland Reserves would be founded on ecological knowledge derived from experimentation. At the present time, we do not have this information, but experiments are being done to provide some of the answers to the questions outlined above, and the rest of this paper describes experiments that are being done on chalk grassland in south England. It is not possible to quote results from many of these experiments because none of them have been down for more than two years, but some of the long-term studies of changes in the vegetation of the chalk, begun by Dr. Thomas and continued by the Conservation Research Section are providing information on the rate of reversion of sown pasture to downland, and results from these observations are discussed later.

3. Experiments on the Chalk.

The work of the Conservation Research Section is concentrated on the Barton Hills in Bedfordshire, 6 miles north of Luton and on the eastern tip of the Chiltern Hills. This area was chosen for detailed work on chalk grassland problems because (i) it was the nearest extensive tract of chalk grassland to Monks Wood, (ii) the owner was willing for experiments to be done on his land, (iii) the Hills had been grazed by sheep for the previous ten years and the present-day management provided an example of how Bromus erectus - dominated grassland could be managed to maintain the biological interest.

The past history of the Hills has been investigated and is worth relating in some detail as it illustrates the way in which the floristic interest in an area can be regained after a long period of neglect. The steepness of the chalk slopes makes it unlikely that the Hills have ever been ploughed and both the Tithe Award Map of 1778 and the Enclosure Award Map of 1814 describe the Hills as common grazing. Sheep have been the main grazing animal, and the number of sheep have fluctuated with changes in agricultural prosperity. We know from the records of the early Bedfordshire botanists that although Bromus erectus was abundant on the Hills in 1884 (Herb. Saunders, Luton Museum), a rich chalk flora was also present and in an excursion made by the Herts. Natural History Society in 1892 to the area, 7 species of orchid were recorded in addition to Anemone pulsatilla. Grazing of the Hills with Dorset Horn sheep continued until 1920 when, because of the general depression in agriculture, sheep farming became uneconomic and was abandoned on the chalk in Bedfordshire. From 1930-45, rabbits were the main crop obtained from the Hills although sheep grazed there on occasions. Nevertheless, neither rabbits nor sheep controlled the spread of Hawthorn scrub or the growth of Bromus erectus and in the late 1940's, the vegetation was 2' - 3' deep, with a deep layer of dead grass leaves at the base. In 1954, the Hills were reclaimed by the present tenant who burnt the dead vegetation at Easter, cut down the scrub by hand and treated the cut stumps with an arboricide, and from then until the present day, Border-Leicester x Cheviot sheep, at a stocking rate of about 3 sheep per acre have grazed the Hills for nine months of the year.

The Hills today are covered with a short, heavily grazed turf in which Bromus erectus is still the dominant, but its habit is more like Festuca rubra than the coarse tussocky habit which one normally associates with Bromus in undergrazed grassland. 45 species of flowering plants have been recorded from one south-facing slope, including species such as Senecio integrifolius, Anemone pulsatilla, Hippocrepis comosa and Filipendula vulgaris. Despite 30 years of neglect, the botanical interest of the area is as high as ever, and this point is further exemplified by Anemone pulsatilla. The distribution of this species in the area was mapped by Miss D. Meyer in 1952 who found it at 5 stations on the Hills. This species was found at the same 5 stations last year while two new sites were discovered on the Hills, and although the plants are not obvious because only a few flower in each year, they appear to be capable of surviving in the vegetative state for long periods.

A sheep and rabbit-proof exclosure was erected in 1963 on the Barton Hills to study the effect of various cutting treatments on the floristic composition of chalk grassland and to compare the effect of cutting with sheep grazing. A replicated experiment has been laid down within the exclosure to investigate the effect of both time of year of cutting and frequency of cutting on floristics, but it is too early to be able to say much about the effect of specific treatments on the flora, although several interesting observations have been made within the exclosure during the first year.

(i) Anemone pulsatilla.

Before the exclosure was erected in 1963, the number of Anemone plants with flowers within the area of the exclosure was six. In 1964, as a result of removing grazing for 9 months, 135 plants of which 100 had flowered were observed and marked. An area of equal size, outside the exclosure, which had been grazed by sheep, yielded 5 plants in flower.

(ii) The biology of individual species requires study if the results from cutting and grazing experiments are to be explained fully. Species differ in the time of year in which they produce leaves, inflorescences, set seed, and the effect of grazing or cutting at one time of the year may be disastrous for some species and have no effect on others. For example Cirsium acaulon produces its leaves at the beginning of May and any cutting treatment applied before that date does not directly affect this species, although its competitive relationships with other species which were defoliated will have been changed. Other species such as Centaurea nemoralis and Succisa pratensis produce their leaves even later, while many of the chalk grasses commence growth early on in the season and are more affected by early defoliation.

Knocking Hoe N.N.R.

(a) A second exclosure was erected at Knocking Hoe in the summer of 1964 to investigate the effect of time of year of cutting on the floristic composition of the grassland, with special reference to the control of Bromus erectus. A split-plot design is being used in which the cut material is removed from half the plots and on the other half the cut material is returned in a finely divided form.

The effect of these treatments will be compared with grazed areas outside the exclosure.

(b) The Autumn Ladies Tresses (Spiranthes spiralis) is one of a group of orchids which is said to fluctuate greatly in number from year to year. It occurs in abundance on the chalk at Knocking Hoe, Bedfordshire. Advantage has been taken of its abundance on a south-facing slope to study changes in the population in relation to sheep and cattle grazing.

	Grazing Pressure	No. of Plants	No. of Intact	Inflorescencies Bitten-off	Present '63 not '64	Present '64 not '63
1963	Light, no grazing in September.	467	447		120	
1964	Heavier, grazed in August and September.	482	217	95		140

In the two years that this orchid species has been studied, there have been no great changes in the total population as has been reported for this species in the past (Perring 1956), although internal changes in the population have occurred. From the management point of view, it would seem undesirable to graze a Reserve where this species is of special interest during late August and September, but is is encouraging to know that more than half the plants which produced inflorescencies came to maturity and shed their seeds, even though grazing had been heavy during the flowering season.

Old Winchester Hill

The effect of light winter grazing by Southdown ewes is being studied on the south-facing slope below the Iron Age Camp at Old Winchester Hill.

Although the grazing is restricted to the winter months, and has usually been for only one month in the year distinct differences are visible between the grazed and ungrazed areas. After eight years under this grazing regime, no species is found in the grazed area which does not occur also in the ungrazed area, but differences in the performance of species in the two areas have been detected. Sheep's Fescue (Festuca ovina), Carnation Sedge (Carex flacca) and Salad Burnet (Poterium sanguisorba) are more abundant in the ungrazed paddock, while Meadow Oat Grass (Avena pratensis), Squinancy Wort (Asperula cynanchica) and Rough Hawkbit (Leontodon hispidus) are more abundant in the grazed paddock. Mosses, especially Pseudoscleropodium purum are more abundant in the deeper turf of the ungrazed paddock.

Aston Rowant

This experiment has already been discussed in a previous paper by Mr. Woodman.

Crundale Down

Many areas of chalk downland have been ploughed up in the last 10 years and some have been sown with strains of cultivated grasses in an attempt to increase production. Many of these areas have been put down to long leys and in the event of a change in agricultural practice, it is likely that they will remain as grassland and will not be ploughed again. It is important to have available information concerning the survival of chalk grassland species in this grassland while the rate of reversion of sown chalk pasture to downland is not known. To provide this information, annual records of changes have been made in an area of downland at Crundale, Wye, Kent, which was ploughed in 1957. Before ploughing, Strawberry Down was an old chalk pasture dominated by Festuca ovina and Brachypodium pinnatum and contained many characteristic chalk species.

The Down was ploughed in 1956 and reseeded with a mixture of:-

Lolium perenne
L. multiflorum
Dactylis glomerata
Trifolium repens
T. pratense

Since 1957, until the present time, the Down has been grazed heavily by sheep and cattle, and the turf has never been more than 2" high when visited each yaar in summer. A permanent transect was marked out by Dr. Thomas in 1956 and this has been recorded annually at the same season, using the vertical point quadrat. The following changes in the sward have occurred.

Lolium multiflorum disappeared after 1957 and Red Clover, which was never very abundant rapidly decreased after 1958 and had also disappeared by 1960.

The three other sown species, Lolium perenne, Dactylis glomerata and Trifolium repens have decreased in cover with time, but still make the largest contribution to the sward in terms of dry matter production.

The most successful invader into the ley has been Agrostis stolonifera which has increased in cover from 4% in 1956 to 50% in 1964. During the last 5 years, 16 species which may be classified as weeds have been recorded, but the contribution made to the sward by these species has been small. 13 species characteristic of chalk grassland have survived ploughing or have invaded the ley from elsewhere, but none of these species are very frequent, except Brachypodium pinnatum: this grass, a tough, unpalatable perennial first appeared in 1960 and the tufts of yellow green leaves are now scattered across the ley. Festuca ovina is also present and had a cover of 11% in 1962, but the indications are that although the pasture contains many species characteristic of chalk grassland, the rate of reversion is slow, and many of the more interesting species such as Hippocrepis comosa and Anthyllis vulneraria are slow in recolonising the sward.

Conclusion

Experimental work is being done which should provide information which will be useful to those with responsibilities for managing Nature Reserves on the chalk. However, many of the problems outlined at the beginning of this paper are not being tackled because of lack of time and staff, and much remains to be done.

Experiments in which sheep and cattle are used demand a great deal of time and money, and many workers (e.g. Hurley) feel that controled experiments can only be done successfully on land attached to experimental stations. Many of the Reserves in England are too small for use, both by the public and research workers, especially when grazing animals are being used in experiments and it is suggested that consideration should be given to purchasing an area of land which should include a farm which could be used solely for management experiments.

RESEARCH IN PROGRESS ON THE RESERVES ON THE CHALK IN SOUTH-EAST REGION

P.A. Gay

All the research on grasslands in progress in the Region is specifically designed to provide information to help in managing the Reserves.

Wye and Crundale Downs

(1) Randomised block experiment to determine the effect of cutting season and height on the sward composition and especially on the control of *Brachypodium pinnatum* which is a problem on the Reserve and widely on the Downs in the S.E. Region.

(2) Plot trial on the mode of action of burning in its effect on *Brachypodium pinnatum*.

(3) Documentation of the voluntary grazing pattern of stock.

(4) Randomised block experiment on the build up and breakdown of litter of *Brachypodium pinnatum*, the effect of cutting season on the lay of grassland regrowth and on subsequent annual growth increment.

Lullington Heath

(5) Field trial on the effect of mowing season on the rehabilitation of chalk heath on former areas of dense gorse scrub.

(6) Plot trial on effect of mowing on maintenance of existing chalk heath.

(7) As for (4) but on *Agrostis stolonifera*. This experiment supersedes a randomised block experiment on the effect of cutting season on the annual growth increment.

Kingley Vale

(8) As for (4) but on *Bromus erectus*.

Knocking Hoe

(9) As for (3)

(10) On all the above Reserves observations are in progress on the year to year persistence of several species which it is important should be conserved. These observations so far are confined to finding the base level of the population as a preliminary to determining the effect of certain management treatments.

Wherever appropriate photographic records are taken to augment other forms of record of the results of the above research.

GENERAL DISCUSSION AND SUMMING UP AT THE END OF THE SYMPOSIUM

Dr. Mellanby, in his summing up, outlined the need for grazing on Reserves and suggested that two quite different approaches could be made which used together would provide the sort of information required for managing grassland reserves.

Careful experimentation, using standard statistical techniques was likely to yield the most useful information, but unfortunately neither staff nor financial resources were sufficient for carrying out the large number of experiments on a range of vegetation types which required study.

At the same time, Reserves had to be managed, and useful work could be done by testing different management techniques on small parts of Reserves which were representative of larger areas of similar vegetation.

Other methods of controlling vegetation, such as burning and mowing, should be considered as alternatives to grazing, especially on land which was not too steep to preclude the use of machinery. Special attention should be given to comparing the effect of different types of livestock and mechanical means of control, on the botanical composition of grassland.

Mr. Skellam made the plea that in all long term experiments which were likely to involve many people, the whole aims, terms of reference, and division of responsibilities should be clearly defined and stated in writing. It was suggested that a Proforma for each experiment should be completed and deposited with the Biometrics Section. It was strongly recommended that before large scale experiments were done using animals, small pilot trials should be made.

Dr. Duffey thought that we had to be certain about what we were actually trying to conserve. Different types of grassland required different management techniques and each site would have to be considered seperately, although general principles would evolve which could be applied to problems in general.

Flexible systems of management using animals not owned by the Conservancy had not been successful in the past, and it was essential for experimental purposes that animals were purchased by the Conservancy.

Dr. Frazer noted that some form of grazing was necessary to maintian the botanical and entomological interest of chalk grassland. He suggested that a committee should be formed to investigate the possibility of using a large flock of sheep for managing grassland on reserves owned by the Conservancy and Naturalists' Trusts.

DISCUSSION FOLLOWING PAPERS BY MR. WELLS AND DR. GAY.

Mr. Thompson mentioned that he had observed specimens of Orchis Fuchsii in Monks Wood in which the inflorescences had been bitten off and left on the ground beside the plant. In details, this agreed with what Mr. Wells had described at Knocking Hoe for Spiranthes spiralis and it would be useful to know whether rabbits or slugs were the responsible animal.

Dr. Perring thought it important to know if burning a grassland occasionally could result in the spread of Brachypodium pinnatum, or whether annual burning was necessary for its spread. At Wye and Crundale Down, burning followed by grazing had improved the turf.

Mr. Collier thought that too much attention was being given to studies on the rarities of chalk grassland and that more work should be done on the common species. This was generally agreed to be desirable although it was noted that rare species were often of national importance and merited special attention.

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