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TEACHING ECONOMICS IN THE VETERINARY CONTEXT

TEACHING ECONOMICS TO POST-EXPERIENCE VETERINARIANS

ALEXANDRA P. M. SHAW*

The need for the application of economic principles in veterinary medicine and especially in preventive medicine is increasingly recognized. In the area of food animal medicine this reflects changes in livestock production methods throughout the world, usually towards greater intensification, or at least towards greater commercialization, with an associated need for more careful financial control. The management of animal health is a major factor, and here the need is for veterinarians to be able to give their advice in financial terms, whether weighing up options or designing preventive medicine packages. In the more general area of government disease control schemes and the public health aspects of animal disease, this need is translated into a requirement that such schemes should be presented in terms of cost-effectiveness or as benefit-cost analyses.

Veterinarians are faced with a choice of acquiring the skills themselves or of consulting economists or financial analysts. Acquiring the necessary techniques themselves means that veterinarians, as those who are the most familiar with the health problems involved and who are in close contact with the farmers themselves, are then in a position to fully argue the case for a particular policy. The veterinarian could thus cover the whole process from designing the measures involved, to costing out its financial implications for the farmer (or the economic implications for the country) and eventually putting the policy into practice and monitoring its effectiveness.

This argument is strengthened by the fact that most of the basic skills frequently needed for such analyses are relatively simple to acquire. Nevertheless, before people from another discipline can apply them with confidence and in the correct context, some basic teaching covering the theoretical background to their use is required. Thus, although the services of a professional economist would still be required for analysing more complex problems, there is a clear case for making training in the subject available to veterinarians. However, to make this transition from accepting the need for economic advice in veterinary decision-making, to training veterinarians in the subject, requires a shift in attitudes and in academic curricula. This leads to a similar set of problems to that raised by the introduction into veterinary curricula of epidemiology, especially quantitative epidemiology (Cripps, 1987).

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In the case of veterinarians who have already had some years of experience, introducing economics as an option in post-experience training can be easier than it would be in undergraduate training for two reasons. Firstly, many will have already recognized a need for such skills and secondly, their careers will have started to develop in a particular direction so that they can relate this need to specific working situations.

From the educationalist's point of view, a first step to investigating the possibilities of teaching economics to veterinarians, is to look at the opinion of the 'client'.

The author has been mainly involved in teaching economics to overseas students, most of whom come from developing countries. Their perceived need for an understanding of the subject is clearly expressed in answers to a questionnaire asking veterinary students what they expected from a multidisciplinary course which included economics. Among the comments were:

"to understand economics of livestock production systems",
"to learn economic principles",

Turning from the demand for the subject, the degree of satisfaction with what was provided is expressed in the comments found in questionnaires filled in after the completion of post-experience courses by a similar group of veterinarians. Most of these held senior posts in government livestock and veterinary services. They were asked which of six subjects offered were found to be most interesting/useful and why. In the scored replies economics obtained nearly half of the total score and epidemiology together with economics was specifically mentioned in over half of replies with justifications such as:

"economics - to evaluate the economics of disease control and epidemiology - to study the essential points needed for undertaking disease control in an economic way",
"economics and epidemiology - because it was possible for us to see the relationship between the two subjects"
"herd dynamics, including modelling for economic analysis",
"economics - because it helps in developing project appraisal and monitoring and evaluation of projects",
"I could clearly understand the economic aspects of livestock production systems"
"economics and epidemiology and the case study because they are closest to our work".

What emerges most clearly from these comments is that the veterinarians involved particularly appreciated the chance to link economics with other subjects, especially with epidemiology. This also reflects the increased demand for more training in epidemiology seen in the veterinary field (Putt & Wilesmith, 1987).

The 'client's' main criterion in evaluating such post-experience training does seem to be relevance to his professional activities, as seen in the last quotation. This is reinforced by the negative feedback obtained:

"this subject was of little relevance to my work"
"the subject matter presented did not reflect our local conditions"

Thus, a first step to analysing what sort of economics could be taught to veterinarians would be to try and understand what practical role the subject does or could play in their work.

THE ROLE OF ECONOMICS IN VETERINARY MEDICINE

Identifying and classifying target groups

Within the areas of food animal medicine and the public health aspects of controlling animal disease, two subdivisions into groups with similar training needs suggest themselves:

- by the type of livestock production system (extensive versus intensive, highly commercial versus mainly subsistence),
- by distinguishing, where appropriate, between veterinarians working in the government sector and in the private sector.

For courses or parts of courses aimed at a very narrowly defined group, divisions according to level of experience, or by a particular sector of the livestock industry could be envisaged.

Geographically mixed groups of students want to feel that information about local livestock production systems is also included. Students in an assessment commented that:

"most of the case study work and examples were decribing African situations, examples from Asia should be included to provide a more balanced exposure",

"aspects of the course related only to the specific conditions of the UK",

"some examples from European agriculture were needed".

Thus it is clearly important to tailor courses to the livestock production systems that students are working in.

Table 1 - Breakdown of veterinary short course students for 1981 - 1987 at VEERU by region and type of employment

	Asia	Africa	Europe	Austra -lia	South America	Middle East	Total
Government: veterinary service	20	18	3	3	3	2	49
Government: project	13	12	3	0	9	0	37
Government: expatriate	0	2	3	0	0	0	5
University	0	5	1	0	1	0	7
Private	0	1	1	0	0	0	2
Total	33	38	11	3	13	2	100

Note: The total number of students involved was 112, based on a target number per course of about 15.

Table 1 gives a breakdown for students attending the three month post-experience course offered at the Veterinary Epidemiology and Economics Research Unit (VEERU) of Reading University for individuals working in the fields of livestock development and disease control. The subjects covered include epidemiology, statistics and computing as well as economics. Over

70% of students came from Asia and Africa, and of the Europeans attending, half normally worked overseas as expatriate staff on aid projects. The vast majority, nearly 90%, worked for the government, either within the veterinary or livestock services or seconded to specific projects. Very few private veterinarians attended, one interesting example being an African who was involved in importing and distributing veterinary products. The type of attendance was also conditioned to a large extent by the duration and location of the course, which by making it relatively costly meant that for overseas students sponsorship was necessary. The sources of finance were the bilateral and multilateral aid agencies in 86% of cases, with 11% of students being financed by their government and only 4% self-financed.

With overseas students it is relatively easy to identify and attract a fairly homogeneous group of veterinarians whose work exposes them to similar problems requiring an economic input. Seminars organized at Reading for British veterinarians have attracted private veterinarians involved in providing financial advice to farmers on managing animal health problems.

<u>Identifying the 'end-user' and the 'end-product'</u>

At this point it becomes important to emphasize that whereas most traditional teaching consists of a person training others to take up his profession, so that knowledge passes from:

ECONOMIST -----> ECONOMIST,

the economist's work may consist of advising others so that the flow is:

ECONOMIST -----> ECONOMIST ------> PERSON ADVISED,

and that when training veterinarians in economics the flow becomes:

ECONOMIST -----> VETERINARIAN.

However, the use that veterinarians wish to make of the subject will often consist of giving advice to others. The presentation could range from partial budgets comparing the relative merits of different ways of tackling a disease on an annual basis, to fully costed investment appraisals for preventive medicine programmes which may require substantial investments. In an overseas situation it could involve introducing simple record-keeping to farmers with a limited level of literacy. It will need to tie in with the sort of epidemiological approach described in Putt and Wilesmith (1987). So the information flow is likely to be:

ECONOMIST -----> VETERINARIAN -----> FARMER

or:

ECONOMIST -----> VETERINARIAN -----> GOVERNMENT DECISION-MAKER.

Often, in the case of veterinarians who are involved in teaching or are returning overseas, they themselves train other veterinarians in the basic economic principles and techniques they have acquired.

Finally, a reverse flow may be taking place, among economists involved in teaching veterinarians, as they pick up some veterinary knowledge leading to a different flow of information:

VETERINARIAN -----> ECONOMIST -----> VETERINARIAN,

but hopefully not to economists opening small animal clinics!

Characterizing the working situation

In order to ensure that the economic and financial techniques taught are applicable, an understanding of the veterinarian's working situation is necessary. The main factor here is some assessment of the type of information the veterinarian will have at his disposal for conducting economic analyses and giving economic advice. The information consists primarily of prices and production relationships. Prices may be relatively easy to estimate, but production relationships, especially the impact of disease on production, are not always clearly established in a quantifiable form. The degree to which the farmer is able to explain the economics of his production system is also variable. Again there is a big contrast between highly commercialized livestock production, smaller units and finally subsistence or semi-subsistence agriculture overseas.

Other factors to be examined can include the type of equipment available for undertaking and presenting economic studies - from hand calculators to micro-computers - and how justifiable investments in more advanced equipment of this type are for the veterinarian.

STRUCTURE AND CONTENT OF ECONOMIC TEACHING

Balance between economic theory and applied techniques

A key issue is the type and amount of economic theory to present. To what extent should this be balanced with teaching the more applied techniques such as farm budgetting and benefit-cost analysis? As Howe (1985) points out, the interpretation of animal disease in economic terms has often been merely terms of benefit-cost analyses of control work or of the costs of disease in terms of wasted inputs. There is a real need to apply economics more rigourously to the study of animal disease, and there have been few attempts to do this or to undertake a more comprehensive theoretical economic analysis of livestock production. Crotty (1980), develops an analytical framework for the economics of cattle production, focussing on the fact that both meat and milk are produced and cattle can either be destined for immediate consumption or regarded as an investment good. Tacher (1985) establishes the necessary theoretical background to an economic analysis of animal disease, and also outlines ways of estimating the costs of disease and of disease control in different situations. Howe's (1985) article provides a useful starting point for an economic analysis of animal disease.

However, the message from the students is very clearly a different one, as shown again by comments on economics course evaluations:
"please concentrate on case studies, not on theory",
"very theoretical",
"please give us more on project monitoring".
These refer to a twenty-hour lecture course in economics of which six dealt directly with economic theory, and the rest concentrated on applied techniques of more immediate relevance to the student.

Thus, on the one hand, there is a danger that in the veterinary field, economics becomes synonymous with benefit-cost analysis. On the other hand, there is the students' desire to learn things of practical value. This is particularly marked in the case of post-experience students, who have limited time available, are funded by themselves or by their employer and have a clear view of the use to which they wish to put their economic training.

A second danger exists: if insufficient theoretical background is provided, the techniques taught may be applied inappropriately. The minimum requirement for the theoretical input must be that students are made aware of the theoretical context within which certain techniques were developed and of any associated areas of controversy.

The following solution appears to be workable. In order to introduce students to a new discipline and to give them sufficient theoretical background, the most practical solution seems to be to teach aspects of theory which are relatively easily assimilated and to break up the theoretical components by linking them to more practical subjects.

One area of theory which seems to lend itself to this easily is price theory, as analysed by examining supply and demand. This has the merit of introducing those outside the discipline to the economist's favorite trick of illustrating and developing theoretical arguments using graphs. Examples can easily be linked to the student's own experience. European agriculture students are well aware of the impact of EEC pricing policy or of fluctuations in prices. Overseas students are used to the creation of gluts and shortages following ill-advised or politically-motived attempts at price-fixing. Whereas to the European student a price is something that is found on a label stuck onto each item, the Asian or African is much more at home with the concept of the market and of prices being the result of a bargaining process. From this discussion it is easy to move on to the fact that different people pay different prices for the same good, and of the importance of taking this into account in financial evaluations of livestock production. After looking at the impact of price-fixing the concept of a 'true' price can be considered. It is then possible to move on to the concept of shadow prices and its application in benefit-cost analysis.

Turning to the prices of the factors of production, the idea of derived demand can be introduced, and this can be related to prices for breeding animals and the price of inputs. An interesting illustration can be given by variations in the demand for particular vaccination in relation to the last known epidemic, and for students familiar with large scale vaccination programmes a price-related demand curve can be drawn. Eventually, in order to achieve a vaccination coverage of over, say 90%, it becomes necessary not just to offer the vaccination free of charge, but to pay owners to bring their animals in for vaccination. Studying the price of breeding stock makes it possible to start to tackle the idea of present values of expected future incomes. From this can follow a discussion of how expected future incomes vary with different economic situations and during the course of an animal's life.

Similarly, a discussion on production functions and on veterinary care, as one of several categories of input, can precede an introduction to farm budgetting, as a way of describing the economics of livestock production systems. The issues involved in choice of technology can then be dealt with. For students from developing countries, the problems of imported capital-intensive technologies versus more cost-effective labour-intensive techniques can be emphasized. Farm budgets involve the concepts of variable and fixed costs, and these can be dealt with in theoretical terms, whilst also introducing the idea of marginal analysis.

Table 2 - Matching theoretical and applied concepts - an example

Theoretical aspects:	Practical applications:
Supply and demand for goods Supply and demand for factors of production Concept of opportunity cost Concept of shadow prices	Choosing correct prices in economic and financial analyses
Production functions Choice of technology	Describing livestock production systems using farm budgets

Nevertheless, there remains a real need for further developing a theoretical framework for animal health economics. Some motivated and academically-oriented individuals will have a great deal to contribute in this area, but most post-experience students have a clear preference for learning practical and readily applicable techniques. The economist teaching his subject to this group must simply ensure that they are given sufficient theory to provide an adequate background and to guide them in their applications of the subject whilst inspiring those who will have something more to contribute towards the subject's development.

Balance between teaching and practicals

Here again questionnaire comments tell their own tale, in response to a request for suggestions:

"to have more practical case studies rather than lectures",
"need more practicals and class exercises",
"practical session and case studies - more exercises would be useful"
"you should have more emphasis on practical examples from the field of veterinary science",
"combine lectures with more practicals/exercises/case studies - lectures may be slightly fewer".

Both the techniques and the approach used in economic analyses will be very unfamiliar to most veterinarians. Experience here dictates that at least half of contact hours should be allocated to practical work, which can be divided into class exercises and case studies, both of which are described below. Table 3 illustrates a mix of theory and applied techniques and of taught and practical work, that has been found to be effective in teaching economics to veterinarians.

Time allocation

The time available to the post-experince veterinarian for for learning economics will always be limited either by the need to return to work or by financial resources. Courses inevitably need to be designed around a fixed time limit. Here it becomes important to distinguish between sensitization exercises, where a target group is shown what contribution economics could make to their work, and training exercises, where the group expects to depart having learnt a new skill which it will be able to use professionally.

Table 3 - Possible structure of economics input on a given topic

Type of input	Example	Time
Taught:		
theoretical concept	laws of supply and demand	1 unit
practical application	choosing prices in a farm budget	2 units
Exercises:		
practical session	class exercise calculating enterprise variable costs for a financial and for an economic analysis	3 units
case study (integrating different disciplines)	examination of costs of disease control at a national level for a specific disease	2 units (for economic element only)

Note: 1 unit refers to a unit of time which can be defined as desired.

Given a limited time period and a training exercise dealing with an unfamiliar subject, it is necessary to provide students with clear guidelines as to where to find certain types of information - from where to look up elements of economic theory to where to find the latest price of milk or concentrates. Concerning economic theory, it is often more practical to refer students to a good economic dictionary rather than to an economics textbook. This makes it possible to look up concepts as they are introduced or as students read or hear of them, and obtain the theoretical background quickly and easily. At VEERU, for the overseas courses, a manual is provided for students which covers all the basic concepts introduced in the multidisciplinary courses (Putt et al., 1987).

The formal teaching component in economics for courses with which VEERU has been involved has varied from two to twenty-five hours. Very short time periods can be used to to do very specialized things - such as teaching one technique plus the associated economic theory, as applied to one relatively narrowly defined livestock production situation.

APPROACH

Numbers, graphs and theories - a potential clash in outlook?

There are some fundamental differences in the way the theoretical economist and the veterinarian approach the learning process in their respective disciplines. These differences are found mainly at three levels.

Firstly, the practicing veterinarian is generally less in the habit of manipulating figures than the applied econonomist. The idea of performing numerical analyses and producing large tables of figures can be daunting, especially when this involves applying totally new theoretical concepts.

Secondly, while the economist is comfortable moving rapidly from one quantitative assumption to another, or using figures with accuracies of plus or minus 50%, the veterinarian prefers to to calculate and quote precise results. This is linked to the difference between veterinary medicine's grounding in the experimental sciences, and economics as a social science, which is often accused of having to find the facts to fit its theories.

Thirdly, to develop theoretical concepts, economists frequently illustrate arguments using graphs. The veterinarian is more used to graphs depicting the results of measurements undertaken in an attempt to see what form the relationship between two parameters might take. Thus the economist's graphs may appear very strange to the veterinarian, with axes lacking any numerical divisions and straight lines where curved ones might seem more realistic.

In fact, understanding the level of abstraction involved in economic theory is a struggle for most economics students. For someone outside the discipline, such as the veterinarian who is exposed to the subject for a strictly limited number of contact hours, this can pose a big problem. The solutions are simplification, cutting down on the volume of material taught and, above all, ensuring that the student is aware of where he is in the syllabus and how its components are related, particularly with respect to the theoretical concepts and their practical applications.

Visual aids

A separate heading for this subject is stimulated by the perennial comment from students that there were "no slides" or "not enough pictures". There is simply a limit to the amount of stimulation that can be provided by multi-coloured charts or a series of graphs overlaid one on the other. Slides of animals belonging to a particular production system, or identifiably ill and suffering from lowered productivity within that system do not really fill the gap, though they may provide a welcome interruption.

The writer has obtained some respite from this criticism by inventing a series of cartoon characters who do fascinating things such as argue out the relative merits of present costs and future values of benefits. They try to answer some of the problems of conceptualization referred to above, comparing the opportunity cost of their labour in relation to alternatives foregone such as doing nothing (or idleness), having constructive discussions while drinking with friends (risk of hangovers) and growing other crops (the right answer?!) .

Catering for the veterinarian's role as advisor

As discussed earlier, the veterinarian, will find that the main market for his economic skills is in advising farmers or decision-makers on animal health policy or in training others to apply these skills. Thus it is essential that veterinarians studying economics are able to transmit their newly-acquired knowledge at the end of the course.

Veterinarians on a multidisciplinary course were asked afterwards how confident they felt about being able to transmit the knowledge they had acquired. Economics scored at least as well as other subjects, but the score itself was not encouraging: 3.5 out of 5 (with the scale defined as: 3 = somewhat, 1 = not at all, 5 = easily). Thus attention needs to be paid to presenting some techniques so that can be passed on by the veterinarian to another user without the need for careful qualification as to how they will be used, or for much adaptation.

Computers

Students at VEERU are taught how to use spreadsheets on micro-computers. New users find them easy to use, and their application to preparing and presenting economic and financial analyses poses few problems. Once familiar with spreadsheets, veterinarians find them to be a relatively inexpensive tool on which they can develop a set of their own standard financial tables corresponding to their professional needs.

Case studies and class exercises

Case studies which simulate as closely as possible the expected working situation in which the veterinarian will use his economic knowledge and applied skills are being used more and more at VEERU. The approach developed at VEERU and outlined below has evolved over several years and is the result of close collaboration by the team listed in the acknowledgements. The emphasis is on combining several disciplines (epidemiology, economics and statistics) with newly acquired computing skills. In economics, it helps the student to understand the relevance of what he is being taught, it fixes the concepts in relation to a practical application and makes it easier for him to transmit these approaches to other people on returning to his work.

For the economics component, the approach outlined in Table 3 is used. When new concepts which have a clear practical application are taught, their teaching is followed as closely as possible by a class exercise. For overseas students who will be involved with project appraisal, the class exercise might consist of calculating an internal rate of return. Both the concept, and its calculation through iteration, often present problems to students. Deriving it using a hand calculator makes the concept of the internal rate of return easier to understand. Subsequently a computer can be used to obtain this result.

The case study could then consist of planning and evaluating a disease control programme for a region of a country. The time taken can vary between an afternoon and three or four days. If a survey is to be undertaken, its costs can be calculated, noting trade-offs between good sampling practice and the cheapest approach. A spreadsheet is used to prepare the financial and economic analyses. The students, working in teams, cost out their chosen control strategy. The benefits can be obtained using a dynamic herd model based on the one given in Shaw (1985). The situation before the project is implemented can be simulated using one set of production parameters, and output without the project from the region's herd is calculated over ten years, using the programme. A second simulation using improved production parameters, say lower mortality, gives output with the project. The increase (if any) in output due to the project is then calculated and compared to the programme's costs using the standard benefit-cost criteria.

Exam questions

A final concern is setting examinations in economics for veterinarians. The economics questions set in a written paper have been selected by veterinary students as often as those on the other subjects included in the paper. There is a slight preference for structured questions involving some calculations than for the more open-ended essay questions covering theoretical issues. Similarly, students writing theses and dissertations have found it relatively easy to incorporate chapters covering the economic or financial aspects of the problem studied.

CONCLUSIONS

Teaching economics to post-experience veterinarians requires a clear identification of exactly how the subject is relevant to them and of what skills can usefully or profitably be applied by them in their work with livestock producers. The economist undertaking such training must understand what the target group's veterinary work involves and be familiar with many aspects of their working environment, especially those apects relating to the production systems, the producers and the type of economic information available.

Most veterinarians choosing to interrupt their work for this kind of training have very clearly defined needs and expectations from the economics course. Whether funded by themselves, by their employer or by a sponsor hoping to benefit their employer (as is often the case for overseas students), the fact is that they are going for specific training in an unfamiliar subject rather than trying to obtain a higher qualification, so they want something that can be fully assimilated and rapidly applied. The veterinarian also needs to be able to transmit some of this knowledge of economics to the farmers he advises, and to argue the financial case for certain preventive health packages or disease control options.

Economic theory involves a level of abstraction and is conceptualized in ways that are very different from those used in veterinary medicine. Applied economics requires a high degree of numeracy which places unfamiliar demands on veterinarians. Thus it is important that the economist teaching his own subject provide sufficient theoretical background both to introduce the subject and to ensure that the veterinarian can apply the practical techniques he has learnt correctly and in the right context. At the same time, the course needs to make a generous provision of time for practical exercises in the skills and in the approach being taught.

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ECONOMICS IN THE VETERINARY CURRICULUM: CRITIQUE

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Some element of economics teaching is incorporated more or less explicitly into the curriculum of many, if not all, veterinary schools. This paper reports on the nature and scope of economics teaching in the veterinary curricula of such schools in the UK and elsewhere, based on information obtained from a number of enquiries directed at people who have responsibility for economics teaching. The main themes and contrasts are identified and discussed, with the objective of relating them to the broad analytical framework used by professional economists.

Although it may appear self-evident to many veterinarians and economists why teaching economics to veterinary students is a useful activity, it is worth considering explicitly some of the preconceptions which may lead to that conclusion. That both veterinarians and economists agree that economics has a place in the veterinary curriculum may be no more than a happy coincidence. Their respective perceptions about the purpose in teaching economics to veterinary students may be quite different. The veterinary schools which replied to the enquiries made in preparation of this paper were unanimous in their opinion that economics is important in training veterinary students. Such approval is put into an interesting perspective by one respondent who stated that several colleagues he had consulted in his school admitted that they did not know a definition of economics. He suspected that most of his colleagues think that they know, but really have very little idea - which puts economics in the same class as epidemiology!

The nature and scope of economics was outlined by the author in the 1985 edition of these Proceedings, and so those ideas are not repeated here. That aside, it is certainly conceivable that the economics taught in veterinary schools may sometimes be a response to the notion that it is obviously a 'good thing' to know about, rather than the outcome of careful deliberation as to precisely how some knowledge of economics will help students to become better veterinary scientists. This thought can usefully be regarded as a working hypothesis which can be tested by (a) reference to what economics is, in practice, taught in veterinary schools, and (b) an interpretation and appraisal of how the specific concepts and analytical frameworks which are taught appear as seen through the eyes of an economist who is not directly involved. It is hoped that as a result of this exercise the veterinary schools which currently teach economics will have some basis for appraising their own approach, while those contemplating the introduction of some economics teaching will find their thoughts clarified and perhaps further stimulated. This session of three papers was in fact conceived as a result of veterinary teachers concerned to introduce more economics to their students asking the question "what should we do?".

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THE SURVEY

Most of the information contained in this paper is from written responses to a letter sent to contacts at all veterinary schools in the UK and certain others in Europe, North America, Africa and Australia. Replies were received from all of the UK schools, but the response from overseas (at least by the time of writing this paper) was generally very poor. The letter requesting information stressed that in no sense was the exercise intended as a means to pass judgement on particular institutions. The names of these, and the details from any course outlines which were returned, would be regarded as strictly confidential. Opinions were invited as to whether or not economics is considered to be important in teaching veterinary students and, if it is, how any teaching which presently takes place might be better integrated into the curriculum. No formal questionnaire was sent because it was felt that the opportunity for each person who was contacted to reply as they wished would increase the likelihood of their making at least some response. It is evident from the replies that some contacts took exceptional pains to enlist the aid of their colleagues and to construct a helpful response, and their efforts are acknowledged with special appreciation.

Despite the poor response from overseas it was nevertheless possible to assemble some details of economics teaching as a follow-up to discussions held over recent months with teachers who are directly involved. In no sense can it be claimed that a representative picture of economics teaching in veterinary schools has been obtained at the international level. However, the information for the UK is expected to be reasonably comprehensive, and such details as are available from elsewhere do serve to show UK concerns in an interesting perspective.

GENERAL OBSERVATIONS

Some element of economics teaching was mentioned as taking place in each of the five years of the typical course structure for veterinary studies in the UK, although mention of economics occurs more frequently later on rather than earlier in the full degree scheme. Of course, the number of times mentioned conveys nothing about the weight which is given to economics in the curriculum nor to precisely where it appears. The overall impression derived from the available information is of very little economics teaching, and what does take place is concentrated in courses on animal husbandry. The time devoted to teaching subjects belonging to what was seen explicitly as economics ranged from 10 minutes to 6 hours, with mention of half an hour to one or two lectures being typical.

There were two exceptions to this broad pattern, neither of them in the UK but both European. In both instances no less than 20 lectures in agricultural economics are taught. Despite some recent revision to the overall curriculum of one of those schools it is clear that agricultural economics has retained its importance. Care must be taken in the interpretation of the brief subject titles which were listed, but both these and the time allocated show marked similarities to much of what is included in Introduction to Agricultural Economics as taught at Exeter University. The Exeter course is available to specialist economics/agricultural economics students and to biological science, operations research, psychology and geography students. It is important to note the range of main subjects followed by these students, because it serves to emphasise that economics is not a discipline whose secrets must remain closed to all but a chosen few.

What is distinctive about both of the European veterinary schools which seem to be so exceptional is that both are in close proximity to a department of agricultural economics. In marked contrast, of the UK veterinary schools Glasgow and Edinburgh are in universities which teach agricultural economics on a relatively modest scale, London University has a substantial commitment to agricultural economics at Wye College - a long way from the Royal Veterinary College, for which Reading is closer - and Cambridge has the Agricultural Economics Unit in the Department of Land Economy close by but, historically, this having rather specialised interests and functions. Liverpool's nearest geographical point of contact with agricultural economics would be Manchester University, while Bristol has the distinction of having no agricultural economists within the parent institution while being located in the no man's land between distant university departments. In short, if a veterinary school wants to teach all but a modicum of economics, it helps to have a department of agricultural economics literally next door.

COURSE DETAILS

The general observations which have been made are concerned exclusively with what might be termed the 'institutional framework' for teaching economics to veterinary students - at what stage, in what context, and how much? These are important parameters without which a more detailed appreciation of the subject matter cannot be made.

It is perhaps unsurprising that animal husbandry is the context within which economics teaching usually takes place. Management decisions concerning farm livestock must be made in the light of what is technically possible or advisable, but also with due regard to the financial and economic implications of those decisions. In fact, it is difficult to see how a course in animal husbandry could escape some economics input and still be considered suitably comprehensive in its coverage.

Those economic concepts and subject areas associated specifically with departments or courses in animal husbandry include the following:

> **Assessment of farm and enterprise profitability; gross margins, variable and fixed costs; net profits; cash flow; return on capital; the basic economic structure of major livestock systems; factors affecting profits, margins and costs; the economic consequences of variations in management policy; cost/benefit analysis of housing; whole-farm planning and linear programming; least-cost ration formulation; European agriculture and the Common Agricultural Policy; agriculture in the national economy; agricultural resources; production, prices and employment trends; the contribution and limitations of agricultural growth in the economy; the farm income problem.**

Several respondents stressed the importance of dealing with economics in an actual farm situation, and the use made of enterprise costings such as those published by the Meat and Livestock Commission.

Comments are made below as to the appropriateness (or otherwise) of the topics listed. However, what is striking about their treatment as part of the veterinary curriculum is the typically short time which is allocated. In one instance just 3 lectures are devoted to enterprise costings, farm planning, and agricultural policy! It should be said, however, that most of the UK veterinary schools which were consulted stressed that what are seen as economic considerations are referred to in various places on different courses, but not in such a way that it is easily possible to estimate the time involved. Even with that in mind, the broad picture which emerges is, on the one hand, of a very brief and highly concentrated discussion of a number of economic concepts and methods and, on the other, of occasional reference to economics as and when it is considered to be appropriate.

A similar pattern is observed elsewhere in veterinary teaching. Epidemiology, clinical studies, medicine, and surgery were other courses and departments mentioned as embracing at least some reference to economics. In these, the topics quoted include:

> **The economics of veterinary intervention in livestock enterprises; cost/benefit analysis, e.g. of vaccination and quarantine; economics of mastitis control; cost of herd infertility; economics of pig production; supply and demand curves; concept of elasticity; the value of the meat industry; types of business.**

A notable feature of both this and the earlier list is that cost/benefit analysis appears as just one of a wide range of topics. This might suggest that the technique is accorded less prominence in veterinary circles than some of us have supposed. However, closer examination of the material used, for example, in one particular lecture on the economics of mastitis control, reveals that some fairly intricate analysis nevertheless emerges neatly packaged as a simple benefit/cost ratio. Possibly other examples for which details were not made available also lead in the same direction, but it remains the case that the information to hand indicates the application in veterinary courses of a range of economic ideas.

For reasons which are developed later, it is encouraging to note the scope of economic analysis as it is found in veterinary studies. It must be said, however, that different topics sometimes find themselves together in what constitutes a rather curious mixture. For example, in one instance gross margins in sheep production, supply and demand curves, elasticity, and mention of the value of the meat industry, all appear in just one lecture hour. In another - this time spread over three lectures - gross margins and related concepts are considered alongside farm planning techniques (sensible enough), utilisation of land, labour and capital, European agriculture and the Common Agricultural Policy.

These examples epitomise another characteristic of economics in the veterinary curriculum as revealed by the survey - the fragmentary treatment of some of the core ideas and analytical methods of economics. One reason for this may be the need to cover a number of topics within severe time constraints. Another reason may be the sheer practical problems of identifying those aspects of economics which will fit most comfortably into courses where economics is not of primary concern. However, these thoughts are pure speculation. In attempting to find at least a partial explanation for what is observed to happen in practice it is helpful to adopt a different perspective. Instead of asking questions about what economics currently is taught in veterinary schools, what might an economist on the outside expect to be taught if starting from first principles?

SOME REFLECTIONS

It is an elementary and maybe obvious starting point to assert that what a veterinary student needs to know depends on what he or she will do during their professional career. The notion that knowledge is valuable for its own sake will not take us very far here. Veterinary science is essentially functional. At root it is about doing good for animals, which enables people to do good for themselves. For example, whether more livestock products are produced, racehorses win more races, or pet owners have more contented animal companions, the outcome always amounts to the same thing - the welfare of people is increased.

Insofar as veterinary practitioners are in direct contact with farmers, it only makes sense to see economic relationships from a farmer's point of view. Any intervention by a veterinarian in a livestock enterprise has implications for the financial costs incurred and returns earned by the farmer. At the most basic level, understanding the financial concerns of a farmer requires some knowledge of simple accounting procedures. From that can be deduced whether or not farming income is likely to improve as a result of veterinary intervention. Commonly, the outcome of a specific change on a farm - such as 'buying-in' the skills of a veterinarian - will cause the farmer to consider if profitability of the farm business is likely to improve overall. Statements of the kind 'margin per cow will go up by £x' are commonly met. Such statements tend to emphasise how financial performance is likely change on the average. Of more interest to the economist 'per se' then to the accountant is what happens at the margin. Marginal analysis - asking what increment of gain (loss) is expected to result from an incremental outlay (reduction) in real (not just money) resource expenditures is central to answering questions about economic efficiency. An astute livestock farmer will always ask himself if what he spends as a result of calling in his vet is recouped in ways seen as beneficial. For sure, the farmer has no interest in acting in ways which will make him feel worse off. At the very least, he will have a much happier relationship with a vet who is capable of seeing decision problems from his point of view.

In all of those respects the study of enterprise costings, gross margin analysis, farm planning techniques and the central concept which underlies cost/benefit technique (the marginal criterion to compare incremental gains with incremental outlays) are precisely what is required. Whether or not linear programming is especially useful is more open to debate. Linear programming (LP) is a mathematical technique which computes the optimal value for what is referred to as an 'objective function'. Given knowledge of the area of land and labour hours available, as well as crop rotations, capacity limits of farm buildings, and the like (resource constraints), plus the coefficients which measure the amounts of each resource required per unit of the various enterprises for the farm, LP is an ingenious way of calculating what combination of enterprises (number of dairy cows, hectares of winter wheat, etc.) will maximise total farm 'profitability'. Profit (strictly total farm gross margin, which is not quite the same thing) is the 'objective function' to be optimised. Whether or not farmers are optimisers in that sense is an open question. Certainly LP is a powerful and useful tool in many economic applications, but the usefulness of veterinary students exploring optimising techniques must be doubted. One thing which is certain is that very little can usefully be said about LP in less than perhaps two hours single-minded application.

For veterinarians who become research scientists or whose focus of concern will be at the level of the livestock sector as opposed to the individual farm, there are sound reasons for developing an appreciation of the aggregate impacts of measures for disease control. This is especially useful for anyone who becomes involved in resource allocation when decisions have to be taken about which diseases should be researched and/or controlled, to what extent, and in whose interests (e.g. farmers, consumers, or society at large). In that context an understanding of supply and demand relationships and the implications of the magnitudes of their respective elasticities is indispensable. So, too, is an appreciation of how disease control programmes have the effect of shifting the supply curve for a livestock product. For that matter, a major disease outbreak also shifts the supply curve but, as might be expected, in the opposite direction to that resulting from disease control. Such movements in supply (and demand) curves have implications both for market prices and the quantities of products which are available. Since governments typically choose to interfere with the free interplay of supply and demand by setting minimum prices, production quotas, and so on, it is a logical step to consider the methods and consequences of agricultural policy interventions, such as the mechanisms of the Common Agricultural Policy. In common with veterinarians who deal with individual farmers, those veterinary scientists concerned with livestock sector problems can only benefit from an appreciation of the possible consequences of their decisions for society at large. If nothing else, it places the application of veterinary science into a social context.

CONCLUSIONS

If the arguments of the previous section are accepted, one conclusion reached is that veterinary schools already appear to be teaching economics with reference to those concepts and methods which, by and large, are appropriate to the context. However, this impression is reinforced, if not created, as a result of taking a global view of economics teaching in veterinary schools rather than taking a detailed look at individual cases. It has been observed that some economics topics which are taught appear in peculiar juxtaposition. Also, the very limited lecture time allocated to economics is suggestive of a very superficial treatment of certain subjects. Nowhere in the UK is economics taught to an extent comparable with the two European schools which were noted.

Possibly the economics which is taught in the UK is about right given the objectives and structure of veterinary courses. Perhaps more economics would mean less of other essential subjects - in economic terms, the opportunity cost of more economics teaching may be simply too high. There is no way of reaching a conclusion without more careful study than has been possible in this brief overview. That is not to say, however, that the crude perspective which has been shown here is without important lessons. The importance attached to economics by the survey respondents was remarkably strong. Some wrote of the need to increase economics teaching, one to the extent of wanting to employ a specialist economics lecturer. For veterinary schools interested in reappraising their current commitments in economics, and for those which might in due course contemplate the scope for expansion, the following steps might prove constructive.

1. Identify those courses in which an economics input is viewed as desirable.

2. Estimate the maximum time potentially available for economics teaching in each course having allocated time to other non-economic subject areas which are considered to be priorities.

3. Provide an economist with (a) course outlines, each with details of the non-economic course content and essential references, and (b) an estimate of the maximum teaching hours in each course available for economics. Then ask the economist to devise a feasible teaching programme in economics for each course.

4. Get acquainted with examples of economics texts which cover what are anticipated to be the most relevant concepts and methods. As we have seen, many of the important ideas already are considered in veterinary courses. Useful texts currently available are Barnard and Nix (1973), Bishop and Toussaint (1958) and Hill (1980).

5. Pool the perceptions of both veterinary science teachers and the economist as the basis for refining and constructing a coherent economics contribution to each course.

A final observation is pertinent. It is reassuring to discover from the survey that applications of economics in UK veterinary schools is not yet regarded as synonymous with running computer models. Unquestionably, computer simulations of livestock systems with the facility to study the effect of interventions aimed at disease control have an important contribution to make. However, there are very many economic problems and issues in the veterinary context which do not, in themselves, need computer models for their analysis. There is no escaping the fact that the skilful application of economics to any problem depends, first and foremost, on a thorough appreciation of fundamental concepts. Veterinary problems are no exception, and it is on that theme which John McInerney builds in the following paper.

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ECONOMICS IN THE VETERINARY CURRICULUM: FURTHER DIMENSIONS

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Although the economics element contained in veterinary curricula varies widely among institutions, the very fact that it always gets some mention shows (presumably) that economic considerations in animal disease are universally accepted as 'important'. However, there is a great divide between simply realising that economics cannot be ignored and recognising precisely **why** it is important, and hence identifying what kind of economics understanding is useful for veterinarians. It is not surprising, therefore, that there seems no clear agreement over what to teach or how to teach it.

It is no criticism that the veterinary profession may not know what economics it needs, for the answer is not at all self-evident. Every discipline has its own abstractions, conceptual frameworks and analytical approaches which derive from the way problems are defined within that discipline. It takes a very long time often to appreciate these fully and develop the intuitions that enable one's specialist training to be used as a mode of thinking, rather than just as a set of rules or technical methods.** It is unlikely that 'outsiders' can ever achieve this appreciation. Even for professional economists, crossing this intellectual divide in relation to their own subject is not easy. It has to be said that most economics graduates don't **understand** economics - they merely know, to a greater or lesser extent, what they have been taught about it (and it is sad that many never develop beyond this point).

Consequently, as non-specialists, veterinary teachers cannot be expected to know automatically what economics content is most appropriate for inclusion in their curricula, and economists as a group have not been very evident in helping them decide. The economic issues relevant to veterinary studies seem never to have been confronted in a structured manner by either of the two interested parties, and this session of the Conference could represent a valuable step forward in this respect.

There are numerous viewpoints on economics, and therefore many contexts in which it can be taught. They vary from generalised notions concerning the creation and distribution of wealth in society, through the establishment of relationships describing the workings of major segments of the economy, to very applied techniques for assessing the financial implications of particular actions. Before any sensible planning of economics training can be conducted it would seem necessary to decide what sort of economics might be relevant to those preparing for a career in veterinary science.

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** Rather like learning to **think** in a foreign language, as opposed to being able to translate words into or from it.

WHAT SORT OF ECONOMICS?

It is unfortunate that the basic notions of economics are frequently summarised and purveyed as 'the economics of .... (animal disease, forestry, home ownership, education, etc.)'. This phrase is generally interpreted as an excuse to detail the financial aspects of the subject, setting monetary costs and returns against one another to yield some figure(s) to indicate the balance of advantage and how it is influenced by various factors. This is, perhaps, an unavoidable element of economic analysis, but is not really what economics is all about. For one thing, it implies no concepts or analytical frameworks, but reduces economic analysis to merely a series of measurements - as though expressing things in monetary terms in itself made some answer obvious. This popular misconception confuses economics with accountancy; it is a major barrier to any functional appreciation of what economics might offer, and lies at the root of the often dismissive attitude that 'real' scientists hold towards the subject. The simple view that veterinary science is all to do with spaying cats, helping with difficult calvings, and treating sick animals is on about the same level.

Three different approaches to the teaching of economics might be considered as appropriate for adoption within veterinary schools.

1. <u>'Pure' economics</u>

It could be argued that everyone should be exposed to the basic principles of economics, simply because the society in which we live and work is fundamentally an economic system. Consequently, an understanding of the elements of how that system functions is an essential part of our general education, in precisely the same way as is a basic appreciation of science, history, geography, literature, etc. The social sciences are not included in the core curriculum at school level (because they require more maturity to be understood?) so they should at least be encountered by the university student, of whatever discipline. This view is common in American universities, where economics, sociology and politics are among the compulsory subjects for virtually all first year students.

However, while there are undoubted failings in the narrow specialisation to which our university students are subject, there is no reason why veterinary students in particular should be taught something to make them better informed citizens if the same principle is not applied everywhere. Because something would be beneficial is not to say that it can be justified. The time constraints on covering the scientific elements of the veterinary curriculum are perceived as severe enough, without diverting resources to teaching more general matters. And it would require a substantial resource commitment to create any self-contained understanding of economics. The selected snippets of the economist's analytical framework (such as the 'explanation' of price formation on markets, elasticity concepts, opportunity cost, discounting, etc.) which frequently gain a mention in non-specialist summaries amount merely to pointing out a few exotic shrubs in an unfamiliar garden. They yield neither specific understanding nor general appreciation of why the study of economics might be important, they make no contact with ideas in veterinary science with which the student is otherwise pre-occupied, and do not even allow him to appreciate any better the economic commentary found in newspapers. To create a workable picture of general economic principles would require emphasis on the structure of economic systems, the elements of both micro-economics and macro-economics, the major relationships that underlie economic analysis, and the way economic forces mould the development of firms, industries and societies. Everyone should know about these things - but they do not belong in the curricula of veterinary schools.

2. The economics of agriculture

On the basis of Keith Howe's survey it seems the dominant form in which economics finds its way into the veterinary curriculum is through association with agricultural production. This is understandable, since much veterinary practice centres on farm animals and so it is likely the economic implications of disease, and disease control, will emerge through their effects on agricultural output. In addition, livestock husbandry and farm management offer a readily identifiable context for appreciating economic issues, compared to rather more vague ideas of costs and benefits which attach to no-one in particular.

However, the focus on agricultural economics represents a very restrictive framework because it suggests that the economic aspects of animal disease are almost entirely **commercial.** In other words, the presumption seems to be that the part of the economy using the services of veterinary science (either directly in practice, or indirectly in research, the pharmaceuticals industry or the state veterinary service) is mainly farming, and so it is the economics of farming that it is most relevant to appreciate. But economics is not synonymous with commerce. Its prime concern is with how economic benefit ('value') is generated for the people who constitute society, not just with monetary revenue to businessmen. It is true that agriculture has the most obviously measurable output that can be affected by disease control, but that is not to say that therefore it is potentially the most important source of economic benefits. The non-commercial customers of the veterinary service - the private individuals whose livestock are companion animals - are just as much a part of the economy, and just as much recipients of genuine economic value.* Indeed, it is arguable in a society such as ours that, overall, people would be made worse off by a reduced availability of veterinary services to the companion animal sector than by an equivalent reduction in services to the farm sector. This statement may or may not be precisely true, but it is designed to highlight the validity of the non-agricultural sector in considering the economic aspects of animal disease.

Thus, an emphasis on costings and margins for farm enterprises, accountancy and farm planning procedures, management variables and their effects on farm incomes, etc., seems a limited addition to the veterinary curriculum. It may constitute no more than an isolated cameo on another world, and unlikely to assist the student in appreciating his training in any wider context. It is only if the vet becomes fully integrated into the farm management decision making process - which occurs in some intensive pig enterprises but nowhere else - that his analytical capabilities need to develop down this pathway. Otherwise, the only 'commercial' decisions he is likely to confront are those connected with the running of a veterinary practice - and conventional agricultural economics has little to offer in this respect.

From a strictly economic point of view it would be more relevant to consider the implications of livestock disease from the standpoint of the overall agricultural sector, rather than detail on the firm-level situation.

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* And many veterinary practices recognise this when they look at where their fee income comes from.

But this is difficult to illuminate very clearly, and is still a limited perception of the economic issues. It is certainly not approximated by summary explanations of the CAP or other aspects of agricultural support policy, which are mostly just administrative and political interventions in the economy's functioning that obscure the underlying economic reality.

3. Veterinary economics

The above comments lead one to conclude that, if veterinary students are to make any useful contact with economics, then what they are taught should link as far as possible with their own starting perceptions and not be presented as some apparently arbitrary statement of things that are 'important'. This implies there could exist a distinct area of study, which we shall call 'veterinary economics', linked conceptually to the wider frame of economics but sufficiently self-contained to be applicable within the context of animal disease. To define it we must seek to establish and illustrate a series of concepts and propositions that demonstrate how veterinary science and practice can be seen as part of the workings of the economy.

This may seem slightly odd, because at first sight veterinary studies are built upon the natural sciences, biological and biochemical processes, clinical diagnosis and treatment, and the objectives of enhancing the welfare of animals. However, it is no less illogical than accepting 'agricultural economics' as an identifiable and valid branch of economics. The science and practice of agriculture is the manipulation of technical processes involving plants and animals; as an area of knowledge it is basic science linked with a few organisational procedures. However, it is because these are conducted solely in order to benefit human beings that agriculture gains its economic connotations, so ultimately some understanding of agriculture as an economic process becomes necessary. If agriculture students need to know aspects of economics that relate particularly to their realm of study, and if a set of economic principles can be defined and packaged in a way that makes them directly applicable, then exactly the same can be said for veterinary students.

Vets never need to function as economists, so there is no purpose in insisting students should be capable of applying the standard concepts and analytical methods that constitute the typical elementary introduction to economics. However, as professionals, they will be operating within an environment that is governed (if not dominated) by economic considerations. This is true whether they go into private practice, research, the pharmaceuticals industry, the state veterinary service, or even university teaching. It is a defensible presumption, therefore, that every veterinarian ought to understand what 'economic considerations' are if they are to condition his lifestyle. Furthermore, if he appreciates how veterinary science fits in the spectrum of scientific knowledge and endeavour (as he must), then equally he should appreciate how the science of animal disease control fits into the spectrum of economic activity that constitutes 'the real world' in which all this takes place.

It is not practical here to set out in detail the appropriate components of a veterinary economics course. However, it is suggested that to gain any useful insight into economics the student of veterinary science should appreciate four general propositions. Each of these is considered in turn.

LIVESTOCK DISEASE IS AN ECONOMIC PROCESS

The conventional view of disease sees it as a biological phenomenon which affects adversely the health status of an individual animal or animal population. From an economic standpoint, however, the important thing about livestock disease is that it adversely affects **people**, not animals. This statement is true not just for zoonoses but any disease condition about which society is sufficiently interested to do something - that is, in which there is an economic interest. If a disease condition affects only livestock of no direct or indirect economic concern (wild shrews?) then for all practical purposes it is not a disease. Except in purely scientific terms, therefore, what we define as a disease depends on an implicit assumption that people may be in some way less well off as a result of it.

To place animal disease in its economic context we first need the concept of an 'economic process' which lies at the core of the economist's model of the world. This is simply any activity in which basic resources are utilised to produce goods and services designed to be of benefit to people. All economic activity, in all forms and at all levels in all societies, is a collection of such basic processes. 'Resources' may be divided into natural resources (land, livestock, etc.), human resources, and capital resources (which are themselves the product of an economic process). The 'goods and services' are the whole diverse array of things that satisfy the needs of human society. And the 'people' for whom this economic activity takes place means society collectively, rather than any particular person or group - though the model can be applied with equal validity at any level of aggregation referring to the people who make up a firm, a village, an industry, a region, a country, or the world.

RESOURCES —'production'→ **GOODS & SERVICES** —'consumption'→ **PEOPLE**

(Cost) **(Value)**

The central economic ideas of 'value' (benefit to people) and 'cost' (resources used up) emerge directly from this simple model, without any need to include the element of 'money'.* In addition, the guiding concept of economic efficiency (gaining maximum benefit from the collection of resources used) can be distinguished from the limited but more common notion of technical efficiency (the ratio of output to just one of the resources used - yield per cow, output per man, return on capital, etc.). In an ideal world this resource use system would work perfectly, so maximum economic efficiency provides the conceptual benchmark against which actual standards of achievement can be assessed (rather like the perfect gas or the frictionless plane in physics).

The economic process of major interest to veterinary science involves transforming resources (grass, feed, labour, animals, etc.) into products (meat, milk, horserides, pet companionship, etc.) that benefit people. As a

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* Contrary to popular presumption, money is not the essential element in economics; it is merely the convenient unit for measuring the varied **real** components, which are positive and negative benefits.

biological phenomenon, disease is an integral part of this system, disease agents being simply one natural form of influence interacting with all the others. From an economic point of view, however, disease is an intrusion into the resource transformation process. It reduces the services gained from any level of resource use, and so lowers the level of benefits available to people collectively.* The economic definition of a disease is then clear. It has no particular aetiological or clinical reference points. It is simply any condition affecting the health status of animals which society would prefer not to exist.

Disease can be viewed as an economic process in itself because it consumes economic resources (i.e. uses up feed or livestock), or because it generates negative benefits for society. The negative aspect of disease is not simply the directly reduced value of output or services from livestock (the commonly perceived 'disease losses'). Benefits are lost also due to an array of indirect, secondary and knock-on effects throughout the whole interconnected system of resource-using processes that constitute the total economy. Before the losses attributable to disease can be measured, their manifestation must first be identified, which implies modelling the way disease effects move through the economic system - impinging on resource use and value creation on farms, in households, via markets to all firms and individuals linked in some way with commercial and domestic livestock. Modelling livestock disease as an economic process has many similarities with epidemiology. As the epidemiologist traces the path of infection, say, from its original source out through the herd, the livestock population and perhaps to other affected livestock types, so the economist will attempt to trace all the (positive and negative) changes in value from the first manifestation of a disease in a livestock process outwards as they appear in related economic activities and processes.

DISEASE CONTROL IS AN ECONOMIC PROCESS

To the veterinarian, disease control involves the use of appropriate drugs, procedures and back-up services to lower or prevent the technical manifestations of some defined condition. In economic terms this is just another variant on the theme of transforming resources into products and services that people want. It is possible - but not particularly fruitful - to wonder whether the outcome should be defined as a negative output (less disease) or a positive one (faster liveweight gain, a happier dog owner). Either way, the basic elements of economic analysis - costs incurred, benefits gained - are an inescapable feature of what is otherwise a veterinary process.

But economic concepts have more to offer than this, because they address questions about **how best** to undertake disease control and **how far** to pursue it. The economist's model of resource use is developed from the concept of a 'production function'. This is simply a generalised statement that there is a systematic relationship between the levels of the resources used (X_i) and the level of output (Q) into which they are transformed.

$$Q = f(X_1 \ldots\ldots X_n)$$

* Although within this overall category the existence of disease may create positive benefits for some sub-groups - e.g. it generates income and employment for vets and drug companies.

The importance of this relationship is not its mathematical form (the determination of which is a strictly empirical matter) but rather its embodied principle that economic resources do not have to be combined in fixed proportions.* A given volume of milk can be produced from countless different combinations of land, labour, feed inputs, cow numbers, capital equipment, etc. - i.e. different dairying systems. Within broad limits, all inputs are substitutes for one another, and economic criteria define how the **best** (most economically efficient) combination can be determined.

In a disease control context, the production function idea highlights the fact that non-veterinary resources (feed, management practices, etc.) and direct veterinary inputs (drugs, professional services) are substitutes in reducing the impacts of disease. For example, allocating more land and labour inputs to a flock of sheep (i.e. a lower stocking rate and rotational grazing) can reduce losses due to intestinal worms in the same way as treating with anthelminthics. Hence no 'best' control practice can be defined for any disease - nor should one be recommended, therefore - based solely on technical criteria. The relative unit costs of veterinary and non-veterinary resources, and their respective productivities in counteracting disease losses - which vary in different countries and between farming systems - will determine the best practices to adopt.

The economist's production model also considers the link between the additions to output and additional resource use. In virtually all situations this is a declining relationship (the widely misquoted 'diminishing returns'), so at some point it is not worth increasing output further because the extra gains do not cover the extra costs. In a disease control context this highlights the (obvious) fact that a stage will always be reached when it will not be economically worthwhile reducing disease losses further. This then introduces the (less obvious) concept that in any livestock system there is potentially 'an optimum amount of disease'.

These ideas are set out with reference to agricultural production simply because that is the easiest context to visualise. They are equally relevant to the expenditure of resources on health care in pets, wildlife or humans. Furthermore, they are applicable at all levels of aggregation - whether individual companion animal, herd or livestock sector - where decisions about disease control are made. Although not developed in detail here, they should serve to emphasise what may not easily emerge from standard veterinary considerations - that disease control is (not only, but also) an economic process.**

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* As compared to transformations at the biochemical level, for example, where the combination of amino acids to produce a molecule of some protein is rigidly defined.

** It should also be clear that 'animal welfare' concerns are essentially part of an economic process too. The animal species for whom welfare issues are important are a matter of social choice (cats, but not rats); and people are prepared to forego some element of consumption benefits (cheaper pork or eggs) and incur extra resource costs in order that **they** feel more comfortable about how livestock live.

ECONOMIC VALUES ARE NOT SIMPLY 'PRICES'

Disease control programmes can be conceived, designed and operated at two distinct levels - the individual animal or herd, and the overall regional, national (or international) livestock sector. Veterinary training needs to clarify the principles of action at both levels, which correspond to the individual veterinary practice and the state veterinary service. The private farmer or pet owner on the one hand, and the general public (referred to by economists as 'society') on the other, represent two quite different customers. More importantly, from an economic point of view, they imply two different contexts for the valuation (measurement) of costs and benefits. Although veterinarians are unlikely to be undertaking formal economic analyses, they should recognise this divergence - if only because it highlights the possibility, when assessing the economic merits of disease control, of conflict between the ('private') economic interests of a farmer and the wider public ('social') interest.*

Measurement of costs and benefits always involves applying appropriate monetary values to physical quantities of resources used and outputs gained. It is the difference in the relevant values to apply at farm and at sector level that gives rise to the divergence between 'private' and 'social' valuations of any scheme. Individual farmers (or householders) mostly buy the resources and services they use and sell their outputs through the usual market channels. To assess the net benefit of expenditures on disease control as perceived by them (whether from farm level or national schemes), it is entirely appropriate to apply observed market (commercial) prices to the elements of cost and benefit they experience. The balance between computed costs and returns captures the net effect on their personal finances, the impact as reflected in their individual bank accounts. Strictly speaking, this is an assessment of the **financial** aspects of disease control (rather than an economic assessment), the term indicating that it is the advantage to the individual(s) concerned that is being measured. It is the appropriate information for deciding whether the individual should choose to participate.

An **economic** assessment, by contrast, seeks to determine the balance of gains and losses as reflected in the economy as a whole - i.e. aggregating across all groups and individuals who may be affected.** The use of market prices in this context may introduce major errors in valuing expenditures incurred and benefits generated. Observed prices may grossly misrepresent the real (economic) values of costs and benefits to the economy due to four main causes. (a) Taxes and subsidies raise or lower prices without in any way affecting the commodity's value to the economy. A gallon of petrol represents the same amount of real resource, and makes the same contribution to real output, regardless of whether its price includes a major or minor element of tax. (b) Other forms of market intervention distort prices so they fail to reflect real economic values. An obvious example is the intervention purchase of surplus agricultural commodities. By definition, they have a zero value to the economy because they are surplus to requirements (and so no benefit would be lost if they were not produced); yet they command a non-zero price in the

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* This potential conflict of interest demonstrates that disease control is a **political** process too.

** Phrases such as 'the national farm' and 'UK Ltd' are frequently used to portray interests at this level.

market thereby creating an illusion of value.* (c) Some things representing real costs and benefits to society have no price (and so appear valueless) simply because the economic system has no markets to generate price data. The obvious examples are wildlife, human health and farm animal welfare. (d) Finally, even if all prices do accurately reflect true economic values, they are sensitive to changes in the level of the commodity in question. If a disease control scheme raised the production of milk by 5 per cent this would cause the price of milk to fall, so the benefit generated cannot be captured by simply applying a price value.

Considerations such as these are complicated, frequently subtle, and always difficult to establish unambiguously. But they are also crucial. The proper measurement of economic quantities is as important to correct decision making as is the accurate measurement of drug doses in disease treatment - adequate within certain limits, but potentially dangerous beyond them. Veterinary students do not need to know how techniques of economic analysis are employed in making corrections to observed prices. But they should appreciate that this is one reason why economists have a genuine role in the analysis of animal disease issues, as distinct from just being the guys who multiply things by prices (which anyone can do).

THE BASIS OF ECONOMIC VALUE

The formal role of the veterinarian as a member of his profession is a commitment to the welfare of animals; as part of an economic process, however, like everyone else his role is directed towards the welfare of people. The veterinary student deserves to be shown how these two link together. In principle, this implies some appreciation of what determines the economic value (benefit to people) placed on veterinary services.

Much of this may be thought self-evident. To the extent that the veterinarian's efforts bring about healthier and more productive farm animals, and hence increased and more secure supplies of food, therein lies his economic contribution. Its value can be traced through a potentially measurable increase in a saleable commodity that has a recognisable price. This price may need some adjusting to correct for distortions, as discussed above, but otherwise the issue seems clear. However, the core of economic thinking emphasises that the value of something is not an intrinsic characteristic like molecular weight. Rather it derives from what people want, balanced against the availability of it - and these vary according to time and place. The value of enhanced pigmeat production to people in Europe, for example, is very different as compared to people in Saudi Arabia or in Ethiopia. The important points to recognise are, first, the supremacy of **preferences** in establishing value; these are not 'scientific' but they are nevertheless real, and become the ultimate determinant of what is important in a society. Second, the value of extra food is not self-evident on the grounds that 'food is an important commodity you cannot live without'. Recognition that the real value of anything can only be measured at the **margin**, not on average, is one of the most fundamental points in economics.

Economic values as identified in commercial production have some tangible base. But what underlies the economic value of veterinary services that produce healthier hamsters or neutered fat cats? Again this varies from one

* This illusion is, of course, a reality to the individual buyer or seller.

situation to another because, in addition to preferences, the observed value of some good or service in an economy is determined by the willingness and ability to pay on the part of the recipient. This reinforces the point that economic values are not intrinsic measures but a function of income levels. Thus the benefit gained from eliminating fleas from dogs in the UK is apparently far greater than it would be in India, and so would justify more resources being directed towards it.

The essential point in all this is that there can be no definitive statements about how 'important' animal health issues are. The potential economic benefit derived from the availability of veterinary services, the appropriate type of services, and the level of resources that ought to be allocated to providing them are all fundamentally economic issues. In poor countries (and to poor people in rich countries) it is their contribution to more and cheaper food that underlies 'the economics of veterinary services'. In high income countries it is increasingly through the provision of health care to companion animals, rather than in agriculture, that the veterinary profession makes its economic contribution to society. Nor can one realistically specify the **need** for resources to be allocated in the veterinary field on the basis of numbers and types of livestock, etc. (although this is essentially what was done by the manpower review body which specified the appropriate number of entrants to UK veterinary schools). It is clear, however, that the **demand** for veterinary services per thousand cows in the UK is greater than it is in Bangladesh.

CONCLUSION

The four propositions set out above would neither serve nor aim to 'teach economics to veterinary students'. Rather they could provide a framework within which the linkage between veterinary science and economic activity (as opposed to its linkage with animal health, or with professional practice) might be appreciated. The purpose would be to emphasise that all information and analysis, in whatever area of study, is directed towards supporting decisions that have to be taken. Decisions are guided by objectives, and the economist would argue that it is economic objectives (i.e. relating to the benefit of people) that ultimately guide all decisions. Furthermore, those decisions always boil down in the end to some variation on a theme of what resources are to be used, and for what purpose. These decisions may be made about treatment of individual animals in commercial veterinary practices; or about allocating public resources to national disease management schemes in the state veterinary service; or about appropriate expenditures in research programmes seeking more effective drugs or a more detailed understanding of a particular disease condition. The basic principles are the same, although the complexity of issues, information and implementation are very different.

If it is insights (rather than techniques) that the veterinary student should gain from the economics content of his curriculum, then perhaps the most useful of these relates to the ultimate aim of veterinary science. Since science is (apparently) free of value judgements, it says nothing about how much disease is correct or acceptable in livestock; the implicit assumption can only be that veterinary science is directed towards the minimisation - or even elimination - of disease. By emphasising its commonality with all other resource-using processes, the economics viewpoint makes clear that veterinary scientists should be trying simply to bring about the **best** amount of disease in the overall livestock population. Economists may not know any more about veterinary science than vets know economics. But they must work together if the above objective is to be pursued, and so each must have some appreciation of how the other thinks.

ANIMAL HEALTH AND PRODUCTION IN EUROPE IN THE 1990s

PROSPECTS FOR THE FARM LIVESTOCK ECONOMY: MEAT PRODUCTION

C.M. PALMER*

The political turmoil surrounding future EEC agricultural policy makes forecasting the likely prospects for producing livestock for meat in Europe in the 1990's very difficult. In order to make such forecasts it is necessary to understand how agricultural policy in the EEC will develop. In order to do this it is necessary to understand the development of the EEC's financial problems and the political problems they have caused.

Agriculture and the Budgetary Problem

In 1987 the EEC was 30 years old and since the original Treaty of Rome was signed, membership has increased from 6 to 12. Today these include, economically and culturally, an extremely diverse group of countries. For example, in economic terms the index of Gross Domestic Product (GDP) per person (EEC = 100) in 1986, ranged from the United Kingdom at 91, upwards to Denmark at 153 and downwards to Portugal at 27. The percentage of the population employed in agriculture varied from 2.6% in the United Kingdom, to 28.9% in Greece, with all the major northern member states having fewer than 8%.

With the decision-making apparatus in the EEC involving negotiations between the governments of individual member states about policy proposals made by an EEC executive body (the EEC Commission), ultimately responsible to the European Parliament, it is hardly surprising that financial issues cause problems. This is especially the case when the negotiations are about agriculture, the major common policy and the most expensive user of EEC resources.

The Common Agricultural Policy (CAP) as a means of increasing European food production has been outstandingly successful. Unfortunately this success has absorbed an even larger share of EEC finances over the years. In addition, despite attempts to reform the system expenditure on the CAP has risen and food surpluses have increased.

In 1986, for example, the CAP accounted for 22,000 million ECU's of an EEC budget of 35,000 million ECU's. The CAP budget had been growing at about 14% a year (in 1977 the CAP accounted for only 6,800 million ECU's). Figure 1 shows this growth.

Not surprisingly, politicians in the EEC member states have looked upon this increase in expenditure with some alarm. In most countries the farm population is only a small proportion of the total population and it has decreased (from an estimated 14 to 10 million during the decade). The concern

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has been increased by the seeming ever increasing complexity of the CAP, as it tried to satisfy both market (increasing production) and the social goals (sustaining the incomes of small producers in marginal areas) in ever diverse economies, (eg. the larger Northern European temperate farms compared with the smaller farms in the Southern European Mediterranean areas).

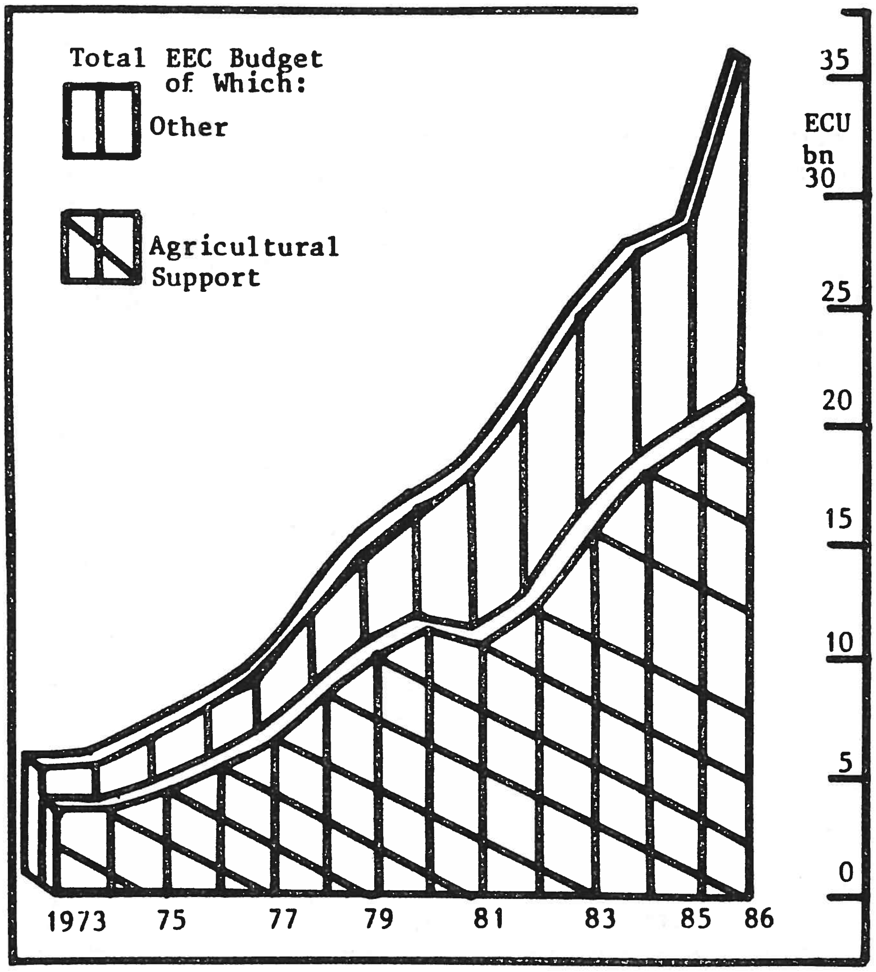

Figure 1 EEC budget and agricultural spending.

This alarm has been intensified by the contentious results that the CAP has produced over the years. For example, despite increasing stocks of farm produce, average real farm incomes in many EEC countries have actually decreased. At the same time many larger farmers have, however, prospered so that today it has been estimated that three quarters of EEC agricultural spending goes to the richest quarter of farmers!

To put the CAP in perspective, however (despite what often amounts to press histrionics about it - with bankruptcy a term often used lately), the EEC budget is still only relatively small in terms of total EEC gross domestic product, only about 0.9%. Unfortunately, such percentages mean little in political terms as in monetary terms the share of this taken by agriculture is huge, and growing.

It is this increase in the monetary size of the CAP budget that is today perceived of as **the problem,** especially when it has been caused by the development of complicated system, that is widely felt not to be doing its job properly. In addition (and increasingly importantly) the current operation of the

CAP is also building up major international problems, with the build up of EEC stocks and the disposal of these on world markets seen as highly disruptive by the other main international farm produce traders.

Halting the Rise in CAP Spending

The EEC's finances and its agricultural policy go hand in hand, and the first major agreement between the EEC Commission and member states to bring agriculture under control was taken at the heads of EEC governments summit at Fountainbleau in June 1984. CAP spending, it was decided, should remain below EEC income, which was actually increased by raising the EEC Commission's claim on national revenues from VAT (from 1.00 to 1.4%). In doing this the agriculture ministers agreed, for the first time, to operate the CAP within **financial guidelines.**

This undertaking was accompanied during the same year by the first attempts to cut back the agricultural surpluses, with the imposition of quotas on milk production and guarantee thresholds for cereals. December 1986 saw a major change to the operation of the beef intervention system, designed to bring the large beef intervention stocks under control, together with a further package of measures on milk. These resulted in further cuts in milk quotas and, from 1987 onwards, a further run-down in the dairy herd throughout Europe.

Unfortunately despite these measures, in practice during the last few years the guidelines have not been respected, and with prices at the annual review set as much in response to political as economic pressures, CAP spending and the agricultural surpluses continued to grow. This growth has been exacerbated by the operation of the green money system and the fall in the value of the $ in recent years (resulting in increased EEC export subsidies). The EEC budget required to cover CAP commitments has, as a result, been pushed up so much that in 1987 it was estimated that the budget would be 5,000 million ECU short of requirements, mostly because of increased spending on the CAP. In 1988 the EEC Commission want even more, some 6,000 million ECU above the present ceiling, and even this assumes savings in farm spending.

Arguments within the EEC about how to resolve these problems, bring agricultural spending under control and revise the EEC budget, have increasingly taken precedence over any other EEC discussion.

The two attempts in 1987, at the Brussels summit in June and Copehagen in December, achieved little except to highlight the impasse that has been reached, with first the British then the Germans being cast in the role of the countrys holding up negotiations. In reality most member states accept that it would be foolish to increase EEC revenues without making sure farm spending was controlled. Unfortunately they cannot all agree as to how this should be accomplished.

Under the German Presidency in 1988 (to be followed in the next twelve months by Greece and Spain), the next attempt at solving the budgetary and agricultural problems should have been in Bonn in June 1988. However, such was the urgency, with the EEC effectively being run without an agreed budget, that a special European summit was scheduled for February. Until agreement on the budget is reached the EEC is running on emergency funding which allows one twelfth of the 1987 budget to be spent each calendar month of 1988.

The longer they take to reach an agreement, the tighter will the EEC get on current spending eg it cut back on intervention spending on beef in December 1987 by switching from hindquarter to forequarter intervention. Whether 1988 will bring a solution to all the EEC budgetary and agricultural problems, particularly those affecting the farm livestock sector, remains to be seen. However, the lengthy discussions that have been held so far have undoubtedly clearly identified the major factors that will affect the farm livestock sector in the 1990's.

All these factors point to a decline in price support for all farm livestock enterprises in the coming years (particularly for the more intensive enterprises) and an almost philosophical change about the nature and role of agriculture within the EEC. The changes, both actual and proposed fall conveniently under the headings of Budgetary Stabilisers, Agricultural Adjustment and Environmental Protection, Support for Marginal Producers, and fourthly the Single European Act. In addition there is a fifth factor, which is the increasing internationalising of the problem with the advent of the GATT Uruguay Round.

Budgetary Stabilisers

These, it is proposed, will operate on all of the agricultural regimes. Such stabilisers would delegate to the EEC powers to take quick remedial action through price cuts, co-responsibility levies and automatic triggers to cut off price support altogether (Germany, however, are not totally in favour of such price cuts).

In the livestock sector, the proposals for the new sheep meat regime include such stabiliser mechanisms, in that guaranteed prices throughout the Community would be reduced if the Community sheep flock exceeds the 1987 figure. This is an effort to limit the increase in ewe numbers throughout the Community. Other measures in the revised sheep meat package are also designed to reduce the incentive to expand sheep meat production but try not to penalise production in the less favoured areas.

In the beef sector, no budgetary stabiliser has yet been proposed but the regime will be re-negotiated in 1988 and it is expected that it will have such a proposal built in. It is probable that, similar to the sheep meat regime, there will be some encouragement both for beef production in the less favoured areas and to build up the beef breeding herd as opposed to beef from the dairy herd. Already the impact of this is being seen in the UK with the interest being taken in single suckled bull calf systems of beef production.

Similar restrictions in the cereals sector, aimed at bringing the cereals surpluses under control, will have an impact on feed prices and affect the intensive livestock sector, particularly pigs and poultry.

All of the stabilisation mechanisms being constructed (and any other future revisions of the agricultural regimes - such as those being proposed for cattle and sheep) also aim to ensure budgetary discipline by adapting production more to market requirements than as has been the case in the past, and will, therefore, be accompanied by re-inforced quality criteria.

Agricultural Adjustment and Environmental Protection

The EEC Commission is also proposing that the stabilisation measures are supplemented by other measures aimed at combating the trend towards increased production. These will range from direct encouragement to cease farming, to the encouragement of the temporary abandonment of land (set asides) and farm extensification schemes. Politically the Germans are much more in favour of such set asides, than to stabilisation and price cutting schemes, but if an agreement is to be reached in the negotiations, a compromise will probably see a combination of the two. Land taken out of use through these schemes should, whether arable (set asides), or grazing (extensification) have limitations written in to its future use, in order to prevent any major switch of resources by farmers between enterprises (ie arable farmers using land for increased sheep production).

The extensification scheme for beef proposed by the UK Government for example, translates the EEC's desire to reduce output of a product by 20 per cent (initially for 5 years), to incentives to reduce livestock units on a farm by at least 20 per cent.

Many of the new policies such set asides will sometimes be disguised in other forms, such as perhaps money for environmentally sensitive areas. Such policy, however, is in keeping with the growing (more consumer orientated) environmental awareness of the EEC Commission and the European Parliament. Indeed the main aims of the proposed extensification scheme have been defined by the EEC and MAFF as, 'to free some land from intensive agricultural production and allow it to be used for conservation, amenity use, foresting etc; foster a changing pattern to improve the general environment and conditions for wild life.'

This change in attitudes in the EEC, that can be seen perhaps to now favour the precedence of the consumer over the farmer, has already been seen in the ban on the use of natural growth hormones in livestock production throughout the EEC, in the face of contrary scientific opinions (and producer complaints). This decision also conveniently acts as a further brake on increases in animal production. Similarly the EEC directives on the monitoring of other veterinary pharmaceutical residues, stilbene compounds, oestrogens, anti-biotics and other veterinary medicines is also indicative of this trend. In the light of these trends the future for the use of newer dairy related productivity boosting techniques, such as bovine somatotrophin (BST) looks very doubtful.

Similarly there is also a growing concern about other aspects of animal welfare for example, calf crates, and sow tethering. Any proposals for action on these matters will, similar to the hormone ban, also further extensification motives. Such a change in attitude also calls into question the future of various other 'hi-tech' animal production techniques, such as embryonic transfers. In the same way other lobbies for a return to more natural (organic) production for example, seem also to favour the changing aims of the EEC Commission. Indeed given the growth of these attitudes in the EEC and the growing green lobby in the European Parliament, some observers have even speculated as to whether some charter for animal rights may be a possibility.

Support for Marginal Producers

Increasingly in the future, the poorer producers in marginal areas will be supported by more direct income support measures (sometimes in a disguised form, such as payments for protecting the environment perhaps). Such direct structural support measures will, the EEC Commission hopes, help break the link between price and income support and increasingly in practice turn more of the CAP into a social as much as an agricultural policy. This will please many of the Southern European countries who would like to see more of the money, at present spent on agricultural support, spent on structural measures. The future of small animal production units in the less favoured areas looks assured, although they will receive little in the way of price support to encourage any major increase in production.

The Single European Act

Changes in the farm livestock sector in the 1990's will be further affected by the declared intention of the EEC member states to make the EEC a 12 nation free trade area by 1992. This ratification of the amendments to the original Treaty of Rome by the member states in 1987 was probably one of the most important actions of that year, although one whose potential impact is, in the United Kingdom anyway, only just beginning to be realised. Over the next few years all EEC countries will begin to notice the changes as the EEC Commission tries to implement the Single European Act (SEA).

This will be done by an increasing effort on the part of the EEC Commission to harmonise the Community rules and regulations and remove the proliferation of non-tarrif barriers to trade. This will see changes in the areas of EEC taxation, such as VAT, fuel and excise duties and moves to common technical standards. Most important from a veterinary point of view will be the implications of moves to harmonise animal health regulations (thereby reducing livestock trade barriers).

In order to try and speed up these changes, the Council has adopted procedures in relation to the implementing powers of the EEC Commission. Some observers believe the new committee procedures will effectively reduce the influence of national governments to the advantage of the EEC Commission. If so, this has profound implications for the lobbying by trade, industry and consumer bodies on animal health/meat hygiene issues. The scope for such organisations to have their views taken into account will probably be reduced. All will now have to lobby the EEC Commission and its new committee structure more directly, and this is already resulting in a proliferation of lobbying bodies (representing individual organisations in different countries) setting up offices in Brussels.

A further effect of the SEA is that the European Parliament has been given more supervisory power over EEC legislation, in that in certain policy areas any bill will have to have two readings before it is passed. Not surprisingly, many members of the European Parliament do not believe that this goes far enough and want much greater budgetary power. The effect on the meat and livestock industry of this increase in influence will be possibly seen in the greater effect that the 'green lobby', much stronger in Europe than the United Kingdom, could have on farm policy.

Again these measures it could be argued tend to favour a move toward the precedence of the consumer over the farm lobby. As a result there is likely to be much greater pressure on environmental matters, more concern about the role of agriculture, and probably more concern about animal welfare, with predictably a greater lobby for 'more natural-less drug based' production systems.

GATT Uruguay Round

The internal pressures on the EEC to bring its agricultural surpluses under control are today being further intensified by international ones.

Increasingly EEC agricultural decisions are being influenced by world surpluses and threatened trade wars. EEC export policies and perceived barriers to entry, such as the hormone ban, upset other meat and livestock trading nations.

Following the decision at Punta del Este in Uruguay, agriculture is now more firmly up for discussion within the GATT as part of the Uruguay round of multilateral trade negotiations. The intention is to toughen the present vague international trade rules, and make general GATT rules about fair export competition apply to agriculture.

The first shots in this international battle were fired by:

a) Australia - during late 1986 and 1987 a report entitled 'The Political Economy of International Agricultural Reform' was being trawled around Western capitals, arguing that international trade in agricultural products was being seriously affected by the surpluses that had resulted from the internal over-subsidisation of agriculture in the larger developed nations ie. USA, EEC, Japan.

b) USA - took the moral high ground with Reagan's statement at the summer 1987 GATT Geneva meeting, proposing that GATT works towards the elimination of all agricultural protectionist policies by the end of the century (during the Uruguay round). Although this is largely seen as rhetoric (the agricultural zero-zero option) it sets the tone for the future.

The Effect on Meat Production in the 1990's

The effect of these proposals on the total production of the four main meats in the EEC 12 will by the early 1990's, however, probably be reflected as much in the nature and quality of production as in the quantity. With the exception of beef and veal, all of the other main meats are still expected to show some increase in production. Total meat consumption in the EEC 12 between 1987 and 1995 is also expected to continue to increase, by about a further 3% to 27,280 thousand tonnes in 1995 (in 1985 total EEC 10 consumption was 89.7 kg per head per year, United Kingdom consumption was 73.9 kg per head per year). It is expected that any shortfall in beef supplies and therefore any increase in prices will cause market share to be lost to the more plentiful and cheaper, pig meat and especially poultry.

Beef and Veal

By far the most significant thrust of actual and proposed EEC policy changes effect the supply of beef and veal. By 1987 the EEC self sufficiency in beef and veal stood at over 106 per cent and intervention stocks amounted, in early 1988, to almost 700,000 tonnes. With over 70% of EEC beef and veal being a by product of the dairy herd, it is the EEC cut back in the dairy sector that will have the greatest effect on beef and veal production. Table 1 shows dairy cow numbers in the EEC falling by 10% between 1987 and 1995, to 22.5 million head.

Table 1 EEC-12 Beef and Veal Production, Consumption and Trade, in 1990 and 1995

	1986	1987 (a)	1988 (b)	1989 (b)	1990 (b)	1995 (b)
	million head					
Cow Numbers (June):						
Dairy	26.2	25.1	24.1	23.7	23.3	22.5
Beef	7.1	7.2	7.4	7.5	7.6	7.8
Total	33.3	32.3	31.5	31.2	30.9	30.3

(a) Estimate
(b) Forecast
(c) Including the meat equivalent of processed products and live animal trade.
Source: MLC 1987

The changes to the beef regime will undoubtedly mean some restructuring of the beef breeding and finishing industry throughout the EEC and some increase in the beed breeding herd will take place. However, it has been estimated that in order to compensate for the decline in the dairy herd, the beef breeding herd would have to expand four times faster than the dairy herd declines. This is highly unlikely.

As a result of these various factors, beef and veal production in the EEC 12 is expected to fall by about 10 per cent between 1987 and 1995, to some 7,260 thousand tonnes. This will give a self sufficiency in the EEC of 99.5 per cent compared with 106.0 per cent in 1987, shown in Table 2.

Table 2 EEC-12 Beef and Veal Production, Consumption and Trade, in 1990 and 1995

	1986	1987 (a)	1988 (b)	1989 (b)	1990 (b)	1995 (b)
	'000 tonnes					
Beef and Veal Production	8,005	8,072	7,810	7,589	7,453	7,260
Beef and Veal Consumption	7,478	7,617	7,554	7,559	7,533	7,300
Changes in Intervention Stocks	-226	+120	-150	-150	-100	- 30
Imports of Cattle, Calves Beef and Veal (c)	465	495	510	520	530	560
Exports of Cattle, Calves Beef and Veal (c)	1,168	850	900	700	550	550
Self Sufficiency (%)	107.1	106.0	103.2	100.4	98.9	99.5

(a) Estimate
(b) Forecast
(c) Including the meat equivalent of processed products and live animal trade.
Source: MLC 1987

Sheep Meat

The rate of expansion that has been seen in recent years in the sheep and goat meat sectors is expected to slowdown in the late 1980's and early 1990's. However, as the EEC in 1987 was still only some 80% self sufficient in sheep meat, and given the structural role of sheep production in the less favoured areas of the Community, a further expansion of about 8% is seen as likely between 1987 and 1995.

This increase is likely to occur, mainly between 1987 and 1990 despite the fact that a budgetary stabiliser has been built into the latest set of proposals about the future sheep meat regime, (a cut in support prices is proposed if the Community ewe flock exceeds the 1987 level. This is because further expansion in production is already in the pipeline, as result of the flock expansion in certain EEC countries, together with a slightly higher build up probably still being allowed in the two new member states, Spain and Portugal. These factors are expected to take total sheep meat production up to 1,020 thousand tonnes by 1995 (which still represents only 4% of total EEC meat production). This is shown in Table 3.

Pigs and Poultry Meat

Pig meat production has also expanded rapidly in the EEC in recent years and self sufficiency is now about 102 per cent. The continuing increase in production has resulted in a very weak pig market in early 1988, which is expected to last throughout the year, and it has therefore, been accompanied by increased consumption largely due to the low prices.

Inspite of the changing attitudes in the EEC Commission towards the nature of intensive livestock production, plus growing consumer and environmental pressures (particularly examplified by the slurry limitations imposed in the Netherlands and Denmark), these are still not expected to greatly influence the overall structure of the pig industry in the next few years.

Table 3 EEC-12 Meat Production in 1990 and 1995 (a)

	1986 (b)	1987 (c)	1988 (c)	1989 (c)	1990 (c)	1995
	'000 tonnes carcase weight equivalent					
Beef and Veal	8,005	8,072	7,810	7,589	7,453	7,260
Share (%)	30	30	29	28	27	26
Sheep & Goat Meat	881	945	981	990	1,000	1,020
Share (%)	3	3	4	4	4	4
Pig Meat	12,098	12,383	12,488	12,630	12,650	13,050
Share (%)	46	46	46	46	46	47
Poultry Meat	5,538	5,761	5,874	6,000	6,130	6,500
Share (%)	21	21	22	22	23	23
Total	**26,522**	**27,161**	**27,153**	**27,209**	**27,233**	**27,830**

(a) Gross indigenous production
(b) Estimate
(c) Forecast
Source: MLC 1987

As a result pig meat production (with a cyclical component) is expected to increase by a further 5% to about 13,000 thousand tonnes, by 1995. This is largely because of the impact of the entry of Spain and Portugal, as well as increased production as a result of a continuing growth in productivity and increased carcase weights.

On present trends, and in the light of expected EEC policy, poultry meat production in the EEC 12 is also expected to continue to increase, although as with pigs, at a lower rate of growth than seen in recent years. From a total of 5,761 thousand tonnes in 1987 (16% of which was turkeys), production is likely to increase to about 6,500 thousands tonnes by 1995.

Conclusion

The most recent attempts to reform overall EEC finances and particularly the CAP, are expected to be even more vigorously pursued in 1988, as a result of both increasing politically motivated financial pressure from within the Community and growing international concern over protectionism and the future of agricultural trade. The inexorable pressure to change current CAP policies will inevitably bring changes to the farm livestock sector throughout the EEC. By the 1990's it is expected that the proposed changes will, as a result of reduced price support and the introduction of various other measures designed to control agricultural production, result in stabilisation of meat production in the Community, designed to bring supply and demand back into alignment.

It is expected that this stabilisation of production, will be made up of a decline in beef and veal production, but slight increases in the production of sheep, pig and poultry meat. The proposed stabilisation process will also see the partial return of the meat and livestock industry to the influence of both internal and international market forces. Changing attitudes about the very nature of farming systems however, will also mean that the stabilisation process will also be accompanied by changes in livestock production (the effect of which happen to coincide with the EEC Commission's attempts to reduce the agricultural budget).

By the 1990's farm livestock production in the EEC may well become increasingly divided into two more distinct forms. On the one hand there will be the truly commercial larger producer, whose returns are based less on price support and more on the market return for a better quality product. On the other hand, there will be the smaller producers, especially in the marginal areas, where animal production is mainly a sideline to income derived from direct support (perhaps disguised as payments to them for being caretakers of the environment) as well as alternative and off farm enterprises.

As a result of the environmental and 'green' pressure groups, farm livestock production in the 1990's is most likely to be less intensive and to partially revert to more traditional patterns. In the cattle and sheep sectors especially, this will see greater emphasis on husbandry and management of livestock and grassland and a move away from the more intensive high input, high output systems of livestock production systems that have grown up over the past 30 years.

All of the pressures are now and will increasingly, when the current EEC proposals come into force, change the structure of livestock farming throughout the EEC in ways, whose effect on meat production will only become apparent in the later part of the next decade.

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PROSPECTS FOR THE FARM LIVESTOCK ECONOMY: MILK PRODUCTION

S.J.AMIES*

More than ever, the political environment dictates the prospects for the dairy industry. By maintenance of quota control the authorities can determine the size of the EEC and UK dairy industry and by the form of the regulations, they can influence its structure. Concurrently, patterns of supply and demand will continue to change, which in time may affect the size of quota. The profitability of milk production is likely to be determined by both economic and political factors and these in turn will determine how the structure of the industry evolves.

INDUSTRY SIZE AND STRUCTURE

The level at which quotas were set, when introduced in 1984, was well in excess of demand. On the basis of the figures shown in Table 1, the EC Council of Ministers imposed a cut in quota of 8½ per cent over the two year period 1987-1989.

Table 1. Balance of EEC supply and consumption (1985)

	Million tonnes
Deliveries to dairies	99.7
Direct sales	3.4
Internal consumption	84.8
Imports	2.4
Available for export	11.9

Reference: EC Commission (1986)

Almost all export sales are subsidised to some extent, but there is a difference in perception between those sales for which there is a real market and those which are effectively dumped through intervention disposals. The 8½ per cent cut in quota distinguishes between the two types of export sale. In their review of the quota system the Commission (1987) proposed an extension of the quota regime for three years (to 1992) at the quota level applying in the 1988/89 quota year. Though the proposed extension is only for three years, there are few who doubt that quota control will be extended indefinitely.

Quota control has resulted in a substantial, and rapid contraction in the industry, both at UK and EC level (Table 2).

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Table 2. Changes in quota level since 1984

		Quota (m tonnes)	
		UK	EC
Wholesale deliveries	in 1983	16.58[a]	103.48[a]
Wholesale quota	1984/85	15.55	99.92
	1985/86	15.39	99.47
	1986/87	15.39	99.73
	1987/88	14.47	93.77
	1988/89	14.09	91.29

Reference: Milk Marketing Board (1987)

Note: [a]adjusted for technical reasons

By the end of 1989, UK deliveries are expected to be some 15 per cent below those in 1983, the year prior to quota introduction. For the EC as a whole, the reduction will be around 12 per cent.

Critics of quota control, as a means of limiting production, point to the fact that it tends to ossify the industry and limit the movement of resources from the less efficient to the more efficient. These generalities will be influenced by the price levels paid for in-quota milk and the ease with which quota can be transferred. The higher the price, the more likely are inefficient producers to remain in the industry, while the regulations governing quota transfer will also influence the rate at which quota moves amongst producers. By nominally attaching quota to land, the EC authorities significantly restricted the movement of quota. However UK interpretation of EEC law has been sufficiently flexible to allow relative freedom of movement of quota, albeit tied to somewhat cumbersome and bureaucratic grass-let arrangements. It is encouraging that the EC Commission (1987) indicates that it may be willing to see more flexible forms of quota transfer in the future. In general terms, therefore, one would expect to see greater mobility of quota as time passes, governed primarily by market forces. This begs the question of whether the industry would wish to intervene with respect to would-be new entrants - the argument being that new entrants have to compete for quota with those buying incremental units to top-up a base that was allocated without charge. In reality the attitude taken in this regard is unlikely to have a major impact on the evolution of the industry.

Prior to quota imposition, producer numbers were falling, albeit erratically from year to year, whilst herd size and milk yield per cow were rising. Table 3 illustrates the changes that have occurred since quota imposition, the most marked being the fall in milk yield per cow, resulting from a substantial reduction in concentrate use.

Table 3. Change in industry structure (England and Wales) resulting from quota imposition

Year	Producer numbers ('000)	Cow numbers (million)	Herd size	Yield per cow (l)
1980	43.3	2.67	58	4715
1984	39.3	2.70	67	4950
1985	37.8	2.58	67	4765
1986	37.1	2.57	68	4930
1987	36.1	2.48	68 (est)	4985

Reference: Milk Marketing Board (1987)

The 6 per cent quota cut imposed in 1987/88 and the further 2½ per cent due in 1988/89 will undoubtedly lead to a reduction of all four factors in the short term. In the longer term one would expect to see a reversion to the upward trend in yield per cow, a continuing decline in producer numbers and a modest increase in herd size. The scale of these changes will be discussed at the end of the paper.

CHANGES IN DEMAND

The three dominant sectors of the UK, and EC, dairy product market are liquid milk, butter and cheese. So-called added-value fresh products, whilst offering considerable potential do not use large quantities of milk.

The rapid shift from whole to low-fat milk within the UK market is well documented. Table 4 quantifies the change.

Table 4. Consumption per head of liquid milk (kg/head)

	UK			EC		
	Whole	Low-fat	Total	Whole	Low-fat	Total
1975	146	-	146	80	15	95
1980	133	-	133	74	21	95
1983	124	5	129	66	25	91
1984	117	8	127	63	28	91
1985	113	15	128	60	31	91
1986	106	20	126	na	na	89

Reference: Milk Marketing Board (1987)

From the trend established one would expect the UK low-fat market to continue to grow, perhaps to around 30 per cent of the total liquid market, which has itself been declining at about 1 per cent per year. In contrast, the EC market as a whole is much more stable. Stability is also a feature of the EC butter and cheese markets (Table 5).

Table 5. Consumption per head of butter and cheese (kg/head)

	Butter		Cheese	
	UK	EC	UK	EC
1975	8.4	6.4	6.3	11.2
1980	6.1	6.0	6.0	13.1
1983	5.4	5.5	6.7	14.0
1984	5.1	5.6	6.9	14.3
1985	5.4	5.6	7.1	14.5
1986	4.5	5.8	7.4	na

Reference: Milk Marketing Board (1987)

Whilst the UK butter consumption has almost halved over the past decade, the EC decline has been much more gradual, and has indeed remained relatively static over the past four years.

Cheese is often cited as a market with potential growth, so far as the UK is concerned. The disparity between UK and EC consumption illustrates the point. Having said this, growth in consumption in both the UK and EC has been relatively sluggish, averaging around 0.2 kg/head/year over the past five years.

Overall, therefore, the demand for butterfat within the EEC market appears to be relatively static, at least for the time being. It is against such a background that maintenance of the 1989 quota levels into the 1990s appears realistic.

Whilst the overall market prospects appear unexciting, there is evidence within the UK market of a movement away from the commodity image of salted butter and hard-pressed cheese to a more innovative approach. Listed below are some of the growth areas and whilst these are not perhaps important in volume terms, any visit to a supermarket will indicate the livelier image of the dairy 'counter'.

Low-fat milks
Added ingredient milks (eg high calcium)
Cream
Cheese-speciality, soft/fresh/low-fat
Yoghurt
Fresh desserts
Butterfat spreads
Ice-cream

Many of these products are at the low-fat end of the range. This prompts the question of whether or not the fat/protein ratio in cows' milk needs reducing, if indeed such a step were possible. In reality, the surplus of milk protein/skim milk powder is considerably greater than that of butterfat (Table 6). It is simply that disposal of butterfat is more difficult, it being an unsuitable foodstuff for many third world countries.

Table 6. Consumption of butterfat and milk protein (kg liquid milk equivalent/head/year)

	UK		EC	
	Butterfat	Milk protein	Butterfat	Milk protein
1973	416	234	320	215
1983	344	234	328	240

Source: Eurostat

PROFITABILITY OF MILK PRODUCTION

The introduction of quotas required a fundamental change in attitude on the part of milk producers. Hitherto, an environment of a guaranteed market for all production at a more or less fixed price meant that output was a key factor in producers' eyes, with milk yield per cow being particularly prized. Inevitably an output led philosophy meant that cost control was relatively weak.

In 1983/84, the year immediately prior to quota introduction, a number of factors conspired against producers. Bad weather resulted in a substantial fall in milk yield, despite increased concentrate use. While milk price remained static, concentrate cost rose by 10 per cent. The result was a drastic fall in profitability (Figure 1). It was against this background that quotas were introduced.

The restrictions on output resulting from quota introduction meant that producers' efforts shifted to reducing the cost of production, primarily through replacing concentrates with forage, but also through an attempt to control overhead costs. With the milk:concentrate price ratio also moving in producers' favour (0.95 in 1983/84 to 1.17 in 1986/87), each year since the introduction of quotas has seen an increase in profitability.

The relative magnitude of the changes that have occurred since quota introduction can be illustrated by comparing some key figures from 1982/83, which was a more average year than 1983/84, and 1986/87 (Table 7).

Table 7. Comparison of key business statistics in 1982/83 and 1986/87

	1982/83	1986/87
Yield (l/cow)	5522	5403
Concentrate use (kg/cow)	1861	1559
Nitrogen use (kg/ha)	269	278
Milk:concentrate price ratio litre milk:kg concentrate	1.04	1.17
Overhead costs excluding depreciation & interest (£/cow)	278	277
Depreciation charges (£/cow)	73	47
Interest charges (£/cow)	62	72

Reference: Poole A H et al (1984) and (1987)

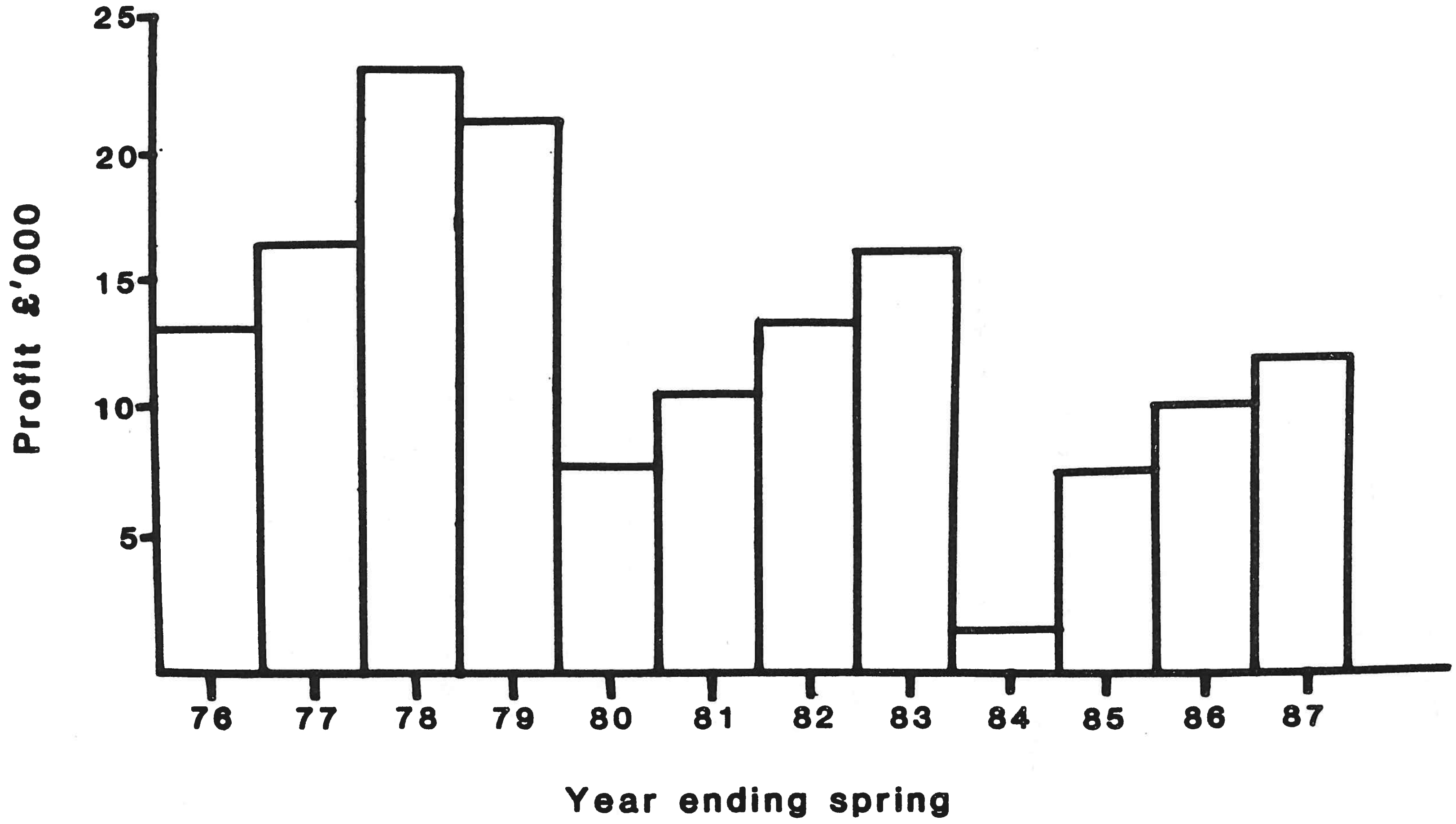

Figure 1 Changes in inflation adjusted farm profitability over the past decade.

Reference: Poole et al. (1987)

Notes: Data taken from a sample of specialist dairy farms that is not constant throughout the period. All profit figures inflation adjusted using RPI (1987=100).

Table 7 (continued)

Notes: 1982/83 financial figures inflation adjusted using RPI (1987 = 100)

The actual overhead costs published have been converted to a per cow basis in a consistent manner between years

Though the figures are not from an identical group of farms, the overall trends are quite marked. Despite a reduction of 300 kg/cow in concentrate use, milk yield has fallen by only 150 litres/cow, indicating a substantial improvement in the efficiency of forage utilisation. Other contributors to the increase in profitability have been the improvement in milk:concentrate price ratio (concentrate cost in particular having fallen markedly) and a substantial reduction in capital expenditure, resulting in lower depreciation charges. The steady level of other overheads masks a slight reduction in labour plus power and machinery, offset by a rise in property charges, primarily rent.

One other important item is the fact that of £10,300 capital expenditure in 1986/87, over £3,300 resulted from quota purchase. Given that 599 million litres (Milk Marketing Board 1987a) was transferred amongst producers in 1986/87, some 4.7 per cent of all quota issued, such expenditure is likely to remain a substantial item for those wishing to expand their business in the future.

With the financial prospects for the current year (1987/88) looking reasonable, producers appear to be relatively optimistic about the future. In a quota controlled, EC environment, such optimism might appear justified. The one cloud, so far as UK producers are concerned might be the possible impact of liquid milk imports from 1989 onwards. Producers' returns from the liquid market are well above those from the manufacturing market. It is possible, though by no means certain, that any resultant competition might drive the liquid price down, without a commensurate increase in manufacturing returns.

Against such a background, the most realistic assumption seems to be that the pressure to reduce production costs will continue and that there will be increased interest in straightforward, 'no-frills' systems.

STRUCTURAL DEVELOPMENTS OVER THE NEXT DECADE

The issues discussed so far appear to point to a fairly stable industry, so far as aggregate size and profitability are concerned. The quota cuts presently being implemented should be more or less adequate, assuming levels of consumption in the EEC as a whole maintain their current levels. From the data provided this looks the most likely outcome.

Given the pressure on other sectors of the industry, it seems unlikely that many producers will leave dairying unless they are either retiring (or running down to retirement) or under extreme financial pressue. An annual reduction of 2.5 per cent in producer numbers seems a realistic possibility, somewhat lower than the average rate over recent years.

Continuation of a quota regime must reinforce concern for cost control. In particular it seems likely that further effort will be directed upon reducing feed costs by continuing to substitute forage for concentrates. This suggests that the annual increase in milk yield will tend to be of a lower magnitude than the 2 per cent figure seen in the years prior to quotas. Furthermore, the current cuts in quota seem likely to reduce yield in the short term. A long term annual yield increase of between 1¼ and 1½ per cent therefore seems likely, once adjustment to the present cuts in quota has taken place.

Taking the projections of change in producer numbers and yield per cow and extrapolating the data in Table 3, results in the following projection for the year 1997 (Table 8).

Table 8. Possible change in industry structure (England and Wales) over the next decade

	1987	1997
Producer numbers ('000)	36.1	28.0
Yield per cow (l)	4985	5560
Sales off farms (ml)	12750	11600[a]
Cow numbers (million)	2.56[b]	2.09
Herd size	71[b]	75

Notes: [a]Assumes production held at 1988/89 quota level

[b]Attained by calculation, and not directly comparable with figures in Table 3

The final question that remains to be addressed is the possible impact of biotechnology in general and BST in particular. Clearly the introduction of BST is dependent upon political decision, which, as with quotas, illustrates the extent to which the industry's size and structure is determined by political forces, particularly at EC level. This paper is not the place to discuss the merits and drawbacks of introduction, but it is perhaps worthwhile considering the possible impact on the figures shown in Table 8.

There is much talk of a yield boost of around 20 per cent, but when one takes into account the difference between results anticipated from the trial of any product and the average response on all farms using the product, one can well imagine an outcome considerably below figures quoted. Other factors to consider are that some use might be of a strategic nature, ie in months of high milk price and that other users will take advantage of the potential increase in dry matter intake to feed a lower density diet and reduce feed costs. The final, vital, factor would be the level of uptake. It would be extremely surprising if more than say, one quarter of cows were to be treated in ten years time. If one adds all these factors together, it is possible to conclude that BST, though a potentially important management aid, would make only a minor difference to the industry trends that are already anticipated.

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REDUCING LIVESTOCK TRADE BARRIERS:

IMPLICATIONS FOR COMMUNITY LEGISLATION AND DISEASE CONTROL

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The European Community is now 31 years old. It was founded out of a dream of Robert Schuman, French Minister of Foreign Affairs, who proposed in 1950 the creation of a united Europe, where the economic entanglement of the club members would effectively render further wars, such as that which had just ended, virtually impossible. The problems of animal health were far from his mind and those of the original signatories of the Treaty of Rome in March 1957. Indeed, it took a further seven years to agree on the harmonised rules for live cattle and pigs, Directive 64/432. Perhaps significantly, to this day it has not been possible to agree on similar rules for other species. Instead, each new member has put its stamp on 64/432, which is now almost unrecognisable, and, some would say, unintelligible. Meanwhile, of course, trade in other species has continued under national rules, with provisions for every disease from agalactia to VEE. This system has been effective for over 30 years, so why interfere? The answer is, in three words, the Single European Act.

On 17th February 1986, in Luxemburg, representatives of the 12 Member States committed the Community to a free internal market by the end of 1992. What is meant by a "free internal market"? To quote from Article 8a of the Treaty,

"The internal market shall comprise an area without internal frontiers, in which the free movement of goods, persons, services and capital is ensured in accordance with the Provisions of the Treaty."

The Acte Unique, as it is also called, was accompanied by several pages of declarations, in which Member States expressed their concern over certain aspects on which they wished to reserve their position. Not one of these reservations, however, was specifically on the subject of animal health.

Nevertheless, it is clear that the free market will have a profound effect in the veterinary sector. To study this, it might be helpful to look at the disease situation in the Community as a whole. This will reveal some fundamental differences which immediately bring into question the wisdom of our political leaders in Luxemburg two years ago. However, such a study might also provide a clue to possible solutions.

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THE EPIZOOTIC DISEASES

At present, out of 16 diseases in the OIE List A, three are present in the Community. African Swine Fever is probably the most serious, being widespread in Spain, Portugal and Sardinia, with 794, 648 and 21 cases in each country respectively during 1987. In the Iberian peninsula the disease reached a peak in the late '70s, with over 6000 outbreaks in 1977, and then began to tail off. A recent rise is in fact related to action under a Community-aided programme rather than to a worsening of the disease situation. However, certain management systems on the Spanish-Portuguese border may make total eradication virtually impossible. This latter comment also applies to Sardinia, where the rather old-fashioned industry has resisted attempts to restructure it, and where, consequently, virtually no progress has been made in the last 10 years.

Contagious Bovine Pleuropneumonia is the second such disease, eradicated from most modern production systems in Europe some 100 years ago, but currently endemic in Portugal, with 749 cases in 1987. Again a recent rise reflects action taken under a Community programme, but eradication has been hampered by the structure of the cattle industry itself.

Classical Swine Fever is the final member of the triad. The current epizootic, which started in the early '80s, spread through Belgium, Holland, Germany and France, reaching a peak of 1272 outbreaks reported in 1985, but now is virtually over in all countries except Belgium. In fact, large parts of the Community have now been designated as officially swine fever free, and others will follow soon. However, the main obstacle here is that of vaccination, a policy which has been held on to for decades, but which has faded as Member States have found that such a policy will exclude them forever from certain markets.

Finally, and perhaps most important of all, one must mention foot and mouth disease. Although apparently now eradicated from Italy after three epizootics starting in 1984, the fact remains that, with nine out of 12 Member States carrying out a vaccination policy in at least part of their country, the situation is far from harmonised. Recent events in Germany, where there has been a series of outbreaks of type 01 near Hannover, have also shown that the risk is ever present.

Table 1 : Epizootic diseases in the Community in 1987

COUNTRY	F.M.D.	C.B.P.P.	C.S.F.	A.S.F.	NEWCASTLE
GERMANY	2		41		
FRANCE			5		
ITALY	167		13	21	15
NEDERLANDS			1		
BELGIUM			83		
LUXEMBURG			1		
U.K.			1		
SPAIN				791	
PORTUGAL		794		648	
TOTAL	169	794	145	1463	15

OTHER DISEASES

Excellent progress has been made towards eradication of TB and bovine brucellosis, although the accession of Spain and Portugal has added to the Community large areas where further work must be done. Certain action has been taken to reduce the impact of EBL, which has never realised the danger once threatened. B. melitensis, however, remains a serious problem for both human and animal health and a barrier to trade, being virtually endemic in the south of the Community. Eradication of this disease is handicapped by the lack of an accurate single animal test, the small flock size in the areas concerned and the lack of finance. Efforts have been made to control the disease, but this largely consists of the use of Rev-1 vaccine in affected flocks. This disease has thus imposed the principal barrier to trade in sheep and goats from south to north, and poses a major dilemma for legislators trying to harmonise trade. In a similar vein, contagious agalactia/contagious caprine pleuropneumonia also presents a problem, although to a lesser extent. The distribution is similar, the test problems the same.

One must also consider those diseases normally dealt with at the herd level, usually by voluntary or industry-sponsored health schemes, such as Maedi/Visna, IBR, Aujeszky's and many poultry diseases. These diseases are mostly not readily diffuseable, and in many cases the exact situation is masked by vaccination. Nevertheless, considerable effort has been expended by the industry and government in order to eradicate these diseases on a national, regional or herd basis. This effort must not be lost, but rather should be built upon. Diseases like scrapie are also problematical. Some countries claim to be free from scrapie, but, in the absence of a test in the live animal, it is difficult to prove this, or to satisfy those countries which claim to be free and wish only to import animals of similar status.

Finally, one must consider the problem of Rabies. This disease has spread gradually through Europe from the east since the war, and now is endemic in parts of France, Germany, Italy, Belgium and Luxemburg, with occasional cases in Greece. Huge efforts have been made to control rabies, with little success until some recent developments, in the field of oral vaccination. This will be discussed later.

THE PROBLEMS FOR LEGISLATORS

Traditionally, once the disease situation is identified in a given country, it is then relatively straightforward to set out conditions to be satisfied before importation from that country. However, a close look at these standards soon reveals that they are usually higher than those imposed on internal movements of animals, other than those set by the industry itself to safeguard herds with a specific disease status. The poultry sector is a good example, often requiring membership of an official health scheme and freedom from many diseases such as Pullorum disease when importing, but without any such requirement for national movement.

It is this dual standard that provides the main veterinary stumbling block for realisation of the free market. Can this two-tier system continue after 1992? Certainly, Article 36 of the Treaty of Rome does allow a Member State to ask for special conditions when it is warranted, but this will be unworkable, even if legal, once border controls are removed. Who will check? Are we to replace the customs with a huge veterinary inspectorate? It would seem to be unlikely. Not only would it be impracticable, but it would not be politically acceptable, as it would negate the efforts made in other sectors. A different solution must be found. And yet, it is vital, for productivity and to maintain trade with third countries, that the Community flocks and herds should be safeguarded from the spread of disease. How is this possible in a free market situation?

POSSIBLE SOLUTIONS

Some see the answer in simply moving the border a few kilometers! In effect, the old rules would apply. Veterinary inspection and certification would be carried out as before, at the farm of origin, but quarantine, where appropriate, would be situated a few miles away. Even if quarantine was not required, checks at destination could be possible, during a period of on-farm isolation, to check compliance with the regulations. There is an attraction in any approach which does not involve major changes in existing legislation, particularly for the legal services, who see a means of achieving their aims by effectively what amounts to a paper exercise.

However, this cannot really be a fully satisfactory solution. How, for example, will it be policed? Without border controls, who will ensure that importers will go voluntarily to an appointed quarantine station? Will such facilities be available? It will be too late if the first sign of an illegal landing is the diagnosis of FMD in the heart of a cattle production area. Every animal, after 1992, will, in theory, have the right to be on the road en route to anywhere else, but how could an inspectorate differentiate between those moving in their native land and those which have just entered from another country? Animal identification systems are not at present sufficiently tamper-proof to give the necessary guarantees. Furthermore, existing legislation provides for differing standards depending on the purpose of export, for example slaughter or breeding. Again this would be very difficult to police, and the system would be wide open to abuse, with higher status animals being presented as a lower category to circumvent some of the requirements.

In veterinary terms, there is only one permanent solution. If animals are to be entitled to move freely across international borders just as they move within their country of origin, then these animls must have a satisfactory disease status. Furthermore, those which do not must be kept under suitable restrictions, which must be equally applicable to national and intraCommunity trade. Let us consider how this could be achieved.

THE VETERINARY APPROACH

The first barrier to this approach is the widely differing situation in various Member States with respect to the epizootic diseases. Firstly, there is the problem of vaccination. It would seem that the policy with respect to this aspect must be harmonised. In simple terms, everyone must stop, or everyone must vaccinate, eventually. Otherwise we will have free trade in disease as well as animals, and one immediate result would be that countries, such as the U.K., which do not currently vaccinate, will loose their "white list" status with respect to exports to the USA. This could be expected if the U.K. is forced to import freely from FMD-affected countries, or if it is forced to adopt a vaccination policy. As a result, huge markets, potential and existing, for Community meat, products and animals would be lost, and corresponding amounts would be left to augment the already vast intervention "mountains". It seems clear that the best approach would be to ban vaccination for FMD and classical swine fever throughout the Community. In fact, closer study shows that progress in this direction has already taken place.

Vaccination against CSF has been discouraged by Community legislation for many years, but it is only now that cessation has become a practical proposition, as the general disease situation has improved. Many countries are officially free, ie. they do not vaccinate, at least in part of their territory, and this is putting pressure on the remainder to stop. Community finance for vaccination will also stop in 2-3 years time, providing further incentives. There are, however, clear dangers in this approach. The density of pigs in Flanders, south Holland and parts of Germany could spell disaster if disease were to get into the herds in these regions. Nevertheless, this policy has been successful in the U.K., Ireland and Denmark, also with areas of high density, mainly becaus of strict import and swill regulations. Holland, France and Germany too have succeeded in keeping the disease out of their officially-free areas to a large extent. It seems that cessation of vaccination need not be accompanied by disaster, but strong Community rules for imports from third countries and waste food would be essential once vaccination is finished.

FMD vaccination may prove more of a problem. Undoubtedly, it will be a difficult decision for many CVOs to make, in countries where it is almost traditional. However, the majority of cost/benefit studies which have been carried out, including those recently done under the auspices of the FAO, show that vaccination costs more than eradication in the medium and long term. Nevertheless, the threat of an FMD epizootic is a powerful psychological barrier to the abandonment of vaccination. There is another side to the coin, however. It has been demonstrated recently (Beck & Strohmaeir, 1987), using virus DNA analysis techniques, that most European outbreaks in the last 20 years were probably caused by escape of virus from a vaccine production plant, or from use of inadequately inactivated vaccine.

This is considered by many experts to be the case in recent outbreaks in Germany, near Hannover, and in the series of epizootics in Italy, with 490 cases in three years. Can one justify the use of a product which has itself been responsible for most of the cases of the disease? Who would use a carcinogen as a treatment for cancer, or an antibiotic which caused infection? Furthermore, no vaccinating country actually achieves full protection of its national herds. Most only vaccinate cattle, and that only during a limited period of the year. Hence probably the majority of animals are unprotected at any one time. Since pigs are probably the most vulnerable to primary infection, via waste food, and yet outbreaks are comparatively rare, it seems that the virus is normally absent from the Community. There is a risk, of course, from third countries. However, the U.K., which imports a great deal from infected African countries, remains free despite a non-vaccination policy. Against what, therefore, are we vaccinating? Surely it is time to stop. And yet, such a move may not be popular amongst vaccine manufacturers and vets who gain a large part of their income from vaccination. As previously mentioned, most cost/benefit studies have shown an advantage to the non-vaccination, eradication-type policy. It is the Commission's intention to promote such studies throughout the Community, based on the recently-developed FAO model, suitably adapted where necessary. Unfortunately, the latter comment, referring to income derived from the production and giving of vaccine, is difficult to assess in such a study.

With regard to Contagious Bovine Pleuropneumonia and African Swine Fever, progress is being made towards eradication, but perhaps it is optimistic to hope that this will be fully achieved by 1993. It seems likely that a regionalisation policy will be necessary to cope with diseases, as well as reinforced movement controls. The Community has already approved an eradication plan in the affected areas for African Swine Fever, including financial aid and regionalisation. Once it is possible to declare areas free, it seems that movement of live pigs and meat will be possible from the Iberian peninsula, even before 1993. Similar action is envisaged for Contagious Bovine Pleuropneumonia.

The second aspect of epizootic diseases to consider is that of control during actual outbreaks. Each Member State has its own policy, for each disease. Clearly, these policies mut be standardised, to encourage mutual confidence. This has already been done for classical swine fever and foot and mouth disease, although there still remains rather too much scope for variation within these Directives for confidence to be cast iron. For example, partial slaughter is possible in a holding where FMD is diagnosed, as long as there is effective separation between the different sections. Other problems, such as the possibility of only slaughtering unvaccinated animals, would be resolved if vaccination were to be stopped throughout the Community.

It is evident that further work is needed on the existing Directives, as well as the development of new control Directives to deal with other diseases including the so-called exotics such as Bluetongue, Rinderpest, Sheep Pox and African Horse Sickness when they appear in the Community.

Finally in this context, and already briefly mentioned, is the problem of import controls. The Community boundaries must be guarded just as at present are the individual Member States themselves. Such measures, including computerisation of data distribution, are already well under way. Help to third countries in their control and eradication policies, and coordination of vaccination policy, especially with close neighbours, will also play a major part in the strategy.

These ideas may seem optimistic, but how else can animals move freely from Member State to Member State? Without frontier controls we only have the possibility to check after the event, once the animals arrive at their destination. The opportunities for fraud will be enormous. Only by achieving a uniform disease status and defending it rigorously can the dangers of such fraud be obviated.

NON-EPIZOOTIC DISEASES

Although the epizootic diseases are the most feared, others are in fact more important in day to day terms. Many have a public as well as an animal health significance. A considerable amount of effort has already been expended in their control, which must not be wasted.

Two possible approaches emerge to help continue these control policies and avoid dissemination of disease. Firstly, infected herds may be identified and put under restrictions pending removal of infected animals and retesting. Whole areas may be recognised as infected and movements confined to within them. These areas may subsequently be subjected to a compulsory or voluntary eradication programme. This approach has been used for TB and bovine brucellosis, and could also be applied to B. melitensis and contagious agalactia, although the accuracy of the current tests needs to be improved to make eradication a financially-possible proposition.

Other, less serious and less widespread diseases such as Maedi/Visna, EBL and IBR could be dealt with on a health scheme basis, ie by identifying flocks and herds which are free from the disease and by introducing measures to maintain their freedom, especially by restricting movements into such herds.

A moments thought will reveal that this system is that which currently is used in the U.K., and the proposals reflect merely its extention to the Community situation.

The final serious disease to discuss is rabies, and this is probably the most difficult. It would be a brave politician in the U.K. who proposed such freedom of movement of dogs and cats which would enable this most emotive of diseases to gain entry. However, current work in Germany, Switzerland, Belgium and Luxemburg using an oral live vaccine on foxes has had very promising results, and the Commission is looking at ways of providing financial support for the implementation of such measures. Perhaps eradication is in sight. There are also several countries which are already free from this disease, and from which the U.K. could import without quarantine now. Perhaps these "free" countries will have to stop vaccination. Perhaps the U.K. will have to introduce vaccination. It is worth noting that there have been no cases in the U.K. in quarantine since vaccination on arrival was introduced. In any event, it is possible that eradication could be achieved on the Continent, and even now limited free imports could be allowed.

ANIMAL MOVEMENTS

It is perhaps relevent to discuss briefly the possibilities for policing animal movements. As already mentioned, all animals should have the right to move anywhere unless they have an unsatisfactory disease status, but how can we ensure that those which are the subject of restrictions do not disregard the rules? In reality, no system can provide 100% safeguards, and most movement controls depend on the honesty of the individual. Luckily, the majority are honest. One possibility would be for the veterinary authorities to establish the status of all holdings with respect to each disease in advance. A pre-printed book of permits would then be provided for each holding, indicating its status. The farmer could issue these documents himself in a disease-free area, to accompany each consignment, or they could be issued by the local authorities. If pre-movement tests were necessary, this could be indicated on the permit, which would have space for the test details and the veterinarian's signature. The use of modern copy paper would provide an automatic record of all animal movements. These documents could then be checked at the destination or en route, by a specially-designated inspectorate. Naturally, no documents would be issued in the event of an outbreak of an epizootic disease, and do-it-yourself type books could be withdrawn. This system would have to be imposed on all animal movements in the foreseeable future, until the disease situation was the same in all countries, which does mean the introduction of extra controls in some areas currently free from such requirements. This may be the penalty that has to be paid for the free market, but may be better than free trade in disease.

Perhaps therefore, a solution is in sight. In brief, the Community must first put its house in order in general terms. A uniform policy for all diseases of importance must be adopted. Allied to this, confidence in each others efforts must be reinforced. It will certainly be necessary to compromise in some areas, and some give and take all round will be essential. However, by sticking to sound veterinary principles and by making a final grand effort it should be possible to reduce the impact of these compromises, allowing the realisation of the Acte Unique without destroying the livestock industry of Europe.

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REDUCING LIVESTOCK TRADE BARRIERS:

IMPLICATIONS FOR CONTROLLING INFECTIOUS DISEASES IN GREAT BRITAIN

G. DAVIES* AND R.B. STEVENSON*

Contagious Bovine Pleuropneumonia was eradicated from Great Britain during the last decade of the 19th century solely by restricting the movement of animals and slaughtering infected stock. Movement controls play a crucial part in restricting the spread of the major epidemic diseases of livestock but the movement of stock is essential to the livestock industry whether it be for breeding, for rearing or fattening or for the eventual disposal of animals to a slaughterhouse. Free movement is consonant with a free trade in livestock that should lead to rapid genetic improvement and the best use of resources such as foodstuffs and grazings.

Great Britain has been able to handle the conflicting demands of disease control and livestock improvement by eradicating the major infectious diseases within the country and preventing their re-entry by taking advantage of the cordon sanitaire provided by our island status. The industry and the government have been able to prosecute disease eradication programmes confident in the knowledge that if successful they will be permanent in their effect.

It is now proposed that trade barriers within the European Community will be reduced or eliminated by the beginning of 1993 and the programme and the timetable for this change has been spelt out in a Commission white paper "Completing the Internal Market". However it is implemented it will mean increased freedom in the movement of animals and animal products within the community. What are the implications for Great Britain which on the face of it will lose its 'cordon sanitaire'?

THE EUROPEAN DISEASE SITUATION

The diseases of major importance are those in the OIE list A and the areas of concern to Great Britain are Contagious Bovine Pleuropneumonia (CBPP), swine vesicular disease (SVD), classical swine fever (CSF), African swine fever (ASF) and foot and mouth disease (FMD).

CBPP is spread only by direct and intimate contact between cattle and it is confined at present to the Iberian Peninsula. It thus poses less of a threat than the other diseases. SVD has not been recorded in the community for some two years. CSF on the other hand has until recently been widespread amongst the dense populations of pigs in West Germany, the Netherlands and Belgium and has spilled over to other Community Member States (Table 1).

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Table 1. Outbreaks of Classical Swine Fever 1983-1987

	1983	1984	1985	1986	1987
Belgium	26	9	66	80	83
Denmark	0	0	0	0	0
Germany (FRG)	535	1041	598	46	41
France	13	19	2	20	5
Great Britain	0	0	0	10	1
Greece	4	2	1	0	0
Italy	48	13	27	29	13
Luxembourg	1	0	0	0	1
Netherlands	161	176	36	1	1
Ireland (ROI)	0	0	0	0	0
Spain	19	10	0	2	0
Portugal	10	1	1	0	0

A major vaccination programme and other measures appear to be bearing fruit in a marked reduction in the number of outbreaks but it remains to be seen whether the continent can free itself of the disease by 1993.

African swine fever (ASF) is now confined to the Iberian Peninsula and Sardinia but it has made a foray into Belgium and the Netherlands and like CSF it can be spread through the agency of contaminated pig products (Table 2).

Table 2. Outbreaks of African Swine Fever 1983-1987

	1983	1984	1985	1986	1987
Belgium	0	0	12	0	0
Italy	48	45	33	21	22
Netherlands	0	0	0	2	0
Portugal	29	87	51	723	645
Spain	299	592	390	393	793

The disease appears to be present in wild pigs as well as in small peasant-owned herds.

Foot and mouth disease (FMD) is an interesting prospect. The outbreaks shown in Table 3 form the tail-end of major European epidemics that have been controlled partly by vaccination and partly by stamping out.

Table 3. Outbreaks of Foot and Mouth Disease 1983-1987

	1983	1984	1985	1986	1987
Denmark	1	0	0	0	0
Germany (FRG)	0	3	0	0	2
Greece	0	2	0	0	0
Italy	0	45	131	150	167
Netherlands	1	3	0	0	0
Portugal	164	22	0	0	0
Spain	1	0	0	1	0

This disease is being tackled in a radical but logical manner.

FOOT AND MOUTH DISEASE CONTROL: A COST/BENEFIT EVALUATION

Great Britain controls FMD by stamping out without recourse to vaccination. This is also the policy of Denmark and the Republic of Ireland. The other member states employ vaccination to some extent or other although Greece only vaccinates cattle in a border zone adjoining Turkey. The employment of vaccine and/or the occurrence of outbreaks seriously affects the export trade in live animals and animal products and there is strong evidence that many of the recent outbreaks have originated either from a leak of virus from a laboratory or from the use of improperly inactivated vaccine. These considerations and the pressing need to have a common policy on FMD control within the community by 1993 led to the construction of a model cost-benefit analysis of the two options: vaccination and stamping out. This was first developed under the aegis of the FAO European Commission for the control of foot and mouth disease but it is now being used by the European Community Member States as an aid to rationalising policy. Essentially the analysis compares the costs of the two options for control; it does not consider the losses due to unfettered disease as it assumes that in Europe the disease will be extinguished as soon as it appears. The elements to be costed are shown in Table 4.

Table 4. The costs of alternative policies - FMD control

Vaccination	Stamping-out
1. The vaccination programme	1. A vaccine bank
(a) Vaccine	2. FMD outbreaks
(b) Vaccination	(a) Controlling outbreaks
(c) Side-effects	(b) Slaughter compensation
2. FMD outbreaks	(c) Loss of production
(a) Controlling outbreaks	(d) Interruption of domestic trade
(b) Slaughter compensationn	3. Loss of export trade
(c) Loss of production	(a) Due to outbreaks
(d) Interruption of domestic trade	
3. Loss of export trade	
(a) Due to vaccination	
(b) Due to outbreaks	

When this analytical frame work was used in the FAO sponsored exercise it was found that the cost of vaccination and the cost of outbreaks did not greatly vary between European countries. The two major uncertainties amongst the costs are the effects on export trades and the number of outbreaks to be expected under either policy.

The effect on export trade of vaccination and of outbreaks is a fertile ground for dispute between economists and veterinarians and any resolution of this is an approximation to the truth. The determination of the number of outbreaks of disease per annum to be expected under either policy is more crucial because the final comparison of costs is:

THE COST OF NATIONAL VACCINATION (pa) + THE COST OF OUTBREAKS OCCURRING (pa) UNDER A VACCINATION POLICY

COMPARED WITH

THE COST OF OUTBREAKS (pa) TO BE EXPECTED UNDER A STAMPING OUT POLICY

If the cost of each individual outbreaks is large and the number of outbreaks to be expected under a stamping out policy is also large then they may easily outweigh the annual costs of national vaccination. The prediction of the number of future outbreaks is crucial and it is being undertaken by looking at the past 10 years of outbreaks in Europe, deciding how many of the primaries are associated with vaccine and using the assessment to predict ahead, for say 10 years, the outbreaks to be expected in the absence and presence of community vaccination. Other risk factors are being taken into account, eg third country imports of meat and other animal products, transit particularly from Eastern Europe and Asia, and airborne infection from outside the Community.

CHANGES IN DISEASE CONTROL AND IN THE STRUCTURE OF THE LIVESTOCK INDUSTRY

Whilst the OIE list A diseases are being dealt with in this manner there remain a number of other infectious diseases that may be important to the British livestock industry and one B.melitensis which may be significant to public health.

Some are subject to disease control programmes in Great Britain, notably Aujeszky's disease and Enzootic bovine leucosis. The others are dealt with in the normal processes of the livestock trade by the old remedy 'caveat emptor'. During the last twenty years we have witnessed a change in livestock trading particularly in the poultry and pig industries whereby movement between herds and flocks is confined to the movement of breeding stock for genetic improvement and the terminal movement of fattening stock to the abattoirs. Herd and flock owners are restricting entry to holdings and in so doing are creating their own cordon sanitaire around animal populations. In this way the industry itself is resolving the dilemma of movement that is necessary for trade but bears with it the risks of disease. For these precautions to work there has to be clearly identified herds or flocks of known disease status, reliable animal identification and secure transit facilities.

As the British livestock industry takes advantage of the opportunities provided by an open European market it may well accelerate these developments and in so doing provide itself with the security previously provided, in part, by national import controls. It seems likely therefore that schemes which establish registers of herds and flocks of known health status will flourish and in this Great Britain starts with the advantage of herd health schemes established by the Government and by private organisations and also by reputable and highly efficient livestock companies that provide breeding stock of known health status.

OVINE EPIDEMIOLOGY AND PREVENTIVE MEDICINE

THE EFFECT OF WEATHER VARIABLES ON THE PREVALENCE OF PLEURISY AND PNEUMONIA IN SHEEP

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Sheep pneumonia is a major disease of production and occurs in all of the major sheep producing countries of the world (Jensen and Swift, 1982). Spectacular mortality rates of up to 15% of affected animals can occur (Harris and Alley, 1977), while growth rate, feed intake, body weight and final carcase composition are all substantially affected in surviving animals (Kirton et al, 1976; Harris and Alley, 1977 and Jones et al, 1982). Although many specific primary pathogens have been implicated in cases of sheep pneumonia (Martin, 1983), stress factors, including inclement weather, are considered to be important both in precipitating the disease and in its subsequent severity (Blood et al, 1983).

The mean monthly percentage of pneumonic lesions in all sheep slaughtered in one Scottish abattoir has recently been used to estimate the prevalence and to investigate the epidemiology of pneumonia (Simmons and Cuthbertson, 1985). In Northern Ireland, a computerised information retrieval system for pathology data from all abattoirs is being used to elucidate the major epidemiological determinants which are important in the occurrence of pneumonia in the sheep population. A unique feature of this system is the ability to integrate the abattoir pathology database with a corresponding database of prevailing weather conditions. This paper presents the results of statistical and epidemiological analyses of the integrated database and quantifies the effect of specific weather variables on the prevalence of sheep pneumonia. The paper also highlights the practical implications of these findings for the prevention of this economically important disease of sheep.

MATERIALS AND METHODS

The monthly and yearly percentage lung condemnation rates in all sheep slaughtered in Northern Ireland are available since 1969. Such condemnations are based on the presence of pleuritic and/or pneumonic lesions. The information is contained within an extensive database of the type and location of specific pathological changes resulting in condemnations in all cattle, sheep and pigs slaughtered in Northern Ireland. The database is

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held on a VAX 11/750 super mini-computer and is dynamically updated on a monthly basis. Complex statistical and epidemiological time series analyses of this database are performed on an interactive basis, using the statistical software package, GENSTAT, and a comprehensive suite of customised FORTRAN 77 programs. The system facilitates the integration of the abattoir pathology database with a corresponding meteorological database and enables the cross- correlation of any defined abattoir or meteorological variables. This unique information retrieval system has been described in detail by McIlroy et al (1987).

The recorded monthly percentage condemnation rates for pleuritic/pneumonic lesions in sheep were examined graphically for each of the 18 years under analysis to determine the existence and consistency of any seasonality pattern. Any overall seasonality pattern was examined by calculating average values of percentage condemnation rates for each month of the year and the corresponding graph produced. These techniques were used to identify months when the prevalence of lesions achieved minimum and maximum values. Such values were used to define a meaningful 12-monthly cycle of pleuritic/pneumonic lesions for subsequent analysis. This 12-month cycle is subsequently referred to as the "pneumonic lesion" year. Average prevalences for each "pneumonic lesion" year were calculated and any trend in the resulting time series examined using standard regression techniques. All major weather variables were subjected to the same analytical procedures.

The overall average monthly prevalences of pleuritic/pneumonic lesions were cross-correlated with the weather variables. Such cross-correlations were performed on data recorded at coincident months and data lagged at any time interval from 1 to 12. Correlograms were produced to facilitate the graphical assessment of any significant cross-correlations. Significances were assessed using the method defined by Bartlett (1966). When significant cross-correlations were obtained with the prevalence of pleuritic/pneumonic lesions, a dependency relationship was postulated and a regression analysis performed and assessed graphically. The residuals obtained were investigated as a new time series. Auto-correlation coefficients were estimated for any relevant number of time lags using least squares techniques. These coefficients were then assessed for statistical significances. Furthermore, when such significant cross-correlations were found, the seasonality pattern of the weather variable was superimposed graphically on the seasonality pattern for pleuritic/pneumonic lesions to assess visually the closeness of the correspondence between the two seasonality patterns. Linear and multiplicative combinations of all statistically significant weather variables were examined using the same cross-correlation and regression techniques defined above.

Deseasonalisation of the pleuritic/pneumonic lesion data and meteorological data was performed by subtracting the overall monthly average from the relevant individual monthly values (Chatfield, 1975). Trends were also removed by fitting a standard regression model and taking the residuals as a new time series. These procedures are deemed necessary when cross-correlating two time series in order to minimize the occurrence of spurious correlations (Jenkins and Watts, 1968). Moving averages of between one and five months were then formed for each variable. These new time series were then subjected to all of the statistical analyses described above.

The 18 year time series under investigation was further analysed, by ranking the "pneumonic lesion" years into ascending order, depending on the overall mean value of each single or combined meteorological variable. The "pneumonic lesion" years were then categorised into two groups, high and low, depending on prevailing weather conditions. The average monthly percentages of pleuritic/ pneumonic lesions within each category of year were subjected to the arcsine root transformation and a paired t-test used to compare the mean monthly values, with individual months taken as blocks. Graphs were also produced for the average monthly values within each category of year.

RESULTS AND DISCUSSION

A distinct seasonality pattern was found in each of the 18 years under investigation in the prevalence of pleuritic/pneumonic lesions in sheep slaughtered in Northern Ireland. This seasonal pattern was found to be consistent from year to year with the highest levels being recorded during the late winter and the lowest during midsummer for all years. The maximum prevalence was most frequently attained during March, while the minimum prevalence was always recorded in August. The "pneumonic lesion" year was therefore defined to begin in August and end in the following July. The overall seasonality pattern is presented in Figure 1. Simmons and Cuthbertson (1985) reported a similar seasonality pattern in the prevalence of pneumonic lesions in sheep slaughtered at a Scottish abattoir. In the present study, predictable seasonality patterns were found for all of the major weather variables.

The average prevalences for each "pneumonic lesion" year are shown in Figure 2. A slight upward trend was found over the 18 year time series. This was found to be on the borderline of significance ($p<0.05$). The regression equation was found to be $y = -0.86 + 0.017\ x$. The standard error of the slope of the regression equation was 0.0076. A similar slight upward trend over the 18 years was detected for rain and windchill. This finding merited the investigation of the hypothesis that the prevalence of pleuritic/pneumonic lesions is dependent on rain and wind chill.

Significant cross-correlations were found between the overall monthly prevalences of pleuritic and pneumonic lesions and the weather variables, rain, wind, temperature and humidity. Such significant correlations were invariably only obtained when these weather variables were lagged by one or two months. Several meteorological equations were formulated to take account of the combined effect of these important weather variables.

The most significant correlations were found using a new multiplicative weather variable, termed the rain/windchill factor, lagged at one (0.88, $p<0.001$) and two (0.92, $p<0.001$) months. The rain/windchill factor (RW) is obtained using the following equation:

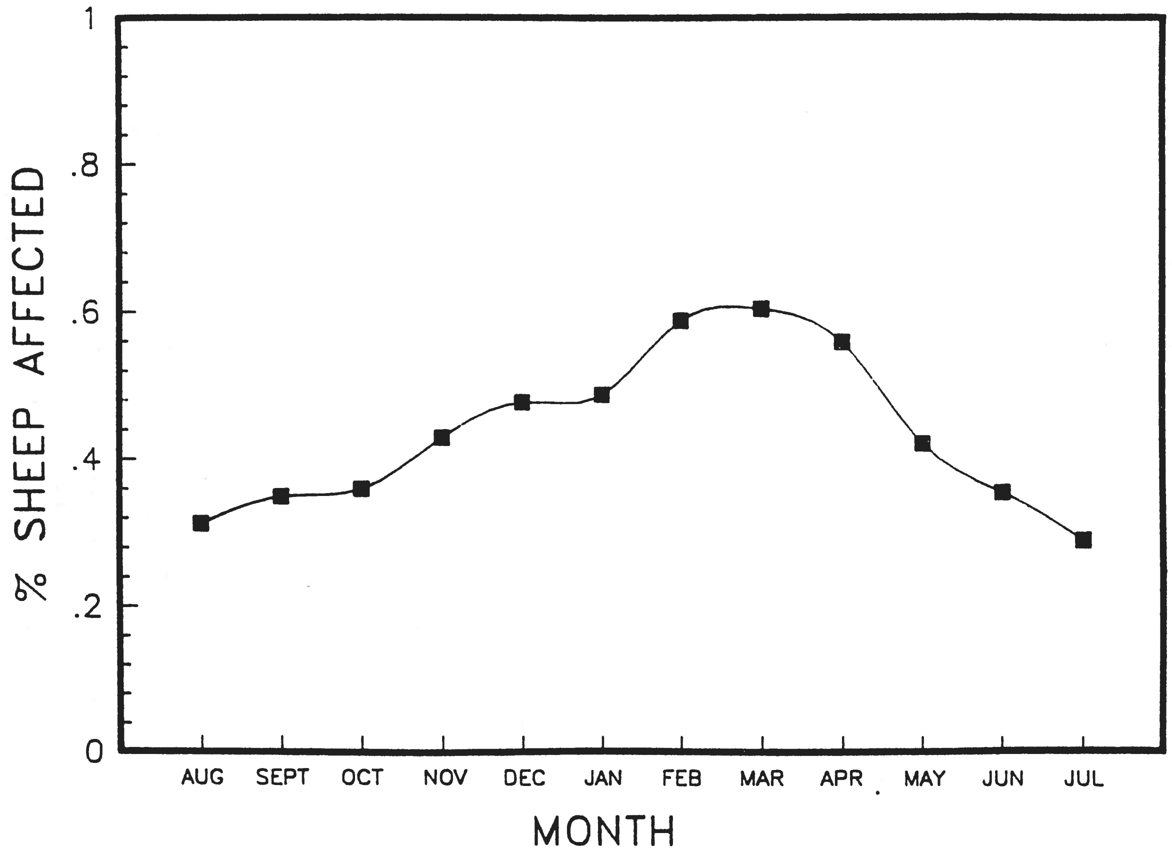

Fig. 1 The average seasonality pattern of pleuritic/pneumonic lesions in sheep from 1969 to 1987.

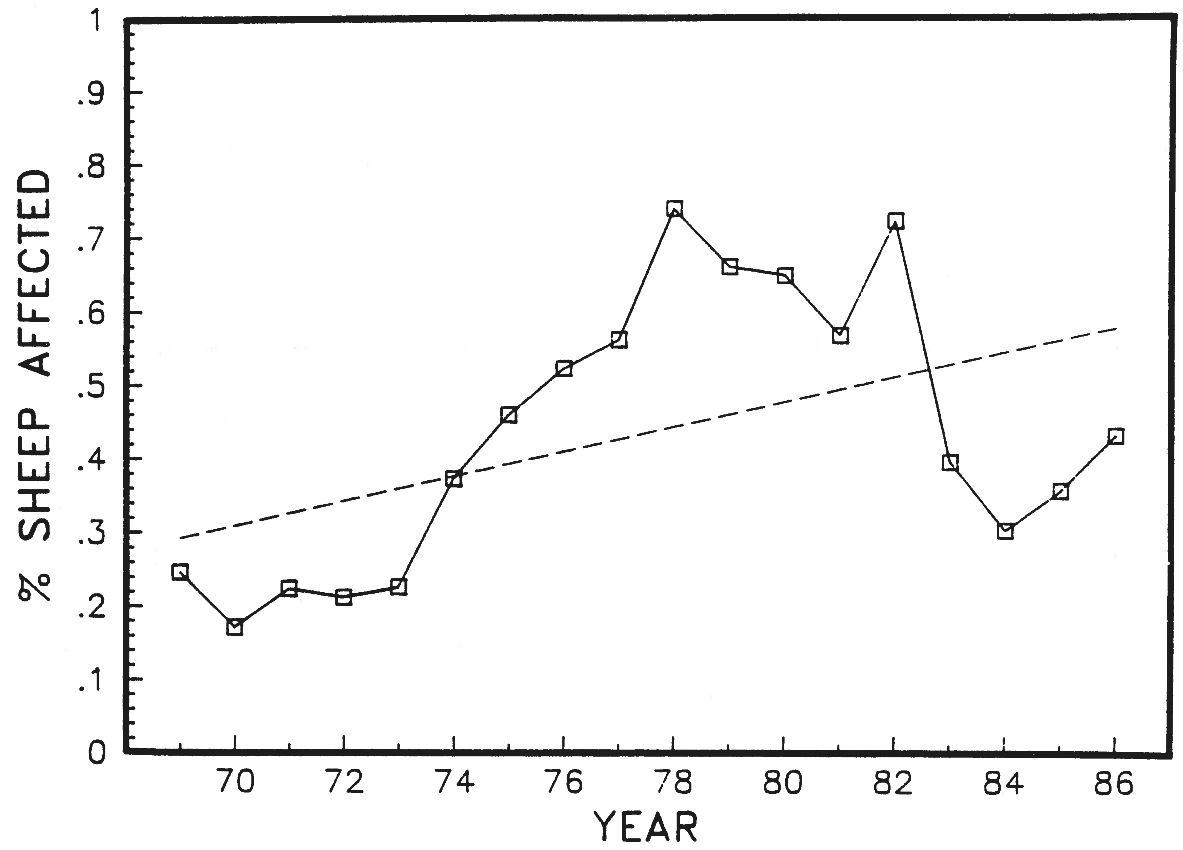

Fig. 2 The average prevalences for each "pneumonic lesion" year from August 1969 to July 1987.

$$RW = WH\,(35-T) + 50\,R$$

where W = wind speed (knots)
H = relative humidity (%)
T = air temperature (° C)
R = rainfall (mm)

This is a modification to include the mean level and variation in rainfall from the equation developed by Steadman (1984) for windchill.

The equation obtained after regressing pleuritic/pneumonic lesions (y) and rain/windchill (x), lagged by two months, was $y = 0.0022 + 0.00149\,x$. The standard error of the slope of the regression equation was 0.0002. The relationship is shown in Figure 3 and demonstrates clearly that the prevalence of pleuritic/ pneumonic lesions in slaughtered sheep increases dramatically when the rain/windchill factor has been high two months previously. In Figure 4, the seasonality pattern of rain/windchill, lagged by two months, is shown superimposed on the seasonality pattern of pleuritic/pneumonic lesions. This graph clearly demonstrates the extremely close correspondence occurring between the two variables when the key lagging factor is taken into consideration. This substantiates the hypothesis that the average monthly level of pleuritic/pneumonic lesions is dependent on the degree of rain/windchill prevailing two months prior to slaughter.

In Figure 5, the seasonality pattern of the rain/windchill factor, lagged by one month is shown superimposed on the seasonality pattern of the pleuritic/pneumonic lesions. It is extremely interesting to note that during the winter period when both variables are high, the correspondence between the two patterns is not as close as was observed at lag two. The correlation coefficient obtained at lag one was only slightly less than at lag two. The superimposition technique, with time taken as the horizontal axis, has obvious advantages in the detailed assessment of the overall effects over time of one variable upon another.

The 18 year time series for pleuritic/pneumonic lesions and the corresponding time series for the rain/windchill factor were detrended. These new time series were cross correlated and a very highly significant correlation of 0.8 ($p<0.001$) was obtained. Such a high level of significance obtained after cross correlating the two detrended time series strongly substantiates the previously formulated hypothesis of the rain/windchill effect.

Deseasonalisation and detrending were then carried out on the time series of individual values for each month of the year for both the pleuritic/pneumonic lesions and the rain/windchill factor. A set of moving averages was formed for each variable and the new series cross-correlated at lagged time intervals. The most meaningful and statistically significant correlations were found using a one point moving average on each variable at lags of one (0.341, $p<0.001$) and two (0.395, $p<0.001$) months. These findings may represent a cumulative effect of rain/windchill over consecutive months on the subsequently observed levels of pleuritic/pneumonic lesions at the abattoir.

The 18 "pneumonic lesion" years were categorised into two groups depending on the recorded level of rain/windchill factor. The groups were

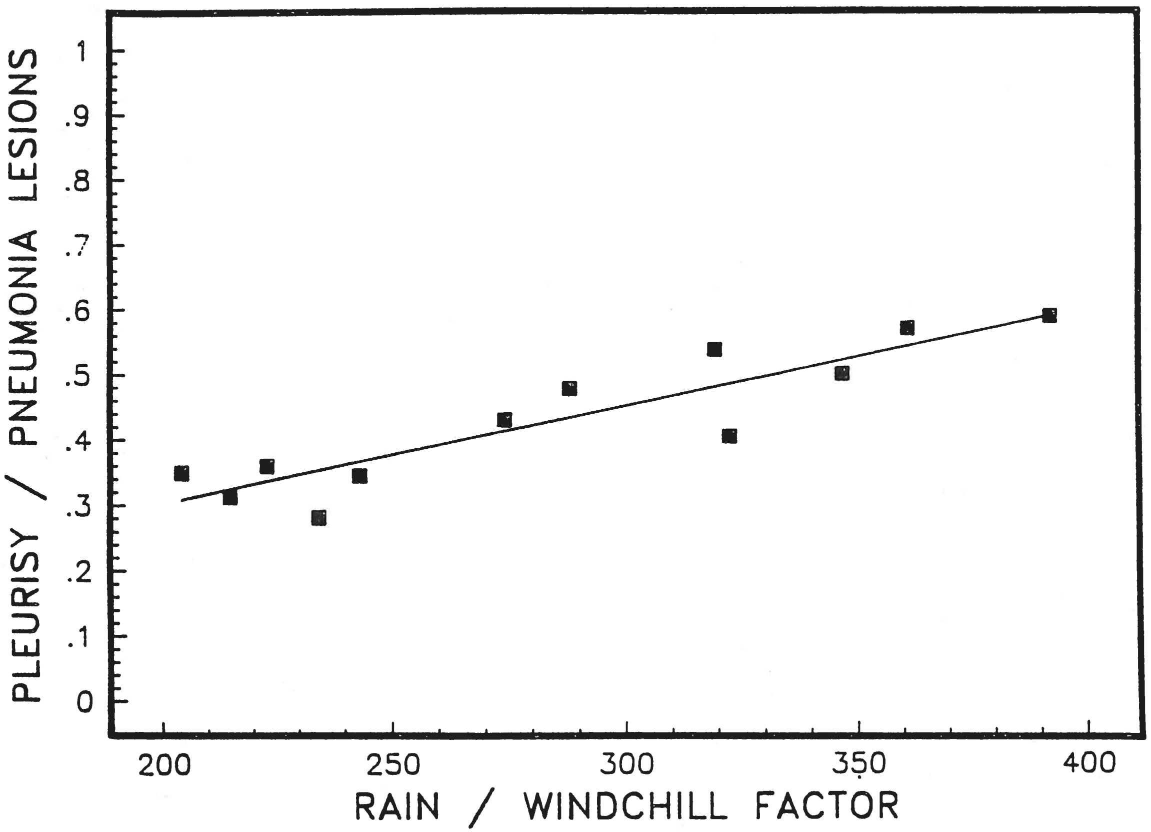

Fig. 3 The relationship between the average monthly level of pleuritic/pneumonic lesions and the average monthly rainchill factor, lagged by two months.

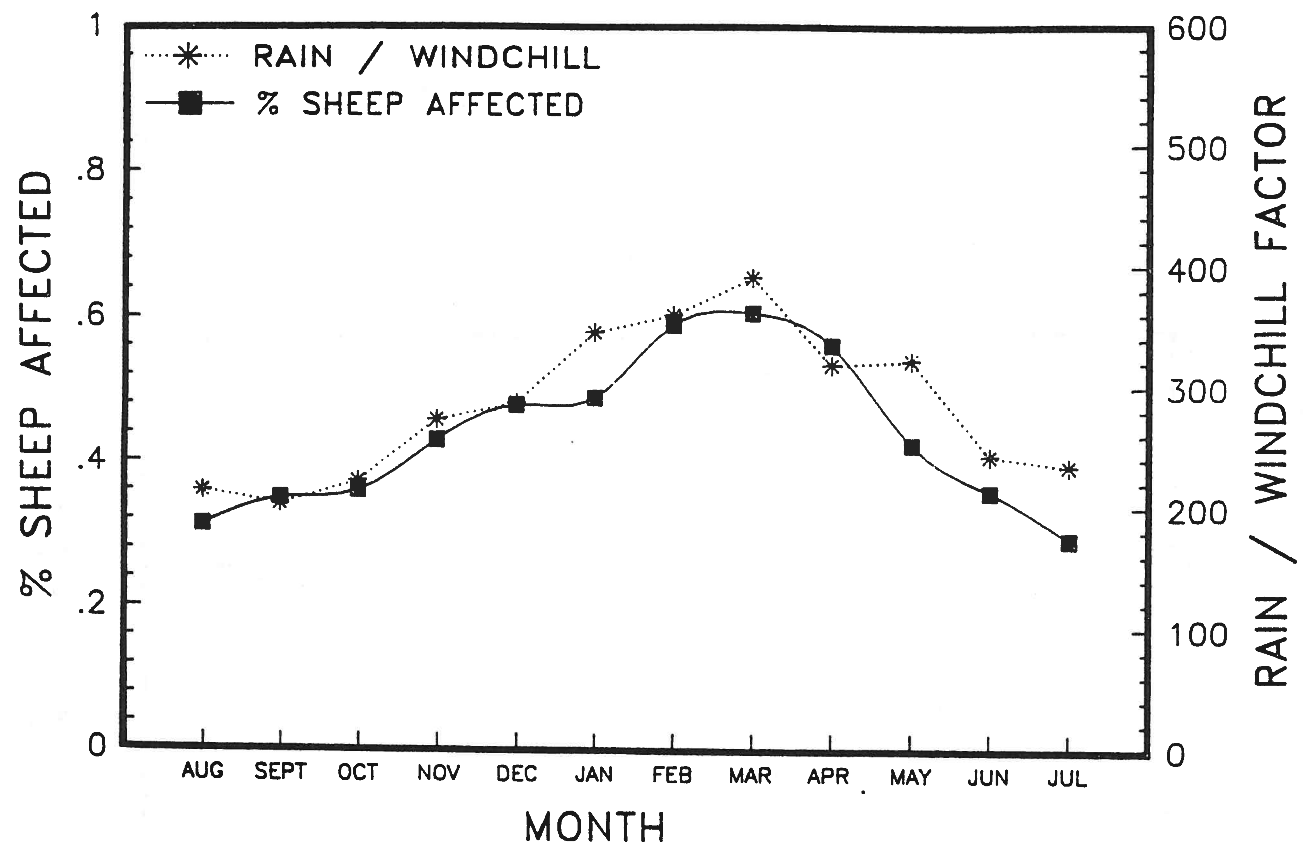

Fig. 4 The seasonality pattern of rain/windchill, lagged by two months, superimposed on the seasonality pattern of pleuritic/pneumonic lesions.

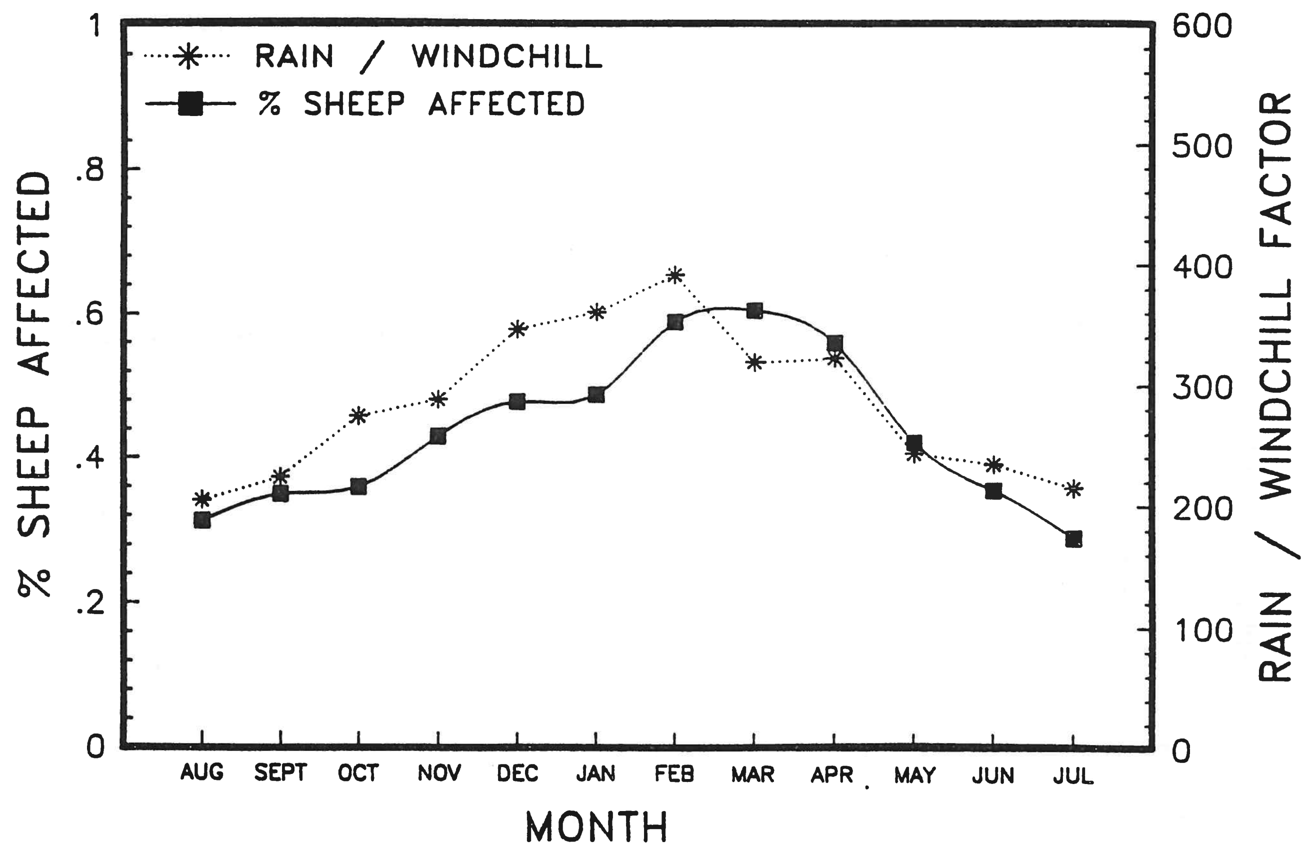

Fig. 5 The seasonality pattern of rain/windchill, lagged by one month, superimposed on the seasonality pattern of pleuritic/pneumonic lesions.

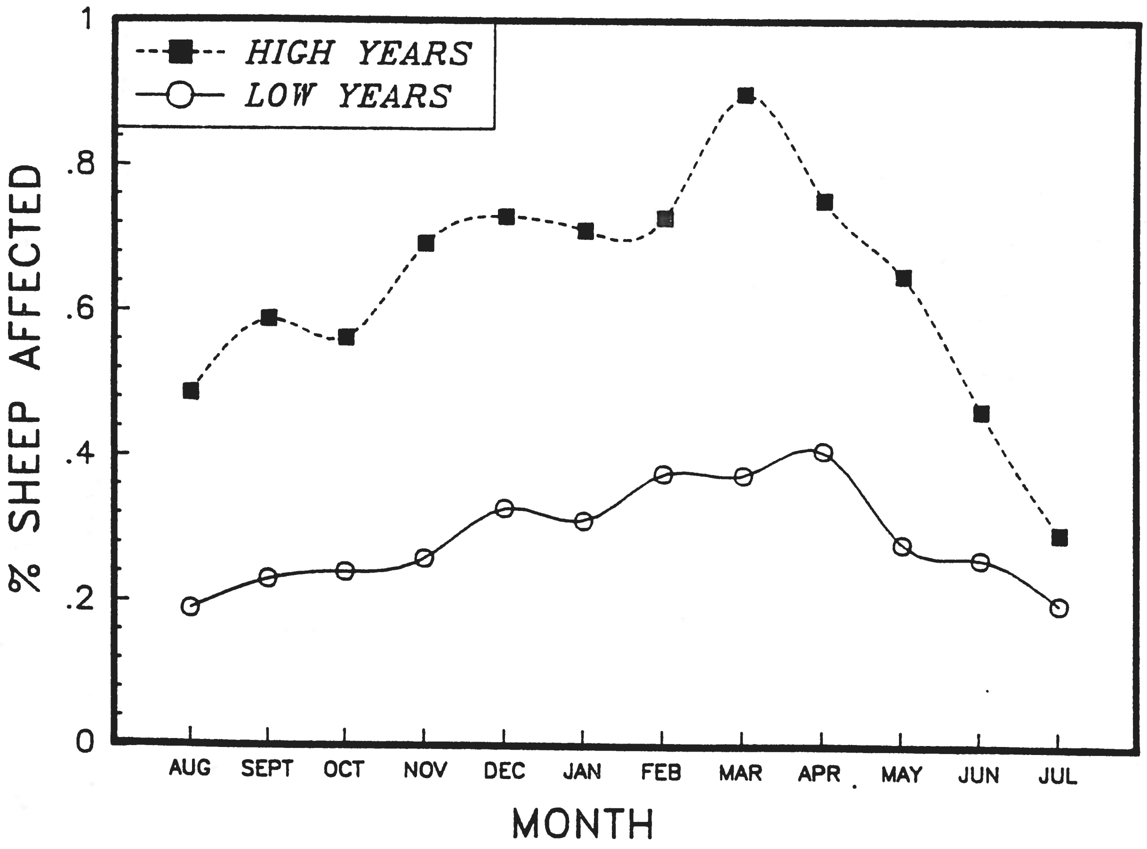

Fig. 6 Average monthly levels of pleuritic/pneumonic lesions in years when the rain/windchill factor was either high or low.

years when the degree of prevailing rain/windchill had been either high or low. The average monthly values for each group are shown in Figure 6. The mean prevalence of pleuritic/pneumonic lesions for the low rain/windchill group was 0.28% and the high rain/windchill group was 0.63%. The standard error of the difference of the means of these two groups was 0.03. After the arcsine root transformation had been carried out and a paired t-test performed, a very highly significant difference between the mean values for each group was found ($p<0.001$). The practical significance of this finding is that, in years when the degree of rain/windchill was high, the level of pleuritic/pneumonic lesions and thus previous incidence of pneumonia more than doubled.

CONCLUSION

These findings are of great practical importance to sheep production in Northern Ireland, an area with high rain and windchill during the winter months. Notably, the majority of the sheep population are not provided with shelter and are thus extremely susceptible to prevailing weather conditions. The results clearly indicate that sheep should be provided with some form of adequate shelter or protection from the combined effect of these two common weather elements. Where it is not practical to provide adequate shelter from rain, then sheep should at least be protected from prevailing wind.

Modern meteorological technology enables the issue of early forecasts of severe weather conditions. It is anticipated that the Department of Agriculture for Northern Ireland, in co-operation with the local Meteorological Office, will issue warnings when the risk of pneumonia is substantially increased. Such warnings will depend on forecasted levels of rain/windchill exceeding critical values for the occurrence of pneumonia.

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THE INFLUENCE OF ALTERNATE GRAZING WITH CATTLE ON *NEMATODIRUS* INFECTION IN LAMBS

R.L. COOP,* F. JACKSON* and E. JACKSON*

Nematodiriasis is an acute disease of young lambs, around 4 to 8 weeks of age, associated with high intakes of infective larvae of the genus *Nematodirus*. The disease has been recognised in Great Britain since the 1920's and increased in prevalence throughout the 1940's. In the early 1950's severe outbreaks of *Nematodirus* disease were recorded in flocks in the North East of England and in Southern Scotland with around 10 per cent lamb mortality (Kingsbury, 1953; Stamp et al., 1955; Thomas & Stevens, 1956). Similarly, in Northern Ireland, Baxter (1957) recorded morbidity rates of 20-75 per cent with a mortality rate of up to 20 per cent. The availability of effective broad spectrum anthelmintics in the 1960's and an increased knowledge of the epidemiology of *Nematodirus* reduced the number of serious outbreaks of disease although *Nematodirus* infection is still an important cause of scour in young lambs (Rodger, 1983; Hosie, 1984; Mitchell et al., 1985; Britt, 1986 & Coop et al., 1988).

The three common species of the genus *Nematodirus* found in the United Kingdom are *N. battus*, *N. filicollis* and *N. spathiger*. *Nematodirus battus* tends to predominate in the northern regions and *N. filicollis* in the south of the country, although both species frequently occur together in disease outbreaks. *N. spathiger* is present only occasionally. This paper will concentrate on *N. battus* as it generally causes more acute disease than *N. filicollis* and is the major cause of nematodiriasis in lambs in the spring.

EPIDEMIOLOGY

The epidemiology of *N. battus* differs from that of other trichostrongyles in that eggs deposited on pasture in the spring develop slowly and usually do not reach the infective stage until late summer. The majority of these embryonated eggs hatch spontaneously in April-May of the following year leading to a rapid rise of infective larvae on pasture, followed by a marked decline to low levels by July (Gibson, 1958; Thomas & Stevens, 1956, 1960; Thomas, 1959; Boag & Thomas, 1975). Thus the complete life-cycle from egg to adult worm usually takes 12 months and involves a prolonged resting phase on the pasture. This pattern of development results in high levels of infective larvae at a time when susceptible lambs are grazing. The stimulus for the rapid hatch of larvae over a short period in the spring is a rising temperature, usually above 10^{o} C, following a period of prolonged cold conditions during the winter (Thomas & Stevens, 1960). Although most *N. battus* eggs do not hatch until

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the following spring a small proportion may hatch within the same year causing additional autumn peak (Gibson & Everett, 1981; McKellar et al., 1983; Hollands, 1984; Bairden & Armour, 1987).

The timing of the hatch of N. battus eggs will influence whether or not disease appears in the lamb crop. In a year when spring is early and mild, the peak larval hatch will often have occurred before susceptible lambs are consuming appreciable quantities of herbage and therefore infection rates will be low. With a cold late spring the mass hatch of eggs will frequently be delayed until May when lambs will be ingesting reasonable amounts of grass and a high incidence of disease frequently results in late May or June. Obviously, the date of lambing will influence the incidence of infection between farms in any year. Lambs rapidly develop resistance to infection, usually within 2 months of being exposed to high numbers of larvae, and therefore only sheep in their first grazing season are susceptible (Thomas, 1959; Gibson & Everett, 1963; Taylor & Thomas, 1986). Adult sheep become only lightly infected, pass relatively few eggs and are considered to play only a very minor role in the epidemiology of infection. Their low faecal egg output will maintain a source of N. battus on pasture which could then be increased by a season's lamb grazing.

CONTROL STRATEGIES

It is clear from the epidemiological studies that N. battus is a lamb to lamb infection, disease primarily occurring on pasture grazed by lambs in the previous season. Two main control strategies are advocated, depending on the availability of alternative grazing. The first is directed against the infrapopulation in the lamb and the second against the pre-parasitic free-living populations. In an all sheep enterprise with permanent pasture it may be difficult to avoid successive lambing on the same area if the pasture is to be fully utilised but since the infrapopulation is resident within the host for a relatively short period reasonable control can be achieved by strategic dosing with anthelmintic. Usually 2 or 3 treatments starting at the beginning of May and continuing at 3 weekly intervals into June will prevent clinical outbreaks of disease. As considered earlier, the larval peak varies from year to year so a fixed period of dosing is a compromise. The timing of the treatments is assisted by the availability of a Ministry of Agriculture, Fisheries & Food forecasting system which, from soil temperatures taken in March, predicts the expected level of disease and the optimum time for dosing lambs or moving them to 'clean' pasture (Ollerenshaw & Smith, 1966; Smith & Thomas, 1972).

Where other livestock and arable crops form part of the management system it is feasible to provide 'safe' pasture (grass which did not carry susceptible sheep in the previous year) for the lamb crop. Newly established grass leys following an arable crop are ideal. Although Nematodirus eggs will survive ploughing and reseeding (Boag & Thomas, 1975) the level of contamination will be too low to cause disease. A further system frequently used to provide 'safe' pasture is an annual alternation of sheep and cattle as Nematodirus species have been considered to be host-specific.

ALTERNATE GRAZING

An annual alternation of cattle and sheep has been introduced as one way of providing 'safe' grazing for either species, particularly in northern areas of Britain where N. battus is prevalent. The gastrointestinal nematodes that infect sheep are generally considered to be host-specific with only minimal cross-transmission to cattle, apart from Cooperia oncophora, Trichostronglus axei and Haemonchus contortus. Grazing the pasture with a different host in the intervening year will allow the existing contamination and infectivity of the herbage to decline to low levels. However, over the last decade there have been several reports of Nematodirus infection in lambs where 'clean' and alternate systems of husbandry have been adopted (Scottish V.I. report, 1981; Coop et al., 1984; Mitchell et al., 1985). This raises the possibility that the parasites are becoming adapted to the alternate host under the selection pressures exerted by an annual alternation of livestock. Indeed, earlier studies (Parfitt & Michel, 1958; Baxter, 1959a; Rose 1968 and Helle, 1981) reported low numbers of N. battus eggs and worms in grazing cattle, and more recently Bairden & Armour (1987) recorded mean N. battus burdens of 27,563 from 5 month old calves which had been grazed on contaminated pastures for 2 weeks in the spring.

In order to investigate further the role of cattle in the epidemiology of Nematodirus infection under these grazing systems two approaches were taken. First, a joint study was conducted with the East of Scotland College of Agriculture to monitor a husbandry system in which cattle and sheep had been alternated annually over several years. The second approach involved a study on the Institute farm to investigate the relative contribution of the cattle contamination to that which results from a two year carry-over of infection on pasture.

Studies on an alternate husbandry system from 1983-1985.

The management system consisted of two areas of permanent pasture, each of approximately 10 hectares which were grazed alternately by sheep and cattle, change over of livestock taking place in the spring. Scottish half-bred ewes with predominantly twin Suffolk cross lambs were lambed in March on a separate area of the farm. In mid-April all the ewes and those lambs over 3 weeks of age were treated with anthelmintic and moved onto the previous year's cattle grazing area at a stocking rate of 13-15 ewes/ha. Winter born Hereford or Charolais/Friesian cross calves were reared conventionally indoors and turned out in mid-May, along with 16 month old finishing cattle, onto the previous season's sheep grazings at 4-7 calves/ha. After the cattle were housed in late autumn the area was grazed by dosed ewes. Herbage samples were taken at 2 to 3 week intervals from April to September from both the sheep and cattle areas and the number of N. battus larvae per kg dry herbage estimated by standard techniques. Faeces samples were taken from the rectum of all the calves and from 50 lambs at approximately 3 week intervals to determine the numbers of Nematodirus eggs per gramme of fresh faeces. Lambs which scoured in May/June were dosed with anthelmintic and excluded from further sampling.

Moderate numbers of N. battus larvae were present on the pasture grazed by the lambs in 1983, a peak of 244 larvae/kg herbage being recorded in May (Fig.1) Grazing this pasture with cattle in the intervening year did not reduce the level of infectivity. The numbers of infective larvae actually increased to reach a peak of 3125 L_3/kg in May 1985 before declining to low levels. Similarly, the number of lambs which scoured and required anthelmintic treatment in May/June increased from 3.3% in 1983 to 28.5% in 1985. It is clear from Fig. 2 that one of the reasons for the increase in transmission was

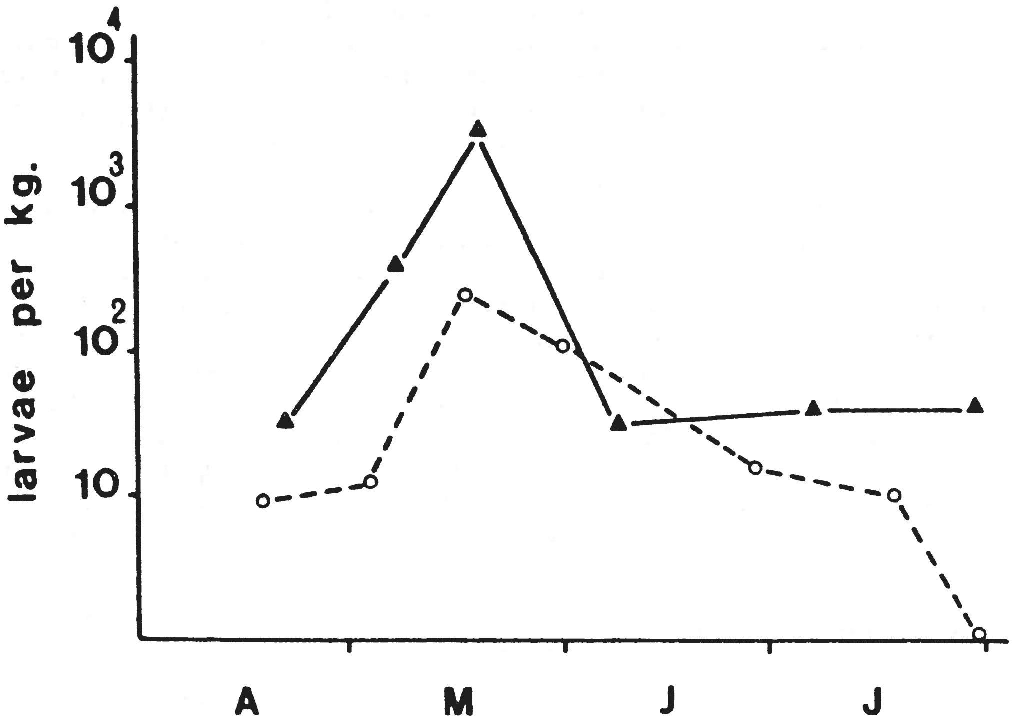

Fig. 1. N. battus larvae per kg of dry herbage on the pasture grazed by lambs in 1983 (○– – –○) and 1985 (▲——▲)

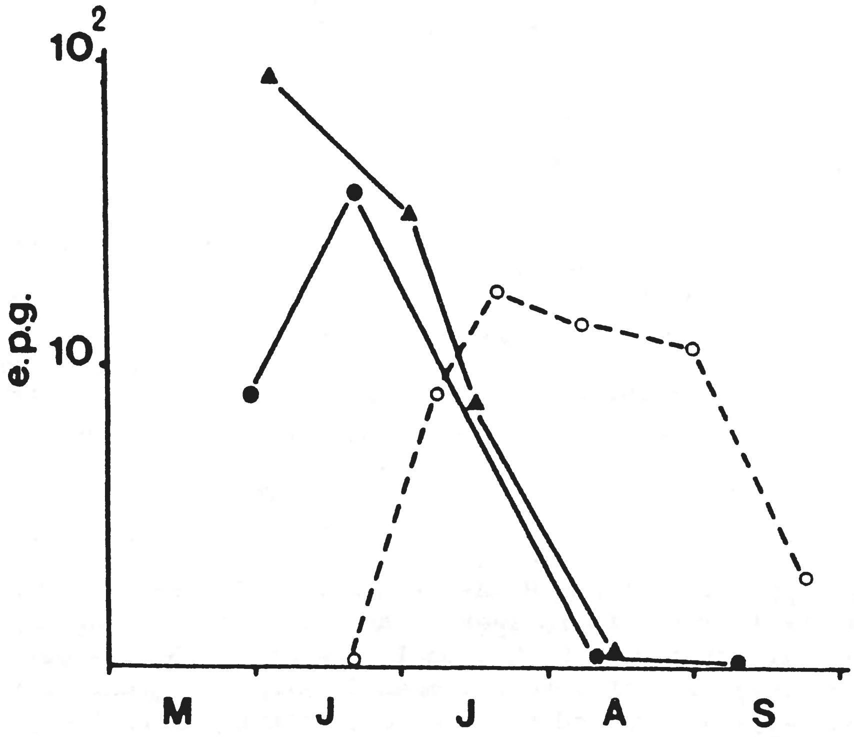

Fig. 2. Mean N. battus faecal egg counts (eggs per gramme) from the calves which grazed in 1983 (○– – –○) 1984 (●——●) and 1985 (▲——▲).

that N. battus was being cycled through the young susceptible calves which were grazed on the pasture in the intervening year. Although the faecal egg counts of the calves were reasonably low (maximum mean values of 18, 38 and 90 e.p.g. for 1983-85 respectively) the daily output of Nematodirus eggs was calculated to be of the order of 1.2 to 5.9 x 10^5 per calf at the peak of production in June/July. Subsequent experiments have shown that the N. battus eggs passed by the calves develop normally and are infective to lambs.

It was significant that the 18-month old finishing cattle passed negligible numbers of eggs and were obviously highly resistant to N. battus. This may be an age effect but is more likely to be due to the fact that they had acquired immunity in the previous year when grazing contaminated pasture as young calves. In this respect, Bairden & Armour (1987) have shown recently that cattle which became infected in the spring and passed N. battus eggs carried no burdens of N. battus in the autumn although they were still grazing pasture which was infective. They suggested that where beef cows and their calves are grazed on these alternate systems then the adult resistant animals would reduce the transmission of N. battus to the calves. This being the case then the levels of contamination in the current study would have been higher had only weaned calves been used.

Studies on the Institute farm from 1985-1987

A grazing trial conducted over 3 consecutive years assessed the relative contribution of cattle contamination to that which results from a two-year carry over of Nematodirus on the pasture. Three 'clean' paddocks, each of approximately 1 hectare, were available. These paddocks were closed for hay production during 1983 and 1984 and were grazed in October/November only by adult ewes treated every 2 weeks with anthelmintic. The trial design (Table 1) allowed a comparison to be made between a 2 year persistence of Nematodirus contamination (paddock A), a 2 year persistence plus further contamination by calves (paddock B) and contamination by calves alone (paddock C).

Table 1. Experimental design and livestock grazing

Paddock	1985	1986	1987
A	Ewes+ twins	Hay	Ewes+ twins
B	Ewes+ twins	Calves ↓	Ewes+ twins
C	Hay	Calves	Ewes+ twins

In 1985 each of paddocks A and B was grazed with 10 Greyface-cross Suffolk ewes with twin lambs from the third week of April. All the lambs were gathered daily and infected with N. battus larvae over a 5 week period to simulate a typical spring hatch (overall mean intake 673 L_3/day; range 50-2500). The ewes and lambs were alternated twice a week between these two paddocks to provide uniformity of contamination with Nematodirus eggs. Paddock C carried no livestock in the spring, a hay crop was taken in July and the pasture topped in the autumn.

In 1986 twenty winter-born calves were grazed on paddock B from turnout in the third week May to acquire N. battus infection. After 16 days' grazing 10 randomly selected calves were transferred to paddock C. The calves were removed from both paddocks in August. Paddock A was closed for conservation and following a hay crop in July grazed only by adult ewes (treated every 2 weeks with anthelmintic) during October/November.

In 1987 each of the 3 paddocks was grazed by 10 Greyface-cross Suffolk ewes with twin lambs from the last week of April. Six lambs were removed from each paddock during mid-June and housed for 2 weeks before slaughter. Total Nematodirus worm burdens, lamb faecal egg counts and the number of N. battus larvae per kg herbage were estimated during the trial using standard sampling techniques.

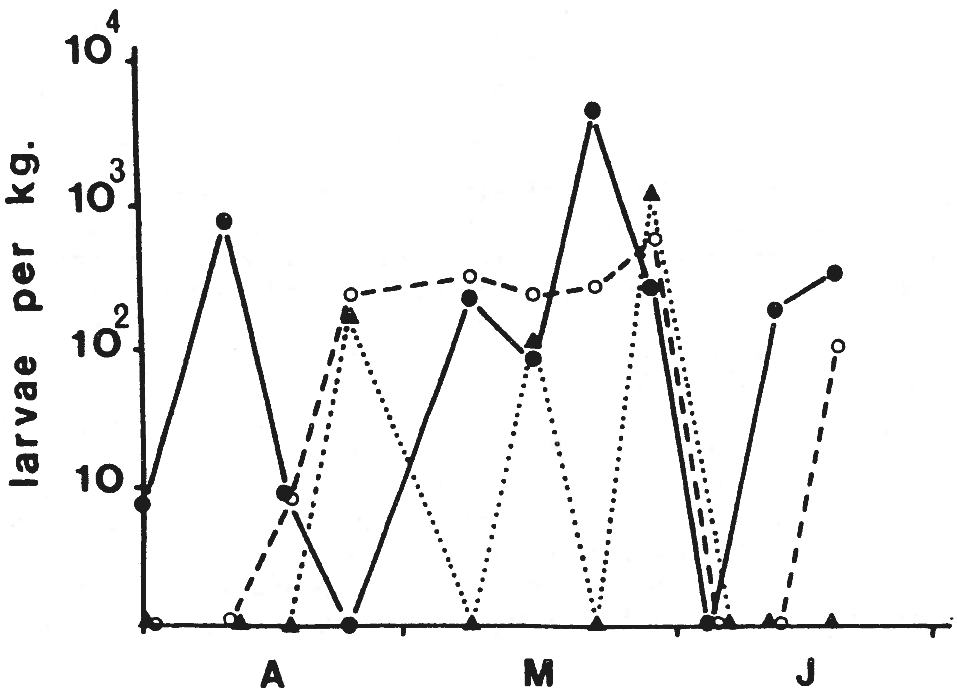

Fig. 3. N. battus larvae per kg of dry herbage on paddocks A(O– – –O), B(●——●) and C(▲·······▲).

The number of N. battus larvae recovered from paddocks A, B and C in 1987 showed considerable variation (Fig. 3). The lowest overall level of infectivity occurred on paddock C and was derived solely from the contamination deposited by the young calves which had grazed in the previous season. This contamination was of sufficient magnitude to allow moderate worm burdens to accumulate in the subsequent lamb crop (Table 2). However, in this particular trial the duration of the output of N. battus eggs from the calves was shorter than previously recorded (peak production for approximately 2 weeks, individual range, 0-394 e.p.g.) and as a consequence only relatively low levels of contamination were deposited. One possible explanation for the short patent period is that the calves were exposed to high levels of N. battus on the pasture and subsequently developed a rapid immunity to infection. In the previous field trials the levels of herbage infectivity were lower and consequently the calves deposited N. battus eggs over a more prolonged period. The data from paddock A showed that considerable numbers of N. battus larvae were able to survive on the pasture for a 2 year period and cause a reasonable level of infection in the grazing lambs (Table 2). Earlier studies (Baxter, 1959b; Gibson, 1959) also showed that where contaminated pasture is ungrazed for about 2 years then sufficient infectivity remains to cause a patent Nematodirus infection in young lambs but the level was generally less than in the current study and was too low to cause outbreaks of clinical disease.

Table 2. Nematodirus battus populations recovered from lambs at slaughter (1987).

Paddock	Geometric mean	Range
A	12036	2200-28240
B	10520	1720-42520
C	5525	3240-8200

Paddock B reflected the normal alternate grazing strategy where the pasture infectivity was derived from the previous lamb crop and cattle contamination in the intervening year. The data confirmed the previous trial and showed that grazing with young calves does not reduce the contamination on the pasture to levels low enough to be considered 'clean' for a subsequent lamb crop. Moderate Nematodirus burdens were recovered from the lambs (Table 2). These lambs were grazed for 7 weeks on the three paddocks and as a consequence it is likely that some of the lambs would have started to reject their worm burdens by the slaughter date. These findings differ from those reported by Boag & Thomas (1975) who showed that withholding sheep for one year and grazing the pasture with cattle was almost as effective at reducing the Nematodirus pasture larval levels as ploughing and reseeding. However, the age of their cattle was not stated and it is possible that older, less susceptible animals were grazed in the intervening year.

CONCLUSIONS

These trials demonstrate that young calves can contaminate pasture with N. battus eggs and supplement a 2 year carry over of infection in management systems involving an annual alternation of cattle and sheep. The age of the cattle is important as yearlings are resistant and produce negligible number of N. battus eggs. The problem appears to be restricted to young weaned dairy calves where turn out in the spring coincides with the increasing availability of infective larvae on the pasture.

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WATERY MOUTH: A DISEASE OF NEONATAL LAMBS

T.J. KING*, L. HAY*, W. DONACHIE* AND J.S. GILMOUR*

Watery mouth has been recognised for many years and is considered by many farmers to be one of the major problems in neonatal lambs.

It is a disease seen only in lambs up to 72hrs old. Initial clinical signs are that of a dull lamb, within hours the lamb will show the excess lacrimation and salivation that are typical of the condition. The lamb becomes progressively more dull, refuses to feed and the salivation becomes more profuse. Abdominal tympany is often noted and occasionally diarrhoea is observed. Within twelve hours of clinical signs being noted the lamb will collapse and unless treatment has started the lamb will die within hours.

Necropsy reveals a mild enteritis, with food and quantities of excess gas usually present in the intestines. Retained meconium, noted by some authors and blamed as the cause of the condition by others,(Collins,1981, Haig,1981, Robinson,1981, Shaw,1981, and Winkler,1981) is not found in all cases. Histologically all that is found is a mild inflammation in the small intestine. An interesting point noted by Gilmour,Donachie and Eales(1985) was that most of the lambs showed evidence of colostrum intake and that 90% of cases had a terminal bacteraemia. The bacteria most commonly isolated were E.coli and they were of several different antigenic types none of which were known pathogens.

The response to a recent questionnaire, in which members of the Animal Diseases Research Association were asked to state the causes of neonatal lamb deaths in their flock, indicated that watery mouth was considered to cause 20% of all such deaths. It was most prevalent in those farms that housed their sheep, even if for only a short time around lambing. The disease was more common in upland and lowground flocks than in hill flocks. Over 50% of farmers were using antibiotic to prevent the condition in their flock.

It has been shown (Eales et al 1986) that watery mouth is more common in triplets or twins than in a single lamb and that lambs born to old ewes ,young ewes or ewes of poor body condition are more likely to develops watery mouth. The incidence is not affected by the weight of the lamb.

These observations, and the results of the survey, suggest certain factors which may influence the prevalence of the disease.

1.Levels of contamination: The prevalence of watery mouth appears to increase in situations where sheep are stocked heavily, such as in housed sheep and lowground flocks. This suggests that levels of contamination may affect the prevalence of the disease.

2.Lambing percentage: Watery mouth is more common in twin and triplet litters but the incidence is not related to the weight of the lambs, suggesting that the timing and amount of colostrum intake may be important. Flocks with a high lambing percentage are therefore more likely to have a problem with watery mouth.

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3.Colostrum production: A lamb born to a ewe not able to produce adequate colostrum for her litter is more likely to develop watery mouth.

To investigate the pathogenesis of the disease further, a series of experiments were done to try to reproduce the disease experimentally.

EXPERIMENTAL REPRODUCTION OF WATERY MOUTH.

To reproduce watery mouth experimentally lambs were dosed with a mixture of three strains of E.coli originally isolated from field cases of watery mouth. To overcome the risk of contamination from the environment by other bacteria, gnotobiotic lambs were used. They were dosed with $1*10^{10}$ colony forming units (c.f.u.) of the E.coli cocktail by mouth at 2.5hrs old and fed UHT milk throughout the experiment. Within 12hrs of infection the lambs became dull, refused to feed and then developed the excess salivation which gives the disease its name, together with slight excess lacrimation,puffiness around the eyes and some abdominal tympany. Within 18hrs they had collapsed and were killed on humane grounds. At necropsy they showed a mild enteritis and all were bacteraemic with the inoculated E.coli strains.

Although some of the clinical signs exhibited by these gnotobiotic lambs were more exaggerated than in field cases and the progress of the disease was more rapid, the experimental procedure had reproduced the condition, providing a useful model for further investigations.

The experiment was repeated using a single strain from the original mixture of three E.coli strains. Again, the disease was successfully reproduced using $1*10^{10}$ c.f.u. of the single strain and this became the standard model for further work.

The above model was tested using 4 different strains of E.coli, two of which were originally isolated from field cases of watery mouth and two that were isolated from other sources. In each case watery mouth occured. The strains used to reproduce the disease all had different "O" antigen serogroups.

These results showed that E.coli played a major role in the pathogenesis of watery mouth but that the specific strain of E.coli appeared unimportant. It is possible that other types of bacteria could cause the disease under suitable conditions, but this hypothesis has yet to be tested.

PREVENTION OF WATERY MOUTH

Epidemiological studies (Eales, 1986) suggest that lambs receiving sufficient colostrum early enough in life do not develop watery mouth.This theory was tested using the gnotobiotic model of the disease.

Prevention of Watery Mouth by feeding colostrum.

Experimental design:15 gnotobiotic lambs were dosed orally at 2.5hrs old with E.coli, a technique known to reproduce watery mouth. Five groups of three lambs were fed as described in Table 1. The lambs were fed at a rate of 50mls/kg at each feed and all groups were fed only on UHT milk after their third feed. Group 5 was fed a mixture of UHT and immunoglobulin extracted from ewes colostrum at 2hrs and UHT milk thereafter. UHT milk is used as the standard diet for gnotobiotic lambs as it is a convenient source of sterile feed.

Table 1 Feeding Regime

GROUP	AGE 2hrs	6hrs	12hrs
1	UHT	UHT	UHT
2	COLOSTRUM	COLOSTRUM	COLOSTRUM
3	COLOSTRUM	UHT	UHT
4	NIL	COLOSTRUM	COLOSTRUM
5	UHT/Ig[a]	UHT	UHT

a)Ig = immunoglobulin fraction of ewes colostrum

Results

All the lambs which obtained colostrum (groups 2,3 and 4) survived and did not develop clinical signs.Lambs in group 5 also remained free of disease. No bacteria were present in the blood of any of these lambs at the end of the experiment.

Two out of the three lambs in the group which did not receive colostrum(group 1) developed watery mouth and a bacteraemia. The remaining lamb in this group did not develop clinical signs.

Conclusions

The results of this experiment agree with the findings of the epidemiological studies which suggested that lambs receiving sufficient colostrum would not develop watery mouth. They also demonstrated that colostrum feeding could be delayed for 6hrs and still be protective if fed in sufficient quantities. Group 5 suggested that the protective factor in colostrum is the immunoglobulin component.

Feeding of colostrum appears to prevent the development of watery mouth and the development of a bacteraemia by transfer of immunity to E.coli infections. It appears that this immunity is derived from the immunoglobulin fraction of colostrum but whether this protection is mediated by specific antibodies or by some other non specific action of the immunoglobulin is not known. Whether the immunoglobulins act locally in the lumen of the intestine, or systemically, also is unknown.

The reason why one of the lambs in group 1 survived and did not develop clinical signs is not known but there are at least two possible explanations;

1. although delivered at 143 days of gestation this lamb may have been more "mature" than others in the group (this idea will be discussed later)
2. there may have been contamination of the lamb by other bacteria which may antagonise the growth of E.coli (Berg and Garlington, 1980), perhaps affecting the outcome of the infection.

RESISTANCE TO WATERY MOUTH

It appeared that lambs were susceptible to watery mouth if they did not receive sufficient colostrum and were exposed to a certain level of infection. However a success rate of 90% in reproducing the disease in colostrum deprived gnotobiotic lambs could not be repeated in conventional colostrum deprived lambs, where only 30% of lambs developed the disease, although both gnotobiotic and conventional lambs were infected with the same dose and strain of E.coli, at the same time after birth and fed only milk. There are two main differences between gnotobiotic lambs and conventionally delivered lambs which could account for this difference in susceptibility;

1. The gnotobiotic lambs are completely free of any bacterial flora until they are infected with the E.coli, whereas conventional lambs develop a large gut flora very rapidly after birth. This flora may protect some of those colostrum deprived lambs from developing watery mouth by interfering with the growth of E.coli possibly by competing for available nutrients or by some other mechanism.

2. Gnotobiotic lambs are delivered by caesarian section at 143 days of gestation which means that they are delivered prematurely. This prematurity may affect their ability to overcome the infection with E.coli perhaps due an increased permeability of the gut, or to a reduced blood flow through the liver.

To investigate the effect of prematurity on the development of watery mouth in gnotobiotic lambs two experiments were performed.

In the first, two groups of two gnotobiotic colostrum deprived lambs, instead of being infected at 2.5hrs of age, were infected at 12hrs and 24hrs respectively with a dose of E.coli sufficient to cause watery mouth. The two lambs infected at 12hrs developed a bacteraemia, showed dullness but continued to feed. They occasionally salivated excessively but did not develop all the typical symptoms of watery mouth. Both lambs survived for several days before having to be destroyed due to the development of swollen and infected joints and blindness due to hypopyon. The two lambs infected at 24hrs developed no clinical signs at all and did not become bacteraemic.

In the second experiment eight gnotobiotic lambs, instead of being delivered at 143 days were delivered on the point of parturition(147-149days). These lambs were then infected at 2.5hrs,as before,with E.coli and fed only UHT milk. Three of these lambs developed watery mouth and a bacteraemia. Five experienced a bacteraemia but did not develop watery mouth. In gnotobiotic lambs delivered at the usual 143 days we would have expected all or at least 7 of the 8 lambs to develop watery mouth.

Summary of evidence to date

Of 23 gnotobiotic lambs delivered at 143 days of gestation and infected with E.coli all became bacteraemic and 21 developed watery mouth.

Of 8 gnotobiotic lambs delivered at term all became bacteraemic and 3 developed watery mouth.

Of the 2 gnotobiotic lambs delivered at 143 days but not infected until 24hrs after delivery neither became bacteraemic or developed watery mouth.

Conclusions

Although group numbers are too small to justify confident statements, it appears that resistance to watery mouth in colostrum deprived lambs may be dependant on the maturity of the lamb. Gnotobiotic lambs delivered at term seem less susceptible to watery mouth than those delivered prematurely and lambs not infected until 24hrs old appear able not only to resist watery mouth but also to avoid bacteraemia.

The reasons for the development of this apparent resistance are unknown but it may be connected with the changes that take place shortly before and after birth. In the last few days of gestation quite marked changes occur in the lambs gut (Shulkes et al, 1985 and Trahair Robinson and Silver, 1984). These may affect the ability of the gut to prevent passage of materials across it, and therefore may affect the outcome of an infection. After birth a lambs gut allows passage of macromolecules for the first 12 to 24hrs of life to allow immunoglobulins from colostrum into the bloodstream. The changes that take place when this pathway is closed down may also make the uncompromised gut impervious to the passage of bacteria or their products.

Other changes also take place after birth that may influence the outcome of an infection. The stomach gradually becomes more acidic over the first 24hrs of life and may prevent E.coli reaching the intestine in large numbers. The blood supply to the liver also changes soon after birth (Zink and Petten 1980) with the closure of the ductus venosus,which allows blood in the umbilical vein to bypass the liver in the foetus. Once this has occurred blood from the intestine must go through the liver, via the portal vein, before reaching the general circulation. The liver acts as a vital defence organ removing toxic substances that are absorbed from the intestine. Any delay in the closure of the ductus venosus, which would allow blood in the portal vein to bypass the liver, may well affect the lambs ability to resist disease.

FURTHER WORK

In the gnotobiotic model of watery mouth a bacteraemia develops early in the course of the disease and is always present but a bacteraemia can also be demonstrated in lambs not exhibiting clinical signs of watery mouth. In earlier studies of field cases of watery mouth although 90% of lambs were bacteraemic just prior to necropsy only 38% were bacteraemic at an earlier stage of the condition. (Eales et al 1986) It appears that while bacteria do play a major role in the pathogenesis of the condition the bacteraemia is a secondary event and not the cause of the clinical signs or death of the animal. Closer study, using the gnotobiotic model, of the biochemical and haematological changes that occur in watery mouth suggest that endotoxins may be involved in the pathogenesis. Work is continuing to test this hypothesis.

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SHEEP AND GOAT HEALTH SCHEMES : THE MINISTRY APPROACH

M. W. H. PRETTEJOHN*

The phrase 'Flock Health Scheme' suggests a planned programme of management to ensure optimum health status of the flock. Every educated, conscientious flock master will be carrying out such a plan, either deliberately or in the course of general management. However, the perception of optimum health status will vary from flock master to flock master depending upon many variables. Included in these will be individual flock management, potential health risks, advice available and advice given, cost benefit analysis, statutory obligations and peer-group pressures. Ideally, decisions based on these variables will result in an individually tailored Health Scheme completely appropriate to the circumstances of that particular flock. However, variables being what they are, the probability is that a number of compromises will be involved resulting in the adoption of a more generalised Scheme applicable to comparable flocks. This development of a bespoke flock Health Scheme may be considered the "bottom up" approach and will be initiated by the flock master.

The natural corollary to this is the Flock Health Scheme evolved through a "top down" approach, where common denominators throughout the industry are used to develop a Scheme applicable to the greatest possible number of flocks. In designing such a Health Scheme cognisance needs to be taken of the requirements of the sheep industry as a whole, of public health responsibilities with regard to zoonoses, of the barriers to international trade created by disease problems and the possible need to include statutory enforcement of notifiable disease. The initiator of such a Health Scheme is likely to be either the leaders of the industry, and I include here leaders of the veterinary profession, or the Government.

In an ideal world a Flock Health Scheme initiated on a "top down" basis would fulfill all the requirements of all individual flock masters. However, in practical terms such a comprehensive Scheme would be unwieldy to operate and too expensive and the evolved compromise is a combination of individual and national Schemes. In the United Kingdom every sheep holding in the country operates such a combination, in that the individual farmer will be taking steps, possibly even unconsciously, to protect the health of his stock and at the same time, under the current regulations, he is required to participate in the control of one notifiable disease, Sheep Scab, under statutory regulation. The concept of a two-ended approach to flock health is therefore not novel.

ESTABLISHING THE REQUIREMENTS OF A FLOCK HEALTH SCHEME

In deciding what health measures to take, the flock master will be seeking to protect his animals from disease transmitted one to the other within the flock, from disease acquired from the environment, and from

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disease acquired from outside the flock. His aim, apart from general welfare of the flock, will be to increase productivity within the flock but his overall objective will be to maximise economic returns and included in this will be income generated from sale of sheep to other farmers. The higher the health status of these sheep and the fewer the problems created for the purchaser, the more likely that a repeat sale will occur with the chance for the vendor to require a premium for such health status (although market forces of supply and demand will be the ultimate arbiter). The export of high health status animals is another attractive outlet for generating above average economic returns. The arbiter in this case will be the veterinary conditions laid down by the importing country, to protect the integrity of its own health status. In some cases it may not be possible to fulfill these conditions despite economic pressures from both importer and exporter.

He (the flock master) will, in a series of decisions, consider each disease entity, assess the risk, quantify the cost of prevention and take action accordingly. Thus, for example, he will consider clostridial diseases as a group entity, quantify the cost of control by vaccination as being minimal compared with the possible loss of even one sheep and incorporate a vaccination programme into his general management. By contrast, control of endoparasites will be achieved by a judicious combination of grazing management and worm dosing based on accepted scientific knowledge and acquired experience since it is difficult for the individual flock master to quantify the potential economic loss from failure to take action in whole or in part.

Within the flock therefore it is fairly easy to evolve a programme capable of handling disease risks as they are known to exist. The difficulty lies in deciding what control measures need to be taken to avoid risk of disease acquired from outside the flock. To maximise health status there should be barriers in space and/or time between the resident flock and all outside sheep. The nature and importance of these barriers will vary from disease to disease, but the major breach of these barriers, whatever the disease, will be through the need to operate a breeding replacement policy. The two extreme situations will be the flock which is almost self-contained, buying in the occasional male replacement, to the other end of the spectrum where a flying flock is operated and everything is bought in and sold out again within a 12 month period or less.

It is in the context of this replacement need that a national flock health policy can best operate in attempting to establish a pool of recognised health status sheep that can be drawn on for replacement purposes. This in fact is the aim of the Sheep and Goat Health Scheme.

PRACTICAL AND TECHNICAL CONSTRAINTS

As indicated earlier, the choice of disease controls to be incorporated in a national Health Scheme will be determined to a large extent by the needs of the industry. However, certain practical and technical constraints may well mean that the Scheme cannot, in the present state of knowledge, be applied as vigorously or as comprehensively as would be desirable. If one considers the ultimate objective to be to move from a state of 'disease-endemic' to 'disease-eradicated' then the practical end point may well fall short of the objective. Firstly, only by making a Health Scheme compulsory and enforceable can eradication be achieved. This involves high resource input and low return particularly in the terminal stages of eradication. Such resource use may not be justified or available. This will bring the end point back to a stage where only some degree of control is achieved. By splitting the population into two parts it may be possible to achieve eradication in one part and some or no degree of control in the other. This splitting can be achieved by closure and self quarantine within a flock which is the basis of voluntary health control. This process can only be effective if there is uniformity throughout the country and needs to be operated and policed nationally.

Selection of diseases in which to operate this regime will be primarily determined by being those of national incidence which are considered to be of greatest importance and in which the flock master by himself is not able to exert effective control. However, these criteria may be negated if the nature of the disease is such that separation of affected and non-affected populations cannot be achieved. The principle of separation is dependent on first identifying the affected animals. However, not only must the affected animals be identified but they must also be identified before they can transmit the disease. One is therefore aiming to identify animals that are infected before they become clinically or sub-clinically affected. Ideally this means only tackling those diseases where there is a test in the live animal before clinical symptoms become apparent and before there is risk of spread; and one must bear in mind that spread may be hereditary and/or congenital in some diseases. One other factor which could affect the selection of disease is the possibility of its existing in a co-habiting population, possibly in wildlife, which would make control difficult and eradication impossible.

Any one individual will have his own view as to the most important diseases affecting the industry but there will not be many who would not include the following in their list: Pasteurellosis, Foot Rot, Orf, Endoparasitism, Abortion and Sheep Scab. In certain areas of the country and within certain breeds two other diseases would feature, Scrapie and Jaagsiekte. These are diseases in which the individual concerned will have had some involvement although not necessarily experience. One other disease which may be mentioned in the sheep industry is Maedi-Visna, although lack of experience or knowledge of the disease will tend to preclude it from most people's minds.

The first 4 on the list, Pasteurellosis, Foot Rot, Orf and Endoparasitism may all be considered as environmental diseases in that they exist, or spend part of their life cycle, outside the host in the environment and although it may be possible to create an environment and control programme to minimise the effect of these diseases on an individual holding it is neither practical nor possible to establish a national programme.

Sheep Scab is a disease for which, at present, there is no test in the live animal prior to it becoming highly infective to other sheep. Furthermore, because of its highly contagious nature it has been necessary to place it in the Notifiable Disease category and exert full statutory control.

Abortion is too much of a catch-all and needs to be broken down into causes and incidence. Currently, the two principle causes of abortion in sheep in this country are enzootic abortion caused by Chlamydia psittaci and Toxoplasmosis caused by Toxoplasma gondii. Between them they account for about 40% of all cases of abortion examined in the Veterinary Investigation Service in roughly equal proportions depending on location. Bearing in mind that 50% of such investigations go undiagnosed through lack of sufficient or suitable investigative material and that the remaining 10% comprising a variety of organisms, it would appear that if abortion is a major concern of the industry, these two causes should be tackled. Toxoplasmosis has a complex life cycle which involves passage through a feline host, it is also a ubiquitous organism where there is a cat population. It does have the advantage that a primary infection generates a life long immunity. If infection can be achieved in the non-pregnant state this immunity can be created. There is not at present a vaccine but research is expected to produce one in the not too distant future.

By contrast Enzootic Abortion, although caused by the equally ubiquitous organism Chlamydia psittaci, does appear to be only associated with a series of ovine strains. Chlamydia psittaci causes a variety of diseases in other species, both avian and mammalian, but those strains causing ovine abortion do not appear to be carried as a reservoir by other species. The ovine abortion strains however can cause human illness and abortion and therefore constitute a zoonotic threat. A serological test exists for the disease but the animal may well sero-convert between time of infection at one parturient period and abortion at the next, so that it is positive at time of infection and abortion but goes through a sero-negative phase in between. Actual time of testing is therefore critical in relation to lambing. Because the disease carries over from one parturient period to the next pregnancy, the actual eradication of the disease presents problems in deciding culling programmes when sero-positives are detected. Further complications are caused by non-ovine abortion strains of the organism and vaccinal strains both producing sero-positive reactions which at present are indistinguishable from the sero reactions of infected animals.

Scrapie is a progressive fatal disease of the nervous system for which the etiology has still not be fully worked out and in which the knowledge of its epidemology is in an even more parlous state. It appears to have an infective component and an hereditary component. There is no test for the disease in the live animal. The morbidity in the flock is normally quite low, and it appears it can exist in a flock without manifesting any symptoms. Only when animals are transferred to another environment does it become apparent. As a disease for which conventional methods and needs for control could operate it would appear to have low priority. Nonetheless it is the greatest inhibiting factor in the exporting of stock to the major sheep keeping areas of the world since most importing countries put an embargo on any sheep with the slightest possible risk of the disease.

Jaagsiekte is another progressive fatal disease, this time of the lungs. Again there is no cure or test in the live animal. In certain areas of the country the incidence is quite high, in others it is virtually unknown, but with the large scale movements of sheep which take place every year there are increasing reports of it from all parts of the country. Its real significance lies in the frequency of association with Maedi Visna and the need for differential diagnosis and assessment of combined infections.

Maedi Visna is a classic 'fear of the unknown' disease. It is another progressive fatal disease for which there is no treatment. Being caused by a lentivirus it may take many years to develop in an individual before clinical symptoms become apparent. During that time the animal is infectious to others and there may be an infection level of 50% in a group before the first animal shows clinical signs. Because it is a comparative newcomer as a disease entity to the United Kingdom and because of the long incubation period, awareness of the threat poised is not great. From countries where the disease has been a major problem, notably Iceland and Holland, the overriding conclusion is the importance of avoiding the 'too little - too late' policy. Pedigree breeders in particular have appreciated the need to set up a control programme at an early stage. Because of this a voluntary Maedi Visna Accreditation Scheme was in being before the concept of a chargeable national Sheep Health Scheme was mooted. As a controllable disease, Maedi Visna has many of the characteristics previously outlined for ease of operation. There is a serological test in the live animal, which becomes positive a long time before clinical signs show, although not necessarily before the animal is infective. There is no known reservoir outside the ovine population. It is possible to maintain a 'disease eradicated' population within the national flock without unduly burdensome movement controls. There is sufficient interest and enthusiasm among the innovative and progressive sectors of the sheep industry, notably the pedigree breeders, to make it a foundation stone on which a more comprehensive health programme can be built.

THE OBJECTIVES AND OPERATION OF THE MINISTRY HEALTH SCHEME

As already outlined, the aim of the Sheep and Goat Health Scheme is to provide for a pool of sheep flocks and goat herds of recognised status. There are two categories of membership. Category I members are required to achieve and maintain Maedi Visna Accredited status. They can also benefit from additional monitoring services for Enzootic Abortion, Scrapie and Jaagsiekte. Category II members may use the Enzootic Abortion monitoring service only. The Scheme is operated by the State Veterinary Service with administrative support from the Departments of Agriculture. The Veterinary staff coordinating the Scheme are drawn from a group of trained officers, both field and laboratory based. Close collaboration is maintained with the member's private veterinary adviser.

A central non-executive advisory group has been established with members drawn from Departments, representative organisations, farmers and their respective veterinary advisers. This group of 10-12 persons meets periodically, maintains continuing informal links with, and gives advice to, the Departments on day-to-day matters, future developments and likely requirements of the industry. Based on the advice of this group the Sheep Health Scheme took the existing Maedi Visna Accreditation Scheme as a basis and added monitoring of those diseases which were considered of greatest relevance, namely Enzootic Abortion, Scrapie and Jaagsiekte. Because of the problems already outlined it was decided that an Accreditation Scheme for any of these 3 diseases was not possible at present. Until such time as tests are available in the live animal adequate control of Scrapie or Jaagsiekte is unlikely. However, the longer the period of flock freedom from the disease, particularly Scrapie, the greater the validity of any certification of such freedom and the more acceptable to importing countries the animals are likely to be. It is on this basis that detailed monitoring of flock records, movements, deaths and culls are undertaken with, in the case of Jaagsiekte, additional inspection of lungs post-mortem.

Enzootic Abortion monitoring is based on post-parturient blood testing of a statistical sample calculated to detect with 95% confidence a 2% reactor level. Background levels of non-specific chlamydial infections can confuse the results so that in some cases interpretation needs to be done on field knowledge of the flock as well as laboratory test results. No movement controls are enforced on the flock other than those necessary to ensure that stock sold from the flock as being from monitored status stock are so i.e. movements on between test and sale are not permitted unless monitored status is forfeited.

Maedi Visna Accreditation still forms the basis for the majority of the Scheme membership and it is heartening to realise how seriously the pedigree side of the industry takes the threat of this disease.
Because of the long latent period for the disease to develop it requires confidence to make the decision to take preventive measures so far ahead.

The signs are that in the commercial, non-accredited flocks the disease is beginning to appear, in some cases in association with Jaagsiekte. Husbandry methods in this country have so far been unfavourable for the widespread dissemination of the disease, but with the increased use of winter housing there is no predicting the future disease pattern. If it does develop into the epidemic proportions that have occurred in other countries the health base of the sheep industry could well be dependent on the Sheep Health Scheme.

The Sheep Health Scheme is not perfect. It is based on disease control patterns which one would not necessarily choose. However, it is a useful basis for future development, giving the opportunity to incorporate new techniques as research evolves, particularly in diagnostic methods. It is sufficiently open-ended to respond to the needs of the industry as represented by the advisory group and it offers the chance to coordinate flock health control and preventive medicine on a national scale never before envisaged.

OPEN SESSION

ESTIMATING ANIMAL DISEASE PREVALENCE USING MULTISTAGE SAMPLING DESIGNS

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Frequently a veterinary epidemiologist or researcher would be interested in estimating the proportion of infected cows as well as the proportion of infected herds in a given geographical region. This leads to the situation where s/he needs to sample herds and then record the given responses for animals within selected herds. In many cases it would not be attractive to herd managers or research staff to be required to sample all the animals in the selected herds, such as bleeding all animals. As an alternative one could employ a two-stage sampling design in which a subsample of the animals in the sampled herds would be selected using some random process. The two-stage designs that would need to be used would have to take into account the fact that the number of animals is variable among herds. The theory of multistage sampling designs may be found in several books on sampling theory (Cochran, 1977; Jessen, 1978; Murthy, 1968; Raj, 1968; Raj, 1972; Yamane, 1967).

In this paper I would like to report on what we have found in terms of the applicability of multistage sampling designs in animal disease prevalence surveys.

METHODS

Perhaps the most intuitive two-stage sampling design is that in which n herds are selected with simple random sampling without replacement and then for the herds selected, animals are subsampled to be tested, bled, etc., using simple random sampling without replacement. This sampling design is designated henceforth as WORWOR indicating two stages of sampling in which units at both stages are selected <u>w</u>ith <u>o</u>ut <u>r</u>eplacement. From a practical point of view it should be possible to select herds by simple random sampling as the selection can be made from lists of herds well in advance of any field work. It may not be as practical to subsample animals from the selected herds by simple random sampling particularly in cases where lists of animals from the selected herds can not be obtained prior to the day the response of interest is to be recorded. In such cases, if it seems reasonable to assume that here is no ordering of the animals in the barn, or in the queue to be milked and no periodicity, then the animals in the selected herd could be subsampled using systematic sampling using the sample size determined in

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assuming simple random sampling. In those cases where moderate ordering is suspected, Scheaffer et al. (1986) suggest using a modified systematic sampling approach in which the starting point is changed from time to time in the selection process.

The parameter to be estimated in the disease prevalence survey is P, the proportion of animals in the population that are positive for the presence of a particular micro-organism.

$$P = \frac{\Sigma M_i P_i}{\Sigma M_i}, \ i=1,N,$$

where M_i = the total number of animals in the ith herd,
and P_i = the proportion of animals in the ith herd that are positive for the presence of a particular micro-organism.

(Σ indicates summation over the herds indexed by i which in this case goes from 1 to N, the total number of herds in the population.)

The unbiased estimate of P based on a two-stage sampling design in which both herds and animals within herds are selected by simple random sampling without replacement is

$$p = \frac{1}{M'n} \Sigma M_i p_i, \ i=1,n,$$

where n = the total number of herds sampled,
M' = the mean number of animals per herd in the population,
p_i = is the estimate of the proportion of animals in the ith herd that are positive for the presence of a particular micro-organism obtained by dividing the number of animals found positive in the subsample from the ith herd by m_i, the total number of animals subsampled from the ith sampled herd.

The variance of the sampling distribution of p is

$$V(p) = (1-f)\frac{N\sigma_b^2}{(N-1)n} + \frac{1}{nN}\Sigma\frac{M_i^2}{M'^2}(1-f_i)\frac{M_i\sigma_{wi}^2}{(M_i-1)m_i}, \ i=1,N,$$

where f = n/N, the proportion of herds in the population sampled,
$f_i = m_i/M_i$, the proportion of animals subsampled from the ith sampled herd,

$$\sigma_b^2 = \frac{1}{N}\Sigma\left(\frac{M_i P_i}{M'} - P\right)^2$$ is the among herd variance in the herd prevalence,

and $\sigma_{wi}^2 = P_i(1 - P_i)$ is the variance within the ith herd of the variable describing animal infection status.

An unbiased estimator of V(p) is:

$$v(p) = (1-f)\frac{s_b^2}{n} + \frac{1}{nN}\Sigma\frac{M_i^2}{M'^2}(1 - f_i)\frac{s_{wi}^2}{m_i}, \ i=1,n,$$

where $s_b^2 = \frac{1}{n-1}\Sigma(\frac{M_i p_i}{M'} - p)^2$, and

$$s_{wi}^2 = m_i p_i(1 - p_i)/(m_i - 1).$$

We were interested in determining the sample size requirements, i.e., the number of herds that would need to be sampled and the number of animals that would need to be subsampled from a selected herd, for a two-stage sampling design. These sample size requirements would indicate whether or not the two-stage sampling design offered any advantage over simple cluster sampling, the approach of selecting herds with simple random sampling and then recording the response on all animals in the selected herd. To this end it was decided to determine the sample size requirements for estimating the prevalence, P, of a population so that the estimate, p, would have the minimum standard deviation for a survey with a fixed cost. Sample size determinations were made using the approach found in Murthy (1967). The basis for this method is that the variance of the sampling distribution of the unbiased estimator can be expressed in the form of the sum of 2 variance components and a constant

$$V(p) = A_1/n + A_2/nm + A_3$$

where A_1 = the coefficient of $1/n$,
A_2 = the coefficient of $1/mn$,
A_3 = a constant term,
n = the number of selected herds, and
m = the mean number of animals subsampled from the selected herds.

It should be noted that A_1, A_2, and A_3 are functions of the population parameters and are independent of the sample sizes n and m; A_1 and A_2 are commonly referred to as coefficients of the variance components. It can be shown with some algebra after assuming that $m_i/m = M_i/M'$ (with m = the mean number of animals to be subsampled from the total number of herds sampled) that

$$A_1 = \frac{1}{N}\Sigma(\frac{M_i P_i}{M'} - P)^2 - \frac{1}{N}\Sigma(\frac{M_i}{M'})^2\frac{P_i(1 - P_i)}{(M_i - 1)},\ i=1,N,$$

$$A_2 = \frac{1}{N}\Sigma(\frac{M_i}{M'})^2\frac{P_i(1 - P_i)M'}{(M_i - 1)},\ i=1,N, \text{ and}$$

$$A_3 = \frac{1}{N(N-1)}\Sigma(\frac{M_i P_i}{M'} - P)^2,\ i=1,N.$$

Once these coefficients have been determined, it is possible to determine the optimum values of n and m which minimize the variance of the estimator for a fixed cost of a survey. The cost function that is usually assumed due to its simplicity and was assumed in the present study was

$$C = C_0 + nC_1 + nmC_2$$

where C = the total cost of the survey,
C_0 = survey overhead,

C_1 = cost per herd sampled, and
C_2 = cost per animal subsampled.

Assuming C fixed, $n = (C-C_0)/(C_1+mC_2)$. Substitution of n into V(p) above (in terms of A_1, A_2, and A_3) followed by some algebra yields

$$V(p) = \frac{C_1A_1}{(C-C_0)}\left[\left(m\frac{C_2}{C_1} + \frac{A_2}{mA_1}\right) + \left(1 + \frac{C_2A_2}{C_1A_1}\right)\right] + A_3.$$

Taking the partial derivative with respect to m and solving for m yields $m = (C_1A_2/C_2A_1)^{\frac{1}{2}}$. Subsequently, n and V(p) are found to be

$$n = (C-C_0)\frac{(A_1/C_1)^{\frac{1}{2}}}{(A_1C_1)^{\frac{1}{2}} + (A_2C_2)^{\frac{1}{2}}}, \text{ and}$$

$$V(p) = \frac{1}{(C-C_0)}[(A_1C_1)^{\frac{1}{2}} + (A_2C_2)^{\frac{1}{2}}]^2 + A_3.$$

These were the equations used to compute the sample size requirements to estimate P and the variance of the sampling distribution of the estimator.

Sample size determinations were made for estimating the population prevalence in dairy cattle of 4 mastitis pathogens: <u>Streptococcus agalactiae</u>, <u>Streptococcus dysgalactiae</u>, <u>Streptococcus uberis</u> and <u>Staphylococcus aureus</u>. The necessary parameters were based to a large extent on information provided by the Central Veterinary Laboratory, Weybridge, England, relating to the 1977 British National Mastitis Survey (Wilson and Richards, 1980; Wilson, et al., 1982). I would like to acknowledge the assistance of Dr. John Wilesmith in making the data available. 501 dairy herds were surveyed for the presence of various mastitis pathogens. Of these 501 herds, 408 had 100 or fewer cows and it was decided for these herds that all cows in-milk would be tested. The mean number of cows in-milk for these 408 herds was 46.6. I decided that the prevalence information for these 408 herds would provide realistic choices of the coefficients A_1, A_2 and A_3 and so what I report today relates to these 408 smaller herds. Additionally the survey report provided costs associated with the survey. The cost of sampling a herd was given as £45.86 per herd sampled and the subsampling cost was given as £0.743 per cow in-milk subsampled. Thus for the present investigation C_1 was set equal to £45.86 and C_2 was set equal to £0.743. Survey overhead was assumed to be negligible and thus C_0 was set equal to zero. The total cost of the survey was assumed to be £32,857 (C) based on 408 herds sampled with a mean number of cows in-milk of 46.6. Given A_1, A_2, A_3, C_1, C_2 and C, n and m could be found along with the variance of the sampling distribution of p.

RESULTS AND DISCUSSION

Table 1 gives for each of the 4 mastitis pathogens considered, the values of the coefficients of the variance components A_1, A_2 and A_3 for the two-stage sampling design WORWOR based on the information available from the 408 smaller herds surveyed in the 1977 British National Mastitis Survey. These coefficients are difficult to relate to so we won't spend much time

Table 1. Coefficients of the variance components of the estimator of the prevalence of 4 mastitis pathogens using the WORWOR[a] two-stage sampling design. Coefficients are based on information from the 408 smaller dairy herds in the 1977 British National Mastitis Survey.

Pathogen (Prevalence)	A_1	A_2	A_3
Streptococcus agalactiae (8.52%)	.0274	.0556	-.0000701
Streptococcus dysgalactiae (3.86%)	.0020	.0351	-.0000066
Streptococcus uberis (4.63%)	.0020	.0425	-.0000072
Staphylococcus aureus (21.42%)	.0376	.1435	-.0000996

[a]Both herds and cows in-milk selected without replacement.

considering this table. I just want to say that these coefficients did not change appreciably when the information from the 93 larger herds was included although I am not prepared to say that they would not change given more information from larger herds.

Table 2 shows that for all 4 pathogens considered, the required number of herds to be sampled, n, exceeds the total number of smaller herds (408) which were sampled in the survey and the mean number of cows in-milk required to be subsampled is lower than the mean of 46.6 cows in-milk in the 408 herds. Table 2 shows that the standard deviation of p for the pathogens S. dysgalactiae and uberis is lower than .6% given as the bench mark in the survey report while that for the pathogens S. agalactiae and S. aureus is higher than the bench mark. The table also shows a substantial difference between the sample size requirements for S. dysgalactiae and uberis on one hand and for S. agalactiae and S. aureus on the other hand. To understand the reason for this difference one needs to look at the prevalence profiles of the pathogens. This is shown in Table 3 which gives for each pathogen the herd prevalence and the distribution of the prevalence for the infected herds. In the case of S. aureus, the pathogen was found in 92.2% of the 408 small herds sampled but the prevalence varied considerably across herds. The range of the herd prevalence for the infected herds was 1.0-94.7%, with the first and third quartiles being 11.5 and 33.3%, respectively. The

Table 2. Sample size requirements for estimating the prevalence of 4 mastitis pathogens in a population of dairy herds using the WORWOR[a] two-stage sampling design and the resulting standard deviations of the estimated prevalence.

Pathogen (Prevalence)	n	m	SQRT(V(p))
Streptococcus agalactiae (8.52%)	607	12	.73%
Streptococcus dysgalactiae (3.86%)	466	34	.25%
Streptococcus uberis (4.63%)	453	37	.27%
Staphylococcus aureus (21.42%)	574	16	.90%

[a]Both herds and cows in-milk selected without replacement.

Table 3. Herd prevalence of 4 mastitis pathogens in 408 smaller herd surveyed in the 1977 British National Mastitis Survey; distribution of the prevalence in the infected herds.

		Distribution of the Prevalence in the Infected Herds		
Pathogen	Herd Prevalence	Range	First Quartile	Third Quartile
S. agalactiae	41.9%	1.0%-89.5%	7.1 %	31.1%
S. dysgalactiae	60.5%	1.0%-46.4%	2.8%	10.2%
S. uberis	71.3%	1.0%-50.0%	3.1%	8.8%
S. aureus	92.2%	1.0%-94.7%	11.5%	33.3%

variability in the prevalence of this pathogen among the 408 herds being large makes the first component of the variance of the sampling distribution of p large. Increasing n is the only way to minimize the impact of this large among herd variability in the prevalence to achieve the goal of a small variance of the sampling distribution of p. In contrast, the herd prevalence of S. agalactiae for the 408 smaller herds was only 41.9%, the lowest herd prevalence for the 4 pathogens. Clearly the herds in this population were more dichotomous in their herd infection status with respect to S. agalactiae. There was additionally a large amount of variability among the herds infected with S. agalactiae in the level of the prevalence (see Table 3). This dichotomy and the large variability among infected herds in the prevalence of S. agalactiae both contribute to the large among herd variability in the prevalence thereby necessitating that n be increased to minimize its impact on the first component of the variance of the sampling distribution of p.

Although the 408 smaller herds were also dichotomous in their herd infection status with respect to S. dysgalactiae and uberis, the prevalence of these pathogens in the infected herds was much closer to zero than noted for S. agalactiae (see Table 3). The among herd variability in the prevalence for these pathogens is relatively smaller than that noted for S. agalactiae resulting in a smaller herd sample size requirement. Instead, because the prevalence for these pathogens is so low in any given infected herd, more cows in-milk need to be subsampled in a selected herd to determine whether a given herd is clean or infected with the pathogen. So in determining whether one needs to sample more herds or to subsample more animals in a selected herd depends on the prevalence profile of the herd for the pathogen in question.

An inspection of the survey reports of the 1977 British National Mastitis Survey indicates a good effort was made to utilize sampling theory to arrive at the final sample size requirements of the survey. The decision to sample all cows in-milk in the 408 smaller herds was based on cost; no significant saving in the cost of the survey was judged possible by examining a subsample of the herd instead of sampling the entire herd. If one is attempting to estimate the prevalence of the 4 pathogens considered in the present investigation in a single survey, one probably would follow the nearly conventional procedure of using the larger subsample size requirement. In the present case this would suggest that a mean of 37 cows in-milk per selected herd would need to be subsampled although this subsample size requirement is much larger than needed to estimate the prevalence of S. agalactiae and S. aureus. Since there is only a mean total of 46.6 cows in-milk per herd in this population anyway, it would be easy to decide to subsample all animals in the selected herds since by doing so there would be no significant impact on the total cost of the survey. This then is no longer a two-stage sampling design but rather is simple cluster sampling. There are other pros and cons for subsampling all animals.

I decided to see what would happen if one were to take the opposite approach. This approach would be a two-stage sampling design in which more herds would be selected but the minimum number of animals would be subsampled from the selected herds. Table 4 gives the details of this sampling design. I assumed the two-stage sampling design WORWOR in which 610 herds are to be selected with a mean of 11 cows in-milk to be subsampled in the selected herds. This design was to be compared with the simple cluster sampling design which was used. Table 4 shows that the total costs for the 2 surveys were about the same. The big difference is the total number of animals that need to be subsampled. With simple cluster sampling 19,013 cows in-milk would need to be subsampled whereas with the two-stage sampling design only 6710 cows in-milk need to be subsampled. When one looks at the standard deviations of p, one notices that with the two-stage design, the standard

Table 4. Standard deviations of estimates of the prevalence of 4 mastitis pathogens in a large[a] population of dairy herds using 2 sampling designs having divergent sample size requirements but the same survey cost.

	Sampling Design	
	Two-stage WORWOR[b]	Simple Cluster
Number of herds sampled	610	408
Mean number of cows in-milk subsampled in sampled herds	11.0	46.6
Total number of cows in-milk sampled	6,710	19,013
Survey cost[c]	£32,960	£32,837
	Standard Deviation of Estimated Prevalence[d]	
Streptococcus agalactiae	.73%	.84%
Streptococcus dysgalactiae	.29%	.26%
Streptococcus uberis	.31%	.27%
Staphylococcus aureus	.91%	1.00%

[a]The population size is assumed to be sufficiently large so that n/N tends to zero.
[b]Both herds and cows in-milk selected without replacement.
[c]Assuming a herd sampling cost of £45.86 per herd sampled and a subsample cost of £0.743 per cow in-milk subsampled.
[d]Based on the coefficients of the variance components in Table 1.

deviations for S. dysgalactiae and uberis were larger than those obtained using the simple cluster design but the difference was very small especially in light of the large difference in subsampling size; the standard deviations were still well below the 0.6% bench mark. On the other hand the standard deviations for the pathogens S. agalactiae and S. aureus obtained by the two-stage sampling design were approximatley one-tenth of a percentage point lower than those obtained with simple cluster sampling. It's clear that the two-stage sampling design came closer than the simple cluster sampling design in meeting a survey goal of estimating the national prevalences of the 4 pathogens in one survey with the standard deviations at or below 0.6%.

It is quite obvious that there is a need to modify the existing probability based sampling designs to increase their efficiency and hence their applicability. A sample size of between 450 and 600 herds in a prevalence survey is too large to make it practically possible for the veterinary epidemiologist to conduct prevalence surveys often enough to adequately monitor the disease status of the animal population. Such monitoring of animal populations is necessary for the epidemiologist to fulfill the anticipatory role of modern epidemiology. For example, sample sizes of more than 80 herds are considered not feasible in the National Animal Health Monitoring System of the United States because of financial constraints. Also while a sample size of 450 to 600 herds may be adequate to obtain a precise global estimate of the prevalence, it would still not be adequate for providing precise parameter estimates of some subpopulations.

The recent media exposure of the results of the 1982-84 United States National Survey (Green, 1987) of salmonella in whole broilers and overflow chill tank water highlights the need here. The incidence of Salmonellae in whole broilers that was reported was based on the examination of roughly 3 whole broilers from each of 573 processing plants or a total of 1719 whole broilers. I am not here and refute their estimate of the incidence (35.2% positive) in whole broilers. With that number of birds examined the estimate no doubt is close to the actual incidence. What they have demonstrated very nicely is that in estimating the national incidence with a two-stage sampling design (here they sampled processing plants and subsampled whole birds from the sampled plants), resources need to be allocated so that one can sample as many primary units (plants) as possible. My research has demonstrated that one can get by with subsampling a very small number of secondary units. This is due to the fact that the variability among primary units is usually larger than the variability within primary units and because the variability among primary units expresses itself in both components of the variance of the incidence while the variability among secondary units expresses itself only in one component. There are 2 problems: 1. Not all that need to do surveys of this type are as affluent as the federal government and thus would not have resources to sample the required number of primary units. Primary units are more costly to sample because there usually are travel costs incurred going from one primary site to another. 2. The subsample sizes required to obtain a precise estimate of the global incidence are grossly inadequate to provide a small area estimate of the incidence such as the plant-specific incidences. After the release of the survey results, individual plants were interested in determining their plant-specific incidence. I quickly informed them that it was not possible to obtain a precise estimate on the basis of an examination of 3 whole birds. So we need to modify our methods so that we can have our cake and eat it too. The challenge here is to find a sampling design which will lower the primary sample size requirement so populations can be monitored at all levels and not just at the federal level and yet provide a subsample size requirement that is both large enough to produce small area estimates that are precise enough and small enough to minimize the labor intensive attributes of subsampling.

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A CASE CONTROL STUDY OF ENVIRONMENTAL AND MANAGERIAL FACTORS IN RELATION TO BOVINE MASTITIS

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The aim of the present project is to develop a causal model for bovine subclinical mastitis at the herd level. The model is, within certain limits, intended to predict the effect of interventions on the level of mastitis in the dairy herd. However, the aim of this paper is to present an approach to study the causal complex of bovine mastitis.

The general hypothesis is that bovine mastitis is initiated by a microbial infection through the teat canal and that a number of factors affect the risk of teat lesions and influence the population of microorganisms on the cow and in the environment and thus impact on the risk of mastitis.

The influence of environmental and managerial factors on bovine mastitis have been studied for years and much knowledge has been accumulated in the literature as reviewed (Klastrup et al., 1987) and is also applied in mastitis control programs around the world (Anon., 1985). However, more precise information on the etiology, and on the interactions of indirect causes of mastitis, is needed. Specifically more information is needed on what is a necessary cause, and what comprises a sufficient cause.

In relation to the evaluation of multifactorial data sets, the analytical and especially the inferential strategy is not always clear. We must decide whether we are making inductive or deductive reasoning or both (Weed, 1986). The hypotheses must be clear, so we know what we test for (deduction). If we in this way improve the quality of biological reasoning, we avoid coming up with overly complicated biological explanations as justification for the analytical results. However induction and deduction must go hand in hand in order e.g. to generate new hypotheses. The frequent problem of getting only very few statistically significant factors in a model, but many insignificant variables that show a biologically expected tendency, makes it difficult to decide, whether a certain variable is important enough to be forced into a causal model. Also the problem of inconsistency among studies tells the researcher to be very careful in drawing too specific conclusions.

It is an often overlooked fact that mastitis is a complex of several diseases in the sense that it is caused by many different microorganisms, each with its own epidemiology. The use of bulk tank somatic cell count

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(BSCC) as the response variable can only create a very general picture of the disease. Also the use of % quarters or cows with mastitis diagnosed as a combination of detected infective agents and a cellular response of the cow (CMT), can only create a very general picture of the disease. In order to get more specific information, it is necessary to use microorganism-specific diagnosis as the response variable, e.g. % quarters or cows with Staphylococcus aureus mastitis, or perhaps even more specific, % quarters or cows with Staphylococcus aureus infection. The difference between mastitis and infection is the cellular response found in the case of mastitis. The degree of cellular response is very much cow-dependent, and also depends on the pathogenicity of the microorganism. On the other hand, if the environmental conditions needed to create a microbial population does not influence the pathogenicity of the microorganisms, then the best measure of the dependent variable will be the infection, i.e. the presence or absence of the specific agent in the udder. (Pathogenicity is partially determined by microbial species, and species is probably influenced by environment.)

For the last 30 years the Danish national mastitis control program has used evaluation of information on environment and management in the recommendations given to farmers in order to reduce a mastitis problem and improve the udder health. The Danish program was initially built on a volunteer basis, but with the new regulation for mastitis control from April 1983 it has been compulsory for all Danish farms delivering milk for consumption, to participate in the national program. Selection of herds for the present study was based on the structure of this program.

MATERIAL AND METHODS

The Danish mastitis control program is based on a surveillance system using monthly estimates of bulk tank somatic cell count (BSCC), and averages of the last six and the last three monthly values are calculated quarterly. If both averages exceed 500,000 cells/ml milk, the herd is subject to further investigation by quarter milk sampling. The mastitis diagnosis at the quarter level is based on the CMT-reaction and microbiological findings and expressed as the percentage of cows with mastitis (equal to the point prevalence rate). If the prevalence of cows with mastitis exceeds 20%, the herd is visited by a technician who will check the milking machine, the environment and the management. Intervention based on the herd investigation and the laboratory results is then recommended by the regional mastitis laboratory.

A case control design was chosen for the present study which began in 1983, and is based on data from 12 dairy districts in the region of Zealand, Lolland, Falster and Moen. The study was carried out in collaboration with the State Veterinary Serumlaboratory, Ringsted, Denmark. Selection of herds was restricted to herd sizes greater than 15 and less than 100 cows, and excluded herds that had been selected as problem herds by the mastitis program during the previous 12 months. Thus the cases and controls were selected among approximately 90% of the 2533 herds in the region. Whenever a case herd (i.e. a herd with both BSCC averages >500,000 cells/ml) was identified, a control herd was selected at random among the non-cases within that dairy district, i.e. cases and controls were matched on time and district. For a few cases more than one control was selected. A total of 76 case herds and 80 control herds were selected during the first, second and third quarter of 1983.

After removal of 4 herds with loose housing systems, the sample only comprises tying stalls divided in 75 case and 77 control herds. This corresponds to about 95% of all the case herds and to about 5% of all the non-case herds in the study region for the 9 months period.

Each herd was visited once in 1983, which means that the collected information is prevalence data. In addition to the routine quarter sampling and the technical evaluation of environment and management carried out by two technicians, a personal interview with the dairy man about the management was carried out by a veterinarian. Data on environment and management thus contained current and historical information.

The environmental information covered general housing variables, and stanchion, hygienic, climatic, milking and milking machine factors. Information about the time and who of the two technicians investigated individual herds was also stored in the data files. Data on management covered herd structure; occurrence of diseases; culling procedures; working routines; feeding, and finally personal information about the dairy man and his opinion about advisers (veterinarians, agronomists and others).

Some of the information was expressed as categorical variables, and some as continuous. Information on subjective factors, eg. grading the hygienic condition of the bedding, was measured on an ordinal scale ranging from 0 to 9, and where 0 was the biological worst condition, and 9 was the best.

A mechanical reduction of the variables, e.g. by a stepwise backward elimination of variables from a full model could easily end up with significant factors even when the model would not be significant. In order to minimize such false associations, the analytical strategy was decided to consist of 2 steps: 1) The development of a conceptual model in order to reduce the number of variables on a biological basis (variable reduction).
2) In this conceptual model, the associations between the independent variables and the case control status were elucidated using single and multifactorial logistic regression (variable selection). Since two technicians participated in the project, a possible bias due to a divergence in the grading of subjective factors was also evaluated.

Among the recorded variables the present paper is concerned with the possible association between mastitis (BSCC) and hygienic factors.

RESULTS

A conceptual model for the environmental factors was developed on a biological basis. Initially it was described, how each variable was expected to be dependent on other factors, and also how the variable acted on other factors leading to mastitis. This approach led to the development of a graphical model for each of the variables, describing the expected sequence in which the indirect causes impact on each other. Within each variable group (see previously) all single variable models were arranged in one bigger model, and finally, these group-models were arranged in one big conceptual environmental model.

This procedure reduced the 282 recorded variables to about 60, either because several variables finally were realized to be "too far" from mastitis in the causal web, or because some factors after the termination of data collection were expected to act in another way than originally hypothesized. The expected positive or negative effect of the variable on the risk of mastitis was also indicated. Of these 60 remaining variables 18 contained information on the hygienic condition.

Before the real analysis was started it was decided to evaluate the possible bias in the estimated association between herd status and subjectively graded environmental factors, due to disagreement among the technicians. There was no reason to expect a difference among technicians in the recording of hard data.

The two technicians (no 1 and no 2) visited 64 and 13 control herds and 52 and 23 problem herds respectively. This means, that technician no 2 visited relative more case herds than no 1. The distribution among technicians was not consistent across the 3 quarters in which the herds were evaluated. Thus technician no 2 visited a higher percentage of case herds in the first quarter of 1983 while the technicians visited an equal number of case and control herds in the third quarter of 1983.

A crude analysis shows that technician no 1 generally gave higher grades than no 2, but this may be explained by no 1's more frequent visit to control herds. Analyses for an association between technician and the total grading of the 18 subjective factors for a given herd status and season indicated that the grading was not independent of the technician. However, these analyses assume, that the gradings are comparable across the 18 subjective variables. Therefore estimates from monofactorial logistic regression analyses for each of the two technicians were compared. The results indicated that there was no difference in the grading of any of the subjective factors for the two technicians. For that reason the interaction element between the hygienic factor and technician was removed from the model, so it only contained a constant, the hygienic factor and the interaction between the technician and season. Monofactorial logistic regression analyses turned out to be significant (α = 0.15) for only 3 variables, i.e. rubber mats in the stanchion, and dryness and slipperiness of the stanchion floor. The three factors also had the expected biological tendency. The three variables were all included in a multivariate logistic regression model. As the correlation between slipperiness and dryness was high (r = 0.79), slipperiness was removed to eliminate colliniarity. Thus the final model for the association between hygienic factors and herd status was reduced to

$$\text{Lambda}_{(i)} = \alpha + \Gamma_{(\text{rubber mats})} + \Gamma_{(\text{dryness})} + \epsilon_{(\text{technician,status})}$$

with the statistically significant odds ratios 7.3 for no rubber mats compared to rubber mats, 3.4 for a very wet stanchion compared to a very dry stanchion, and a non-significant estimate of 1.5 for a medium wet stanchion compared to a very dry stanchion. This means that rubber mats and dry litter in the stanchion occurs significantly more frequent in the control herds than in the case herds.

DISCUSSION

It should not be concluded from the results that rubber mats, litter and to a less extent slipperiness are the only specific hygienic variables of importance among the 18 recorded ones. It may rather be taken as an indication that the general condition of the stanchion floor is very important for the occurrence of mastitis. The results corresponds generally to findings by other authors as reviewed (Klastrup et al., 1987).

It is important to stress, that several of the non significant variables may still be essential indirect causes to mastitis. The only reason that they did not show up statistically significant in the analyses is that there is too little variation in these variables among the case and control herds.

However, these variables can still be manipulated by intervention, and therefore it may be relevant to force some of them into a final causal model.

Even though the results compare to other studies, many questions are still left open. The case control design has the advantage of being reasonably cheap and quick to do, but has the disadvantage of not explaining the temporal relationship very clearly. However this depends on the type of variable. In the present study one can not be sure that a wet stanchion floor and a low grade of slipperiness really preceded a high level of BSCC (cases); both because BSCC is an average estimate of the last 6 months prior to the prevalence measures of wetness and slipperiness, and because the levels of wetness and slipperiness may change from day to day. It is though a general experience, that hygienic conditions, including wetness, are rather constant within the same herd (stable). Many other environmental factors are fixed and the rubber mats may have been in the stanchion for a long time. A follow-up study would have kept better track of the temporal relationship for the hygienic factors, but it would also have exceeded the costs of the case control study.

Regardless of the study design the response variable (BSCC) can only generate a very broad picture of the disease, because it more is a measure of the dairy cows response to infection, rather than it measures whether microorganisms are introduced into the udder or not. Further analyses using microorganism-specific diagnoses may clarify the causal relationships.

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METHODS OF DATA COLLECTION AND ANALYSIS FOR CASES OF CLINICAL BOVINE MASTITIS

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Computerised recording systems for herd fertility management have been used for several years (e.g. Lucey et al., 1983; Pharo, 1983) but not to our knowledge for the monitoring of clinical mastitis. Blowey (1984) described a manual system for summarising mastitis records at 6-monthly intervals. Average values in his system are presented in the form of a league table enabling farmers to see how well they are performing in relation to others. Noordhuizen (1984) has also looked at ways of handling clinical mastitis records in Holland. During 6 years Blowey (1986) demonstrated a reduction from 52 to 32 cases of clinical mastitis per 100 cows and attributed part of this decline to increased awareness on the part of farmers of clinical mastitis levels in their herds. Blowey's study, however, was uncontrolled and the composition of herds varied during the 6 years. To ascertain in a controlled study the extent to which greater awareness of clinical mastitis levels in their own herds may stimulate farmers to improve mastitis control and thus save themselves money, a study has been undertaken in which half the herds receive computer summaries monthly, the other half do not.

The purpose of this paper is to describe the methods of presentation of computer analysis to farmers and to show how particular methods of analysis may highlight abnormal patterns of clinical mastitis.

Blowey (1986) and Wilesmith et al. (1986) have estimated the average cost of a clinical case of mastitis to be £40 and £50 respectively. Data collected in our study will enable more precise estimates to be made, and some examples are included in this paper on how such costs might be calculated.

MATERIALS AND METHODS

Herds

Forty-eight herds in Wiltshire, Somerset and Dorset were chosen from dairy herds using the Milk Marketing Board Mastitis Control Service. These were randomised into two groups of 24 taking into account herd size and number of years (0-12) that the farmer had subscribed to the service. Herd sizes range from 50 to 220 with an average of 124. All herds use teat dips and apply dry cow therapy. One group, the 'trial' group, receive a monthly computer analysis of their clinical mastitis incidence, the other group, the 'control' group, do not. Data on clinical mastitis cases are collected from all 48 herds, and all herds receive regular advice through the MMB Mastitis Control Service.

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The trial began in September 1986 and will continue until 31st August 1988. Two herds, one from each group, were sold in September 1987, leaving 23 in each group for the second year of the study.

Data recording

Each herdsman records every clinical case requiring treatment on a standard recording sheet. For each case he records both the cow and quarters affected, the severity of the case, the dates and times (i.e. a.m. or p.m.) that each intramammary syringe is administered and the name of the manufactured preparation used. For acute cases a systemic injection may also be given, and the preparation used, together with a code indicating whether this was given by the veterinary surgeon or herdsman, is recorded. To describe the severity of the condition the herdsman uses one of three codes: C for clots in the milk only, H to signify in addition hardness in the quarter and S for a sick cow. A cow which requires retreatment is recorded on a new line as if it were a new case. Calculations are included in the computer program to decide how successive treatments are to be interpreted (see definitions).

Data collection

Trial herds are visited every month between September and March, and once in May and July. Data on clinical cases occurring during the previous month(s) are entered onto magnetic tape using an Epson HX20 portable computer. The magnetic tape is then brought to the Compton Laboratory of the Institute for Animal Health for direct transfer to a VAX 11/750 computer. Dates of calving, drying off and disposal are similarly extracted from monthly MMB National Milk Record sheets and sent to Compton. At each visit to the farm the reasons for disposal of cows from the herd are collected.

Data for control herds are similarly handled, but visits to farms are at approximately three monthly intervals.

Data processing

Each month the database held on the VAX computer is updated and reports returned to the farmer and his veterinary surgeon via the Milk Marketing Board's Veterinary Laboratory at Worcester. Reports were first circulated at the end of January 1987, 5 months after the trial started, once sufficient data had been collected. The computer programs have been written using the Digital Datatrieve database software package.

Definitions

A clinical case of mastitis is defined for the purpose of this study as a case occurring in a lactating cow and diagnosed and treated by the herdsman. Suspected cases, subsequently not treated, are not included, nor are untreated cases occurring in culled cows. For the purposes of computer analysis three further definitions are used:-

(i) A case is the occurrence of clinical signs in one or more quarters affected simultaneously. Thus clots found at the same time in two quarters constitute one case.

(ii) Retreatment of the same quarter starting 7 or fewer days from the end of a previous treatment is considered to be a continuation of the same case. Thus consecutive clinical cases occurring in the same quarter are distinct if the period elapsing between the end and restarting of treatment is greater than 7 days.

(iii) A recurring case is one that occurs in a quarter previously infected more than 7 days ago in the same lactation.

RESULTS

Monthly reports

The monthly computer print-out presents (1) a clinical mastitis history for each cow, (2) a summary of clinical mastitis by month and (3) a 'league table' of mastitis cases per 100 cows showing the farmer how his herd compares with others.

(1) The first page of the print-out gives a list of all clinical cases recorded for cows treated since the first day of September. During the second year of the study, i.e. for cases occurring since 1st September 1987, details are also included of cases occurring during the first year for the cow concerned. Cows are listed in order so that those with the most recent cases occur at the foot of the table. The print-out shows for each cow its lactation number, the dates when clinical cases have occurred, the number of the case in the lactation, the stage of lactation when it occurred, the quarters affected, the severity of the infection, the number of intramammary syringes and preparation used and the number of days for which milk was discarded. This latter period is calculated using the recommended withdrawal time for the antibiotic, and where necessary, taking into account the MMB contractual requirement for a 4 day withholding period after calving.

(2) An example of the second page of the printout is shown in Fig. 1.

Month	Av. no. of cows in herd	No. of cases of mastitis	No. of cases which recurred	No. of cows affected	affected 3 or more times	Av. no. of quarters per case	No. of tubes used	Days of lost milk	Annual mean cell count
Nov 86	155	7	0			1.00	12	33.0	461
Dec 86	149	6	2			1.00	13	26.0	458
Jan 87	151	6	1			1.00	11	33.5	460
Feb 87	148	8	0			1.13	13	37.5	460
Mar 87	148	7	3			1.00	18	49.0	455
Apr 87	144	11	3			1.09	30	67.5	452
May 87	136	9	2			1.00	19	50.5	457
Jun 87	136	6	2			1.00	11	25.0	463
Jul 87	132	3	0			1.00	3	8.5	459
Aug 87	132	6	2			1.00	9	23.0	492
Sep 87	130	0	0				0	0.0	529
Oct 87	143	0	0				0	0.0	515
Nov 87	143	0	0				0	0.0	509
Annual means									
First year:	143	72	15	50	5	1.04	143	358.0	492
Last 12 months:	141	62	15	43	3	1.03	127	320.5	509
Change	-2	-10	+0	-7	-2	-0.01	-16	-37.5	+17

Fig. 1. An illustration of the computer print-out showing a summary of clinical mastitis incidence by month for herd 563 from November 1986 to November 1987.

This figure illustrates some of the columns printed. During the first year the table included only monthly values to date, but since September 1987 a 12 month rolling mean has been included. This allows the farmer to see whether he is doing better or worse than in the first year of the project. The example used for herd 563 shows that no cases were recorded between September and November 1987, and this is reflected in reductions in the annual means for all variables except mean cell count.

Group	Herd	Av. no. of cows in herd	No. of cases per 100 cows	% of cases which recurred	% of cows affected	% of cows affected 3 or more times	Av. no. of quarters per case	Tubes used	Days of lost milk	Annual mean cell count
1	271	111	5	17	5	0	1.00	25	41	311
	420	140	6	0	6	0	1.11	30	61	133
	187	120	9	0	8	0	1.00	39	63	216
	698	217	11	13	9	0	1.04	48	42	332
	307	106	13	14	11	0	1.07	49	76	194
	644	192	15	14	12	1	1.34	140	127	428
2	188	130	18	22	12	2	1.30	81	115	278
	684	85	19	0	19	0	1.00	50	65	506
	308	107	21	9	18	1	1.09	102	120	190
	690	166	23	10	20	1	1.18	159	179	257
	479	115	25	3	22	1	1.28	200	187	139
	627	68	32	9	22	3	1.09	78	114	238
3	538	198	35	13	27	2	1.04	230	346	233
	536	114	36	46	18	5	1.17	163	226	256
	537	160	38	25	26	3	1.25	246	312	243
	635	111	38	5	31	0	1.14	133	213	519
	678	120	39	32	26	2	1.17	213	261	313
	666	62	47	17	32	5	1.17	66	152	411
4	712	104	50	13	33	3	1.10	163	178	615
	563	143	50	21	35	3	1.04	143	358	492
	705	135	56	25	35	4	1.07	301	440	228
	708	51	57	21	37	2	1.03	114	179	346
	648	117	72	21	42	9	1.05	306	495	174
	699	56	102	19	70	11	1.21	333	339	169
Average		122	34	15	24	2	1.12	142	195	275

Fig. 2. An illustration of the computer print-out showing a league table of clinical mastitis incidence from 1st September 1986 to 31st August 1987. Herds are listed in order of number of cases of mastitis per 100 cows.

(3) The third page is a league table which lists the herds in order of number of cases per 100 cows (Fig. 2). This allows the farmer to see how his herd compares with other herds and whether month by month he is moving up or down the table. Figure 2, which shows the results at the end of the first year, demonstrates the wide range in incidence from 5 to 102 cases of mastitis per 100 cows and the associated variation in discarded milk among herds. Herd 563, for example, is in the bottom quartile with 50 cases per 100 cows compared with an average of 34. The herd milk cell count is higher than those of many of the others in the bottom quarter of the table.

First 12 months

Clinical incidence was unrelated to mean herd milk cell count and, ignoring one herd receiving homoeopathic treatment, led to between 37 and 605 days of discarded milk for a 100 cow herd. Mean values for trial and control groups at the end of the first year are shown in Table 1. The incidence of mastitis was highest in November to February (a median of from 3.5 to 4.5 cases/month/100 cows/herd) and lowest in May to September (averaging one case/month/100 cows/herd) (Fig. 3). A high proportion of cases occurred in early lactation (10% in the first 4 days, 23% in the first 2 weeks), but the distribution varied markedly with herd. Figure 4 contrasts the average number of cases per day occurring in 2 herds. 42% of cases in herd 699 occurred during the first 2 weeks compared with only 8% of cases in herd 563.

Table 1. Average incidence rates of clinical mastitis, numbers of syringes used and days of discarded milk between 1st September 1986 and 31st August 1987

	Trial herds (n = 24)	Control herds (n = 24)
Cases per 100 cows	34	38
Quarters per case	1.12	1.19
% of cases recurring	15	20
% of cows affected	24	25
Syringes used per 100 cows	132	144
Days of discarded milk per 100 cows	178	193

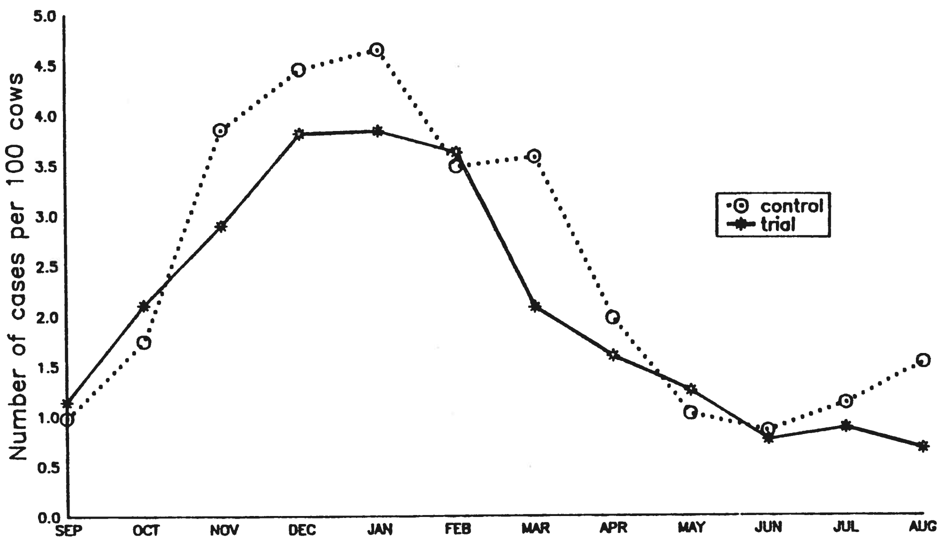

Fig. 3. The month to month variation between control and trial herds in the median numbers of cases of clinical mastitis per 100 cows per herd.

It is too early to compare mean values between control and trial herds. Although all variables showed similar trends with trial values lower than control values (Table 1) there were large month to month variations among herds as illustrated in Fig. 3. First print-outs were not received by farmers in the trial group until the end of January 1987, and so data collected up to that time were not influenced by 'treatment'. The variation between control and trial means up to January 1987 was as large as after.

Examples of possible costs incurred are shown in Tables 2 and 3 for three herds: 187 and 644 in the top quartile and 563 in the bottom quartile of Fig. 2. Table 2 gives the costs of treatment for each case together with an estimated cost based on 10% loss in milk production for the remainder of lactation for cases occurring within the first 3 weeks of lactation and 5% for cases occurring between 4 and 7 weeks. The basis for this is described later. Average costs for these 3 herds were between £28 and £38 per case (Table 2).

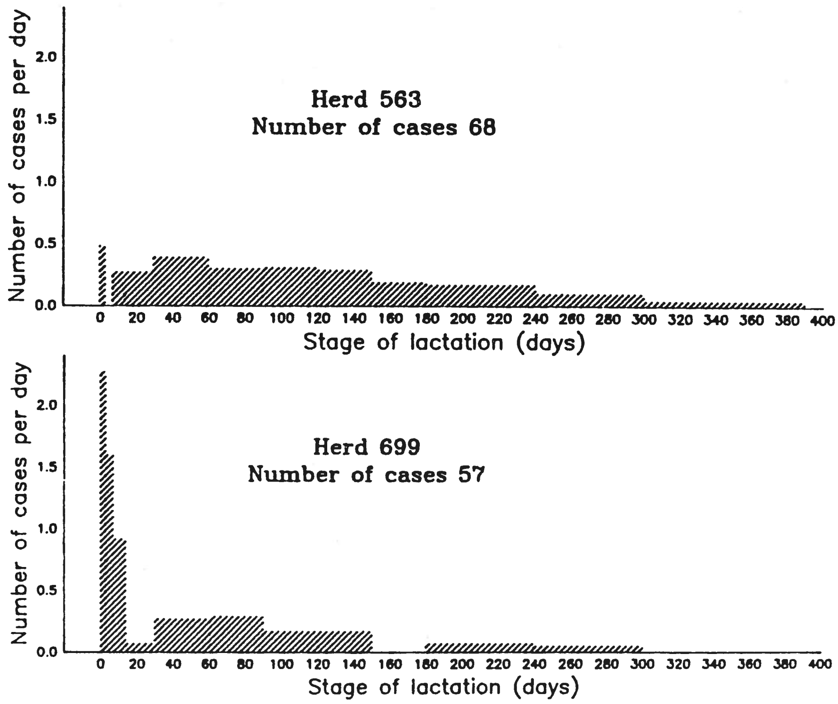

Fig. 4. A comparison between the distributions with stage of lactation of the numbers of cases of clinical mastitis occurring per day in 2 herds.

Table 2. Estimates of costs of treatment of clinical mastitis incurred by 3 herds between 1st September 1986 and 31st August 1987

	Herds					
	187 (120 cows)		644 (192 cows)		563 (144 cows)	
	Cases	Cost (£)	Cases	Cost (£)	Cases	Cost (£)
Intramammary syringes[a]	11	35	29	125	72	490
Milk discarded[b]		200		385		1120
For cases occurring before peak yield						
Loss of milk production[c]	(4)	180	(11)	420	(12)	370
Total		420		935		1980
Cost per case (£)		38		32		28
Cost per head (£)		3.5		4.9		13.8

[a] Assumes average costs of 90 p/syringe for an average 3 course recommended treatment and £3.80/syringe for an average single course treatment used. Herds 187 and 644 used recommended 3-course treatments (on average 3.5 and 4.8 syringes per case respectively) and herd 563 mainly a recommended single course treatment (on average 1.8 syringes/case).

[b] Assumes average production of 20 litres/day at 16 p/litre.

[c] Assumes a 6000 litre cow with a margin over feed profit of 8 p/litre, showing a 5-10% loss in milk yield for the remainder of lactation (see text).

It would appear that costs of clinical mastitis might be doubled when additional costs of culling due to mastitis are added (Table 3). These costs are based on an estimated loss in profit from lost milk production for cows culled whilst lactating (using a figure of 8 p/litre), death of a cow during treatment (£500), failure of a pregnant cow to produce a calf (£100) and the cost of replacement (£100-£400). In estimating this latter cost account has been taken of the age of the cow (Table 3). Of the 7 cows culled for mastitis in herd 644, for example, 6 had completed at least their fourth lactation and have been assumed, therefore, to have incurred no extra cost to replace.

Table 3. Estimates of costs due to culling for clinical mastitis incurred by 3 herds between 1st September 1986 and 31st August 1987

	Herds					
	187 (120 cows)		644 (192 cows)		563 (144 cows)	
	Cows	Cost (£)	Cows	Cost (£)	Cows	Cost (£)
Cows culled	1		7		8	
Loss of milk production[a]	(1)	40	(4)	820	(4)	1310
Death of cow	(0)	0	(0)	0	(0)	0
Loss of calves[b]	(0)	0	(2)	200	(1)	100
Cost of heifer replacement[c]	(1)	200	(1)	200	(3)	700
Total		240		1220		2110
Cost per head (£)		2		6		14

[a]Assumes a 6000 litre cow with a margin over feed profit of 8 p/litre.

[b]Assumes £100/calf/pregnant cow.

[c]Calculated on a sliding scale starting at a cost of £400 for the replacement of a cow at the beginning of her first lactation and reducing by £100 a year.

DISCUSSION

The average annual incidence of clinical mastitis in trial herds was 34 cases/100 cows. This is based on the definition of a case being a single event affecting one or more quarters. Other authors (Wilesmith et al., 1986; Blowey, 1986) define a case as being one quarter affected once. The average number of quarters affected per case in trial herds in our study was 1.12 (Table 1) and so the number of quarters affected per 100 cows in the first 12 months was 38. This was within the annual range of 32 to 51 cases/100 cows reported by Blowey (1986) but below the range of 41 to 55 cases reported by Wilesmith et al. (1986). There are other slight differences in definitions. We define the occurrence of a quarter requiring retreatment within 7 days of the finish of the last treatment as being a continuation of the same case and not a new one. Blowey and Wilesmith et al. use similar definitions but their maximum intervals are respectively 5 days 'elapsing between treatments of the same quarter' and 6 days 'after a previous clinical episode'. Variations in definitions are likely to affect both incidence and recurrence rates and this emphasises the need for standard definitions. The choice of 5, 6 or 7 days elapsing between successive treatments would appear to be arbitrary, and a statistical analysis of the effect of varying this definition, say from 5 to 14 days, on the magnitude of incidence and recurrence rates might be useful. The definition of a case as being one or more quarters affected simultaneously, however, seemed to us preferable as being the one that the farmer would more readily understand.

Our methods of presentation of results have received favourable reactions from farmers. None have suggested additions or deletions, and the amount of information being provided would therefore seem about right. The first page, which lists cows with clinical cases is of value in that it highlights recurrent cases. It would appear that farmers may have paid some attention to this table for an analysis of reasons for culling over the first 12 months showed a slightly higher, though not statistically significant, percentage of cows culled for mastitis in trial herds (17% of cows culled) than in controls (12%).

The summary of mastitis incidence by month (Fig. 1) is proving to be of increasing value as the second year of the project progresses, for it enables the farmer to look back at patterns in incidence over the previous 12 months and see whether management decisions are resulting in any improvement. For example, on the basis of the high incidence of mastitis observed throughout the year in herd 563, new liners were installed in September in the milking equipment. No cases have been diagnosed since (Fig. 1). It is too early to know whether this trend will persist in this herd but comparisons of 12 month rolling means up to November with those to August show that 10 fewer cases have occurred, 16 fewer single course antibiotic syringes have been used and 37.5 fewer days of milk have been lost than in the first full year (Fig. 1). These reductions in syringe use and loss of milk amount to a financial saving to date on this farm of £180. This, of course, is only one example and it is too early to know whether farmers overall have benefitted from the information provided. Although all variables in Table 1 showed a trend to reduced incidence of clinical mastitis in trial herds, some of the variation between trial and control herds was apparent before print-outs were first received. A full 12 months from February 1987 to January 1988 will need to elapse before any possible benefits can be statistically evaluated. 'Days of lost milk' appears to be a column in Fig. 1 of particular interest for it brings home the significant financial savings that can be made (Table 2). It will be of particular interest to see whether any differences develop in this variable between trial and control groups.

The main attraction of the system to the farmer is undoubtedly the competitive element of the 'league table' (Fig. 2) for it shows him where he stands relative to others. Clearly standards of recording and diagnosis vary from herd to herd. It is possible that a herdsman anxious to rise up the league table might fail to record clinical cases. Likewise a herdsman at the bottom of the table may be overtreating for mastitis. Some checks are being made. For example, veterinary surgeons are providing data on annual sales of intramammary syringes to their clients which can be correlated with those recorded as being used for treatment of mastitis. Bacteriological samples are also being taken during the winter of 1987/88 to identify pathogens involved in the different herds. There is little doubt that the discipline instilled by regular data collection and analysis has improved the overall standards of data quality, and although this may vary from herd to herd, herdsmen, when questioned, have said that it would not be in their interests to be dishonest. It is possible that standards of data recording may differ between trial and control herds because the latter are neither receiving regular feedback nor are they visited so frequently. Our impression is that any such bias is likely to be very slight. Nevertheless, the lower incidence of clinical mastitis in trial herds, particularly between November 1986 and January 1987 when no print-outs were being received (Fig. 3), could, although not significant, be due solely to an increased interest brought about by the more frequent collection of records (monthly versus 3-monthly). This will need to be taken into account in the 12 month analysis of results following receipt of the first print-outs at the end of January 1987.

Blowey (1986) proposed target values and interference levels beyond which herds ought to be investigated as 'problems'. For example, for cases per 100 cows, he suggested a target of 30 with an interference level of 35. Eleven of the 24 trial herds in the present study are already meeting this target (Fig. 2). The idea of including targets for individual herds was considered, but farmers were not keen. They felt that the league table in itself provided a sufficient target, namely to 'get better'.

In view of previous reports of correlation coefficients of about 0.5 or 0.6 among herds between bulk milk cell count and percentage of infected quarters (see, for example, Westgarth, 1975), a small positive correlation might have been expected in this study. However, cell counts were generally low with more than half the herds with counts averaging below 300,000 cells/ml. A high milk cell count is indicative of a high level of subclinical infection and the size of the correlation might depend, therefore, on the pattern of incidence of mastitis relative to stage of lactation. If so, these patterns might be used to indicate a likely pathogen as the primary source of infection. For example, herd 699 had a very high proportion of cases in early lactation (Fig. 4). This may be indicative of an infection associated with an organism such as Escherichia coli or Streptococcus uberis predominating at the end of the dry period (Wilesmith et al., 1986). The milk cell count of 169,000 cells/ml was low (Fig. 2). Herd 563, on the other hand, with a higher cell count of 459,000 cells/ml showed no trend with stage of lactation, suggesting a persistent subclinical infection perhaps due to faulty milking equipment, poor hygiene or poor therapy. As has already been described, a modification has been made to the milking equipment at this farm with, so far, apparent beneficial effects (Fig. 2). Farmers have not yet received graphical analysis of results, but these could form a very useful aid in directing attention to possible roots of the problem. Wilesmith et al. (1986) found that the relationship between age and the incidence of mastitis depended on the pathogen involved, and a histogram with age as well as stage of lactation could be useful.

A valuable database is now being developed for epidemiological and economic analysis. Some attempts at calculating costs have been undertaken (Table 2), but various assumptions have been made. Lucey & Rowlands (1984) observed an average 11% reduction in 305 day yield in cows with clinical mastitis before peak yield, but this was based on only four herds under one management. We have used figures of 5% and 10% depending on number of weeks from calving. Once 305 day yields are available at the end of the 2 year study the statistical analyses undertaken by Lucey & Rowlands can be repeated. The quantities of milk lost have been calculated assuming a 6000 litre cow yielding 20 litres/day. Again, more precise estimates will be possible once individual lactation yields are known. The average cost of a case of mastitis, taking into account some of the possible costs of premature culling, have previously been estimated as £40 by Blowey (1986) and £50 by Wilesmith et al. (1986). However, when a final financial appraisal of the present study is completed it would appear that the average cost per case could be even higher. Such costs would, of course, need to be fitted into a more extensive farm mathematical and economic model which takes into account milk quota levels and other factors such as alternative uses of land brought about by more efficient milk production.

In conclusion, a data collection and analysis scheme has been developed for recording cases of mastitis. As well as providing the farmer with the information he needs to identify problem areas it is also providing a database for research purposes. Monthly collection and reporting disciplines the herdsman into keeping records up to date and this ensures data of good quality. Statistical analysis of the variations in mastitis incidence with such factors as age and stage of lactation and linking such associations with recurrence rates and average milk cell counts could make this system a powerful management tool for use in diagnosing the cause of mastitis problems. This approach to disease management could also be applied to other diseases, and since September 1987 herdsmen in the trial have also been recording cases of lameness in their cows. A similar monthly report is being prepared.

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THE USE OF ABATTOIR PATHOLOGY DATA TO ESTIMATE THE COST OF DISEASES OCCURRING DURING PRODUCTION

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There are well known difficulties associated with the measurement of animal disease prevalence. Two main systems of animal disease recording systems are available for researchers: systems based on veterinary laboratory tests and abattoir pathology data. The former tend to underestimate true prevalence indices for clinical disease: "The specimens received by V.I. Centres represent a biased sample of the field problems of animal disease.... The figures in the tabulation show the number of incidents diagnosed. Subsequent repeated diagnoses relating to the same incident are not included in the data.... (The significant proportion of diagnosis not reached is largely) due to an inadequate history and unsuitable or inadequate specimens." (ADAS, VIDA-II).

Abattoir pathology data, on the other hand, detect mainly the impact of sub-clinical forms of disease as well as remaining signs from illness. These systems have the advantage of recording incidents for the entire population of slaughtered animals although national data bases are not easily available for the UK. Also, recorded pathological signs which remain from clinical disease may define an overlap area with the laboratory-based systems.

Research in the field of animal health economics, broadly defined to include financial studies, has traditionally required information on true prevalence indices to estimate production losses. This paper argues that, in some cases, abattoir pathology and farm cost information data may be sufficient to estimate short-run production losses associated with animal disease. Although this paper is methodological in nature, a numerical example is provided using an aggregate data base for Northern Ireland.

Animal disease imposes both 'visible' and 'invisible' costs on livestock producers and the economic system as a whole. Most of the visible costs are in the form of physical production losses at the farm and abattoir levels, such as delayed growth, milk losses, part condemnation, etc. Invisible costs may represent long-term losses at the farm level, for instance associated with lower fertility rates, or affect other economic agents such as consumers via price increases. This paper is only concerned with the estimation of short-run visible costs associated with animal disease.

The basic idea is rather simple: in cases when there are well-defined livestock production and disease cycles, systematic shifts in slaughtering peak periods may be observed in years with high prevalence of diseases which may only be detected at the abattoir level. These shifts represent increased production costs at the farm level which can be estimated using routinely collected farm accounting data. In instances when clear production or disease

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cycles cannot be identified, expenditures on veterinary labour and drugs can be used as a mathematical lower bound for production losses at the farm level.

ASSUMPTIONS

Modelling economic activity is typically a troublesome effort, largely due to the enormous number of factors influencing decisions and the variety of links between economic agents. It is often necessary to 'slice' components of the economy for closer examination, based on a set of simplifying assumptions. Partial equilibrium analysis is a commonly used technique which traces the effect of an external shock (such as animal disease) on a particular sector of the economy (for instance, a selected livestock sector), as it shifts from an original position of equilibrium to a new equilibrium point. The term equilibrium simply means that the effects of the shock will be traced until they cease to be important or "interrelated variables (are) so adjusted to one another that no inherent tendency to change prevails in the model which they constitute". (Machlup, 1958.)

The difference between short and long-runs is another concept from economic theory which is relevant for this analysis. The short-run is a time period during which only variable costs can be altered in response to an external shock, normally assumed to be a single production period which is 'frozen' for analysis. Decisions concerning, for instance, capital investments and the technology applied to livestock production can only be incorporated in long-run analysis. This paper is concerned with the short-run impact of animal disease on a particular livestock sector, thus applying partial equilibrium analysis to a single production period. The analytical 'slicing' of real life will thus require a series of assumptions which are specified below.

First of all, price effects will be ignored. In other words, even if disease causes growth delays, the farmer will realise the same gross revenue when the sale finally occurs (at least in real terms).* Similarly, abattoir revenue losses will be computed ignoring the fact that the burden can be shifted backwards (to producers) or forwards (to consumers).

Both farmers and abattoirs are assumed to display rational economic behaviour, implying that their behaviour will reveal clear intents towards profit-maximisation or cost-minimisation. This assumption has a critical implication in the absence of perfect information about risks and potential production losses. Based upon their training and experience, actual disease incidents, technical information made available, contact with rural extension services, etc., farmers will develop **perceived boundaries on potential losses.** Expenditures on disease control at the farm level will not exceed those perceived boundaries, that is, the farmer will not allocate financial resources to disease control in excess to the maximum anticipated losses resulting from an outbreak.** In effect, since losses due to sub-clinical disease may not be included in this implicit computation, actual losses might

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* Gross revenue is defined simply as the product of unit price and volume sold. Real prices are obtained by dividing nominal (or market) prices by an inflation index such as the retail price index.

** For an application of the same principle concerning public expenditures on animal disease contral in the EEC, see Barros and Howe (1987).

exceed expenditures by a significant amount. Of course, the degree of accuracy of such perceptions will tend to increase with the amount and quality of the information available to farmers, the farmers' educational level and experience, etc.

Another assumption requires the particular livestock sector under examination to display identifiable seasonal production cycles. For instance, when meat is the main output from the system (as in the case of sheep), there should be well-defined annual slaughtering peaks. This assumption is necessary to establish average growth delays which can be correlated with disease prevalence, as discussed in the next section. In addition, abattoir pathology data should also display seasonality or definite time trends in order to allow the identification of periods with high and low disease prevalence.

Finally, it is assumed that animal diseases can be roughly classified under two broad headings for the purposes of this analysis: (a) diseases which are noticeable at the farm level, typically in clinical form, due to their visible impact on production and productivity; and (b) diseases which remain largely unnoticed at the farm level, as with sub-clinical disease forms, but which may affect current and/or future production, and may only be detected at the abattoir level.

THE MODEL

The relevant economic variable used to measure the impact of disease in the short-run at farm and abattoir levels is **net revenue**, or the difference between gross revenue (the product of market price and quantity sold) and total variable costs.* Animal disease may not impact farm and abattoir net revenues in the same way. For example, fascioliasis is responsible for most abattoir liver condemnations although growth delays at the farm level may remain largely undetected. The impact of lameness or mastitis is much more significant at the farm level.

Table 1 summarises the proposed model which uses a simplified disease classification scheme to evaluate the impact on net revenue at farm and abattoir levels, in terms of its two components: gross revenue and variable (or operating) costs.

Diseases in category A, typically in clinical form and with a visible impact on production at the field, tend to increase farm operating costs while gross revenue remains largely unaffected, under the assumed condition of market and price stability. The impact at the abattoir level is probably insignificant unless pathological signs remain after an outbreak or treatment. Changes in disease prevalence over time are probably best approximated by systems based on veterinary laboratory tests, such as VIDA-II.

Diseases in category B cause largely unquantifiable impact on production at the farm level while abattoir gross revenues may be significantly affected due to organ condemnation rates, although operating costs may not be affected. This disease category is well suited to the methodology proposed here, particularly when there are clearly identifiable production and disease prevalence cycles, as in the case of sheep and fascioliasis, for instance. By

* Fixed costs can be ignored in short-run analysis.

comparing periods with high and low disease prevalence indices, as indicated by abattoir pathology data, growth delays may be approximated by systematic shifts in peak slaughtering periods. Standard accounting coefficients can then be applied to estimate the corresponding increase in farm operating costs.

Table 1 Disease impact at farm and abattoir levels

Disease class	Farm impact	Abattoir impact
A. Typically clinical disease with visible impact on production	Cost increase -- Case A1 --	Insignificant -- Case A2 --
B. Typically sub-clinical disease with unmeasured impact on production	Unknown (growth delays?) -- Case B1 --	Lower revenue -- Case B2 --

There are some problems with the proposed modelling approach. First, the causal link which attributes peak shifts to changes in disease prevalence may be rather weak in some cases, particularly if the analysis pertains to a single disease. It may hold stronger for groups of diseases which follow clear seasonal patterns, often associated with weather conditions. For example, abattoir pathology data for Northern Ireland shows systematic lower sheep slaughtering rates in years with high chill factors which are highly and positively correlated with the prevalence of fascioliasis, parasitic liver disease, pleurisy and pneumonia.

In addition, animal disease prevalence may have decreased steadily over time at the same time as production technology changed substantially, thus making the analysis of long time series more difficult. There are, of course, statistical techniques to remove trends from the time series although the main concern of this paper is seasonality.

The basic idea is then to estimate **changes in net revenue** at farm and abattoir levels associated with **changes in disease prevalence rates.** The simplest exercise is to generate estimates for case A1 which only requires aggregate expenditures on veterinary labour and drugs, probably the component of variable cost which responds more promptly to disease outbreaks. Case A2 requires the identification of diseases which have a measurable impact on farm production costs **and** leave pathological signs after treatment. It is not clear at this stage if diseases in this sub-category have any economic importance.

Estimation of the short-run economic impact of diseases in category B requires more data and sophisticated statistical techniques. Case B2 requires information on condemnation rates as well as market prices for parts and carcases (probably deflated by the retail price index). Case B1 requires the identification of annual slaughtering and disease prevalence cycles, in addition to the data required for case B2.

A NUMERICAL EXAMPLE

In this section the methodology proposed is applied to the computation of net revenue losses associated with sheep fascioliasis in Northern Ireland. The livestock sector, the disease and geographic location were selected because they fit comfortably under the set of assumptions imposed.

Why sheep? Sheep production follows clear production and price cycles, as shown in Figure 1. Meat is the main output of the production system: lamb sales in the UK were responsible for more that 80 per cent of the sheep farming sector gross revenue in 1985. Technological advancement in this sector has also been much slower than for other livestock. As shown in Table 2 variable costs and gross returns per ewe have not shown any upward trend in the period 1975-85, when measured in real terms. Even lamb prices have remained rather stable over time, again in real terms. These figures seem to suggest that, although stocking rates have increased steadily as have returns per hectare, traditional technology has been applied to larger flocks.*

Fascioliasis has been selected for the illustration because its prevalence displays cyclical behaviour although decreasing steadily over time, as shown in Figure 2. In addition, the great majority of the cases are identified at the abattoir level: for the period 1975-85, VIDA-II has reported 601 cases in sheep while abattoir pathology data for Northern Ireland showed liver condemnation due to fascioliasis in excess of 250,000. Consequently, it is a disease in category B, as discussed in the previous section.

Finally, Northern Ireland was selected for the analysis because of data availability and accessibility in the form of a computerised system which contains monthly records with aggregate abattoir pathology and slaughtering data for the period 1969-1986 (McIlroy et al, 1987).

Price time series proved almost impossible to obtain, particularly on a monthly basis. Similarly, it is difficult to obtain estimates of veterinary labour and drug costs for a particular livestock sector or disease. However, informal estimates of sheep liver prices were obtained from a local abattoir and expenditures on antifluke drugs could be obtained for the period 1969-71 (Pout and Kelsey, 1973). These figures were extrapolated to the sample period, using the ratio between liver and lamb prices, and the proportion of veterinary to total variable costs respectively.

THE PROCEDURE

Years with high and low prevalence of fascioliasis, as indicated by liver condemnation rates, were selected based on 't' tests comparing annual means with the global mean for the entire period 1969-86. Condemnation rates and the relevant statistics are presented in Table 3. Three years displayed statistically significant and positive 't' values, thus being considered high prevalence periods (1969, 1971 and 1972). Five years were considered low prevalence periods due to statistically significant and negative 't' values (1976, 1983 to 1986).

*Note that cost figures apply to lowland sheep which is largely responsible for the production of slaughter lambs.

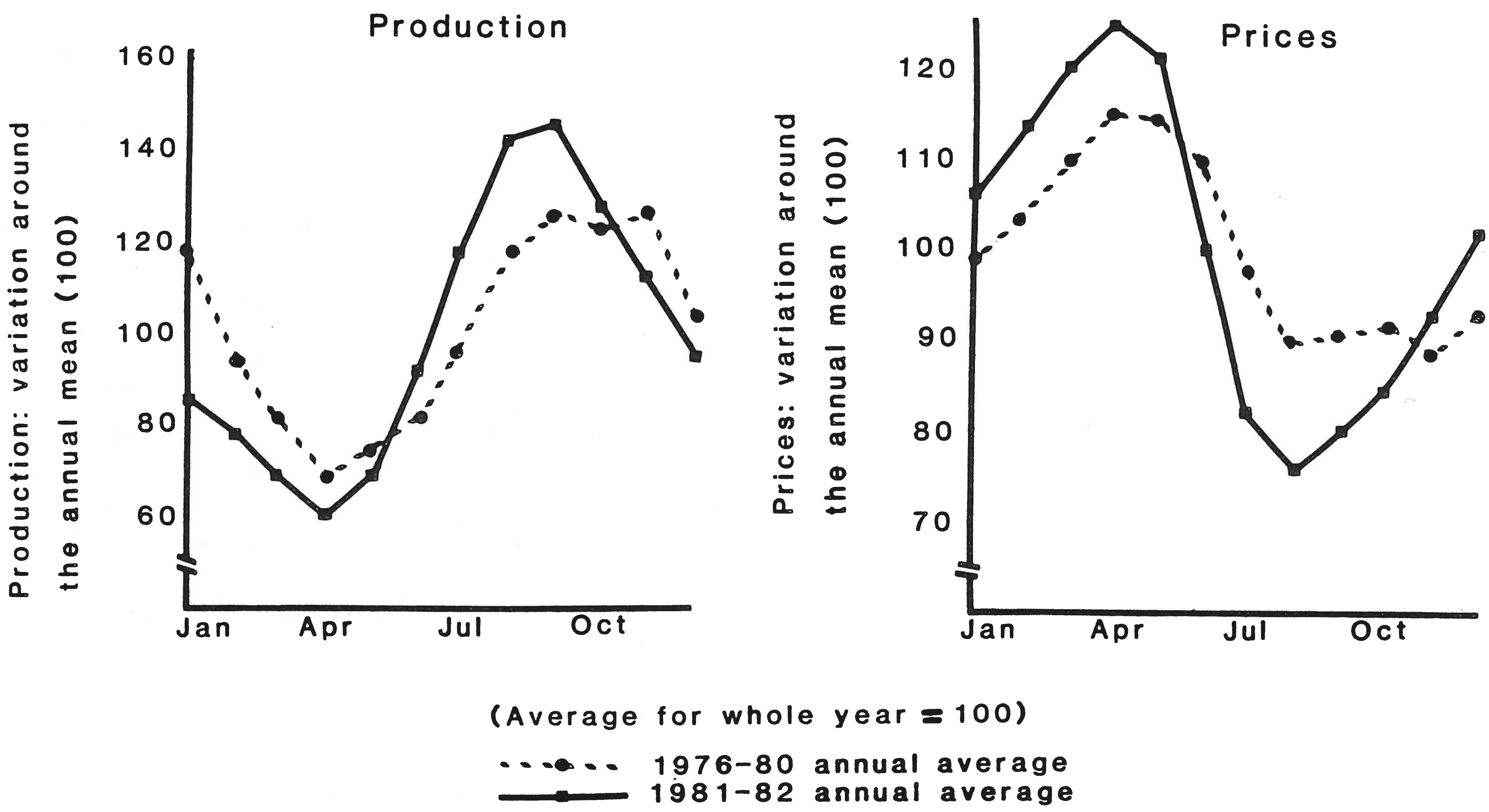

Fig. 1 Seasonal pattern of lamb production and prices.

Reference: MLC Sheep Yearbook, 1983.

Table 2 Lowland sheep farm production costs. Nominal and real values for the UK, 1975–85

Cost in £/ewe	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Average	St.Dev.	Coef.Var.
Nominal values:														
Lamb sales	18.96	26.20	31.70	36.60	34.20	38.50	45.80	52.70	53.30	53.70	54.40	40.55	11.73	0.29
Wool sales	1.81			3.10	3.20	3.20	2.90	2.80	2.80	2.80	3.00	2.85	0.40	0.14
Flock repl.	2.31	2.10	4.00	5.70	6.10	6.50	7.20	8.70	9.20	9.50	9.50	6.44	2.60	0.40
Feed/For.cost	6.01	7.70	9.20	9.80	11.40	11.10	12.30	14.20	15.30	17.30	16.40	11.88	3.46	0.29
Var.cost/ewe	7.37	9.00	10.60	11.80	13.70	13.90	15.50	17.70	19.10	21.40	21.00	14.64	4.54	0.31
Gr.margin/ewe	11.09	17.30	20.10	22.20	17.60	21.30	27.80	30.40	28.90	31.40	31.10	23.56	6.47	0.27
Gr.margin/ha	111.69	180.20	209.70	236.00	195.00	246.00	352.00	386.00	379.00	380.00	373.00	277.14	94.55	0.34
Ave.pr./lamb	13.64	18.00	22.50	26.20	25.00	27.30	32.00	35.60	36.50	36.30	36.70	28.16	7.62	0.27
Real values (1980 prices):														
Lamb sales	36.46	42.26	42.84	45.75	38.48	38.50	42.41	45.04	44.05	42.28	41.53	41.78	2.76	0.07
Wool sales	3.48			3.88	3.60	3.20	2.69	2.39	2.31	2.20	2.29	2.89	0.61	0.21
Flock repl.	4.44	3.39	5.41	7.13	6.85	6.50	6.67	7.44	7.60	7.48	7.25	6.38	1.32	0.21
Feed/For.cost	11.56	12.42	12.43	12.25	12.81	11.10	11.39	12.14	12.64	13.62	12.52	12.26	0.68	0.06
Var.cost/ewe	14.17	14.52	14.32	14.75	15.39	13.90	14.35	15.13	15.79	16.85	16.03	15.02	0.87	0.06
Gr.margin/ewe	21.33	27.90	27.16	27.75	19.78	21.30	25.74	25.98	23.88	24.72	23.74	24.48	2.64	0.11
Gr.margin/ha	214.79	290.65	283.38	295.00	219.10	246.00	325.93	329.91	313.22	299.21	284.73	281.99	37.56	0.13
Ave.pr./lamb	26.23	29.03	30.41	32.75	28.09	27.30	29.63	30.43	30.17	28.58	28.02	29.15	1.71	0.06
Physical indicators:														
Lamb/ewe	1.39	1.45	1.41	1.40	1.37	1.41	1.43	1.48	1.46	1.48	1.48	1.43	0.40	0.03
Stocking rate	10.13	10.40	10.40	10.60	11.10	11.50	12.70	12.70	13.10	12.10	12.00	11.52	1.01	0.09

Source: MLC, Sheep Yearbook, 1980-1986.

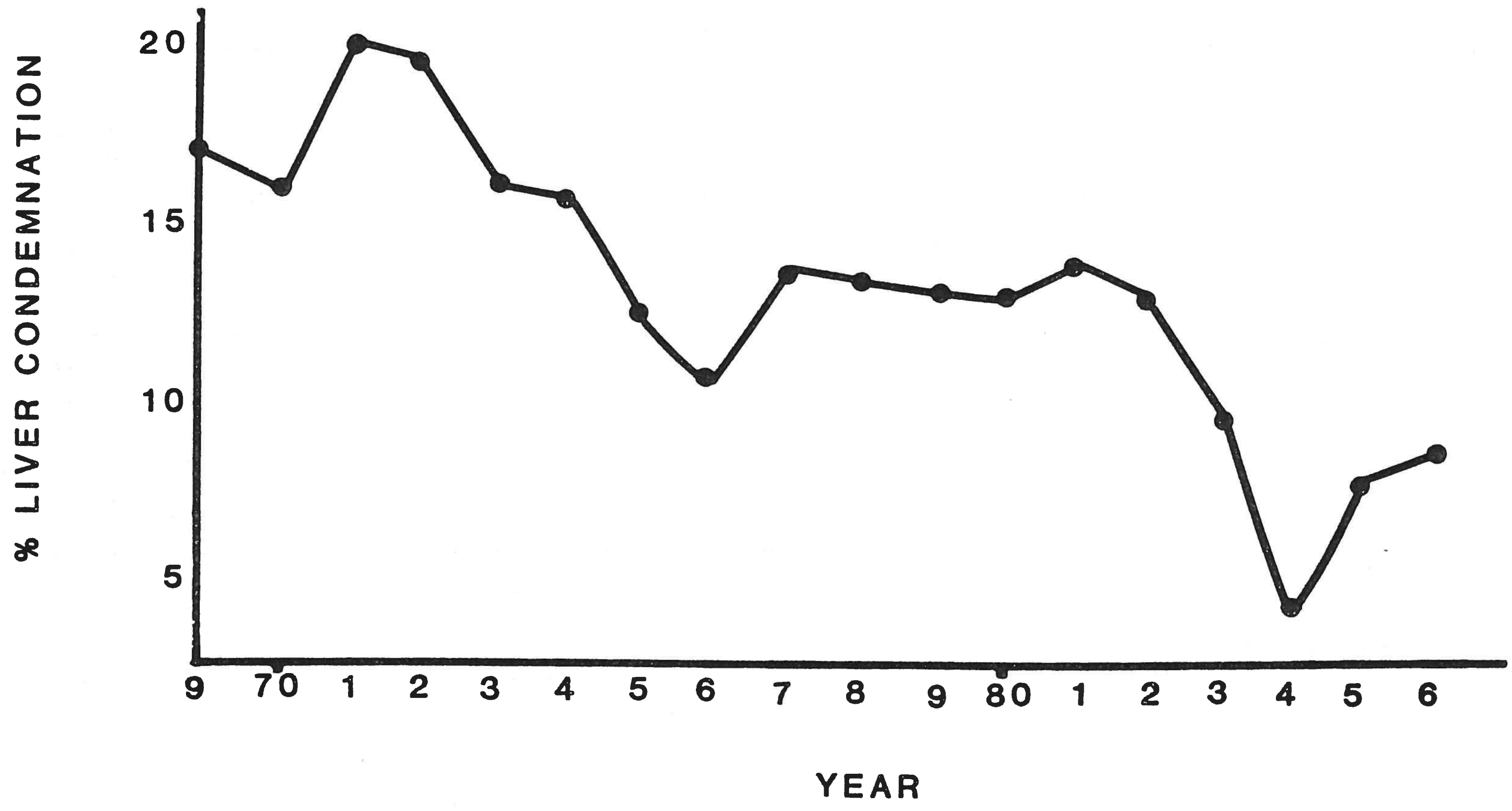

Fig. 2 Percentage liver condemnation due to fascioliasis.

Annual data for Northern Ireland, 1969-86

Table 3 Liver condemnation due to fascioliasis, Northern Ireland, 1969-1986

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.	Var.	T-test
	% Liver condemnation														
1969	15.24	19.52	21.81	19.51	17.64	21.12	21.95	16.15	17.02	12.51	10.98	10.82	17.02	14.67	3.49
1970	11.32	13.19	15.39	18.19	18.60	21.21	22.35	16.70	19.81	13.10	12.04	9.80	16.14	16.11	2.57
1971	11.68	16.53	20.80	21.74	26.15	29.11	27.37	23.62	22.27	14.14	12.23	14.48	20.01	33.63	4.09
1972	17.77	21.12	22.92	26.60	25.80	25.45	24.13	20.59	17.58	12.77	9.61	10.12	19.54	33.35	3.82
1973	14.27	15.26	18.55	18.63	20.60	21.45	16.43	18.35	15.60	11.75	10.00	10.00	15.91	13.64	2.57
1974	11.60	12.40	18.50	20.70	21.50	20.93	19.54	18.69	15.94	10.63	9.07	9.50	15.75	21.11	1.95
1975	9.90	10.90	12.60	14.20	14.70	14.23	16.18	15.39	12.52	11.30	9.68	8.68	12.52	5.49	-0.95
1976	7.75	8.95	8.83	12.24	14.30	11.88	10.61	10.94	11.15	9.01	20.19	11.43	10.61	2.98	-5.13
1977	12.20	11.27	12.00	11.95	14.59	15.70	17.51	15.51	15.95	12.88	10.60	10.28	13.32	4.12	0.23
1978	11.61	11.67	12.69	13.65	15.89	15.12	15.27	13.36	15.20	12.74	12.00	9.99	13.16	4.82	-0.00
1979	12.04	12.53	12.14	12.99	15.28	15.31	17.47	16.57	13.40	10.17	9.18	9.66	12.92	6.48	-0.34
1980	8.96	10.22	12.24	13.92	14.85	15.88	15.87	15.80	14.11	11.67	10.35	9.36	12.77	6.33	-0.55
1981	8.79	9.03	14.28	17.94	18.42	18.34	19.41	18.68	12.75	10.87	8.72	9.43	13.89	18.08	0.59
1982	14.02	11.09	11.71	14.66	11.56	17.42	17.74	17.26	13.95	10.35	5.98	6.22	12.66	14.43	-0.46
1983	7.80	7.71	9.65	11.52	10.13	14.44	13.29	13.01	9.45	6.03	4.92	4.53	9.37	9.93	-4.17
1984	4.79	4.24	3.55	4.43	4.45	5.51	5.60	5.50	7.15	5.40	4.10	3.12	4.82	1.08	-27.82
1985	3.42	4.87	6.36	8.03	9.16	7.63	12.41	11.58	10.64	8.05	7.08	5.79	7.92	6.65	-7.05
1986	7.12	7.66	8.39	10.81	8.67	11.00	12.40	10.16	10.48	5.25	6.04	5.91	8.66	4.93	-7.03
Average	10.57	11.56	13.47	15.10	15.68	16.76	16.97	15.55	14.17	10.48	9.04	8.84	13.17		
Variance	12.57	18.98	27.16	26.63	31.14	33.03	25.38	17.26	13.26	6.97	5.70	7.09	14.74		
T-test	-2.11	-1.56	0.25	1.59	1.91	2.66	3.21	2.43	1.16	-4.32	-7.33	-6.89	14.55		

Source: Listings from the Department of Agriculture for Northern Ireland.

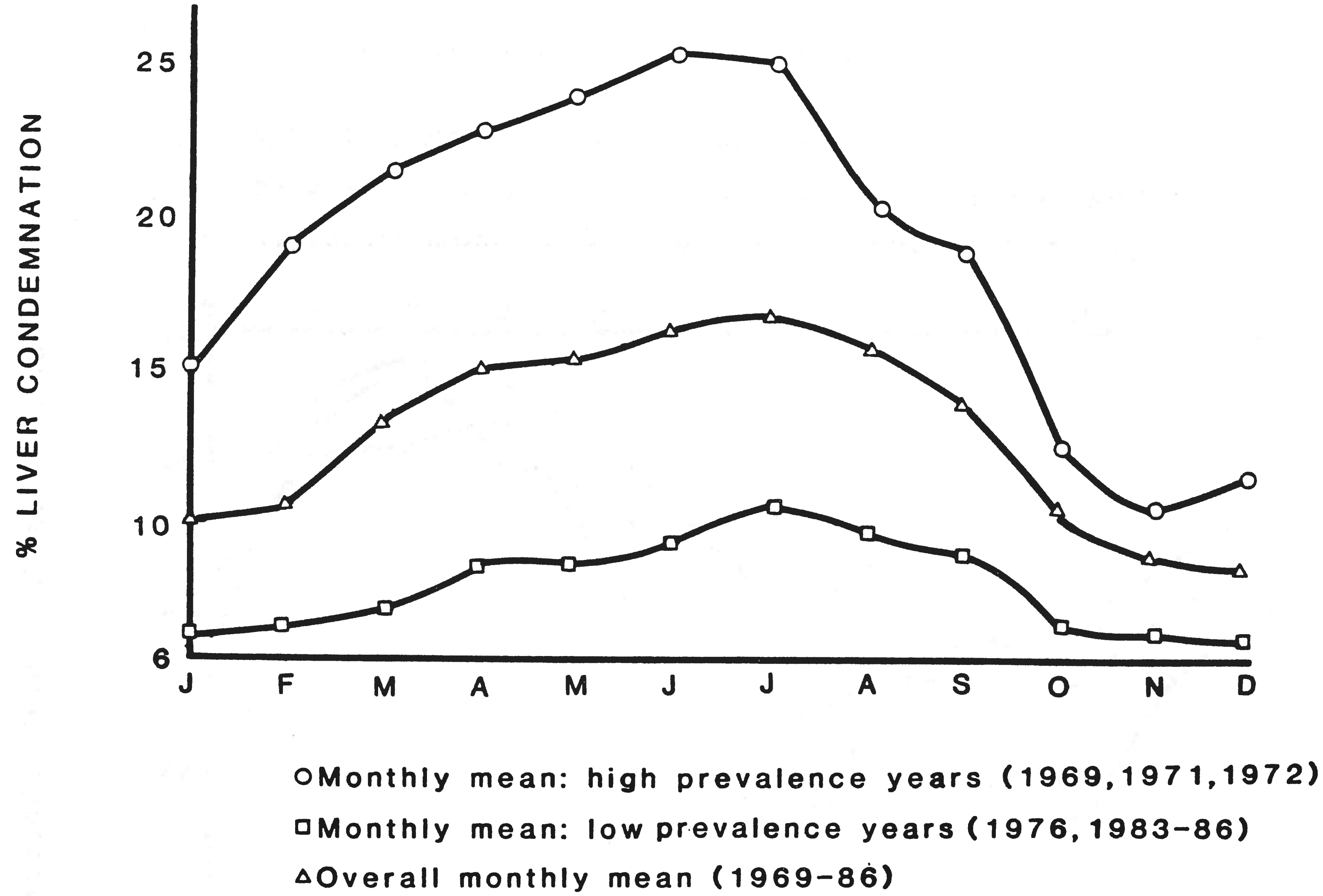

Fig. 3 Percentage liver condemnation due to fascioliasis.

Monthly data for Northern Ireland, 1969-86.

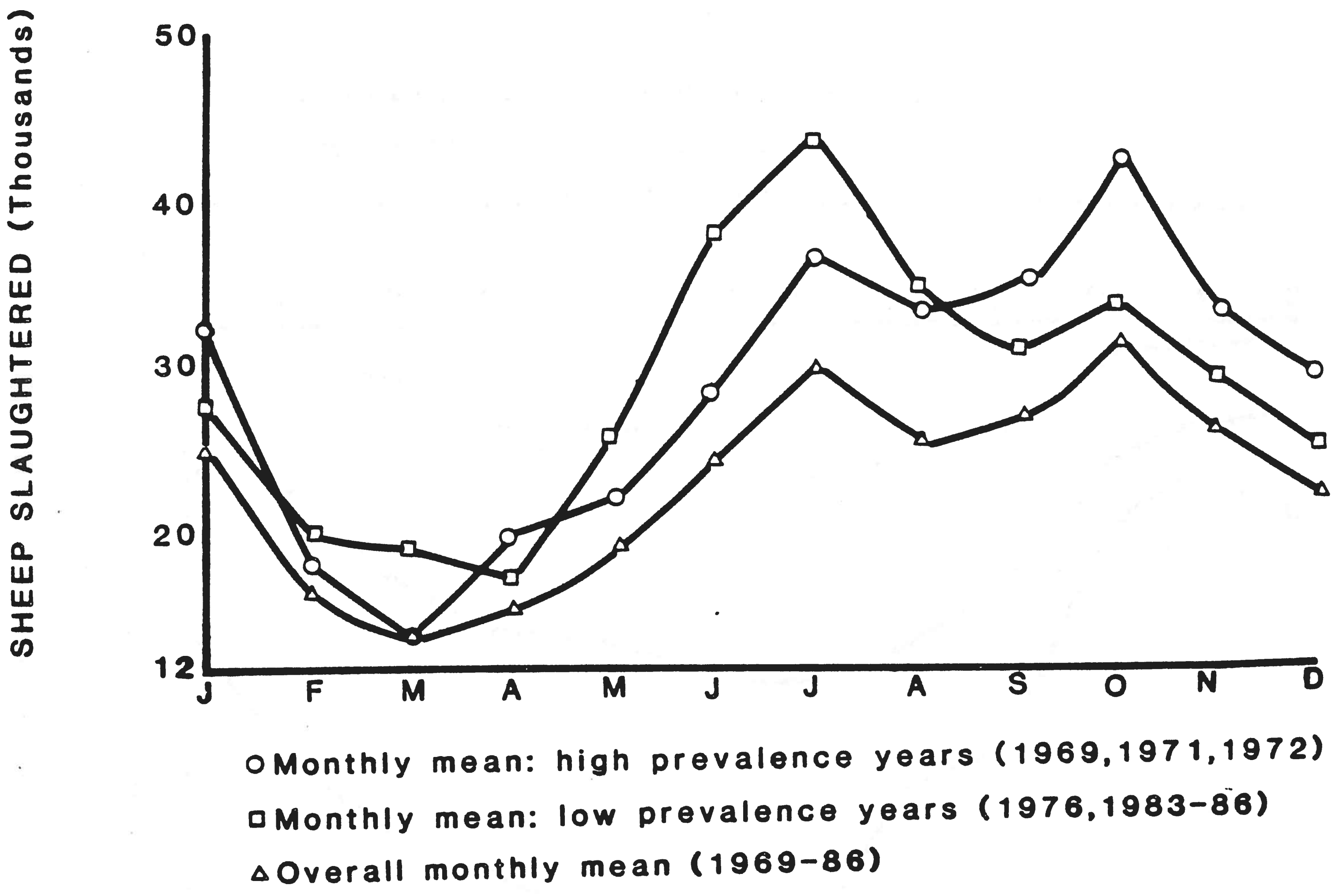

Fig. 4 Sheep slaughtered in relation to the prevalence of fascioliasis.

Monthly data for Northern Ireland, 1969-86.

Table 4 Estimated net revenue losses due to fascioliasis, Northern Ireland, 1975–1985

	Abattoir level				Farm level						Net revenue loss	
	Livers condemned		Lost revenue		Annual cost/ewe		Weekly costs		Costs for 9 wks			
Year	Ave/Mo	Total	Nominal[a]	Real	Variable	Drugs[b]	Variable	Drugs	Variable	Drugs	Nominal terms	Real terms
1975	2851	17108	10770	20712	7.37	0.06	2425	21	21822	186	32779	63036
1976	2381	28577	23741	38291	9.00	0.08	4946	42	44514	380	68634	110701
1977	2782	27818	28888	39037	10.60	0.09	5671	48	51035	436	80358	108592
1978	1778	21331	25794	32240	11.80	0.10	4841	41	43565	372	69731	87164
1979	1089	13069	15080	16944	13.70	0.12	3443	29	30990	265	46334	52061
1980	1538	15379	19378	19378	13.90	0.12	4111	35	36999	316	56694	56694
1981	1715	20578	30393	28141	15.50	0.13	6134	52	55206	471	86070	79694
1982	2148	25778	42355	36201	17.70	0.15	8774	75	78970	674	121999	104273
1983	2308	27701	46666	38567	19.10	0.16	10175	87	91573	782	139021	114893
1984	1432	17189	28799	22676	21.40	0.18	7074	60	63667	544	93009	73236
1985	3234	35572	60254	45996	21.00	0.18	14366	123	129292	1104	190650	145535

[a] The proportion between liver and lamb prices in 1988 was maintained for the entire period (£1.20/26 = £.046153).

[b] The proportion of antifluke drugs expenditures to total veterinary and variable costs estimated for 1969-71 was maintained for the entire period (antifluke drugs represented 6% of all veterinary costs).

Sources: Listings from the Department of Agriculture for Northern Ireland, 1987.
Informal liver price quotes from Lloyd Maunders Abattoirs.
MLC, Sheep Yearbook, 1986.

The next step was to compare seasonal patterns for average, high and low prevalence periods. Figure 3 shows that all periods display similar cyclical pattern throughout the year, with prevalence being highest during early summer months. The most critical result, however, is displayed in Figure 4: slaughtering peaks in years of high prevalence of fascioliasis seem to occur about 3 months later than for years of low prevalence, giving the average curve a dual peak format. The computation below uses a conservative 9 weeks growth delay at the farm level.

Table 4 reports the results obtained from this procedure. Abattoir lost revenue is simply obtained by multiplying the number of livers condemned by their market value (in real terms, if subsequently deflated by the retail price index). Annual farm variable costs per ewe* were converted to weekly averages and subsequently multiplied by the number of animals infected with fascioliasis. Antifluke drug costs were computed in a similar manner and the two figures were multiplied by an average 9 week growth delay period. Finally, abattoir lost revenue and farm cost increases were summed up to generate the overall negative impact on net revenues. Real estimates were obtained after deflating nominal figures by the retail price index.

In general, it is important to examine the figures in real terms, as displayed in Table 4 which uses 1980 as a base year. If changes in net revenue which are fully compensated by price increases, it is expected that no significant alteration in the behaviour of economic agents will result. In our example, of course, price effects are ignored.

It should also be observed that, since the variable of interest is changes in net revenues, it is correct to sum up decreases in gross revenue (at abattoir level) and increases in variable costs (at the farm level). The assumption is, of course, that variable costs and gross revenue will remain constant in each of the two levels, respectively. For 1985, for example, the figures are as follows (all measured as changes):

Table 5 Summary of cost computation for 1985

Level	Gross revenue (A)	Variable cost (B)	Net revenue (A - B)
Abattoir	- 60,254	No change	- 60,254
Farm	No change	+ 129,292 + 1,104	- 130,396
Change in net revenue			- 190,650

The estimated loss in net revenue in a year with relatively low prevalence of fascioliasis represents about 2 per cent of the variable cost incurred to produce all the sheep slaughtered in Northern Ireland in 1985. Alternatively, £190,650 represents an average cost of £5.36 per infected sheep or 25 per cent of the total variable cost incurred during production.

*The cooperation of FADN staff members at the University of Exeter was invaluable to the completion of this paper.

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EPIDEMIOMOGICAL ASPECTS OF BOVINE HYPOMAGNESAEMIA IN NORTHERN IRELAND

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Bovine hypomagnesaemia can result from either inadequate concentrations of magnesium in the diet or from high concentrations of other nutrients, such as potassium, which reduce the availability of dietary magnesium. The resulting sub-optimal magnesium status can induce a variety of production problems. Deficient cows may develop hypomagnesaemic tetany when stressed, frequently resulting in death. Furthermore, hypomagnesaemia in dairy cows has been associated with an increased incidence of milk fever (Van de Braak, et al, 1987) and with a decreased digestability of food (Wilson, 1980). The condition has also been associated with reduced milk fat percentages (Young et al, 1981) and with reduced voluntary food intake (Scott et al, 1980).

Bovine hypomagnesaemia can be controlled by a variety of methods. These include the provision of high magnesium feed concentrates, high magnesium mineral licks and blocks, the application of magnesium oxide to soil or pasture, the addition of magnesium to the water supply and the use of an intra-rumenal magnesium bolus. Despite the availability of these control measures, cases of hypomagnesaemic tetany still commonly occur. In view of the association of sub-optimal magnesium status with several economically important production problems and the lack of quantitative information on the distribution of the condition, a stratified longitudinal survey of blood magnesium levels in dairy and suckler cows was carried out in 1985. This paper reports the results from the analyses of this survey and discusses their relevance to the epidemiology and control of the deficiency.

MATERIALS AND METHODS

Blood samples submitted to the Veterinary Research Laboratories for statutory testing for the Northern Ireland Brucella Eradication Scheme were used as the basis of the sampling frame of this study. All dairy and suckler herds are routinely tested every 12 months under this Scheme. Suckler and dairy herds were selected on the basis of cow herd size and geographical location defined by County. The survey was carried out between 1 March and 31 October with 10 samples randomly selected from each herd.

The serum magnesium levels were determined by using an Optimize magnesium test kit (CAT. No. Mg. 15091, Central Laboratory Supplies, Basingstoke) on an Hitachi 705 clinical chemistry analyser (Boehringer, Manheim). Atomic absorption spectrophotometry was used for quality control purposes to monitor the sensitivity, specificity and repeatability of the testing procedure. The magnesium status of sampled cows was defined as adequate if serum magnesium levels were greater than 0.8 umol/l, marginal if between 0.6 and 0.8 umol/l and deficient if less than 0.6 umol/l. Where appropriate, statistical analyses were performed on constructed contingency tables using the chi-squared test.

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RESULTS

A total of 728 suckler and 646 dairy herds were sampled. The frequency distribution of sampled herds in each defined category of herd size is given in Table 1. The distribution of sampled herds was reasonably uniform throughout the main grazing season with approximately 100 suckler and 100 dairy herds being sampled in the months April to September (Table 2).

Table 3 demonstrates the distribution of sampled cows in each of the six counties. The total number of cows sampled in the survey was 6,979 suckler and 6,345 dairy cows. Overall, 83% of dairy and 57% of suckler cows had an adequate magnesium status. Twelve per cent of dairy and 27% of suckler cows sampled had marginal serum magnesium levels, whilst 5% and 15% respectively were found to be deficient. The monthly percentages in each of these three categories of serum magnesium status are given in Table 4.

The percentage of cows found to have a deficient magnesium status in each county is given in Table 5. Meaningful differences in these percentages were found between counties for both dairy and suckler cows. Many of these differences were statistically significant and the levels of significance are given in Table 6.

Sixty-one per cent of dairy herds and 25% of suckler herds had no deficient cows in the samples submitted. The relative frequency distribution of deficient cows for dairy and suckler herds is given in Table 7. Notably, 7% of dairy and 26% of suckler herds had 50% or more of their cows deficient. The relative frequency distribution of herds in which at least one deficient cow was found is given in Table 8, for each herd size strata. Generally, the percentage of deficient herds was greatest in small herds, attaining a maximum of 28% and 44% respectively in dairy and suckler herds with between 20 and 40 cows.

DISCUSSION

The results of this survey clearly indicate that hypomagnesaemia is prevalent in both dairy and suckler herds in Northern Ireland with 39% and 75% respectively having at least one cow deficient in the level of serum magnesium. Although most herds had only a small percentage of deficient cows, 7% of dairy and 26% of suckler herds had 50% or more of their cows deficient. In all samples submitted, 5% of dairy and 15% of suckler cows were found to be deficient. The overall level and distribution of hypomagnesaemia recorded in this survey would account for the continued occurred of hypomagnesaemic tetany. The results would also suggest that, despite the availability of a wide variety of control measures for a number of years, such measures are not being implemented by a large number of farmers. In particular, farmers with suckler herds are not effectively controlling the condition.

The months with the lowest recorded levels of deficient and marginal cows were March and April. This was most apparent for dairy herds. However, many cows are deficient or marginal in their serum magnesium levels for the remainder of the grazing season, with the highest levels being recorded in September. Notably, many dairy and suckler cows were deficient during July and August which are traditionally regarded as months when hypomagnesaemic tetany is not considered to be a problem.

Table 1. The total number of herds sampled catagorized by herd size

Herd Size (Cows)	Dairy	Suckler
0-20	82	218
20-40	179	315
40-60	140	98
60-80	83	43
80-100	51	20
>100	111	34
TOTAL	646	728

Table 2. The total number of herds sampled each month

Month	Dairy	Suckler
March	30	29
April	90	89
May	100	110
June	94	123
July	100	105
August	110	121
September	85	119
October	37	32
TOTAL	646	728

Table 3. The total number of cows sampled in each county

County	Dairy	Suckler
Down	1077	1099
Antrim	1322	1231
Armagh	876	885
Fermanagh	1014	1223
Tyrone	1285	1341
Londonderry	781	1200
TOTAL	6345	6979

Table 4. The percentage of cows in each blood magnesium category for each month

	Blood magnesium concentration (umol/L)					
	Dairy Cows			Suckler cows		
Month	0-0-6	0.6-0.8	<0.8	0-0.6	0.6-0.8	<0.8
March	0	2.6	97.4	5.1	27.3	67.6
April	1.9	7.8	90.3	9.4	25.7	64.9
May	3.1	13.4	83.6	17.0	27.8	55.2
June	6.9	13.0	80.1	20.5	27.7	51.8
July	5.6	10.8	83.6	13.2	27.4	59.3
August	6.0	13.6	80.4	11.1	22.7	66.2
September	7.1	17.1	74.8	21.7	29.0	51.3
October	4.3	15.8	79.9	20.3	32.8	46.6
Mean	5.0	12.3	82.7	15.3	27.6	57.2

Table 5. The percentage of cows deficient in magnesium for each county

	Dairy cows	Suckler cows
Down	2.9	19.4
Antrim	3.7	22.4
Armagh	5.0	10.7
Fermanagh	6.4	7.0
Tyrone	6.0	13.5
Londonderry	4.6	18.1
Mean	5.0	15.3

Table 6. Levels of significance between counties in the percentages of magnesium deficient cows

	Antrim		Armagh		Fermanagh		Tyrone		Londonderry	
	D	S	D	S	D	S	D	S	D	S
Down	NS	NS	X	XXX	XXX	XXX	XXX	XXX	NS	NS
Antrim			NS	XXX	XX	XXX	X	XXX	NS	XX
Armagh					NS	XX	NS	NS	NS	XXX
Fermanagh							NS	XXX	NS	XXX
Tyrone									NS	XX

D = Dairy
S = Suckler
NS = Not significant

X = <0.05
XX = <0.01
XXX = <0.001

Table 7. Relative frequency distribution of herds with magnesium deficiency

% of cows deficient	% of dairy herds	% of suckler herds
0	60.6	24.8
10	15.0	17.3
20	9.1	12.1
30	4.6	11.9
40	4.0	8.2
50	1.7	4.5
60	2.5	5.3
70	0.8	6.2
80	0.5	5.1
90	0.6	3.4
100	0.6	1.1

Table 8. The percentage of herds with magnesium deficiency catagorized by size of herd

Herd Size (cows)	Dairy	Suckler
0-20	13.3	27.6
20-40	27.5	44.1
40-60	25.9	14.8
60-80	12.5	5.7
80-100	7.5	2.9
>100	13.3	4.9
TOTAL	100	100

Van de Braak et al (1987) in some elegant experimental work have conclusively shown that hypomagnesaemia predisposes to milk fever. In Northern Ireland there has been an increased incidence of an acute and often unresponsive form of milk fever in cows grazing on autumn pasture. This may well be associated with the high incidence of hypomagnesaemia observed in September, in this study.

An extremely interesting result identified by this survey is that herd size would appear to be a major determinant in the occurrence of hypomagnesaemia. Sixty seven per cent of dairy and 87% of suckler herds which recorded deficient cows were from herds containing less than 60 cows. Obviously, this finding would indicate that specific advice on the prevention of hypomagnesaemia could effectively be targetted at farmers with herds of this size. This is particularly relevant when resources of advisory staff are limited.

Another extremely interesting result from the survey is the statistically significant differences in levels of hypomagnesaemia for the different counties of Northern Ireland. These differences are not consistent in both dairy and suckler herds. Counties Down and Antrim recorded the lowest percentage of deficient dairy cows, but had the highest percentage of suckler cows. The opposite was found in County Fermanagh. These results might reflect the differences in the targeting and uptake of specific advice in different counties, rather than geographical differences in the availability of magnesium in herbage.

Dairy farmers can utilise the feeding of high magnesium concentrates, foliar application of calcined magnesite or soluble magnesium salts in the water supply, as their principal methods of preventing hypomagnesaemia. Since the introduction of "milk quotas" within the European Community, it has become uneconomical to feed concentrates simply as a vehicle for magnesium supplementation. Dusting of pastures is successfully practised by some dairy farmers and is a very economical method of prevention. It is however labour intensive. Supplying magnesium in the water supply suffers from the disadvantage of being least effective when it is most required, ie during periods of high rainfall when cows do not need a large intake of water from troughs.

With regard to suckler cows on extensive grazing locations, prevention of hypomagnesaemia is more difficult. Concentrate feeding has rarely been economical as a means of supplying magnesium to suckler cows. The traditional approach has been the use of "high magnesium" blocks and licks. However, recent initial studies at the Veterinary Research Laboratories at Stormont have suggested that some of these may not perform satisfactorily under field conditions (Rice, unpublished data). These factors may partially explain the high prevalence of the deficiency observed in dairy and suckler cows in this study.

These survey results are of great concern to those involved in Veterinary Preventive Medicine in Northern Ireland. In addition, they may have certain welfare aspects as such hypomagnesaemic cows are at risk from the unpleasant and often fatal disease of hypomagnesaemic tetany. Certainly, animal rights groups are putting increasing pressure on the farming community to ensure that animals are kept in conditions which are adequate to support their nutritional, physiological and emotional needs (Council of Europe 1976).

CONCLUSIONS

Although hypomagnesaemia in cows may result in hypomagnesaemic tetany and loss of production, the results of this survey would indicate that the level of this condition is still high in both dairy and suckler herds in Northern Ireland. This is in spite of the availability of several control methods. Farmers may not be implementing control measures due to ignorance, apathy or failure to appreciate the potential cost effectiveness of such measures. Alternatively, where control measures are being implemented, they may be inappropriate to the specific requirements on that particular farm and thus ineffective.

These results strongly suggest that specific advice should be given to all farmers in Northern Ireland with suckler and dairy herds. Furthermore it is essential that Veterinarians evaluate the blood magnesium status of cows in herds under their supervision and target detailed strategic advice and control measures where indicated. The survey results may also reflect the effectiveness of control measures when implemented. The low level of hypomagnesaemia recorded in suckler herds in County Fermanagh may be due to the uptake of advice from a local agricultural college where staff have conducted a specific campaign targetted directly at suckler herd owners over many years.

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